P40 Agile P14D

Technical Manual

Feeder Management IED

Platform Hardware Version: A
Platform Software Version: 50
Publication Reference: P14D-B/G/L/Z-TM-EN-1

GRID | ALSTOM

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INTRODUCTION

CHAPTER 1

1 CHAPTER OVERVIEW

This chapter contains the following sections:

2 FOREWORD

This technical manual provides a functional and technical description of Alstom Grid's P14D, as well as a comprehensive set of instructions for using the device.

We have attempted to make this manual as accurate, comprehensive and user-friendly as possible. However we cannot guarantee that it is free from errors. Nor can we state that it cannot be improved. We would therefore be very pleased to hear from you if you discover any errors, or have any suggestions for improvement. All feedback should be sent to our contact centre via the following URL:

http://www.alstom.com/grid/contactcentre/

2.1 TARGET AUDIENCE

This manual is aimed towards all professionals charged with installing, commissioning, maintaining, troubleshooting, or operating any of the products within the specified product range. This includes installation and commissioning personnel as well as engineers who will be responsible for operating the product.

The level at which this manual is written assumes that installation and commissioning engineers have knowledge of handling electronic equipment and that system and protection engineers have a thorough knowledge of protection systems and associated equipment.

2.2 TYPOGRAPHICAL CONVENTIONS

The following typographical conventions are used throughout this manual.

- The names for special keys and function keys appear in capital letters.
  For example: ENTER
- When describing software applications, menu items, buttons, labels etc as they appear on the screen are written in bold type.
  For example: Select **Save** from the file menu.
- Menu hierarchies in documentation describing software applications use the > sign to indicate the next level
  For example: Select **File > Save**
- Filenames and paths use the courier font
  For example: `Example\File.text`
- Special terminology is written with leading capitals
  For example: Sensitive Earth Fault
- When reference is made to Alstom Grid's Courier database, the column text is written in upper case
  For example: The SYSTEM DATA column
- When reference is made to Alstom Grid's Courier database, the cell text is written in bold type
  For example: The **Language** cell in the SYSTEM DATA column
- When reference is made to Alstom Grid's Courier database, the value of a cell's content is enclosed in single quotation marks
  For example: The **Language** cell in the SYSTEM DATA column contains the value 'English'

2.3 NOMENCLATURE

Due to the technical nature of this manual, many special terms, abbreviations and acronyms are used throughout the manual. Some of these terms are well-known industry-specific terms while others may be special product-specific terms used by Alstom Grid. A glossary at the back of this manual provides a complete description of all special terms used throughout the manual.

We would like to highlight the following changes of nomenclature however:

- The word 'relay' is no longer used for the device itself. Instead, the device is referred to as an 'IED' (Intelligent Electronic Device), the 'device', the 'product', or the 'unit'. The word 'relay' is used purely to describe the electromechanical components within the device, i.e. the output relays.
- British English is used throughout this manual.
- The British term 'Earth' is used in favour of the American term 'Ground'.

2.4 MANUAL STRUCTURE

The manual consists of the following chapters:

- Chapter 1: Introduction
- Chapter 2: Safety Information
- Chapter 3: Hardware Design
- Chapter 4: Configuration
- Chapter 5: Current Protection Functions
- Chapter 6: Voltage and Frequency Protection Functions
- Chapter 7: Power Protection Functions
- Chapter 8: Autoreclose Functions
- Chapter 9: Monitoring and Control Functions
- Chapter 10: Communications
- Chapter 11: Cyber Security
- Chapter 12: Settings Application Software
- Chapter 13: Scheme Logic
- Chapter 14: Installation
- Chapter 15: Commissioning Instructions
- Chapter 16: Maintenance & Troubleshooting
- Chapter 17: Technical Specifications
- Appendix A: Symbols and Glossary
- Appendix B: Commissioning Record Forms
- Appendix C: Wiring diagrams

2.5 PRODUCT SCOPE

The P14D feeder management IED has been designed for the protection of a wide range of overhead lines and underground cables. The P14D provides integral directional and non-directional overcurrent, overvoltage and earth-fault protection and is suitable for application on solidly earthed, impedance earthed, Petersen coil earthed, and isolated systems.

In addition to the protection features, the devices include a comprehensive range of other features and measurements and recording facilities to aid with power system diagnosis and fault analysis.

The P14D can be used in various applications, depending on the chosen firmware. There are four different models according to which firmware is installed: P14DB, P14DG, P14DL, P14DZ

- The P14DB is the base device for general application
- The P14DG is for small generator applications
- The P14DL is for line protection
- The P14DZ is for high impedance earth fault applications

The P14D IED is supplied with the following hardware:

Item	Details
Case	30TE
Number of CT Inputs (1A or 5A)	4 (1 of these can be chosen to be standard or sensitive)
Number of VT inputs	4
Optically coupled digital inputs	8 to 13, depending on chosen options
Standard relay output contacts	8 to 12, depending on chosen options
Programmable function keys	3
Programmable LEDs	8

3 FEATURES AND FUNCTIONS

3.1 PROTECTION FUNCTIONS

The P14D models offer the following protection functions:

ANSI	IEC61850	Protection Function	P14DB	P14DG	P14DL	P14DZ
37		Undercurrent detection (low load)	Yes	Yes	Yes	Yes
46	NgcPTOC	Negative sequence overcurrent	Yes	Yes	Yes	Yes
46BC		Broken Conductor	Yes	Yes	Yes	Yes
49	ThmPTTR	Thermal Overload	Yes	Yes	Yes	Yes
50 SOTF		Switch onto Fault	Yes	Yes	Yes	Yes
50BF	RBRF	CB Failure	Yes	Yes	Yes	Yes
50	OcpPTOC	Definite time overcurrent protection	6 stages	6 stages	6 stages	6 stages
50N	EfdPTOC	Neutral/Ground Definite time overcurrent protection Measured and Derived (standard EF CT), Derived (SEF CT)	4 stages	4 stages	4 stages	4 stages
51	OcpPTOC	IDMT overcurrent protection (stages)	Yes	Yes	Yes	Yes
51N	EfdPTOC	Neutral/Ground IDMT overcurrent protection	Yes	Yes	Yes	Yes
67	OcpPTOC	Directional Phase Overcurrent	Yes	Yes	Yes	Yes
67N	EfdPTOC	Directional Neutral Overcurrent	Yes	Yes	Yes	Yes
		>Wattmetric Earth Fault	Yes	Yes	Yes	Yes
		Cold load pick up	Yes	Yes	Yes	Yes
VTS		VT supervision	Yes	Yes	Yes	Yes
CTS		CT supervision	Yes	Yes	Yes	Yes
64N	RefPDIF	Restricted Earth Fault	Yes	Yes	Yes	Yes
		Sensitive Earth Fault (with SEF CT only)	Yes	Yes	Yes	Yes
68		2nd Harmonic Blocking	Yes	Yes	Yes	Yes
27	VtpPhsPTUV	Undervoltage	3 stages	3 stages	3 stages	3 stages
47		Negative sequence overvoltage	Yes	Yes	Yes	Yes
59	VtpPhsPTOV	Overvoltage	3 stages	3 stages	3 stages	3 stages
59N	VtpResPTOV	Residual Overvoltage	3 stages	3 stages	3 stages	3 stages
81O	FrqPTOF	Overfrequency	Yes	Yes	Yes	Yes
81U	FrqPTUF	Underfrequency	Yes	Yes	Yes	Yes
81df/dt		Rate of change of frequency (df/dt)	Yes	Yes	Yes	Yes
81V	DfpPFRC	Undervoltage blocking of frequency protection	Yes	Yes	Yes	Yes
		Programmable curves	Yes	Yes	Yes	Yes
51V		Voltage Controlled Overcurrent	Yes	Yes	Yes	Yes
		Voltage Restrained Overcurrent	No	Yes	Yes	Yes
25		Check synchronising	No	Yes	Yes	Yes
32		Phase Directional Power	No	Yes	Yes	Yes
		Sensitive power	No	Yes	Yes	Yes
		Load Encroachment supervision (Load Blinders)	No	No	Yes	Yes

ANSI	IEC61850	Protection Function	P14DB	P14DG	P14DL	P14DZ
79	RREC	Autoreclose (3 phases)	No	No	4 shots	4 shots
21FL		Fault Locator	No	No	Yes	Yes
81RF	DfpPFRC	Frequency supervised rate of change of frequency	No	No	Yes	Yes
81RAV	DfpPFRC	Frequency supervised average rate of change of frequency	No	No	Yes	Yes
81R		Load Restoration	No	No	Yes	Yes
		Rate of change of voltage (dv/dt)	No	No	4 stages	4 stages
		Blocking scheme	Yes	Yes	Yes	Yes
		Programmable curves	Yes	Yes	Yes	Yes
		High Impedance Earth Fault	No	No	No	Yes
		CB Monitoring	Yes	Yes	Yes	Yes
86		Latching output contacts (Lockout)	Yes	Yes	Yes	Yes

3.2 CONTROL FUNCTIONS

The device offers the following control functions:

- Programmable Scheme Logic (PSL)
- Trip circuit supervision (TCS)
- 4 x Setting groups
- Watchdog contacts (1NO and 1NC)
- Self-monitoring (diagnostics)
- Manual CB control (local/remote)
- Read Only Mode

3.3 MEASUREMENT FUNCTIONS

The device offers the following measurement functions:

Measurement Function	Details
Measurements (Exact range of measurements depend on the device model)	- Measured currents and calculated sequence and RMS currents - Measured voltages and calculated sequence and RMS voltages - Power and energy quantities - Peak, fixed and rolling demand values - Frequency measurements - Others measurements
Disturbance records (waveform capture, oscillography) Channels / duration each or total / samples per cycle	9 / 10, 5 / 24
Fault Records	10
Maintenance Records	10
Event Records / Event logging	2048
Time Stamping of Opto-inputs	Yes

3.4 COMMUNICATION FUNCTIONS

The device offers the following communication functions:

Communication Function	Details
Local HMI	Yes
Multi-language HMI (English, French, German, Italian, Portuguese, Spanish, Russian)	Yes
Front port	USB
1st rear port	RS485 or IRIG-B
2nd rear port (optional)	RS485 or IRIG-B
Protocols available	IEC60870-5-103, IEC 61850, MODBUS, Courier, DNP3, DNP3 over Ethernet
IEC61850 available	option
Virtual inputs	32
Cyber security	Yes
Enhanced Studio (S1 Agile)	Yes

4 COMPLIANCE

The device has undergone a range of extensive testing and certification processes to ensure and prove compatibility with all target markets. Below is a list of standards with which the device is compliant. A detailed description of these criteria can be found in the Technical Specifications (on page 619) chapter.

Compliance Standards

Condition	Compliance
EMC compliance (compulsory)	2004/108/EC (demonstrated by EN50263:2000)
Product safety (compulsory)	2006/95/EC (demonstrated by EN60255-27:2005)
R&TTE Compliance (compulsory)	99/5/EC
EMC	EN50263, IEC 60255-22-1/2/3/4, IEC 61000-4-5/6/8/9/10, EN61000-4-3/18, IEEE/ANSI C37.90.1/2, ENV50204, EN55022
Product Safety for North America	UL/CL File No. UL/CUL E202519
Environmental conditions	IEC 60068-2-1/30/60/78
Power supply interruption	IEC 60255-11, IEC 61000-4-11
Type tests for Insulation, creepage distance and clearances, high voltage dielectric withstand, and impulse voltage withstand	IEC 60255-27:2005
Enclosure protection	IEC 60529:1992 – IP10, IP30, IP52
Mechanical robustness	IEC 60255-21-1/2/3
Documentation	IEC 60255-151

5 FUNCTIONAL OVERVIEW

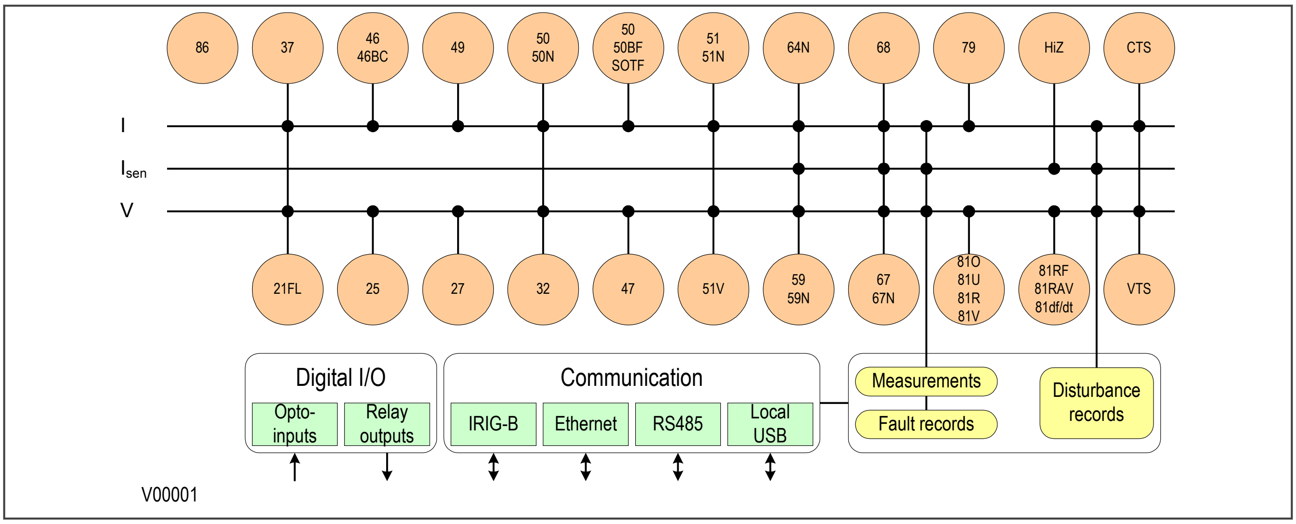


Figure 1: Functional Overview

6 ORDERING OPTIONS

Variants	Order Number										
	1 - 4	5	6	7	8	9	10	11	12-13	14	15
Model Type											
Feeder Management Protection IED - Directional	P14D										
Application											
Base		B									
Small Generator		G									
Load / Line Management		L									
HIF (SEF CT only)		Z									
Current/Voltage Transformers											
Standard Earth CT			1								
SEF CT			2								
Hardware Options											
EIA RS485				1							
Two ports - EIA RS 485 and Ethernet - Single channel Fibre/Copper				6							
Two ports - EIA RS485 & EIA RS485 / IRIG-B (demodulated)				8							
I/O Options											
Standard (8 logic inputs + 8 relay outputs)					A						
Total (11 logic inputs + 12 relay outputs)					B						
Total (11 logic inputs + 12 relay outputs) suitable for trip circuit supervision					C						
Total (13 logic inputs + 12 relay outputs)					D						
Communication protocol											
K-Bus						1					
Modbus						2					
IEC60870-5-103 (VDEW)						3					
DNP3.0						4					
IEC 61850 and Courier via rear K-Bus/RS485						6					
IEC 61850 over Ethernet and with IEC60870-5-103 via rear EIA RS485						7					
DNP3.0 over Ethernet and Courier via K-Bus/RS485						8					
Case											
30TE Flush (3 function keys with LEDs, 8 programmable LEDs)							C				
Software only							0				
30TE Flush (Adapted field voltage for KCEG retrofit)							3				
Language											
Multilingual (English, French, German, Spanish)								0			
Multilingual (English, Russian, Italian, Portuguese)								6			
Software Reference											
Initial release									50		
Customisation / Regionalisation											
Default										0	
Customer specific										A	
Hardware design suffix											
Initial release											A

V00004

SAFETY INFORMATION

CHAPTER 2

1 CHAPTER OVERVIEW

This chapter provides information about the safe handling of the equipment. The equipment must be properly installed and handled in order to maintain it in a safe condition and to keep personnel safe at all times. You must be familiar with information contained in this chapter before unpacking, installing, commissioning, or servicing the equipment.

This chapter contains the following sections:

2 HEALTH AND SAFETY

Personnel associated with the equipment must be familiar with the contents of this Safety Information chapter as well as the Safety Guide (SFTY/4L).

When electrical equipment is in operation, dangerous voltages are present in certain parts of the equipment. Improper use of the equipment and failure to observe warning notices will endanger personnel.

Only qualified personnel may work on or operate the equipment. Qualified personnel are individuals who:

- Are familiar with the installation, commissioning, and operation of the equipment and the system to which it is being connected.
- Are familiar with accepted safety engineering practises and are authorised to energise and de-energise equipment in the correct manner.
- Are trained in the care and use of safety apparatus in accordance with safety engineering practises
- Are trained in emergency procedures (first aid).

Although the documentation provides instructions for installing, commissioning and operating the equipment, it cannot cover all conceivable circumstances. In the event of questions or problems, do not take any action without proper authorisation. Please contact the appropriate technical sales office and request the necessary information.

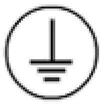
3 SYMBOLS

Throughout this manual you will come across the following symbols. You will also see these symbols on parts of the equipment.

Caution:
Refer to equipment documentation. Failure to do so could result in damage to the equipment

Warning:
Risk of electric shock

Earth terminal



Protective Earth terminal

4 INSTALLATION, COMMISSIONING AND SERVICING

4.1 LIFTING HAZARDS

Plan carefully, identify any possible hazards and determine whether the load needs to be moved at all. Look at other ways of moving the load to avoid manual handling. Use the correct lifting techniques and Personal Protective Equipment to reduce the risk of injury.

Many injuries are caused by:

- Lifting heavy objects
- Lifting things incorrectly
- Pushing or pulling heavy objects
- Using the same muscles repetitively

4.2 ELECTRICAL HAZARDS

Caution:
All personnel involved in installing, commissioning, or servicing of this equipment must be familiar with the correct working procedures.

Caution:
Consult the equipment documentation before installing, commissioning, or servicing the equipment.

Caution:
Always use the equipment in a manner specified by the manufacturer. Failure to do will jeopardise the protection provided by the equipment.

Warning:
Removal of equipment panels or covers may expose hazardous live parts. Do not touch until the electrical power is removed. Take extra care when there is unlocked access to the rear of the equipment.

Warning:
Isolate the equipment before working on the terminal strips.

Warning:
A suitable protective barrier should be provided for areas with restricted space, where there is a risk of electric shock due to exposed terminals.

Caution:
Disconnect power before disassembling. Disassembly of the equipment may expose sensitive electronic circuitry. Take suitable precautions against electrostatic voltage discharge (ESD) to avoid damage to the equipment.

Caution:
NEVER look into optical fibres. Always use optical power meters to determine operation or signal level.

Caution:
Insulation testing may leave capacitors charged up to a hazardous voltage. At the end of each part of the test, discharge the capacitors by reduce the voltage to zero, before disconnecting the test leads.

Caution:
Operate the equipment within the specified electrical and environmental limits.

Caution:
Before cleaning the equipment, ensure that no connections are energised. Use a lint free cloth dampened with clean water.

Note:
Contact fingers of test plugs are normally protected by petroleum jelly, which should not be removed.

4.3 UL/CSA/CUL REQUIREMENTS

Caution:
Equipment intended for rack or panel mounting is for use on a flat surface of a Type 1 enclosure, as defined by Underwriters Laboratories (UL).

Caution:
To maintain compliance with UL and CSA/CUL, the equipment should be installed using UL/CSA-recognised parts for: cables, protective fuses, fuse holders and circuit breakers, insulation crimp terminals, and replacement internal batteries.

Caution:
For external fuse protection, a UL or CSA Listed fuse must be used. The listed protective fuse type is: Class J time delay fuse, with a maximum current rating of 15 A and a minimum DC rating of 250 V dc (for example type AJT15).

Caution:
Where UL/CSA listing of the equipment is not required, a high rupture capacity (HRC) fuse type with a maximum current rating of 16 Amps and a minimum dc rating of 250 V dc may be used (for example Red Spot type NIT or TIA.

4.4 EQUIPMENT CONNECTIONS

Warning:
Terminals exposed during installation, commissioning and maintenance may present a hazardous voltage unless the equipment is electrically isolated.

Caution:
Clamping screws of heavy duty terminal block connectors using M4 screws must be tightened to a nominal torque of 1.3 Nm.

Caution:
Always use insulated crimp terminations for voltage and current connections.

Caution:
Always use the correct crimp terminal and tool according to the wire size.

Caution:
Watchdog (self-monitoring) contacts are provided to indicate the health of the device. We strongly recommend that you hard wire these contacts into the substation's automation system, for alarm purposes.

4.5 PROTECTION CLASS 1 EQUIPMENT REQUIREMENTS

Caution:
Earth the equipment with the supplied PCT (Protective Conductor Terminal).

Caution:
Do not remove the PCT.

Caution:
The PCT is sometimes used to terminate cable screens. Always check the PCT's integrity after adding or removing such earth connections.

Caution:
Use a locknut or similar mechanism to ensure the integrity of M4 stud-connected PCTs.

Caution:
The recommended minimum PCT wire size is 2.5 mm² for countries whose mains supply is 230 V (e.g. Europe) and 3.3 mm² for countries whose mains supply is 110 V (e.g. North America). This may be superseded by local or country wiring regulations.

Caution:
The PCT connection must have low-inductance and be as short as possible.

Caution:
All connections to the equipment must have a defined potential. Connections that are pre-wired, but not used, should be earthed when binary inputs and output relays are isolated. When binary inputs and output relays are connected to a common potential, unused pre-wired connections should be connected to the common potential of the grouped connections.

4.6 PRE-ENERGIZATION CHECKLIST

Caution:
Check voltage rating/polarity (rating label/equipment documentation).

Caution:
Check CT circuit rating (rating label) and integrity of connections.

Caution:
Check protective fuse or miniature circuit breaker (MCB) rating.

Caution:
Check integrity of the PCT connection.

Caution:
Check voltage and current rating of external wiring, ensuring it is appropriate for the application.

4.7 PERIPHERAL CIRCUITRY

Warning:
Do not open the secondary circuit of a live CT since the high voltage produced may be lethal to personnel and could damage insulation. The secondary of the line CT should be shorted before opening any connections to it.

Note:
For most Alstom equipment with ring-terminal connections, the threaded terminal block for current transformer termination has automatic CT shorting on removal of the module. Therefore external shorting of the CTs may not be required. Check the equipment documentation first to see if this applies.

Caution:
Where external components, such as resistors or voltage dependent resistors (VDRs), are used, these may present a risk of electric shock or burns, if touched.

Warning:
Take extreme care when using external test blocks and test plugs such as the MMLG, MMLB and MiCOM ALSTOM P990, as hazardous voltages may be exposed. CT shorting links must be in place before inserting or removing MMLB test plugs, to avoid potentially lethal voltages.

4.8 UPGRADING/SERVICING

Warning:
Modules, PCBs, or expansion boards must not be inserted into or withdrawn from the equipment while energised, as this may result in damage to the equipment. Hazardous live voltages would also be exposed, thus endangering personnel.

Caution:
Internal modules and assemblies can be heavy. Take care when inserting or removing modules into or out of the IED.

5 DECOMMISSIONING AND DISPOSAL

Caution:
Before decommissioning, isolate completely the equipment power supplies (both poles of any dc supply). The auxiliary supply input may have capacitors in parallel, which may still be charged. To avoid electric shock, discharge the capacitors via the external terminals prior to decommissioning.

Avoid incineration or disposal to water courses. The equipment should be disposed of in a safe, responsible, in an environmentally friendly manner, and if applicable, in accordance with country-specific regulations.

HARDWARE DESIGN

CHAPTER 3

1 CHAPTER OVERVIEW

This chapter provides information about the product's hardware design.

This chapter contains the following sections:

2 HARDWARE ARCHITECTURE

The main components comprising devices based on the P40Agile platform are as follows:

- The housing, consisting of a front panel and connections at the rear
- The Main processor module consisting of the main CPU (Central Processing Unit), memory and an interface to the front panel HMI (Human Machine Interface)
- An I/O board consisting of output relay contacts and digital opto-inputs
- Communication modules
- Power supply

All modules are connected by a parallel data and address bus, which allows the processor module to send and receive information to and from the other modules as required. There is also a separate serial data bus for conveying sampled data from the input module to the CPU. These parallel and serial databuses are shown as a single interconnection module in the figure, which shows the modules and the flow of information between them.

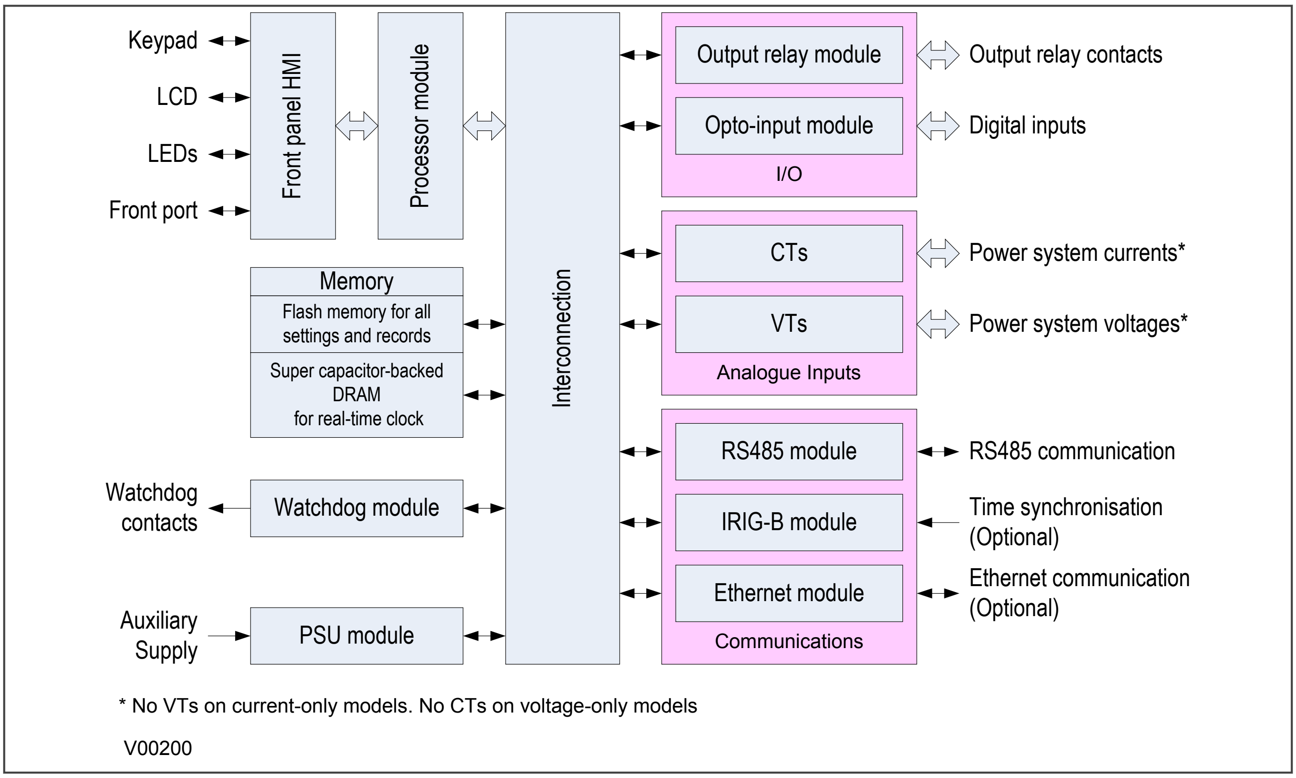


Figure 2: Hardware design overview

2.1 MEMORY AND REAL TIME CLOCK

The IED contains flash memory for storing the following operational information:

- Fault, Maintenance and Disturbance Records
- Events
- Alarms
- Measurement values
- Latched trips
- Latched contacts

Flash memory is non-volatile and therefore no backup battery is required.

A dedicated Supercapacitor keeps the on board real time clock operational for up to four days after power down.

3 MECHANICAL IMPLEMENTATION

All products based on the P40Agile platform have common hardware architecture. The hardware comprises two main parts; the cradle and the housing.

The cradle consists of the front panel which is attached to a carrier board into which all of the hardware boards and modules are connected. The products have been designed such that all the boards and modules comprising the product are fixed into the cradle and are not intended to be removed or inserted after the product has left the factory.

The housing comprises the housing metalwork and connectors at the rear into which the boards in the cradle plug into.

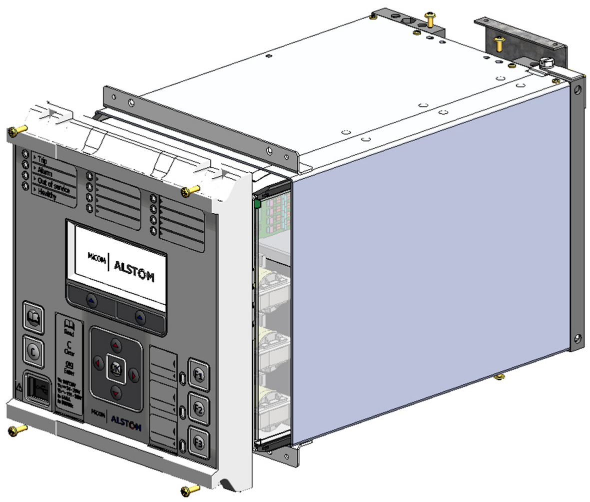


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Figure 3: Exploded view of IED

3.1 HOUSING VARIANTS

The P40 Agile range of products are implemented in one of two case sizes. Case dimensions for industrial products usually follow modular measurement units based on rack sizes. These are: U for height and TE for width, where:

- 1U = 1.75" = 44.45 mm
- 1TE = 0.2 inches = 5.08 mm

The products are available in panel-mount or standalone versions. All products are nominally 4U high. This equates to 177.8 mm or 7 inches.

The cases are pre-finished steel with a conductive covering of aluminium and zinc. This provides good grounding at all joints, providing a low impedance path to earth that is essential for performance in the presence of external noise.

The case width depends on the product type and its hardware options. There are two different case widths for the described range of products: 20TE and 30TE. The products in the P40 Agile range can be used as a

K-series refit and the cases, cradle, and pin-outs are completely inter-compatible. The case dimensions and compatibility criteria are as follows:

Case width (TE)	Case width (mm)	Equivalent K series	Products
20TE	102.4 mm (4 inches)	KCGG140/142	P14N
30TE	154.2 mm (6 inches)	KCEG140/142	P14N (with extra I/O), P14D

3.2 30TE REAR PANEL

The 30TE rear panel consists of either:

- Three MIDOS heavy duty terminal blocks
- Two MIDOS heavy duty terminal blocks and a communication board
- Two MIDOS heavy duty terminal blocks and a blanking panel

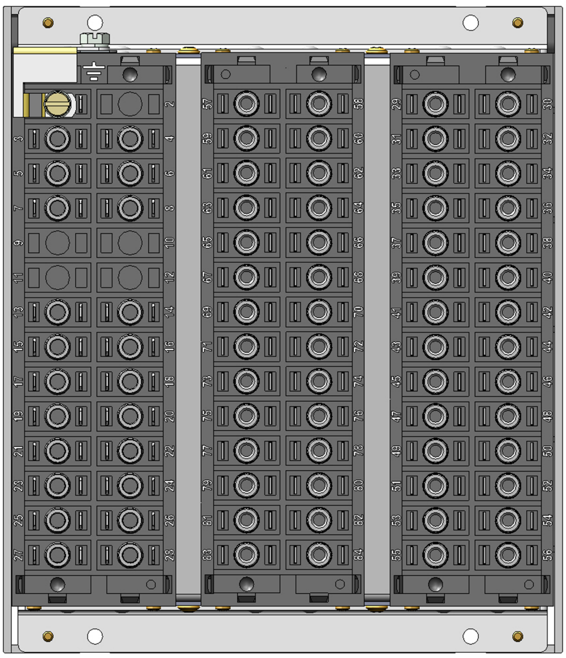

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Figure 4: 30TE Three-MIDOS block rear panel

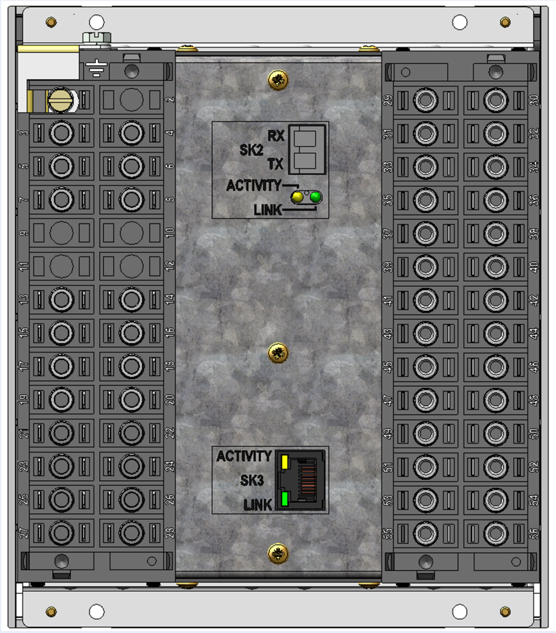

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Figure 5: 30TE Two-MIDOS block + communications rear panel

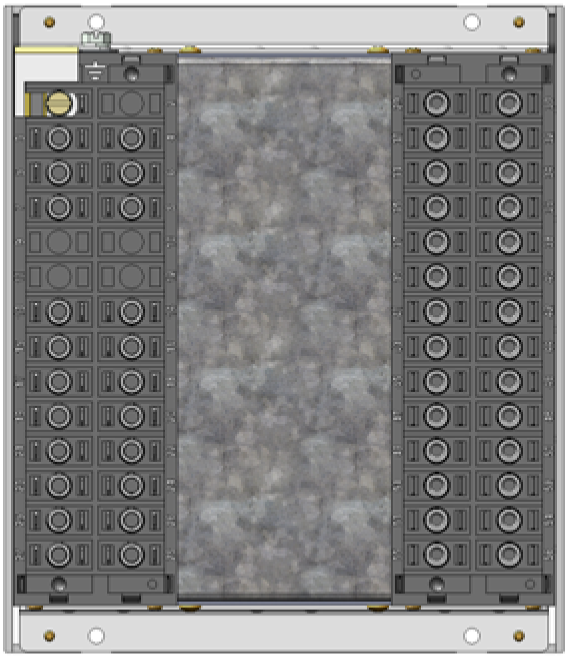

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Figure 6: 30TE Two-MIDOS block + blanking plate

4 TERMINAL CONNECTIONS

4.1 I/O OPTIONS

Component	I/O option A	I/O option B	I/O option C	I/O option D
Digital inputs	8 (1 group of 3 and 1 group of 5)	11 (2 groups of 3 and 1 group of 5)	11 (1 group of 3, 1 group of 5 and 3 individual)	13 (1 group of 3 and 2 groups of 5)
Output relays	8	12	12	12

> *Note:*
> *I/O option C is suitable for Trip Circuit Supervision (TCS) applications*

4.2 P14D HARDWARE CONFIGURATION 1

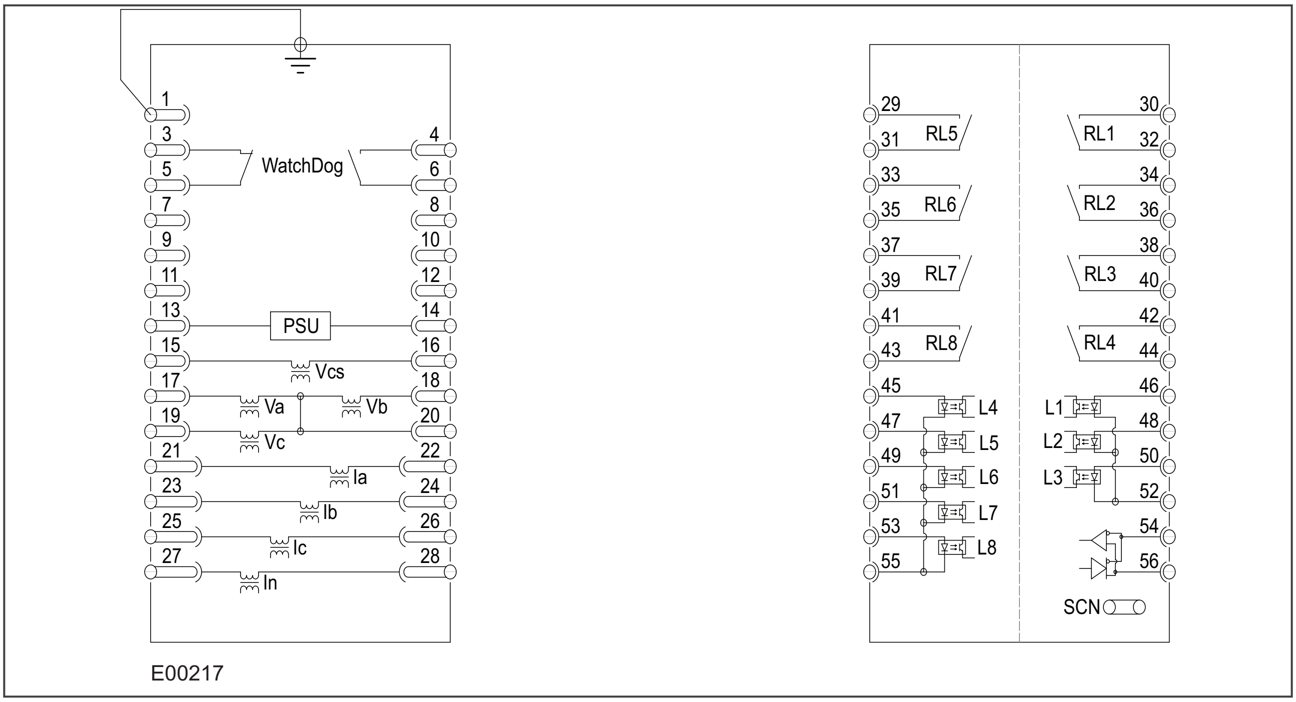


Figure 7: P14D with I/O option A

Terminal Block Left (as viewed from rear)

Terminal	Description
1	Earth
2	Not used
3 + 5	Watchdog, normally closed
4 + 6	Watchdog, normally open
7 to 12	Not used
13 + 14	Power Supply Unit
15 + 16	Voltage Transformer Vcs
17 + 18	Voltage Transformers Va and Vb

Terminal	Description
19 + 20	Voltage Transformer Vc
21 + 22	Current Transformer Ia
23 + 24	Current Transformer Ib
25 + 26	Current Transformer Ic
27 + 28	Current Transformer In

Terminal Block Right (as viewed from rear)

Terminal	Description
30 + 32	Relay 1, normally open
34 + 36	Relay 2, normally open
38 + 40	Relay 3, normally open
42 + 44	Relay 4, normally open
29 + 31	Relay 5, normally open
33 + 35	Relay 6, normally open
37 + 39	Relay 7, normally open
41 + 43	Relay 8, normally open
46 + 52	Opto-input L1 (group 1)
48 + 52	Opto-input L2 (group 1)
50 + 52	Opto-input L3 (group 1)
45 + 55	Opto-input L4 (group 2)
47 + 55	Opto-input L5 (group 2)
49 + 55	Opto-input L6 (group 2)
51 + 55	Opto-input L7 (group 2)
53 + 55	Opto-input L8 (group 2)
54 + 56	EIA(RS)485 or Demodulated IRIG-B

4.3 P14D HARDWARE CONFIGURATION 2

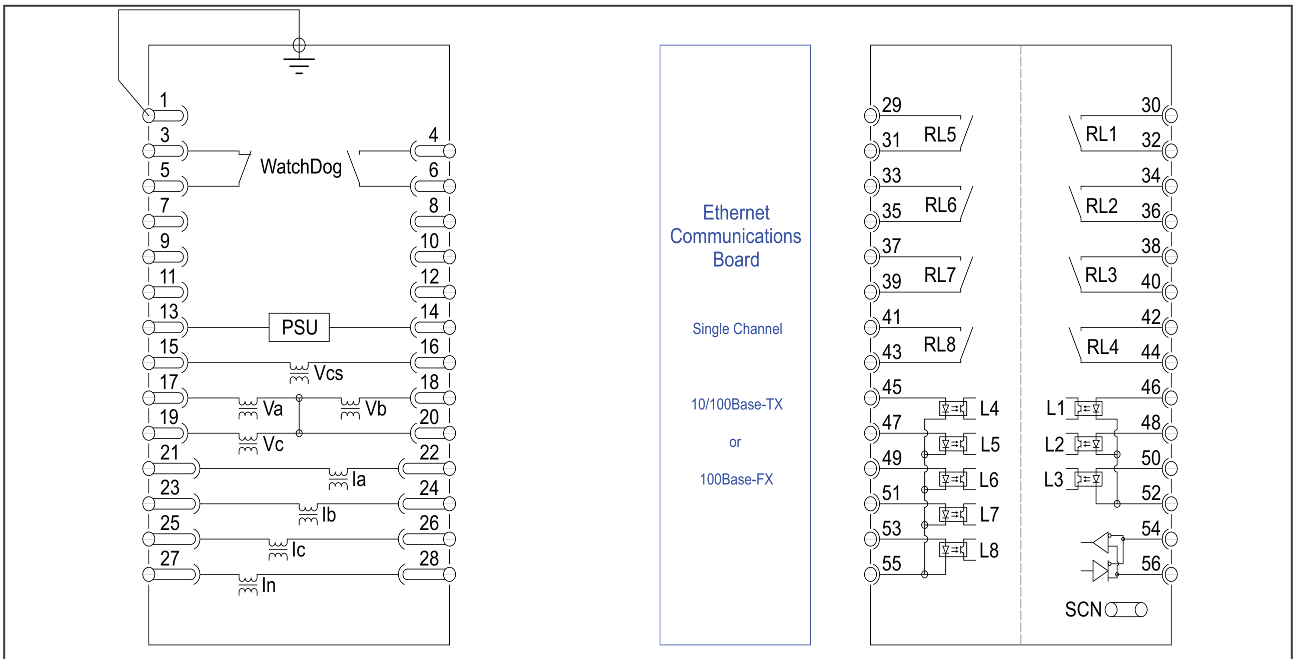


Figure 8: P14D with I/O option A + Ethernet communications

Terminal Block Left (as viewed from rear)

Terminal	Description
1	Earth
2	Not used
3 + 5	Watchdog, normally closed
4 + 6	Watchdog, normally open
7 to 12	Not used
13 + 14	Power Supply Unit
15 + 16	Voltage Transformer Vcs
17 + 18	Voltage Transformers Va and Vb
19 + 20	Voltage Transformer Vc
21 + 22	Current Transformer Ia
23 + 24	Current Transformer Ib
25 + 26	Current Transformer Ic
27 + 28	Current Transformer In

Terminal Block Right (as viewed from rear)

Terminal	Description
30 + 32	Relay 1, normally open
34 + 36	Relay 2, normally open
38 + 40	Relay 3, normally open
42 + 44	Relay 4, normally open
29 + 31	Relay 5, normally open

Terminal	Description
33 + 35	Relay 6, normally open
37 + 39	Relay 7, normally open
41 + 43	Relay 8, normally open
46 + 52	Opto-input L1 (group 1)
48 + 52	Opto-input L2 (group 1)
50 + 52	Opto-input L3 (group 1)
45 + 55	Opto-input L4 (group 2)
47 + 55	Opto-input L5 (group 2)
49 + 55	Opto-input L6 (group 2)
51 + 55	Opto-input L7 (group 2)
53 + 55	Opto-input L8 (group 2)
54 + 56	EIA(RS)485 or Demodulated IRIG-B

4.4 P14D HARDWARE CONFIGURATION 3

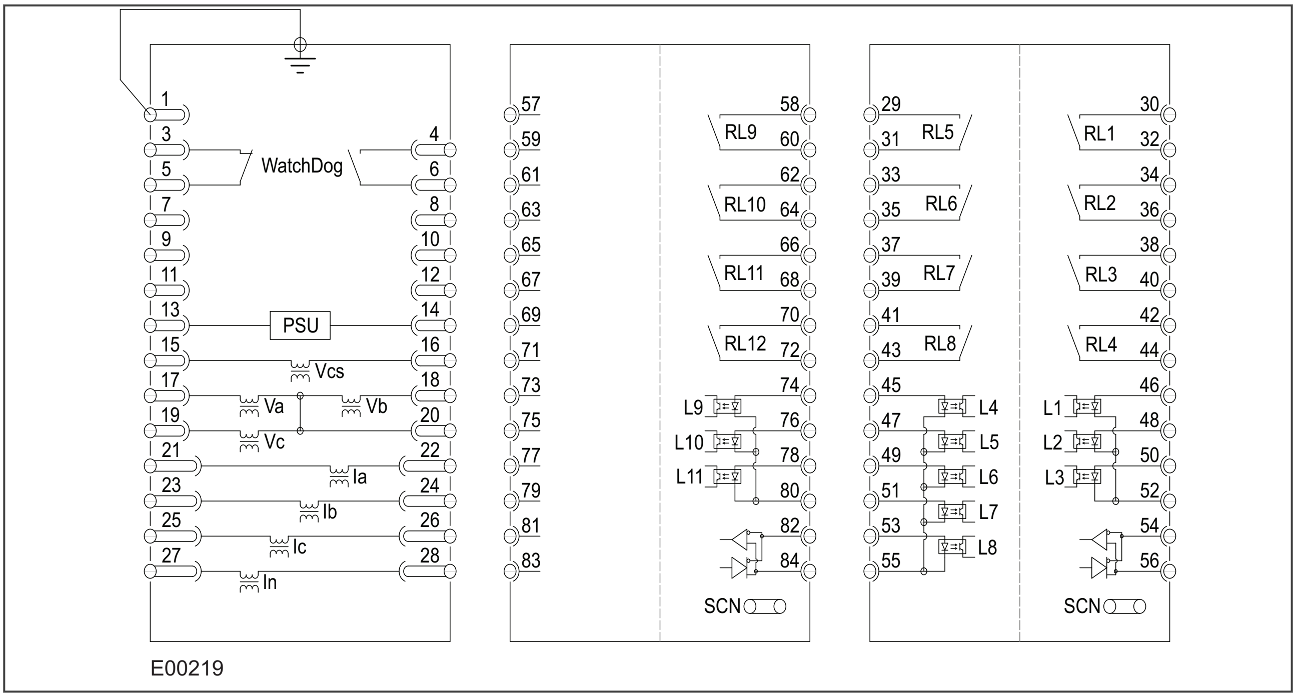


Figure 9: P14D with I/O option B

Terminal Block Left (as viewed from rear)

Terminal	Description
1	Earth
2	Not used
3 + 5	Watchdog, normally closed
4 + 6	Watchdog, normally open
7 to 12	Not used
13 + 14	Power Supply Unit
15 + 16	Voltage Transformer Vcs

Terminal	Description
17 + 18	Voltage Transformers Va and Vb
19 + 20	Voltage Transformer Vc
21 + 22	Current Transformer Ia
23 + 24	Current Transformer Ib
25 + 26	Current Transformer Ic
27 + 28	Current Transformer In

Terminal Block Right (as viewed from rear)

Terminal	Description
30 + 32	Relay 1, normally open
34 + 36	Relay 2, normally open
38 + 40	Relay 3, normally open
42 + 44	Relay 4, normally open
29 + 31	Relay 5, normally open
33 + 35	Relay 6, normally open
37 + 39	Relay 7, normally open
41 + 43	Relay 8, normally open
46 + 52	Opto-input L1 (group 1)
48 + 52	Opto-input L2 (group 1)
50 + 52	Opto-input L3 (group 1)
45 + 55	Opto-input L4 (group 2)
47 + 55	Opto-input L5 (group 2)
49 + 55	Opto-input L6 (group 2)
51 + 55	Opto-input L7 (group 2)
53 + 55	Opto-input L8 (group 2)
54 + 56	EIA(RS)485 or Demodulated IRIG-B

Terminal Block Centre

Terminal	Description
58 + 60	Relay 9, normally open
62 + 64	Relay 10, normally open
66 + 68	Relay 11, normally open
70 + 72	Relay 12, normally open
74 + 80	Opto-input L9 (group 3)
76 + 80	Opto-input L10 (group 3)
78 + 80	Opto-input L11 (group 3)
82 + 84	EIA(RS)485 or Demodulated IRIG-B
The rest	Not used

4.5 P14D HARDWARE CONFIGURATION 4

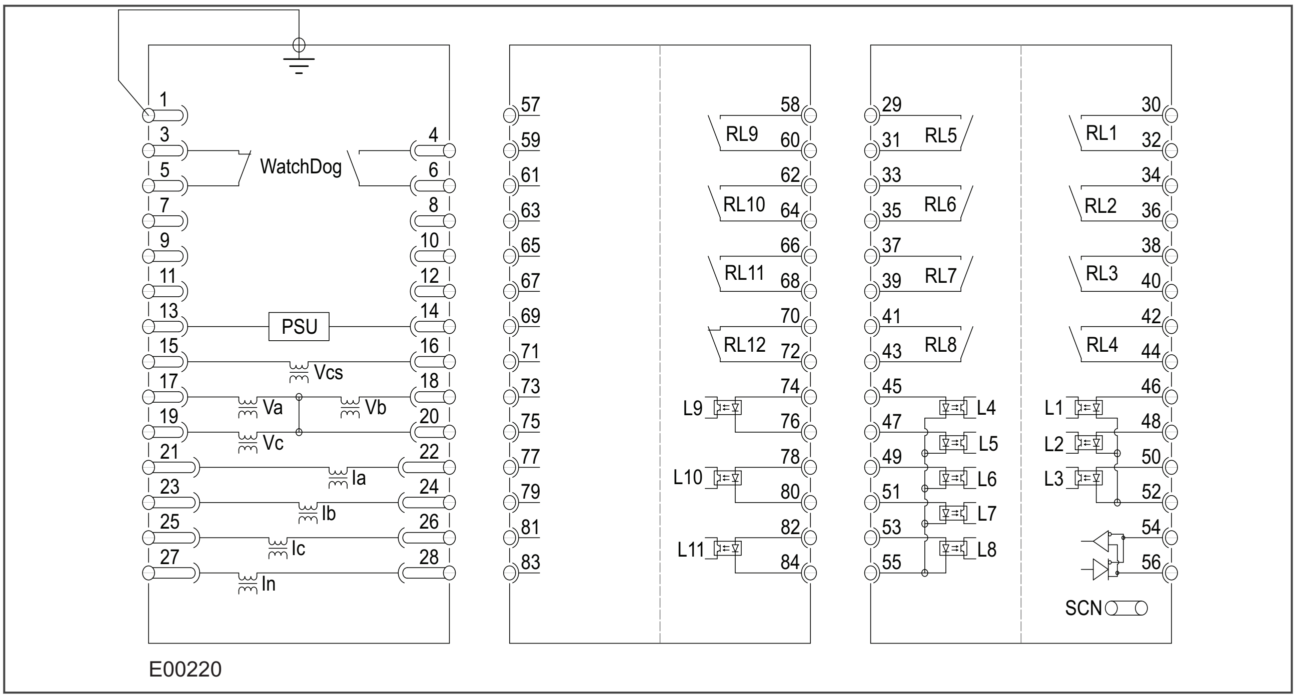


Figure 10: P14D with I/O option C

Terminal Block Left (as viewed from rear)

Terminal	Description
1	Earth
2	Not used
3 + 5	Watchdog, normally closed
4 + 6	Watchdog, normally open
7 to 12	Not used
13 + 14	Power Supply Unit
15 + 16	Voltage Transformer Vcs
17 + 18	Voltage Transformers Va and Vb
19 + 20	Voltage Transformer Vc
21 + 22	Current Transformer Ia
23 + 24	Current Transformer Ib
25 + 26	Current Transformer Ic
27 + 28	Current Transformer In

Terminal Block Right (as viewed from rear)

Terminal	Description
30 + 32	Relay 1, normally open
34 + 36	Relay 2, normally open
38 + 40	Relay 3, normally open
42 + 44	Relay 4, normally open
29 + 31	Relay 5, normally open

Terminal	Description
33 + 35	Relay 6, normally open
37 + 39	Relay 7, normally open
41 + 43	Relay 8, normally open
46 + 52	Opto-input L1 (group 1)
48 + 52	Opto-input L2 (group 1)
50 + 52	Opto-input L3 (group 1)
45 + 55	Opto-input L4 (group 2)
47 + 55	Opto-input L5 (group 2)
49 + 55	Opto-input L6 (group 2)
51 + 55	Opto-input L7 (group 2)
53 + 55	Opto-input L8 (group 2)
54 + 56	EIA(RS)485 or Demodulated IRIG-B

Terminal Block 3 Centre

Terminal	Description
58 + 60	Relay 9, normally open
62 + 64	Relay 10, normally open
66 + 68	Relay 11, normally open
70 + 72	Relay 12, normally open
74 + 76	Opto-input L9
78 + 80	Opto-input L10
82 + 84	Opto-input L11
The rest	Not used

4.6 P14D HARDWARE CONFIGURATION 5

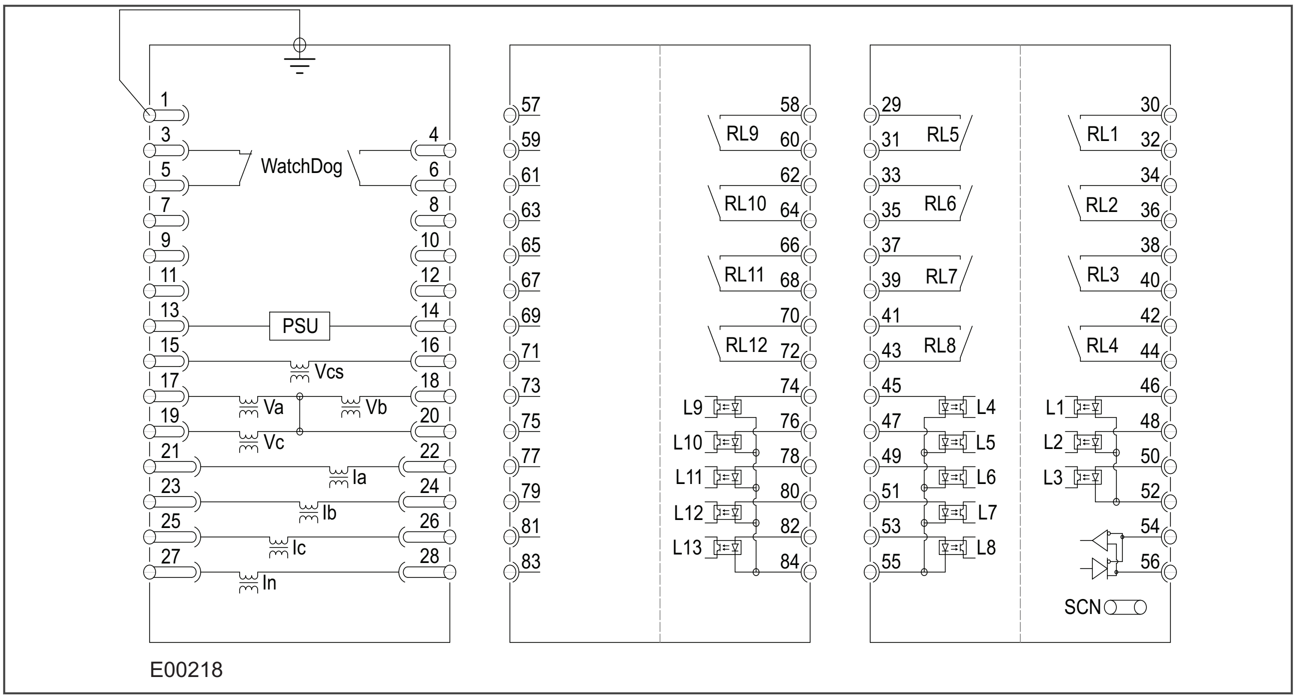


Figure 11: P14D with I/O option D

Terminal Block Left (as viewed from rear)

Terminal	Description
1	Earth
2	Not used
3 + 5	Watchdog, normally closed
4 + 6	Watchdog, normally open
7 to 12	Not used
13 + 14	Power Supply Unit
15 + 16	Voltage Transformer Vcs
17 + 18	Voltage Transformers Va and Vb
19 + 20	Voltage Transformer Vc
21 + 22	Current Transformer Ia
23 + 24	Current Transformer Ib
25 + 26	Current Transformer Ic
27 + 28	Current Transformer In

Terminal Block Right (as viewed from rear)

Terminal	Description
30 + 32	Relay 1, normally open
34 + 36	Relay 2, normally open
38 + 40	Relay 3, normally open
42 + 44	Relay 4, normally open
29 + 31	Relay 5, normally open

Terminal	Description
33 + 35	Relay 6, normally open
37 + 39	Relay 7, normally open
41 + 43	Relay 8, normally open
46 + 52	Opto-input L1 (group 1)
48 + 52	Opto-input L2 (group 1)
50 + 52	Opto-input L3 (group 1)
45 + 55	Opto-input L4 (group 2)
47 + 55	Opto-input L5 (group 2)
49 + 55	Opto-input L6 (group 2)
51 + 55	Opto-input L7 (group 2)
53 + 55	Opto-input L8 (group 2)
54 + 56	EIA(RS)485 or Demodulated IRIG-B

Terminal Block Centre

Terminal	Description
58 + 60	Relay 9, normally open
62 + 64	Relay 10, normally open
66 + 68	Relay 11, normally open
70 + 72	Relay 12, normally open
74 + 84	Opto-input L9 (group 3)
76 + 84	Opto-input L10 (group 3)
78 + 84	Opto-input L11 (group 3)
80 + 84	Opto-input L12 (group 3)
82 + 84	Opto-input L13 (group 3)
The rest	Not used

5 FRONT PANEL

5.1 30TE FRONT PANEL

R00206

Figure 12: Front panel (30TE)

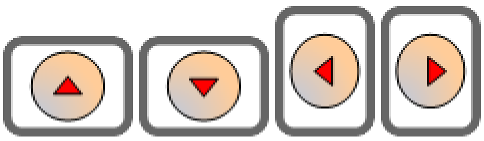
The figures show the front panels for the 30TE variant.

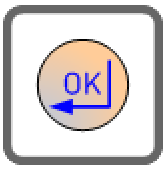
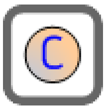
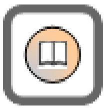
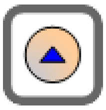
It consists of:

- LCD display
- Keypad
- USB port
- 4 x fixed function tri-colour LEDs
- 8 x programmable tri-colour LEDs
- 3 x function keys
- 3 x tri-colour LEDs for the function keys

5.2 KEYPAD

The keypad consists of the following keys:

4 arrow keys to navigate the menus	

An enter key for executing the chosen option	
A clear key for clearing the last command	
A read key for viewing larger blocks of text (arrow keys now used for scrolling)	
2 hot keys for scrolling through the default display and for control of setting groups	

5.3 LIQUID CRYSTAL DISPLAY

The LCD is a high resolution monochrome display with 16 characters by 3 lines and controllable back light.

5.4 USB PORT

The USB port is situated on the front panel in the bottom left hand corner, and is used to communicate with a locally connected PC. It has two main purposes:

- To transfer settings information to/from the PC from/to the device.
- For downloading firmware updates and menu text editing.

The port is intended for temporary connection during testing, installation and commissioning. It is not intended to be used for permanent SCADA communications. This port supports the Courier communication protocol only. Courier is a proprietary communication protocol to allow communication with a range of protection equipment, and between the device and the Windows-based support software package.

You can connect the unit to a PC with a USB cable up to 15 m in length.

The inactivity timer for the front port is set to 15 minutes. This controls how long the unit maintains its level of password access on the front port. If no messages are received on the front port for 15 minutes, any password access level that has been enabled is cancelled.

Note:
The front USB port does not support automatic extraction of event and disturbance records, although this data can be accessed manually.

Caution:
When not in use, always close the cover of the USB port to prevent contamination.

5.5 FIXED FUNCTION LEDS

Four fixed-function LEDs on the left-hand side of the front panel indicate the following conditions.

- Trip (Red) switches ON when the IED issues a trip signal. It is reset when the associated fault record is cleared from the front display. Also the trip LED can be configured as self-resetting.
- Alarm (Yellow) flashes when the IED registers an alarm. This may be triggered by a fault, event or maintenance record. The LED flashes until the alarms have been accepted (read), then changes to constantly ON. When the alarms are cleared, the LED switches OFF.
- Out of service (Yellow) is ON when the IED's protection is unavailable.
- Healthy (Green) is ON when the IED is in correct working order, and should be ON at all times. It goes OFF if the unit’s self-tests show there is an error in the hardware or software. The state of the healthy LED is reflected by the watchdog contacts at the back of the unit.

5.6 FUNCTION KEYS

The programmable function keys are available for custom use for devices using 30TE cases or larger.

Factory default settings associate specific functions to these keys, but by using programmable scheme logic, you can change the default functions of these keys to fit specific needs. Adjacent to these function keys are programmable tri-colour LEDs, which are set to be associated with their respective function keys.

5.7 PROGRAMABLE LEDS

The device has a number of programmable LEDs. All of the programmable LEDs on the unit are tri-colour and can be set to RED, YELLOW or GREEN.

In the 20TE case, four programmable LEDs are available. In 30TE, eight are available.

CONFIGURATION

CHAPTER 4

1 CHAPTER OVERVIEW

Each product has different configuration parameters according to the functions it has been designed to perform. There is, however, a common methodology used across the entire product series to set these parameters.

This chapter describes an overview of this common methodology, as well as providing concise instructions of how to configure the device.

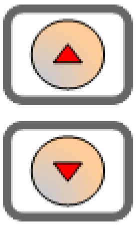
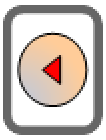
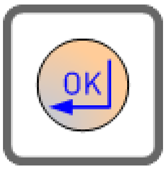
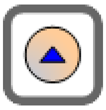
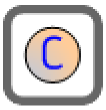
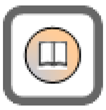
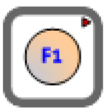
This chapter contains the following sections:

2 USING THE HMI PANEL

Using the HMI, you can:

- Display and modify settings
- View the digital I/O signal status
- Display measurements
- Display fault records
- Reset fault and alarm indications

The keypad provides full access to the device functionality by means of a range of menu options. The information is displayed on the LCD.

Keys	Description	Function
	Up and down cursor keys	To change the menu level or change between settings in a particular column, or changing values within a cell
	Left and right cursor keys	To change default display, change between column headings, or changing values within a cell
	ENTER key	For changing and executing settings
	Hotkeys	For executing commands and settings for which shortcuts have been defined
	Cancel key	To return to column header from any menu cell
	Read key	To read alarm messages
	Function keys (not for 20TE devices)	For executing user programmable functions

Note:
As the LCD display has a resolution of 16 characters by 3 lines, some of the information is in a condensed mnemonic form.

2.1 NAVIGATING THE HMI PANEL

The cursor keys are used to navigate the menus. These keys have an auto-repeat function if held down continuously. This can be used to speed up both setting value changes and menu navigation. The longer the key is held pressed, the faster the rate of change or movement.

The navigation map below shows how to navigate the menu items.

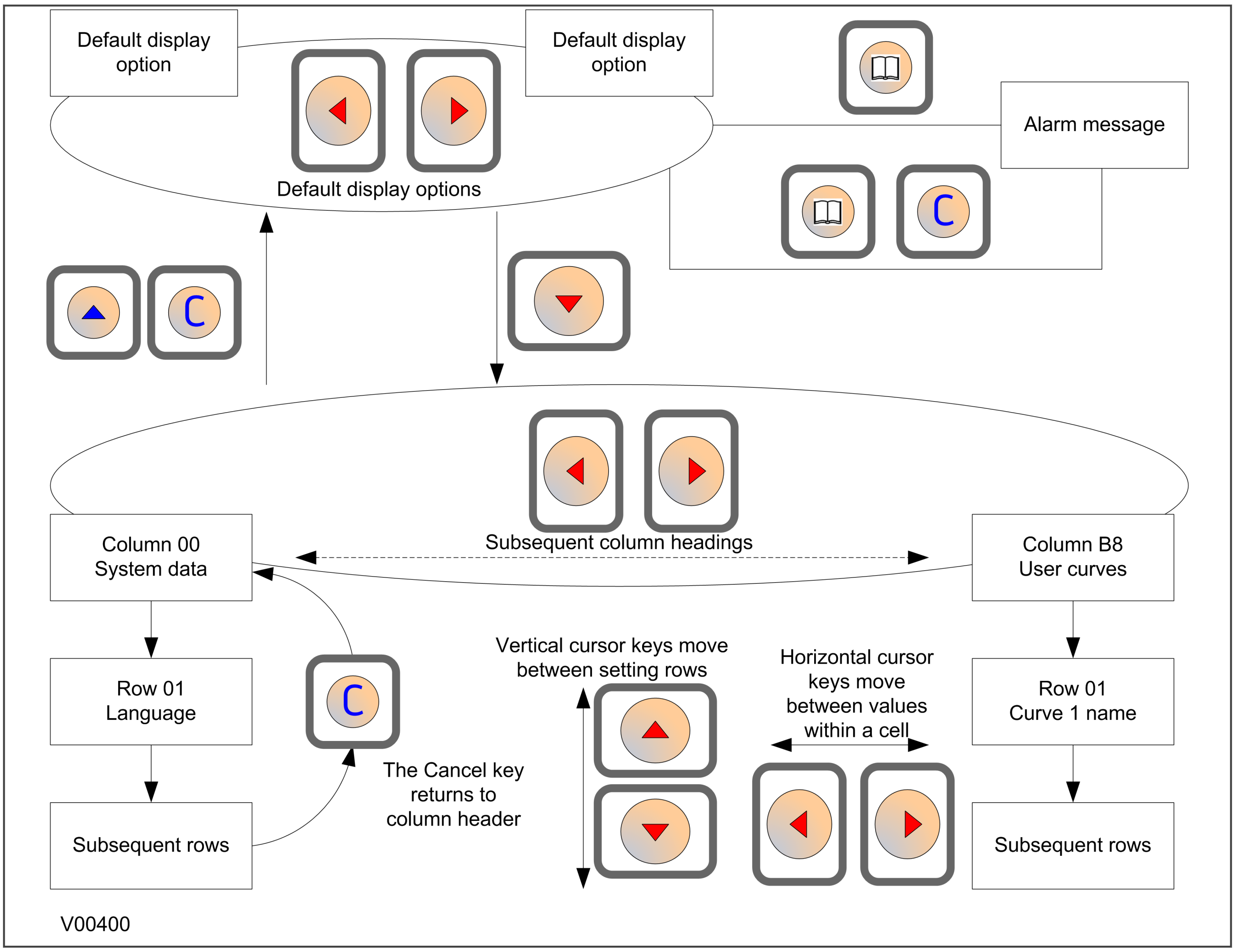


Figure 13: Menu navigation

2.2 GETTING STARTED

When you first start the IED, it will go through its power up procedure. After a few seconds it will settle down into one of the top level menus. There are two menus at this level:

- The Alarms menu for when there are alarms present
- The default display menu for when there are no alarms present.

If there are alarms present, the yellow Alarms LED will be flashing and the menu display will read as follows:

```
Alarms / Faults
Present
HOTKEY
```

Even though the device itself should be in full working order when you first start it, an alarm could still be present, for example, if there is no network connection for a device fitted with a network card. If this is the case, you can read the alarm by pressing the 'Read' key.

```
ALARMS
NIC Link Fail
```

If the device is fitted with an Ethernet card (not applicable to 20TE IEDs), the only way you will be able to completely clear this alarm will be by connecting the device into an Ethernet network. This is also the only way you will be able to get into the default display menu.

If there are other alarms present, these must also be cleared before you can get into the default display menu options.

2.3 DEFAULT DISPLAY

The default display menu contains a range of possible options that you can choose to be the default display. The options available are:

NERC Compliant banner

The IED is delivered with a NERC-compliant default display:

```
ACCESS ONLY FOR
AUTHORISED USERS
HOTKEY
```

Date and time

For example:

```
11:09:15
23 Nov 2011
HOTKEY
```

Description (user-defined)

For example:

```
Description
MiCOM P14NB
HOTKEY
```

Plant reference (user-defined)

For example:

```
Plant Reference
MiCOM
HOTKEY
```

Access Level

For example:

```
Access Level
3
HOTKEY
```

In addition to the above, there are also displays for the system voltages, currents, power and frequency etc., depending on the device model.

2.4 DEFAULT DISPLAY NAVIGATION

The default display navigation is best represented diagrammatically.

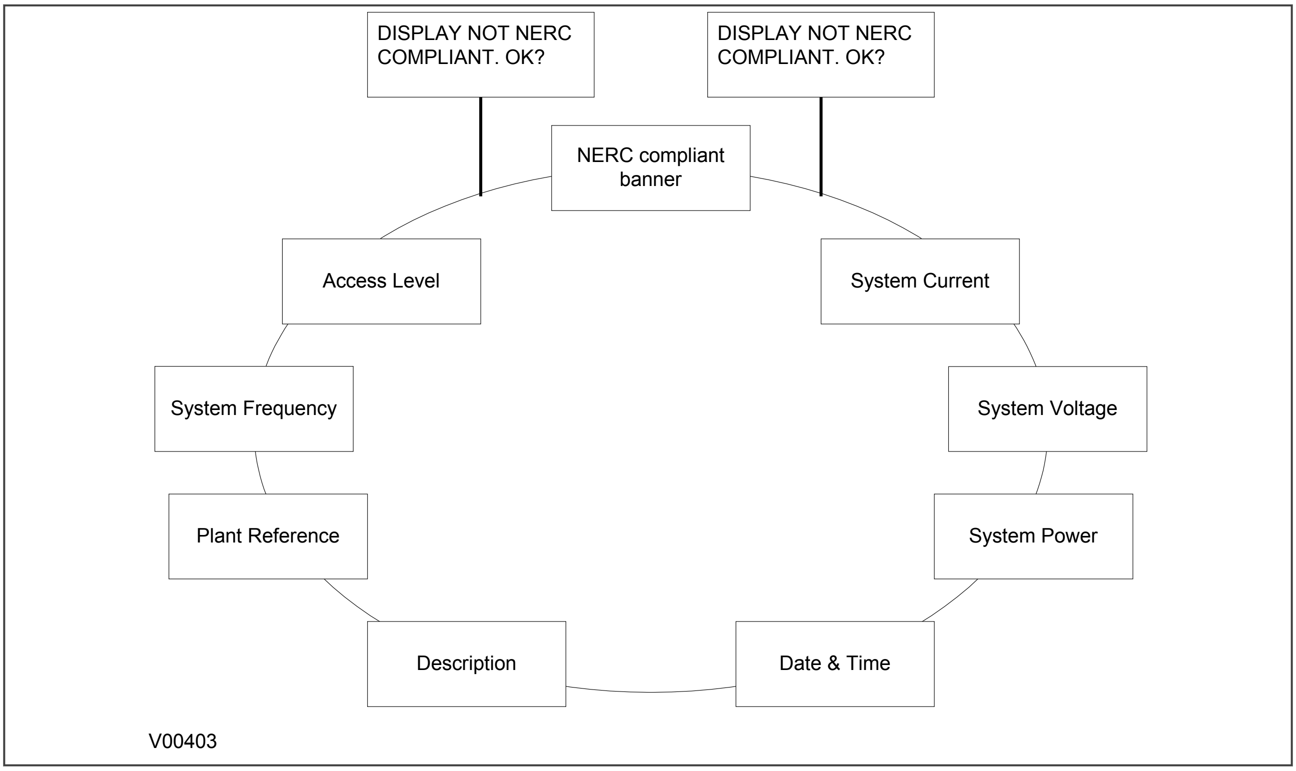


Figure 14: Default display navigation

If the device is not yet configured for NERC compliance (see Cyber-Security chapter (on page 473)) a warning will appear when moving from the "NERC compliant" banner. The warning message is as follows:

```
DISPLAY NOT NERC
COMPLIANT. OK?
```

You will have to confirm with the ENTER button before you can go any further.

> *Note:*
> *Whenever the IED has an uncleared alarm the default display is replaced by the text Alarms/ Faults present. You cannot override this default display. However, you can enter the menu structure from the default display, even if the display shows the Alarms/Faults present message.*

2.5 PASSWORD ENTRY

Configuring the default display (in addition to modification of other settings) requires level 3 access. You will be prompted for a password before you can make any changes, as follows. The default level 3 password is AAAA.

```
Enter Password
```

1. A flashing cursor shows which character field of the password can be changed. Press the up or down cursor keys to change each character (tip: pressing the up arrow once will return an upper case "A" as required by the default level 3 password).
2. Use the left and right cursor keys to move between the character fields of the password.
3. Press the Enter key to confirm the password. If you enter an incorrect password, an invalid password message is displayed then the display reverts to **Enter password**. Upon entering a valid password a message appears indicating that the password is correct and which level of access has been unlocked. If this level is sufficient to edit the selected setting, the display returns to the setting page to allow the edit to continue. If the correct level of password has not been entered, the password prompt page appears again.
4. To escape from this prompt press the **Clear** key. Alternatively, enter the password using **System data > Password**. If the keypad is inactive for 15 minutes, the password protection of the front panel user interface reverts to the default access level.

To manually reset the password protection to the default level, select **System data > Password**, then press the **Clear** key instead of entering a password.

2.6 PROCESSING ALARMS AND FAULT RECORDS

If there are any alarm messages, they will appear on the default display and the yellow alarm LED flashes. The alarm messages can either be self-resetting or latched. If they are latched, they must be cleared manually.

1. To view the alarm messages, press the **Read** key. When all alarms have been viewed but not cleared, the alarm LED changes from flashing to constantly on, and the latest fault record appears (if there is one).
2. Scroll through the pages of the latest fault record, using the cursor keys. When all pages of the fault record have been viewed, the following prompt appears.

```
Press Clear To
Reset Alarms
```

3. To clear all alarm messages, press the Clear key. To return to the display showing alarms or faults present, and leave the alarms uncleared, press the **Read** key.
4. Depending on the password configuration settings, you may need to enter a password before the alarm messages can be cleared.
5. When all alarms are cleared, the yellow alarm LED switches off. If the red LED was on, this will also be switched off.

> *Note:*
> *To speed up the procedure, you can enter the alarm viewer using the **Read** key and subsequently pressing the **Clear** key. This goes straight to the fault record display. Press the **Clear** key again to move straight to the alarm reset prompt, then press the **Clear** key again to clear all alarms.*

2.7 MENU STRUCTURE

Settings, commands, records and measurements are stored in a local database inside the IED. When using the Human Machine Interface (HMI) it is convenient to visualise the menu navigation system as a table. Each item in the menu is known as a cell, which is accessed by reference to a column and row address. Each column and row is assigned a 2-digit hexadecimal numbers, resulting in a unique 4-digit cell address for every cell in the database. The main menu groups are allocated columns and the items within the groups are allocated rows, meaning a particular item within a particular group is a cell.

Each column contains all related items, for example all of the disturbance recorder settings and records are in the same column.

There are three types of cell:

- Settings: This is for parameters that can be set to different values
- Commands: This is for commands to be executed
- Data: this is for measurements and records to be viewed, which are not settable

> *Note:*
> *Sometimes the term "Setting" is used generically to describe all of the three types.*

The table below, provides and example of the menu structure:

SYSTEM DATA (Col 00)	VIEW RECORDS (Col 01)	MEASUREMENTS 1 (Col 02)	…
Language (Row 01)	"Select Event [0...n]" (Row 01)	IA Magnitude (Row 01)	…
Password (Row 02)	Menu Cell Ref (Row 02)	IA Phase Angle (Row 02)	…
Sys Fn Links Row 03)	Time & Date (Row 03)	IB Magnitude (Row 03)	…
…	…	…	…

It is more convenient to specify all the settings in a single column, detailing the complete Courier address for each setting. The above table may therefore be represented as follows:

Setting	Column	Row	Description
SYSTEM DATA	**00**	**00**	**First Column definition**
Language (Row 01)	00	01	First setting within first column
Password (Row 02)	00	02	Second setting within first column
Sys Fn Links Row 03)	00	03	Third setting within first column
…	…	…	
VIEW RECORDS	**01**	**00**	**Second Column definition**
Select Event [0...n]	01	01	First setting within second column

Setting	Column	Row	Description
Menu Cell Ref	01	02	Second setting within second column
Time & Date	01	03	Third setting within second column
…	…	…	
MEASUREMENTS 1	**02**	**00**	**Third Column definition**
IA Magnitude	02	01	First setting within third column
IA Phase Angle	02	02	Second setting within third column
IB Magnitude	02	03	Third setting within third column
…	…	…	

The first three column headers are common throughout the entire series of products. However the rows within each of these column headers may differ according to the product type. Many of the column headers are the same for all products within the series. However, there is no guarantee that the addresses will be the same for a particular column header. Therefore you should always refer to the product settings documentation and not make any assumptions.

2.8 CHANGING THE SETTINGS

1. Starting at the default display, press the Down cursor key to show the first column heading.
2. Use the horizontal cursor keys to select the required column heading.
3. Use the vertical cursor keys to view the setting data in the column.
4. To return to the column header, either press the Up cursor key for a second or so, or press the **Cancel** key once. It is only possible to move across columns at the column heading level.
5. To return to the default display, press the Up cursor key or the **Cancel** key from any of the column headings. If you use the auto-repeat function of the Up cursor key, you cannot go straight to the default display from one of the column cells because the auto-repeat stops at the column heading.
6. To change the value of a setting, go to the relevant cell in the menu, then press the **Enter** key to change the cell value. A flashing cursor on the LCD shows that the value can be changed. You may be prompted for a password first.
7. To change the setting value, press the Up and Down cursor keys. If the setting to be changed is a binary value or a text string, select the required bit or character to be changed using the Left and Right cursor keys.
8. Press the **Enter** key to confirm the new setting value or the **Clear** key to discard it. The new setting is automatically discarded if it is not confirmed within 15 seconds.
9. For protection group settings and disturbance recorder settings, the changes must be confirmed before they are used. When all required changes have been entered, return to the column heading level and press the Down cursor key. Before returning to the default display, the following prompt appears.

```
Update settings?
ENTER or CLEAR
```

10. Press the **Enter** key to accept the new settings or press the **Clear** key to discard the new settings.

> *Note:*
> *If the menu time-out occurs before the setting changes have been confirmed, the setting values are also discarded. Control and support settings are updated immediately after they are entered, without the **Update settings?** prompt.*

2.9 DIRECT ACCESS (THE HOTKEY MENU)

It can be quite an onerous process to configure settings using the HMI panel, especially for settings and commands that need to be executed quickly or on a regular basis. The IED provides a pair of keys directly below the LCD display, which can be used to execute specified settings and commands directly.

The functions available for direct access using these keys are:

- Setting group selection
- Control Inputs
- CB Control functions

The availability of these functions is controlled by the **Direct Access** cell in the CONFIGURATION column. There are four options: 'Disabled', 'Enabled', 'CB Ctrl only' and 'Hotkey only'.

For the Setting Group selection and Control inputs, this cell must be set to either 'Enabled' or 'Hotkey only'. For CB Control functions, the cell must be set to 'Enabled' or 'CB Ctrl only'.

2.9.1 SETTING GROUP SELECTION

By default, only Setting group 1 is enabled. Other setting groups will only be available if they are first enabled. To be able to select a different setting group, you must first enable them in the CONFIGURATION column.

To access the hotkey menu from the default display, you press the key directly below the HOTKEY text on the LCD. The following screen will appear.

```
←User32 STG GP→
HOTKEY MENU
           EXIT
```

Use the right cursor keys to enter the Setting Group menu.

```
←Menu User01→
SETTING GROUP 1
Nxt Grp Select
```

Select the setting group with **Nxt Grp** and confirm by pressing **Select**. If neither of the cursor keys is pressed within 20 seconds of entering a hotkey sub menu, the device reverts to the default display.

2.9.2 CONTROL INPUTS

The control inputs are user-assignable functions. You can use the CTRL I/P CONFIG column to configure the control inputs for the hotkey menu. In order to do this, use the first setting **Hotkey Enabled** cell to enable or disable any of the 32 control inputs. You can then set each control input to latched or pulsed and set its command to 'On/Off', 'Set/Reset', 'In/Out', or 'Enabled/Disabled'.

By default, the hotkey is enabled for all 32 control inputs and they are set to "Set/Reset" and are "Latched".

To access the hotkey menu from the default display, you press the key directly below the HOTKEY text on the LCD. The following screen will appear.

```
←User32 STG GP→
HOTKEY MENU
           EXIT
```

Press the right cursor key twice to get to the first control input, or the left cursor key to get to the last control input.

```
←STP GP User02→
Control Input 1
EXIT SET
```

Now you can execute the chosen function (Set/Reset in this case).

If neither of the cursor keys is pressed within 20 seconds of entering a hotkey sub menu, the device reverts to the default display.

2.9.3 CB CONTROL

You can open and close the controlled circuit breaker with the direct access key to the right, if enabled as described above. By default direct access to the circuit breakers is disabled.

If direct access to the circuit breakers has been enabled, the bottom right hand part of the display will read "Open or Close" depending on whether the circuit breaker is closed or open respectively:

For example:

```
Plant Reference
MiCOM
HOTKEY  CLOSE
```

To close the circuit breaker (in this case), press the key directly below CLOSE. You will be given an option to cancel or confirm.

```
Execute
CB CLOSE
Cancel Confirm
```

More detailed information on CB Control (on page 384) can be found in the CB Control section in the Monitoring and Control chapter.

2.10 FUNCTION KEYS

With the exception of products housed in 20TE cases, the IED has a number of function keys for programming control functionality using the programmable scheme logic (PSL).

Each function key has an associated programmable tri-colour LED that can be programmed to give the desired indication on function key activation.

These function keys can be used to trigger any function that they are connected to as part of the PSL. The function key commands are in the FUNCTION KEYS column.

The first cell down in the FUNCTION KEYS column is the **Fn Key Status** cell. This contains a 10 bit word, which represents the 10 function key commands. Their status can be read from this 10 bit word.

```
FUNCTION KEYS
Fn Key Status
0000000000
```

The next cell down (**Fn Key 1**) allows you to activate or disable the first function key (1). The **Lock** setting allows a function key to be locked. This allows function keys that are set to ‘Toggled’ mode and their DDB signal active ‘high’, to be locked in their active state, preventing any further key presses from deactivating the associated function. Locking a function key that is set to the Normal mode causes the associated DDB signals to be permanently off. This safety feature prevents any inadvertent function key presses from activating or deactivating critical relay functions.

```
FUNCTION KEYS
Fn Key 1
Unlocked
```

The next cell down (Fn Key 1 Mode) allows you to set the function key to 'Normal' or 'Toggled'. In the Toggle mode the function key DDB signal output stays in the set state until a reset command is given, by activating the function key on the next key press. In the Normal mode, the function key DDB signal stays energised for as long as the function key is pressed then resets automatically. If required, a minimum pulse width can be programmed by adding a minimum pulse timer to the function key DDB output signal.

```
FUNCTION KEYS
Fn Key 1 Mode
Toggled
```

The next cell down (Fn Key 1 Label) allows you to change the label of the function. The default label is "Function key 1" in this case. To change the label you need to press the enter key and then change the text on the bottom line, character by character. This text is displayed when a function key is accessed in the function key menu, or it can be displayed in the PSL.

```
FUNCTION KEYS
Fn Key 1 Label
Function Key 1
```

Subsequent cells allow you to carry out the same procedure as above for the other function keys.

The status of the function keys is stored in non-volatile memory. If the auxiliary supply is interrupted, the status of all the function keys is restored. The IED only recognises a single function key press at a time and a minimum key press duration of approximately 200 ms is required before the key press is recognised in PSL. This feature avoids accidental double presses.

3 CONFIGURING THE DATA PROTOCOLS

Different protocols can be used with the various ports. The choice of protocol depends on the chosen model. Only one data protocol can be configured at any one time on any one IED. The range of available communication settings depend on which protocol has been chosen.

3.1 COURIER CONFIGURATION

To use the rear port with Courier, you can configure the settings using the HMI panel.

1. Select the CONFIGURATION column and check that the **Comms settings** cell is set to Visible.
2. Select the COMMUNICATIONS column.
3. Move to the first cell down (**RP1 protocol**). This is a non-settable cell, which shows the chosen communication protocol – in this case Courier.

```
COMMUNICATIONS
RP1 Protocol
Courier
```

4. Move down to the next cell (**RP1 Address**). This cell controls the address of the IED. Up to 32 IEDs can be connected to one spur. It is therefore necessary for each IED to have a unique address so that messages from the master control station are accepted by one IED only. Courier uses an integer number between 1 and 254 for the IED address. It is set to 255 by default, which has to be changed. It is important that no two IEDs share the same address.

```
COMMUNICATIONS
RP1 Address
100
```

5. Move down to the next cell (**RP1 InactivTimer**). This cell controls the inactivity timer. The inactivity timer controls how long the IED waits without receiving any messages on the rear port before it reverts to its default state, including revoking any password access that was enabled. For the rear port this can be set between 1 and 30 minutes.

```
COMMUNICATIONS
RP1 Inactivtimer
10.00 mins.
```

6. If the optional fibre optic connectors are fitted, the **RP1 PhysicalLink** cell is visible. This cell controls the physical media used for the communication (Copper or Fibre optic).

```
COMMUNICATIONS
RP1 PhysicalLink
Copper
```

7. Move down to the next cell (**RP1 Card Status**). This cell is not settable. It just displays the status of the chosen physical layer protocol for RP1.

```
COMMUNICATIONS
RP1 Card Status
K-Bus OK
```

8. Move down to the next cell (**RP1 Port Config**). This cell controls the type of serial connection. Select between K-Bus or RS485.

```
COMMUNICATIONS
RP1 Port Config
K-Bus
```

9. If using EIA(RS)485, the next cell (**RP1 Comms Mode**) selects the communication mode. The choice is either IEC 60870 FT1.2 for normal operation with 11-bit modems, or 10-bit no parity. If using K-Bus this cell will not appear.

```
COMMUNICATIONS
RP1 Comms Mode
IEC 60870 FT1.2
```

10. If using EIA(RS)485, the next cell down controls the baud rate. Three baud rates are supported; 9600, 19200 and 38400. If using K-Bus this cell will not appear as the baud rate is fixed at 64 kbps.

```
COMMUNICATIONS
RP1 Baud rate
19200
```

> *Note:*
> *If you modify protection and disturbance recorder settings using an on-line editor such as PAS&T, you must confirm them. To do this, from the Configuration column select the Save changes cell. Off-line editors such as MiCOM S1 Agile do not need this action for the setting changes to take effect.*

3.2 DNP3 CONFIGURATION

To use the rear port with DNP3.0, you can configure the settings using the HMI panel.

1. Select the CONFIGURATION column and check that the **Comms settings** cell is set to Visible.
2. Select the COMMUNICATIONS column.
3. Move to the first cell down (**RP1 protocol**). This is a non-settable cell, which shows the chosen communication protocol – in this case DNP3.0.

```
COMMUNICATIONS
RP1 Protocol
DNP3.0
```

4. Move down to the next cell (**RP1 Address**). This cell controls the DNP3.0 address of the IED. Up to 32 IEDs can be connected to one spur, therefore it is necessary for each IED to have a unique address so that messages from the master control station are accepted by only one IED. DNP3.0 uses a decimal number between 1 and 65519 for the IED address. It is important that no two IEDs have the same address.

```
COMMUNICATIONS
RP1 Address
1
```

5. Move down to the next cell (**RP1 Baud Rate**). This cell controls the baud rate to be used. Six baud rates are supported by the IED 1200 bps, 2400 bps, 4800 bps, 9600 bps, 19200 bps and 38400 bps. Make sure that the baud rate selected on the IED is the same as that set on the master station.

```
COMMUNICATIONS
RP1 Baud rate
9600 bits/s
```

6. Move down to the next cell (**RP1 Parity**). This cell controls the parity format used in the data frames. The parity can be set to be one of None, Odd or Even. Make sure that the parity format selected on the IED is the same as that set on the master station.

```
COMMUNICATIONS
RP1 Parity
None
```

7. If the optional fibre optic connectors are fitted, the **RP1 PhysicalLink** cell is visible. This cell controls the physical media used for the communication (Copper or Fibre optic).

```
COMMUNICATIONS
RP1 PhysicalLink
Copper
```

8. Move down to the next cell (**RP1 Time Sync**). This cell sets the time synchronisation request from the master by the IED. It can be set to enabled or disabled. If enabled it allows the DNP3.0 master to synchronise the time.

```
COMMUNICATIONS
RP1 Time sync
Enabled
```

3.2.1 DNP3 CONFIGURATOR

A PC support package for DNP3.0 is available as part of the supplied settings application software (MiCOM S1 Agile) to allow configuration of the device's DNP3.0 response. The configuration data is uploaded from the device to the PC in a block of compressed format data and downloaded in a similar manner after modification. The new DNP3.0 configuration takes effect after the download is complete. To restore the default configuration at any time, from the CONFIGURATION column, select the **Restore Defaults** cell then select 'All Settings'.

In MiCOM S1 Agile, the DNP3.0 data is shown in three main folders, one folder each for the point configuration, integer scaling and default variation (data format). The point configuration also includes screens for binary inputs, binary outputs, counters and analogue input configuration.

3.3 IEC 60870-5-103 CONFIGURATION

To use the rear port with IEC 60870-5-103, you can configure the settings using the HMI panel.

The device operates as a slave in the system, responding to commands from a master station.

1. Select the CONFIGURATION column and check that the **Comms settings** cell is set to Visible.
2. Select the COMMUNICATIONS column.
3. Move to the first cell down (**RP1 protocol**). This is a non-settable cell, which shows the chosen communication protocol – in this case IEC 60870-5-103.

```
COMMUNICATIONS
RP1 Protocol
IEC 60870-5-103
```

4. Move down to the next cell (**RP1 Address**). This cell controls the IEC 60870-5-103 address of the IED. Up to 32 IEDs can be connected to one spur. It is therefore necessary for each IED to have a unique address so that messages from the master control station are accepted by one IED only. IEC 60870-5-103 uses an integer number between 0 and 254 for the IED address. It is important that no two IEDs have the same IEC 60870 5 103 address. The IEC 60870-5-103 address is then used by the master station to communicate with the IED.

```
COMMUNICATIONS
RP1 address
162
```

5. Move down to the next cell (**RP1 Baud Rate**). This cell controls the baud rate to be used. Two baud rates are supported by the IED, ‘9600 bits/s’ and ‘19200 bits/s’. Make sure that the baud rate selected on the IED is the same as that set on the master station.

```
COMMUNICATIONS
RP1 Baud rate
9600 bits/s
```

6. Move down to the next cell (**RP1 Meas. period**). The next cell down controls the period between IEC 60870-5-103 measurements. The IEC 60870-5-103 protocol allows the IED to supply measurements at regular intervals. The interval between measurements is controlled by this cell, and can be set between 1 and 60 seconds.

```
COMMUNICATIONS
RP1 Meas. Period
30.00 s
```

7. If the optional fibre optic connectors are fitted, the **RP1 PhysicalLink** cell is visible. This cell controls the physical media used for the communication (Copper or Fibre optic).

```
COMMUNICATIONS
RP1 PhysicalLink
Copper
```

8. The next cell down (**RP1 CS103Blcking**) can be used for monitor or command blocking.

```
COMMUNICATIONS
RP1 CS103Blcking
Disabled
```

9. There are three settings associated with this cell; these are:

Setting:	Description:
Disabled	No blocking selected.
Monitor Blocking	When the monitor blocking DDB Signal is active high, either by energising an opto input or control input, reading of the status information and disturbance records is not permitted. When in this mode the device returns a "Termination of general interrogation" message to the master station.
Command Blocking	When the command blocking DDB signal is active high, either by energising an opto input or control input, all remote commands will be ignored (i.e. CB Trip/Close, change setting group etc.). When in this mode the device returns a "negative acknowledgement of command" message to the master station.

3.4 MODBUS CONFIGURATION

To use the rear port with Modbus, you can configure the settings using the HMI panel.

1. Select the CONFIGURATION column and check that the **Comms settings** cell is set to Visible.
2. Select the COMMUNICATIONS column.
3. Move to the first cell down (**RP1 protocol**). This is a non settable cell, which shows the chosen communication protocol – in this case Modbus.

```
COMMUNICATIONS
RP1 Protocol
Modbus
```

4. Move down to the next cell (**RP1 Address**). This cell controls the Modbus address of the IED. Up to 32 IEDs can be connected to one spur, therefore it is necessary for each IED to have a unique address so that messages from the master control station are accepted by only one IED. Modbus uses a decimal number between 1 and 247 for the IED address. It is important that no two IEDs have the same address.

```
COMMUNICATIONS
RP1 Address
1
```

5. Move down to the next cell (**RP1 InactivTimer**). This cell controls the inactivity timer. The inactivity timer controls how long the IED waits without receiving any messages on the rear port before it reverts to its default state, including revoking any password access that was enabled. For the rear port this can be set between 1 and 30 minutes.

```
COMMUNICATIONS
RP1 Inactivtimer
10.00 mins
```

6. Move down to the next cell (**RP1 Baud Rate**). This cell controls the baud rate to be used. Six baud rates are supported by the IED 1200 bits/s, 2400 bits/s, 4800 bits/s, 9600 bits/s, 19200 bits/s and 38400 bits/s. Make sure that the baud rate selected on the IED is the same as that set on the master station.

```
COMMUNICATIONS
RP1 Baud rate
9600 bits/s
```

7. Move down to the next cell (**RP1 Parity**). This cell controls the parity format used in the data frames. The parity can be set to be one of None, Odd or Even. Make sure that the parity format selected on the IED is the same as that set on the master station.

```
COMMUNICATIONS
RP1 Parity
None
```

8. Move down to the next cell (**Modbus IEC Time**). This cell controls the order in which the bytes of information are transmitted. There is a choice of Standard or Reverse. When ‘Standard’ is selected the time format complies with IEC 60870-5-4 requirements such that byte 1 of the information is transmitted first, followed by bytes 2 through to 7. If ‘Reverse’ is selected the transmission of information is reversed.

```
COMMUNICATIONS
Modbus IEC Time
Standard
```

3.5 IEC 61850 CONFIGURATION

You cannot configure the device for IEC 61850 using the HMI panel on the product. For this you must use the IED Configurator.

IEC 61850 allows IEDs to be directly configured from a configuration file. The IED’s system configuration capabilities are determined from an IED Capability Description file (ICD), supplied with the product. By using ICD files from the products to be installed, you can design, configure and even test (using simulation tools), a substation’s entire protection scheme before the products are even installed into the substation.

To help with this process, the settings application software provides an IED Configurator tool, which allows the pre-configured IEC 61850 configuration file to be imported and transferred to the IED. As well as this, you can manually create configuration files for MiCOM IEDs, based on their original IED capability description (ICD file).

Other features include:

- The extraction of configuration data for viewing and editing.
- A sophisticated error checking sequence to validate the configuration data before sending to the IED.

Note:
To help the user, some configuration data is available in the IED CONFIGURATOR column, allowing read-only access to basic configuration data.

3.5.1 IEC 61850 CONFIGURATION BANKS

To help version management and minimise down-time during system upgrades and maintenance, the MiCOM IEDs have incorporated a mechanism consisting of multiple configuration banks. These configuration banks fall into two categories:

- Active Configuration Bank
- Inactive Configuration Bank

Any new configuration sent to the IED is automatically stored in the inactive configuration bank, therefore not immediately affecting the current configuration.

When the upgrade or maintenance stage is complete, the IED Configurator tool can be used to transmit a command, which authorises activation of the new configuration contained in the inactive configuration bank. This is done by switching the active and inactive configuration banks. The capability of switching the configuration banks is also available using the IED CONFIGURATOR column of the HMI.

The SCL Name and Revision attributes of both configuration banks are also available in the IED CONFIGURATOR column of the HMI.

3.5.2 IEC 61850 NETWORK CONNECTIVITY

Configuration of the IP parameters and SNTP time synchronisation parameters is performed by the IED Configurator tool. If these parameters are not available using an SCL file, they must be configured manually.

As the IP addressing will be completely detached and independent from any public network, it is up to the company's system administrator to establish the IP addressing strategy. Every IP address on the network must be unique. This applies to all devices on the network. Duplicate IP addresses will result in conflict and must be avoided. The IED will check for a conflict on every IP configuration change and at power up. An alarm will be raised if an IP conflict is detected.

The IED can be configured to accept data from other networks using the Gateway setting. If multiple networks are used, the IP addresses must be unique across networks.

4 DATE AND TIME CONFIGURATION

The Date and Time setting will normally be updated automatically by the chosen UTC (Universal Time Coordination) time synchronisation mechanism when the device is in service. This does not mean that you should dispense with configuring the date and time parameters during commissioning. It is desirable to have the correct date and time represented for the commissioning process, therefore this should be the first item to configure during the commissioning process.

The date and time is set in the **Date/Time** cell in the DATE AND TIME column.

4.1 TIME ZONE COMPENSATION

The UTC time standard uses Greenwich Mean Time as its standard. Without compensation, this would be the date and time that would be displayed on the device irrespective of its location.

It is obviously desirable for the device to display the local time corresponding to its geographical location. For this reason, it is possible to compensate for any difference between the local time and the UTC time. This is achieved with the settings **LocalTime Enable** and **LocalTime Offset**

The **LocalTime Enable** has three setting options; 'Disabled', 'Fixed', and 'Flexible'.

With 'Disabled', no local time zone is maintained. Time synchronisation from any interface will be used to directly set the master clock. All times displayed on all interfaces will be based on the master clock with no adjustment.

With 'Fixed', a local time zone adjustment is defined using the **LocalTime Offset** setting and all non-IEC 61850 interfaces (which uses SNTP) are compensated to display the local time.

With 'Flexible', a local time zone adjustment is defined using the **LocalTime Offset** setting and the non-local and non-IEC 61850 interfaces can be set to either the UTC zone or the local time zone. The local interfaces are always set to the local time zone and the Ethernet interface is always set to the UTC zone.

The interfaces where you can select between UTC and Local Time are the serial interfaces RP1, RP2, DNP over Ethernet (if applicable) and Tunnelled Courier (if applicable). This is achieved by means of the following settings:

- RP1 Time Zone
- RP2 Time Zone
- DNPOE Time Zone
- Tunnel Time Zone

The **LocalTime Offset** setting allows you to enter the local time zone compensation from -12 to + 12 hours at 15 minute intervals.

4.2 DAYLIGHT SAVING TIME COMPENSATION

It is possible to compensate for Daylight Saving time using the following settings

- DST Enable
- DST Offset
- DST Start
- DST Start Day
- DST Start Month
- DST Start Mins
- DST End

- DST End Day
- DST End Month
- DST End Mins

These settings are described in the DATE AND TIME settings table in the configuration chapter.

5 CONFIGURATION SETTINGS

5.1 SYSTEM DATA

Menu Text	Col	Row	Default Setting	Available Options
Description				
SYSTEM DATA	00	00		
This column contains general system settings and records				
Language	00	01	English	0 = English, 1 = French 2 = German 3 = Spanish
This setting defines the default language used by the device for ordering option language = 0				
Language	00	01	English	0 = English, 1 = Italian, 2 = Portuguese, 3 = Russian
This setting defines the default language used by the device for ordering option language = 6				
Password	00	02		ASCII text (characters 33 to 122 inclusive)
This setting defines the plain text password.				
Sys Fn Links	00	03	0	Binary flag (data type G95) Bit 0 = 0: Disable self reset Bit 0 = 1: Enable self reset
This setting allows the fixed function trip LED to be self resetting (set to 1 to extinguish the LED after a period of healthy restoration of load current). Only bit 0 is used.				
Description	00	04	MiCOM P14N MiCOM P14D MiCOM P94V	ASCII text
In this cell, you can enter and edit a 16 character IED description.				
Plant Reference	00	05	MiCOM	Extended ASCII text (characters 32 to 234 inclusive)
In this cell, you can enter and edit a 16 character plant description.				
Model Number	00	06	Model Number	<Model number>
This cell displays the IED model number. This cannot be edited.				
Serial Number	00	08	Serial Number	<Serial number>
This cell displays the IED serial number. This cannot be edited				
Frequency	00	09	50	50 Hz, 60 Hz
This cell sets the mains frequency to either 50 Hz or 60 Hz				
Comms Level	00	0A	2	<Conformance level>
This cell displays the Courier communications conformance level				
IED Address	00	0B	255	0 to 255 (Courier) 0 to 247 (Modbus) 0 to 254 (CS103) 0 to 65519 (DNP3.0)
This cell sets the first rear port IED address. Available settings are dependent on the protocol. This setting can also be made in the COMMUNICATIONS column.				
IED Address	00	0B	1	0 to 255 (Courier) 0 to 247 (Modbus) 0 to 254 (CS103) 0 to 65519 (DNP3.0)
This cell sets the first rear port IED address. Available settings are dependent on the protocol. This setting can also be made in the COMMUNICATIONS column.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
IED Address	00	0B	1	0 to 255 (Courier) 0 to 247 (Modbus) 0 to 254 (CS103) 0 to 65519 (DNP3.0)
This cell sets the first rear port IED address. Available settings are dependent on the protocol. This setting can also be made in the COMMUNICATIONS column.				
IED Address	00	0B	1	0 to 255 (Courier) 0 to 247 (Modbus) 0 to 254 (CS103) 0 to 65519 (DNP3.0)
This cell sets the first rear port IED address. Available settings are dependent on the protocol. This setting can also be made in the COMMUNICATIONS column.				
Plant Status	00	0C		Binary flag (data type G4) Bit 0 = CB 1 52A state (0 = closed 1 = open) Bit 1 = CB 2 52B state (0 = open, 1 = closed)
This cell displays the circuit breaker plant status. The first two bits are used. One to indicate the 52A state and one to indicate the 52B state.				
Control Status	00	0D		Not used
This cell is not used				
Active Group	00	0E	1	1, 2, 3, 4
This cell displays the active settings group				
CB Trip/Close	00	10	No Operation	0 = No Operation, 1 = Trip, 2 = Close
Supports trip and close commands if enabled in the Circuit Breaker Control menu.				
CB Trip/Close	00	10	No Operation	0 = No Operation, 1 = Trip, 2 = Close
Supports trip and close commands if enabled in the Circuit Breaker Control menu.				
Software Ref. 1	00	11		<Software Ref. 1>
This cell displays the IED software version including the protocol and IED model.				
Software Ref. 2	00	12		<Software Ref. 2>
This cell displays the software version of the Ethernet card for models equipped with IEC 61850.				
Opto I/P Status	00	20		32 bit binary flag (data type G8): 0 = energised 1 = de-energised
This cell displays the status of the available opto-inputs. This information is also available in the COMMISSIONING TESTS column				
Relay O/P Status	00	21		32 bit binary flag (data type G9): 0 = operated state 1 = non-operated state
This cell displays the status of the available output relays.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
Alarm Status 1	00	22		Binary flag (data type G96-1): Bit 2 = SG-opto Invalid 3 = Prot'n Disabled 4 = F out of Range 5 = VT Fail Alarm 6 = CT Fail Alarm 7 = CB Fail Alarm 8 = I^ Maint Alarm 9 = I^ Lockout Alarm 10 = CB Ops Maint 11 = CB Ops Lockout 12 = CB Op Time Maint 13 = CB Op Time Lock 14 = Fault Freq Lock 15 = CB Status Alarm 16 = Man CB Trip Fail ON/OFF 17 = Man CB Cls Fail ON/OFF 18 = Man CB Unhealthy ON/OFF 19 = Man No Checksync ON/OFF 20 = A/R Lockout ON/OFF 21 = A/R CB Unhealthy ON/OFF 22 = A/R No Checksync ON/OFF 23 = System Split ON/OFF 24 = UV Block ON/OFF Bits 25 to 31 = SR User Alarms 1 to 7
This cell displays the status of the first 32 alarms as a binary string, including fixed and user settable alarms. This information is repeated for system purposes.				
Opto I/P Status	00	30		Binary flag (data type G8): 0 = energised, 1 = de-energised
This cell display the status of the available opto-inputs. This information is repeated for system purposes.				
Relay O/P Status	00	40		Binary flag (data type G9): 0 = operated state, 1 = non-operated state
This cell displays the status of the available output relays.This information is repeated for system purposes.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
Alarm Status 1	00	50		Binary flag (data type G96-1): Bit 2 = SG-opto Invalid 3 = Prot'n Disabled 4 = F out of Range 5 = VT Fail Alarm 6 = CT Fail Alarm 7 = CB Fail Alarm 8 = I^ Maint Alarm 9 = I^ Lockout Alarm 10 = CB Ops Maint 11 = CB Ops Lockout 12 = CB Op Time Maint 13 = CB Op Time Lock 14 = Fault Freq Lock 15 = CB Status Alarm 16 = Man CB Trip Fail ON/OFF 17 = Man CB Cls Fail ON/OFF 18 = Man CB Unhealthy ON/OFF 19 = Man No Checksync ON/OFF 20 = A/R Lockout ON/OFF 21 = A/R CB Unhealthy ON/OFF 22 = A/R No Checksync ON/OFF 23 = System Split ON/OFF 24 = UV Block ON/OFF Bits 25 to 31 = SR User Alarms 1 to 7
This cell displays the status of the first 32 alarms as a binary string, including fixed and user settable alarms. This information is repeated for system purposes.				
Alarm Status 2	00	51		32 bit Binary flag (data type G96-2): Bits 4 to 13 = SR User Alarms 8 to 35 Bits 14 to 31 = MR user alarms 18 to 35
This cell displays the status of the second set of 32 alarms as a binary string, including fixed and user settable alarms. This cell uses data type G96-2.				
Alarm Status 3	00	52		32 bit Binary flag (data type G228): Bit 0 = DC Supply Fail Bit 3 = GOOSE IED Absent Bit 4 = NIC Not Fitted Bit 5 = NIC No Response Bit 6 = NIC Fatal Error Bit 8 = Bad TCP/IP Cfg. Bit 10 = NIC Link Fail Bit 11 = NIC SW Mis-Match Bit 12 = IP Addr Conflict Bit 18 = Bad DNP Settings
This cell displays the status of the third set of alarms as a binary string, including fixed and user settable alarms. This cell uses data type G228.				
Access Level	00	D0		0 = Read Some, 1 = Read All, 2 = Read All + Write Some, 3 = Read All + Write All
This cell displays the current access level.				
Password Level 1	00	D2	blank	ASCII text (characters 33 to 122 inclusive)
This setting allows you to change password level 1.				
Password Level 1	00	D2	blank	ASCII text (characters 33 to 122 inclusive)
This setting allows you to change password level 1 for Modbus only.				
Password Level 2	00	D3	AAAA	ASCII text (characters 33 to 122 inclusive)
This setting allows you to change password level 2.				
Password Level 2	00	D3	AAAA	ASCII text (characters 33 to 122 inclusive)

Menu Text	Col	Row	Default Setting	Available Options
Description				
This setting allows you to change password level 2 for Modbus only.				
Password Level 3	00	D4	AAAA	ASCII text (characters 33 to 122 inclusive)
This setting allows you to change password level 3.				
Password Level 3	00	D4	AAAA	ASCII text (characters 33 to 122 inclusive)
This setting allows you to change password level 3 for Modbus only.				
Security Feature	00	DF		<cyber security level>
This setting displays the level of cyber security implemented, 1 = phase 1.				
Password	00	E1		ASCII text (characters 33 to 122 inclusive)
This cell allows you to enter the encrypted password. It is not visible via the user interfaced.				
Password Level 1	00	E2	blank	ASCII text (characters 33 to 122 inclusive)
This setting allows you to change the encrypted password level 1. This is not visible via the user interface.				
Password Level 2	00	E3	AAAA	ASCII text (characters 33 to 122 inclusive)
This setting allows you to change the encrypted password level 2. This is not visible via the user interface.				
Password Level 3	00	E4	AAAA	ASCII text (characters 33 to 122 inclusive)
This setting allows you to change the encrypted password level 3. This is not visible via the user interface.				

5.2 DATE AND TIME

Menu Text	Col	Row	Default Setting	Available Options
Description				
DATE AND TIME	08	00		
This column contains Date and Time stamp settings				
Date/Time	08	01		
This setting defines the IED's current date and time.				
IRIG-B Status	08	04		0 = Disabled 1 = RP1 2 = RP2
This setting enables or disables IRIG-B synchronisation and defines which rear port is to be used as an IRIG-B input.				
IRIG-B Status	08	05		0 = No Signal 1 = Signal Healthy 2 = No Error
This cell displays the IRIG-B status				
SNTP Status	08	13		Not Settable
This cell displays the SNTP time synchronisation status for IEC 61850 or DNP3 over Ethernet versions.				
LocalTime Enable	08	20	Fixed	0 = Disabled, 1 = Fixed or 2 = Flexible
Disabled: No local time zone will be maintained Fixed - Local time zone adjustment can be defined (all interfaces) Flexible - Local time zone adjustment can be defined (non-local interfaces)				
LocalTime Offset	08	21	0	From -720 mins to 720 mins step 15m
This setting specifies the offset for the local time zone from -12 hours to +12 hours in 15 minute intervals. This adjustment is applied to the time based on the UTC/GMT master clock.				
DST Enable	08	22	Enabled	0 = Disabled or 1 = Enabled
This setting turns daylight saving time adjustment on or off.				
DST Offset	08	23	60	30 minutes, 60 minutes

Menu Text	Col	Row	Default Setting	Available Options
Description				
This setting defines the daylight saving offset used for the local time adjustment.				
DST Start	08	24	Last	0 = First, 1 = Second, 2 = Third, 3 = Fourth or 4 = Last
This setting specifies the week of the month in which daylight saving time adjustment starts.				
DST Start Day	08	25	Sunday	0 = Sunday, 1 = Monday, 2 = Tuesday, 3 = Wednesday, 4 = Thursday, 5 = Friday or 6 = Saturday
This setting specifies the day of the week in which daylight saving time adjustment starts				
DST Start Month	08	26	March	0 = January, 1 = February, 2 = March, 3 = April, 4 = May, 5 = June, 6 = July, 7 = August, 8 = September, 9 = October, 10 = November or 11 = December
This setting specifies the month in which daylight saving time adjustment starts				
DST Start Mins	08	27	60	From 0 mins to 1425 mins step 15 mins
Setting to specify the time of day in which daylight saving time adjustment starts. This is set relative to 00:00 hours on the selected day when time adjustment is to start				
DST End	08	28	Last	0 = First, 1 = Second, 2 = Third, 3 = Fourth or 4 = Last
This setting specifies the week of the month in which daylight saving time adjustment ends				
DST End Day	08	29	Sunday	0 = Sunday, 1 = Monday, 2 = Tuesday, 3 = Wednesday, 4 = Thursday, 5 = Friday or 6 = Saturday
This setting specifies the day of the week in which daylight saving time adjustment ends.				
DST End Month	08	2A	October	0 = January, 1 = February, 2 = March, 3 = April, 4 = May, 5 = June, 6 = July, 7 = August, 8 = September, 9 = October, 10 = November or 11 = December
This setting specifies the month in which daylight saving time adjustment ends.				
DST End Mins	08	2B	60	From 0m to 1425m step 15m
This setting specifies the time of day in which daylight saving time adjustment ends. This is set relative to 00:00 hours on the selected day when time adjustment is to end.				
RP1 Time Zone	08	30	Local	0 = UTC or 1 = Local
Setting for the rear port 1 interface to specify if time synchronisation received will be local or universal time co-ordinated.				
RP2 Time Zone	08	31	Local	0 = UTC or 1 = Local
Setting for the rear port 2 interface to specify if time synchronisation received will be local or universal time co-ordinated				
DNPOE Time Zone	08	32	Local	0 = UTC or 1 = Local
This setting specifies whether DNP3.0 over Ethernet time synchronisation is coordinated by local time or universal time.				
Tunnel Time Zone	08	33	Local	0 = UTC or 1 = Local
This setting specifies whether tunnelled Courier time synchronisation is coordinated by local time or universal time.				

5.3 GENERAL CONFIGURATION

Menu Text	Col	Row	Default Setting	Available Options
Description				
CONFIGURATION	09	00		
This column contains the general configuration options				

Menu Text	Col	Row	Default Setting	Available Options
Description				
Restore Defaults	09	01	No Operation	0 = No Operation, 1 = All Settings, 2 = Setting Group 1, 3 = Setting Group 2, 4 = Setting Group 3, 5 = Setting Group 4
This setting restores the chosen setting groups to factory default values. Note: Restoring defaults to all settings includes the rear communication port settings, which may result in communication via the rear port being disrupted if the new (default) settings do not match those of the master station.				
Setting Group	09	02	Select via Menu	0 = Select via Menu or 1 = Select via PSL
This setting allows you to choose whether the setting group changes are to be initiated via an Opto-input or the HMI menu.				
Active Settings	09	03	Group 1	0 = Group 1, 1 = Group 2, 2 = Group 3, 3 = Group 4
This setting selects the active settings group.				
Save Changes	09	04	No Operation	0 = No Operation, 1 = Save, 2 = Abort
This command saves all IED settings.				
Copy From	09	05	Group 1	0 = Group 1, 1 = Group 2, 2 = Group 3, 3 = Group 4
This setting copies settings from a selected setting group.				
Copy To	09	06	No Operation	0 = No Operation, 1 = Group 1, 2 = Group 2, 3 = Group 3
This command allows the displayed settings to be copied to a selected setting group.				
Setting Group 1	09	07	Enabled	0 = Disabled or 1 = Enabled
This setting enables or disables settings Group 1.				
Setting Group 2	09	08	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables settings Group 2.				
Setting Group 3	09	09	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables settings Group 3.				
Setting Group 4	09	0A	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables settings Group 4.				
System Config	09	0B	Invisible	0 = Invisible or 1 = Visible
This setting hides or unhides the System Config menu.				
Overcurrent	09	10	Enabled	0 = Disabled or 1 = Enabled
This setting enables or disables the Phase Overcurrent Protection function.				
Neg Sequence O/C	09	11	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the Negative Sequence Overcurrent Protection function.				
Broken Conductor	09	12	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the Broken Conductor function.				
Earth Fault 1	09	13	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the measured Earth Fault Protection function.				
Earth Fault 2	09	14	Enabled	0 = Disabled or 1 = Enabled
This setting enables or disables the derived Earth Fault Protection function.				
SEF Protection	09	15	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the Sensitive Earth Fault Protection function.				
Residual O/V NVD	09	16	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the Residual Overvoltage Protection function.				
Thermal Overload	09	17	Disabled	0 = Disabled or 1 = Enabled

Menu Text	Col	Row	Default Setting	Available Options
Description				
This setting enables or disables the Thermal Overload Protection function.				
Neg Sequence O/V	09	18	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the Negative Sequence Overvoltage Protection function.				
Cold Load Pickup	09	19	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the Cold Load Pickup protection.				
Selective Logic	09	1A	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the the Selective Logic element.				
Power Protection	09	1C	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the Power protection function.				
Power Protection	09	1C	Disabled	0 = Disabled
This setting disables the Power protection function for Model B				
Volt Protection	09	1D	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the Voltage protection.				
REF Protection	09	1E	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the Restricted Earth Fault Protection.				
DC SupplyMonitor	09	1F	Enabled	0 = Disabled or 1 = Enabled
This setting enables or disables the DC Supply Monitoring supervision function.				
CB Fail	09	20	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the Circuit Breaker Fail Protection function.				
Supervision	09	21	Enabled	0 = Disabled or 1 = Enabled
This setting enables or disables the Supervision (VTS & CTS) functions.				
Fault Locator	09	22	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the Fault Locator function.				
Fault Locator	09	22	Disabled	0 = Disabled
This setting disables the Fault Locator function for models B and G.				
System Checks	09	23	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the System Checks function (Check Synchronisation and Voltage Monitor).				
System Checks	09	23	Disabled	0 = Disabled
This setting disables the System Checks function (Check Synchronisation and Voltage Monitor) for some models				
Auto-Reclose	09	24	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the Autoreclose function.				
Auto-Reclose	09	24	Disabled	0 = Disabled
This setting disables the Autoreclose function for some models				
Input Labels	09	25	Visible	0 = Invisible or 1 = Visible
This setting hides or unhides the Input Labels menu from the IED display.				
Output Labels	09	26	Visible	0 = Invisible or 1 = Visible
This setting hides or unhides the Output Labels menu from the IED display.				
Freq Protection	09	27	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the Frequency Protection function.				
TransformerRatio	09	28	Visible	0 = Invisible or 1 = Visible
This setting hides or unhides the Transformer Ratios menu from the IED display.				
Record Control	09	29	Invisible	0 = Invisible or 1 = Visible

Menu Text	Col	Row	Default Setting	Available Options
Description				
This setting hides or unhides the Record Control menu from the IED display.				
Disturb Recorder	09	2A	Invisible	0 = Invisible or 1 = Visible
This setting hides or unhides the Disturbance Recorder menu from the IED display.				
Measure't Setup	09	2B	Invisible	0 = Invisible or 1 = Visible
This setting hides or unhides the Measurement Setup menu from the IED display.				
Comms Settings	09	2C	Visible	0 = Invisible or 1 = Visible
This setting hides or unhides the Communication Settings menu from the IED display.				
Commission Tests	09	2D	Visible	0 = Invisible or 1 = Visible
This setting hides or unhides the Commission Tests menu from the IED display.				
Setting Values	09	2E	Primary	0 = Primary or 1 = Secondary
This setting determines the reference for all settings dependent on the transformer ratios; either referenced to the primary or the secondary.				
Control Inputs	09	2F	Visible	0 = Invisible or 1 = Visible
Activates the Control Input status and operation menu further on in the IED setting menu.				
Ctrl I/P Config	09	35	Visible	0 = Invisible or 1 = Visible
Sets the Control Input Configuration menu visible further on in the IED setting menu.				
Ctrl I/P Labels	09	36	Visible	0 = Invisible or 1 = Visible
Sets the Control Input Labels menu visible further on in the IED setting menu.				
HIF Detection	09	37	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the High Impedance (HIF) function.				
Direct Access	09	39	Enabled	0 = Disabled or 1 = Enabled
This setting enables or disables direct control of the Circuit Breakers from the IED's hotkeys.				
Function Key	09	50	Visible	0 = Disabled or 1 = Enabled
This setting enables or disables the Function Key menu.				
RP1 Read Only	09	FB	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables Read Only Mode for Rear Port 1.				
RP2 Read Only	09	FC	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables Read Only Mode for Rear Port 2.				
NIC Read Only	09	FD	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables Read Only Mode of the Network Interface Card for Ethernet models.				
LCD Contrast	09	FF	11	0 to 31 step 1
This setting sets the LCD contrast.				

5.4 TRANSFORMER RATIOS

Menu Text	Col	Row	Default Setting	Available Options
Description				
TRANS. RATIOS	0A	00		
This column contains settings for Current and Voltage Transformer ratios				
Main VT Primary	0A	01	110	100 V to 1 MV step 1 V
This setting sets the main voltage transformer input primary voltage.				
Main VT Sec'y	0A	02	110	80 V to 140 V step 0.2 V
This setting sets the main voltage transformer input secondary voltage.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
C/S VT Primary	0A	03	110	100 V to 1 MV step 1 V
This setting sets the System Check Synchronism voltage transformer input primary voltage.				
C/S VT Secondary	0A	04	110	80 V to 140 V step 0.2 V
This setting sets the System Check Synchronism voltage transformer input secondary voltage.				
NVD VT Primary	0A	05	110	100 V to 1 MV step 1 V
This setting sets the NVD transformer input primary voltage.				
NVD VT Secondary	0A	06	110	80 V to 140 V step 0.2 V
This setting sets the NVD transformer input secondary voltage.				
Phase CT Primary	0A	07	1	From 1A to 30000A step 1A
This setting sets the phase current transformer input primary current rating.				
Phase CT Sec'y	0A	08	1	1A or 5A
This setting sets the phase current transformer input secondary current rating.				
E/F CT Primary	0A	09	1	From 1A to 30000A step 1A
This setting sets the earth fault current transformer input primary current rating.				
E/F CT Secondary	0A	0A	1	1A or 5A
This setting sets the earth fault current transformer input secondary current rating.				
SEF CT Primary	0A	0B	1	From 1A to 30000A step 1A
This setting sets the sensitive earth fault current transformer input primary current rating.				
SEF CT Secondary	0A	0C	1	1A or 5A
Sets the sensitive earth fault current transformer input secondary current rating.				
C/S Input	0A	0F	A-N	0 = AN, 1 = BN, 2 = CN, 3 = AB, 4 = BC, 5 = CA
This setting selects the System Check Synchronism Input voltage measurement.				
Main VT Location	0A	10	Line	0 = Line or 1 = Bus
This setting defines the Main VT Location.				
C/S V kSM	0A	14	1	From 0.1 to 5 step 0.001
This setting sets the voltage magnitude correction factor for check synchronism in case of different VT ratios.				
C/S Phase kSA	0A	15	0	From -150 to 180 step 30
This setting sets the phase angle correction factor for check synchronism.				

5.5 SYSTEM CONFIGURATION

Menu Text	Col	Row	Default Setting	Available Options
Description				
GROUP 1 SYSTEM CONFIG	30	00		
This column contains settings for setting the phase rotation and 2nd harmonic blocking				
Phase Sequence	30	02	Standard ABC	0=Standard ABC 1=Reverse ACB
This setting sets the phase rotation to standard (ABC) or reverse (ACB). Warning: This will affect the positive and negative sequence quantities calculated by the IED as well as other functions that are dependant on phase quantities.				

5.6 SECURITY CONFIGURATION

Menu Text	Col	Row	Default Setting	Available Options
Description				
SECURITY CONFIG	25	00		
This column contains settings for the Cyber Security configuration				
User Banner	25	01	ACCESS ONLY FOR AUTHORISED USERS	ASCII 32 to 234
With this setting, you can enter text for the NERC compliant banner.				
Attempts Limit	25	02	3	0 to 3 step 1
This setting defines the maximum number of failed password attempts before action is taken.				
Attempts Timer	25	03	2	1 to 3 step 1
This setting defines the time window used in which the number of failed password attempts is counted.				
Blocking Timer	25	04	5	1 to 30 step 1
This setting defines the time duration for which the user is blocked, after exceeding the maximum attempts limit.				
Front Port	25	05	Enabled	0 = Disabled or 1 = Enabled
This setting enables or disables the physical Front Port.				
Rear Port 1	25	06	Enabled	0 = Disabled or 1 = Enabled
This setting enables or disables the primary physical rear port (RP1).				
Rear Port 2	25	07	Enabled	0 = Disabled or 1 = Enabled
This setting enables or disables the secondary physical rear port (RP2).				
Ethernet Port	25	08	Enabled	0 = Disabled or 1 = Enabled
This setting enables or disables the physical Ethernet Port				
Courier Tunnel	25	09	Enabled	0 = Disabled or 1 = Enabled
This setting enables or disables the logical tunnelled Courier port				
IEC 61850	25	0A	Enabled	0 = Disabled or 1 = Enabled
This setting enables or disables the logical IEC 61850 port.				
DNP3 OE	25	0B	Enabled	0 = Disabled or 1 = Enabled
This setting enables or disables the logical DNP3 over Ethernet port.				
Attempts Remain	25	11		Not Settable
This cell displays the number of password attempts remaining				
Blk Time Remain	25	12		Not Settable
This cell displays the remaining blocking time.				
Fallbck PW level	25	20		0 = Password Level 0, 1 = Password Level 1, 2 = Password Level 2, 3 = Password Level 3
This cell displays the password level adopted by the IED after an inactivity timeout, or after the user logs out. This will be either the level of the highest level password that is blank, or level 0 if no passwords are blank.				
Security Code	25	FF		Not Settable
This cell displays the 16-character security code required when requesting a recovery password.				

CURRENT PROTECTION FUNCTIONS

CHAPTER 5

1 CHAPTER OVERVIEW

The P14D provides a wide range of current protection functions. This chapter describes the operation of these functions including the principles, logic diagrams and applications.

This chapter contains the following sections:

2 OVERCURRENT PROTECTION PRINCIPLES

Most power system faults result in an overcurrent of one kind or another. It is the job of protection devices, formerly known as 'relays' but now known as Intelligent Electronic Devices (IEDs) to protect the power system from such faults. The general principle is to isolate the faults as quickly as possible to limit the danger and prevent unwanted fault currents flowing through systems, which can cause severe damage to equipment and systems. At the same time, we wish to switch off only the parts of the grid that are absolutely necessary, to prevent unnecessary blackouts. The protection devices that control the tripping of the grid's circuit breakers are highly sophisticated electronic units, providing an array of functionality to cover the different fault scenarios for a multitude of applications.

The described products offer a range of overcurrent protection functions including:

- Phase Overcurrent protection
- Earth Fault Overcurrent protection
- Negative Sequence Overcurrent protection
- Sensitive Earth Fault protection
- Restricted Earth Fault protection

To ensure that only the necessary circuit breakers are tripped and that these are tripped with the smallest possible delay, the IEDs in the protection scheme need to co-ordinate with each other. Various methods are available to achieve correct co-ordination between IEDs in a system. These are:

- By means of time alone
- By means of current alone
- By means of a combination of both time and current.

Grading by means of current is only possible where there is an appreciable difference in fault level between the two locations where the devices are situated. Grading by time is used by some utilities but can often lead to excessive fault clearance times at or near source substations where the fault level is highest.

For these reasons the most commonly applied characteristic in co-ordinating overcurrent devices is the IDMT (Inverse Definite Minimum Time) type.

2.1 IDMT CHARACTERISTICS

There are two basic requirements to consider when designing protection schemes:

- All faults should be cleared as quickly as possible to minimise damage to equipment
- Fault clearance should result in minimum disruption to the electrical power grid.

The second requirement means that the protection scheme should be designed such that only the circuit breaker(s) in the protection zone where the fault occurs, should trip.

These two criteria are actually in conflict with one another, because to satisfy (1), we increase the risk of shutting off healthy parts of the grid, and to satisfy (2) we purposely introduce time delays, which increase the amount of time a fault current will flow. This problem is exacerbated by the nature of faults in that the protection devices nearest the source, where the fault currents are largest, actually need the longest time delay.

The old electromechanical relays countered this problem somewhat due to their natural operate time v. fault current characteristic, whereby the higher the fault current, the quicker the operate time. The characteristic typical of these electromechanical relays is called Inverse Definite Minimum Time or IDMT for short.

2.1.1 IEC60255 IDMTCURVES

There are three well-known variants of this characteristic, as defined by IEC 60255:

- Inverse
- Very inverse
- Extremely inverse

These equations and corresponding curves governing these characteristics are very well known in the power industry.

Inverse

The curve is very steep. The relay can operate at low values of fault current, but at high fault currents has a significant operate time. The inverse characteristic equation is as follows:

$$t_{op} = T\frac{0.14}{\left(\frac{I}{I_s}\right)^{0.02} - 1}$$

Very Inverse

The curve lies somewhere between inverse and extremely inverse. The inverse characteristic equation is as follows.

$$t_{op} = T\frac{13.5}{\left(\frac{I}{I_s}\right) - 1}$$

Extremely Inverse

The curve is very shallow. The relay does not operate at very low values of fault current, but operates very quickly at high levels of fault current.

$$t_{op} = T\frac{80}{\left(\frac{I}{I_s}\right)^{2} - 1}$$

In the above equations:

- t_{op} is the operating time
- T is the time multiplier setting
- I is the measured current
- I_S is the current threshold setting.

The ratio I/I_S is sometimes defined as 'M' or 'PSM' (Plug Setting Multiplier).

These three curves are plotted as follows:

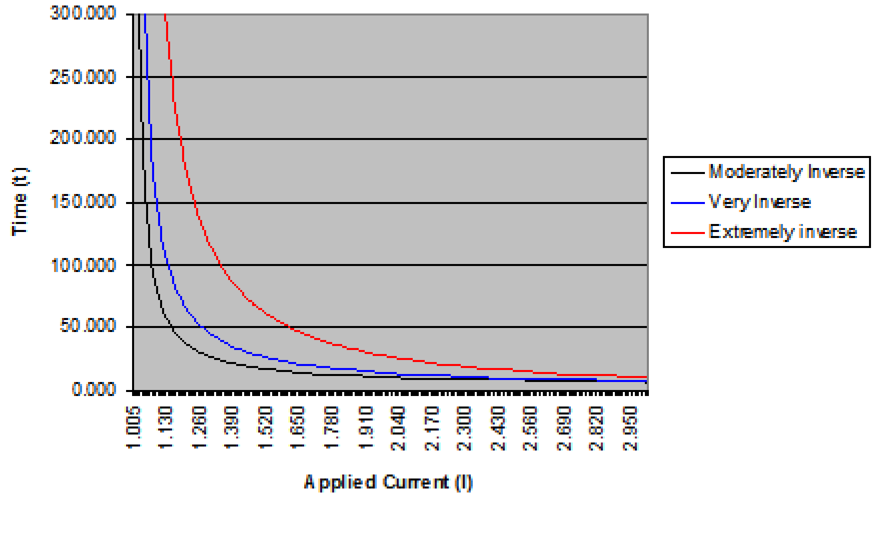


Figure 15: IEC 60255 IDMT curves

2.1.2 EUROPEAN STANDARDS

The IEC 60255 IDMT Operate equation is:

$$t_{op} = \left(T \frac{\beta}{M^{\alpha} - 1} + L \right) + C$$

and the IEC 60255 IDMT Reset equation is:

$$t_r = \left(T \frac{\beta}{1 - M^{\alpha}} + L \right) + C$$

where:

- t_{op} is the operating time
- T is the Time Multiplier setting
- M is the ratio of the measured current divided by the threshold current (I/Is)
- β is a constant, which can be chosen to satisfy the required curve characteristic
- α is a constant, which can be chosen to satisfy the required curve characteristic
- C is a constant for adding Definite Time (Definite Time adder)
- L is a constant (usually only used for ANSI/IEEE curves)

The constant values for the IEC IDMT curves are as follows:

Curve Description	β constant	α constant	L constant
IEC Standard Inverse Operate	0.14	0.02	0
IEC Standard Inverse Reset	8.2	6.45	0
IEC Very Inverse Operate	13.5	1	0
IEC Very Inverse Reset	50.92	2.4	0
IEC Extremely Inverse Operate	80	2	0

Curve Description	β constant	α constant	L constant
IEC Extremely Inverse Reset	44.1	3.03	0
UK Long Time Inverse Operate*	120	1	0
BPN (EDF) Operate*	1000	2	0.655
UK Rectifier Operate*	45900	5.6	0
FR Short Time Inverse Operate	0.05	0.04	0

Rapid Inverse (RI) characteristic

The RI operate curve is represented by the following equation:

$$t_{op} = K\left(\frac{1}{0.339 - \frac{0.236}{M}}\right)$$

where:

- t_{op} is the operating time
- K is the Time Multiplier setting
- M is the ratio of the measured current divided by the threshold current (I/I_S)

> *Note:*
> ** When using UK Long Time Inverse, BPN, UK Rectifier, FR Short Time Inverse, or RI for the Operate characteristic, DT is always used for the Reset characteristic.*

2.1.3 NORTH AMERICAN STANDARDS

The IEEE IDMT Operate equation is:

$$t_{op} = \left(TD\frac{\beta}{M^{\alpha} - 1} + L\right) + C$$

and the IEEE IDMT Reset equation is:

$$t_{op} = \left(TD\frac{\beta}{1 - M^{\alpha}} + L\right) + C$$

where:

- t_{op} is the operating time
- TD is the Time Dial setting
- M is the ratio of the measured current divided by the threshold current (I/I_S)
- β is a constant, which can be chosen to satisfy the required curve characteristic
- α is a constant, which can be chosen to satisfy the required curve characteristic
- C is a constant for adding Definite Time (Definite Time adder)
- L is a constant (usually only used for ANSI/IEEE curves)

The constant values for the IEEE curves are as follows:

Curve Description	β constant	α constant	L constant
IEEE Moderately Inverse Operate	0.0515	0.02	0.114

Curve Description	β constant	α constant	L constant
IEEE Moderately Inverse Reset	4.85	2	0
IEEE Very Inverse Operate	19.61	2	0.491
IEEE Very Inverse Reset	21.6	2	0
IEEE Extremely Inverse Operate	28.2	2	0.1217
IEEE Extremely Inverse Reset	29.1	2	0
CO8 US Inverse Operate	5.95	2	0.18
CO8 US Inverse Reset	5.95	2	0
CO2 US Short Time Inverse Operate	0.16758	0.02	0.11858
CO2 US Short Time Inverse Reset	2.261	2	0
ANSI Normally Inverse Operate	8.9341	2.0938	0.17966
ANSI Normally Inverse Reset	9	2	0
ANSI Short Time Inverse Operate	0.03393	1.2969	0.2663
ANSI Short Time Inverse Reset	0.5	2	0
ANSI Long Time Inverse Operate	2.18592	1	5.6143
ANSI Long Time Inverse Reset	15.75	2	0

Note:
** When using UK Long Time Inverse, BPN, UK Rectifier, or FR Short Time Inverse for the Operate characteristic, DT is always used for the Reset characteristic.*

2.1.4 DIFFERENCES BETWEEN THE NORTH AMERICAN AND EUROPEAN STANDARDS

The IEEE and US curves are set differently to the IEC/UK curves, with regard to the time setting. A time multiplier setting (TMS) is used to adjust the operating time of the IEC curves, whereas a time dial setting is used for the IEEE/US curves. The menu is arranged such that if an IEC/UK curve is selected, the **I> Time Dial** cell is not visible and vice versa for the TMS setting. For both IEC and IEEE/US type curves, a definite time adder setting is available, which will increase the operating time of the curves by the set value.

2.1.5 PROGRAMMABLE CURVES

As well as the standard curves as defined by various countries and standardising bodies, it is possible to program custom curves using Alstom Grid's User Programmable Curve Tool, described in the MiCOM S1 Agile chapter. This is a user-friendly tool by which you can create curves either by formula or by entering data points. Programmable curves help you to match more closely the withstand characteristics of the electrical equipment than standard curves.

2.2 PRINCIPLES OF IMPLEMENTATION

The MiCOM range of protection products provides a very wide range of protection functionality. Despite the diverse range of functionality provided, there is some commonality between the way many of the protection functions are implemented. It is important to describe some of these basic principles before going deeper into the individual protection functions.

A very simple representation of protection functionality is shown in the following diagram:

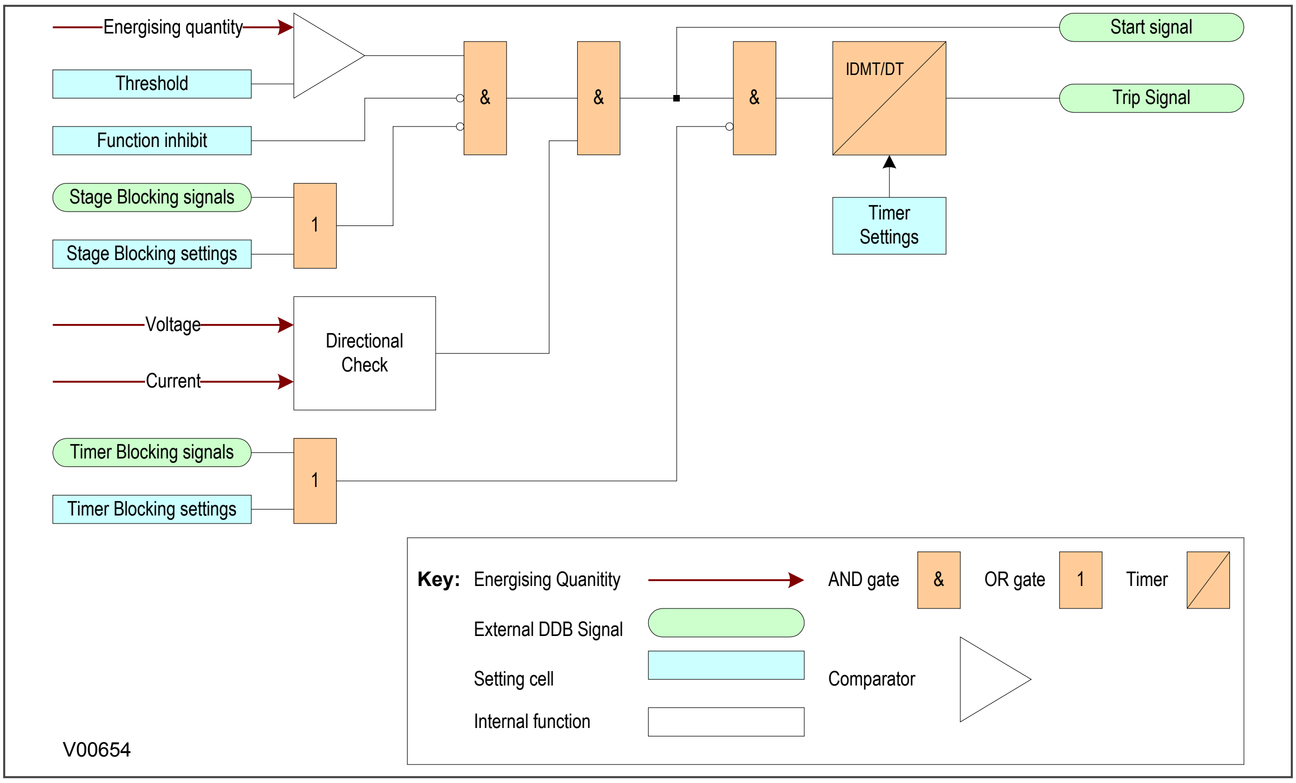


Figure 16: Principle of Protection Function Implementation

An energising quantity is either a voltage input from a system voltage transformer, a current input from a system current transformer or another quantity derived from one or both of these. The energising quantities are extracted from the power system and presented to the IED in the form of analogue signals. These analogue signals are then converted to digital quantities where they can be processed by the IEDs internal computer.

In general, an energising quantity, be it a current, voltage, power, frequency, or phase quantity, is compared with a threshold value, which may be settable, or hard-coded depending on the function. If the quantity exceeds (for overvalues) or falls short of (for undervalues) the threshold, a signal is produced, which when gated with the various inhibit and blocking functions becomes the Start signal for that protection function. This Start signal is generally made available to Fixed Scheme logic and Programmable scheme logic for further processing. It is also passed through a timer function to produce the Trip signal. The timer function may be an IDMT curve, or a Definite Time delay, depending on the function. This timer may also be blocked with timer blocking signals and settings. The timer can be configured by a range of settings to define such parameters as the type of curve, The Time Multiplier Setting, the IDMT constants, the Definite Time delay etc.

Many protection functions require a direction-dependent decision. Such functions can only be implemented where both current and voltage inputs are available. For such functions, a directional check is required, whose output can block the Start signal should the direction of the fault be wrong.

In MiCOM products, there are usually several independent stages for each of the functions, and for three-phase functions, there are usually independent stages for each of the three phases.

Typically in MiCOM products, stages 1,2 and 5 (if available) use an IDMT timer function, whilst stages 3,4 and 6 (if available) use a Definite Time timer function. If the DT time delay is set to '0', then the function is known to be "instantaneous". In many instances, the term 'instantaneous protection" is used loosely to describe Definite Time protection stages, even when the stage may not theoretically be instantaneous.

2.2.1 TIMER HOLD FACILITY

This feature may be useful in certain applications, such as when grading with upstream electromechanical overcurrent relays, which have inherent reset time delays. If you set the hold timer to a value other than zero, the resetting of the protection element timers will be delayed for this period. This allows the element to behave in a similar way to an electromechanical relay. If you set the hold timer to zero, the overcurrent timer for that stage will reset instantaneously as soon as the current falls below a specified percentage of the current setting (typically 95%).

Another possible situation where the timer hold facility may be used to reduce fault clearance times is for intermittent faults. An example of this may occur in a plastic insulated cable. In this application it is possible that the fault energy melts and reseals the cable insulation, thereby extinguishing the fault. This process repeats to give a succession of fault current pulses, each of increasing duration with reducing intervals between the pulses, until the fault becomes permanent.

When the reset time is instantaneous, the device will repeatedly reset and not be able to trip until the fault becomes permanent. By using the Timer Hold facility the device will integrate the fault current pulses, thereby reducing fault clearance time.

The Timer Hold facility is only available for stages with IDMT functionality , and is controlled by the timer reset settings for the relevant stages (e.g. **I>1 tReset, I>2 tReset**). These cells are not visible for the IEEE/US curves if an inverse time reset characteristic has been selected, because in this case the reset time is determined by the time dial setting (TDS).

3 PHASE OVERCURRENT PROTECTION

Phase current faults are faults where fault current flows between two or more phases of a three-phase power system. The fault current may be between the phase conductors only or, between two or more phase conductors and earth. There are three types of phase fault:

- Line to Line (accounting for approximately 8% of all faults)
- Line to Line to Earth (accounting for approximately 5% of all faults)
- Line to Line to Line (accounting for approximately 2% of all faults)

Although not as common as earth faults (single line to earth), phase faults are typically more severe.

An example of a phase fault is where a fallen tree branch bridges two or more phases of an overhead line.

3.1 PHASE OVERCURRENT PROTECTION IMPLEMENTATION

Phase Overcurrent Protection is implemented in the OVERCURRENT column of the relevant settings group.

The product provides six stages of three-phase overcurrent protection with independent time delay characteristics. All settings apply to all three phases but are independent for each of the six stages.

Stages 1, 2 and 5 provide a choice of operate and reset characteristics, where you can select between:

- A range of standard IDMT (Inverse Definite Minimum Time) curves
- A range of User-defined curves
- DT (Definite Time)

This is achieved using the cells

- **I>**(n) **Function** for the overcurrent operate characteristic
- **I>**(n) **Reset Char** for the overcurrent reset characteristic
- **I>**(n) **Usr RstChar** for the reset characteristic for user -defined curves

where (n) is the number of the stage.

The IDMT-capable stages, (1,2 and 5) also provide a Timer Hold facility (on page 88). This is configured using the cells **I>**(n) **tReset**, where (n) is the number of the stage. This is not applicable for curves based on the IEEE standard.

Stages 3, 4 and 6 can have definite time characteristics only.

3.2 NON-DIRECTIONAL OVERCURRENT LOGIC

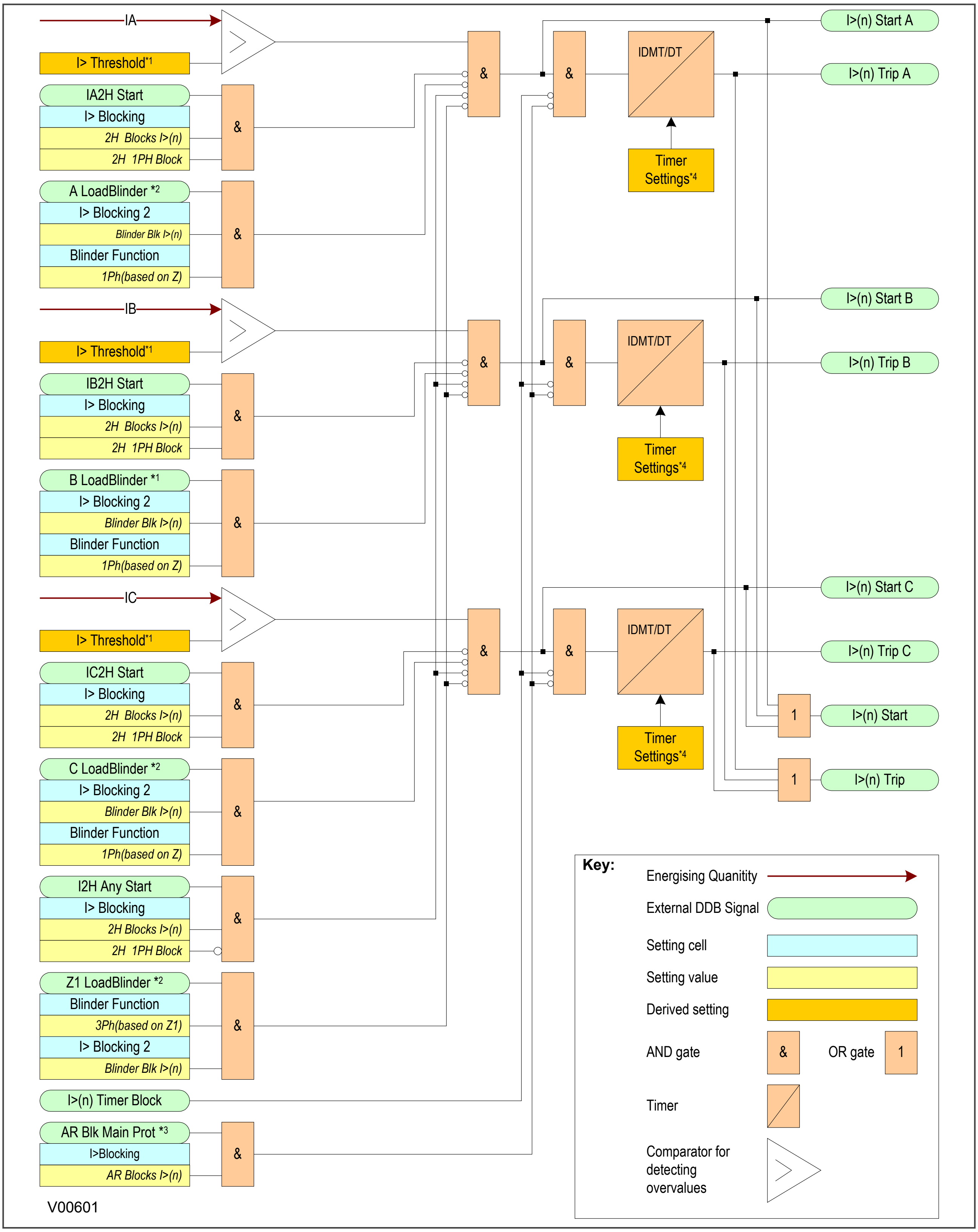


Figure 17: Non-directional Overcurrent Logic Diagram

Note:
**1 The threshold settings are influenced by Voltage Dependent and Cold Load Pickup functionality*
**2 Load blinder functionality is only available for stages 1,2 and 5 and on selected models*
**3 Autoreclose blocking is only available for stages 3,4 and 6 and on selected models*
**4 The timer settings are influenced by Cold Load Pickup and Selective Overcurrent Logic*

Phase Overcurrent Modules are level detectors that detect when the current magnitude exceeds a set threshold. When this happens, the Phase Overcurrent Module in question issues a signal, which is gated with some blocking signals to produce the **Start** signal. This **Start** signal is gated with other blocking signals and applied to the IDMT/DT timer module. It is also made available directly to the user for use in the PSL. For each stage, there are three Phase Overcurrent Modules, one for each phase. The three **Start** signals from each of these phases are OR'd together to create a **3-phase Start** signal.

The outputs of the IDMT/DT timer modules are the trip signals which are used to drive the tripping output relay. These tripping signals are also OR'd together to create a **3-phase Trip** signal.

The IDMT/DT timer modules can be blocked by:

- A Phase Overcurrent Timer Block (**I>(n) Timer Block**)
- For models with Autoreclose functionality, an Autoreclose blocking signal, produced by the DDB **AR Blk Main Prot** and the relevant settings in the **I>Blocking** cell. This is only valid for the DT-only stages

If any one of the above signals is high, or goes high before the timer has counted out, the IDMT/DT timer module is inhibited (effectively reset) until the blocking signal goes low again. There are separate phase overcurrent timer block signals, which are independent for each overcurrent stage.

The start signal can be blocked by:

- The Second Harmonic blocking function on a per phase basis or for all three phases. The relevant bits are set in the **I> Blocking** cell and this is combined with the relevant second harmonic blocking DDBs.
- The Load Blinder function, on a per phase basis or for all three phases. The relevant bits are set in the **I> Blocking 2** cell and this is combined with the relevant Load Blinder blocking DDBs.

The G14 Data type is used for the **I>Blocking** setting:

Bit number	I> Blocking function
Bit 0	VTS Blocks I>1
Bit 1	VTS Blocks I>2
Bit 2	VTS Blocks I>3
Bit 3	VTS Blocks I>4
Bit 4	VTS Blocks I>5
Bit 5	VTS Blocks I>6
Bit 6	AR Blocks I>3
Bit 7	AR Blocks I>4
Bit 8	AR Blocks I>6
Bit 9	2H Blocks I>1
Bit 10	2H Blocks I>2
Bit 11	2H Blocks I>3
Bit 12	2H Blocks I>4
Bit 13	2H Blocks I>5
Bit 14	2H Blocks I>6
Bit 15	2H 1PH Block

These can be set via the Front panel HMI or with the settings application software.

The Phase Overcurrent threshold setting can be influenced by the Cold Load Pickup (CLP) (on page 114) and Voltage Dependent Overcurrent (VDep OC) (on page 108) functions, if this functionality is available and used. Likewise, the timer settings can be influenced by the Selective Logic (on page 120) function.

3.3 CURRENT SETTING THRESHOLD SELECTION

The threshold setting used in the level detector depends on whether there is a Voltage Dependent condition or a Cold Load Pickup condition. The Overcurrent function selects the threshold setting according to the following diagram:

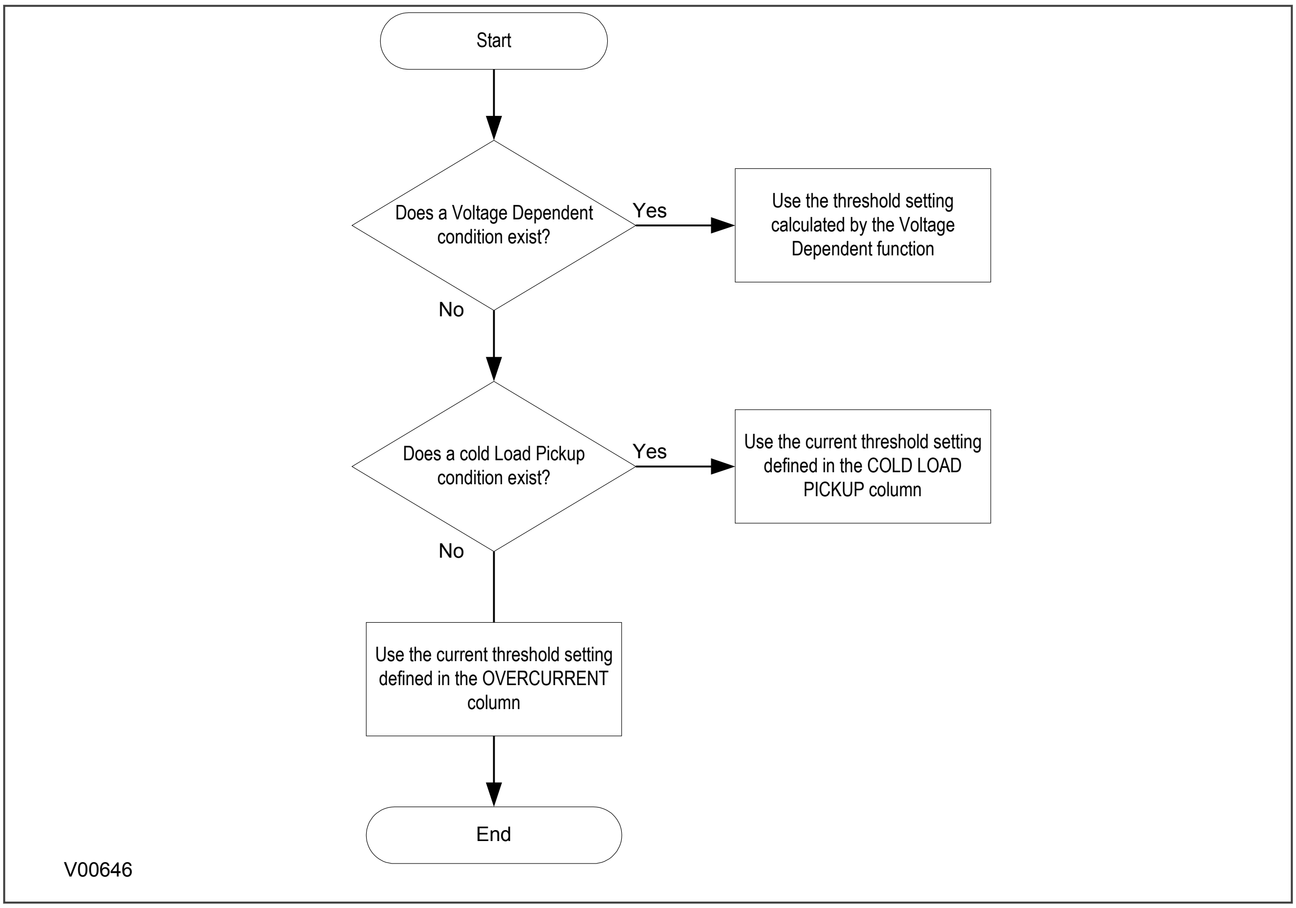


Figure 18: Selecting the current threshold setting

3.4 TIMER SETTING SELECTION

The timer settings used depend on whether there is a Selective Overcurrent condition or a Cold Load Pickup condition. The Overcurrent function selects the settings according to the following flow diagram:

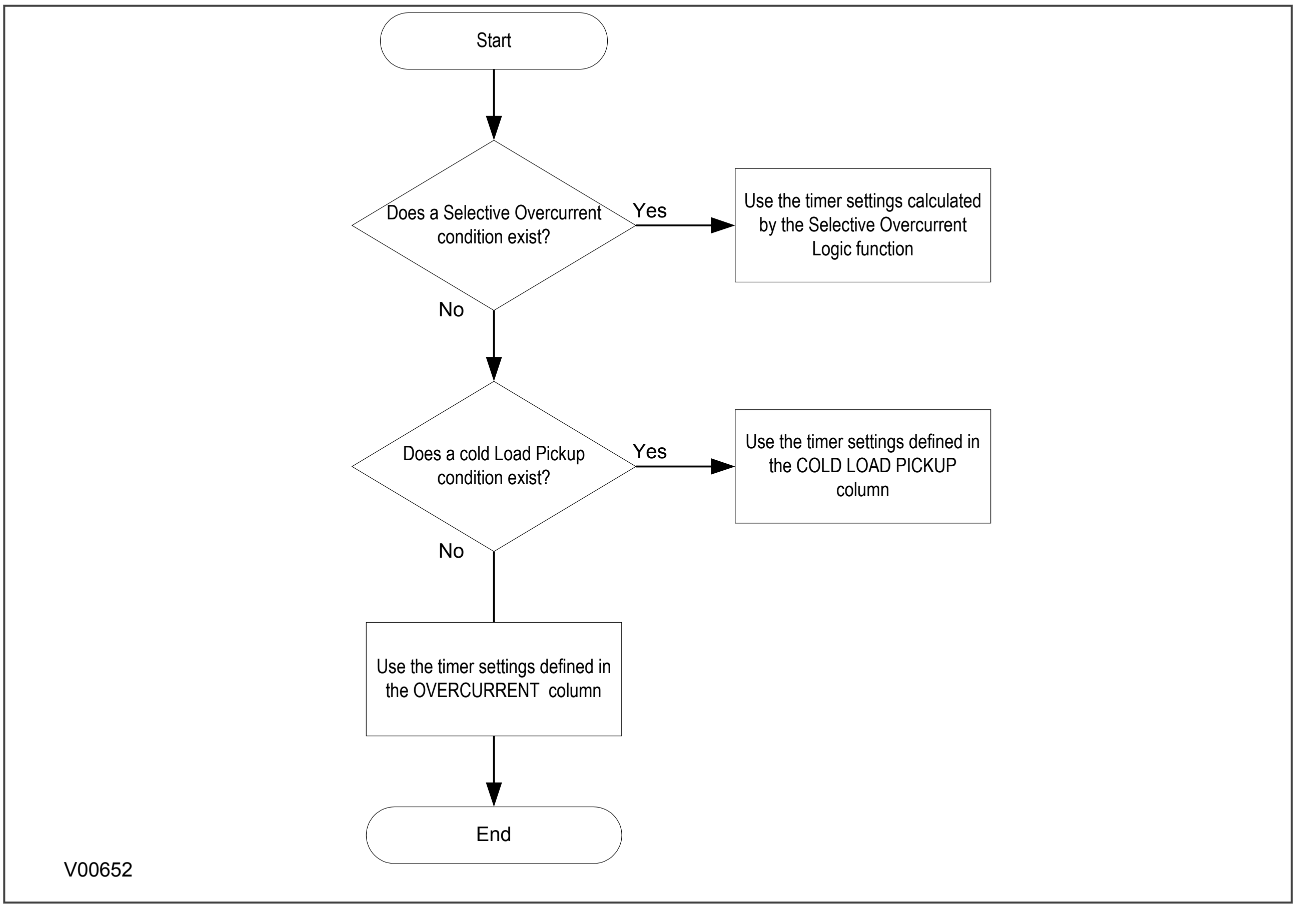


Figure 19: Selecting the timer settings

3.5 DIRECTIONAL ELEMENT

If fault current can flow in both directions through a protected location, you will need to use a directional overcurrent element to determine the direction of the fault. Typical systems that require such protection are parallel feeders (both plain and transformer) and ring main systems, each of which are relatively common in distribution networks.

To determine the direction of a phase overcurrent fault, the device must provide a voltage transformer input for each phase. Direction can be determined by establishing the phase angle between the measured voltage and the fault current.

A directional element is available for all of the phase overcurrent stages in this device. These are found in the direction setting cells for the relevant stage (e.g. **I>1 Direction, I>2 Direction**). They can be set to non-directional, directional forward, or directional reverse.

Under system fault conditions, the fault current vector will lag its nominal phase voltage by an angle dependent upon the system X/R ratio. Therefore the device must operate with maximum sensitivity for currents lying in this region. This is achieved by means of the characteristic angle (RCA) setting, which defines the angle by which the applied current must be displaced from the applied voltage in order to obtain maximum sensitivity. This is set in cell **I>Char Angle**. You can set characteristic angles anywhere in the range from –95° to +95°.

3.5.1 SYNCHRONOUS POLARISATION

For a close up three-phase fault, all three voltages will collapse to zero and no healthy phase voltages will be present. For this reason, the device includes a synchronous polarisation feature that stores the pre-fault voltage information and continues to apply this to the directional overcurrent elements for a time period of a few seconds. This ensures that either instantaneous or time-delayed directional overcurrent elements will be allowed to operate, even with a three-phase voltage collapse.

3.5.2 DIRECTIONAL OVERCURRENT LOGIC

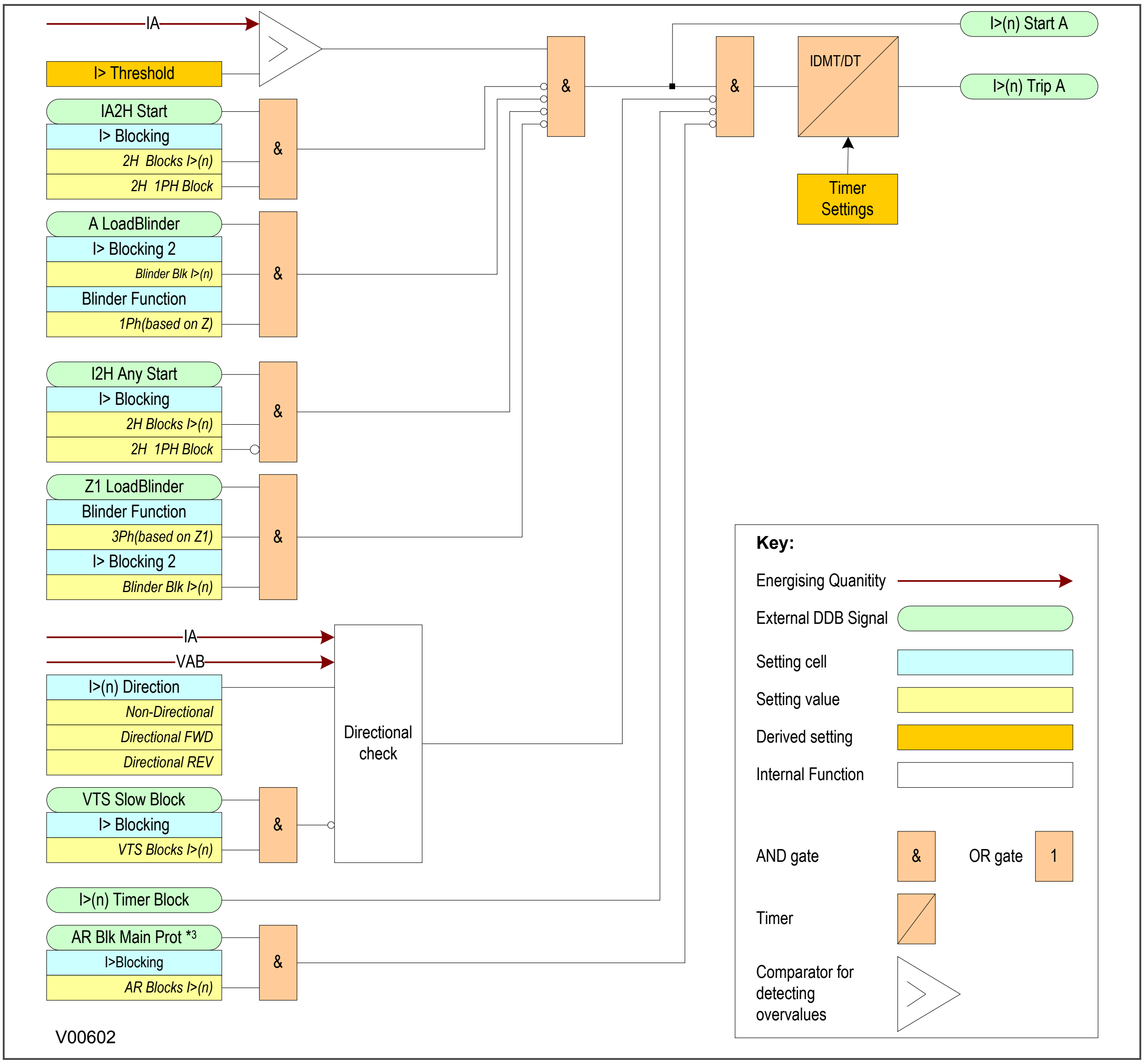


Figure 20: Directional Overcurrent Logic Diagram

The directional logic overcurrent logic works the same way as non-directional logic (on page 90) except that there is a Directional Check function, based on the following criteria:

- Directional forward: -90° < (angle(I) - angle(V) - RCA) < 90°
- Directional reverse: -90° > (angle(I) - angle(V) - RCA) > 90°

The polarising voltages for each phase are as follows:

Phase of Protection	Operate Current	Polarising Voltage
A Phase	IA	VBC
B Phase	IB	VCA

Phase of Protection	Operate Current	Polarising Voltage
C Phase	IC	VAB

When the element is selected as directional, blocking of the Voltage Transformer Supervision (VTS Block) is available (**I>Blocking** cell). When the relevant bit is set to 1, operation of the VTS will block the stage if directionalised. When set to 0, the stage will revert to non-directional upon operation of the VTS. This is shown in the G14 Data Type table in the non-directional logic (on page 90) section.

3.6 OVERCURRENT DDB SIGNALS

Ordinal	Signal Name	Source	Type	Response
Description				
203	I>1 Timer Block	Programmable Scheme Logic	PSL Output	No response
This DDB signal blocks the first stage overcurrent time delay				
204	I>2 Timer Block	Programmable Scheme Logic	PSL Output	No response
This DDB signal blocks the second stage overcurrent time delay				
205	I>3 Timer Block	Programmable Scheme Logic	PSL Output	No response
This DDB signal blocks the third stage overcurrent time delay				
206	I>4 Timer Block	Programmable Scheme Logic	PSL Output	No response
This DDB signal blocks the fourth stage overcurrent time delay				
243	I>1 Trip	Software	PSL Input	Protection event
This DDB signal is the first stage any-phase Phase Overcurrent trip signal				
244	I>1 Trip A	Software	PSL Input	Protection event
This DDB signal is the first stage A-phase Phase Overcurrent trip signal				
245	I>1 Trip B	Software	PSL Input	Protection event
This DDB signal is the first stage B-phase Phase Overcurrent trip signal				
246	I>1 Trip C	Software	PSL Input	Protection event
This DDB signal is the first stage C-phase Phase Overcurrent trip signal				
247	I>2 Trip	Software	PSL Input	Protection event
This DDB signal is the second stage any-phase Phase Overcurrent trip signal				
248	I>2 Trip A	Software	PSL Input	Protection event
This DDB signal is the second stage A-phase Phase Overcurrent trip signal				
249	I>2 Trip B	Software	PSL Input	Protection event
This DDB signal is the second stage B-phase Phase Overcurrent trip signal				
250	I>2 Trip C	Software	PSL Input	Protection event
This DDB signal is the second stage C-phase Phase Overcurrent trip signal				
251	I>3 Trip	Software	PSL Input	Protection event
This DDB signal is the third stage any-phase Phase Overcurrent trip signal				
252	I>3 Trip A	Software	PSL Input	Protection event
This DDB signal is the third stage A-phase Phase Overcurrent trip signal				
253	I>3 Trip B	Software	PSL Input	Protection event
This DDB signal is the third stage B-phase Phase Overcurrent trip signal				
254	I>3 Trip C	Software	PSL Input	Protection event
This DDB signal is the third stage C-phase Phase Overcurrent trip signal				
255	I>4 Trip	Software	PSL Input	Protection event

Ordinal	Signal Name	Source	Type	Response
Description				
This DDB signal is the fourth stage any-phase Phase Overcurrent trip signal				
256	I>4 Trip A	Software	PSL Input	Protection event
This DDB signal is the fourth stage A-phase Phase Overcurrent trip signal				
257	I>4 Trip B	Software	PSL Input	Protection event
This DDB signal is the fourth stage B-phase Phase Overcurrent trip signal				
258	I>4 Trip C	Software	PSL Input	Protection event
This DDB signal is the fourth stage C-phase Phase Overcurrent trip signal				
295	I>1 Start	Software	PSL Input	Protection event
This DDB signal is the first stage any-phase Overcurrent start signal				
296	I>1 Start A	Software	PSL Input	Protection event
This DDB signal is the first stage A-phase Overcurrent start signal				
297	I>1 Start B	Software	PSL Input	Protection event
This DDB signal is the first stage B-phase Overcurrent start signal				
298	I>1 Start C	Software	PSL Input	Protection event
This DDB signal is the first stage C-phase Overcurrent start signal				
299	I>2 Start	Software	PSL Input	Protection event
This DDB signal is the second stage any-phase Overcurrent start signal				
300	I>2 Start A	Software	PSL Input	Protection event
This DDB signal is the second stage A-phase Overcurrent start signal				
301	I>2 Start B	Software	PSL Input	Protection event
This DDB signal is the second stage B-phase Overcurrent start signal				
302	I>2 Start C	Software	PSL Input	Protection event
This DDB signal is the second stage C-phase Overcurrent start signal				
303	I>3 Start	Software	PSL Input	Protection event
This DDB signal is the third stage any-phase Overcurrent start signal				
304	I>3 Start A	Software	PSL Input	Protection event
This DDB signal is the third stage A-phase Overcurrent start signal				
305	I>3 Start B	Software	PSL Input	Protection event
This DDB signal is the third stage B-phase Overcurrent start signal				
306	I>3 Start C	Software	PSL Input	Protection event
This DDB signal is the third stage C-phase Overcurrent start signal				
307	I>4 Start	Software	PSL Input	Protection event
This DDB signal is the fourth stage any-phase Overcurrent start signal				
308	I>4 Start A	Software	PSL Input	Protection event
This DDB signal is the fourth stage A-phase Overcurrent start signal				
309	I>4 Start B	Software	PSL Input	Protection event
This DDB signal is the fourth stage B-phase Overcurrent start signal				
310	I>4 Start C	Software	PSL Input	Protection event
This DDB signal is the fourth stage C-phase Overcurrent start signal				
351	VTS Slow Block	Software	PSL Input	No response
This DDB signal is a purposely delayed output from the VTS which can block other functions				
358	AR Blk Main Prot	Software	PSL Input	Protection event

Ordinal	Signal Name	Source	Type	Response
Description				
This DDB signal, generated by the Autoreclose function, blocks the Main Protection elements (POC, EF1, EF2, NPSOC)				
567	I>5 Timer Block	Programmable Scheme Logic	PSL Output	No response
This DDB signal blocks the fifth stage overcurrent time delay				
568	I>6 Timer Block	Programmable Scheme Logic	PSL Output	No response
This DDB signal blocks the sixth stage overcurrent time delay				
570	I>5 Trip	Software	PSL Input	Protection event
This DDB signal is the fifth stage three-phase Phase Overcurrent trip signal				
571	I>5 Trip A	Software	PSL Input	Protection event
This DDB signal is the fifth stage A-phase Phase Overcurrent trip signal				
572	I>5 Trip B	Software	PSL Input	Protection event
This DDB signal is the fifth stage B-phase Phase Overcurrent trip signal				
573	I>5 Trip C	Software	PSL Input	Protection event
This DDB signal is the fifth stage C-phase Phase Overcurrent trip signal				
574	I>6 Trip	Software	PSL Input	Protection event
This DDB signal is the sixth stage three-phase Phase Overcurrent trip signal				
575	I>6 Trip A	Software	PSL Input	Protection event
This DDB signal is the sixth stage A-phase Phase Overcurrent trip signal				
576	I>6 Trip B	Software	PSL Input	Protection event
This DDB signal is the sixth stage B-phase Phase Overcurrent trip signal				
577	I>6 Trip C	Software	PSL Input	Protection event
This DDB signal is the sixth stage C-phase Phase Overcurrent trip signal				
579	I>5 Start	Software	PSL Input	Protection event
This DDB signal is the fifth stage three-phase Phase Overcurrent start signal				
580	I>5 Start A	Software	PSL Input	Protection event
This DDB signal is the fifth stage A-phase Phase Overcurrent start signal				
581	I>5 Start B	Software	PSL Input	Protection event
This DDB signal is the fifth stage B-phase Phase Overcurrent start signal				
582	I>5 Start C	Software	PSL Input	Protection event
This DDB signal is the fifth stage C-phase Phase Overcurrent start signal				
583	I>6 Start	Software	PSL Input	Protection event
This DDB signal is the sixth stage three-phase Phase Overcurrent start signal				
584	I>6 Start A	Software	PSL Input	Protection event
This DDB signal is the sixth stage A-phase Phase Overcurrent start signal				
585	I>6 Start B	Software	PSL Input	Protection event
This DDB signal is the sixth stage B-phase Phase Overcurrent start signal				
586	I>6 Start C	Software	PSL Input	Protection event
This DDB signal is the sixth stage C-phase Phase Overcurrent start signal				
538	IA2H Start	Software	PSL Input	Protection event
This DDB signal is the A-phase 2nd Harmonic start signal				
539	IB2H Start	Software	PSL Input	Protection event
This DDB signal is the B-phase 2nd Harmonic start signal				
540	IC2H Start	Software	PSL Input	Protection event

Ordinal	Signal Name	Source	Type	Response
Description				
This DDB signal is the C-phase 2nd Harmonic start signal				
541	I2H Any Start	Software	PSL Input	Protection event
This DDB signal is the 2nd Harmonic start signal for any phase				
630	A LoadBlinder	Software	PSL Input	Protection event
This DDB signal is the Phase A Load Blinder signal, either direction				
633	B LoadBlinder	Software	PSL Input	Protection event
This DDB signal is the Phase B Load Blinder signal, either direction				
636	C LoadBlinder	Software	PSL Input	Protection event
This DDB signal is the Phase C Load Blinder signal, either direction				
639	Z1 LoadBlinder	Software	PSL Input	Protection event
This DDB signal is the 3-phase Load Blinder signal, either direction				

3.7 OVERCURRENT SETTINGS

Menu Text	Col	Row	Default Setting	Available Options
Description				
GROUP 1 OVERCURRENT	35	00		
This column contains settings for Overcurrent				
I>1 Function	35	23	IEC S Inverse	0=Disabled 1=DT 2=IEC S Inverse 3=IEC V Inverse 4=IEC E Inverse 5=UK LT Inverse 6=UK Rectifier 7=RI 8=IEEE M Inverse 9=IEEE V Inverse 10=IEEE E Inverse 11=US Inverse 12=US ST Inverse 13=User curve 1 14=User curve 2 15=User curve 3 16=User curve 4
This setting determines the tripping characteristic for the first stage overcurrent element.				
I>1 Direction	35	24	Non-Directional	0 = Non-Directional 1 = Directional Fwd 2 = Directional Rev
This setting determines the direction of measurement for the first stage overcurrent element.				
I>1 Current Set	35	27	1	From 0.05*In to 4.0*In step 0.01In
This setting sets the pick-up threshold for the first stage overcurrent element.				
I>1 Time Delay	35	29	1	From 0s to 100s step 0.01s
This setting sets the DT time delay for the first stage overcurrent element.				
I>1 TMS	35	2A	1	From 0.025 to 1.2 step 0.005
This is the Time Multiplier Setting to adjust the operate time of IEC IDMT curves.				
I>1 Time Dial	35	2B	1	From 0.01 to 100 step 0.01

Menu Text	Col	Row	Default Setting	Available Options
Description				
This is the Time Multiplier Setting to adjust the operate time of IEEE/US IDMT curves.				
I>1 k (RI)	35	2C	1	From 0.1 to 10 step 0.05
This setting defines the TMS constant to adjust the operate time of the RI curve.				
I>1 DT Adder	35	2D	0	From 0s to 100s step 0.01s
This setting adds an additional fixed time delay to the IDMT Operate characteristic.				
I>1 Reset Char	35	2E	DT	0=DT 1=Inverse
This setting determines the type of Reset characteristic used for the IEEE/US curves.				
I>1 tRESET	35	2F	0	From 0s to 100s step 0.01s
This setting determines the Reset time for the Definite Time Reset characteristic				
I>1 Usr RstChar	35	30	DT	0 = DT 1=User Curve 1 2=User Curve 2 3=User Curve 3 4=User Curve 4
This setting determines the type of Reset characteristic used for the user defined curves.				
I>2 Function	35	32	Disabled	0=Disabled 1=DT 2=IEC S Inverse 3=IEC V Inverse 4=IEC E Inverse 5=UK LT Inverse 6=UK Rectifier 7=RI 8=IEEE M Inverse 9=IEEE V Inverse 10=IEEE E Inverse 11=US Inverse 12=US ST Inverse 13=User curve 1 14=User curve 2 15=User curve 3 16=User curve 4
This setting determines the tripping characteristic for the second stage overcurrent element.				
I>2 Direction	35	33	Non-Directional	0 = Non-Directional 1 = Directional Fwd 2 = Directional Rev
This setting determines the direction of measurement for the second stage overcurrent element.				
I>2 Current Set	35	36	1	From 0.05*In to 4.0*In step 0.01In
This setting sets the pick-up threshold for the second stage overcurrent element.				
I>2 Time Delay	35	38	1	From 0s to 100s step 0.01s
This setting sets the DT time delay for the second stage element.				
I>2 TMS	35	39	1	From 0.025 to 1.2 step 0.005
This is the Time Multiplier Setting to adjust the operate time of IEC IDMT curves.				
I>2 Time Dial	35	3A	1	From 0.01 to 100 step 0.01
This is the Time Multiplier Setting to adjust the operate time of IEEE/US IDMT curves.				
I>2 k (RI)	35	3B	1	From 0.1 to 10 step 0.05
This setting defines the TMS constant to adjust the operate time of the RI curve.				
I>2 DT Adder	35	3C	0	From 0s to 100s step 0.01s

Menu Text	Col	Row	Default Setting	Available Options
Description				
This setting adds an additional fixed time delay to the IDMT Operate characteristic.				
I>2 Reset Char	35	3D	DT	0=DT 1=Inverse
This setting determines the type of Reset characteristic used for the IEEE/US curves.				
I>2 tRESET	35	3E	0	From 0s to 100s step 0.01s
This setting determines the Reset time for the Definite Time Reset characteristic				
I>2 Usr RstChar	35	3F	DT	0 = DT 1=User Curve 1 2=User Curve 2 3=User Curve 3 4=User Curve 4
This setting determines the type of Reset characteristic used for the user defined curves.				
I>3 Status	35	40	Disabled	0 = Disabled, 1 = Enabled
This setting enables or disables the third stage overcurrent element. There is no choice of curves because this stage is DT only.				
I>3 Direction	35	41	Non-Directional	0 = Non-Directional, 1 = Directional Fwd, 2 = Directional Rev
This setting determines the direction of measurement for the third stage overcurrent element.				
I>3 Current Set	35	44	20	From 0.05*In to 32.0*In step 0.01In
This setting sets the pick-up threshold for the third stage overcurrent element.				
I>3 Time Delay	35	45	0	From 0s to 100s step 0.01s
This setting sets the DT time delay for the third stage overcurrent element.				
I>4 Status	35	47	Disabled	0 = Disabled, 1 = Enabled
This setting enables or disables the fourth stage overcurrent element. There is no choice of curves because this stage is DT only.				
I>4 Direction	35	48	Non-Directional	0 = Non-Directional, 1 = Directional Fwd, 2 = Directional Rev
This setting determines the direction of measurement for the third stage overcurrent element.				
I>4 Current Set	35	4B	20	From 0.05*In to 32.0*In step 0.01In
This setting sets the pick-up threshold for the fourth stage overcurrent element.				
I>4 Time Delay	35	4C	0	From 0s to 100s step 0.01s
This setting sets the DT time delay for the fourth stage overcurrent element.				
I> Blocking	35	4E	0x003F	Bit 0=VTS Blocks I>1 Bit 1=VTS Blocks I>2 Bit 2=VTS Blocks I>3 Bit 3=VTS Blocks I>4 Bit 4=VTS Blocks I>5 Bit 5=VTS Blocks I>6 Bit 6=AR Blocks I>3 Bit 7=AR Blocks I>4 Bit 8=AR Blocks I>6 Bit 9=2H Blocks I>1 Bit 10=2H Blocks I>2 Bit 11=2H Blocks I>3 Bit 12=2H Blocks I>4 Bit 13=2H Blocks I>5 Bit 14=2H Blocks I>6 Bit 15=2H 1PH Block

Menu Text	Col	Row	Default Setting	Available Options
Description				
This setting cell contains a binary string where you can define which blocking signals block which stage. The available settings depend on the model chosen. This description is for models with Autoreclose, VTS and second harmonic blocking				
I> Blocking	35	4E	0x003F	Bit 0=VTS Blocks I>1 Bit 1=VTS Blocks I>2 Bit 2=VTS Blocks I>3 Bit 3=VTS Blocks I>4 Bit 4=VTS Blocks I>5 Bit 5=VTS Blocks I>6 Bit 6=Unused Bit 7=Unused Bit 8=Unused Bit 9=2H Blocks I>1 Bit 10=2H Blocks I>2 Bit 11=2H Blocks I>3 Bit 12=2H Blocks I>4 Bit 13=2H Blocks I>5 Bit 14=2H Blocks I>6 Bit 15=2H 1PH Block
This setting cell contains a binary string where you can define which blocking signals block which stage. The available settings depend on the model chosen. This description is for models with VTS and second harmonic blocking.				
I> Char Angle	35	4F	45	From -95 to 95 step 1
This setting defines the characteristic angle for the directional element. This setting is aplicable to all overcurrent stages.				
I> Blocking 2	35	50	0x0	Bit 0=Blinder Blk I>1 Bit 1=Blinder Blk I>2 Bit 2=Blinder Blk I>5 Bit 3=unused
This setting cell contains a binary string (data type G406), where you can define which Load Blinder blocking signals block which stage.				
I>5 Function	35	63	Disabled	0=Disabled 1=DT 2=IEC S Inverse 3=IEC V Inverse 4=IEC E Inverse 5=UK LT Inverse 6=UK Rectifier 7=RI 8=IEEE M Inverse 9=IEEE V Inverse 10=IEEE E Inverse 11=US Inverse 12=US ST Inverse 13=User curve 1 14=User curve 2 15=User curve 3 16=User curve 4
This setting determines the tripping characteristic for the fifth stage overcurrent element.				
I>5 Direction	35	64	Non-Directional	0 = Non-Directional, 1 = Directional Fwd, 2 = Directional Rev
This setting determines the direction of measurement for the fifth stage overcurrent element.				
I>5 Current Set	35	67	1	From 0.05*In to 4.0*In step 0.01In
This setting sets the pick-up threshold for the fifth stage overcurrent element.				
I>5 Time Delay	35	69	1	From 0s to 100s step 0.01s

Menu Text	Col	Row	Default Setting	Available Options
Description				
This setting sets the DT time delay for the fifth stage overcurrent element.				
I>5 TMS	35	6A	1	From 0.025 to 1.2 step 0.005
This is the Time Multiplier Setting to adjust the operate time of IEC IDMT curves.				
I>5 Time Dial	35	6B	1	From 0.01 to 100 step 0.01
This is the Time Multiplier Setting to adjust the operate time of IEEE/US IDMT curves.				
I>5 k (RI)	35	6C	1	From 0.1 to 10 step 0.05
This setting defines the TMS constant to adjust the operate time of the RI curve.				
I>5 DT Adder	35	6D	0	From 0s to 100s step 0.01s
This setting adds an additional fixed time delay to the IDMT Operate characteristic.				
I>5 Reset Char	35	6E	DT	0=DT 1=Inverse
This setting determines the type of Reset characteristic used for the IEEE/US curves.				
I>5 tRESET	35	6F	0	From 0s to 100s step 0.01s
This setting determines the Reset time for the Definite Time Reset characteristic				
I>5 Usr RstChar	35	70	DT	0 = DT 1=User Curve 1 2=User Curve 2 3=User Curve 3 4=User Curve 4
This setting determines the type of Reset characteristic used for the user defined curves.				
I>6 Status	35	71	Disabled	0 = Disabled, 1 = Enabled
This setting enables or disables the sixth stage overcurrent element. There is no choice of curves because this stage is DT only.				
I>6 Direction	35	72	Non-Directional	0 = Non-Directional, 1 = Directional Fwd, 2 = Directional Rev
This setting determines the direction of measurement for the sixth stage overcurrent element.				
I>6 Current Set	35	75	20	From 0.05*In to 32.0*In step 0.01In
This setting sets the pick-up threshold for the sixth stage overcurrent element.				
I>6 Time Delay	35	76	0	From 0s to 100s step 0.01s
This setting sets the DT time delay for the sixth stage overcurrent element.				
V DEPENDANT O/C	35	81		
The settings under this sub-heading relate to				
V Dep OC Status	35	82	Disabled	0=Disabled 1=VCO I>1 2=VCO I>2 3=VCO I>1 & I>2 4=VCO I>5 5=VCO I>1&I>2&I>5 6=VCO I>1 & I>5 7=VCO I>2 & I>5 8=VRO I>1 9=VRO I>2 10=VRO I>5 11=VRO I>1 & I>2 12=VRO I>1 & I>5 13=VRO I>2 & I>5 14=VRO I>1&I>2&I>5
This setting cell contains a binary string (data type G100), where you can define which stages are influenced by the Voltage Controlled Overcurrent (VCO) and Voltage Restrained Overcurrent (VRO) functions. Note: Some models do not provide VRO.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
V Dep OC Status	35	82	Disabled	0=Disabled 1=VCO I>1 2=VCO I>2 3=VCO I>1 & I>2 4=VCO I>5 5=VCO I>1&I>2&I>5 6=VCO I>1 & I>5 7=VCO I>2 & I>5
Allows selection of whether voltage control should be applied to each of the first or second stage overcurrent elements.				
V Dep OC V<1 Set	35	83	80	From 10 to 120 step 1
This setting sets the voltage V1 threshold at which the current setting of the overcurrent stages becomes reduced. This is on a per phase basis.				
V Dep OC k Set	35	84	0.25	From 0.1 to 1 step 0.05
This setting determines the Overcurrent multiplier factor used to reduce the pick-up overcurrent setting.				
V Dep OC V<2 Set	35	85	60	From 10 to 120 step 1
This setting sets the voltage V2 threshold at which the current setting of the overcurrent stages becomes reduced. This is on a per phase basis.				
LOAD BLINDER	35	90		
The settings under this sub-heading relate to the Load Blinder function				
Blinder Status	35	91	Disabled	0 = Disabled, 1 = Enabled
This setting enables or disables the Load Blinder blocking function.				
Blinder Status	35	91	Disabled	0 = Disabled
This setting disables the Load Blinder blocking function for models B and G				
Blinder Function	35	92	3Ph(based on Z1)	0=3Ph(based on Z1) 1=1Ph(based on Z)
This setting sets the Load Blinder to three-phase or single-phase blocking.				
Blinder Mode	35	93	Both	0=Reverse 1=Forward 2=Both
This setting sets the Load Blinder direction measurement.				
FWD Z Impedance	35	94	15	From 0.1 to 500 step 0.01
This setting sets the Forward Impedance (in ohms) for the Load Blinder function.				
FWD Z Angle	35	95	30	From 5 to 85 step 1
This setting sets the Forward Angle (in degrees) for the Load Blinder function.				
RVS Z Impedance	35	97	15	From 0.1 to 500 step 0.01
This setting sets the Reverse Impedance (in ohms) for the Load Blinder function.				
RVS Z Angle	35	98	30	From 5 to 85 step 1
This setting sets the Reverse Angle (in degrees) for the Looad Blinder function.				
Blinder V< Block	35	9A	15	From 10 to 120 step 1
This setting sets the undervoltage threshold for the Load Blinder function.				
Blinder I2>Block	35	9B	0.2	From 0.08*I1 to 4*I1 step 0.01*I1
This setting sets the Negative Phase Sequence current threshold for the Load Blinder function.				
PU Cycles	35	9C	1	From 0 to 50 step 0.5
This setting sets the pick-up count threshold for the Load Blinder function.				
DO Cycles	35	9D	1	From 0 to 50 step 0.5
This setting sets the drop-off count threshold for the Load Blinder function.				

3.8 APPLICATION NOTES

3.8.1 PARALLEL FEEDERS

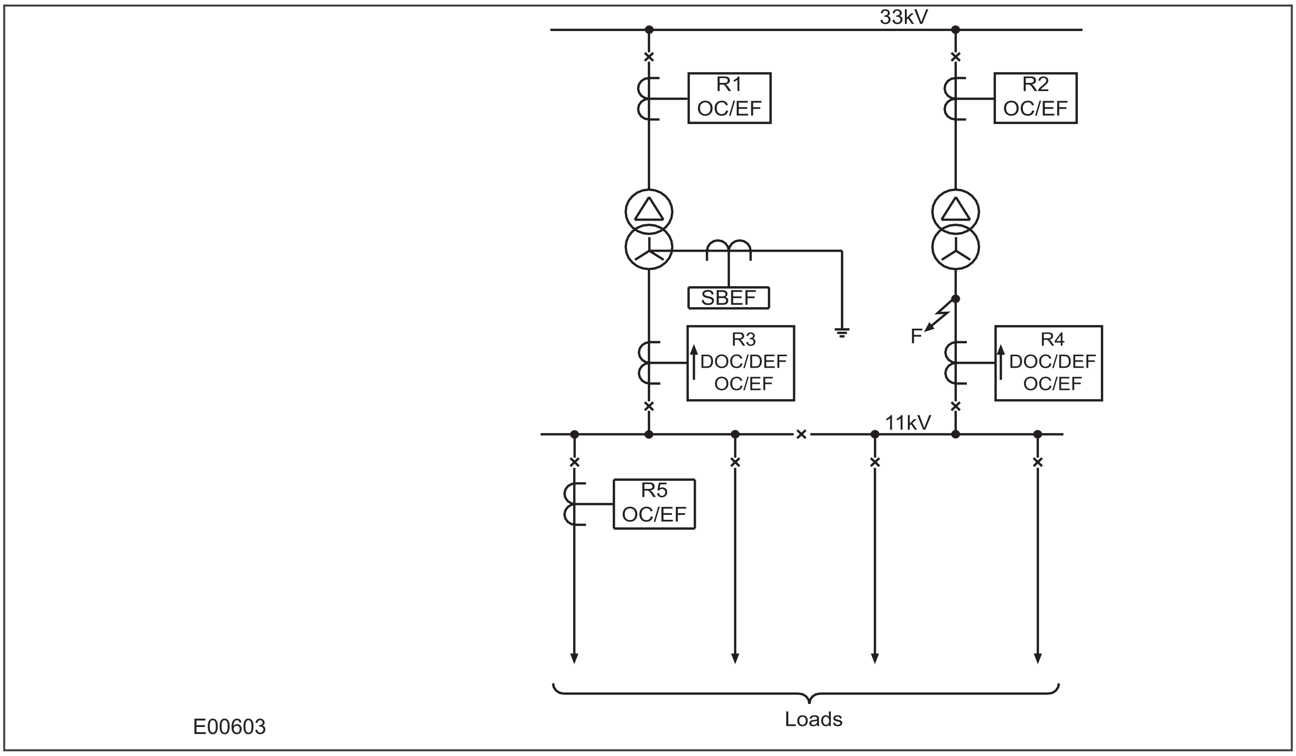


Figure 21: Typical distribution system using parallel transformers

In the application shown in the diagram, a fault at 'F' could result in the operation of both R3 and R4 resulting in the loss of supply to the 11 kV busbar. Hence, with this system configuration, it is necessary to apply directional protection devices at these locations set to 'look into' their respective transformers. These devices should co-ordinate with the non-directional devices, R1 and R2, to ensure discriminative operation during such fault conditions.

In such an application, R3 and R4 may commonly require non-directional overcurrent protection elements to provide protection to the 11 kV busbar, in addition to providing a back-up function to the overcurrent devices on the outgoing feeders (R5).

For this application, stage 1 of the R3 and R4 overcurrent protection would be set to non-directional and time graded with R5, using an appropriate time delay characteristic. Stage 2 could then be set to directional (looking back into the transformer) and also have a characteristic which provides correct co-ordination with R1 and R2. Directionality for each of the applicable overcurrent stages can be set in the cell **I>Direction**.

> *Note:*
> *The principles outlined for the parallel transformer application are equally applicable for plain feeders that are operating in parallel.*

3.8.2 RING MAIN ARRANGEMENTS

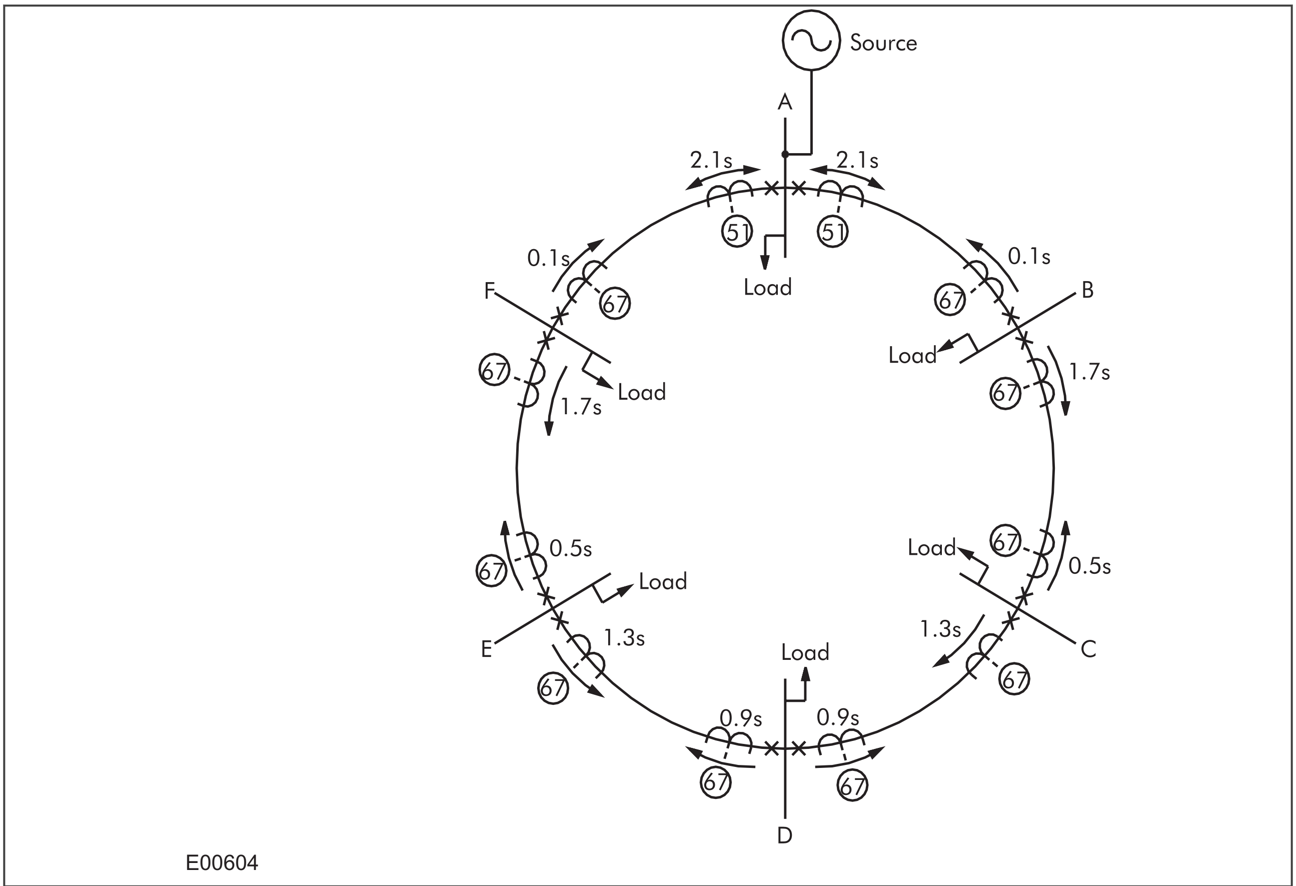


Figure 22: Typical ring main with associated overcurrent protection

Current may flow in either direction through the various device locations, therefore directional overcurrent devices are needed to achieve correct discrimination.

The normal grading procedure for overcurrent devices protecting a ring main circuit is to open the ring at the supply point and to grade the devices first clockwise and then anti-clockwise. The arrows shown at the various device locations depict the direction for forward operation of the respective devices (i.e. the directional devices are set to look into the feeder that they are protecting).

The diagram shows typical time settings (assuming definite time co-ordination is used), from which it can be seen that any faults on the interconnections between stations are cleared discriminatively by the devices at each end of the feeder.

Any of the overcurrent stages may be configured to be directional and co-ordinated, but bear in mind that IDMT characteristics are not selectable on all the stages.

3.8.3 SETTING GUIDELINES

Standard principles should be applied in calculating the necessary current and time settings. The example detailed below shows a typical setting calculation and describes how the settings are applied.

This example is for a device feeding a LV switchboard and makes the following assumptions:

- CT Ratio = 500/1
- Full load current of circuit = 450A
- Slowest downstream protection = 100A Fuse

The current setting on the device must account for both the maximum load current and the reset ratio, therefore:

I> must be greater than: 450/0.95 = 474A.

The device allows the current settings to be applied in either primary or secondary quantities. This is done by setting the **Setting Values** cell of the CONFIGURATION column. When this cell is set to primary, all phase overcurrent setting values are scaled by the programmed CT ratio, which is found in the TRANS. RATIOS column [0A].

In this example, assuming primary currents are to be used, the ratio should be programmed as 500/1.

The required setting is therefore 0.95A in terms of secondary current or 475A in terms of primary.

A suitable time delayed characteristic will now need to be chosen. When co-ordinating with downstream fuses, the applied characteristic should be closely matched to the fuse characteristic. Therefore, assuming IDMT co-ordination is to be used, an Extremely Inverse (EI) characteristic would normally be chosen. This is found under the **I>1** Function cell as 'IEC E Inverse'.

Finally, a suitable time multiplier setting (TMS) must be calculated and entered in cell **I>1 TMS.**

3.8.4 SETTING GUIDELINES (DIRECTIONAL ELEMENT)

The applied current settings for directional overcurrent devices are dependent upon the application in question. In a parallel feeder arrangement, load current is always flowing in the non-operate direction. Hence, the current setting may be less than the full load rating of the circuit; typically 50% of In.

Note:
The minimum setting that may be applied has to take into account the IEDs thermal rating. Some electro-mechanical directional overcurrent devices have continuous withstand ratings of only twice the applied current setting and hence 50% of rating was the minimum setting that could be applied. With the Px4x devices, the continuous current rating is 4 times rated current and so it is possible to apply much more sensitive settings if required.

You need to observe some setting constraints when applying directional overcurrent protection at the receiving-end of parallel feeders. These minimum safe settings are designed to ensure that there is no possibility of undesired tripping during clearance of a source fault. For a linear system load, these settings are as follows:

- Parallel plain feeders: Set to 50% pre-fault load current
- Parallel transformer feeders: Set to 87% pre-fault load current

When the above setting constraints are infringed, independent-time protection is more likely to issue an unwanted trip than time-dependent protection, during clearance of a source fault. Where the above setting constraints are unavoidably infringed, secure phase fault protection can be provided with devices having '2-out-of-3 directional protection' tripping logic.

In a ring main application, it is possible for load current to flow in either direction through the relaying point. Therefore, the current setting must be above the maximum load current, as in a standard non-directional application.

The required characteristic angle settings for directional devices will differ depending on the exact application in which they are used. Recommended characteristic angle settings are as follows:

- Plain feeders, or applications with an earthing point (zero sequence source) behind the device location, should use a +30° RCA setting
- Transformer feeders, or applications with a zero sequence source in front of the device location, should use a +45° RCA setting

Whilst it is possible to set the RCA to exactly match the system fault angle, we recommend that you adhere to the above guidelines, as these settings provide satisfactory performance and stability under a wide range of system conditions.

4 VOLTAGE DEPENDENT OVERCURRENT ELEMENT

Overcurrent IEDs are co-ordinated throughout a system such that a cascaded operation is achieved. This means that the failure of a downstream circuit breaker to trip for a fault condition, whether due to the failure of a protection device, or of the breaker itself, should result in the tripping of the next upstream circuit breaker.

However, where long feeders are protected by overcurrent IEDs, the detection of remote phase-to-phase faults may prove difficult due to the fact that the current pick-up of phase overcurrent elements must be set above the maximum load current, thereby limiting the element's minimum sensitivity.

If the current seen by a local device for a remote fault condition is below its overcurrent setting, a voltage dependent element may be used to increase the sensitivity to such faults. As a reduction in system voltage will occur during overcurrent conditions, this may be used to enhance the sensitivity of the overcurrent protection by reducing the pick up level.

Voltage dependent overcurrent devices are often applied in generator protection applications in order to give adequate sensitivity for close up fault conditions. The fault characteristic of this protection must then co-ordinate with any of the downstream overcurrent devices that are responsive to the current decrement condition. It therefore follows that if the device is to be applied to an outgoing feeder from a generator station, the use of voltage dependent overcurrent protection in the feeder device may allow better co-ordination with the Voltage Dependent device on the generator.

4.1 VOLTAGE DEPENDENT OVERCURRENT PROTECTION IMPLEMENTATION

Voltage Dependent Overcurrent Protection (VDep OC) is implemented in the OVERCURRENT column of the relevant settings group, under the sub-heading V DEPENDANT O/C.

The function is available for stages 1,2 and 5 of the main overcurrent element. When VDep OC is enabled, the overcurrent threshold setting is modified when the voltage falls below a set threshold.

If voltage dependant overcurrent operation is selected, the element can be set in one of two modes, voltage controlled overcurrent or voltage restrained overcurrent. The mode of operation is set in the V Dep OC Status cell according to the data type G100 as follows:

The G100 Data type is an indexed string and is used for the **V Dep OC Status** setting:

String number	V Dep OC Options
0	Disabled
1	VCO I>1
2	VCO I>2
3	VCO I>1 & I>2
4	VCO I>5
5	VCO I>1&I>2&I>5
6	VCO I>1 & I>5
7	VCO I>2 & I>5
8	VRO I>1
9	VRO I>2
10	VRO I>5
11	VRO I>1 & I>2
12	VRO I>1 & I>5
13	VRO I>2 & I>5
14	VRO I>1&I>2&I>5

4.1.1 VOLTAGE CONTROLLED OVERCURRENT PROTECTION

In Voltage Controlled Operation (VCO) mode of operation, the under voltage detector is used to produce a step change in the relay current setting, when the voltage falls below the voltage setting V Dep OC V<1 Set. The operating characteristic of the current setting when voltage controlled mode is selected is as follows:

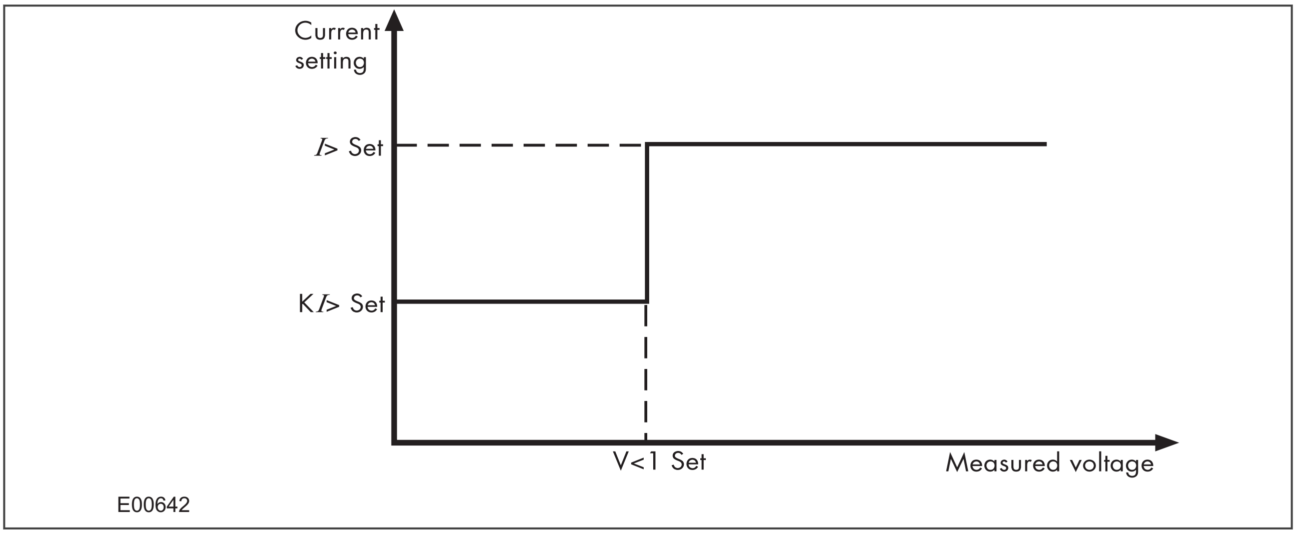


Figure 23: Modification of current pickup level for voltage controlled overcurrent protection

4.1.2 VOLTAGE RESTRAINED OVERCURRENT PROTECTION

In Voltage Restrained Operation (VRO) mode the effective operating current of the protection element is continuously variable as the applied voltage varies between two voltage thresholds. This protection mode is considered to be better suited to applications where the generator is connected to the system via a generator transformer.

With indirect connection of the generator, a solid phase-phase fault on the local busbar will result in only a partial phase-phase voltage collapse at the generator terminals.

The voltage-restrained current setting is related to measured voltage as follows:

- If V is greater than **V<1**, the current setting (Is) = I>
- If V is greater than **V<2** but less than **V<1**, the current setting (Is) =

$$KI > +(I > -KI)\frac{V - V < 2}{V < 1 - V < 2}$$

- If V is less than V<2, the current setting (Is) = K.I>

where:

- I> = Over current stage setting
- Is = Current setting at voltage V
- V = Voltage applied to relay element
- V<1 = V Dep OC V<1 Set
- V<2 = V Dep OC V<2 Set

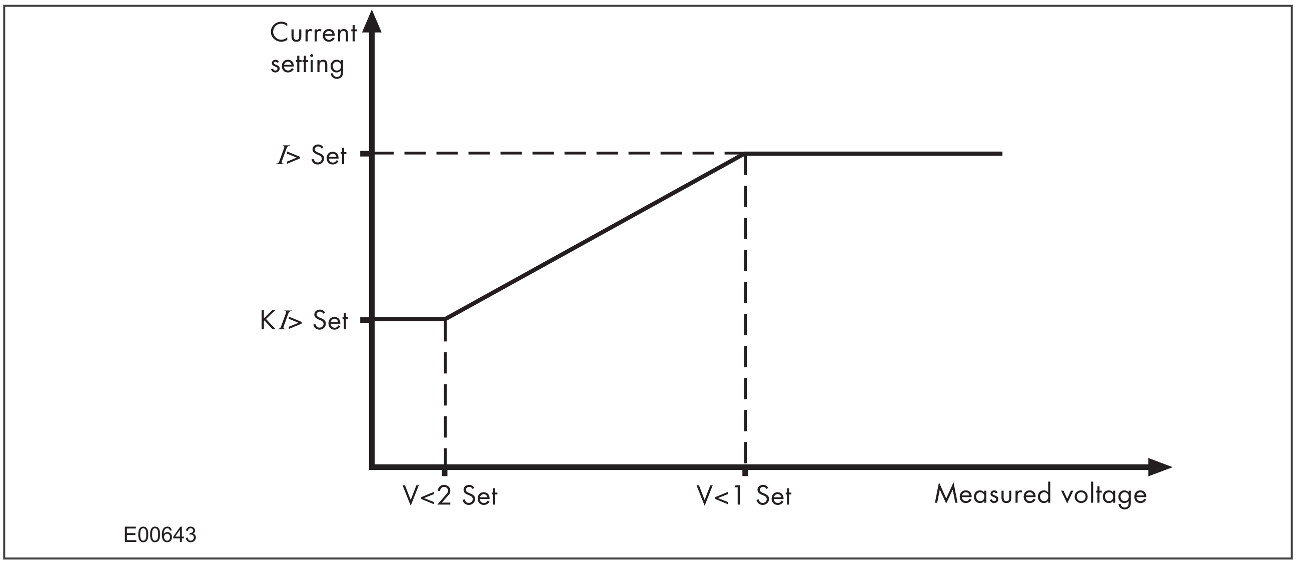


Figure 24: Modification of current pickup level for voltage restrained overcurrent protection

4.2 VOLTAGE DEPENDENT OVERCURRENT LOGIC

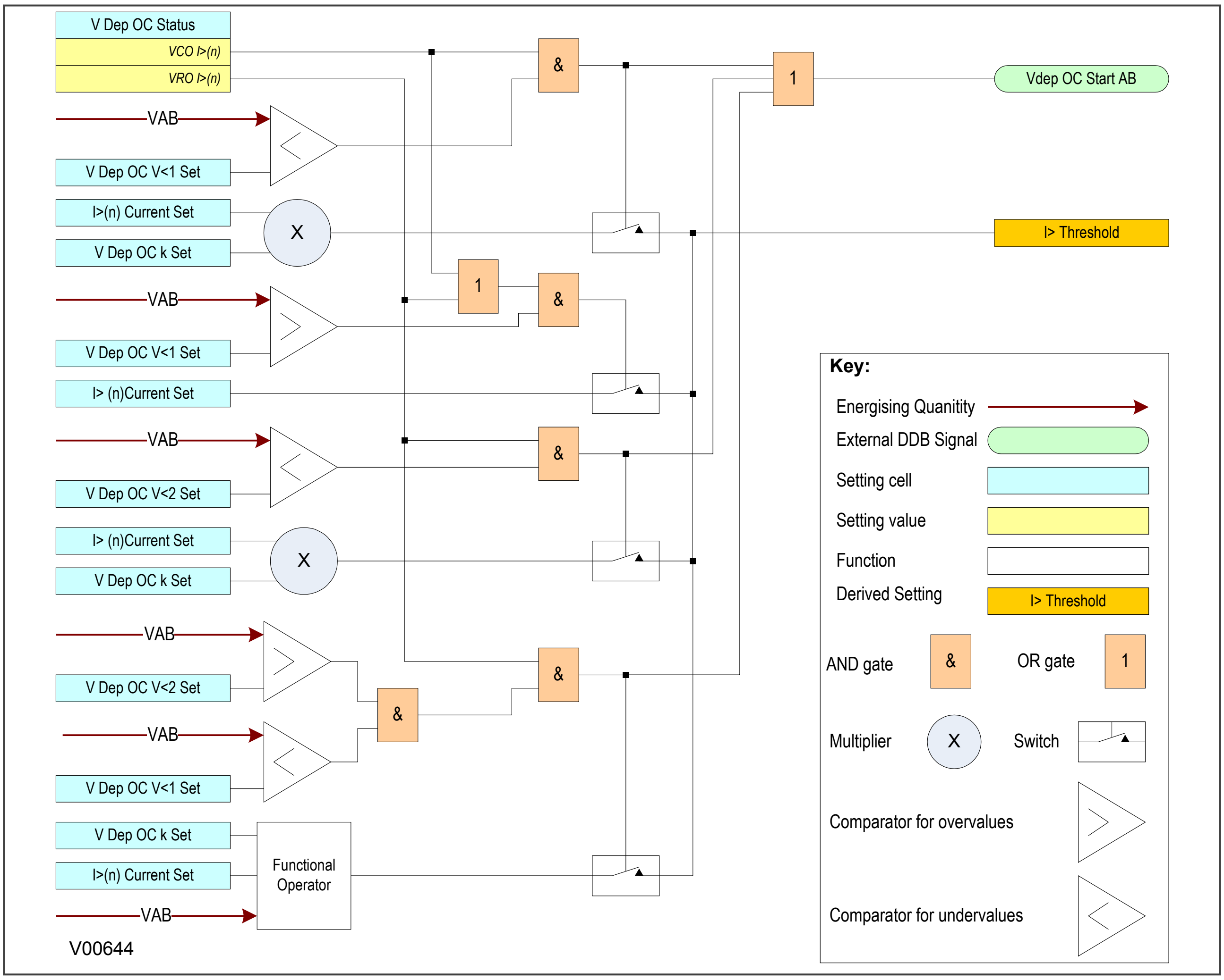


Figure 25: Voltage dependant overcurrent logic (Phase A to phase B)

The current threshold setting for the Overcurrent function is determined by the voltage.

If the voltage is greater than **V<1 Set**, the normal overcurrent setting **I>(n) current set** is used. this applies to both VCO and VRO modes.

If the voltage is less than **V<1 Set** AND it is in VCO mode, the overcurrent setting **I>(n) current set** is multiplied by the factor set by **V Dep OC k set**.

If the voltage is less than **V<2 Set** AND it is in VRO mode, the overcurrent setting **I>(n) current set** is multiplied by the factor set by **V Dep OC k set.**

If the voltage is between **V<1 Set** and **V<2 Set** AND it is in VRO mode, the overcurrent setting is multiplied by a functional operator to determine the setting.

4.3 VOLTAGE DEPENDENT OVERCURRENT DDB SIGNALS

Ordinal	English Text	Source	Type	Response Function
Description				
311	VDep OC Start AB	Software	PSL Input	Protection event
This DDB signal is the Voltage Dependent Overcurrent start signal for phase A-B				
312	VDep OC Start BC	Software	PSL Input	Protection event
This DDB signal is the Voltage Dependent Overcurrent start signal for phase B-C				
313	VDep OC Start CA	Software	PSL Input	Protection event
This DDB signal is the Voltage Dependent Overcurrent start signal for phase C-A				

4.4 VOLTAGE DEPENDENT OVERCURRENT SETTINGS

Menu Text	Col	Row	Default Setting	Available Options
Description				
V DEPENDANT O/C	35	81		
The settings under this sub-heading relate to				
V Dep OC Status	35	82	Disabled	0=Disabled 1=VCO I>1 2=VCO I>2 3=VCO I>1 & I>2 4=VCO I>5 5=VCO I>1&I>2&I>5 6=VCO I>1 & I>5 7=VCO I>2 & I>5 8=VRO I>1 9=VRO I>2 10=VRO I>5 11=VRO I>1 & I>2 12=VRO I>1 & I>5 13=VRO I>2 & I>5 14=VRO I>1&I>2&I>5
This setting cell contains a binary string (data type G100), where you can define which stages are influenced by the Voltage Controlled Overcurrent (VCO) and Voltage Restrained Overcurrent (VRO) functions. Note: Some models do not provide VRO.				
V Dep OC Status	35	82	Disabled	0=Disabled 1=VCO I>1 2=VCO I>2 3=VCO I>1 & I>2 4=VCO I>5 5=VCO I>1&I>2&I>5 6=VCO I>1 & I>5 7=VCO I>2 & I>5
Allows selection of whether voltage control should be applied to each of the first or second stage overcurrent elements.				
V Dep OC V<1 Set	35	83	80	From 10 to 120 step 1
This setting sets the voltage V1 threshold at which the current setting of the overcurrent stages becomes reduced. This is on a per phase basis.				
V Dep OC k Set	35	84	0.25	From 0.1 to 1 step 0.05
This setting determines the Overcurrent multiplier factor used to reduce the pick-up overcurrent setting.				
V Dep OC V<2 Set	35	85	60	From 10 to 120 step 1
This setting sets the voltage V2 threshold at which the current setting of the overcurrent stages becomes reduced. This is on a per phase basis.				

4.5 APPLICATION NOTES

4.5.1 SETTING GUIDELINES

The **V Dep OC k** setting should be set low enough to allow operation for remote phase-to-phase faults, typically:

$$k = \frac{I_F}{1.2I >}$$

where:

- I_F = Minimum fault current expected for the remote fault
- I> = Phase current setting for the element to have VCO control

Example

If the overcurrent device has a setting of 160% In, but the minimum fault current for the remote fault condition is only 80% In, then the required k factor is given by:

$$k = \frac{0.8}{1.6 \times 1.2} = 0.42$$

The voltage threshold, **Vdep OC V<** setting would be set below the lowest system voltage that may occur under normal system operating conditions, whilst ensuring correct detection of the remote fault.

5 COLD LOAD PICKUP

When a feeder circuit breaker is closed in order to energise a load, the current levels that flow for a period of time following energisation may be far greater than the normal load levels. Consequently, overcurrent settings that have been applied to provide overcurrent protection may not be suitable during this period of energization (cold load), as they may initiate undesired tripping of the circuit breaker. This scenario can be prevented with Cold Load Pickup (CLP) functionality.

The Cold Load Pick-Up (CLP) logic works by either:

- Inhibiting one or more stages of the overcurrent protection for a set duration
- Raising the overcurrent settings of selected stages, for the cold loading period.

The CLP logic therefore provides stability, whilst maintaining protection during the start-up.

5.1 COLD LOAD PICKUP

Cold Load Pickup Protection is implemented in the COLD LOAD PICKUP column of the relevant settings group.

This function acts upon the following protection functions:

- All overcurrent stages (both non-directional and directional if applicable)
- The first stage of Earth Fault 1 (both non-directional and directional if applicable)
- The first stage of Earth Fault 2 (both non-directional and directional if applicable)

The principle of operation is identical for the 3-phase overcurrent protection and the first stages of Earth Fault overcurrent protection for both EF1 and EF2.

CLP operation occurs when the circuit breaker remains open for a time greater than **tcold** and is subsequently closed. CLP operation is applied after **tcold** and remains for a set time delay of **tclp** following closure of the circuit breaker. The status of the circuit breaker is provided either by means of the CB auxiliary contacts or by means of an external device via logic inputs. Whilst CLP operation is in force, the CLP settings are enabled After the time delay **tclp** has elapsed, the normal overcurrent settings are applied and the CLP settings are disabled.

If desired, instead of applying different current setting thresholds for the cold load time, it is also possible to completely block the overcurrrent operation during this time, for any of the overcurrent stages.

Voltage-dependent operation can also affect the overcurrent settings. If a Voltage Dependent condition arises, this takes precedence over the CLP. If the CLP condition prevails and the Voltage Dependent function resets, the device will operate using the CLP settings. Time-delayed elements are reset to zero if they are disabled during the transitions between normal settings and CLP settings.

Note:
In the event of a conflict between Selective Logic and CLP, Selective Logic takes precedence.

5.2 CLP LOGIC

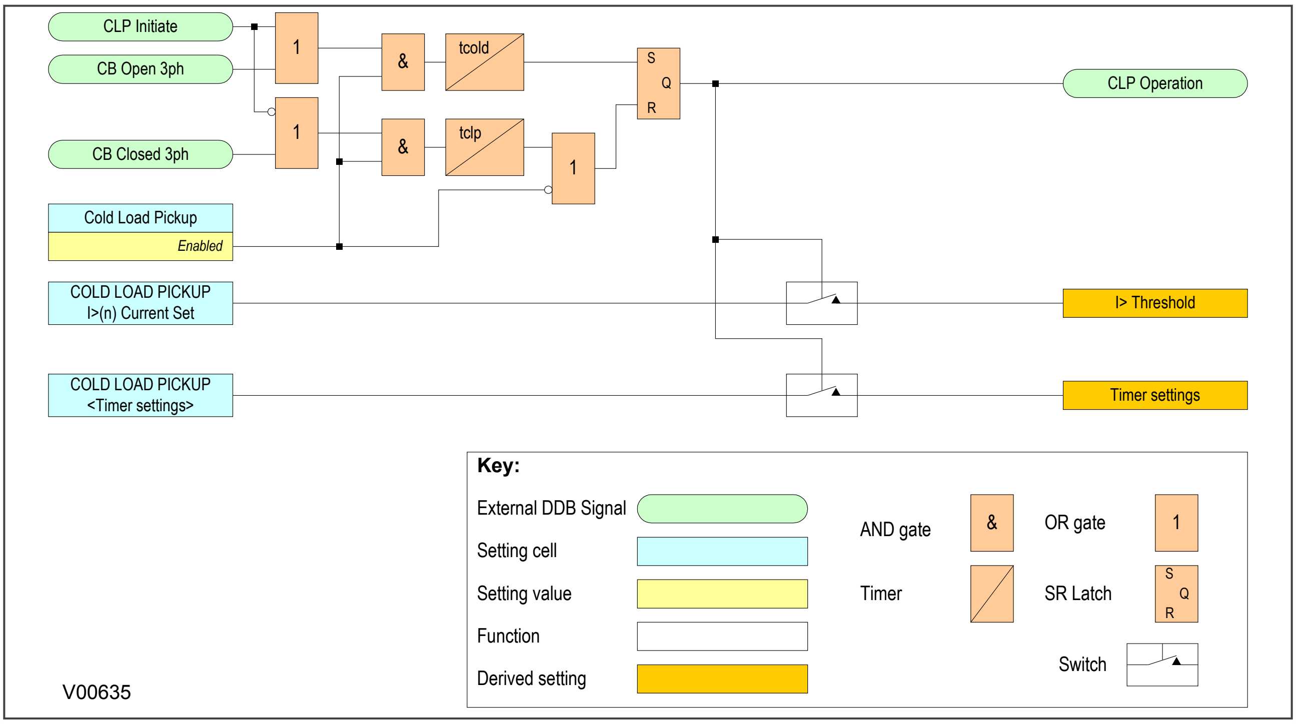


Figure 26: Cold Load Pickup logic

The CLP Operation signal indicates that CLP logic is in operation. This only happens when CLP is enabled AND CLP is initiated either externally or from a CB Open condition after the tcold period has elapsed. The CLP Operation indicator goes low when CLP is disabled or when the external CLP trigger is removed or when there is a CB closed condition.

tcold and **tclp** are initiated via the CB open and CB closed signals generated within the device. These signals are produced by connecting auxiliary contacts from the circuit breaker or starting device to the IED's opto-inputs

If dual CB contacts are not available (one for Open (52a) and for Close (52b)) you can configure the device to be driven from a single contact (either 52a or 52b). The device would then simply invert one signal to provide the other. This option is available using the **CB status input** cell in the CB CONTROL column. The setting can be set to 'None', '52a', '52b' or '52a and 52b'.

5.3 CLP DDB SIGNALS

Ordinal	Signal Name	Source	Type	Response
Description				
226	CLP Initiate	Programmable Scheme Logic	PSL Output	No response
This DDB signal initiates the CLP operation				
347	CLP Operation	Software	PSL Input	Protection event
This DDB signal indicates that the CLP is operating and informs the Overcurrent protection to use the CLP settings				
378	CB Open 3 ph	Software	PSL Input	Protection event
This DDB signal indicates that the CB is open on all 3 phases				
379	CB Closed 3 ph	Software	PSL Input	Protection event
This DDB signal indicates that the CB is closed on all 3 phases				

5.4 CLP SETTINGS

Menu Text	Col	Row	Default Setting	Available Options
Description				
GROUP 1 COLD LOAD PICKUP	3E	00		
This column contains settings for Cold Load Pickup				
tcold Time Delay	3E	01	7200	From 0s to 14400s step 1s
This setting determines the time the load needs to be de-energised (dead time) before the new settings are applied.				
tclp Time Delay	3E	02	7200	From 0s to 14400s step 1s
This setting controls the period of time for which the relevant overcurrent and earth fault settings are altered or inhibited following circuit breaker closure.				
OVERCURRENT	3E	20		
The settings under this sub-heading relate to the Phase Overcurrent elements				
I>1 Status	3E	21	Enable	0=Block 1=Enable
Selecting 'Enable' means that the current and time settings in these cells will be used during the "tclp" time. Selecting 'Block' simply blocks the protection stage during the "tclp" time.				
I>1 Current Set	3E	22	1.5	0.05*In to 4*In step 0.01In
This setting determines the new pick-up setting for the first stage Overcurrent element during the tclp time delay.				
I>1 Time Delay	3E	24	1	From 0s to 100s step 0.01s
This setting sets the new operate DT time delay for the first stage Overcurrent element during the tclp time.				
I>1 TMS	3E	25	1	From 0.025 to 1.2 step 0.005
This is the Time Multiplier Setting to adjust the operate time of IEC IDMT curves.				
I>1 Time Dial	3E	26	1	From 0.01 to 100 step 0.01
This is the Time Multiplier Setting to adjust the operate time of IEE/US IDMT curves.				
I>1 k (RI)	3E	27	1	From 0.1 to 10 step 0.05
This setting sets the new time multiplier setting to adjust the operate time of the RI curve during the tclp time.				
I>2 Status	3E	29	Enable	0=Block 1=Enable
Selecting 'Enable' means that the current and time settings in these cells will be used during the "tclp" time. Selecting 'Block' simply blocks the protection stage during the "tclp" time.				
I>2 Current Set	3E	2A	1.5	0.05*In to 4*In step 0.01In
This setting determines the new pick-up setting for the second stage Overcurrent element during the tclp time delay.				
I>2 Time Delay	3E	2C	1	From 0s to 100s step 0.01s
This setting sets the new operate DT time delay for the second stage Overcurrent element during the tclp time.				
I>2 TMS	3E	2D	1	From 0.025 to 1.2 step 0.005
This setting sets the new time multiplier setting for the second stage Overcurrent element to adjust the operate time of the IEC IDMT characteristic during the tclp time.				
I>2 Time Dial	3E	2E	1	From 0.01 to 100 step 0.01
This setting sets the new time multiplier setting to adjust the operate time of the IEEE/US IDMT curves during the tclp time.				
I>2 k (RI)	3E	2F	1	From 0.1 to 10 step 0.05
This setting defines the TMS constant to adjust the operate time of the RI curve.				
I>3 Status	3E	31	Block	0=Block 1=Enable
Selecting 'Enable' means that the current and time settings in these cells will be used during the "tclp" time. Selecting 'Block' simply blocks the protection stage during the "tclp" time.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
I>3 Current Set	3E	32	25	0.05*In to 32*In step 0.01In
This setting sets the new pick-up setting for the third stage Overcurrent element during the tclp time delay.				
I>3 Time Delay	3E	33	0	From 0s to 100s step 0.01s
This setting sets the new operate DT time delay for the first stage Overcurrent element during the tclp time.				
I>4 Status	3E	35	Block	From 0 to 1 step 1
Selecting 'Enable' means that the current and time settings in these cells will be used during the "tclp" time. Selecting 'Block' simply blocks the protection stage during the "tclp" time.				
I>4 Current Set	3E	36	25	0.05*In to 32*In step 0.01In
This setting sets the new pick-up setting for the fourth stage Overcurrent element during the tclp time delay.				
I>4 Time Delay	3E	37	0	From 0s to 100s step 0.01s
Setting for the new operate time delay for the fourth stage definite time element during the tclp time.				
STAGE 1 E/F 1	3E	39		
The settings under this sub-heading relate to measured Earth Fault protection (EF1)				
IN1>1 Status	3E	3A	Enable	0=Block 1=Enable
Selecting 'Enable' means that the current and time settings in these cells will be used during the "tclp" time. Selecting 'Block' simply blocks the protection stage during the "tclp" time.				
IN1>1 Current	3E	3B	0.2	0.05*In to 4*In step 0.01In
This setting sets the new pick-up setting for the measured Earth Fault element during the tclp time delay.				
IN1>1 IDG Is	3E	3C	1.5	From 1 to 4 step 0.1
This setting defines the new TMS of the IDG curve during the tclp time.				
IN1>1 Time Delay	3E	3E	1	From 0s to 200s step 0.01s
This setting sets the new operate DT time delay for the measured Earth Fault element during the tclp time.				
IN1>1 TMS	3E	3F	1	From 0.025 to 1.2 step 0.005
This is the Time Multiplier Setting to adjust the operate time of IEC IDMT curves.				
IN1>1 Time Dial	3E	40	1	From 0.01 to 100 step 0.01
This is the Time Multiplier Setting to adjust the operate time of IEEE/IDMT curves.				
IN1>1 k (RI)	3E	41	1	From 0.1 to 10 step 0.05
This setting defines the TMS constant to adjust the operate time of the RI curve.				
STAGE 1 E/F 2	3E	43		
The settings under this sub-heading relate to derived Earth Fault protection (EF2)				
IN2>1 Status	3E	44	Enable	0=Block 1=Enable
Selecting 'Enable' means that the current and time settings in these cells will be used during the "tclp" time. Selecting 'Block' simply blocks the protection stage during the "tclp" time.				
IN2>1 Current	3E	45	0.2	0.05*In to 4*In step 0.01In
This setting sets the new pick-up setting for the derived Earth Fault element during the tclp time delay.				
IN2>1 IDG Is	3E	46	1.5	From 1 to 4 step 0.1
This setting defines the new TMS of the IDG curve during the tclp time.				
IN2>1 Time Delay	3E	48	1	From 0s to 200s step 0.01s
This setting sets the new operate DT time delay for the derived Earth Fault element during the tclp time.				
IN2>1 TMS	3E	49	1	From 0.025 to 1.2 step 0.005
This is the Time Multiplier Setting to adjust the operate time of IEC IDMT curves.				
IN2>1 Time Dial	3E	4A	1	From 0.01 to 100 step 0.01

Menu Text	Col	Row	Default Setting	Available Options
Description				
This is the Time Multiplier Setting to adjust the operate time of IEEE/IDMT curves.				
IN2>1 k (RI)	3E	4B	1	From 0.1 to 10 step 0.05
This setting defines the TMS constant to adjust the operate time of the RI curve.				
OVERCURRENT	3E	4F		
The settings under this sub-heading relate to the Phase Overcurrent elements				
I>5 Status	3E	50	Enable	0=Block 1=Enable
Selecting 'Enable' means that the current and time settings in these cells will be used during the "tclp" time. Selecting 'Block' simply blocks the protection stage during the "tclp" time.				
I>5 Current Set	3E	51	1.5	0.05*In to 4*In step 0.01In
This setting sets the new pick-up setting for the fifth stage Overcurrent element during the tclp time delay.				
I>5 Time Delay	3E	53	1	From 0s to 100s step 0.01s
This setting sets the new operate DT time delay for the fifth stage Overcurrent element during the tclp time.				
I>5 TMS	3E	54	1	From 0.025 to 1.2 step 0.005
This is the Time Multiplier Setting to adjust the operate time of IEC IDMT curves.				
I>5 Time Dial	3E	55	1	From 0.01 to 100 step 0.01
This is the Time Multiplier Setting to adjust the operate time of IEE/US IDMT curves.				
I>5 k (RI)	3E	56	1	From 0.1 to 10 step 0.05
This setting sets the new time multiplier setting to adjust the operate time of the RI curve during the tclp time.				
I>6 Status	3E	58	Block	From 0 to 1 step 1
Selecting 'Enable' means that the current and time settings in these cells will be used during the "tclp" time. Selecting 'Block' simply blocks the protection stage during the "tclp" time.				
I>6 Current Set	3E	59	25	0.05*In to 32*In step 0.01In
This setting sets the new pick-up setting for the sixth stage Overcurrent element during the tclp time delay.				
I>6 Time Delay	3E	5A	0	From 0s to 100s step 0.01s
This setting sets the new operate DT time delay for the sixth stage Overcurrent element during the tclp time.				

5.5 APPLICATION NOTES

5.5.1 CLP FOR RESISTIVE LOADS

A typical example of where CLP logic may be used is for resistive heating loads such as such as air conditioning systems. Resistive loads typically offer less resistance when cold than when warm, hence the start-up current will be higher.

To set up the CLP, you need to select 'Enable' from the **I> status** option to enable the settings of the temporary current and time settings. These settings should be chosen in accordance with the expected load profile. Where it is not necessary to alter the setting of a particular stage, the CLP settings should be set to the same level as the standard overcurrent settings.

It may not be necessary to alter the protection settings following a short supply interruption. In this case a suitable **tcold** timer setting can be used.

5.5.2 CLP FOR MOTOR FEEDERS

In general, a dedicated motor protection device would protect feeders supplying motor loads. However, if CLP logic is available in a feeder device, this may be used to modify the overcurrent settings during start-up.

Depending on the magnitude and duration of the motor starting current, it may be sufficient to simply block operation of instantaneous elements. If the start duration is long, the time-delayed protection settings may also need to be raised. A combination of both blocking and raising of the overcurrent settings may be adopted. The CLP overcurrent settings in this case must be chosen with regard to the motor starting characteristic.

This may be useful where instantaneous earth fault protection needs to be applied to the motor. During motor start-up conditions, it is likely that incorrect operation of the earth fault element would occur due to asymmetric CT saturation. This is due to the high level of starting current causing saturation of one or more of the line CTs feeding the overcurrent/earth fault protection. The resultant transient imbalance in the secondary line current quantities is thus detected by the residually connected earth fault element. For this reason, it is normal to either apply a nominal time delay to the element, or to use a series stabilising resistor.

The CLP logic may be used to allow reduced operating times or current settings to be applied to the earth fault element under normal running conditions. These settings could then be raised prior to motor starting, by means of the logic.

5.5.3 CLP FOR SWITCH ONTO FAULT CONDITIONS

In some feeder applications, fast tripping may be required if a fault is already present on the feeder when it is energised. Such faults may be due to a fault condition not having been removed from the feeder, or due to earthing clamps having been left on following maintenance. In either case, it is desirable to clear the fault condition quickly, rather than waiting for the time delay imposed by IDMT overcurrent protection.

The CLP logic can cater for this situation. Selected overcurrent/earth fault stages could be set to instantaneous operation for a defined period following circuit breaker closure (typically 200 ms). Therefore, instantaneous fault clearance would be achieved for a switch onto fault (SOTF) condition.

6 SELECTIVE OVERCURRENT LOGIC

With Selective Overcurrent Logic you can use the Start contacts to control the time delays of upstream IEDs, as an alternative to simply blocking them. This provides an alternative approach to achieving non-cascading types of overcurrent scheme, which may be more familiar to some utilities than blocked overcurrent schemes.

6.1 SELECTIVE LOGIC IMPLEMENTATION

Selective Overcurrent Logic is implemented in the SELECTIVE LOGIC column of the relevant settings group.

The Selective Logic function works by temporarily increasing the time delay settings of the chosen overcurrent elements. This logic is initiated by energising the relevant opto-input on the upstream IED.

This function acts upon the following protection functions:

- Non-Directional/Directional phase overcurrent (3rd, 4th and 6th stages)
- Non-Directional/Directional earth fault – 1 (3rd, 4th and 6th stages)
- Non-Directional/Directional earth fault – 2 (3rd, 4th and 6th stages)
- Non-Directional/Directional sensitive earth fault (3rd, 4th and 6th stages)

6.2 SELECTIVE OVERCURRENT LOGIC DIAGRAM

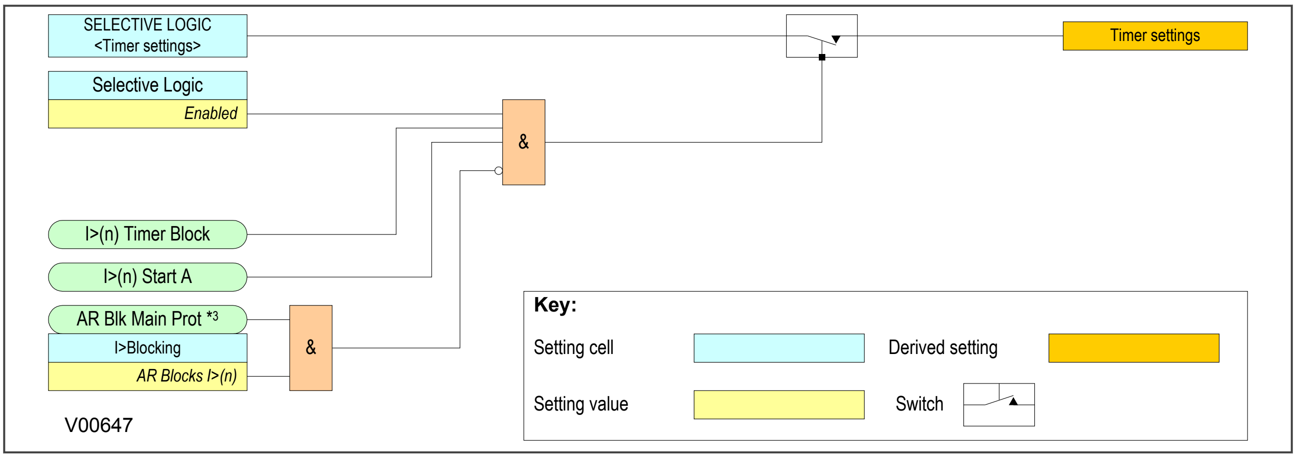


Figure 27: Selective Overcurrent Logic

The logic diagram is shown for overcurrent phase A, but is valid for all three phases for each of the stages 3,4 and 6. the principle of operation is also identical for EF1, EF2 and SEF.

When the selective logic function is enabled, the action of the blocking input is as follows:

No block applied

In the event of a fault condition that continuously asserts the start output, the function will assert a trip signal after the normal time delay has elapsed.

Logic input block applied

In the event of a fault condition that continuously asserts the start output, the function will assert a trip signal after the selective logic time delay has elapsed.

Auto-reclose input block applied

In the event of a fault condition that continuously asserts the start output, when an auto-reclose block is applied the function will not trip. The auto-reclose block also overrides the logic input block and will block the selective logic timer.

Noted that the Auto-reclose function outputs two signals that block protection, namely; **AR Blk Main Prot** and **AR Blk SEF Prot**.

AR Blk Main Prot is common to Phase Overcurrent, Earth Fault 1 and Earth Fault 2, whereas **AR Blk SEF Prot** is used for SEF protection.

6.3 SELECTIVE OVERCURRENT LOGIC SETTINGS

Menu Text	Col	Row	Default Setting	Available Options
Description				
GROUP 1 SELECTIVE LOGIC	3F	00		
This column contains settings for selective logic				
OVERCURRENT	3F	01		
The settings under this sub-heading relate to Phase Overcurrent Protection (POC). Selective Logic is only available for stages 3 and 4 and 6.				
I>3 Time Delay	3F	02	1	From 0s to 100s step 0.01s
This setting sets the new operate DT time delay for the third stage Overcurrent element when the Selective Logic function is active.				
I>4 Time Delay	3F	03	1	From 0s to 100s step 0.01s
This setting sets the new operate DT time delay for the fourth stage Overcurrent element when the Selective Logic function is active.				
I>6 Time Delay	3F	0D	1	From 0s to 100s step 0.01s
This setting sets the new operate DT time delay for the sixth stage Overcurrent element when the Selective Logic function is active.				
EARTH FAULT 1	3F	14		
The settings under this sub-heading relate to measured Earth Fault Protection (EF1). Selective Logic is only available for stages 3 and 4.				
IN1>3 Time Delay	3F	15	2	From 0s to 200s step 0.01s
Setting for the third stage definite time earth fault (measured) element operate time when the selective logic is active.				
IN1>4 Time Delay	3F	16	2	From 0s to 200s step 0.01s
Setting for the fourth stage definite time earth fault (measured) element operate time when the selective logic is active.				
EARTH FAULT 2	3F	17		
The settings under this sub-heading relate to derived Earth Fault Protection (EF1). Selective Logic is only available for stages 3 and 4.				
IN2>3 Time Delay	3F	18	2	From 0s to 200s step 0.01s
Setting for the third stage definite time earth fault (derived) element operate time when the selective logic is active.				
IN2>4 Time Delay	3F	19	2	From 0s to 200s step 0.01s
Setting for the fourth stage definite time earth fault (derived) element operate time when the selective logic is active.				
SENSITIVE E/F	3F	1A		
The settings under this sub-heading relate to Sensitive Earth Fault Protection (EF1). Selective Logic is only available for stages 3 and 4.				
ISEF>3 Delay	3F	1B	1	From 0s to 200s step 0.01s
Setting for the third stage definite time sensitive earth fault element operate time when the selective logic is active.				
ISEF>4 Delay	3F	1C	0.5	From 0s to 200s step 0.01s
Setting for the fourth stage definite time sensitive earth fault element operate time when the selective logic is active.				

7 NEGATIVE SEQUENCE OVERCURRENT PROTECTION

When applying standard phase overcurrent protection, the overcurrent elements must be set significantly higher than the maximum load current, thereby limiting the element's sensitivity. Most protection schemes also use an earth fault element operating from residual current, which improves sensitivity for earth faults. However, certain faults may arise which can remain undetected by such schemes. Negative Sequence Overcurrent elements can be used in such cases.

Any unbalanced fault condition will produce a negative sequence current component. Therefore, a negative phase sequence overcurrent element can be used for both phase-to-phase and phase-to-earth faults. Negative Sequence Overcurrent protection offers the following advantages:

- Negative phase sequence overcurrent elements are more sensitive to resistive phase-to-phase faults, where phase overcurrent elements may not operate.
- In certain applications, residual current may not be detected by an earth fault element due to the system configuration. For example, an earth fault element applied on the delta side of a delta-star transformer is unable to detect earth faults on the star side. However, negative sequence current will be present on both sides of the transformer for any fault condition, irrespective of the transformer configuration. Therefore, a negative phase sequence overcurrent element may be used to provide time-delayed back-up protection for any uncleared asymmetrical faults downstream.
- Where rotating machines are protected by fuses, loss of a fuse produces a large amount of negative sequence current. This is a dangerous condition for the machine due to the heating effect of negative phase sequence current. An upstream negative phase sequence overcurrent element could therefore be applied to provide back-up protection for dedicated motor protection relays.
- It may be sufficient to simply trigger an alarm to indicate the presence of negative phase sequence currents on the system. Operators may then investigate the cause of the imbalance.

7.1 NEGATIVE SEQUENCE OVERCURRENT PROTECTION IMPLEMENTATION

Negative Sequence Overcurrent Protection is implemented in the NEG SEQ O/C column of the relevant settings group.

The product provides four stages of negative sequence overcurrent protection with independent time delay characteristics.

Stages 1, 2 provide a choice of operate and reset characteristics, where you can select between:

- A range of standard IDMT (Inverse Definite Minimum Time) curves
- A range of User-defined curves
- DT (Definite Time)

This is achieved using the cells

- **I2>**(n) **Function** for the overcurrent operate characteristic
- **I2>**(n) **Reset Char** for the overcurrent reset characteristic
- **I2>**(n) **Usr RstChar** for the reset characteristic for user -defined curves

where (n) is the number of the stage.

The IDMT-capable stages, (1 and 2) also provide a Timer Hold facility (on page 88). This is configured using the cells **I2>**(n) **tReset**, where (n) is the number of the stage. This is not applicable for curves based on the IEEE standard.

Stages 3 and 4 can have definite time characteristics only.

7.2 NON-DIRECTIONAL NEGATIVE SEQUENCE OVERCURRENT LOGIC

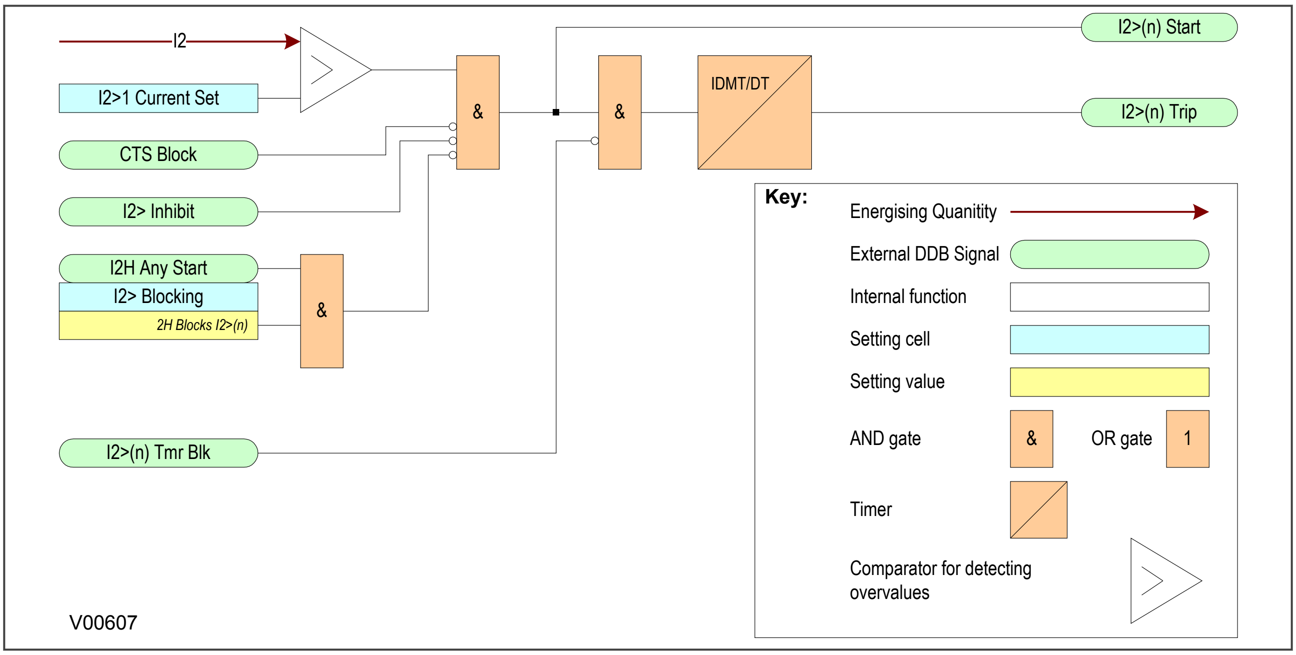


Figure 28: Negative Sequence Overcurrent logic - non-directional operation

For Negative Phase Sequence Overcurrent Protection, the energising quanitity **I2>** is compared with the threshold voltage **I2>1 Current Set**. If the value exceeds this setting a Start signal (**I2>(n) Start**) is generated, provided there are no blocks. 5% hysteresis is built into the comparator such that the drop-off value is 0.95 x of the current set threshold.

The function can be blocked by an Inhibit signal, CTS, or second harmonic blocking.

The I2>Start signal is fed into a timer to produce the I2> trip signal. The timer can be blocked by the timer block signal **I2> (n) Tmr Blk**.

This diagram and description applies to each stage.

7.3 DIRECTIONAL ELEMENT

Where negative phase sequence current may flow in either direction through an IED location, such as parallel lines or ring main systems, directional control should be used.

Directionality is achieved by comparing the angle between the negative phase sequence voltage and the negative phase sequence current. A directional element is available for all of the negative sequence overcurrent stages. This is found in the **I2> Direction** cell for the relevant stage. It can be set to non-directional, directional forward, or directional reverse.

A suitable characteristic angle setting (**I2> Char Angle**) is chosen to provide optimum performance. This setting should be set equal to the phase angle of the negative sequence current with respect to the inverted negative sequence voltage (**–V2**), in order to be at the centre of the directional characteristic.

7.3.1 DIRECTIONAL NEGATIVE SEQUENCE OVERCURRENT LOGIC

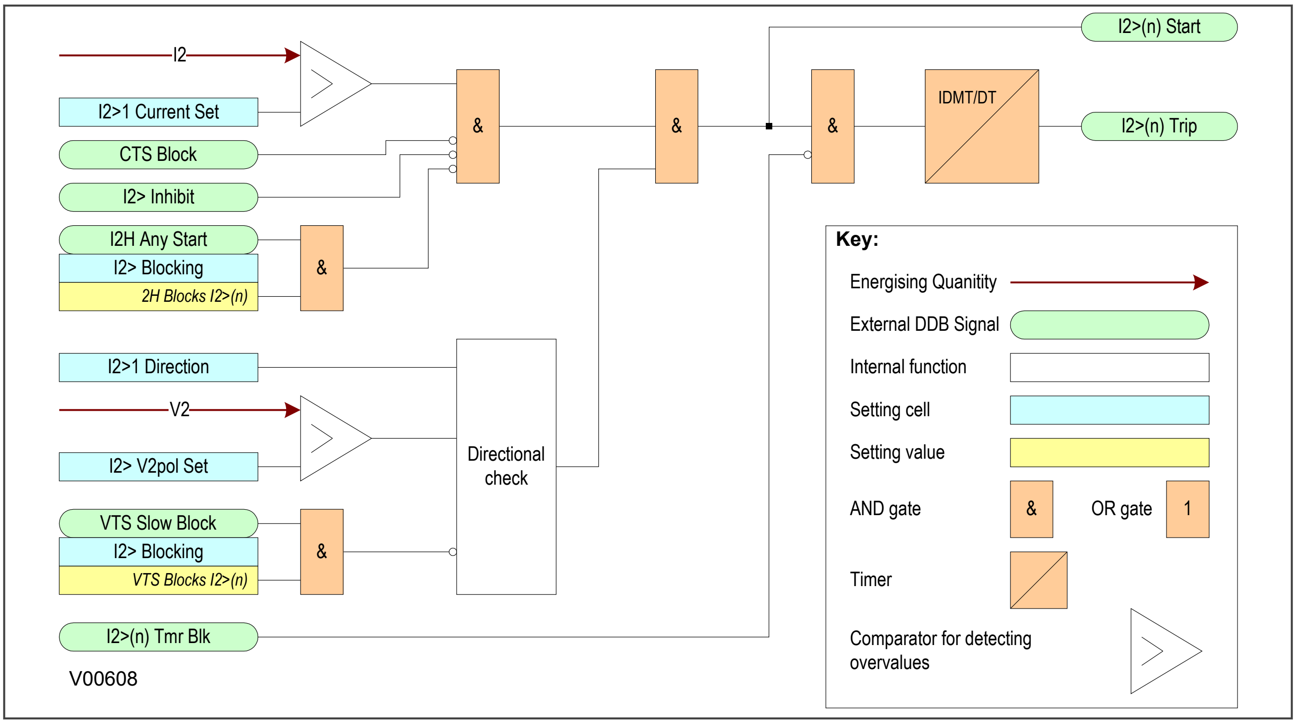


Figure 29: Negative Sequence Overcurrent logic - directional operation

Directionality is achieved by comparing the angle between the negative phase sequence voltage and the negative phase sequence current. The element may be selected to operate in either the forward or reverse direction. A suitable characteristic angle setting (**I2>Char Angle)** is chosen to provide optimum performance. This setting should be set equal to the phase angle of the negative sequence current with respect to the inverted negative sequence voltage (–V2), in order to be at the centre of the directional characteristic.

For the negative phase sequence directional elements to operate, the device must detect a polarising voltage above a minimum threshold, **I2>V2pol** Set. This must be set in excess of any steady state negative phase sequence voltage. This may be determined during the commissioning stage by viewing the negative phase sequence measurements in the device.

When the element is selected as directional (directional devices only), a VTS Block option is available. When the relevant bit is set to 1, operation of the Voltage Transformer Supervision (VTS) will block the stage. When set to 0, the stage will revert to non-directional.

7.4 NPS OVERCURRENT DDB SIGNALS

Ordinal	English Text	Source	Type	Response Function
		Description		
351	VTS Slow Block	Software	PSL Input	No response
This DDB signal is a purposely delayed output from the VTS which can block other functions				
352	CTS Block	Software	PSL Input	No response
This DDB signal is an instantaneously blocking output from the CTS which can block other functions				
504	I2> Inhibit	Programmable Scheme Logic	PSL Output	No response
This DDB signal inhibits the Negative Phase Overcurrent protection				
505	I2>1 Tmr Blk	Programmable Scheme Logic	PSL Output	No response
This DDB signal blocks the first stage Negative Phase Overcurrent timer				

Ordinal	English Text	Source	Type	Response Function
Description				
506	I2>2 Tmr Blk	Programmable Scheme Logic	PSL Output	No response
This DDB signal blocks the second stage Negative Phase Overcurrent timer				
507	I2>3 Tmr Blk	Programmable Scheme Logic	PSL Output	No response
This DDB signal blocks the third stage Negative Phase Overcurrent timer				
508	I2>4 Tmr Blk	Programmable Scheme Logic	PSL Output	No response
This DDB signal blocks the fourth stage Negative Phase Overcurrent timer				
509	I2>1 Start	Software	PSL Input	Protection event
This DDB signal is the first stage NPSOC start signal				
510	I2>2 Start	Software	PSL Input	Protection event
This DDB signal is the second stage NPSOC start signal				
511	I2>3 Start	Software	PSL Input	Protection event
This DDB signal is the third stage NPSOC start signal				
512	I2>4 Start	Software	PSL Input	Protection event
This DDB signal is the fourth stage NPSOC start signal				
513	I2>1 Trip	Software	PSL Input	Protection event
This DDB signal is the first stage NPSOC trip signal				
514	I2>2 Trip	Software	PSL Input	Protection event
This DDB signal is the second stage NPSOC trip signal				
515	I2>3 Trip	Software	PSL Input	Protection event
This DDB signal is the third stage NPSOC trip signal				
516	I2>4 Trip	Software	PSL Input	Protection event
This DDB signal is the fourth stage NPSOC trip signal				
541	I2H Any Start	Software	PSL Input	Protection event
This DDB signal is the 2nd Harmonic start signal for any phase				

7.5 NEGATIVE SEQUENCE OVERCURRENT SETTINGS

Menu Text	Col	Row	Default Setting	Available Options
Description				
GROUP 1 NEG SEQ O/C	36	00		
This column contains settings for Negative Sequence overcurrent				
I2>1 Status	36	10	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the first stage NPSOC element.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
I2>1 Function	36	11	DT	0=DT 1=IEC S Inverse 2=IEC V Inverse 3=IEC E Inverse 4=UK LT Inverse 5=IEEE M Inverse 6=IEEE V Inverse 7=IEEE E Inverse 8=US Inverse 9=US ST Inverse 10=User Curve 1 11=User Curve 2 12=User Curve 3 13=User Curve 4
This setting determines the tripping characteristic for the first stage NPSOC element.				
I2>1 Direction	36	12	Non-Directional	0 = Non-Directional, 1 = Directional Fwd, 2 = Directional Rev
This setting determines the direction of measurement for the first stage NPSOC element.				
I2>1 Current Set	36	15	0.2	0.08*In to 4*In step 0.01In
This setting sets the pick-up threshold for the first stage NPSOC element.				
I2>1 Time Delay	36	17	10	From 0s to 100s step 0.01s
This setting sets the DT time delay for the first stage NPSOC element.				
I2>1 TMS	36	18	1	0.025 to 1.2 step 0.005
This is the Time Multiplier Setting to adjust the operate time of IEC IDMT curves.				
I2>1 Time Dial	36	19	1	0.01 to 100 step 0.01
This is the Time Multiplier Setting to adjust the operate time of IEEE/US IDMT curves.				
I2>1 DT Adder	36	1B	0	From 0s to 100s step 0.01s
This setting adds an additional fixed time delay to the IDMT Operate characteristic.				
I2>1 Reset Char	36	1C	DT	0 = DT or 1 = Inverse
This setting determines the type of Reset characteristic used for the IEEE/US curves.				
I2>1 tRESET	36	1D	0	From 0s to 100s step 0.01s
This setting determines the Reset time for the Definite Time Reset characteristic				
I2>1 Usr RstChar	36	1E	DT	0 = DT 1=User Curve 1 2=User Curve 2 3=User Curve 3 4=User Curve 4
This setting determines the type of Reset characteristic used for the user defined curves.				
I2>2 Status	36	20	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the second stage NPSOC element.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
I2>2 Function	36	21	DT	0=DT 1=IEC S Inverse 2=IEC V Inverse 3=IEC E Inverse 4=UK LT Inverse 5=IEEE M Inverse 6=IEEE V Inverse 7=IEEE E Inverse 8=US Inverse 9=US ST Inverse 10=User Curve 1 11=User Curve 2 12=User Curve 3 13=User Curve 4
This setting determines the tripping characteristic for the second stage overcurrent element.				
I2>2 Direction	36	22	Non-Directional	0 = Non-Directional, 1 = Directional Fwd, 2 = Directional Rev
This setting determines the direction of measurement for the second stage NPSOC element.				
I2>2 Current Set	36	25	0.2	0.08*In to 4*In step 0.01In
This setting sets the pick-up threshold for the second stage NPSOC element.				
I2>2 Time Delay	36	27	10	From 0s to 100s step 0.01s
This setting sets the DT time delay for the second stage NPSOC element.				
I2>2 TMS	36	28	1	0.025 to 1.2 step 0.005
This is the Time Multiplier Setting to adjust the operate time of IEC IDMT curves.				
I2>2 Time Dial	36	29	1	0.01 to 100 step 0.01
This is the Time Multiplier Setting to adjust the operate time of IEEE/US IDMT curves.				
I2>2 DT Adder	36	2B	0	From 0s to 100s step 0.01s
This setting adds an additional fixed time delay to the IDMT Operate characteristic.				
I2>2 Reset Char	36	2C	DT	0 = DT or 1 = Inverse
This setting determines the type of Reset characteristic used for the IEEE/US curves.				
I2>2 tRESET	36	2D	0	From 0s to 100s step 0.01s
This setting determines the Reset time for the Definite Time Reset characteristic				
I2>2 Usr RstChar	36	2E	DT	0 = DT 1=User Curve 1 2=User Curve 2 3=User Curve 3 4=User Curve 4
This setting determines the type of Reset characteristic used for the user defined curves.				
I2>3 Status	36	30	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the third stage NPSOC element. There is no choice of curves because this stage is DT only.				
I2>3 Direction	36	32	Non-Directional	0 = Non-Directional, 1 = Directional Fwd, 2 = Directional Rev
This setting determines the direction of measurement for the third stage NPSOC element.				
I2>3 Current Set	36	35	0.2	0.08*In to 32*In step 0.01In
This setting sets the pick-up threshold for the third stage NPSOC element.				
I2>3 Time Delay	36	37	10	From 0s to 100s step 0.01s
This setting sets the DT time delay for the third stage NPSOC element.				
I2>4 Status	36	40	Disabled	0 = Disabled or 1 = Enabled

Menu Text	Col	Row	Default Setting	Available Options
Description				
This setting enables or disables the fourth stage NPSOC element. There is no choice of curves because this stage is DT only.				
I2>4 Direction	36	42	Non-Directional	0 = Non-Directional, 1 = Directional Fwd, 2 = Directional Rev
This setting determines the direction of measurement for the fourth stage NPSOC element.				
I2>4 Current Set	36	45	0.2	0.08*In to 32*In step 0.01In
This setting sets the pick-up threshold for the fourth stage NPSOC element.				
I2>4 Time Delay	36	47	10	From 0s to 100s step 0.01s
This setting sets the DT time delay for the fourth stage NPSOC element.				
I2> Blocking	36	50	0x0F	Bit 0=VTS Blocks I2>1 Bit 1=VTS Blocks I2>2 Bit 2=VTS Blocks I2>3 Bit 3=VTS Blocks I2>4 Bit 4=2H Blocks I2>1 Bit 5=2H Blocks I2>2 Bit 6=2H Blocks I2>3 Bit 7=2H Blocks I2>4
This setting cell contains a binary string (data type G158), where you can define which blocking signals block which stage. The available settings depend on the model chosen. This description is for models with VTS blocking and second harmonic blocking.				
I2> Char Angle	36	51	-60	From -95 to 95 step 1
This setting defines the characteristic angle for the directional element. This setting is aplicable to all NPSOC stages.				
I2> V2pol Set	36	52	5	From 0.5*V1 to 25*V1 step 0.5*V1
This setting determines the minimum negative sequence voltage threshold that must be present to determine directionality.				

7.6 APPLICATION NOTES

7.6.1 SETTING GUIDELINES (CURRENT THRESHOLD)

The current pick-up threshold must be set higher than the negative phase sequence current due to the maximum normal load imbalance. This can be set practically at the commissioning stage, making use of the measurement function to display the standing negative phase sequence current. The setting should be at least 20% above this figure.

Where the negative phase sequence element needs to operate for specific uncleared asymmetric faults, a precise threshold setting would have to be based on an individual fault analysis for that particular system due to the complexities involved. However, to ensure operation of the protection, the current pick-up setting must be set approximately 20% below the lowest calculated negative phase sequence fault current contribution to a specific remote fault condition.

7.6.2 SETTING GUIDELINES (TIME DELAY)

Correct setting of the time delay for this function is vital. You should also be very aware that this element is applied primarily to provide back-up protection to other protection devices or to provide an alarm. It would therefore normally have a long time delay.

The time delay set must be greater than the operating time of any other protection device (at minimum fault level) that may respond to unbalanced faults, such as:

- Phase overcurrent elements
- Earth fault elements
- Broken conductor elements
- Negative phase sequence influenced thermal elements

7.6.3 SETTING GUIDELINES (DIRECTIONAL ELEMENT)

Where negative phase sequence current may flow in either direction through an IED location, such as parallel lines or ring main systems, directional control of the element should be employed.

Directionality is achieved by comparing the angle between the negative phase sequence voltage and the negative phase sequence current and the element may be selected to operate in either the forward or reverse direction. A suitable characteristic angle setting (I2> Char Angle) is chosen to provide optimum performance. This setting should be set equal to the phase angle of the negative sequence current with respect to the inverted negative sequence voltage (–V2), in order to be at the centre of the directional characteristic.

The angle that occurs between V2 and I2 under fault conditions is directly dependent upon the negative sequence source impedance of the system. However, typical settings for the element are as follows:

- For a transmission system the RCA should be set equal to –60°
- For a distribution system the RCA should be set equal to –45°

For the negative phase sequence directional elements to operate, the device must detect a polarizing voltage above a minimum threshold, **I2>V2pol Set**. This must be set in excess of any steady state negative phase sequence voltage. This may be determined during the commissioning stage by viewing the negative phase sequence measurements in the device.

8 EARTH FAULT PROTECTION

Earth faults are simply overcurrent faults where the fault current flows to earth (as opposed to between phases). They are the most common type of fault. There are a few different kinds of earth fault, but the most common is the single phase-to-earth fault. Consequently this is the first and foremost type of fault that protection devices must cover.

Typical settings for earth fault IEDs are around 30-40% of the full load current. If greater sensitivity is required, then Sensitive Earth Fault should be used.

Earth faults can be measured directly from the system by means of:

- A separate CT located in a power system earth connection
- A separate Core Balance CT (CBCT)
- A residual connection of the three line CTs, whereby the Earth faults can be derived mathematically by summing the three measured phase currents.

Depending on the device model, it will provide one or more of the above means for Earth fault protection.

8.1 EARTH FAULT PROTECTION ELEMENTS

Earth fault protection is implemented in the columns EARTH FAULT 1 and EARTH FAULT 2 of the relevant settings group.

Each column contains an identical set of elements, whereby the EARTH FAULT 1 (EF1) column is used for earth fault current that is measured directly from the system, whilst the EARTH FAULT 2 (EF2) column contains cells, which operate from a residual current quantity that is derived internally from the summation of the three-phase currents.

The product provides four stages of Earth Fault protection with independent time delay characteristics, for each EARTH FAULT column.

Stages 1 and 2 provide a choice of operate and reset characteristics, where you can select between:

- A range of standard IDMT (Inverse Definite Minimum Time) curves
- A range of User-defined curves
- DT (Definite Time)

For the EF1 column, this is achieved using the cells:

- **IN1>**(n) **Function** for the overcurrent operate characteristics
- **IN1>**(n) **Reset Char** for the overcurrent reset characteristic
- **IN1>**(n) **Usr RstChar** for the reset characteristic for user-defined curves

For the EF2 column, this is achieved using the cells:

- **IN2>**(n) **Function** for the overcurrent operate characteristics
- **IN2>**(n) **Reset Char** for the overcurrent reset characteristic
- **IN2>**(n) **Usr RstChar** for the reset characteristic for user-defined curves

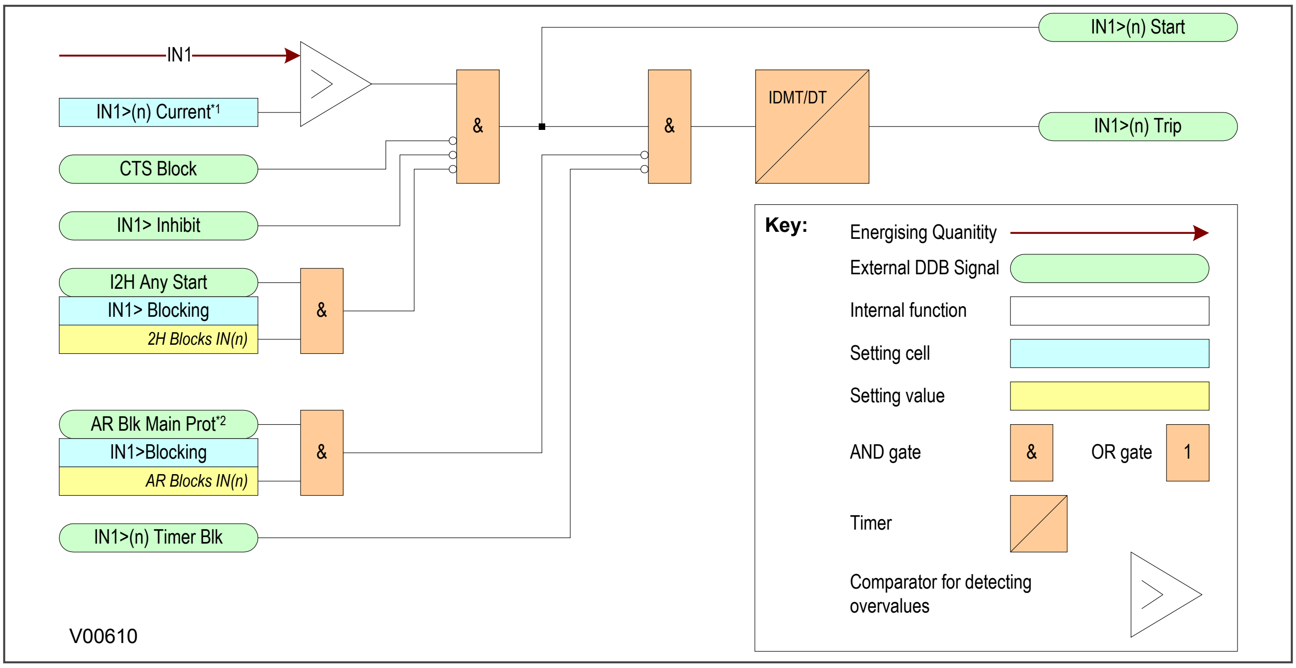
where (n) is the number of the stage.

Stages 1 and 2 provide a Timer Hold facility (on page 88). This is configured using the cells **IN1>**(n) **tReset** for EF1 and **IN2>**(n) **tReset** for EF2.

Stages 3 and 4 can have definite time characteristics only.

The fact that both EF1 and EF2 elements may be enabled at the same time leads to a number of applications advantages. For example, some applications may require directional earth fault protection for upstream equipment and backup earth fault protection for downstream equipment. This can be achieved with a single IED, rather than two.

8.2 NON-DIRECTIONAL EARTH FAULT LOGIC



Note:
**1 If a CLP condition exists, the I>(n) Current Set threshold is taken from the COLD LOAD PICKUP column*
**2 Autoreclose blocking is only available for stages 3,4 and 6 and on selected models*

Figure 30: Non-directional EF logic (single stage)

The Earth Fault current is compared with a set threshold (**IN1>(n) Current**) for each stage. If it exceeds this threshold, a Start signal is triggered, providing it is not blocked. This can be blocked by the second harmonic blocking function, or an Inhibit Earth Fault DDB signal.

The autoreclose logic can be set to block the Earth Fault trip after a prescribed number of shots (set in AUTORECLOSE column). This is achieved using the **AR Blk Main Prot** setting. this can also be blocked by the relevant timer block signal **IN1>(n)TimerBlk DDB** signal.

Earth Fault protection can follow the same IDMT characteristics as described in the Overcurrent Protection Principles section. Please refer to this section for details of IDMT characteristics.

The diagram and description also applies to the Earth Fault 2 element (IN2).

8.3 IDG CURVE

The IDG curve is commonly used for time delayed earth fault protection in the Swedish market. This curve is available in stage 1 of the Earth Fault protection.

The IDG curve is represented by the following equation:

$$t_{op} = 5.8 - 1.35 \log_e \left(\frac{I}{IN > Setting} \right)$$

where:

t_{op} is the operating time

I is the measured current

IN> Setting is an adjustable setting, which defines the start point of the characteristic

> *Note:*
> *Although the start point of the characteristic is defined by the "IN>" setting, the actual current threshold is a different setting called "IDG Is". The "IDG Is" setting is set as a multiple of "IN>".*

> *Note:*
> *When using an IDG Operate characteristic, DT is always used with a value of zero for the Rest characteristic.*

An additional setting "IDG Time" is also used to set the minimum operating time at high levels of fault current.

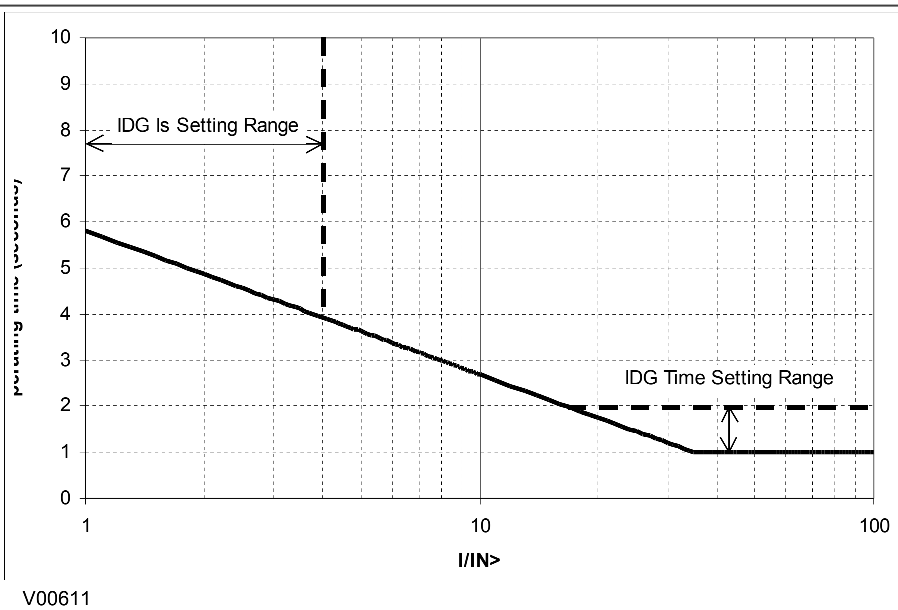


Figure 31: IDG Characteristic

8.4 DIRECTIONAL ELEMENT

If Earth fault current can flow in both directions through a protected location, you will need to use a directional overcurrent element to determine the direction of the fault. Typical systems that require such protection are parallel feeders (both plain and transformer) and ring main systems, each of which are relatively common in distribution networks.

A directional element is available for all of the Earth Fault stages for both Earth fault columns. These are found in the direction setting cells for the relevant stage (e.g. **IN1>1 Direction, IN2>2 Direction**). They can be set to non-directional, directional forward, or directional reverse.

For standard earth fault protection, two options are available for polarisation; Residual Voltage or Negative Sequence.

8.4.1 RESIDUAL VOLTAGE POLARISATION

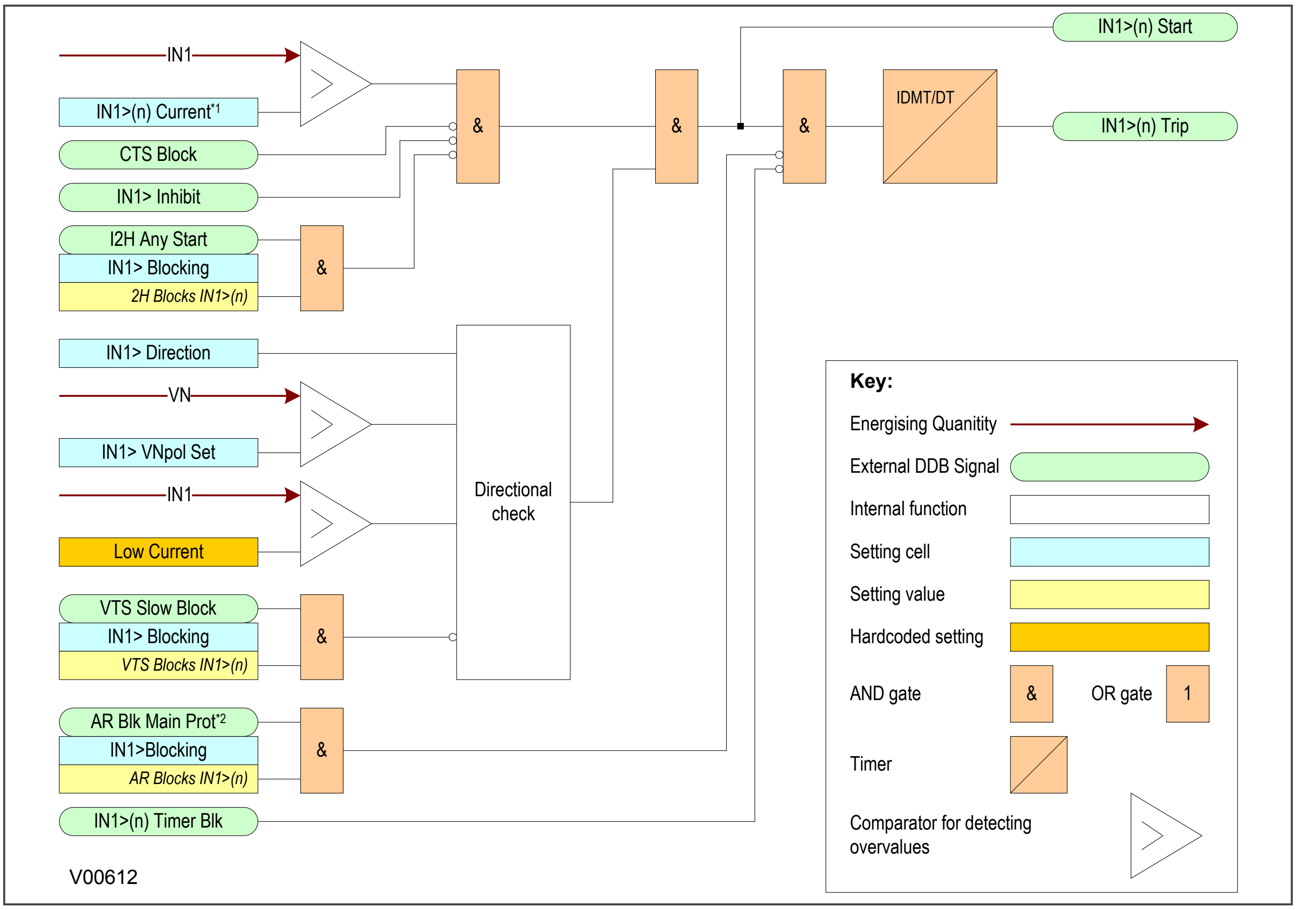
With earth fault protection, the polarising signal needs to be representative of the earth fault condition. As residual voltage is generated during earth fault conditions, this quantity is commonly used to polarise directional earth fault elements. This is known as Residual Voltage polarisation or Neutral Displacement Voltage (NVD) polarisation.

Some of the models derive this voltage internally, from the 3-phase voltage input supplied from either a 5-limb or three single-phase VTs. With some models (those with no Check Synchronism function) the voltage transformer may be used to measure the Residual Voltage VN. This gives a more accurate result than with derived voltage.

Small levels of residual voltage could be present under normal system conditions due to system imbalances, VT inaccuracies, device tolerances etc. for this reason, the device includes a user settable threshold (**IN>VNPol set**), which must be exceeded in order for the DEF function to become operational. The residual voltage measurement provided in the MEASUREMENTS 1 column of the menu may assist in determining the required threshold setting during the commissioning stage, as this will indicate the level of standing residual voltage present.

Note:
Residual voltage is nominally 180° out of phase with residual current. Consequently, the DEF elements are polarized from the "-Vres" quantity. This 180° phase shift is automatically introduced within the device.

8.4.1.1 DIRECTIONAL EARTH FAULT LOGIC WITH RESIDUAL VOLTAGE POLARISATION



Note:
**1 If a CLP condition exists, the I>(n) Current Set threshold is taken from the COLD LOAD PICKUP column*
**2 Autoreclose blocking is only available for stages 3,4 and 6 and on selected models*

Figure 32: Directional EF logic with neutral voltage polarization (single stage)

Voltage Transformer Supervision (VTS) selectively blocks the directional protection or causes it to revert to non-directional operation. When selected to block the directional protection, VTS blocking is applied to the directional checking which effectively blocks the Start outputs as well.

8.4.2 NEGATIVE SEQUENCE POLARISATION

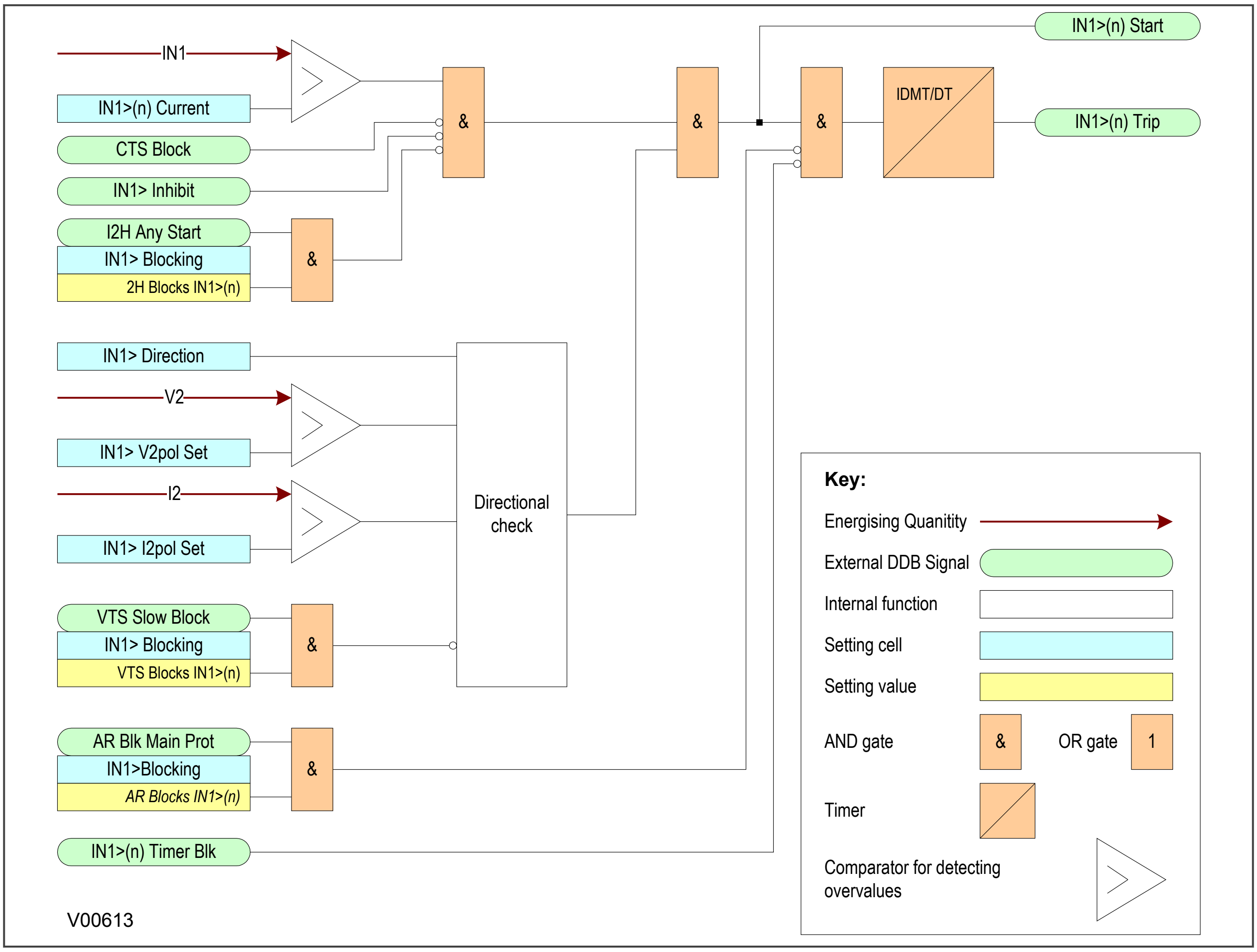
In some applications, the use of residual voltage polarization may be not possible to achieve, or at the very least, problematic. For example, a suitable type of VT may be unavailable, or an HV/EHV parallel line application may present problems with zero sequence mutual coupling.

In such situations, the problem may be solved by using Negative Phase Sequence (NPS) quantities for polarization. This method determines the fault direction by comparing the NPS voltage with the NPS current. The operate quantity, however, is still residual current.

This can be used for both the derived and measured standard earth fault elements (EF1 and EF2) but not on the SEF protection. It requires a suitable voltage and current threshold to be set in cells **IN>V2pol set** and **IN>I2pol set** respectively.

Negative sequence polarising is not recommended for impedance earthed systems regardless of the type of VT feeding the relay. This is due to the reduced earth fault current limiting the voltage drop across the negative sequence source impedance to negligible levels. If this voltage is less than 0.5 volts the device will stop providing DEF.

8.4.2.1 DIRECTIONAL EARTH FAULT LOGIC WITH NPS POLARISATION



Note:
**1 If a CLP condition exists, the I>(n) Current Set threshold is taken from the COLD LOAD PICKUP column*
**2 Autoreclose blocking is only available for stages 3,4 and 6 and on selected models*

Figure 33: Directional Earth Fault logic with negative sequence polarisation (single stage)

Voltage Transformer Supervision (VTS) selectively blocks the directional protection or causes it to revert to non-directional operation. When selected to block the directional protection, VTS blocking is applied to the directional checking which effectively blocks the Start outputs as well.

The directional criteria with negative sequence polarisation is given below:

- Directional forward: -90° < (angle(I2) - angle(V2 + 180°) - RCA) < 90°
- Directional reverse : -90° > (angle(I2) - angle(V2 + 180°) - RCA) > 90°

8.5 MEASURED AND DERIVED EARTH FAULT DDB SIGNALS

Ordinal	English Text	Source	Type	Response Function
Description				
208	IN1>1 Timer Blk	Programmable Scheme Logic	PSL Output	No response
This DDB signal blocks the first stage measured Earth Fault time delay				

Ordinal	English Text	Source	Type	Response Function
Description				
209	IN1>2 Timer Blk	Programmable Scheme Logic	PSL Output	No response
This DDB signal blocks the second stage measured Earth Fault time delay				
210	IN1>3 Timer Blk	Programmable Scheme Logic	PSL Output	No response
This DDB signal blocks the third stage measured Earth Fault time delay				
211	IN1>4 Timer Blk	Programmable Scheme Logic	PSL Output	No response
This DDB signal blocks the fourth stage measured Earth Fault time delay				
212	IN2>1 Timer Blk	Programmable Scheme Logic	PSL Output	No response
This DDB signal blocks the first stage derived Earth Fault time delay				
213	IN2>2 Timer Blk	Programmable Scheme Logic	PSL Output	No response
This DDB signal blocks the second stage derived Earth Fault time delay				
214	IN2>3 Timer Blk	Programmable Scheme Logic	PSL Output	No response
This DDB signal blocks the third stage derived Earth Fault time delay				
215	IN2>4 Timer Blk	Programmable Scheme Logic	PSL Output	No response
This DDB signal blocks the fourth stage derived Earth Fault time delay				
351	VTS Slow Block	Software	PSL Input	No response
This DDB signal is a purposely delayed output from the VTS which can block other functions				
352	CTS Block	Software	PSL Input	No response
This DDB signal is an instantaneously blocking output from the CTS which can block other functions				
358	AR Blk Main Prot	Software	PSL Input	Protection event
This DDB signal, generated by the Autoreclose function, blocks the Main Protection elements (POC, EF1, EF2, NPSOC)				
528	IN1> Inhibit	Programmable Scheme Logic	PSL Output	No response
This DDB signal inhibits the measured Earth Fault protection				
529	IN2> Inhibit	Programmable Scheme Logic	PSL Output	No response
This DDB signal inhibits the derived Earth Fault protection				
541	I2H Any Start	Software	PSL Input	Protection event
This DDB signal is the 2nd Harmonic start signal for any phase				

8.6 EARTH FAULT PROTECTION 1 SETTINGS

Menu Text	Col	Row	Default Setting	Available Options
Description				
GROUP 1 EARTH FAULT 1	38	00		
This column contains settings for Measured Earth Fault protection (EF1)				
IN1> Input	38	01	Measured	Not Settable
This cell displays the input type. For EF1 it is always 'Measured'				

Menu Text	Col	Row	Default Setting	Available Options
Description				
IN1>1 Function	38	25	IEC S Inverse	0=Disabled 1=DT 2=IEC S Inverse 3=IEC V Inverse 4=IEC E Inverse 5=UK LT Inverse 6=RI 7=IEEE M Inverse 8=IEEE V Inverse 9=IEEE E Inverse 10=US Inverse 11=US ST Inverse 12=IDG 13=User curve 1 14=User curve 2 15=User curve 3 16=User curve 4
This setting determines the tripping characteristic for the first stage EF1 element.				
IN1>1 Direction	38	26	Non-Directional	0 = Non-Directional, 1 = Directional Fwd, 2 = Directional Rev
This setting determines the direction of measurement for the first stage EF1 element.				
IN1>1 Current	38	29	0.2	0.08*In to 4*In step 0.01In
This setting sets the pick-up threshold for the first stage EF1 element.				
IN1>1 IDG Is	38	2A	1.5	1 to 4 step 0.1
This setting is set as a multiple of the Earth Fault overcurent setting IN> for the IDG curve. It determines the actual current threshold at which the element starts.				
IN1>1 Time Delay	38	2C	1	From 0s to 200s step 0.01s
This setting sets the DT time delay for the first stage EF1 element.				
IN1>1 TMS	38	2D	1	0.025 to 1.2 step 0.005
This is the Time Multiplier Setting to adjust the operate time of IEC IDMT curves.				
IN1>1 Time Dial	38	2E	1	0.01 to 100 step 0.01
This is the Time Multiplier Setting to adjust the operate time of IEEE/US IDMT curves.				
IN1>1 k (RI)	38	2F	1	From 0.1 to 10 step 0.05
This setting defines the TMS constant to adjust the operate time of the RI curve.				
IN1>1 IDG Time	38	30	1.2	From 1s to 2s step 0.01s
This setting sets the minimum operate time at high levels of fault current for IDG curves.				
IN1>1 DT Adder	38	31	0	From 0s to 100s step 0.01s
This setting adds an additional fixed time delay to the IDMT Operate characteristic.				
IN1>1 Reset Char	38	32	DT	0 = DT or 1 = Inverse
This setting determines the type of Reset characteristic used for the IEEE/US curves.				
IN1>1 tRESET	38	33	0	From 0s to 100s step 0.01s
This setting determines the Reset time for the Definite Time Reset characteristic				
IN1>1 Usr RstChr	38	34	DT	0 = DT 1=User Curve 1 2=User Curve 2 3=User Curve 3 4=User Curve 4
This setting determines the type of Reset characteristic used for the user defined curves.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
IN1>2 Function	38	36	Disabled	0=Disabled 1=DT 2=IEC S Inverse 3=IEC V Inverse 4=IEC E Inverse 5=UK LT Inverse 6=RI 7=IEEE M Inverse 8=IEEE V Inverse 9=IEEE E Inverse 10=US Inverse 11=US ST Inverse 12=IDG 13=User curve 1 14=User curve 2 15=User curve 3 16=User curve 4
This setting determines the tripping characteristic for the second stage EF1 element.				
IN1>2 Direction	38	37	Non-Directional	0 = Non-Directional, 1 = Directional Fwd, 2 = Directional Rev
This setting determines the direction of measurement for the second stage EF1 element.				
IN1>2 Current	38	3A	0.2	0.08*In to 4*In step 0.01In
This setting sets the pick-up threshold for the second stage EF1 element.				
IN1>2 IDG Is	38	3B	1.5	1 to 4 step 0.1
This setting is set as a multiple of the Earth Fault overcurent setting IN> for the IDG curve. It determines the actual current threshold at which the element starts.				
IN1>2 Time Delay	38	3D	1	From 0s to 200s step 0.01s
This setting sets the DT time delay for the second stage EF1 element.				
IN1>2 TMS	38	3E	1	0.025 to 1.2 step 0.005
This is the Time Multiplier Setting to adjust the operate time of IEC IDMT curves.				
IN1>2 Time Dial	38	3F	1	0.01 to 100 step 0.01
This is the Time Multiplier Setting to adjust the operate time of IEEE/US IDMT curves.				
IN1>2 k (RI)	38	40	1	From 0.1 to 10 step 0.05
This setting defines the TMS constant to adjust the operate time of the RI curve.				
IN1>2 IDG Time	38	41	1.2	From 1s to 2s step 0.01s
This setting sets the minimum operate time at high levels of fault current for IDG curves.				
IN1>2 DT Adder	38	42	0	From 0s to 100s step 0.01s
This setting adds an additional fixed time delay to the IDMT Operate characteristic.				
IN1>2 Reset Char	38	43	DT	0 = DT or 1 = Inverse
This setting determines the type of Reset characteristic used for the IEEE/US curves.				
IN1>2 tRESET	38	44	0	From 0s to 100s step 0.01s
This setting determines the Reset time for the Definite Time Reset characteristic				
IN2>1 Usr RstChr	38	45	DT	0 = DT 1=User Curve 1 2=User Curve 2 3=User Curve 3 4=User Curve 4
This setting determines the type of Reset characteristic used for the user defined curves.				
IN1>3 Status	38	46	Disabled	0 = Disabled, 1 = Enabled

Menu Text	Col	Row	Default Setting	Available Options
Description				
This setting enables or disables the third stage EF1 element. There is no choice of curves because this stage is DT only.				
IN1>3 Direction	38	47	Non-Directional	0 = Non-Directional, 1 = Directional Fwd, 2 = Directional Rev
This setting determines the direction of measurement for the third stage EF1 element.				
IN1>3 Current	38	4A	0.2	0.08*In to 32*In step 0.01In
This setting sets the pick-up threshold for the third stage EF1 element.				
IN1>3 Time Delay	38	4B	1	From 0s to 200s step 0.01s
This setting sets the DT time delay for the third stage EF1 element.				
IN1>4 Status	38	4D	Disabled	0 = Disabled, 1 = Enabled
This setting enables or disables the fourth stage EF1 element. There is no choice of curves because this stage is DT only.				
IN1>4 Direction	38	4E	Non-Directional	0 = Non-Directional, 1 = Directional Fwd, 2 = Directional Rev
This setting determines the direction of measurement for the fourth stage EF1 element.				
IN1>4 Current	38	51	0.2	0.08*In to 32*In step 0.01In
This setting sets the pick-up threshold for the fourth stage EF1 element.				
IN1>4 Time Delay	38	52	1	From 0s to 200s step 0.01s
This setting sets the DT time delay for the fourth stage EF1 element.				
IN1> Blocking	38	54	0x00F	Bit 0=VTS Blocks IN>1 Bit 1=VTS Blocks IN>2 Bit 2=VTS Blocks IN>3 Bit 3=VTS Blocks IN>4 Bit 4=AR Blocks IN>3 Bit 5=AR Blocks IN>4 Bit 6=2H Blocks IN>1 Bit 7=2H Blocks IN>2 Bit 8=2H Blocks IN>3 Bit 9=2H Blocks IN>4
This setting cell contains a binary string (data type G63), where you can define which blocking signals block which stage. The available settings depend on the model chosen. This description is for models with Autoreclose.				
IN1> Blocking	38	54	0x00F	Bit 0=VTS Blocks IN>1 Bit 1=VTS Blocks IN>2 Bit 2=VTS Blocks IN>3 Bit 3=VTS Blocks IN>4 Bit 4=Not Used Bit 5=Not Used Bit 6=2H Blocks IN>1 Bit 7=2H Blocks IN>2 Bit 8=2H Blocks IN>3 Bit 9=2H Blocks IN>4
This setting cell contains a binary string (data type G63A), where you can define which blocking signals block which stage. The available settings depend on the model chosen. This description is for models without Autoreclose.				
IN1> POL	38	55		
The settings under this sub-heading relate to the polarisation for directional control for EF1 (measured)				
IN1> Char Angle	38	56	-45	-95 to 95 step 1
This setting defines the characteristic angle used for the directional decision.				
IN1> Pol	38	57	Zero Sequence	0=Zero Sequence 1=Neg Sequence
This setting determines whether the directional function uses zero sequence or negative sequence voltage polarisation.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
IN1> VNpol Set	38	59	5 20	0.5V to 80V step 0.5V
This setting sets the minimum zero sequence voltage polarising quantity required for a directional decision.				
IN1> VNpol Set	38	59	5 20	0.5V to 80V step 0.5V
This setting sets the minimum zero sequence voltage polarising quantity required for a directional decision.				
IN1> V2pol Set	38	5A	5	0.5V to 80V step 0.5V
This setting sets the minimum zero sequence voltage polarising quantity required for a directional decision. Derived				
IN1> I2pol Set	38	5B	0.08	0.08*In to 1*In step 0.01In
This setting sets the minimum negative sequence current polarising quantity for directional decision.				

8.7 EARTH FAULT PROTECTION 2 SETTINGS

Menu Text	Col	Row	Default Setting	Available Options
Description				
GROUP 1 EARTH FAULT 2	39	00		
This column contains settings for Derived Earth Fault				
IN2> Input	39	01	Derived	Not Settable
This cell displays the input type. For EF2 it is always 'Derived'				
IN2>1 Function	39	25	IEC S Inverse	0=Disabled 1=DT 2=IEC S Inverse 3=IEC V Inverse 4=IEC E Inverse 5=UK LT Inverse 6=RI 7=IEEE M Inverse 8=IEEE V Inverse 9=IEEE E Inverse 10=US Inverse 11=US ST Inverse 12=IDG 13=User curve 1 14=User curve 2 15=User curve 3 16=User curve 4
This setting determines the tripping characteristic for the first stage EF2 element.				
IN2>1 Direction	39	26	Non-Directional	0 = Non-Directional, 1 = Directional Fwd, 2 = Directional Rev
This setting determines the direction of measurement for the first stage EF2 element.				
IN2>1 Current	39	29	0.2	0.08*In to 4*In step 0.01In
This setting sets the pick-up threshold for the first stage EF2 element.				
IN2>1 IDG Is	39	2A	1.5	1 to 4 step 0.1
This setting is set as a multiple of the Earth Fault overcurrent setting IN> for the IDG curve. It determines the actual current threshold at which the element starts.				
IN2>1 Time Delay	39	2C	1	From 0s to 200s step 0.01s
This setting sets the DT time delay for the first stage EF2 element.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
IN2>1 TMS	39	2D	1	0.025 to 1.2 step 0.005
This is the Time Multiplier Setting to adjust the operate time of IEC IDMT curves.				
IN2>1 Time Dial	39	2E	1	0.01 to 100 step 0.01
This is the Time Multiplier Setting to adjust the operate time of IEEE/US IDMT curves.				
IN2>1 k (RI)	39	2F	1	From 0.1 to 10 step 0.05
This setting defines the TMS constant to adjust the operate time of the RI curve.				
IN2>1 IDG Time	39	30	1.2	1s to 2s step 0.01s
This setting sets the minimum operate time at high levels of fault current for IDG curves.				
IN2>1 DT Adder	39	31	0	From 0s to 100s step 0.01s
This setting adds an additional fixed time delay to the IDMT Operate characteristic.				
IN2>1 Reset Char	39	32	DT	0 = DT or 1 = Inverse
This setting determines the type of Reset characteristic used for the IEEE/US curves.				
IN2>1 tRESET	39	33	0	From 0s to 100s step 0.01s
This setting determines the Reset time for the Definite Time Reset characteristic				
IN2>1 Usr RstChr	39	34	DT	0 = DT 1=User Curve 1 2=User Curve 2 3=User Curve 3 4=User Curve 4
This setting determines the type of Reset characteristic used for the user defined curves.				
IN2>2 Function	39	36	Disabled	0=Disabled 1=DT 2=IEC S Inverse 3=IEC V Inverse 4=IEC E Inverse 5=UK LT Inverse 6=RI 7=IEEE M Inverse 8=IEEE V Inverse 9=IEEE E Inverse 10=US Inverse 11=US ST Inverse 12=IDG 13=User curve 1 14=User curve 2 15=User curve 3 16=User curve 4
This setting determines the tripping characteristic for the second stage EF2 element.				
IN2>2 Direction	39	37	Non-Directional	0 = Non-Directional, 1 = Directional Fwd, 2 = Directional Rev
This setting determines the direction of measurement for the second stage EF2 element.				
IN2>2 Current	39	3A	0.2	0.08*In to 4*In step 0.01In
This setting sets the pick-up threshold for the second stage EF2 element.				
IN2>2 IDG Is	39	3B	1.5	1 to 4 step 0.1
This setting is set as a multiple of the Earth Fault overcurent setting IN> for the IDG curve. It determines the actual current threshold at which the element starts.				
IN2>2 Time Delay	39	3D	1	From 0s to 200s step 0.01s
This setting sets the DT time delay for the second stage EF2 element.				
IN2>2 TMS	39	3E	1	0.025 to 1.2 step 0.005

Menu Text	Col	Row	Default Setting	Available Options
Description				
This is the Time Multiplier Setting to adjust the operate time of IEC IDMT curves.				
IN2>2 Time Dial	39	3F	1	0.01 to 100 step 0.01
This is the Time Multiplier Setting to adjust the operate time of IEEE/US IDMT curves.				
IN2>2 k (RI)	39	40	1	From 0.1 to 10 step 0.05
This setting defines the TMS constant to adjust the operate time of the RI curve.				
IN2>2 IDG Time	39	41	1.2	From 1s to 2s step 0.01s
This setting sets the minimum operate time at high levels of fault current for IDG curves.				
IN2>2 DT Adder	39	42	0	From 0s to 100s step 0.01s
This setting adds an additional fixed time delay to the IDMT Operate characteristic.				
IN2>2 Reset Char	39	43	DT	0 = DT or 1 = Inverse
This setting determines the type of Reset characteristic used for the IEEE/US curves.				
IN2>2 tRESET	39	44	0	From 0s to 100s step 0.01s
This setting determines the Reset time for the Definite Time Reset characteristic				
IN2>2 Usr RstChr	39	45	DT	0 = DT 1=User Curve 1 2=User Curve 2 3=User Curve 3 4=User Curve 4
This setting determines the type of Reset characteristic used for the user defined curves.				
IN2>3 Status	39	46	Disabled	0 = Disabled, 1 = Enabled
This setting enables or disables the third stage EF2 element. There is no choice of curves because this stage is DT only.				
IN2>3 Direction	39	47	Non-Directional	0 = Non-Directional, 1 = Directional Fwd, 2 = Directional Rev
This setting determines the direction of measurement for the third stage EF2 element.				
IN2>3 Current	39	4A	0.2	0.08*In to 32*In step 0.01In
This setting sets the pick-up threshold for the third stage EF2 element.				
IN2>3 Time Delay	39	4B	1	From 0s to 200s step 0.01s
This setting sets the DT time delay for the third stage EF2 element.				
IN2>4 Status	39	4D	Disabled	0 = Disabled, 1 = Enabled
This setting enables or disables the fourth stage EF2 element. There is no choice of curves because this stage is DT only.				
IN2>4 Direction	39	4E	Non-Directional	0 = Non-Directional, 1 = Directional Fwd, 2 = Directional Rev
This setting determines the direction of measurement for the fourth stage EF2 element.				
IN2>4 Current	39	51	0.2	0.08*In to 32*In step 0.01In
This setting sets the pick-up threshold for the fourth stage EF2 element.				
IN2>4 Time Delay	39	52	1	From 0s to 200s step 0.01s
This setting sets the DT time delay for the fourth stage EF2 element.				
IN2> Blocking	39	54	0x00F	Bit 0=VTS Blocks IN>1 Bit 1=VTS Blocks IN>2 Bit 2=VTS Blocks IN>3 Bit 3=VTS Blocks IN>4 Bit 4=AR Blocks IN>3 Bit 5=AR Blocks IN>4 Bit 6=2H Blocks IN>1 Bit 7=2H Blocks IN>2 Bit 8=2H Blocks IN>3 Bit 9=2H Blocks IN>4

Menu Text	Col	Row	Default Setting	Available Options
Description				
This setting cell contains a binary string (data type G63), where you can define which blocking signals block which stage. The available settings depend on the model chosen. This description is for models with Autoreclose.				
IN2> Blocking	39	54	0x00F	Bit 0=VTS Blocks IN>1 Bit 1=VTS Blocks IN>2 Bit 2=VTS Blocks IN>3 Bit 3=VTS Blocks IN>4 Bit 4=Not Used Bit 5=Not Used Bit 6=2H Blocks IN>1 Bit 7=2H Blocks IN>2 Bit 8=2H Blocks IN>3 Bit 9=2H Blocks IN>4
This setting cell contains a binary string (data type G63A), where you can define which blocking signals block which stage. The available settings depend on the model chosen. This description is for models without Autoreclose.				
IN2> POL	39	55		
The settings under this sub-heading relate to the polarisation for directional control for EF2 derived				
IN2> Char Angle	39	56	-45	-95 to 95 step 1
This setting defines the characteristic angle used for the directional decision.				
IN2> Pol	39	57	Zero Sequence	0=Zero Sequence 1=Neg Sequence
This setting determines whether the directional function uses zero sequence or negative sequence voltage polarisation.				
IN2> VNpol Set	39	59	5 20	0.5V to 80V step 0.5V
This setting sets the minimum zero sequence voltage polarising quantity required for a directional decision. Derived				
IN2> VNpol Set	39	59	5 20	0.5V to 80V step 0.5V
This setting sets the minimum zero sequence voltage polarising quantity required for a directional decision. Measured				
IN2> V2pol Set	39	5A	5	0.5V to 80V step 0.5V
This setting sets the minimum zero sequence voltage polarising quantity required for a directional decision. Derived				
IN2> I2pol Set	39	5B	0.08	0.08*In to 1*In step 0.01In
This setting sets the minimum negative sequence current polarising quantity for directional decision.				

8.8 APPLICATION NOTES

8.8.1 SETTING GUIDELINES (DIRECTIONAL ELEMENT)

With directional earth faults, the residual current under fault conditions lies at an angle lagging the polarizing voltage. Hence, negative RCA settings are required for DEF applications. This is set in the cell **I>Char Angle** in the relevant earth fault menu.

We recommend the following RCA settings:

- Resistance earthed systems: 0°
- Distribution systems (solidly earthed): -45°
- Transmission systems (solidly earthed): -60°

8.8.2 PETERSON COIL EARTHED SYSTEMS

Power systems are usually earthed to limit transient overvoltages during arcing faults and also to assist with detection and clearance of earth faults. Impedance earthing has the advantage of limiting damage incurred by plant during earth fault conditions and also limits the risk of explosive failure of switchgear, which is a danger to personnel. In addition, it limits touch and step potentials at a substation or in the vicinity of an earth fault.

If a high impedance device is used for earthing the system, the earth fault current will be reduced but the steady state and transient overvoltages on the sound phases can be very high. Consequently, high impedance earthing is generally only used in distribution voltage networks, where it is not expensive to provide the necessary insulation against such overvoltages.

One way of providing high impedance earthing is where the inductive earthing reactance is made equal to the total system capacitive reactance to earth at system frequency. This practice is known as Petersen Coil Earthing, or Resonant Coil Earthing. With a correctly tuned system, the steady state earth fault current is zero, so that arcing earth faults become self-extinguishing. Such a system can be run with one phase earthed for a long period until the cause of the fault is identified and rectified.

The figure below shows a source earthed through a Petersen Coil, with an earth fault applied on the A Phase. Under this situation, the A phase shunt capacitance becomes short-circuited by the fault. Consequently, the calculations show that if the reactance of the earthing coil is set correctly, the resulting steady state earth fault current is zero.

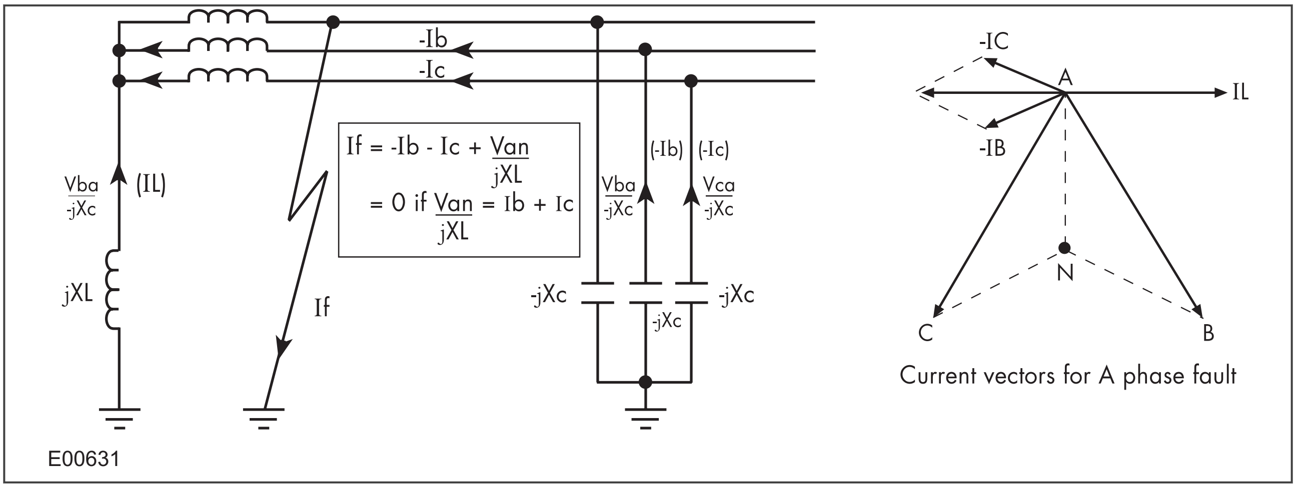


Figure 34: Current distribution in Petersen Coil earthed system

The figure below shows a three-feeder radial distribution system with a source that is earthed via a Petersen Coil, where a phase-to-earth fault is present on the C-phase.

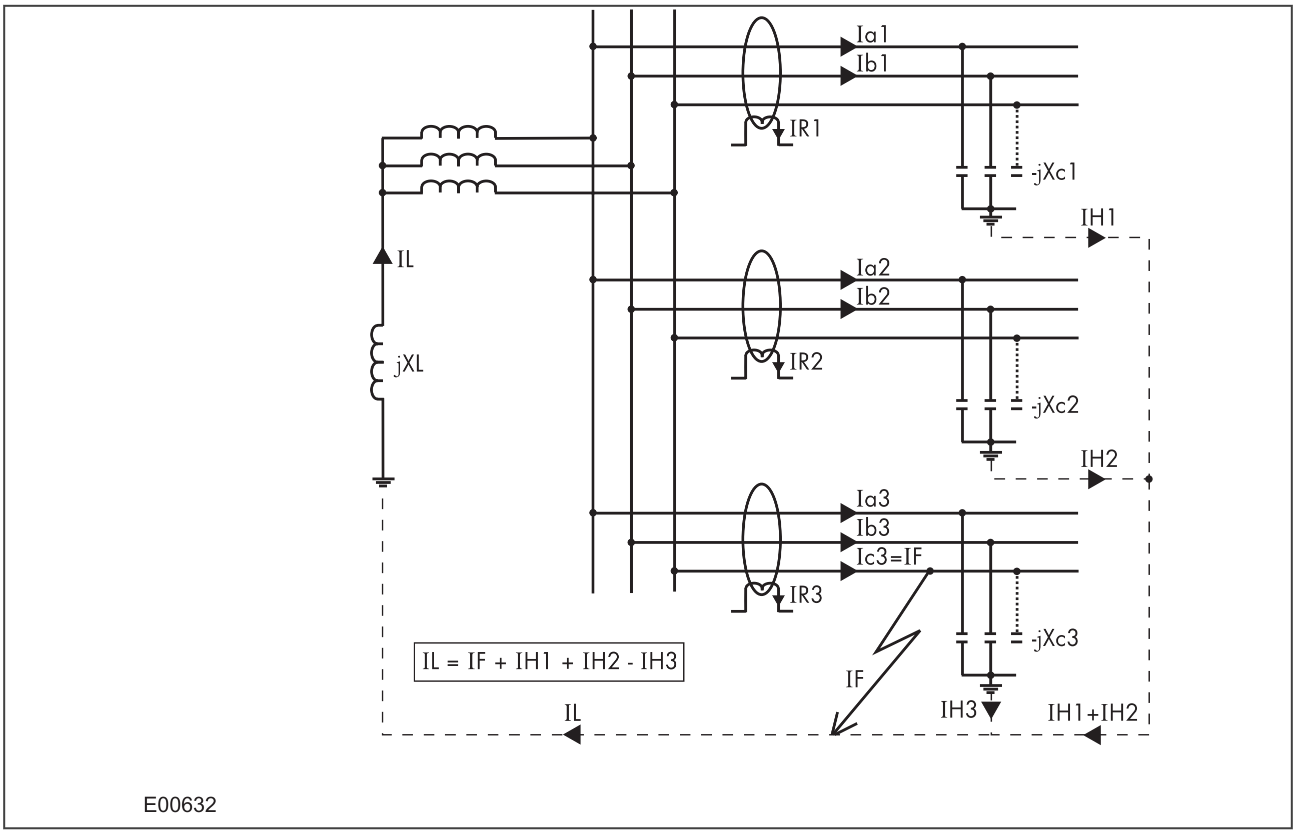


Figure 35: Distribution of currents during a C phase to earth fault

The associated vector diagrams shown below assume that it is fully compensated (i.e. coil reactance fully tuned to system capacitance), and that the resistance in the earthing coil and in the feeder cables is negligible.

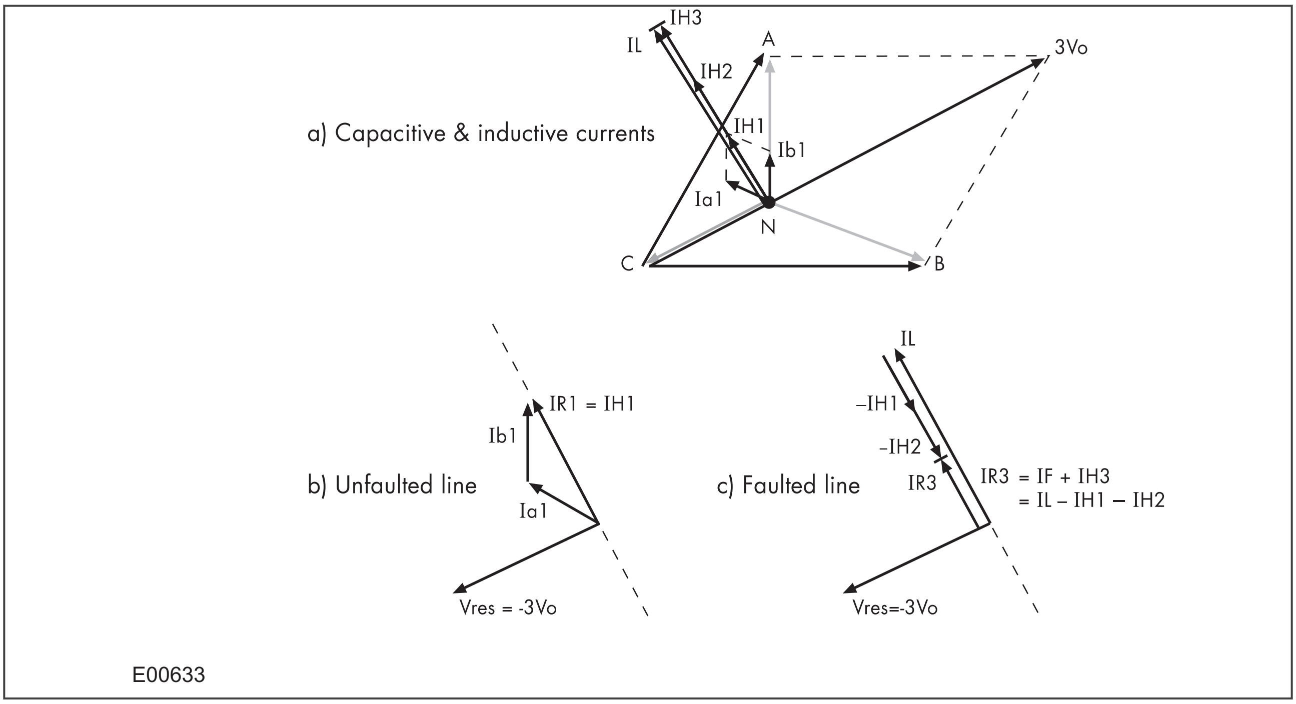


Figure 36: Theoretical case - no resistance present in XL or XC

In figure (a), the C phase to earth fault causes the voltages on the healthy phases to rise by a factor of √3. The A phase charging currents (Ia1, Ia2 and Ia3), then lead the resultant A phase voltage by 90°; likewise for the B phase charging currents with respect to the resultant Vb.

The imbalance detected by a core balanced current transformer on the healthy feeders is a simple vector addition of Ia1 and Ib1, giving a residual current which lies at exactly 90° lagging the residual voltage (figure (b)). As the healthy phase voltages have risen by a factor of √3, the charging currents on these phases are also √3 times larger than their steady state values. Therefore the magnitude of residual current IR1 is equal to 3 times the steady state per phase charging current.

The actual residual voltage used as a reference signal for directional earth fault IEDs is phase shifted by 180° and is therefore shown as –3Vo in the vector diagrams. This phase shift is automatically introduced within the IEDs.

On the faulted feeder, the residual current is the addition of the charging current on the healthy phases (IH3) plus the fault current (IF). The net imbalance is therefore equal to IL-IH1-IH2, as shown below.

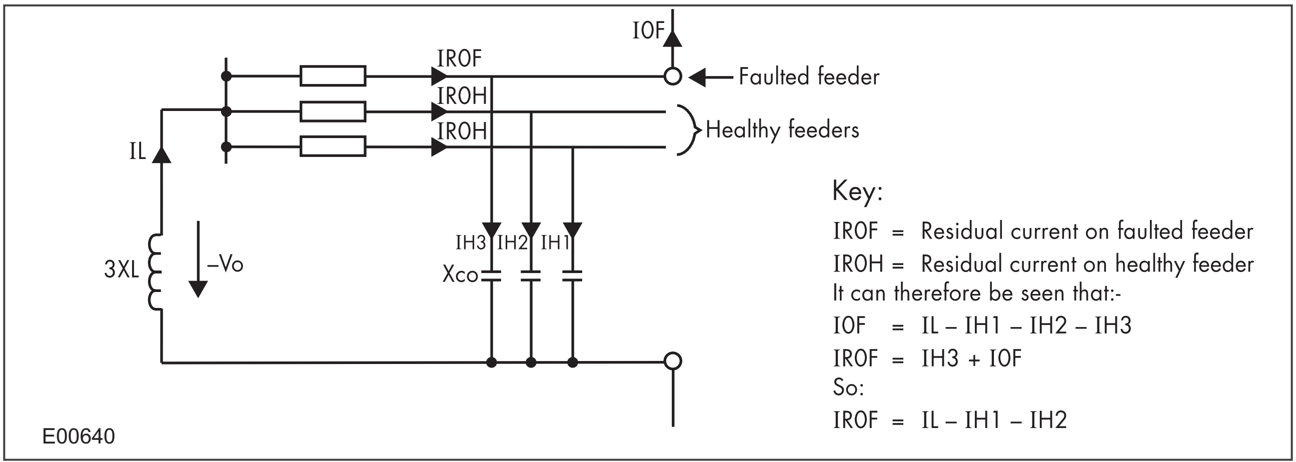


Figure 37: Zero sequence network showing residual currents

When comparing the residual currents occurring on the healthy and faulted feeders, using the above analysis, it can be seen that the currents would be similar in both magnitude and phase; hence it would not be possible to apply an IED, which could provide discrimination.

However, the scenario of negligible resistance being present in the coil or feeder cables is purely theoretical. Therefore further consideration needs to be given to a practical application in which the resistive component is no longer ignored. This situation may be more readily explained by considering the zero sequence network for this fault condition.

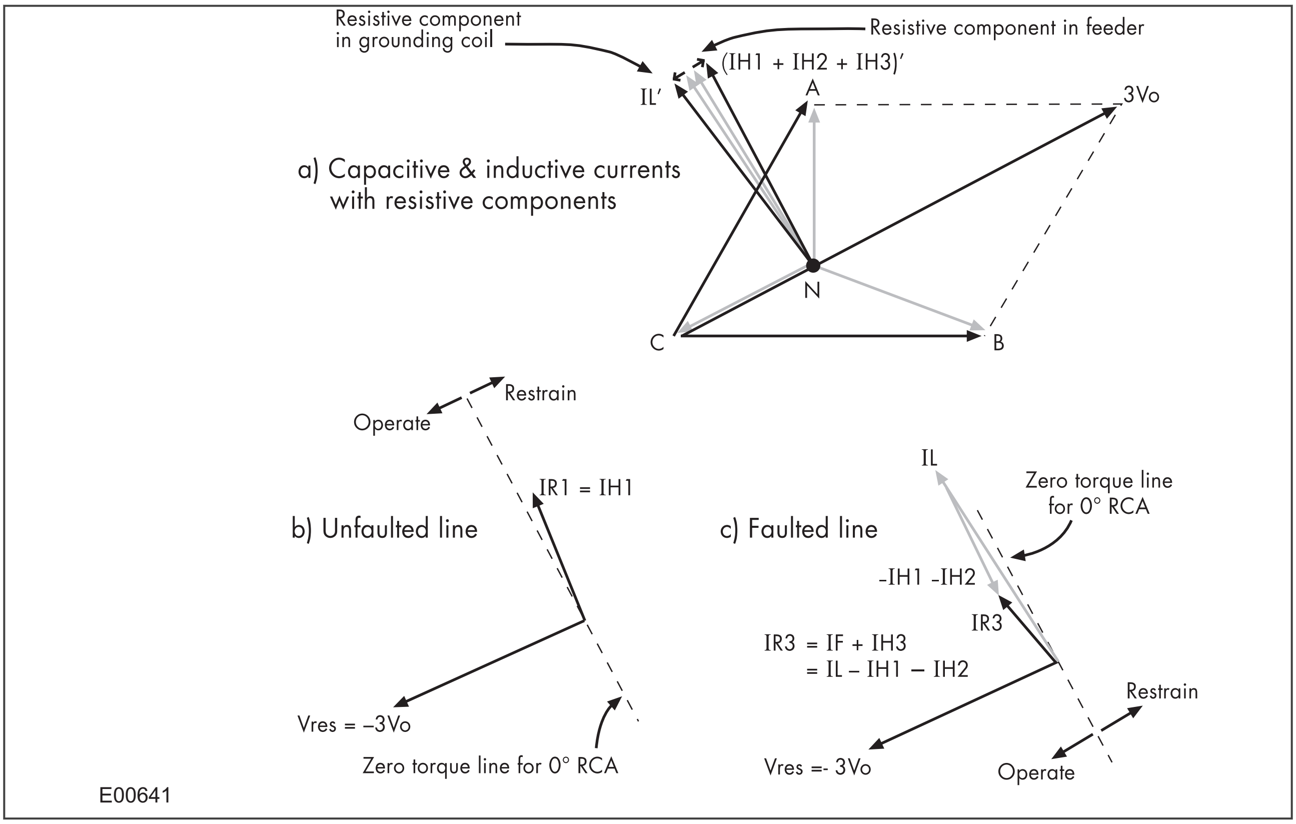


Figure 38: Practical case - resistance present in XL and Xc

Due to the presence of resistance in the feeders, the healthy phase charging currents are now leading their respective phase voltages by less than 90°. In a similar manner, the resistance present in the earthing coil has the effect of shifting the current IL to an angle less than 90° lagging.

The residual current now appears at an angle in excess of 90° from the polarising voltage for the healthy feeder and less than 90° on the faulted feeder. Therefore, a directional IED having a characteristic angle setting of 0° (with respect to the polarising signal of -3Vo) could be applied to provide discrimination. The healthy feeder residual current would appear within the restrain section of the characteristic but the residual current on the faulted feeder would lie within the operate region.

In practical systems, it may be found that a value of resistance is purposely inserted in parallel with the earthing coil. This serves two purposes; firstly to increase the earth fault current to a more practically detectable level and secondly to increase the angular difference between the residual signals in order to facilitate discriminating protection.

8.8.3 SETTING GUIDELINES (COMPENSATED NETWORKS)

The directional setting should be such that the forward direction is looking down into the protected feeder (away from the busbar), with a 0° RCA setting.

For a fully compensated system, the residual current detected by the relay on the faulted feeder is equal to the coil current minus the sum of the charging currents flowing from the rest of the system. Further, the addition of the two healthy phase charging currents on each feeder gives a total charging current which has a magnitude of three times the steady state per phase value. Therefore, for a fully compensated system, the detected unbalanced current is equal to three times the per phase charging current of the faulted circuit. A typical setting may therefore be in the order of 30% of this value, i.e. equal to the per phase charging current of the faulted circuit. In practise, the exact settings may well be determined on site, where system faults can be applied and suitable settings can be adopted based on practically obtained results.

In most situations, the system will not be fully compensated and consequently a small level of steady state fault current will be allowed to flow. The residual current seen by the IED on the faulted feeder may therefore be a larger value, which further emphasises the fact that the IED settings should be based upon practical current levels, wherever possible.

The above also holds true for the RCA setting. As has been shown, a nominal RCA setting of 0º is required. However, fine-tuning of this setting on-site may be necessary in order to obtain the optimum setting in accordance with the levels of coil and feeder resistances present. The loading and performance of the CT will also have an effect in this regard. The effect of CT magnetising current will be to create phase lead of current. Whilst this would assist with operation of faulted feeder IEDs, it would reduce the stability margin of healthy feeder IEDs. A compromise can therefore be reached through fine adjustment of the RCA. This is adjustable in 1° steps.

9 SENSITIVE EARTH FAULT PROTECTION

With some earth faults, the fault current flowing to earth is limited by either intentional resistance (as is the case with some HV systems) or unintentional resistance (e.g. in very dry conditions and where the substrate is high resistance, such as sand or rock).

To provide protection in such cases, it is necessary to provide an earth fault protection system with a setting that is considerably lower than for normal line protection. Such sensitivity cannot be provided with conventional CTs, therefore SEF would normally be fed from a core balance current transformer (CBCT) mounted around the three phases of the feeder cable. Also a special measurement class SEF transformer should be used in the IED.

With SEF protection, settings as low as 10% can be used

9.1 SEF PROTECTION IMPLEMENTATION

Sensitive Earth Fault protection is implemented in the SEF PROTECTION column of the relevant settings group.

The product provides four stages of SEF protection with independent time delay characteristics.

Stages 1, 2 provide a choice of operate and reset characteristics, where you can select between:

- A range of standard IDMT (Inverse Definite Minimum Time) curves
- A range of User-defined curves
- DT (Definite Time)

This is achieved using the cells

- **ISEF>**(n) **Function** for the overcurrent operate characteristic
- **ISEF>**(n) **Reset Char** for the overcurrent reset characteristic
- **ISEF>**(n) **Usr RstChar** for the reset characteristic for user -defined curves

where (n) is the number of the stage.

Stages 1 and 2 also provide a Timer Hold facility (on page 88). This is configured using the cells **ISEF>**(n) **tReset**.

Stages 3 and 4 can have definite time characteristics only.

9.2 NON-DIRECTIONAL SEF LOGIC

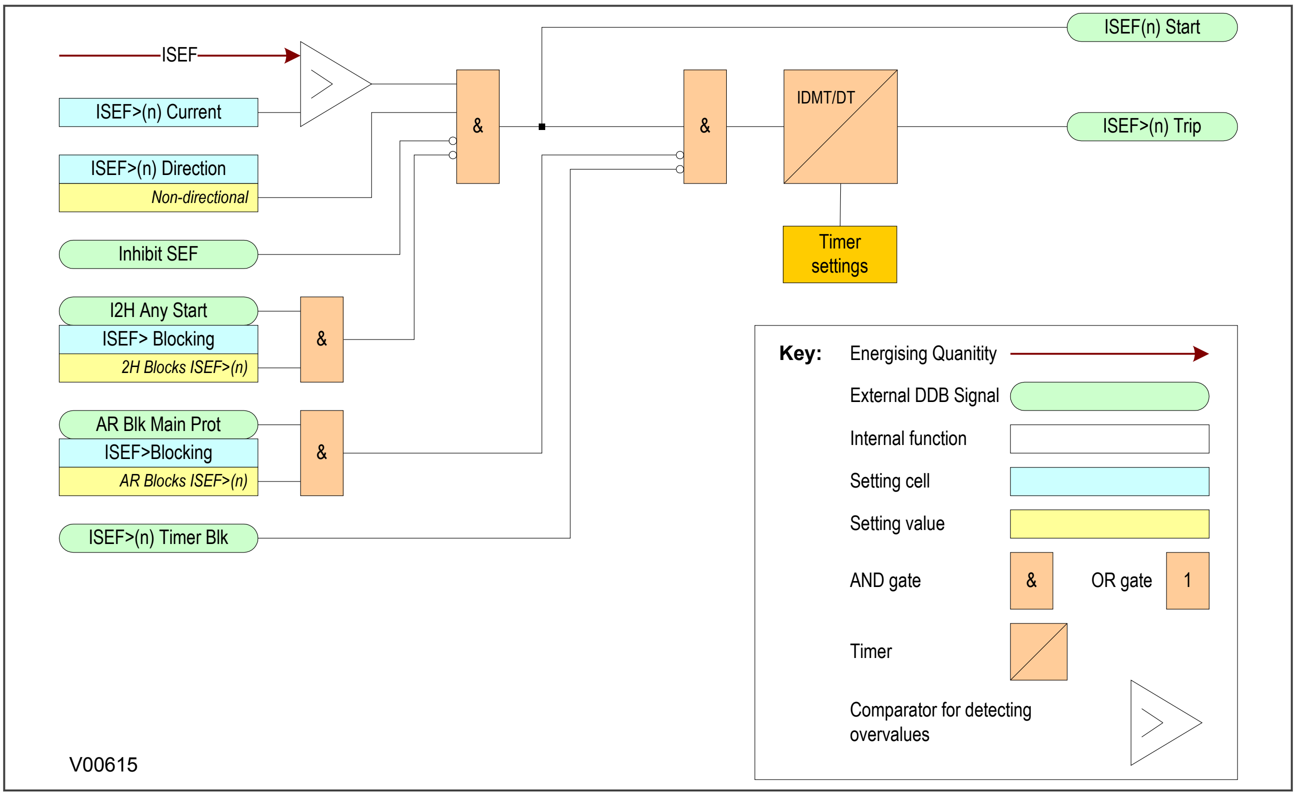


Figure 39: Non-directional SEF logic

The SEF current is compared with a set threshold (**ISEF>(n) Current**) for each stage. If it exceeds this threshold, a Start signal is triggered, providing it is not blocked. This can be blocked by the second harmonic blocking function, or an Inhibit SEF DDB signal.

The autoreclose logic can be set to block the SEF trip after a prescribed number of shots (set in AUTORECLOSE column). This is achieved using the **AR Blk Main Prot** setting. this can also be blocked by the relevant timer block signal **ISEF>(n)TimerBlk DDB** signal.

SEF protection can follow the same IDMT characteristics as described in the Overcurrent Protection Principles section. Please refer to this section for details of IDMT characteristics.

9.3 EPATR B CURVE

The EPATR B curve is commonly used for time-delayed Sensitive Earth Fault protection in certain markets. This curve is only available in the Sensitive Earth Fault protection stages 1 and 2. It is based on primary current settings, employing a SEF CT ratio of 100:1 A.

The EPATR_B curve has 3 separate segments defined in terms of the primary current. It is defined as follows:

Segment	Primary Current Range Based on 100A:1A CT Ratio	Current/Time Characteristic
1	ISEF = 0.5A to 6.0A	t = 432 x TMS/ISEF 0.655 secs
2	ISEF = 6.0A to 200A	t = 800 x TMS/ISEF secs
3	ISEF above 200A	t = 4 x TMS secs

where TMS (time multiplier setting) is 0.025 - 1.2 in steps of 0.025.

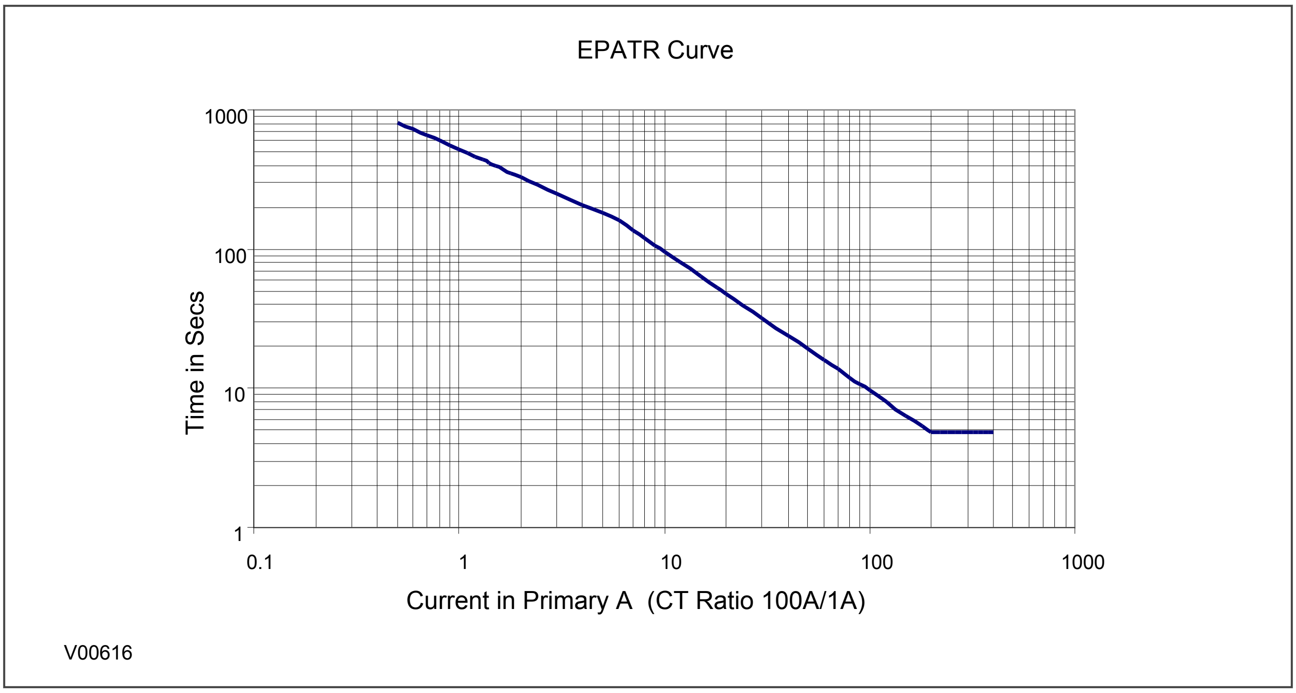


Figure 40: EPATR B characteristic shown for TMS = 1.0

9.4 DIRECTIONAL ELEMENT

Where SEF current may flow in either direction through an IED location, directional control should be used.

A directional element is available for all of the SEF overcurrent stages. This is found in the **ISEF>**(n) **Direction** cell for the relevant stage. It can be set to non-directional, directional forward, or directional reverse.

Directionality is achieved by using different techniques depending on the application and design philosophy. With reference to the figure below, you can see that directional SEF can be used for:

- Solidly earthed systems
- Unearthed systems (insulated systems)
- Compensated systems
- Resistance earthed systems

The diagram shows which type of directional control can be used for which systems

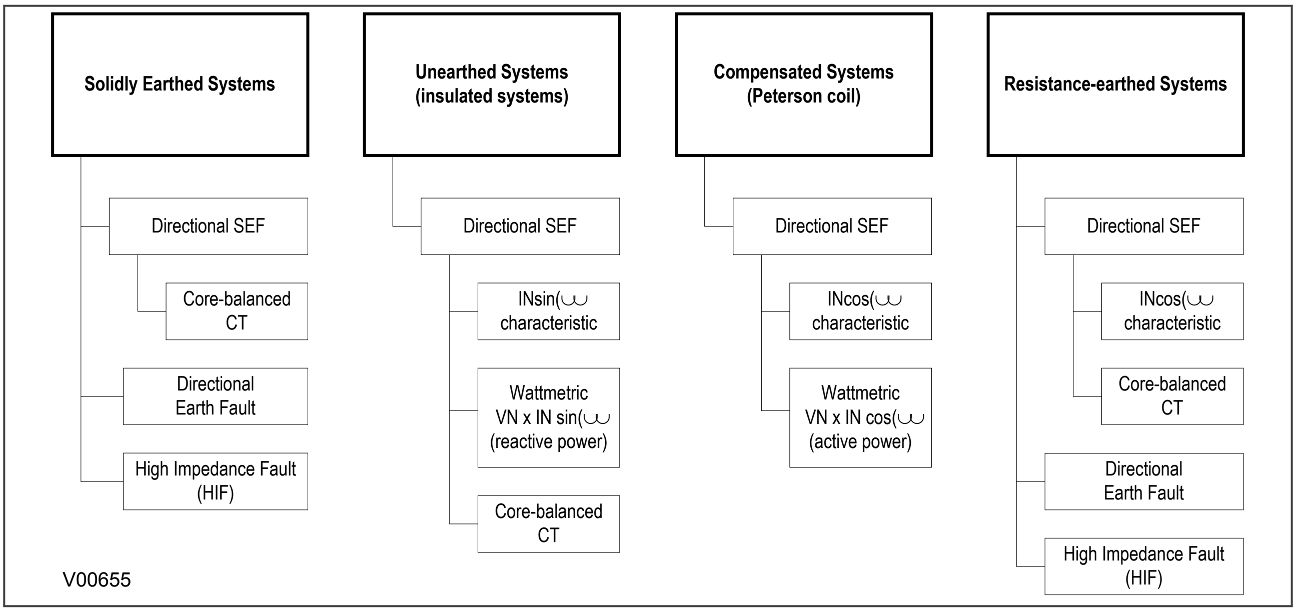


Figure 41: Types of directional control

The device supports standard core-balanced directional control as well as Isin(phi), Icos(phi) and Wattmetric characteristics.

9.4.1 WATTMETRIC CHARACTERISTIC

Analysis has shown that a small angular difference exists between the spill current on healthy and faulted feeders for earth faults on compensated networks. This angular difference gives rise to active components of current which are in anti-phase to one another.

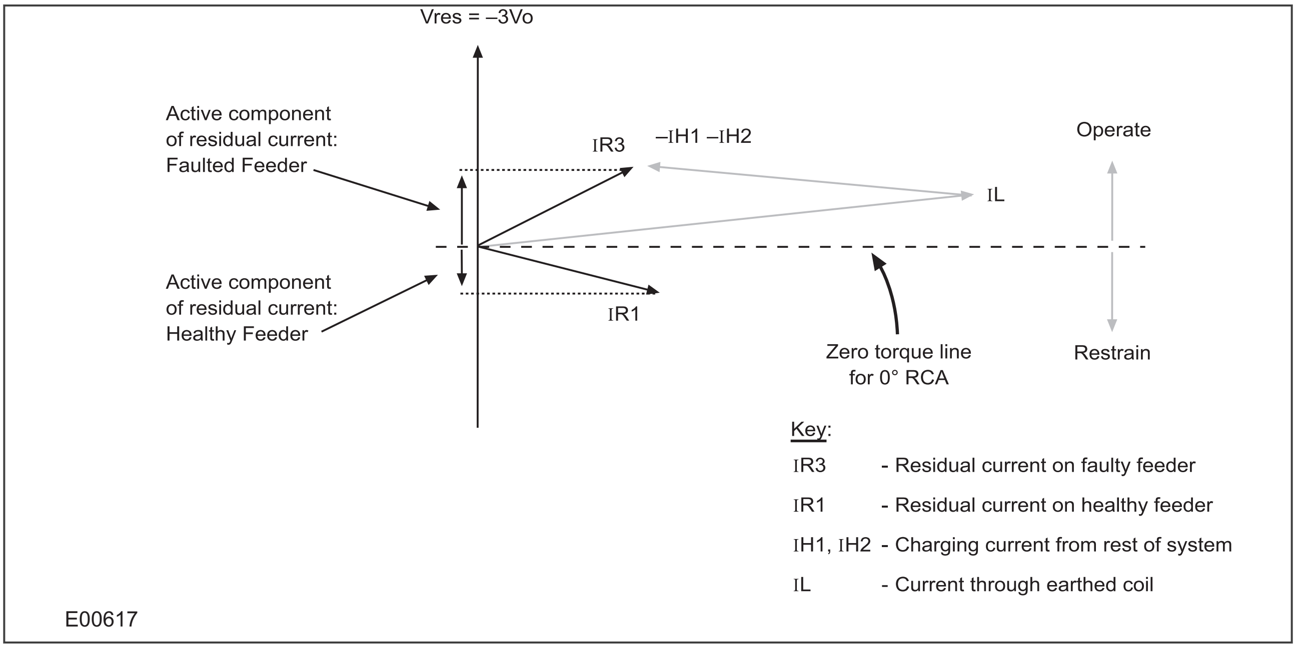


Figure 42: Resistive components of spill current

Consequently, the active components of zero sequence power will also lie in similar planes, meaning an IED capable of detecting active power can make discriminatory decisions. If the Wattmetric component of zero sequence power is detected in the forward direction, then this would indicate fault on that feeder. If power is detected in the reverse direction, then the fault must be present on an adjacent feeder or at the source.

For operation of the directional earth fault element, all three of the settable thresholds must be exceeded; namely the current **ISEF>**, the voltage **ISEF>VNpol Set** and the power **PN> Setting**.

The power setting is called **PN>** and is therefore calculated using residual rather than zero sequence quantities. Residual quantities are three times their respective zero sequence values and so the complete formula for operation is as shown below:

The **PN>** setting corresponds to:

$$V_{res} I_{res} cos(\phi - \phi_c) = 9 V_o I_o cos(\phi - \phi_c)$$

where:

- ϕ = Angle between the Polarising Voltage (**-Vres**) and the Residual Current
- ϕ_C = Relay Characteristic Angle (RCA) Setting (**ISEF> Char. Angle**)
- V_{res} = Residual Voltage
- I_{res} = Residual Current
- V_o = Zero Sequence Voltage
- I_o = Zero Sequence Current

The action of setting the **PN>** threshold to zero would effectively disable the wattmetric function and the device would operate as a basic, sensitive directional earth fault element. However, if this is required, then the SEF option can be selected from the **SEF/REF Options** cell in the menu.

Note:
*The residual power setting, **PN>**, is scaled by the programmed Transformer ratios.*

A further point to note is that when a power threshold other than zero is selected, a slight alteration is made to the angular boundaries of the directional characteristic. Rather than being ±90° from the RCA, they are made slightly narrower at ±85°.

The directional check criteria is as follows:

Directional forward: -85° < (angle(IN) - angle(VN + 180°) - RCA) < 85°

Directional reverse: -85° > (angle(IN) - angle(VN + 180°) - RCA) > 85°

9.4.2 ICOS PHI / ISIN PHI CHARACTERISTIC

In some applications, the residual current on the healthy feeder can lie just inside the operating boundary following a fault condition. The residual current for the faulted feeder lies close to the operating boundary.

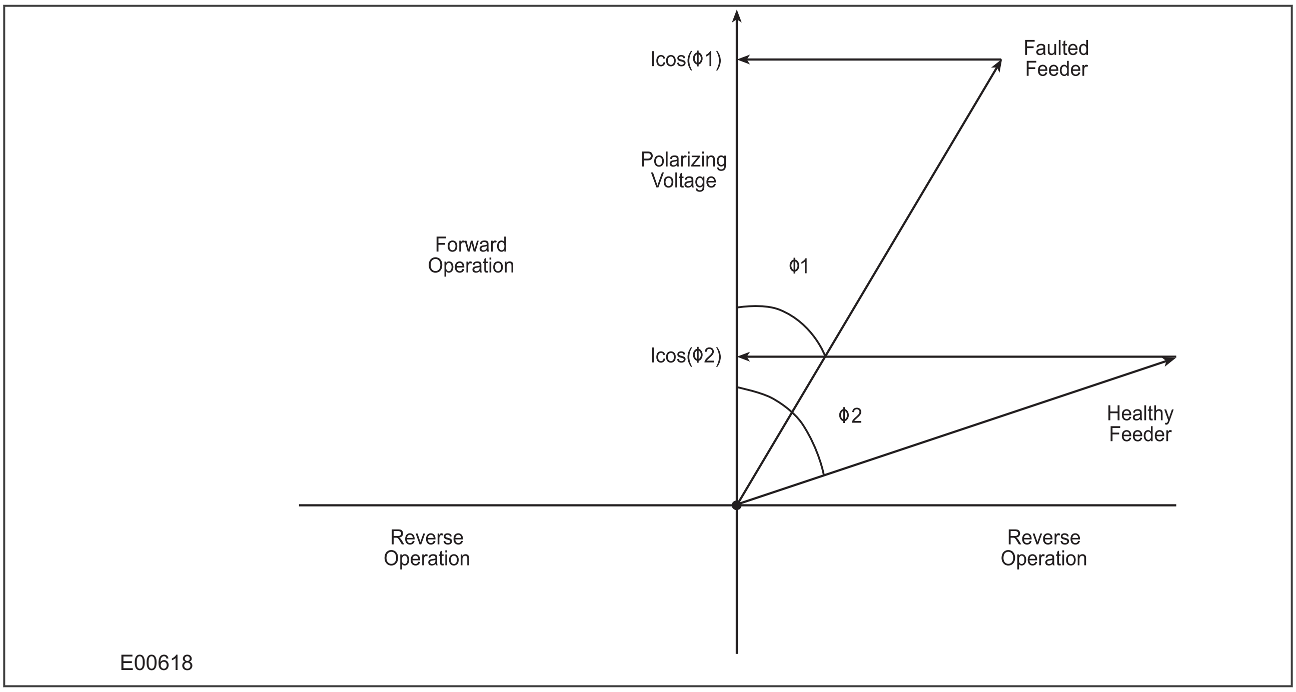


Figure 43: Operating characteristic for Icos

The diagram illustrates the method of discrimination when the real (cosϕ) component is considered. Faults close to the polarising voltage will have a higher magnitude than those close to the operating boundary. In the diagram, we assume that the current magnitude I is in both the faulted and non-faulted feeders.

- For the active component Icos, the criterion for operation is: Icosϕ > Isef
- For the reactive component Isin, the criterion for operation is: Isinϕ > Isef

Where Isef is the sensitive earth fault current setting for the stage in question

If any stage is set to non-directional, the element reverts back to normal operation based on current magnitude I with no directional decision. In this case, correct discrimination is achieved by means of an Icos characteristic as the faulted feeder will have a large active component of residual current, whilst the healthy feeder will have a small value.

For insulated earth applications, it is common to use the Isin characteristic.

All of the relevant settings can be found under the SEF column.

9.4.3 DIRECTIONAL SEF LOGIC

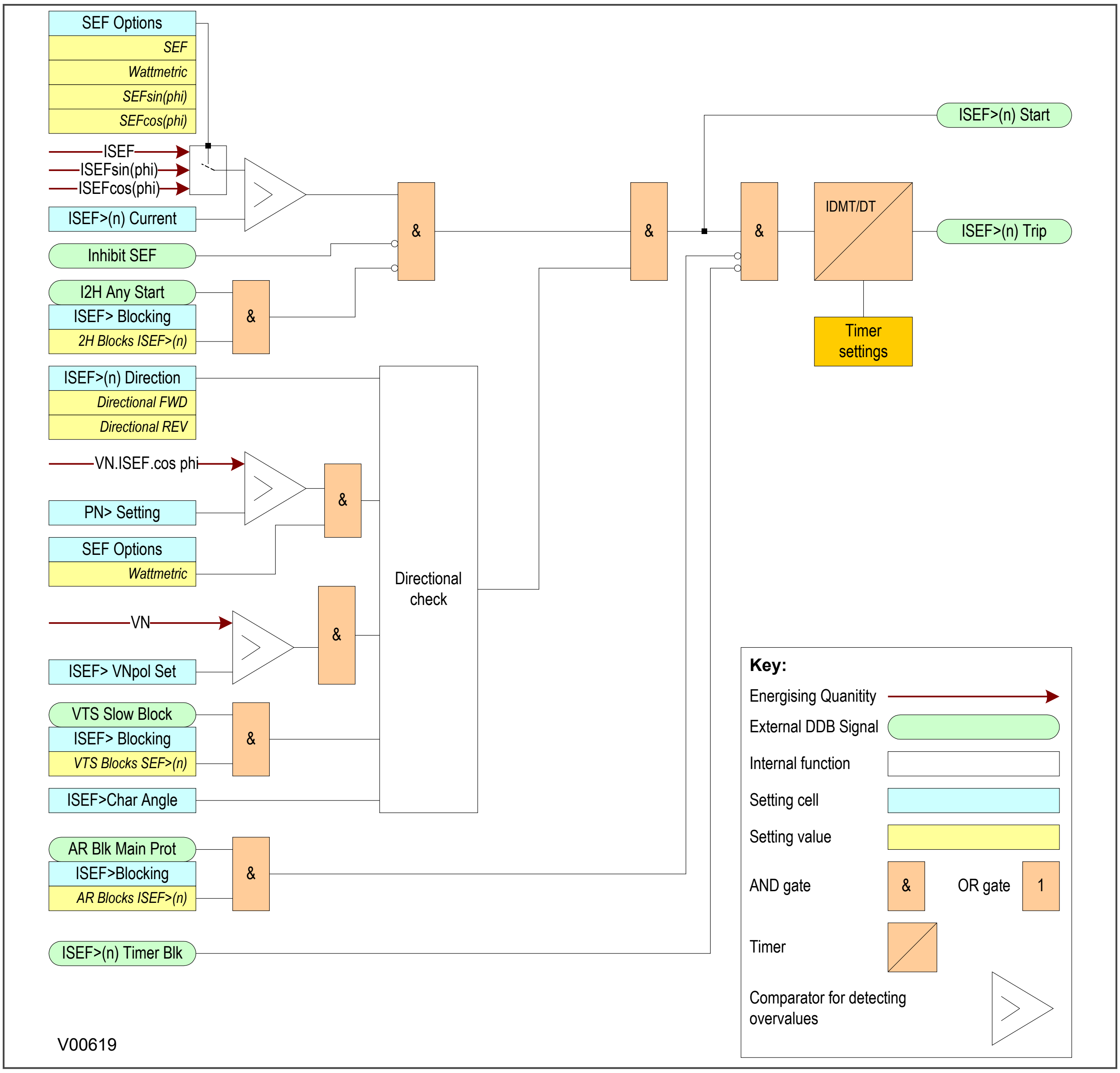


Figure 44: Directional SEF with VN polarisation (single stage)

The sensitive earth fault protection can be set IN/OUT of service using the appropriate DDB inhibit signal, which can be operated from an opto-input or control command. VT Supervision (VTS) selectively blocks the directional protection or causes it to revert to non-directional operation. When selected to block the directional protection, VTS blocking is applied to the directional checking which effectively blocks the start outputs as well.

The directional check criteria are given below for the standard directional sensitive earth fault element:

- Directional forward: -90° < (angle(IN) - angle(VN + 180°) - RCA) < 90°
- Directional reverse: -90° > (angle(IN) - angle(VN + 180°) - RCA) > 90°

Three possibilities exist for the type of protection element that you can use for sensitive earth fault detection:

- A suitably sensitive directional earth fault IED having a characteristic angle setting (RCA) of zero degrees, with the possibility of fine adjustment about this threshold.
- A sensitive directional zero sequence wattmetric IED having a characteristic angle setting (RCA) of zero degrees, with the possibility of fine adjustment about this threshold.
- A sensitive directional earth IED having Icosϕ and Isinϕ characteristics.

All stages of the sensitive earth fault element can be set down to 0.5% of rated current and would therefore fulfil the requirements of the first method listed above. These could therefore be applied successfully if desired. However, many utilities (particularly in central Europe) have standardised on the wattmetric method for sensitive earth fault detection.

9.5 SEF DDB SIGNALS

Ordinal	English Text	Source	Type	Response Function
Description				
216	ISEF>1 Timer Blk	Programmable Scheme Logic	PSL Output	No response
This DDB signal blocks the first stage Sensitive Earth Fault time delay				
217	ISEF>2 Timer Blk	Programmable Scheme Logic	PSL Output	No response
This DDB signal blocks the second stage Sensitive Earth Fault time delay				
218	ISEF>3 Timer Blk	Programmable Scheme Logic	PSL Output	No response
This DDB signal blocks the third stage Sensitive Earth Fault time delay				
219	ISEF>4 Timer Blk	Programmable Scheme Logic	PSL Output	No response
This DDB signal blocks the fourth stage Sensitive Earth Fault time delay				
216	ISEF>1 Timer Blk	Programmable Scheme Logic	PSL Output	No response
This DDB signal blocks the first stage Sensitive Earth Fault time delay				
217	ISEF>2 Timer Blk	Programmable Scheme Logic	PSL Output	No response
This DDB signal blocks the second stage Sensitive Earth Fault time delay				
218	ISEF>3 Timer Blk	Programmable Scheme Logic	PSL Output	No response
This DDB signal blocks the third stage Sensitive Earth Fault time delay				
219	ISEF>4 Timer Blk	Programmable Scheme Logic	PSL Output	No response
This DDB signal blocks the fourth stage Sensitive Earth Fault time delay				
269	ISEF>1 Trip	Software	PSL Input	Protection event
This DDB signal is the first stage Sensitive Earth Fault trip signal				
270	ISEF>2 Trip	Software	PSL Input	Protection event
This DDB signal is the second stage Sensitive Earth Fault trip signal				
271	ISEF>3 Trip	Software	PSL Input	Protection event
This DDB signal is the third stage Sensitive Earth Fault trip signal				
272	ISEF>4 Trip	Software	PSL Input	Protection event
This DDB signal is the fourth stage Sensitive Earth Fault trip signal				
323	ISEF>1 Start	Software	PSL Input	Protection event
This DDB signal is the first stage Sensitive Earth Fault start signal				
324	ISEF>2 Start	Software	PSL Input	Protection event
This DDB signal is the second stage Sensitive Earth Fault start signal				
325	ISEF>3 Start	Software	PSL Input	Protection event
This DDB signal is the third stage Sensitive Earth Fault start signal				

Ordinal	English Text	Source	Type	Response Function
Description				
326	ISEF>4 Start	Software	PSL Input	Protection event
This DDB signal is the fourth stage Sensitive Earth Fault start signal				
351	VTS Slow Block	Software	PSL Input	No response
This DDB signal is a purposely delayed output from the VTS which can block other functions				
352	CTS Block	Software	PSL Input	No response
This DDB signal is an instantaneously blocking output from the CTS which can block other functions				
358	AR Blk Main Prot	Software	PSL Input	Protection event
This DDB signal, generated by the Autoreclose function, blocks the Main Protection elements (POC, EF1, EF2, NPSOC)				
442	Inhibit SEF	Programmable Scheme Logic	PSL Output	No response
This DDB signal inhibits Sensitive Earth Fault protection				
541	I2H Any Start	Software	PSL Input	Protection event
This DDB signal is the 2nd Harmonic start signal for any phase				
626	ISEF> Any Start	Fixed Scheme Logic	PSL Input	Protection event
This DDB signal is the any-phase start signal for SEF				

9.6 SEF SETTINGS

Menu Text	Col	Row	Default Setting	Available Options
Description				
GROUP 1 SEF PROTECTION	3A	00		
This column contains settings for Sensitive Earth Fault protection				
SEF Options	3A	01	SEF	0=SEF, 1=SEF cos(PHI), 2=SEF sin(PHI), 3=Wattmetric
This setting selects the type of sensitive earth fault protection function.				
ISEF>1 Function	3A	2A	DT	0=Disabled1=DT 2=IEC S Inverse 3=IEC V Inverse 4=IEC E Inverse 5=UK LT Inverse 6=IEEE M Inverse 7=IEEE V Inverse 8=IEEE E Inverse 9=US Inverse 10=US ST Inverse 11=IDG 12=EPATR B 13=User curve 1 14=User curve 2 15=User curve 3 16=User curve 4
This setting determines the tripping characteristic for the first stage SEF element.				
ISEF>1 Direction	3A	2B	Non-Directional	0 = Non-Directional, 1 = Directional Fwd, 2 = Directional Rev
This setting determines the direction of measurement for the first stage SEF element.				
ISEF>1 Current	3A	2E	0.05	0.001*In to 0.1*In step 0.00025In
This setting sets the pick-up threshold for the first stage SEF element.				
ISEF>1 IDG Is	3A	2F	1.5	1 to 4 step 0.1

Menu Text	Col	Row	Default Setting	Available Options
Description				
This setting is set as a multiple of ISEF> setting for the IDG curve (Scandinavian) and determines the actual IED current threshold at which the element starts.				
ISEF>1 Delay	3A	31	1	From 0s to 200s step 0.01s
This setting sets the DT time delay for the first stage SEF element.				
ISEF>1 TMS	3A	32	1	0.025 to 1.2 step 0.005
This is the Time Multiplier Setting to adjust the operate time of IEC IDMT curves.				
ISEF>1 Time Dial	3A	33	1	0.01 to 100 step 0.01
This is the Time Multiplier Setting to adjust the operate time of IEEE/US IDMT curves.				
ISEF>1 IDG Time	3A	34	1.2	From 1s to 2s step 0.01s
This setting sets the minimum operate time at high levels of fault current for IDG curves.				
ISEF>1 DT Adder	3A	35	0	From 0s to 100s step 0.01s
This setting adds an additional fixed time delay to the IDMT Operate characteristic.				
ISEF>1 Reset Chr	3A	36	DT	0 = DT or 1 = Inverse
This setting determines the type of Reset characteristic used for the IEEE/US curves.				
ISEF>1 tRESET	3A	37	0	From 0s to 100s step 0.01s
This setting determines the Reset time for the Definite Time Reset characteristic				
ISEF>1 Usr RstChr	3A	38	DT	0 = DT 1=User Curve 1 2=User Curve 2 3=User Curve 3 4=User Curve 4
This setting determines the type of Reset characteristic used for the user defined curves.				
ISEF>2 Function	3A	3A	Disabled	0=Disabled1=DT 2=IEC S Inverse 3=IEC V Inverse 4=IEC E Inverse 5=UK LT Inverse 6=IEEE M Inverse 7=IEEE V Inverse 8=IEEE E Inverse 9=US Inverse 10=US ST Inverse 11=IDG 12=EPATR B 13=User curve 1 14=User curve 2 15=User curve 3 16=User curve 4
This setting determines the tripping characteristic for the first stage SEF element.				
ISEF>2 Direction	3A	3B	Non-Directional	0 = Non-Directional, 1 = Directional Fwd, 2 = Directional Rev
This setting determines the direction of measurement for the first stage SEF element.				
ISEF>2 Current	3A	3E	0.05	0.005*In to 0.1*In step 0.00025In
This setting sets the pick-up threshold for the first stage SEF element.				
ISEF>2 IDG Is	3A	3F	1.5	1 to 4 step 0.1
This setting is set as a multiple of ISEF> setting for the IDG curve (Scandinavian) and determines the actual IED current threshold at which the element starts.				
ISEF>2 Delay	3A	41	1	From 0s to 200s step 0.01s
This setting sets the DT time delay for the first stage SEF element.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
ISEF>2 TMS	3A	42	1	0.025 to 1.2 step 0.005
This is the Time Multiplier Setting to adjust the operate time of IEC IDMT curves.				
ISEF>2 Time Dial	3A	43	1	0.01 to 100 step 0.01
This is the Time Multiplier Setting to adjust the operate time of IEEE/US IDMT curves.				
ISEF>2 IDG Time	3A	44	1.2	From 1s to 2s step 0.01s
This setting sets the minimum operate time at high levels of fault current for IDG curves.				
ISEF>2 DT Adder	3A	45	0	From 0s to 100s step 0.01s
This setting adds an additional fixed time delay to the IDMT Operate characteristic.				
ISEF>2 Reset Chr	3A	46	DT	0 = DT or 1 = Inverse
This setting determines the type of Reset characteristic used for the IEEE/US curves.				
ISEF>2 tRESET	3A	47	0	From 0s to 100s step 0.01s
This setting determines the Reset time for the Definite Time Reset characteristic				
ISEF>2 Usr RstChr	3A	48	DT	0 = DT 1=User Curve 1 2=User Curve 2 3=User Curve 3 4=User Curve 4
This setting determines the type of Reset characteristic used for the user defined curves.				
ISEF>3 Status	3A	49	Disabled	0 = Disabled, 1 = Enabled
This setting enables or disables the third stage SEF element. There is no choice of curves because this stage is DT only.				
ISEF>3 Direction	3A	4A	Non-Directional	0 = Non-Directional, 1 = Directional Fwd, 2 = Directional Rev
This setting determines the direction of measurement for the third stage SEF element.				
ISEF>3 Current	3A	4D	0.4	0.08*In to 32*In step 0.01In
This setting sets the pick-up threshold for the third stage SEF element.				
ISEF>3 Delay	3A	4E	0.5	From 0s to 200s step 0.01s
This setting sets the DT time delay for the third stage SEF element.				
ISEF>4 Status	3A	50	Disabled	0 = Disabled, 1 = Enabled
This setting enables or disables the fourth stage SEF element. There is no choice of curves because this stage is DT only.				
ISEF>4 Direction	3A	51	Non-Directional	0 = Non-Directional, 1 = Directional Fwd, 2 = Directional Rev
This setting determines the direction of measurement for the fourth stage SEF element.				
ISEF>4 Current	3A	54	0.6	0.08*In to 32*In step 0.01In
This setting sets the pick-up threshold for the fourth stage SEF element.				
ISEF>4 Delay	3A	55	0.25	From 0s to 200s step 0.01s
This setting sets the DT time delay for the fourth stage SEF element.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
ISEF> Blocking	3A	57	0x00F	Bit 0=VTS Blks ISEF>1, Bit 1=VTS Blks ISEF>2, Bit 2=VTS Blks ISEF>3, Bit 3=VTS Blks ISEF>4, Bit 4=AR Blks ISEF>3, Bit 5=AR Blks ISEF>4, Bit 6=2H Blocks ISEF>1, Bit 7=2H Blocks ISEF>2, Bit 8=2H Blocks ISEF>3, Bit 9=2H Blocks ISEF>4, Bit 10=Not Used Bit 11=Not Used
This setting cell contains a binary string (data type G64), where you can define which blocking signals block which stage. The available settings depend on the model chosen. This description is for models with Autoreclose.				
ISEF> Blocking	3A	57	0x00F	Bit 0=VTS Blks ISEF>1, Bit 1=VTS Blks ISEF>2, Bit 2=VTS Blks ISEF>3, Bit 3=VTS Blks ISEF>4, Bit 4=Not Used, Bit 5=Not Used, Bit 6=2H Blocks ISEF>1, Bit 7=2H Blocks ISEF>2, Bit 8=2H Blocks ISEF>3, Bit 9=2H Blocks ISEF>4, Bit 10=Not Used Bit 11=Not Used
This setting cell contains a binary string (data type G64A), where you can define which blocking signals block which stage. The available settings depend on the model chosen. This description is for models without Autoreclose.				
ISEF POL	3A	58		
ISEF> Char Angle	3A	59	90	From -95 to 95 step 1
This setting defines the characteristic angle used for the directional decision.				
ISEF> VNpol Set	3A	5B	5	0.5V to 80V step 0.5V
This setting sets the minimum zero sequence voltage polarising quantity required for a directional decision.				
ISEF> VNpol Set	3A	5B	5	0.5V to 80V step 0.5V
This setting sets the minimum zero sequence voltage polarising quantity required for a directional decision.				
WATTMETRIC SEF	3A	5D		
The settings under this sub-heading relate to Wattmetric directional control for SEF				
PN> Setting	3A	5E	9	0.0 to 20 step 0.05
This setting sets the threshold for the wattmetric component of zero sequence power.				
PN> Setting	3A	5E	9	0.0 to 20 step 0.05
This setting sets the threshold for the wattmetric component of zero sequence power.				

9.7 APPLICATION NOTES

9.7.1 INSULATED SYSTEMS

When insulated systems are used, it is not possible to detect faults using standard earth fault protection. It is possible to use a residual overvoltage device to achieve this, but even with this method full discrimination is not possible. Fully discriminative earth fault protection on this type of system can only be achieved by using a SEF (Sensitive Earth Fault) element. This type of protection detects the resultant imbalance in the system charging currents that occurs under earth fault conditions. A core balanced CT must be used for this application. This eliminates the possibility of spill current that may arise from slight mismatches between residually connected line CTs. It also enables a much lower CT ratio to be applied, thereby allowing the required protection sensitivity to be more easily achieved.

The following diagram shows an insulated system with a C-phase fault.

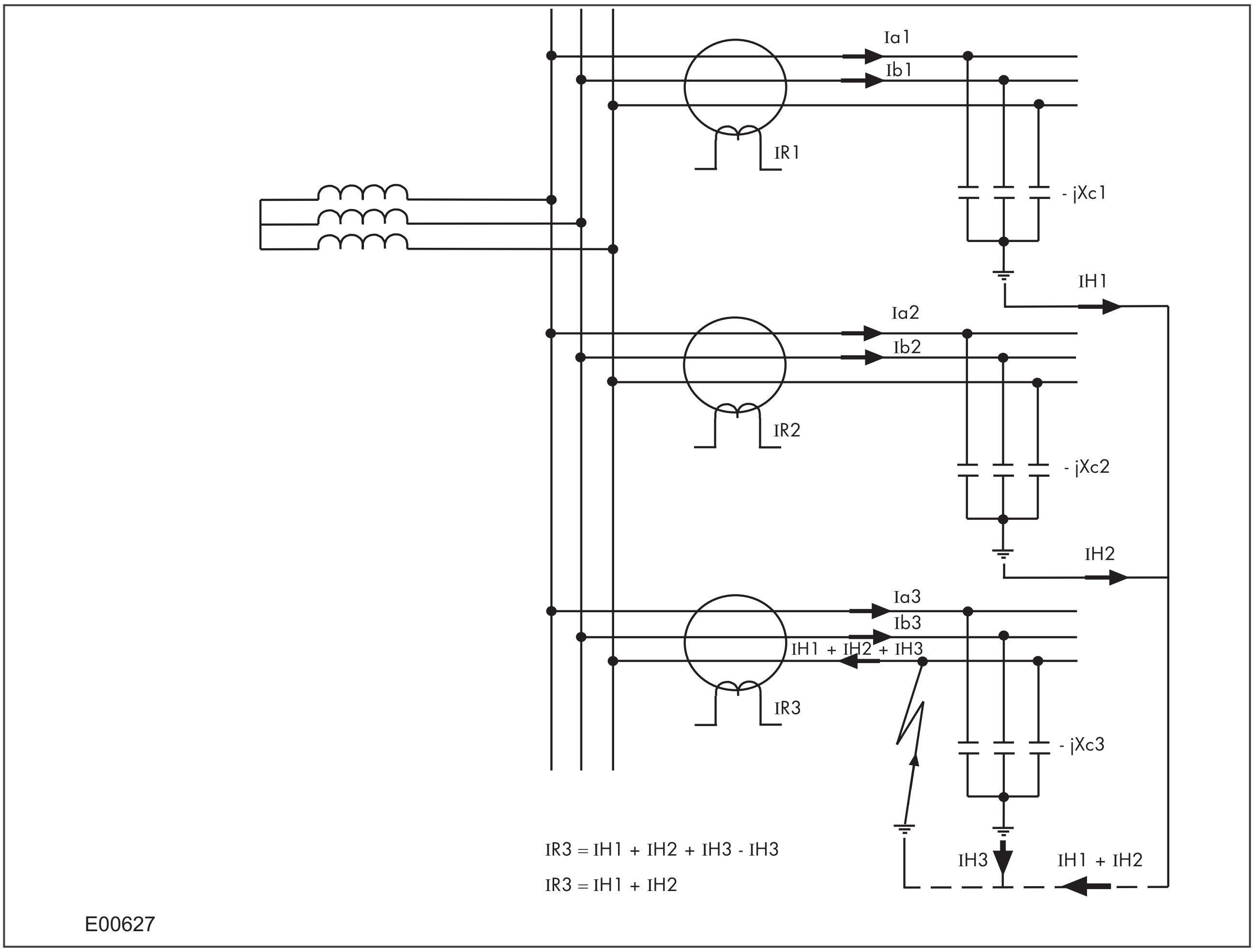


Figure 45: EL00627 Current distribution in an insulated system with C phase fault

The IEDs on the healthy feeders see the charging current imbalance for their own feeder. The IED on the faulted feeder, however, sees the charging current from the rest of the system (IH1 and IH2 in this case). Its own feeder's charging current (IH3) is cancelled out.

With reference to the associated vector diagram, it can be seen that the C-phase to earth fault causes the voltages on the healthy phases to rise by a factor of √3. The A-phase charging current (Ia1), leads the resultant A phase voltage by 90°. Likewise, the B-phase charging current leads the resultant Vb by 90°.

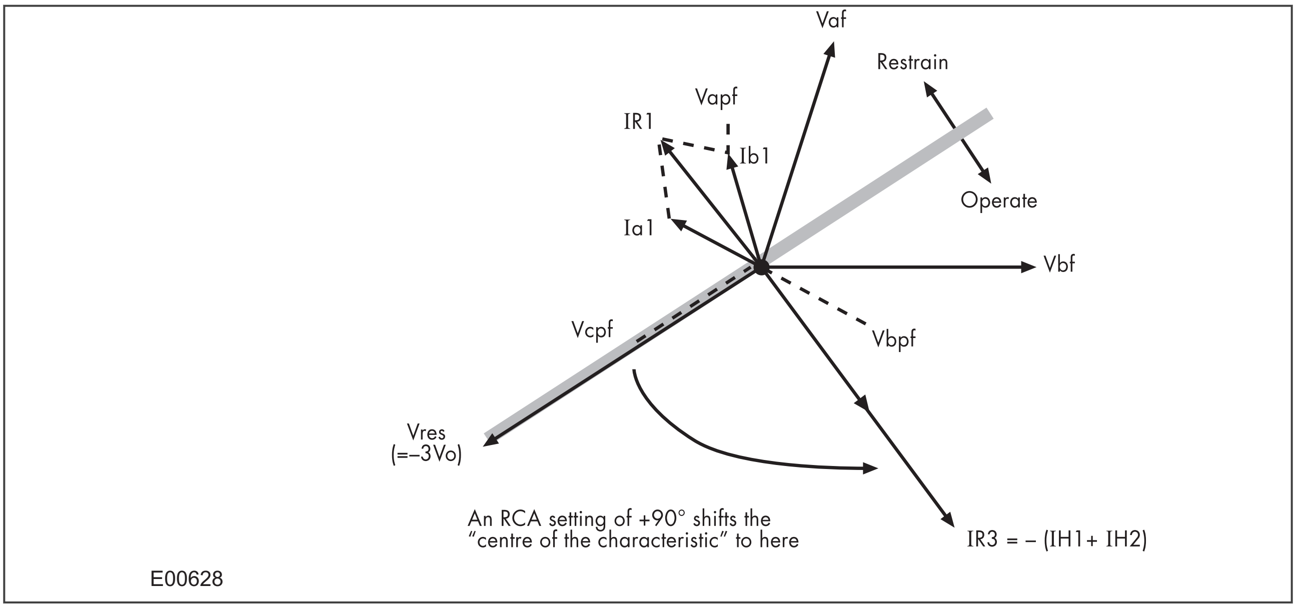


Figure 46: EL00628 Phasor diagrams for insulated system with C phase fault

The current imbalance detected by a core balanced current transformer on the healthy feeders is the vector addition of Ia1 and Ib1. This gives a residual current which lags the polariing voltage (–3Vo) by 90°. As the healthy phase voltages have risen by a factor of Ö3, the charging currents on these phases are also Ö3 times larger than their steady state values. Therefore, the magnitude of the residual current IR1, is equal to 3 times the steady state per phase charging current.

The phasor diagrams indicate that the residual currents on the healthy and faulted feeders (IR1 and IR3 respectively) are in anti-phase. A directional element could therefore be used to provide discriminative earth fault protection.

If the polarising is shifted through +90°, the residual current seen by the relay on the faulted feeder will lie within the operate region of the directional characteristic and the current on the healthy feeders will fall within the restrain region.

We have said that the required characteristic angle setting for the SEF element when applied to insulated systems, is +90°. This is for the case when the IED is connected such that its direction of current flow for operation is from the source busbar towards the feeder. If the forward direction for operation were set such that it is from the feeder into the busbar, (which some utilities may standardise on), then a –90° RCA would be required.

Note:
Discrimination can be provided without the need for directional control. This can only be achieved, however, if it is possible to set the IED in excess of the charging current of the protected feeder and below the charging current for the rest of the system.

9.7.2 SETTING GUIDELINES (INSULATED SYSTEMS)

The residual current on the faulted feeder is equal to the sum of the charging currents flowing from the rest of the system. Further, the addition of the two healthy phase charging currents on each feeder gives a total charging current which has a magnitude of three times the per phase value. Therefore, the total imbalance current is equal to three times the per phase charging current of the rest of the system. A typical setting may therefore be in the order of 30% of this value, i.e. equal to the per phase charging current of the remaining system. Practically though, the required setting may well be determined on site, where suitable settings can be adopted based on practically obtained results.

When using a core-balanced transformer, care must be taken in the positioning of the CT with respect to the earthing of the cable sheath:

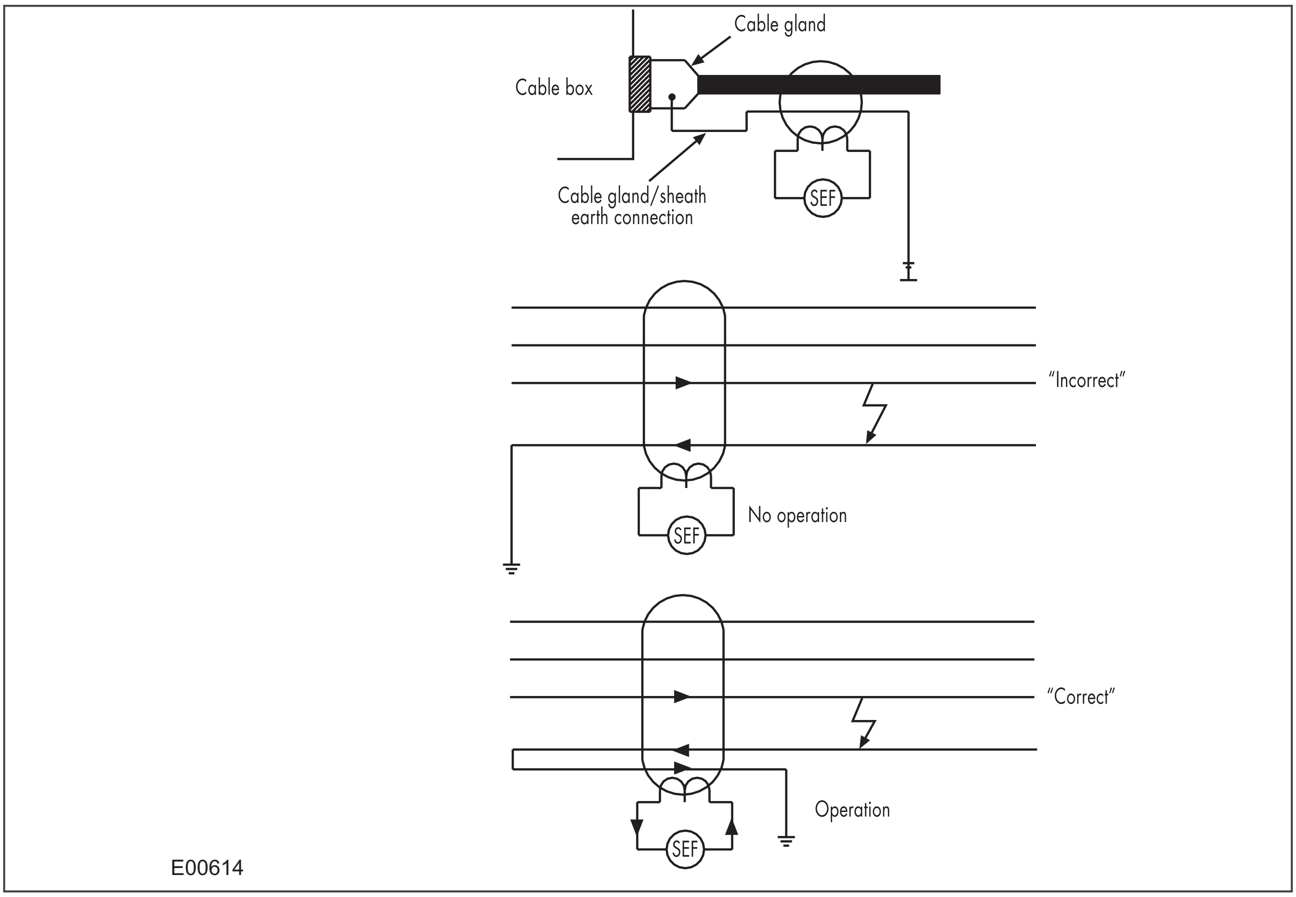


Figure 47: Positioning of core balance current transformers

If the cable sheath is terminated at the cable gland and directly earthed at that point, a cable fault (from phase to sheath) will not result in any unbalanced current in the core balance CT. Therefore, prior to earthing, the connection must be brought back through the CBCT and earthed on the feeder side. This then ensures correct relay operation during earth fault conditions.

10 RESTRICTED EARTH FAULT PROTECTION

Winding-to-core faults in a transformer are quite common due to insulation breakdown. Such faults can have very low fault currents, but they are faults nevertheless and have to be picked up, as they can still severely damage expensive equipment. Often the fault currents are even lower than the nominal load current. Clearly, neither overcurrent nor percentage differential protection is sufficiently sensitive in this case. We therefore require a different type of protection arrangement. Not only should the protection arrangement be sensitive, but it must create a protection zone, which is limited to the transformer windings. Restricted Earth Fault (REF) protection satisfies these conditions.

The first figure shows an REF protection arrangement for the delta side of a delta-star transformer. The current transformers measuring the currents in each phase are connected in parallel. A fault outside the protection zone (i.e. outside the delta winding) will not result in a spill current, as the fault current would simply circulate in the delta windings. However, if any of the three delta windings were to develop a fault, the impedance of the faulty winding would change and that would result in a mismatch between the phase currents, resulting in a spill current, sufficient to trigger a trip command.

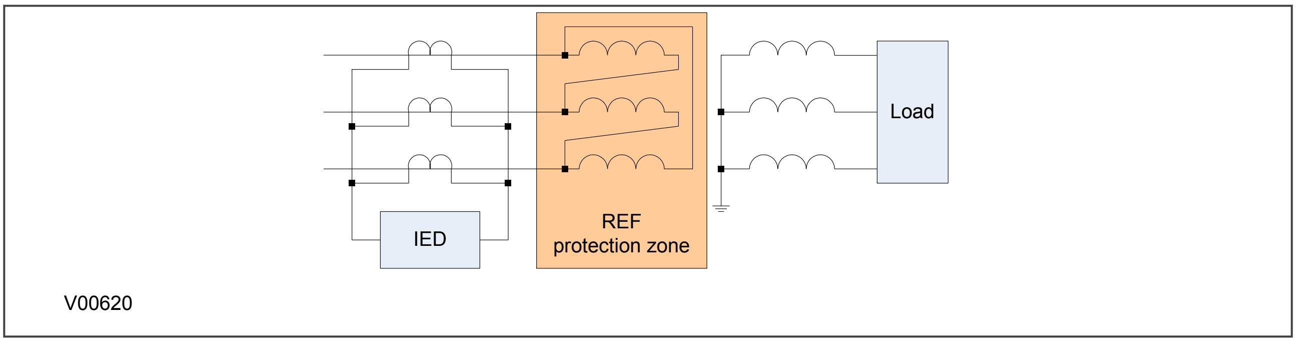


Figure 48: REF protection for delta side

The second figure shows an REF protection arrangement for the star side of a delta-star transformer. Here we have a similar arrangement of current transformers connected in parallel. The only difference is that we need to measure the zero sequence current in the neutral line as well. We know that an external unbalanced fault causes zero sequence current to flow through the neutral line, resulting in uneven currents in the phases, which would cause the IED to maloperate. By measuring this zero sequence current and placing the current transformer in parallel with the other three, the currents are balanced up resulting in stable operation. Now only a fault inside the star winding can create an imbalance sufficient to cause the IED to issue a trip command.

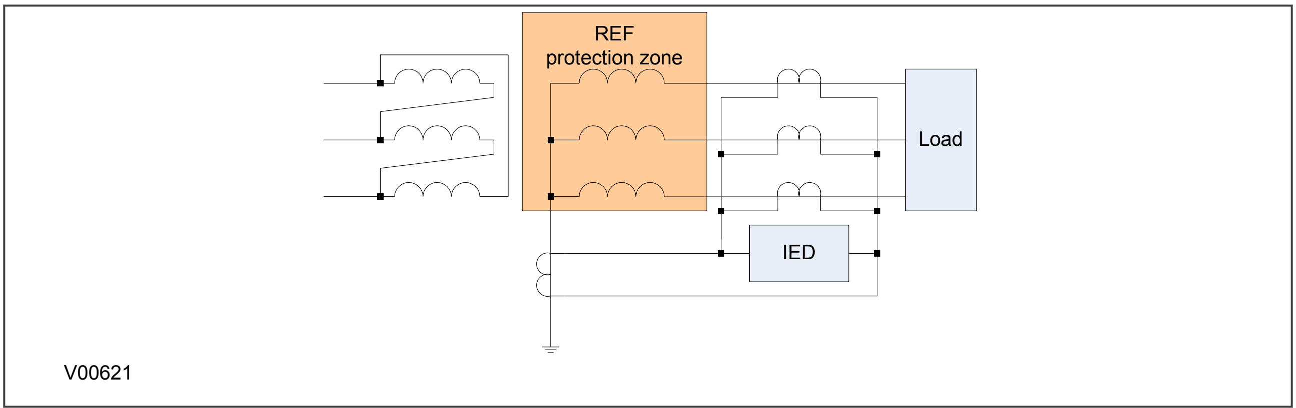


Figure 49: REF protection for star side

Two methods of REF are commonly used; bias or high impedance. The biasing technique operates by measuring the level of through-current flowing and altering the protection device sensitivity accordingly. In a biased differential IED, the through-current is measured and used to increase the setting of the differential element. For heavy through-faults, one CT in the scheme can be expected to become more saturated than the other and so differential current can be produced. However, biasing will increase the IED setting such that the resulting differential current is insufficient to cause the IED to operate, therefore ensuring the integrity of the tripping scheme.

The high impedance technique ensures that the circuit is of sufficiently high impedance such that the differential voltage that may occur under external fault conditions is less than that required to drive setting current through the device.

10.1 RESTRICTED EARTH FAULT PROTECTION IMPLEMENTATION

Restricted Earth Fault Protection is implemented in the Restricted E/F column of the relevant settings group. It is here that the constants and bias currents are set.

The REF protection may be configured to operate as either a high impedance or biased element.

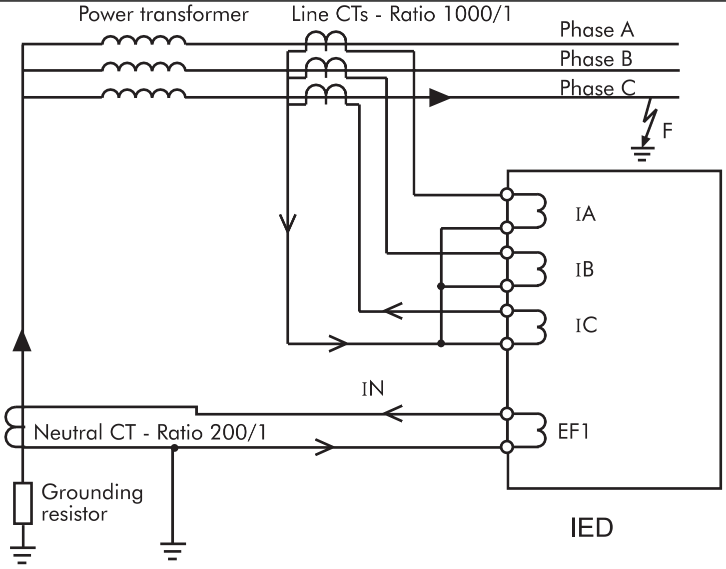
10.2 REF SETTINGS

Menu Text	Col	Row	Default Setting	Available Options
Description				
GROUP 1 RESTRICTED E/F	43	00		
This column contains settings for Restricted Earth Fault Protection				
REF Options	43	01	Lo Z REF	0=Hi Z REF or 1=Lo Z REF
This setting determines the Restricted Earth Fault mode of operation - high impedance or low impedance.				
IREF> k1	43	02	20	From 0 to 20 step 1
This setting sets the first slope constant of the low impedance biased characteristic.				
IREF> k2	43	03	150	From 0 to 150 step 1
This setting sets the second slope constant of the low impedance biased characteristic.				
IREF> Is1	43	04	0.2	From 0.08 to 1 step 0.01
This setting sets the bias current threshold for the first slope of the low impedance characteristic.				
IREF> Is2	43	05	1	From 0.1 to 1.5 step 0.01
This setting sets the bias current threshold for the second slope of the low impedance characteristic.				
IREF> Is	43	06	0.2	From 0.05 to 1 step 0.01
Setting that determines the minimum differential operate current for the hi-impedance element.				

10.3 APPLICATION NOTES

10.3.1 BIASED DIFFERENTIAL PROTECTION

The three line CTs are connected to the three-phase CTs, and the neutral CT is connected to the EF1 CT input. These currents are then used internally to derive both a bias and a differential current quantity for use by the low impedance REF protection (Lo-Z). The advantage of this mode of connection is that the line and neutral CTs are not differentially connected, so the neutral CT can also be used to drive the EF1 protection to provide Standby Earth Fault Protection. Also, no external components such as stabilizing resistors or Metrosils are required.



$$\text{IBias} = \frac{(\text{Highest of } I_A,\ I_B \text{ or } I_C) + (I_N \times \text{Scaling factor})}{2}$$

$$\text{Where scaling factor} = \frac{\text{Neutral CT ratio}}{\text{Line CT ratio}} \quad \left(= \frac{200}{1000} = 0.2 \text{ in this case} \right)$$

$$\text{IDiff} = \overline{I_A} + \overline{I_B} + \overline{I_C} + (\text{Scaling factor} \times \overline{I_N})$$

E00623

Figure 50: REF bias principle

Where the neutral CT also drives the EF1 protection element to provide standby earth fault protection, you may require that the neutral CT has a lower ratio than the line CTs in order to provide better earth fault sensitivity. This must be accounted for in the REF protection, otherwise the neutral current value used would be incorrect. For this reason, the device automatically scales the level of neutral current used in the bias calculation by a factor equal to the ratio of the neutral to line CT primary ratings. The use of this scaling factor is shown in the figure, where the formulae for bias and differential currents are given.

10.3.2 SETTING GUIDELINES FOR BIASED DIFFERENTIAL OPERATION

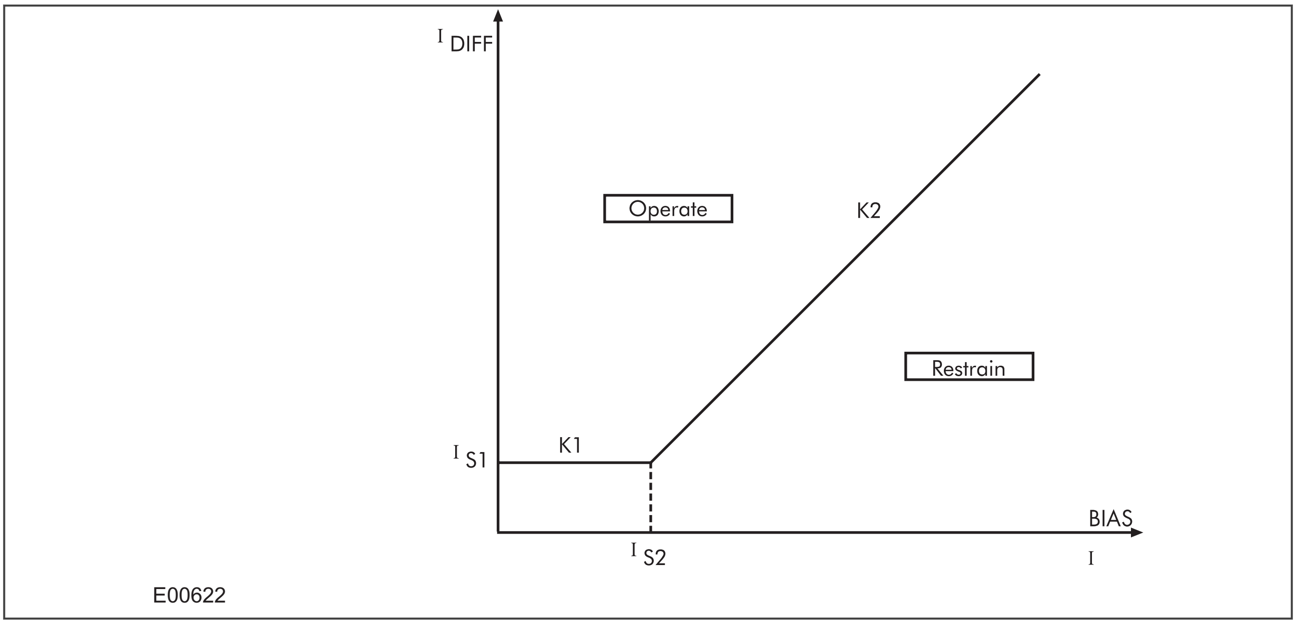


Figure 51: REF bias characteristic

The formulae used by the device to calculate the required bias quantity is as follows:

I_{BIAS} = {(Highest of Ia, Ib or Ic) + ($I_{neutral}$ x Scaling Factor)}/2

For I_{BIAS} < Is1: Operate when I_{DIFF} > Is1 + K1(I_{BIAS})

For I_{BIAS} = Is2: Operate when I_{DIFF} > Is1 + K1(Is2)

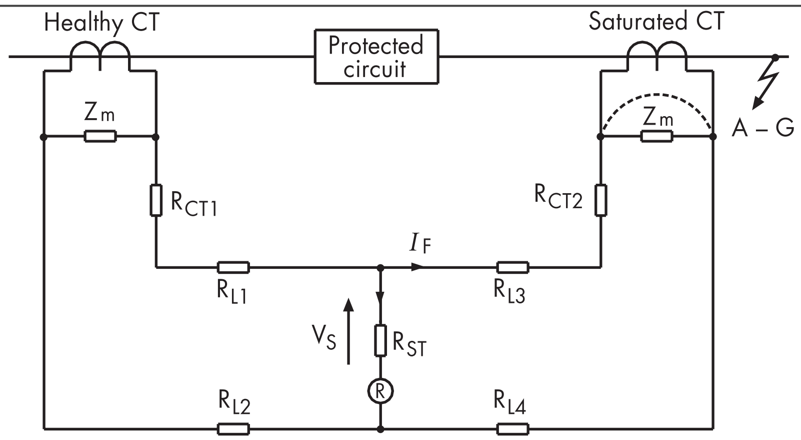
For I_{BIAS} > Is2: Operate when I_{DIFF} > Is1 + K1(Is2) + K2(I_{BIAS}-Is2)

Two bias settings are provided in the REF characteristic. The K1 level of bias is applied up to through currents of Is2, which is normally set to the rated current of the transformer. K1 should normally be set to 0% to give optimum sensitivity for internal faults. However, if any CT mismatch is present under normal conditions, then K1 may be increased accordingly, to compensate.

K2 bias is applied for through currents above Is2 and would typically be set to 150%.

10.3.3 HIGH IMPEDANCE REF

The high impedance principle is best explained by considering a differential scheme where one CT is saturated for an external fault, as shown below.



Voltage across relay circuit

$$V_S = I_F \ (R_{CT} + 2R_L)$$

Stabilising resistor R_{ST} limits spill current to I_S (relay setting)

$$R_{ST} = \frac{V_S}{I_S} - R_R$$

Where
I_F = Maximum secondary through fault current
R_R = Relay burden
R_{CT} = Current transformer secondary winding resistance
R_L = Resistance of a single lead from the relay to the current transformer

E00624

Figure 52: High Impedance principle

If the IED circuit has a very high impedance, the secondary current produced by the healthy CT will flow through the saturated CT. If CT magnetising impedance of the saturated CT is considered to be negligible, the maximum voltage across the circuit will be equal to the secondary fault current multiplied by the connected impedance, ($R_{L3} + R_{L4} + R_{CT2}$).

The IED can be made stable for this maximum applied voltage by increasing the overall impedance of the circuit, such that the resulting current through it is less than its current setting. As the impedance of the IED input alone is relatively low, a series connected external resistor is required. The value of this resistor, R_{ST}, is calculated by the formula shown. An additional non-linear, Metrosil, may be required to limit the peak secondary circuit voltage during internal fault conditions.

To ensure that the protection will operate quickly during an internal fault, the CTs used to operate the protection must have a knee-point voltage of at least 4 Vs.

The necessary connections for high impedance REF are as follows:

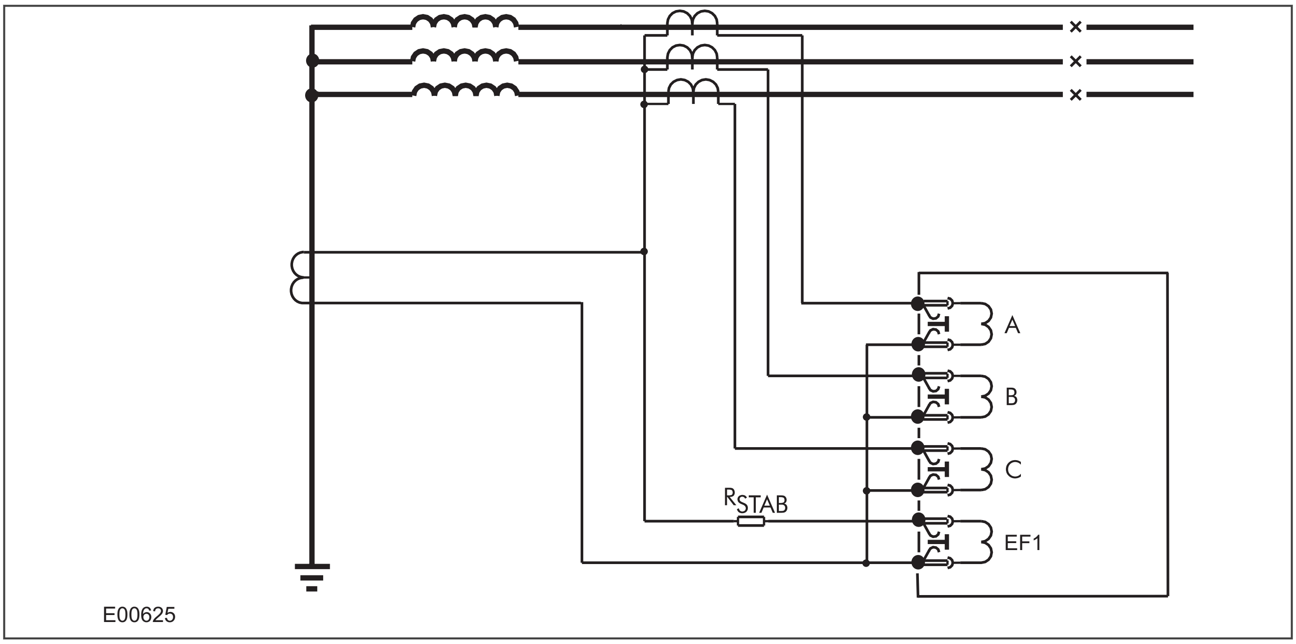


Figure 53: High Impedance REF connectivity

10.3.4 SETTING GUIDELINES FOR HIGH IMPEDANCE OPERATION

First, go to the SEF PROT'N column and set the **SEF/REF Options** cell to 'Hi Z' to enable this protection.

The only setting cell then visible in the RESTRICTED E/F column is **IREF>Is**, which may be programmed with the required differential current setting. This would typically be set to give a primary operating current of either 30% of the minimum earth fault level for a resistance earthed system or between 10 and 60% of rated current for a solidly earthed system.

The primary operating current (Iop) will be a function of the current transformer ratio, the IED operating current (**IREF>Is1**), the number of current transformers in parallel with an IED element (n) and the magnetising current of each current transformer (Ie) at the stability voltage (Vs). This relationship can be expressed in three ways:

1) To determine the maximum current transformer magnetising current to achieve a specific primary operating current with a particular relay operating current:

$$I_e < \frac{1}{n}\left(\frac{I_{op}}{CT\,Ratio} - I_{REF} > I_s\right)$$

2) To determine the minimum current setting to achieve a specific primary operating current with a given current transformer magnetising current:

$$I_{REF} > I_s < \left(\frac{I_{op}}{CT\,Ratio} - nI_e\right)$$

3) To express the protection primary operating current with a particular level of magnetising current:

$$I_{OP} = (CT\,Ratio)(I_{REF}) > I_s + nI_c$$

In order to achieve the required primary operating current with the current transformers that are used, a current setting (IREF>Is) must be selected for the high impedance element, as detailed in expression (ii) above. The setting of the stabilising resistor (RST) must be calculated in the following manner, where the setting is a function of the required stability voltage setting (Vs) and the relay current setting (IREF>Is).

$$R_{st} = \frac{V_s}{I_{REF} > I_s} = \frac{I_f\left(R_{CT} + 2R_L\right)}{I_{REF} > I_s}$$

The stabilising resistor that can be supplied is continuously adjustable up to its maximum declared resistance.

Note:
The above formula assumes negligible relay burden.

11 THERMAL OVERLOAD PROTECTION

The heat generated within an item of plant, such as a cable or a transformer, is the resistive loss (I2Rt). The thermal time characteristic is therefore based on the square of the current integrated over time. The device automatically uses the largest phase current for input to the thermal model.

Equipment is designed to operate continuously at a temperature corresponding to its full load rating, where the heat generated is balanced with heat dissipated. Over-temperature conditions occur when currents in excess of their maximum rating are allowed to flow for a period of time. It is known that temperature changes during heating follow exponential time constants.

The device provides two characteristics that may be selected according to the application; single time constant characteristic and dual time constant characteristic.

11.1 SINGLE TIME CONSTANT CHARACTERISTIC

This characteristic is used to protect cables, dry type transformers (e.g. type AN), and capacitor banks.

The single constant thermal characteristic is given by the equation:

$$t = -\tau \, log_e \left[\frac{I^2 - (KI_{FLC})^2}{I^2 - I_p^2} \right]$$

where:

- t = time to trip, following application of the overload current I
- τ = heating and cooling time constant of the protected plant
- I = largest phase current
- I_{FLC} full load current rating (the Thermal Trip setting)
- K = a constant with the value of 1.05
- I_p = steady state pre-loading before application of the overload

11.2 DUAL TIME CONSTANT CHARACTERISTIC

This characteristic is used to protect oil-filled transformers with natural air cooling (e.g. type ONAN). The thermal model is similar to that with the single time constant, except that two timer constants must be set.

For marginal overloading, heat will flow from the windings into the bulk of the insulating oil. Therefore, at low current, the replica curve is dominated by the long time constant for the oil. This provides protection against a general rise in oil temperature.

For severe overloading, heat accumulates in the transformer windings, with little opportunity for dissipation into the surrounding insulating oil. Therefore at high current levels, the replica curve is dominated by the short time constant for the windings. This provides protection against hot spots developing within the transformer windings.

Overall, the dual time constant characteristic serves to protect the winding insulation from ageing and to minimise gas production by overheated oil. Note however that the thermal model does not compensate for the effects of ambient temperature change.

The dual time constant thermal characteristic is given by the equation:

$$0.4e^{(-t/\tau_1)} + 0.6e^{(-t/\tau_2)} = \left[\frac{I^2 - (KI_{FLC})^2}{I^2 - I_p^2} \right]$$

where:

- τ_1 = heating and cooling time constant of the transformer windings
- τ_2 = heating and cooling time constant of the transformer windings

11.3 THERMAL OVERLOAD PROTECTION IMPLEMENTATION

The device incorporates a current-based thermal characteristic, using RMS load current to model heating and cooling of the protected plant. The element can be set with both alarm and trip stages.

Thermal Overload Protection is implemented in the THERMAL OVERLOAD column of the relevant settings group.

This column contains the settings for the characteristic type, the alarm and trip thresholds and the time constants.

11.4 THERMAL OVERLOAD PROTECTION LOGIC

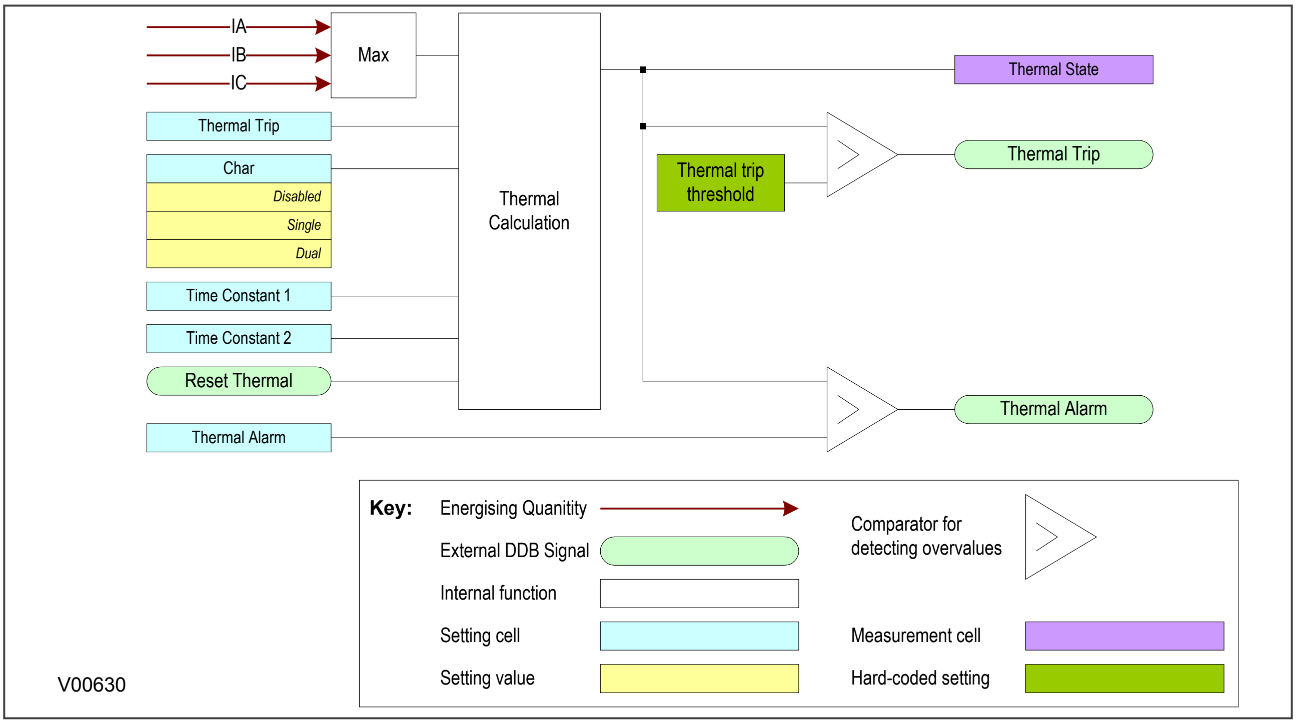


Figure 54: Thermal overload protection logic diagram

The magnitudes of the three phase input currents are compared and the largest magnitude is taken as the input to the thermal overload function. If this current exceeds the thermal trip threshold setting a start condition is asserted.

The Start signal is applied to the chosen thermal characteristic module, which has three outputs signals; alarm trip and thermal state measurement. The thermal state measurement is made available in the MEASUREMENTS 3 column.

The thermal state can be reset by either an opto-input (if assigned to this function using the programmable scheme logic) or the HMI panel menu. This reset command is also found in the MEASUREMENTS 3 column.

11.5 THERMAL OVERLOAD DDB SIGNALS

Ordinal	English Text	Source	Type	Response Function
Description				
236	Reset Thermal	Programmable Scheme Logic	PSL Output	No response
This DDB signal resets the Thermal State				
329	Thermal Alarm	Software	PSL Input	Protection event
This DDB signal is the Thermal Overload start signal				
276	Thermal Trip	Software	PSL Input	Protection event
This DDB signal is the Thermal Overload trip signal				

11.6 THERMAL OVERLOAD SETTINGS

Menu Text	Col	Row	Default Setting	Available Options
Description				
GROUP 1 THERMAL OVERLOAD	3C	00		
This column contains settings for Thermal Overload				
Characteristic	3C	01	Single	0 = Disabled, 1 = Single, 2 = Dual
This setting determines the operate characteristic for the thermal overload element.				
Thermal Trip	3C	02	1	0.08*In to 4*In step 0.01In
This setting sets the pick-up threshold of the thermal characteristic. This would normally be the maximum full load current.				
Thermal Alarm	3C	03	70	50 to 100 step 1
This setting sets the thermal state threshold at which an alarm will be generated. This corresponds to a percentage of the trip threshold				
Time Constant 1	3C	04	10	1 to 200 step 1
This setting sets the thermal time constant for a single time constant characteristic.				
Time Constant 2	3C	05	5	1 to 200 step 1
This setting sets the thermal time constant for a dual time constant characteristic.				

11.7 APPLICATION NOTES

11.7.1 SETTING GUIDELINES FOR DUAL TIME CONSTANT CHARACTERISTIC

The easiest way of solving the dual time constant thermal equation is to express the current in terms of time and to use a spreadsheet to calculate the current for a series of increasing operating times using the following equation, then plotting a graph.

$$I = \sqrt{\frac{0.4{I_p}^2.e^{(-t/\tau 1)} + 0.6{I_p}^2.e^{(-t/\tau 2)} - k^2.{I_{FLC}}^2}{0.4e^{(-t/\tau 1)} + 0.6e^{(-t/\tau 2)} - 1}}$$

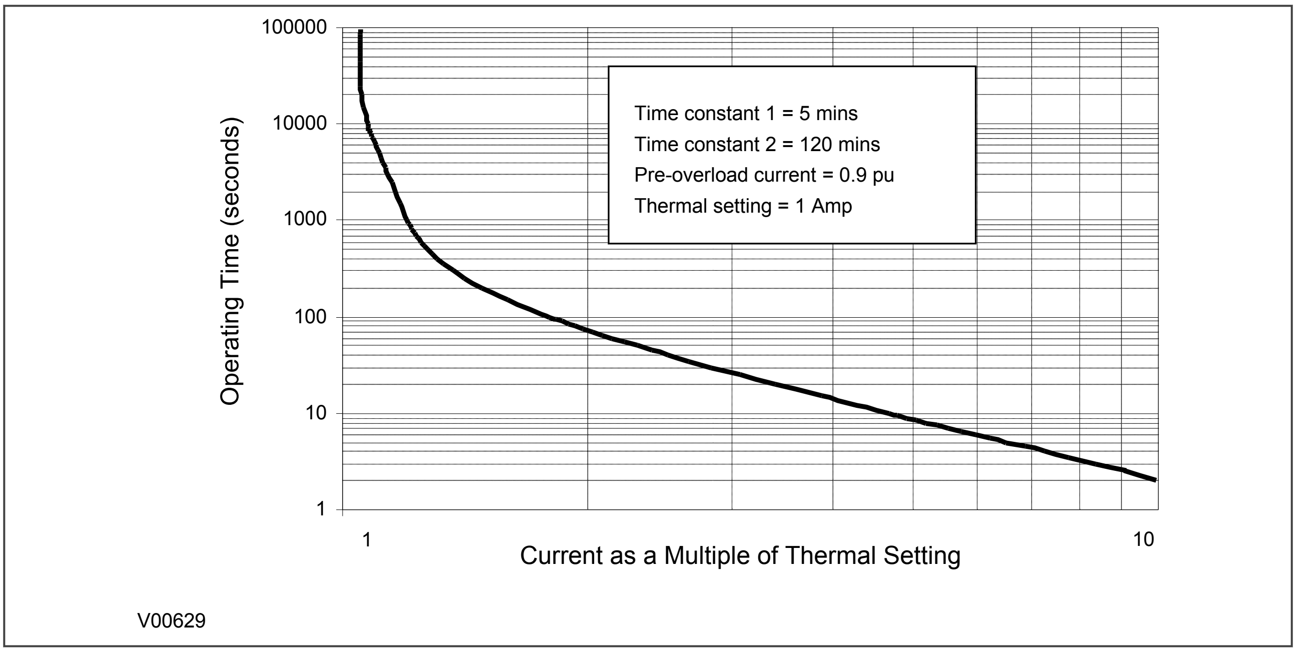


Figure 55: Dual time constant thermal characteristic

The current setting is calculated as:

Thermal Trip = Permissible continuous loading of the transformer item/CT ratio.

For an oil-filled transformer with rating 400 to 1600 kVA, the approximate time constants are:

- τ_1 = 5 minutes
- τ_2 = 120 minutes

An alarm can be raised on reaching a thermal state corresponding to a percentage of the trip threshold. A typical setting might be "Thermal Alarm" = 70% of thermal capacity.

> *Note:*
> *The thermal time constants given in the above tables are typical only. Reference should always be made to the plant manufacturer for accurate information.*

11.7.2 SETTING GUIDELINES FOR SINGLE TIME CONSTANT CHARACTERISTIC

The time to trip varies depending on the load current carried before application of the overload, i.e. whether the overload was applied from hot or cold.

The thermal time constant characteristic may be rewritten as:

$$e^{(-t/\tau)} = {}_e\left[\frac{\theta - \theta_p}{\theta - 1}\right]$$

where:

- θ = thermal state = $I^2/K^2I_{FLC}^2$
- θ_p = pre-fault thermal state = $I_p^2/K^2I_{FLC}^2$

Note: A current of 105%Is (KIFLC) has to be applied for several time constants to cause a thermal state measurement of 100%

The current setting is calculated as:

Thermal Trip = Permissible continuous loading of the plant item/CT ratio.

The following tables show the approximate time constant in minutes, for different cable rated voltages with various conductor cross-sectional areas, and other plant equipment.

Area mm2	6 - 11 kV	22 kV	33 kV	66 kV
25 – 50	10 minutes	15 minutes	40 minutes	–
70 – 120	15 minutes	25 minutes	40 minutes	60 minutes
150	25 minutes	40 minutes	40 minutes	60 minutes
185	25 minutes	40 minutes	60 minutes	60 minutes
240	40 minutes	40 minutes	60 minutes	60 minutes
300	40 minutes	60 minutes	60 minutes	90 minutes

Plant type	Time Constant (Minutes)
Dry-type transformer <400 kVA	40
Dry-type transformers 400 – 800 kVA	60 - 90
Air-core Reactors	40
Capacitor Banks	10
Overhead Lines with cross section > 100 mm^2	10
Overhead Lines	10
Busbars	60

12 BROKEN CONDUCTOR PROTECTION

One type of unbalanced fault is the 'Series' or 'Open Circuit' fault. This type of fault can arise from, among other things, broken conductors. Series faults do not cause an increase in phase current and so cannot be detected by overcurrent IEDs. However, they do produce an imbalance, resulting in negative phase sequence current, which can be detected.

It is possible to apply a negative phase sequence overcurrent element to detect broken conductors. However, on a lightly loaded line, the negative sequence current resulting from a series fault condition may be very close to, or less than, the full load steady state imbalance arising from CT errors and load imbalances, making it very difficult to distinguish. A regular negative sequence element would therefore not work at low load levels. To overcome this, the device incorporates a special Broken Conductor protection element.

The Broken Conductor element measures the ratio of negative to positive phase sequence current (I2/I1). This ratio is approximately constant with variations in load current, therefore making it more sensitive to series faults than standard negative sequence protection.

12.1 BROKEN CONDUCTOR PROTECTION IMPLEMENTATION

Broken Conductor protection is implemented in the BROKEN CONDUCTOR column of the relevant settings group.

This column contains the settings to enable the function, for the pickup threshold and the time delay.

12.2 BROKEN CONDUCTOR PROTECTION LOGIC

The ratio of I_2/I_1 is calculated and compared with the threshold. If the threshold is exceeded, the delay timer is initiated. The CTS block signal is used to block the operation of the delay timer.

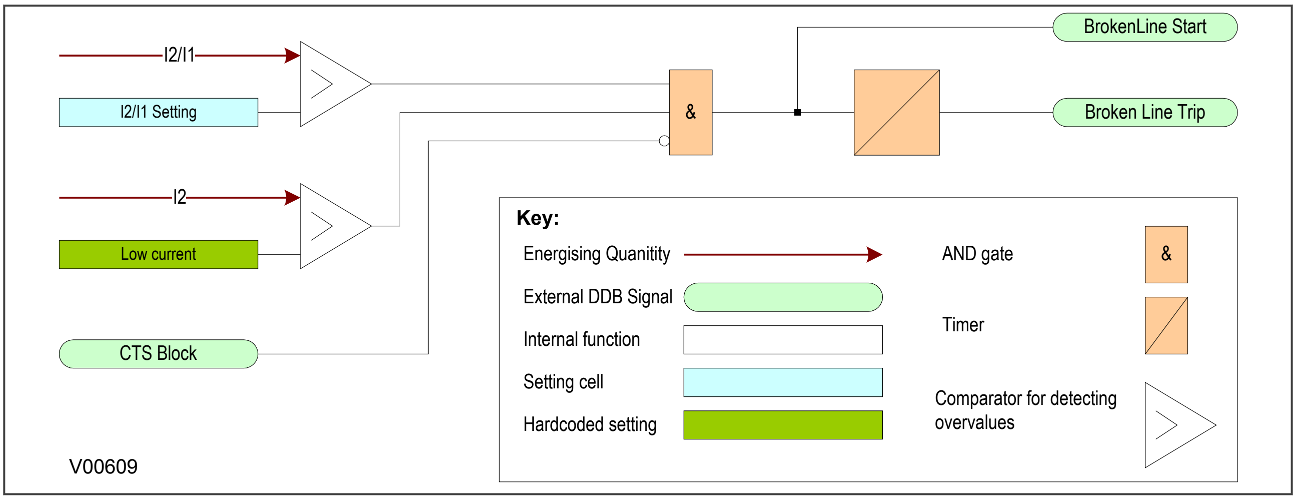


Figure 56: Broken conductor logic

12.3 BROKEN CONDUCTOR DDB SIGNALS

Ordinal	English Text	Source	Type	Response Function
Description				
260	Broken Line Trip	Software	PSL Input	Protection event
This DDB signal is the Broken Conductor trip signal				

Ordinal	English Text	Source	Type	Response Function
Description				
352	CTS Block	Software	PSL Input	No response
This DDB signal is an instantaneously blocking output from the CTS which can block other functions				
535	BrokenLine Start	Software	PSL Input	Protection event
This DDB signal is the Broken Conductor start signal				

12.4 BROKEN CONDUCTOR SETTINGS

Menu Text	Col	Row	Default Setting	Available Options
Description				
GROUP 1 BROKEN CONDUCTOR	37	00		
This column contains settings for Broken Conductor				
Broken Conductor	37	01	Enabled	0 = Disabled or 1 = Enabled
This setting enables or disables the Broken Conductor function.				
I2/I1 Setting	37	02	0.2	From 0.2 to 1 step 0.01
This setting determines the pick-up threshold of the negative to positive sequence current ratio.				
I2/I1 Time Delay	37	03	60	From 0s to 100s step 0.1s
This setting sets the time delay for the broken conductor element				

12.5 APPLICATION NOTES

12.5.1 SETTING GUIDELINES

For a broken conductor affecting a single point earthed power system, there will be little zero sequence current flow and the ratio of I_2/I_1 that flows in the protected circuit will approach 100%. In the case of a multiple earthed power system (assuming equal impedance's in each sequence network), the ratio I_2/I_1 will be 50%.

In practise, the levels of standing negative phase sequence current present on the system govern this minimum setting. This can be determined from a system study, or by making use of the measurement facilities at the commissioning stage. If the latter method is adopted, it is important to take the measurements during maximum system load conditions, to ensure that all single-phase loads are accounted for.

> *Note:*
> *A minimum value of 8% negative phase sequence current is required for successful operation.*

Since sensitive settings have been employed, we can expect that the element will operate for any unbalanced condition occurring on the system (for example, during a single pole autoreclose cycle). For this reason, a long time delay is necessary to ensure co-ordination with other protection devices. A 60 second time delay setting may be typical.

The following example was recorded by an IED during commissioning:

$$I_{full\ load} = 500A$$

$$I_2 = 50A$$

therefore the quiescent I_2/I_1 ratio = 0.1

To allow for tolerances and load variations a setting of 20% of this value may be typical: Therefore set:

$$I_2/I_1 = 0.2$$

In a double circuit (parallel line) application, using a 40% setting will ensure that the broken conductor protection will operate only for the circuit that is affected. A setting of 0.4 results in no pick-up for the parallel healthy circuit.

Set I_2/I_1 Time Delay = 60 s to allow adequate time for short circuit fault clearance by time delayed protections.

13 CIRCUIT BREAKER FAIL PROTECTION

When a fault occurs, one or more protection devices will operate and issue a trip command to the relevant circuit breakers. Operation of the circuit breaker is essential to isolate the fault and prevent, or at least limit, damage to the power system. For transmission and sub-transmission systems, slow fault clearance can also threaten system stability.

For these reasons, it is common practise to install Circuit Breaker Failure protection (CBF). CBF protection monitors the circuit breaker and establishes whether it has opened within a reasonable time. If the fault current has not been interrupted following a set time delay from circuit breaker trip initiation, the CBF protection will operate, whereby the upstream circuit breakers are back-tripped to ensure that the fault is isolated.

CBF operation can also reset all start output contacts, ensuring that any blocks asserted on upstream protection are removed.

13.1 CIRCIUIT BREAKER FAIL IMPLEMENTATION

Circuit Breaker Failure Protection is implemented in the CB FAIL & I< column of the relevant settings group.

The circuit breaker failure protection incorporates two timers, **CB Fail 1 Timer** and **CB Fail 2 Timer**, allowing configuration for the following scenarios:

- Simple CBF, where only **CB Fail 1 Timer** is enabled. For any protection trip, the **CB Fail 1 Timer** is started, and normally reset when the circuit breaker opens to isolate the fault. If breaker opening is not detected, the CB Fail 1 Timer times out and closes an output contact assigned to breaker fail (using the programmable scheme logic). This contact is used to back-trip upstream switchgear, generally tripping all infeeds connected to the same busbar section.
- A re-tripping scheme, plus delayed back-tripping. Here, **CB Fail 1 Timer** is used to issue a trip command to a second trip circuit of the same circuit breaker. This requires the circuit breaker to have duplicate circuit breaker trip coils. This mechanism is known as re-tripping. Should re-tripping fail to open the circuit breaker, then a back-trip may be issued following an additional time delay. The back-trip uses **CB Fail 2 Timer**, which was also started at the instant of the initial protection element trip.

13.2 CIRCIUIT BREAKER FAIL LOGIC

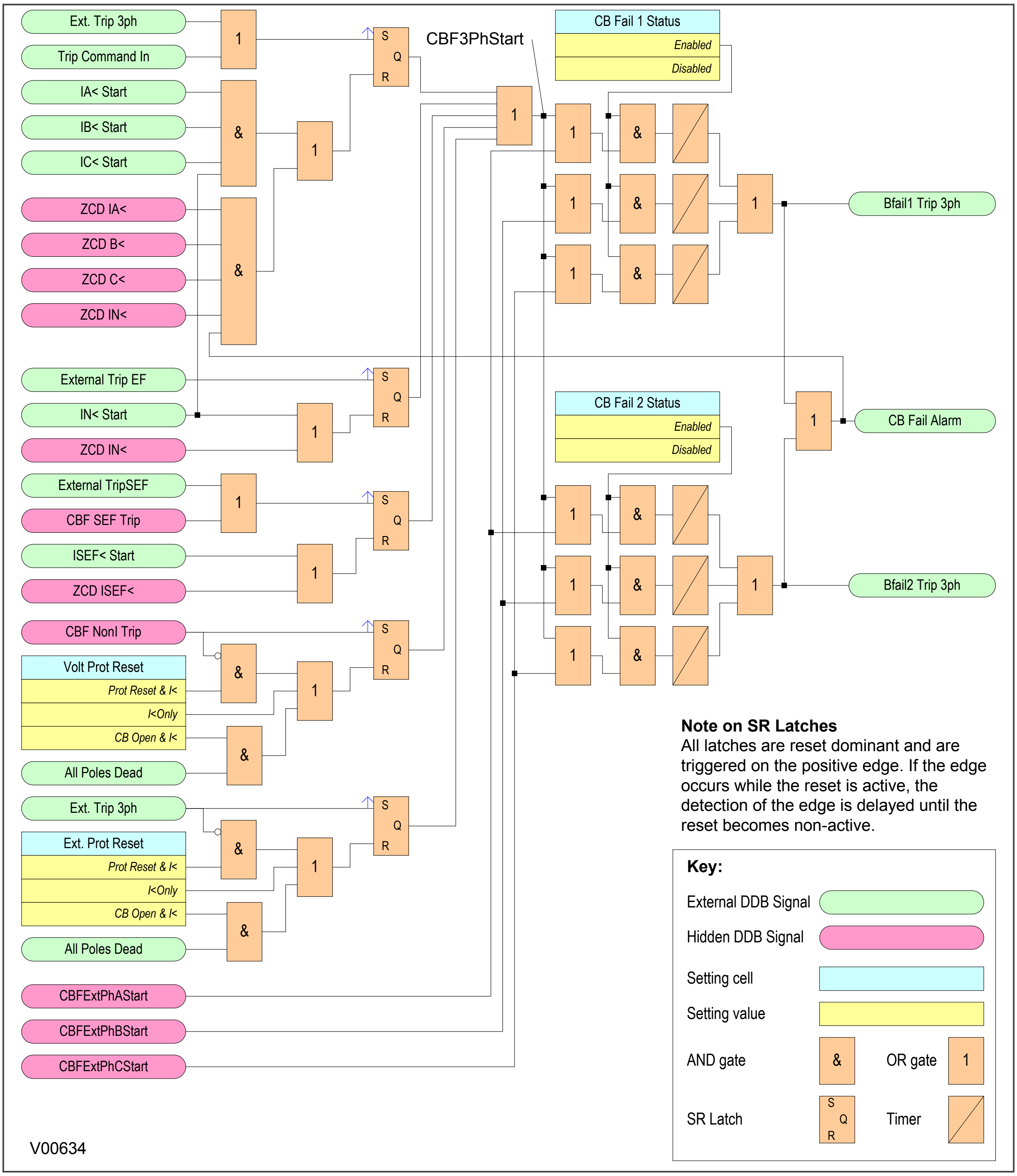


Figure 57: Circuit Breaker Fail Logic - three phase start

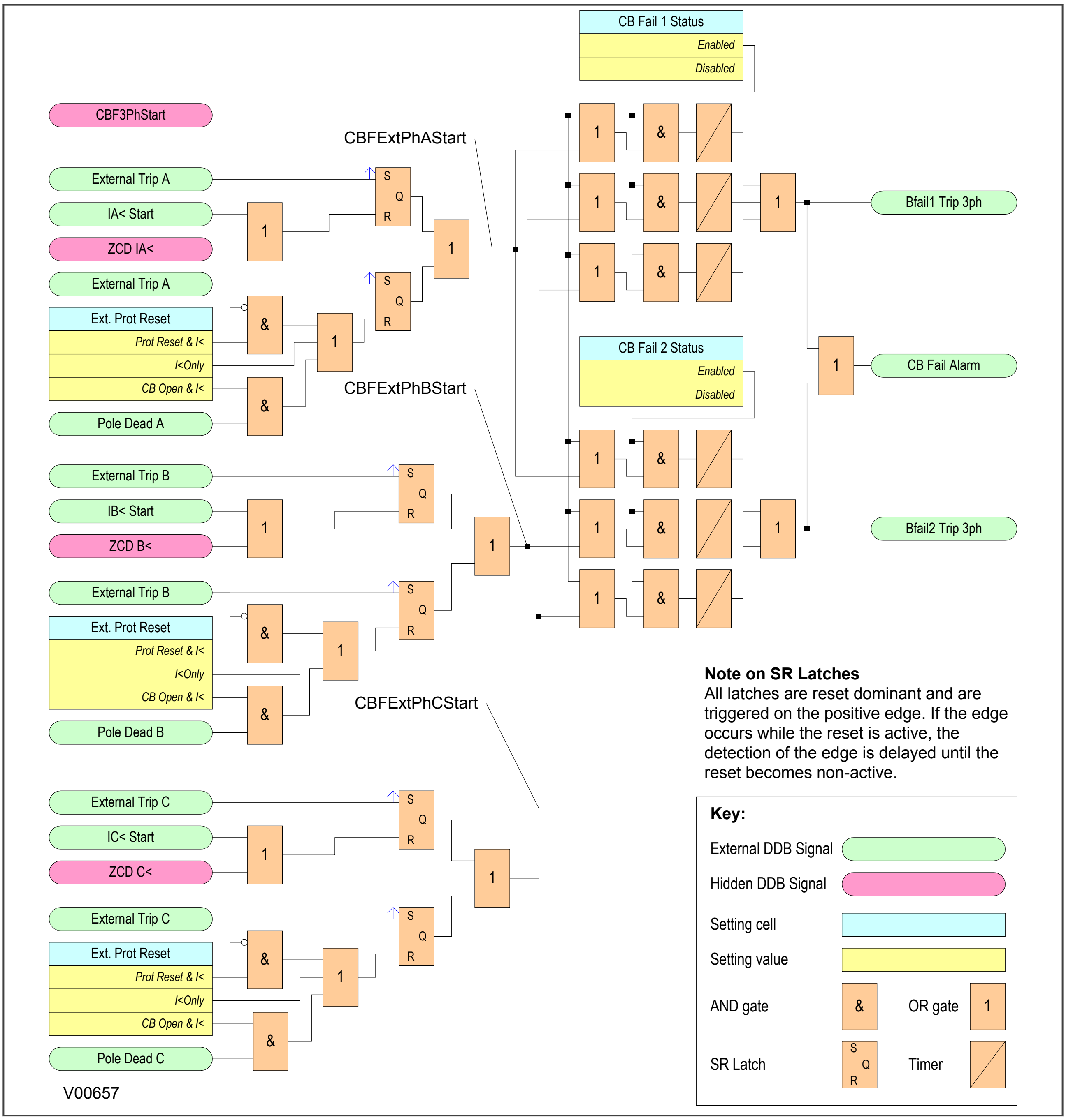


Figure 58: Circuit Breaker Fail Logic - single phase start

CBF elements **CB Fail 1 Timer** and **CB Fail 2 Timer** can be configured to operate for trips triggered by protection elements within the device or via an external protection trip. The latter is achieved by allocating one of the opto-isolated inputs to "External Trip" using the programmable scheme logic.

It is possible to reset the CBF from a breaker open indication (from the Pole Dead logic) or from a protection reset. In these cases resetting is only allowed provided the undercurrent elements have also been reset. The resetting options are summarised in the following table:

Initiation (Menu Selectable)	CB Fail Timer Reset Mechanism
Current based protection	The resetting mechanism is fixed (e.g. 50/51/46/21/87) IA< operates AND IB< operates AND IC< operates AND IN< operates

Initiation (Menu Selectable)	CB Fail Timer Reset Mechanism
Sensitive Earth Fault element	The resetting mechanism is fixed. ISEF< Operates
Non-current based protection (e.g. 27/59/81/32L)	Three options are available: - All I< and IN< elements operate - Protection element reset AND all I< and IN< elements operate - CB open (all 3 poles) AND all I< and IN< elements operate
External protection	Three options are available. - All I< and IN< elements operate - External trip reset AND all I< and IN< elements operate - CB open (all 3 poles) AND all I< and IN< elements operate

The **Remove I> Start** and **Remove IN>** Start settings are used to remove starts issued from the overcurrent and earth elements respectively following a breaker fail time out. The start is removed when the cell is set to 'Enabled'.

13.3 CB FAIL DDB SIGNALS

Ordinal	English Text	Source	Type	Response Function
Description				
150	CB Fail Alarm	Software	PSL Input	Alarm latched event
This DDB signal is an alarm indicating CB Failure				
227	Ext. Trip 3ph	Programmable Scheme Logic	PSL Output	No response
This DDB signal receives an external three-phase trip signal				
353	Bfail1 Trip 3ph	Software	PSL Input	Protection event
This DDB signal is the three-phase trip signal for the stage 1 CB Fail function				
354	Bfail2 Trip 3ph	Software	PSL Input	Protection event
This DDB signal is the three-phase trip signal for the stage 2 CB Fail function				
373	IA< Start	Software	PSL Input	No response
This DDB signal is the A-phase Phase Undercurrent start signal				
374	IB< Start	Software	PSL Input	No response
This DDB signal is the B-phase Phase Undercurrent start signal				
375	IC< Start	Software	PSL Input	No response
This DDB signal is the C-phase Phase Undercurrent start signal				
376	IN< Start	Software	PSL Input	No response
This DDB signal is the Earth Fault undercurrent start signal				
377	ISEF< Start	Software	PSL Input	No response
This DDB signal is the Sensitive Earth Fault undercurrent start signal				
380	All Poles Dead	Software	PSL Input	No response
This DDB signal indicates that all poles are dead				
382	Pole Dead A	Software	PSL Input	No response
This DDB signal indicates that the A-phase pole is dead.				
383	Pole Dead B	Software	PSL Input	No response
This DDB signal indicates that the B-phase pole is dead.				
384	Pole Dead C	Software	PSL Input	No response
This DDB signal indicates that the C-phase pole is dead.				

Ordinal	English Text	Source	Type	Response Function
Description				
499	External Trip A	Programmable Scheme Logic	PSL Output	No response
This DDB signal is connected to an external A-Phase trip, which initiates a CB Fail condition				
500	External Trip B	Programmable Scheme Logic	PSL Output	No response
This DDB signal is connected to an external B-Phase trip, which initiates a CB Fail condition				
501	External Trip C	Programmable Scheme Logic	PSL Output	No response
This DDB signal is connected to an external C-Phase Trip, which initiates a CB Fail condition				
502	External Trip EF	Programmable Scheme Logic	PSL Output	No response
This DDB signal is connected to an external Earth Fault trip, which initiates a CB Fail condition				
503	External TripSEF	Programmable Scheme Logic	PSL Output	No response
This DDB signal is connected to an external Sensitive Earth Fault trip, which initiates a CB Fail condition				
536	Trip Command In	Programmable Scheme Logic	PSL Output	Protection event
This DDB signal is the Trip Command In signal, which triggers the fixed trip LED and is mapped to the Trip Command Out signal in the FSL.				

13.4 CB FAIL SETTINGS

Menu Text	Col	Row	Default Setting	Available Options
Description				
GROUP 1 CB FAIL & I<	45	00		
This column contains settings for Circuit Fail and Under Current.				
BREAKER FAIL	45	01		
The settings under this sub-heading relate to Circuit Breaker Fail (CB Fail) settings				
CB Fail 1 Status	45	02	Enabled	0 = Disabled or 1 = Enabled
This setting enables or disables the first stage of the CB Fail protection.				
CB Fail 1 Timer	45	03	0.2	From 0s to 50s step 0.01s
This setting sets the first stage CB Fail timer in which the CB opening must be detected.				
CB Fail 2 Status	45	04	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the second stage of the CB Fail protection.				
CB Fail 2 Timer	45	05	0.4	From 0s to 50s step 0.01s
This setting sets the second stage CB Fail timer in which the CB opening must be detected.				
Volt Prot Reset	45	06	CB Open & I<	0=I< Only 1=CB Open & I< 2=Prot Reset & I<
This setting determines the elements that will reset the CB fail timer for CB Failures, which were initiated by the voltage protection function.				
Ext Prot Reset	45	07	CB Open & I<	0=I< Only 1=CB Open & I< 2=Prot Reset & I<
This setting determines the elements that will reset the CB fail timer for CB Failures initiated by external protection functions.				
UNDER CURRENT	45	08		
The settings under this sub-heading relate to Undercurrent settings				
I< Current Set	45	09	0.1	From 0.02*I1 to 3.2*I1 step 0.01*I1
This setting determines the current threshold, which will reset the CB Fail timer for Overcurrent-based protection				
IN< Current Set	45	0A	0.1	From 0.02*I2 to 3.2*I2 step 0.01*I2
This setting determines the current threshold, which will reset the CB Fail timer for Earth Fault-based protection				

Menu Text	Col	Row	Default Setting	Available Options
Description				
ISEF< Current	45	0B	0.02	From 0.001*I3 to 0.8*I3 step 0.0005*I3
This setting determines the current threshold, which will reset the CB Fail timer for SEF-based protection				
BLOCKED O/C	45	0C		
The settings under this sub-heading relate to Blocked Overcurrent settings				
Remove I> Start	45	0D	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the Remove I>Start signal				
Remove IN> Start	45	0E	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the Remove IN>Start signal				

13.5 APPLICATION NOTES

13.5.1 RESET MECHANISMS FOR CB FAIL TIMERS

It is common practise to use low set undercurrent elements to indicate that circuit breaker poles have interrupted the fault or load current. This covers the following situations:

- Where circuit breaker auxiliary contacts are defective, or cannot be relied on to definitely indicate that the breaker has tripped
- Where a circuit breaker has started to open but has become jammed. This may result in continued arcing at the primary contacts, with an additional arcing resistance in the fault current path. Should this resistance severely limit fault current, the initiating protection element may reset. Therefore, reset of the element may not give a reliable indication that the circuit breaker has opened fully

For any protection function requiring current to operate, the device uses operation of undercurrent elements to detect that the necessary circuit breaker poles have tripped and reset the CB fail timers. However, the undercurrent elements may not be reliable methods of resetting CBF in all applications. For example:

- Where non-current operated protection, such as under/overvoltage or under/overfrequency, derives measurements from a line connected voltage transformer. Here, I< only gives a reliable reset method if the protected circuit would always have load current flowing. In this case, detecting drop-off of the initiating protection element might be a more reliable method.
- Where non-current operated protection, such as under/overvoltage or under/overfrequency, derives measurements from a busbar connected voltage transformer. Again using I< would rely upon the feeder normally being loaded. Also, tripping the circuit breaker may not remove the initiating condition from the busbar, and hence drop-off of the protection element may not occur. In such cases, the position of the circuit breaker auxiliary contacts may give the best reset method.

13.5.2 SETTING GUIDELINES (CB FAIL TIMER)

The following examples consider direct tripping of a 2-cycle circuit breaker. Typical timer settings to use are as follows:

CB Fail Reset Mechanism	tBF Time Delay	Typical Delay For 2 Cycle Circuit Breaker
Initiating element reset	CB interrupting time + element reset time (max.) + error in tBF timer + safety margin	50 + 50 + 10 + 50 = 160 ms
CB open	CB auxiliary contacts opening/ closing time (max.) + error in tBF timer + safety margin	50 + 10 + 50 = 110 ms
Undercurrent elements	CB interrupting time + undercurrent element (max.) + safety margin operating time	50 + 25 + 50 = 125 ms

> *Note:*
> *All CB Fail resetting involves the operation of the undercurrent elements. Where element resetting or CB open resetting is used, the undercurrent time setting should still be used if this proves to be the worst case.*
> *Where auxiliary tripping relays are used, an additional 10-15ms must be added to allow for trip relay operation.*

13.5.3 SETTING GUIDELINES (UNDERCURRENT)

The phase undercurrent settings (I<) must be set less than load current to ensure that I< operation correctly indicates that the circuit breaker pole is open. A typical setting for overhead line or cable circuits is 20%In. Settings of 5%In are common for generator circuit breaker CBF.

The SEF protection and standard earth fault undercurrent elements must be set less than the respective trip setting, typically as follows:

$$ISEF< \; = (ISEF> \; trip)/2$$

$$IN< \; = (IN> \; trip)/2$$

14 BLOCKED OVERCURRENT PROTECTION

With Blocked Overcurrent schemes, you connect the start contacts from downstream IEDs to the timer blocking inputs of upstream IEDs. This allows identical current and time settings to be used on each of the IEDs in the scheme, as the device nearest to the fault does not receive a blocking signal and so trips discriminatively. This type of scheme therefore reduces the number of required grading stages, and consequently fault clearance times.

The principle of Blocked Overcurrent protection may be extended by setting fast-acting overcurrent elements on the incoming feeders to a substation, which are then arranged to be blocked by start contacts from the devices protecting the outgoing feeders. The fast-acting element is thus allowed to trip for a fault condition on the busbar, but is stable for external feeder faults due to the blocking signal.

This type of scheme provides much reduced fault clearance times for busbar faults than would be the case with conventional time-graded overcurrent protection. The availability of multiple overcurrent and earth fault stages in the Alstom Grid IEDs allows additional time-graded overcurrent protection for back-up purposes.

14.1 BLOCKED OVERCURRENT IMPLEMENTATION

Blocked Overcurrent schemes are implemented using the PSL. The start outputs, available from each stage of the overcurrent and earth fault elements (including the sensitive earth fault element) can be mapped to output relay contacts. These outputs can then be connected to the relevant timer block inputs of the upstream IEDs via opto-inputs.

14.2 BLOCKED OVERCURRENT LOGIC

To facilitate the implementation of blocked overcurrent schemes, the device provides the following logic to provide a Blocked Overcurrent Start signal **I>BlockStart**:

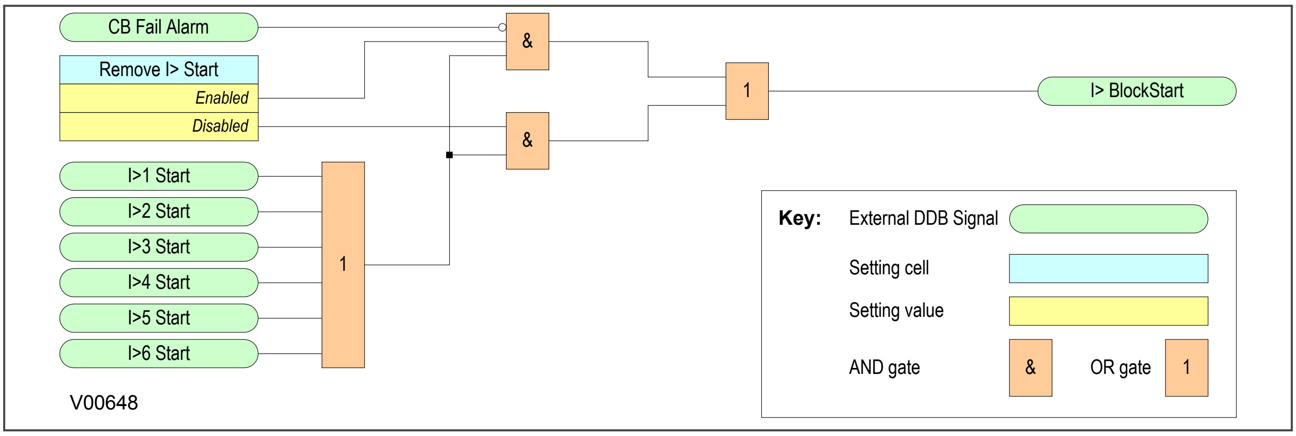


Figure 59: Blocked Overcurrent logic

The **I>BlockStart** signal is derived from the logical OR of the phase overcurrent start outputs. This output is then gated with the **CB Fail Alarm** DDB signal and the setting **Remove I>** Start setting.

14.3 BLOCKED EARTH FAULT LOGIC

To facilitate the implementation of blocked overcurrent schemes, the device provides the following logic to provide the Blocked Earth Fault signal **IN/ISEF Blk Start:**

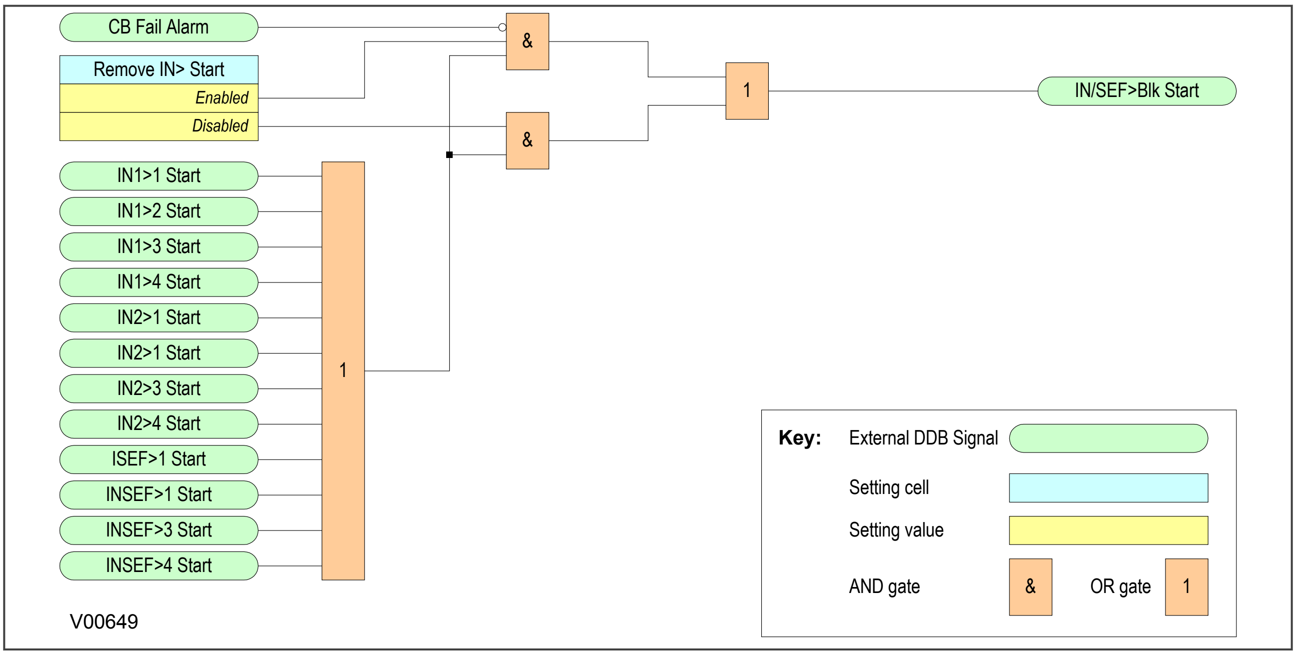


Figure 60: Blocked Earth Fault logic

The **IN/SEF Blk Start** signal is derived from the logical OR of the phase overcurrent start outputs. This output is then gated with the **CB Fail Alarm** DDB signal and the **Remove IN>** Start setting.

14.4 BLOCKED OVERCURRENT DDB SIGNALS

Ordinal	English Text	Source	Type	Response Function
Description				
150	CB Fail Alarm	Software	PSL Input	Alarm latched event
This DDB signal is an alarm indicating CB Failure				
295	I>1 Start	Software	PSL Input	Protection event
This DDB signal is the first stage any-phase Overcurrent start signal				
299	I>2 Start	Software	PSL Input	Protection event
This DDB signal is the second stage any-phase Overcurrent start signal				
303	I>3 Start	Software	PSL Input	Protection event
This DDB signal is the third stage any-phase Overcurrent start signal				
307	I>4 Start	Software	PSL Input	Protection event
This DDB signal is the fourth stage any-phase Overcurrent start signal				
315	IN1>1 Start	Software	PSL Input	Protection event
This DDB signal is the first stage measured Earth Fault start signal				
316	IN1>2 Start	Software	PSL Input	Protection event
This DDB signal is the second stage measured Earth Fault start signal				
317	IN1>3 Start	Software	PSL Input	Protection event
This DDB signal is the third stage measured Earth Fault start signal				
318	IN1>4 Start	Software	PSL Input	Protection event
This DDB signal is the fourth stage measured Earth Fault start signal				
319	IN2>1 Start	Software	PSL Input	Protection event
This DDB signal is the first stage derived Earth Fault start signal				

Ordinal	English Text	Source	Type	Response Function
Description				
320	IN2>2 Start	Software	PSL Input	Protection event
This DDB signal is the second stage derived Earth Fault start signal				
321	IN2>3 Start	Software	PSL Input	Protection event
This DDB signal is the third stage derived Earth Fault start signal				
322	IN2>4 Start	Software	PSL Input	Protection event
This DDB signal is the fourth stage derived Earth Fault start signal				
323	ISEF>1 Start	Software	PSL Input	Protection event
This DDB signal is the first stage Sensitive Earth Fault start signal				
324	ISEF>2 Start	Software	PSL Input	Protection event
This DDB signal is the second stage Sensitive Earth Fault start signal				
325	ISEF>3 Start	Software	PSL Input	Protection event
This DDB signal is the third stage Sensitive Earth Fault start signal				
326	ISEF>4 Start	Software	PSL Input	Protection event
This DDB signal is the fourth stage Sensitive Earth Fault start signal				
348	I> BlockStart	Software	PSL Input	Protection event
This DDB signal is the start signl for Blocked Overcurrent functionality				
349	IN/SEF>Blk Start	Software	PSL Input	Protection event
This DDB signal is the start signal for Blocked Earth Fault functionality				
579	I>5 Start	Software	PSL Input	Protection event
This DDB signal is the fifth stage three-phase Phase Overcurrent start signal				
583	I>6 Start	Software	PSL Input	Protection event
This DDB signal is the sixth stage three-phase Phase Overcurrent start signal				

14.5 BLOCKED OVERCURRENT SETTINGS

Menu Text	Col	Row	Default Setting	Available Options
Description				
BLOCKED O/C	45	0C		
The settings under this sub-heading relate to Blocked Overcurrent settings				
Remove I> Start	45	0D	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the Remove I>Start signal				
Remove IN> Start	45	0E	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the Remove IN>Start signal				

14.6 APPLICATION NOTES

14.6.1 BUSBAR BLOCKING SCHEME

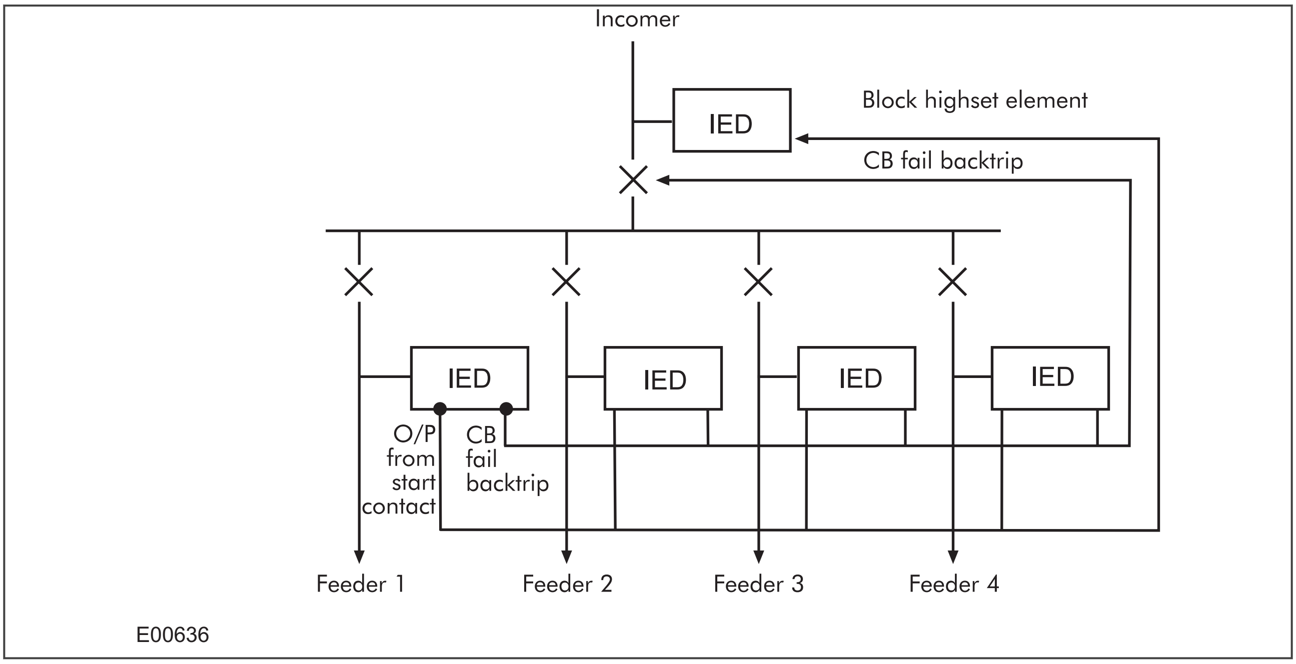


Figure 61: Simple busbar blocking scheme

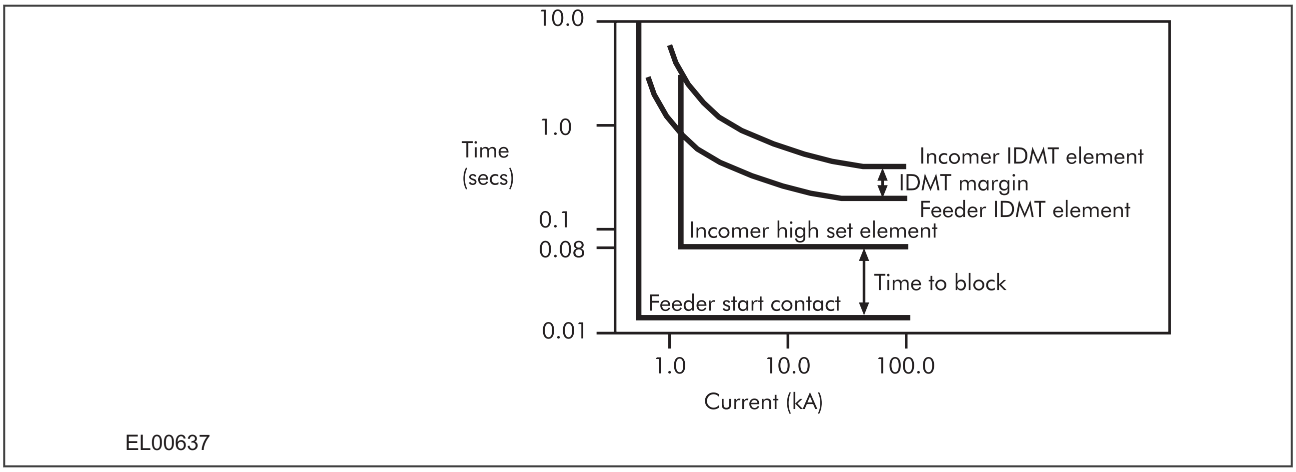


Figure 62: Simple busbar blocking scheme characteristics

15 SECOND HARMONIC BLOCKING

When a transformer is initially connected to a source of AC voltage, there may be a substantial surge of current through the primary winding called inrush current. This is analogous to the inrush current exhibited by an electric motor that is started up by sudden connection to a power source, although transformer inrush is caused by a different phenomenon.

In an ideal transformer, the magnetizing current would rise to approximately twice its normal peak value as well, generating the necessary MMF to create this higher-than-normal flux. However, most transformers are not designed with enough of a margin between normal flux peaks and the saturation limits to avoid saturating in a condition like this, and so the core will almost certainly saturate during this first half-cycle of voltage. During saturation, disproportionate amounts of MMF are needed to generate magnetic flux. This means that winding current, which creates the MMF to cause flux in the core, could rise to a value way in excess of its steady state peak value. Furthermore, if the transformer happens to have some residual magnetism in its core at the moment of connection to the source, the problem could be further exacerbated.

We can see that inrush current is a regularly occurring phenomenon and should not be considered a fault, as we do not wish the protection device to issue a trip command whenever a transformer, or machine is switched on. This presents a problem to the protection device, because it should always trip on an internal fault. The problem is that typical internal transformer faults may produce overcurrents which are not necessarily greater than the inrush current. Furthermore faults tend to manifest themselves on switch on, due to the high inrush currents. For this reason, we need to find a mechanism that can distinguish between fault current and inrush current. Fortunately this is possible due to the different natures of the respective currents. An inrush current waveform is rich in harmonics, whereas an internal fault current consists only of the fundamental. We can thus develop a restraining method based on the harmonic content of the inrush current. The mechanism by which this is achieved is called second harmonic blocking.

15.1 SECOND HARMONIC BLOCKING IMPLEMENTATION

Second harmonic blocking can be applied to the following overcurrent protection types:

- Phase Overcurrent protection (POC)
- Earth Fault protection (derived and measured) (EF1 and EF2)
- Sensitive Earth Fault protection (SEF)
- Negative Phase Sequence Overcurrent protection (NPSOC)

Second harmonic blocking is implemented in the GROUP (n) SYSTEM CONFIG column, where (n) is the number of the setting group.

Second harmonic blocking It is applicable to all stages of each of the elements. For POC, 2nd harmonic blocking can be applied to each phase individually (phase segregated), or to all three phases at once (cross-block).

The function works by identifying and measuring the inrush currents present at switch on. It does this by comparing the value of the second harmonic current components to the value of the fundamental component. If this ratio exceeds the set thresholds, then the blocking signal is generated. The threshold is defined by the **2ndHarm Thresh** setting.

We only want the function to block the protection if the fundamental current component is within the normal range. If this exceeds the normal range, then this is indicative of a fault, which must be protected. For this reason there is another settable trigger **I> lift 2H**, which when exceeded, stops the 2nd harmonic blocking function.

Each overcurrent protection element has an **I>Blocking** setting with which the type of blocking is defined. It is with this setting that phase segregated or 3-phase blocking is chosen.

The G14 Data type is used for the **I>Blocking** setting:

Bit number	I> Blocking function
Bit 0	VTS Blocks I>1
Bit 1	VTS Blocks I>2
Bit 2	VTS Blocks I>3
Bit 3	VTS Blocks I>4
Bit 4	VTS Blocks I>5
Bit 5	VTS Blocks I>6
Bit 6	AR Blocks I>3
Bit 7	AR Blocks I>4
Bit 8	AR Blocks I>6
Bit 9	2H Blocks I>1
Bit 10	2H Blocks I>2
Bit 11	2H Blocks I>3
Bit 12	2H Blocks I>4
Bit 13	2H Blocks I>5
Bit 14	2H Blocks I>6
Bit 15	2H 1PH Block

15.2 SECOND HARMONIC BLOCKING LOGIC

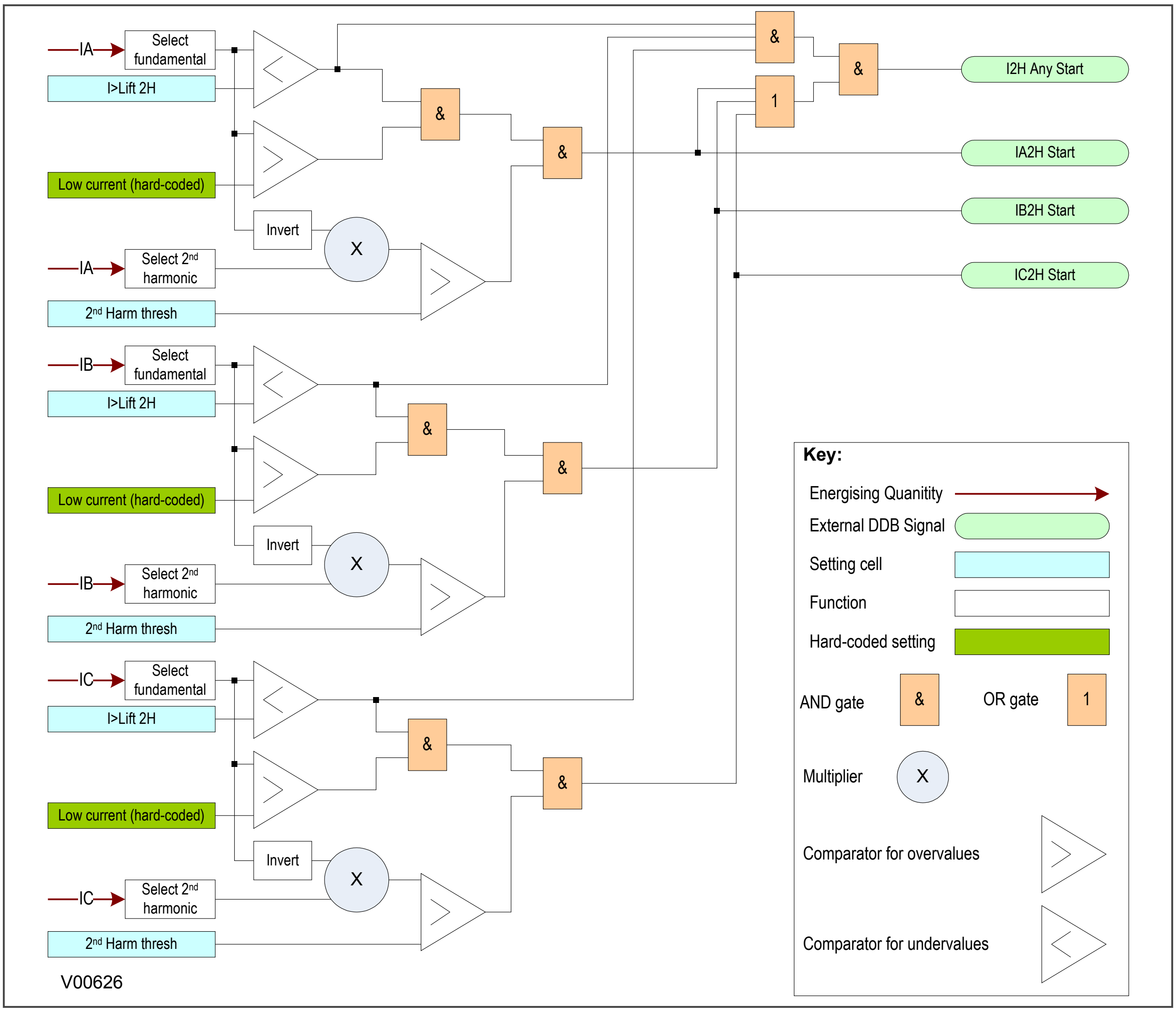


Figure 63: 2nd Harmonic Blocking Logic

15.3 SECOND HARMONIC DDB SIGNALS

Ordinal	English Text	Source	Type	Response Function
Description				
538	IA2H Start	Software	PSL Input	Protection event
This DDB signal is the A-phase 2nd Harmonic start signal				
539	IB2H Start	Software	PSL Input	Protection event
This DDB signal is the B-phase 2nd Harmonic start signal				
540	IC2H Start	Software	PSL Input	Protection event
This DDB signal is the C-phase 2nd Harmonic start signal				
541	I2H Any Start	Software	PSL Input	Protection event
This DDB signal is the 2nd Harmonic start signal for any phase				

15.4 SECOND HARMONIC SETTINGS

Menu Text	Col	Row	Default Setting	Available Options
Description				
GROUP 1 SYSTEM CONFIG	30	00		
This column contains settings for setting the phase rotation and 2nd harmonic blocking				
Phase Sequence	30	02	Standard ABC	0=Standard ABC 1=Reverse ACB
This setting sets the phase rotation to standard (ABC) or reverse (ACB). Warning: This will affect the positve and negative sequence quantities calculated by the IED as well as other functions that are dependant on phase quantities.				
2NDHARM BLOCKING	30	03		
The settings under this sub-heading relate to 2nd harmonic blocking				
2nd Harmonic	30	04	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the 2nd Harmonic blocking of the overcurrent protection.				
2ndHarm Thresh	30	05	20	From 5% to 70% step 1
This setting sets the lower threshold for 2nd harmonic blocking in percent. If the 2nd harmonic component exceeds this threshold, the overcurrent protection will be blocked.				
I>lift 2H	30	06	10	From 4A to 32A step 0.01
This setting sets the upper threshold for 2nd harmonic blocking in amps If the 2nd harmonic exceeds this threshold, there wil be no blocking applied.				

15.5 APPLICATION NOTES

15.5.1 SETTING GUIDELINES

During the energization period, the second harmonic component of the inrush current may be as high as 70%. The second harmonic level may be different for each phase, which is why phase segregated blocking is available.

If the setting is too low, the 2nd harmonic blocking may prevent tripping during some internal transformer faults. If the setting is too high, the blocking may not operate for low levels of inrush current which could result in undesired tripping of the overcurrent element during the energization period. In general, a setting of 15% to 20% is suitable.

16 LOAD BLINDERS

Load blinding is a mechanism, whereby IEDs are prevented from tripping under heavy load, but healthy conditions. In the past this mechanism was mainly used for transmission systems and was rarely needed at distribution voltage levels. In the last few years, however, distribution networks have become more subject to periods of sustained heavy loads. This is due to a number of reasons, one of which is the increase of distributed generation. For this reason, it has become very desirable to equip overcurrent IEDs, normally targeted at distribution networks, with load blinding functionality.

Load blinders work by measuring, not only the system current levels, but also the system voltage levels and making tripping decisions based on analysis of both of these measurements. This is known as Impedance measurement.

When the measured current is higher than normal, this can be caused by one of two things; either a fault or a heavy load. If the cause is a fault, the system voltage level will reduce significantly. However, if the cause is a heavy, but healthy load, the voltage will not decrease significantly. Therefore, by measuring the both the system voltage and currents, the IED can make a decision not to trip under heavy load conditions.

The principle of a load blinder is to configure a blinder envelope, which surrounds the expected worst case load limits, and to block tripping for any impedance measured within this blinder region. Only fault impedance outside the load area is allowed to cause a trip. It is possible to set the impedance and angle setting independently for the forward and reverse regions in the Z plane.

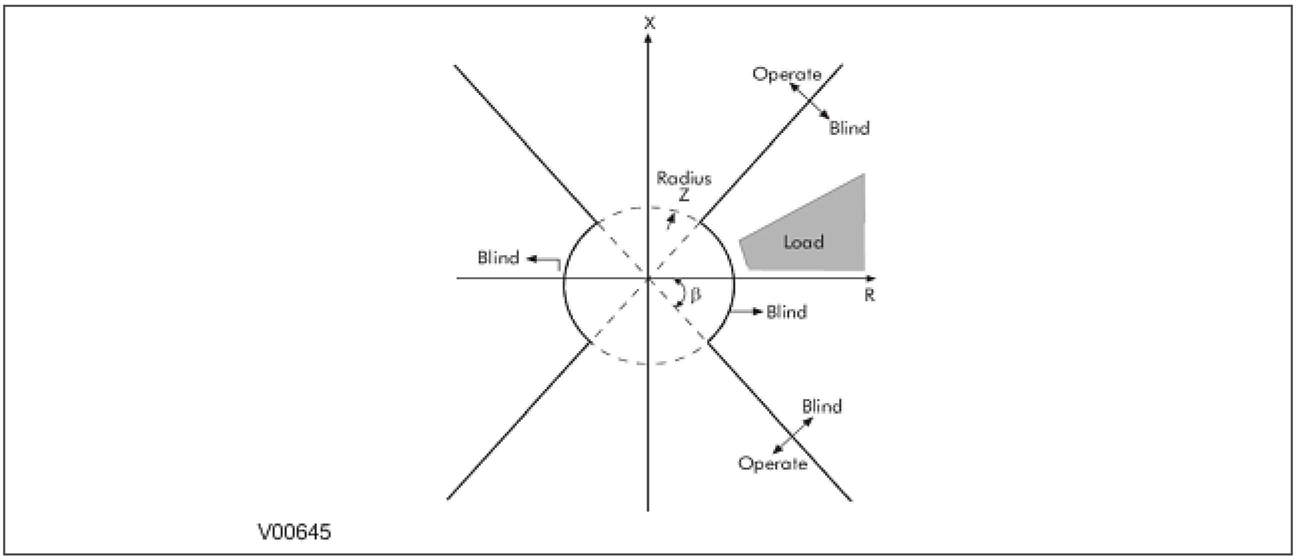


Figure 64: Load blinder and angle

16.1 LOAD BLINDER IMPLEMENTATION

The Load blinder function is implemented in the OVERCURRENT column of the relevant settings group, under the sub-heading LOAD BLINDER.

The settings allow you to set the impedance and angle limits for both reverse and forward directions, the undervoltage and negative sequence current thresholds for blocking the function, and the operation mode.

There are two modes of operation; single phase and three phase;

The single phase mode uses the normal impedance (Z) of each phase. When single phase mode is selected, the overcurrent blocking is phase segregated and is dependant on the individual overcurrent settings per phase. In single phase mode, only the undervoltage threshold (**Blinder V<Block**) can block the function.

The three phase mode uses positive sequence impedance (Z1). The three phase mode uses both the negative sequence overcurrent threshold (**Blinder I2>Block**) and the undervoltage threshold (**Blinder V<Block**) to block the function.

16.2 LOAD BLINDER LOGIC

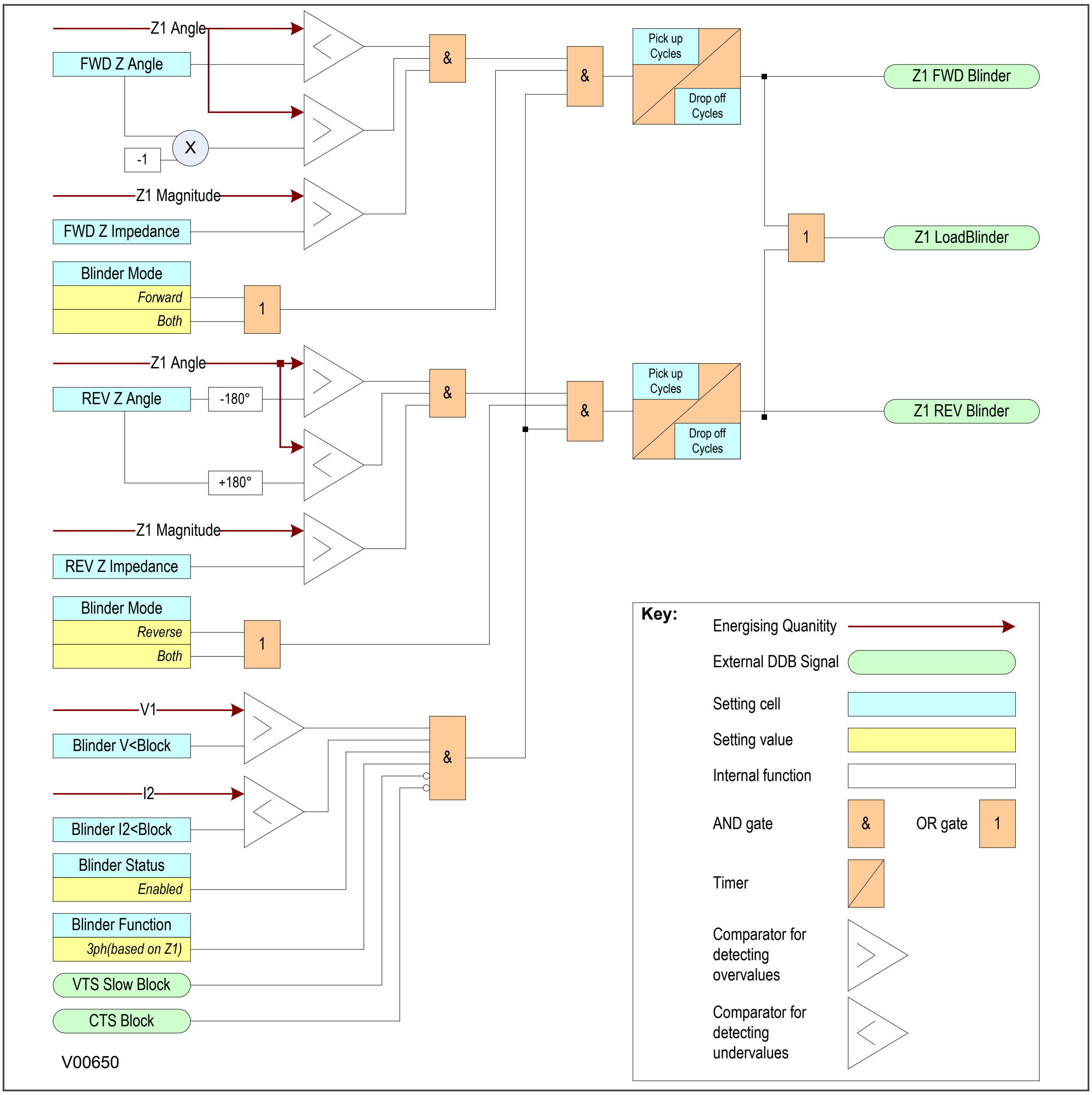


Figure 65: Load Blinder logic 3phase

For the forward direction, the positive sequence impedance magnitude is compared with a set value, and the positive sequence impedance angle is compared with two values, which define the angular range. If the criteria are satisfied and the Blinder mode is in the direction Forward or Both, the blinder signals **Z1 FWD Blinder** and **Z1 LoadBlinder** are produced.

For the reverse direction, the positive sequence impedance magnitude is compared with a set value, and the positive sequence impedance angle is compared with two values, which define the angular range. If the criteria are satisfied and the Blinder mode is in the direction Forward or Both, the blinder signals **Z1 REV Blinder** and **Z1 LoadBlinder** are produced.

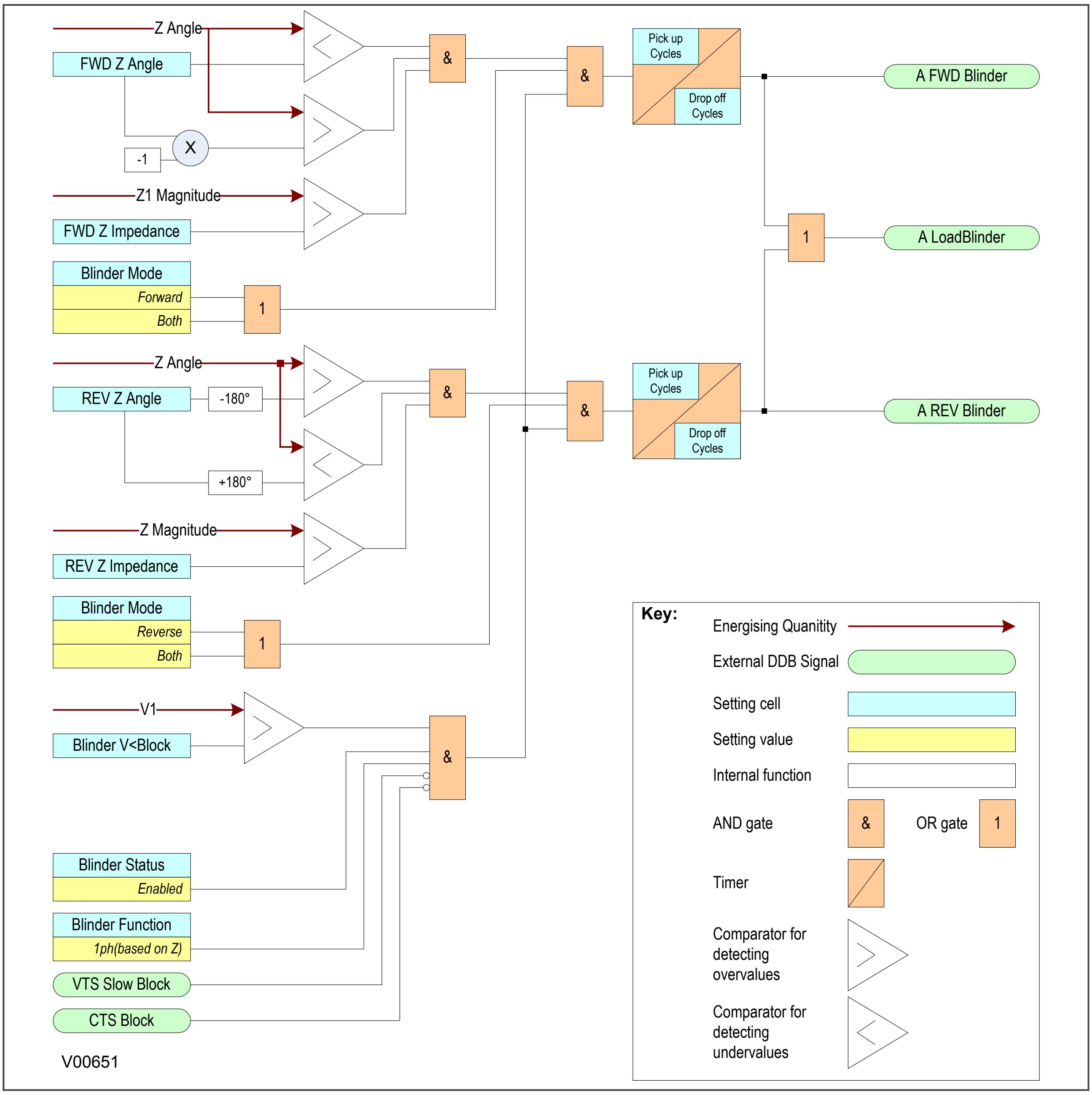


Figure 66: Load Blinder logic phase A

The diagram shows the single-phase Load Blinder logic for phase A. The same principle applies to phases B and C. The single phase Load Blinder logic is very similar to the three-phase Load Blinder logic. The main differences are:

The single-phase function does not use positive sequence impedance, it uses normal impedance measurment. It also does not use negative sequence overcurrent to block the function.

16.3 LOAD BLINDER DDB SIGNALS

Ordinal	English Text	Source	Type	Response Function
Description				
351	VTS Slow Block	Software	PSL Input	No response
This DDB signal is a purposely delayed output from the VTS which can block other functions				
352	CTS Block	Software	PSL Input	No response
This DDB signal is an instantaneously blocking output from the CTS which can block other functions				
627	Blinder Inhibit	Programmable Scheme Logic	PSL Output	Protection event
This DDB signal inhibits the Load Blinder function				
628	A FWD Blinder	Software	PSL Input	Protection event
This DDB signal is the Phase A Load Blinder signal for the forward direction				
629	A REV Blinder	Software	PSL Input	Protection event
This DDB signal is the Phase A Load Blinder signal for the reverse direction				
630	A LoadBlinder	Software	PSL Input	Protection event
This DDB signal is the Phase A Load Blinder signal, either direction				
631	B FWD Blinder	Software	PSL Input	Protection event
This DDB signal is the Phase B Load Blinder signal for the forward direction				
632	B REV Blinder	Software	PSL Input	Protection event
This DDB signal is the Phase B Load Blinder signal for the reverse direction				
633	B LoadBlinder	Software	PSL Input	Protection event
This DDB signal is the Phase B Load Blinder signal, either direction				
634	C FWD Blinder	Software	PSL Input	Protection event
This DDB signal is the Phase C Load Blinder signal for the forward direction				
635	C REV Blinder	Software	PSL Input	Protection event
This DDB signal is the Phase C Load Blinder signal for the reverse direction				
636	C LoadBlinder	Software	PSL Input	Protection event
This DDB signal is the Phase C Load Blinder signal, either direction				
637	Z1 FWD Blinder	Software	PSL Input	Protection event
This DDB signal is the 3-phase Load Blinder signal for the forward direction				
638	Z1 REV Blinder	Software	PSL Input	Protection event
This DDB signal is the 3-phase Load Blinder signal for the reverse direction				
639	Z1 LoadBlinder	Software	PSL Input	Protection event
This DDB signal is the 3-phase Load Blinder signal, either direction				

16.4 LOAD BLINDER SETTINGS

Menu Text	Col	Row	Default Setting	Available Options
Description				
LOAD BLINDER	35	90		
The settings under this sub-heading relate to the Load Blinder function				
Blinder Status	35	91	Disabled	0 = Disabled, 1 = Enabled
This setting enables or disables the Load Blinder blocking function.				
Blinder Status	35	91	Disabled	0 = Disabled

Menu Text	Col	Row	Default Setting	Available Options
Description				
This setting disables the Load Blinder blocking function for models B and G				
Blinder Function	35	92	3Ph(based on Z1)	0=3Ph(based on Z1) 1=1Ph(based on Z)
This setting sets the Load Blinder to three-phase or single-phase blocking.				
Blinder Mode	35	93	Both	0=Reverse 1=Forward 2=Both
This setting sets the Load Blinder direction measurement.				
FWD Z Impedance	35	94	15	From 0.1 to 500 step 0.01
This setting sets the Forward Impedance (in ohms) for the Load Blinder function.				
FWD Z Angle	35	95	30	From 5 to 85 step 1
This setting sets the Forward Angle (in degrees) for the Looad Blinder function.				
RVS Z Impedance	35	97	15	From 0.1 to 500 step 0.01
This setting sets the Reverse Impedance (in ohms) for the Load Blinder function.				
RVS Z Angle	35	98	30	From 5 to 85 step 1
This setting sets the Reverse Angle (in degrees) for the Looad Blinder function.				
Blinder V< Block	35	9A	15	From 10 to 120 step 1
This setting sets the undervoltage threshold for the Load Blinder function.				
Blinder I2>Block	35	9B	0.2	From 0.08*I1 to 4*I1 step 0.01*I1
This setting sets the Negative Phase Sequence current threshold for the Load Blinder function.				
PU Cycles	35	9C	1	From 0 to 50 step 0.5
This setting sets the pick-up count threshold for the Load Blinder function.				
DO Cycles	35	9D	1	From 0 to 50 step 0.5
This setting sets the drop-off count threshold for the Load Blinder function.				

17 HIGH IMPEDANCE FAULT DETECTION

A High Impedance Fault, also known as a *Downed Conductor*, happens when a primary conductor makes unwanted electrical contact with a road surface, pathway, tree etc., whereby due to the high impedance of the fault path, the fault current is restricted to a level below that which can be reliably detected by standard overcurrent devices. Even in cases where the instantaneous fault current may exceed the thresholds, the duration of this transient is usually so small that the standard overcurrent IED will not pick up. It is quite a challenging problem to detect such faults, and it requires a special method combining multiple techniques.

Due to the high impedance and transient nature of such faults it is not possible to derive the fault calculation from short-circuit computing. HIF detection therefore relies on the detection of the fault current and voltage waveform signatures. These waveforms may be very different from fault to fault, but they often have commonalities typified by:

- Third harmonic content
- The transient bursting (intermittent change of amplitude)

We can use these phenomena to detect the fault.

We may need to establish the direction of the fault. For this, we can use instantaneous power measurement. Hence we can see there are three components necessary to provide a reliable HIF detection function:

- Component harmonic Analysis (CHA)
- Fundamental Analysis (FA) (with or without directional analysis (DIR)

17.1 HIGH IMPEDANCE FAULT PROTECTION IMPLEMENTATION

17.1.1 FUNDAMENTAL ANALYSIS

Fundamental Analysis (FA) captures the intermittent characteristics associated with a fault current. Generally, the system current is fairly stable and it tracks the load conditions. An average of this current is calculated by continually averaging the latest samples, and this value is stored in a buffer. This value is being continually compared with latest current value. If there is a sudden increase in current, its value will significantly exceed the average value. It is this increment that is used to start the fault evaluation process.

The averaged current load tracks system load conditions using an averaging process. A discrepancy between the actual amplitude and the average amplitude starts the fault evaluation process. If the increment is greater than a start threshold, determined by the setting **FA> Start Thresh**, the FA will start fault evaluation. A Burst Valid (BV) threshold, determined by the setting **FA> Burst Thresh**, is used to judge whether the increment indicates conduction of fault current. By counting the changes of the BV states within a time window, an event is issued and it is possible to establish whether an intermittent fault has been detected.

FA detection can be triggered by any sudden increase of the amplitude. However, only those sustained series of changes within a specified time-window can be evaluated as a High Impedance Fault (HIF). Fault classification criteria can be determined using timing and counting of these bursts. The following table shows the classification criteria.

Counter Status	Timer Status	Result
BV state changes exceed count limit	Within time window of one FA section	HIF
BV stage changes do not exceed count limit, but are more than two	Within time window of one FA section	Transient Event
Less than two changes	While fundamental amplitude remains above BV threshold within time window	Steady Event
Others		Noises

17.1.2 COMPONENT HARMONIC ANALYSIS

The Component Harmonic Analysis (CHA) function monitors the measured SEF current, compares this with the average current value and uses the increment of the sampled value to extract the 3rd harmonic component. By evaluating the phase and amplitude differences between the fundamental and the third harmonic, it is possible to establish criteria, which can help determine the presence of a High Impedance Fault.

> *Note:*
> *CHA is ONLY applicable in directly grounded or lower to medium resistance grounded systems.*

An array of increment samples is obtained and used to calculate the fault characteristic. A so called Satisfied State (SS) is a value that meets the criteria to indicate HIF non-linearity. Fault evaluation and classification are mainly based on measuring the duration of the Satisfied State. The fault evaluation process can be triggered internally or externally.

The criteria determining non-linearities characteristic of high impedance faults consists of the following:

- The fundamental amplitude is above a set threshold (setting **CHA> Fund Thresh**)
- The phase difference between 3rd harmonic and fundamental is within a range around 180° (settings **CHA Del Ang180-x** and **CHA Del Ang180+x**)
- The amplitude ratio between 3rd harmonic and fundamental is above a set threshold (setting **CHA> 3rdharmThrsh**) and not above 90% of the fundamental.
- The above requirements last for a significant time duration.

The CHA function detects a fault by timing the duration of the Satisfied State (SS). If this time duration is longer than the HIF Setting time, a HIF event is reported. If the time duration is shorter, but still longer than a Transient Setting time, a Transient event is reported.

Harmonic State	SS Timer Status	Result
Persisting Satisfied State	Lasts for HIF duration setting (CHA tDuration)	HIF established
Intermittent Satisfied State	Lasts for transient setting time (CHA tTransient)	Transient Event established
Others		Noises

Similar to Fundamental Analysis, a Transient Event needs further confirmation. Three individual timers are activated once the CHA function starts.

- A reset timer is used to reset all the procedures of CHA.
- A HIF duration timer is used to measure the duration of this Satisfied State to issue HIF.
- A Transient timer is used to detect any transient event:

If the Satisfied State lasts for the entire time duration set by the HIF timer, an HIF is reported and all procedures are reset.

If the Satisfied State lasts for less then the HIF duration but is still more than the Transient time duration, a Transient Suspicion event is reported and the detection process will evaluate another section. If any HIF requirement is satisfied within the reset time, a HIF is reported and the detection is reset.

If there are more than three Transient Suspicion events reported within the reset time, a HIF is reported.

17.1.3 DIRECTIONAL ANALYSIS

The described FA algorithm has no capability of detecting direction. It can be used in a system with limited capacitance, or a system with directly grounded neutral point. In these cases, the fault current on healthy lines are limited. However, when a system is resistance-grounded with a relatively large distributed capacitance, the fault-generated transient may be distributed along both healthy and faulted lines due to the large distributed capacitance. Therefore, a directional element is needed to enhance the FA performance.

Transient directionality is obtained by using the instantaneous power direction of the fault component. The instantaneous power is calculated directly from the samples of the fault component. In Transient situations, this is a more accurate method than using phasor based power calculations .

The fault component circuit is used for analysis. The source is the fault itself. The capacitive branch produces the reactive power while the inductance branch absorbs the reactive power. The resistance branch absorbs the active power. The active power is from the source. The reactive power from the source balances the total consumption of the reactive power by the other part of the circuit.

	Resistor in Neutral		Peterson Coil in Neutral		Isolated	
	Faulty Line	Healthy Line	Faulty Line	Healthy Line	Faulty Line	Healthy Line
P	Rev	Fwd	Rev	Fwd	Rev	Fwd
Q	Fwd	Rev	-	-	Fwd	Rev

Generally, the reactive power is more distinctive, since the distributed capacitance is often greater than the distributed conductance. Therefore, in resistance-grounded or isolated systems, the reactive power direction is used for transient direction detection.

In Peterson coil grounded systems, the active power direction is used to detect the direction because the Peterson coil distorts the reactive power flow.

The output of the direction detection function (DIR) are flags indicating the fault direction: **FA DIR Forward** and **FA DIR Reverse**.

These flags are set if the algorithm is in the Start stage and the criteria have been met. The FA function uses the flag status to determine whether it is a forward fault or a reverse fault. An alarm can also be set to indicate the faulted line. When counting a spike into the FA function's counter, the FA first refers to the direction flag. Only spikes with forward direction (Forward transient) are counted for fault evaluation.

17.1.4 SUMMARY

The type of High Impedance Fault detection solution should be selected according to the different system grounding conditions. The solution consists of two major algorithms and a facility algorithm that forms a matrix to cover these different conditions.

CHA detects situations where there is a continuous earth fault harmonic. CHA should only be used for directly grounded or low resistance grounded system.

FA detects intermittent faults where the fault current is changing between conducting and non-conducting. This can be used in any system grounding conditions. However, a continuous fault will only be detected as a steady event. The solution matrix is as follows:

	Solid	Resistor	Peterson Coil	Isolated
FA+DIR(Active P)	Applicable	Applicable	Recommended	Applicable
FA+DIR(Reactive Q)	Applicable	Recommended	Not applicable	Recommended
FA (non DIR)	Recommended	Not applicable	Not applicable	Not applicable
CHA	Recommended	Recommended	Not applicable	Not applicable
Recommended Solution	CHA+FA	CHA+FA+DIR(Q)	FA+DIR(P)	FA+DIR(Q)

17.2 HIGH IMPEDANCE FAULT PROTECTION LOGIC

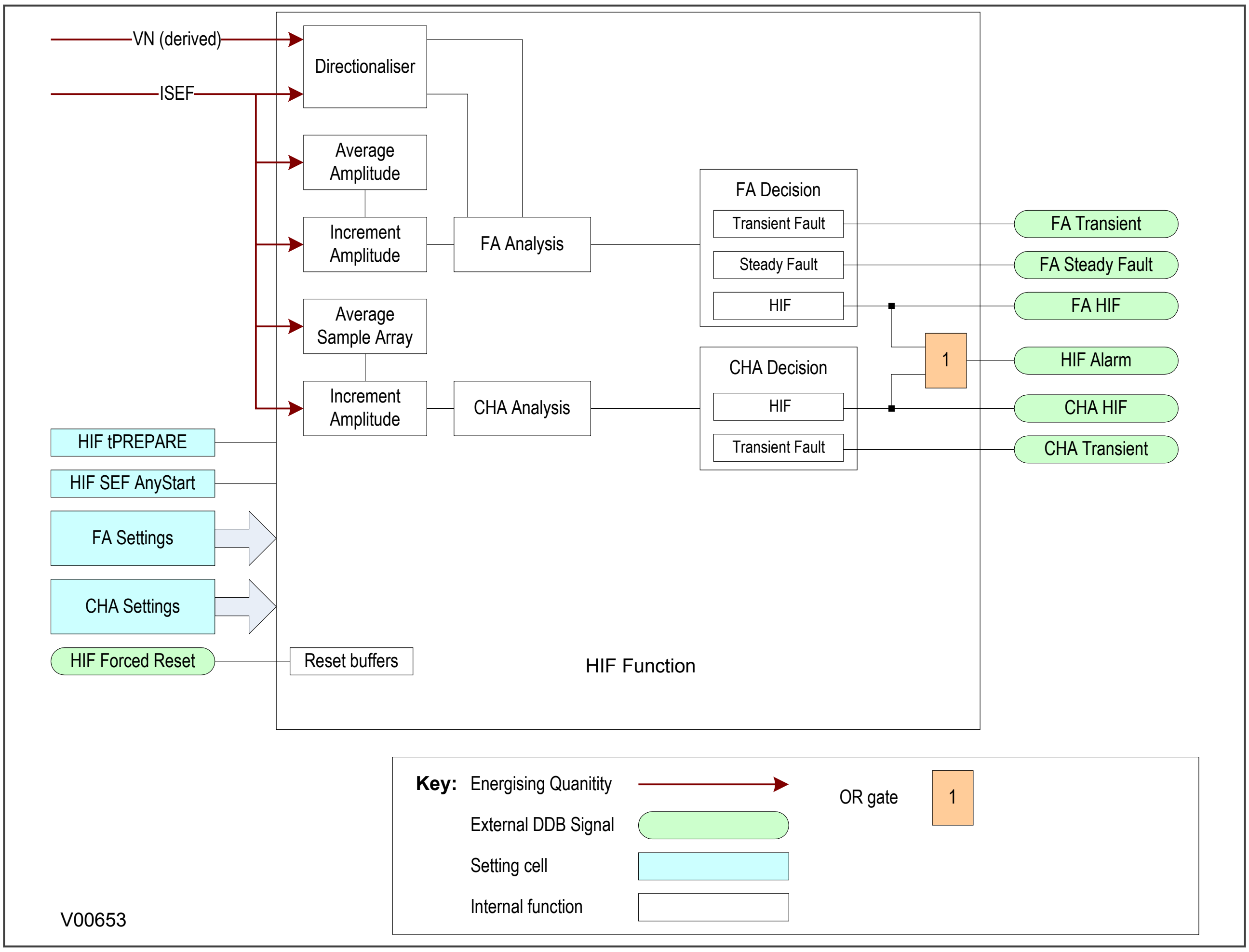


Figure 67: HIF Protection Logic

17.3 HIGH IMPEDANCE PROTECTION DDB SIGNALS

Ordinal	Signal Name	Source	Type	Response
Description				
1209	HIF Alarm	Software	PSL Input	Alarm latched event
This DDB signal indicates that the High Impedance Fault Alarm is active				
1210	FA HIF	Software	PSL Input	Protection event
This DDB signal indicates that Fundamental Analysis has detected a high impedance fault				
1211	FA Transient	Software	PSL Input	Protection event
This DDB signal indicates that Fundamental Analysis has detected a Transient Event				
1212	FA Steady Fault	Software	PSL Input	Protection event
This DDB signal indicates that Fundamental Analysis has detected a steady state Fault				
1213	CHA HIF	Software	PSL Input	Protection event
This DDB signal indicates that Component Harmonic Analysis has detected a high impedance fault				
1214	CHA Transient	Software	PSL Input	Protection event
This DDB signal indicates that Component Harmonic Analysis has detected a Transient Event				

Ordinal	Signal Name	Source	Type	Response
Description				
1216	HIF Forced Reset	Programmable Scheme Logic	PSL Output	No response
This DDB signal forces a HIF Reset				

17.4 HIGH IMPEDANCE PROTECTION SETTINGS

Menu Text	Col	Row	Default Setting	Available Options
Description				
GROUP 1 HIF DETECTION	4C	00		
This column contains settings for High Impedance Fault Detection				
HIF SEF AnyStart	4C	01	Disabled	0 = Disabled or 1 = Enabled
This setting allows the ISEF> Any Start DDB signal to trigger the HIF detection				
HIF tPREPARE	4C	02	2	From 0.03s to 30s step 0.01s
This setting sets the preparation time required to produce the initial data, such as the average amplitude value.				
FUNDAMENT.ANALYS	4C	05		
This sub-heading contains settings for the Fundamental Analysis (FA) algorithm.				
FA Status	4C	06	Enabled	0 = Disabled or 1 = Enabled
This setting enables or disables Fundamental Analysis.				
FA> Start Thresh	4C	07	0.01	From 0.00025A to 2A step 0.00025A
This setting defines the Fundamental Analysis increment Start threshold. The FA algorithm starts the evaluation process when the current increments exceeds this threshold.				
AdaptBurstThresh	4C	08	Enabled	0 = Disabled or 1 = Enabled
This setting enables or disables the Adaptive Burst Threshold setting. When enabled, the Burst Threshold is adapted automatically.				
FA> Burst Thresh	4C	09	0.05	From 0.00025A to 2A step 0.00025A
This setting defines the Burst Valid threshold. When the measured current amplitude exceeds this threshold, a valid burst is recognised.				
FA tAVERAGE	4C	0A	10	From 1s to 60s step 1s
This setting defines the time duration window for calculating the average value.				
FA tINTERMITTENT	4C	0B	2	From 0.5s to 5s step 0.5s
This setting defines the time duration in which the Burst Valid shots are counted for a HIF to be recognised.				
FA tRESET	4C	0C	10	From 10s to 60s step 5s
This setting defines the reset time for the FA evaluation process.				
FA> Burst Count	4C	0D	8	From 3 to 30 step 1
This setting sets the number of burst valid shots which is used to determine a HIF condition.				
FA Trans Sec Lmt	4C	0E	3	From 1 to 10 step 1
This setting sets the number of sections which are evaluated for determining a FA transient event.				
FA DIR Status	4C	10	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables FA Direction Detection.				
FA DIR P or Q	4C	11	Reactive Q	0=Active P 1=Reactive Q
This setting determines whether real power (P) or reactive power (Q) is to be used for detection.				
FA DIR>Power Fwd	4C	12	1	From 0.05 watts to 100 watts in steps of 0.05 watts
This setting defines the power value threshold for a forward event.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
FA DIR>Power Rev	4C	13	-1	From -100 watts to -0.05 watts in steps of 0.05 watts
This setting defines the power value threshold for a reverse event.				
FA DIR AutoThrsh	4C	14	Enabled	0 = Disabled or 1 = Enabled
This setting enables or disables the auto-adjust power threshold.				
COMP.HARM.ANALYS	4C	20		
This sub-heading contains settings for the Component Harmonic Analysis (CHA) algorithm.				
CHA Status	4C	21	Enabled	0 = Disabled or 1 = Enabled
This setting enables or disables CHA.				
CHA> Fund Thresh	4C	22	0.01	From 0.00025A to 2A step 0.00025A
This setting defines the CHA amplitude threshold.				
CHA>3rdHarmThrsh	4C	23	2	From 0.5% to 70% step 0.5%
This setting defines the amplitude ratio (3Harmonic to fundamental).				
CHA Del Ang180-x	4C	24	85	From 0deg to 90deg step 1deg
This setting sets the lower angle boundary of the phase angle between third harmonic and fundamental.				
CHA Del Ang180+x	4C	25	0	From 0deg to 90deg step 1deg
This setting sets the upper angle boundary of the phase angle between third harmonic and fundamental.				
CHA tAVERAGE	4C	26	20	From 5s to 60s step 1s
This setting defines the time duration window for calculating the average value.				
CHA tTRANSIENT	4C	27	0.2	From 0.04s to 1s step 0.02s
This setting defines the time duration for determining a transient event				
CHA tDURATION	4C	28	2	From 1s to 5s step 1s
This setting defines the time duration for determining a HIF condition.				
CHA tRESET	4C	29	10	From 10s to 30s step 5s
This setting defines the reset time for the CHA evaluation process.				
CHA Trans SecLmt	4C	2A	3	From 1 to 10 step 1
This setting sets the number of sections which are evaluated for determining a CHA transient event.				

18 CURRENT TRANSFORMER REQUIREMENTS

The current transformer requirements are based on a maximum fault current of 50 times the rated current (In) with the device having an instantaneous overcurrent setting of 25 times the rated current. The current transformer requirements are designed to provide operation of all protection elements.

Where the criteria for a specific application are in excess of this, or the lead resistance exceeds the limiting lead resistance shown in the following table, the CT requirements may need to be modified according to the formulae in the subsequent sections:

Nominal Rating	Nominal Output	Accuracy Class	Accuracy Limited Factor	Limiting Lead Resistance
1A	2.5VA	10P	20	1.3 ohms
5A	7.5VA	10P	20	0.11 ohms

The formula subscripts used in the subsequent sections are as follows:

V_K = Required CT knee-point voltage (volts)

I_f = Maximum through-fault current level (amps)

I_{fn} = Maximum prospective secondary earth fault current (amps)

I_{fp} = Maximum prospective secondary phase fault current (amps)

I_{cn} = Maximum prospective secondary earth fault current or 31 times I> setting (whichever is lower) (amps)

I_{cp} = Maximum prospective secondary phase fault current or 31 times I> setting (whichever is lower) (amps)

I_n = Rated secondary current (amps)

I_{sn} = Stage 2 & 3 earth fault setting (amps)

I_{sp} = Stage 2 and 3 setting (amps)

R_{CT} = Resistance of current transformer secondary winding (ohms)

R_L = Resistance of a single lead from relay to current transformer (ohms)

R_p = Impedance of the phase current input at 30In (ohms)

R_n = Impedance of the neutral current input at 30In (ohms)

R_{st} = Value of stabilising resistor for REF applications (ohms)

I_s = Current setting of REF elements (amps)

18.1 OVERCURRENT AND EARTH FAULT PROTECTION

18.1.1 DIRECTIONAL ELEMENTS

Time-delayed phase overcurrent elements

$$V_K = \frac{I_{cp}}{2}(R_{CT} + R_L + R_p)$$

Instantaneous phase overcurrent elements

$$V_K = \frac{I_{fp}}{2}(R_{CT} + R_L + R_p)$$

Instantaneous earth fault overcurrent elements

$$V_K = \frac{I_{fn}}{2}(R_{CT} + 2R_L + R_p + Rn)$$

18.1.2 NON-DIRECTIONAL ELEMENTS

Time-delayed phase overcurrent elements

$$V_K = \frac{I_{cp}}{2}(R_{CT} + R_L + R_p)$$

Time-delayed earth fault overcurrent elements

$$V_K = \frac{I_{cn}}{2}(R_{CT} + 2R_L + R_p + R_n)$$

Instantaneous phase overcurrent elements

$$V_K = I_{sp}(R_{CT} + R_L + R_p)$$

Instantaneous earth fault overcurrent elements

$$V_K = I_{sn}(R_{CT} + 2R_L + R_p + R_n)$$

18.2 SEF PROTECTION (RESIDUALLY CONNECTED)

18.2.1 DIRECTIONAL ELEMENTS

Time delayed SEF protection

$$V_K \geq \frac{I_{cn}}{2}(R_{CT} + 2R_L + R_p + Rn)$$

Instantaneous SEF protection

$$V_K \geq \frac{I_{fn}}{2}(R_{CT} + 2R_L + R_p + Rn)$$

18.2.2 NON-DIRECTIONAL ELEMENTS

Time delayed SEF protection

$$V_K \geq \frac{I_{cn}}{2}(R_{CT} + 2R_L + R_p + Rn)$$

Instantaneous SEF protection

$$V_K \geq \frac{I_{sn}}{2}(R_{CT} + 2R_L + R_p + Rn)$$

18.3 SEF PROTECTION (CORE-BALANCED CT)

18.3.1 DIRECTIONAL ELEMENTS

Instantaneous element

$$V_K \geq \frac{I_{fn}}{2}(R_{CT} + 2R_L + Rn)$$

Note:
Ensure that the phase error of the applied core balance current transformer is less than 90 minutes at 10% of rated current and less than 150 minutes at 1% of rated current.

18.3.2 NON-DIRECTIONAL ELEMENTS

Time delayed element

$$V_K \geq \frac{I_{cn}}{2}(R_{CT} + 2R_L + Rn)$$

Instantaneous element

$$V_K \geq I_{sn}(R_{CT} + 2R_L + Rn)$$

Note:
Ensure that the phase error of the applied core balance current transformer is less than 90 minutes at 10% of rated current and less than 150 minutes at 1% of rated current.

18.4 LOW IMPEDANCE REF PROTECTION

For X/R < 40 and $I_f < 15I_n$

$$V_K \geq 24I_n(R_{CT} + 2R_L)$$

For 40 < X/R < 120 and $15I_n$ < If < $40I_n$

$$V_K \geq 48I_n(R_{CT} + 2R_L)$$

> *Note:*
> *Class x or Class 5P CTs should be used for low impedance REF applications.*

18.5 HIGH IMPEDANCE REF PROTECTION

The high impedance REF element will maintain stability for through-faults and operate in less than 40ms for internal faults, provided the following equations are met:

$$R_{st} = \frac{I_f (R_{CT} + 2R_L)}{I_s}$$

$$V_K \geq 4 I_s R_{st}$$

> *Note:*
> *Class x CTs should be used for high impedance REF applications.*

18.6 USE OF ANSI C-CLASS CTS

Where American/IEEE standards are used to specify CTs, the C class voltage rating can be used to determine the equivalent knee point voltage according to IEC. The equivalence formula is:

$$V_K = 1.05(C\,rating\,in\,volts) + 100R_{CT}$$

VOLTAGE & FREQUENCY PROTECTION FUNCTIONS

CHAPTER 6

1 CHAPTER OVERVIEW

The P14D provides a wide range of voltage and frequency protection functions. This chapter describes the operation of these functions including the principles, logic diagrams and applications.

This chapter contains the following sections:

2 UNDERVOLTAGE PROTECTION

Undervoltage conditions may occur on a power system for a variety of reasons, some of which are outlined below:

- Undervoltage conditions can be related to increased loads, whereby the supply voltage will decrease in magnitude. This situation would normally be rectified by voltage regulating equipment such as AVRs (Auto Voltage Regulators) or On Load Tap Changers. However, failure of this equipment to bring the system voltage back within permitted limits leaves the system with an undervoltage condition, which must be cleared.
- If the regulating equipment is unsuccessful in restoring healthy system voltage, however, then tripping by means of an undervoltage element is required.
- Faults occurring on the power system result in a reduction in voltage of the faulty phases. The proportion by which the voltage decreases is dependent on the type of fault, method of system earthing and its location. Consequently, co-ordination with other voltage and current-based protection devices is essential in order to achieve correct discrimination.
- Complete loss of busbar voltage. This may occur due to fault conditions present on the incomer or busbar itself, resulting in total isolation of the incoming power supply. For this condition, it may be necessary to isolate each of the outgoing circuits, such that when supply voltage is restored, the load is not connected. Therefore, the automatic tripping of a feeder on detection of complete loss of voltage may be required. This can be achieved by a three-phase undervoltage element.
- Where outgoing feeders from a busbar are supplying induction motor loads, excessive dips in the supply may cause the connected motors to stall, and should be tripped for voltage reductions that last longer than a pre-determined time.

2.1 UNDERVOLTAGE PROTECTION IMPLEMENTATION

Undervoltage Protection is implemented in the VOLT PROTECTION column of the relevant settings group. The Undervoltage parameters are contained within the sub-heading UNDERVOLTAGE.

The product provides three stages of Undervoltage protection with independent time delay characteristics.

Stages 1 and 3 provide a choice of operate characteristics, where you can select between:

- An IDMT characteristic
- DT (Definite Time)

You set this using the **V<1 Function** and **V<3 Function** cells depending on the stage.

The IDMT characteristic is defined by the following formula:

$$t = K/(M-1)$$

where:

- K = Time multiplier setting
- t = Operating time in seconds
- M = Measured voltage / IED setting voltage (**V< Voltage Set**)

The undervoltage stages can be configured either as phase-to-neutral or phase-to-phase voltages in the **V< Measure't mode** cell.

There is no Timer Hold facility for Undervoltage.

Stage 2 can have definite time characteristics only. This is set in the **V<2** status cell.

Three stages are included in order to provide multiple output types, such as alarm and trip stages. Alternatively, different time settings may be required depending upon the severity of the voltage dip. For example, motor loads will be able to cope with a small voltage dip for a longer time than a major one.

Outputs are available for single or three-phase conditions via the **V<Operate Mode** cell for each stage.

2.2 UNDERVOLTAGE PROTECTION LOGIC

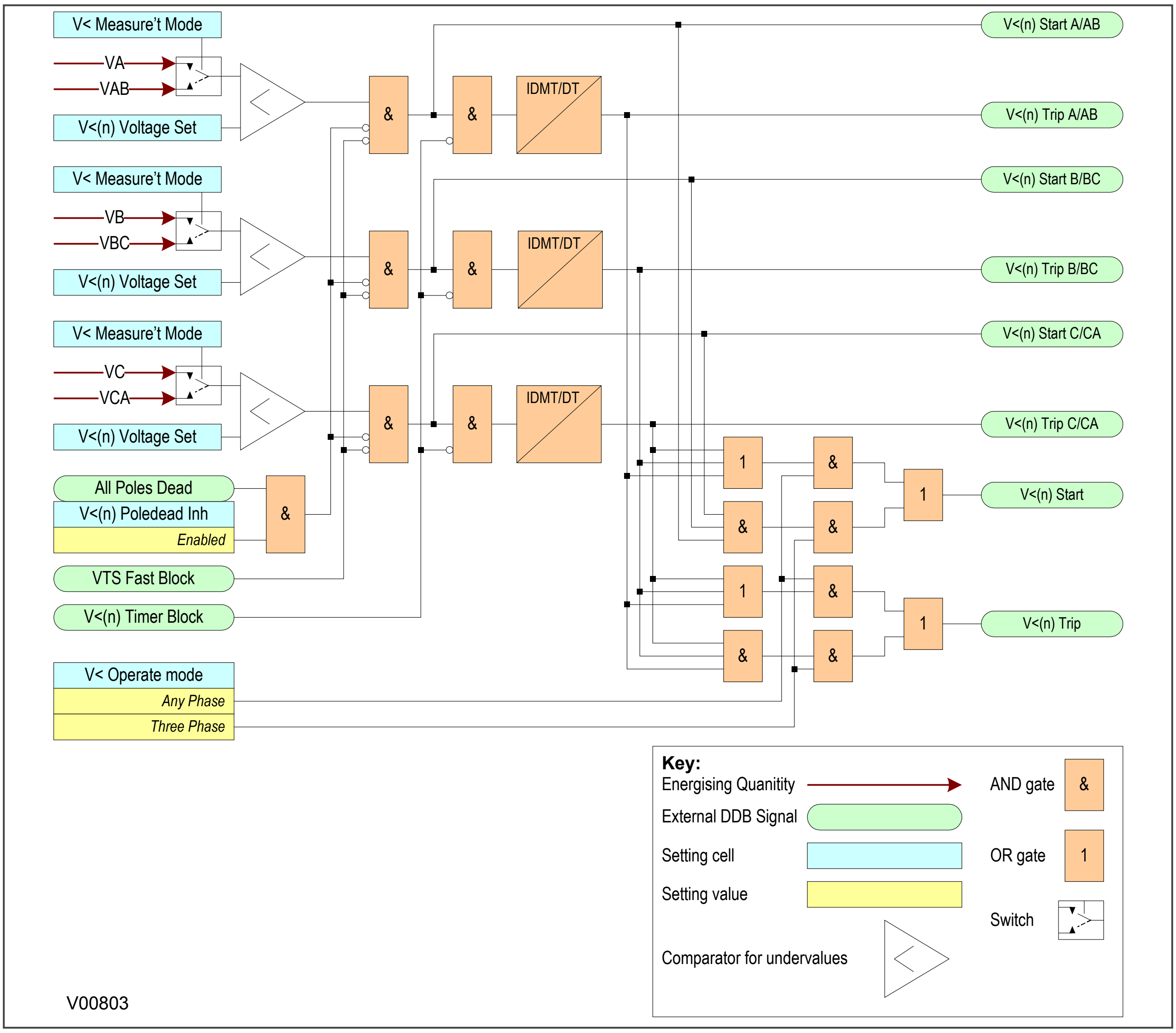


Figure 68: Undervoltage - single and three phase tripping mode (single stage)

The Undervoltage protection function detects when the voltage magnitude for a certain stage falls short of a set threshold. If this happens a **Start** signal, signifying the "Start of protection", is produced. This Start signal can be blocked by the **VTS Fast Block** signal and an **All Poles Dead signal**. This **Start** signal is applied to the timer module to produce the **Trip** signal, which can be blocked by the undervoltage timer block signal (**V<(n) Timer Block**). For each stage, there are three Phase undervoltage detection modules, one for each phase. The three **Start** signals from each of these phases are OR'd together to create a 3-phase Start signal (**V<(n) Start**), which can be be activated when any of the three phases start (Any Phase), or when all three phases start (Three Phase), depending on the chosen **V<Operate Mode** setting.

The outputs of the timer modules are the trip signals which are used to drive the tripping output relay. These tripping signals are also OR'd together to create a 3-phase Trip signal, which are also controlled by the **V<Operate Mode** setting.

If any one of the above signals is low, or goes low before the timer has counted out, the timer module is inhibited (effectively reset) until the blocking signal goes high.

In some cases, we do not want the undervoltage element to trip; for example, when the protected feeder is de-energised, or the circuit breaker is opened, an undervoltage condition would obviously be detected, but we would not want to start protection. To cater for this, an "All Poles Dead" signal is blocks the **Start** signal for each phase. This is controlled by the **V<Poledead Inh** cell, which is included for each of the stages. If the cell is enabled, the relevant stage will be blocked by the integrated pole dead logic. This logic produces an output when it detects either an open circuit breaker via auxiliary contacts feeding the opto-inputs or it detects a combination of both undercurrent and undervoltage on any one phase.

2.3 UNDERVOLTAGE DDB SIGNALS

Ordinal	Signal Name	Source	Type	Response
Description				
222	V<1 Timer Block	Programmable Scheme Logic	PSL Output	No response
This DDB signal blocks the first stage Phase Undervoltage time delay				
223	V<2 Timer Block	Programmable Scheme Logic	PSL Output	No response
This DDB signal blocks the second stage Phase Undervoltage time delay				
278	V<1 Trip	Software	PSL Input	Protection event
This DDB signal is the first stage three-phase or any-phase Undervoltage trip signal				
279	V<1 Trip A/AB	Software	PSL Input	Protection event
This DDB signal is the first stage A-phase Undervoltage trip signal				
280	V<1 Trip B/BC	Software	PSL Input	Protection event
This DDB signal is the first stage B-phase Undervoltage trip signal				
281	V<1 Trip C/CA	Software	PSL Input	Protection event
This DDB signal is the first stage C-phase Undervoltage trip signal				
282	V<2 Trip	Software	PSL Input	Protection event
This DDB signal is the second stage three-phase or any-phase Undervoltage trip signal				
283	V<2 Trip A/AB	Software	PSL Input	Protection event
This DDB signal is the second stage A-phase Undervoltage trip signal				
284	V<2 Trip B/BC	Software	PSL Input	Protection event
This DDB signal is the second stage B-phase Undervoltage trip signal				
285	V<2 Trip C/CA	Software	PSL Input	Protection event
This DDB signal is the second stage C-phase Undervoltage trip signal				
331	V<1 Start	Software	PSL Input	Protection event
This DDB signal is the first stage three-phase or any-phase Undervoltage start signal				
332	V<1 Start A/AB	Software	PSL Input	Protection event
This DDB signal is the first stage A-phase Phase Undervoltage start signal				
333	V<1 Start B/BC	Software	PSL Input	Protection event
This DDB signal is the first stage B-phase Phase Undervoltage start signal				
334	V<1 Start C/CA	Software	PSL Input	Protection event
This DDB signal is the first stage C-phase Phase Undervoltage start signal				
335	V<2 Start	Software	PSL Input	Protection event
This DDB signal is the second stage three-phase or any-phase Undervoltage start signal				
336	V<2 Start A/AB	Software	PSL Input	Protection event
This DDB signal is the second stage A-phase Phase Undervoltage start signal				
337	V<2 Start B/BC	Software	PSL Input	Protection event
This DDB signal is the second stage B-phase Phase Undervoltage start signal				

Ordinal	Signal Name	Source	Type	Response
Description				
338	V<2 Start C/CA	Software	PSL Input	Protection event
This DDB signal is the second stage C-phase Phase Undervoltage start signal				
350	VTS Fast Block	Software	PSL Input	No response
This DDB signal is an instantaneously blocking output from the VTS which can block other functions				
380	All Poles Dead	Software	PSL Input	No response
This DDB signal indicates that all poles are dead (not all models)				
608	V<3 Start	Software	PSL Input	Protection event
This DDB signal is the third stage three-phase or any-phase Phase Undervoltage start signal				
609	V<3 Start A/AB	Software	PSL Input	Protection event
This DDB signal is the third stage A-phase Phase Undervoltage start signal				
610	V<3 Start B/BC	Software	PSL Input	Protection event
This DDB signal is the third stage B-phase Phase Undervoltage start signal				
611	V<3 Start C/CA	Software	PSL Input	Protection event
This DDB signal is the third stage C-phase Phase Undervoltage start signal				
612	V<3 Trip	Software	PSL Input	Protection event
This DDB signal is the first stage three-phase or any-phase Phase Undervoltage trip signal				
613	V<3 Trip A/AB	Software	PSL Input	Protection event
This DDB signal is the first stage A-phase Phase Undervoltage trip signal				
614	V<3 Trip B/BC	Software	PSL Input	Protection event
This DDB signal is the first stage B-phase Phase Undervoltage trip signal				
615	V<3 Trip C/CA	Software	PSL Input	Protection event
This DDB signal is the first stage C-phase Phase Undervoltage trip signal				
624	V<3 Timer Block	Programmable Scheme Logic	PSL Output	No response
This DDB signal blocks the third stage Phase Undervoltage time delay				

2.4 UNDERVOLTAGE SETTINGS

Menu Text	Col	Row	Default Setting	Available Options
Description				
GROUP 1 VOLT PROTECTION	42	00		
This column contains settings for Voltage protection				
UNDER VOLTAGE	42	01		
The settings under this sub-heading relate to Undervoltage				
V< Measur't Mode	42	02	Phase-Phase	0=Phase-Phase 1=Phase-Neutral
This set determines the voltage input mode - phase-to-phase or phase-to-neutral.				
V< Operate Mode	42	03	Any Phase	0=Any Phase 1=Three Phase
This setting determines whether any one of the phases or all three of the phases has to satisfy the undervoltage criteria before a decision is made.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
V<1 Function	42	04	DT	0 = Disabled, 1 = DT, 2 = IDMT, 3= User Curve 1, 4= User Curve 2, 5= User Curve 3, 6= User Curve 4
This setting determines the tripping characteristic for the first stage undervoltage element.				
V<1 Voltage Set	42	05	80	From 10*V1 to 120*V1 step 1*V1
This setting sets the pick-up threshold for the first stage undervoltage element.				
V<1 Time Delay	42	06	10	From 0s to 100s step 0.01s
This setting sets the DT time delay for the first stage undervoltage element.				
V<1 TMS	42	07	1	From 0.5 to 100 step 0.5
This is the Time Multiplier Setting to adjust the operate time of IEC IDMT curves.				
V<1 Poledead Inh	42	08	Enabled	0 = Disabled or 1 = Enabled
This setting enables or disables the Pole Dead inhibit logic (not all models)				
V<2 Status	42	09	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the second stage undervoltage element. There is no choice of curves because this stage is DT only.				
V<2 Voltage Set	42	0A	60	From 10*V1 to 120*V1 step 1*V1
This setting sets the pick-up threshold for the second stage undervoltage element.				
V<2 Time Delay	42	0B	5	From 0s to 100s step 0.01s
This setting sets the DT time delay for the second stage undervoltage element.				
V<2 Poledead Inh	42	0C	Enabled	0 = Disabled or 1 = Enabled
This setting enables or disables the Pole Dead inhibit logic.				
V<3 Function	42	0D		0 = Disabled, 1 = DT, 2 = IDMT, 3= User Curve 1, 4= User Curve 2, 5= User Curve 3, 6= User Curve 4
This setting determines the tripping characteristic for the third stage undervoltage element.				
V<3 Voltage Set	42	0E		From 10*V1 to 120*V1 step 1*V1
This setting sets the pick-up threshold for the third stage undervoltage element.				
V<3 Time Delay	42	0F		From 0s to 100s step 0.01s
This setting sets the DT time delay for the third stage undervoltage element.				
V<3 TMS	42	10		From 0.5 to 100 step 0.5
This is the Time Multiplier Setting to adjust the operate time of IEC IDMT curves.				
V<3 Poledead Inh	42	11		0 = Disabled or 1 = Enabled
This setting enables or disables the Pole Dead inhibit logic.				

2.5 APPLICATION NOTES

2.5.1 UNDERVOLTAGE SETING GUIDELINES

In most applications, undervoltage protection is not required to operate during system earth fault conditions. If this is the case you should select phase-to-phase voltage measurement, as this quantity is less affected by single-phase voltage dips due to earth faults.

The voltage threshold setting for the undervoltage protection should be set at some value below the voltage excursions that may be expected under normal system operating conditions. This threshold is dependent on the system in question but typical healthy system voltage excursions may be in the order of 10% of nominal value.

The same applies to the time setting. The required time delay is dependent on the time for which the system is able to withstand a reduced voltage.

If motor loads are connected, then a typical time setting may be in the order of 0.5 seconds.

3 OVERVOLTAGE PROTECTION

Overvoltage conditions are generally related to loss of load conditions, whereby the supply voltage increases in magnitude. This situation would normally be rectified by voltage regulating equipment such as AVRs (Auto Voltage Regulators) or On Load Tap Changers. However, failure of this equipment to bring the system voltage back within permitted limits leaves the system with an overvoltage condition which must be cleared.

> *Note:*
> *During earth fault conditions on a power system there may be an increase in the healthy phase voltages. Ideally, the system should be designed to withstand such overvoltages for a defined period of time.*

3.1 OVERVOLTAGE PROTECTION IMPLEMENTATION

Overvoltage Protection is implemented in the VOLT PROTECTION column of the relevant settings group. The Overvoltage parameters are contained within the sub-heading OVERVOLTAGE.

The product provides three stages of overvoltage protection with independent time delay characteristics.

Stages 1 and 3 provide a choice of operate characteristics, where you can select between:

- An IDMT characteristic
- DT (Definite Time)

You set this using the **V>1 Function** and **V>3 Function** cells depending on the stage.

The IDMT characteristic is defined by the following formula:

$$t = K/(M - 1)$$

where:

- K = Time multiplier setting
- t = Operating time in seconds
- M = Measured voltage setting voltage (**V> Voltage Set**)

The overvoltage stages can be configured either as phase-to-neutral or phase-to-phase voltages in the **V> Measure't mode** cell.

There is no Timer Hold facility for Overvoltage.

Stage 2 can have definite time characteristics only. This is set in the **V>2** status cell.

Three stages are included in order to provide multiple output types, such as alarm and trip stages. Alternatively, different time settings may be required depending upon the severity of the voltage increase.

Outputs are available for single or three-phase conditions via the **V>Operate Mode** cell for each stage.

3.2 OVERVOLTAGE PROTECTION LOGIC

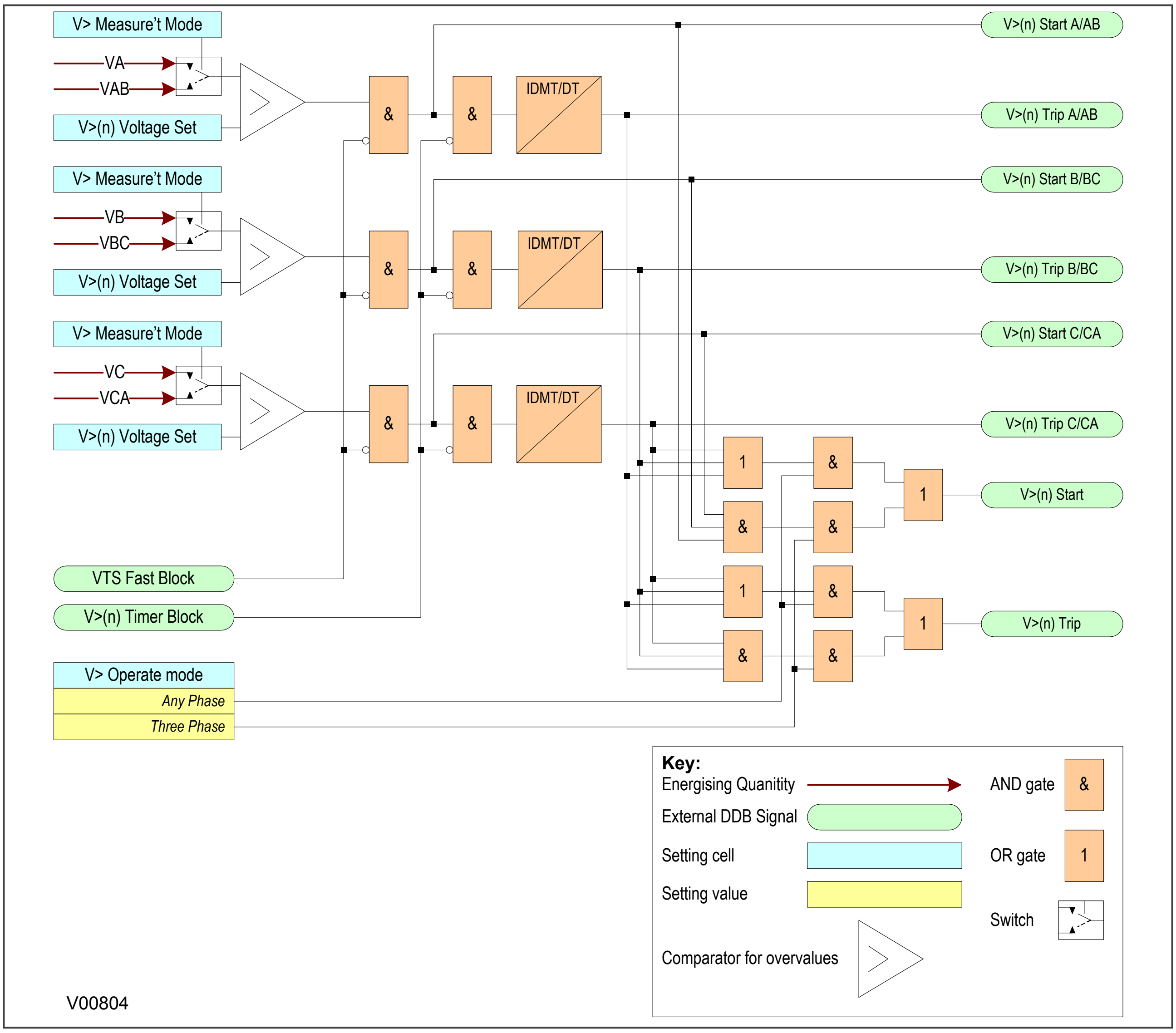


Figure 69: Overvoltage - single and three phase tripping mode (single stage)

The Overvoltage protection function detects when the voltage magnitude for a certain stage exceeds a set threshold. If this happens a **Start** signal, signifying the "Start of protection", is produced. This Start signal can be blocked by the **VTS Fast Block** signal. This **Start** signal is applied to the timer module to produce the **Trip** signal, which can be blocked by the overvoltage timer block signal (**V>(n) Timer Block**). For each stage, there are three Phase overvoltage detection modules, one for each phase. The three **Start** signals from each of these phases are OR'd together to create a 3-phase Start signal (**V>(n) Start**), which can be be activated when any of the three phases start (Any Phase), or when all three phases start (Three Phase), depending on the chosen **V>Operate Mode** setting.

The outputs of the timer modules are the trip signals which are used to drive the tripping output relay. These tripping signals are also OR'd together to create a 3-phase Trip signal, which are also controlled by the **V>Operate Mode** setting.

If any one of the above signals is low, or goes low before the timer has counted out, the timer module is inhibited (effectively reset) until the blocking signal goes high.

3.3 OVERVOLTAGE DDB SIGNALS

Ordinal	Signal Name	Source	Type	Response
Description				
222	V<1 Timer Block	Programmable Scheme Logic	PSL Output	No response
This DDB signal blocks the first stage Phase Undervoltage time delay				
223	V<2 Timer Block	Programmable Scheme Logic	PSL Output	No response
This DDB signal blocks the second stage Phase Undervoltage time delay				
286	V>1 Trip	Software	PSL Input	Protection event
This DDB signal is the first stage three-phase or any-phase Overvoltage trip signal				
287	V>1 Trip A/AB	Software	PSL Input	Protection event
This DDB signal is the first stage A-phase Overvoltage trip signal				
288	V>1 Trip B/BC	Software	PSL Input	Protection event
This DDB signal is the first stage B-phase Overvoltage trip signal				
289	V>1 Trip C/CA	Software	PSL Input	Protection event
This DDB signal is the first stage C-phase Overvoltage trip signal				
290	V>2 Trip	Software	PSL Input	Protection event
This DDB signal is the second stage three-phase or any-phase Overvoltage trip signal				
291	V>2 Trip A/AB	Software	PSL Input	Protection event
This DDB signal is the second stage A-phase Overvoltage trip signal				
292	V>2 Trip B/BC	Software	PSL Input	Protection event
This DDB signal is the second stage B-phase Overvoltage trip signal				
293	V>2 Trip C/CA	Software	PSL Input	Protection event
This DDB signal is the second stage C-phase Overvoltage trip signal				
339	V>1 Start	Software	PSL Input	Protection event
This DDB signal is the first stage three-phase or any-phase Overvoltage start signal				
340	V>1 Start A/AB	Software	PSL Input	Protection event
This DDB signal is the first stage A-phase Phase Overvoltage start signal				
341	V>1 Start B/BC	Software	PSL Input	Protection event
This DDB signal is the first stage B-phase Phase Overvoltage start signal				
342	V>1 Start C/CA	Software	PSL Input	Protection event
This DDB signal is the first stage C-phase Phase Overvoltage start signal				
343	V>2 Start	Software	PSL Input	Protection event
This DDB signal is the second stage three-phase or any-phase Overvoltage start signal				
344	V>2 Start A/AB	Software	PSL Input	Protection event
This DDB signal is the second stage A-phase Phase Overvoltage start signal				
345	V>2 Start B/BC	Software	PSL Input	Protection event
This DDB signal is the second stage B-phase Phase Overvoltage start signal				
346	V>2 Start C/CA	Software	PSL Input	Protection event
This DDB signal is the second stage C-phase Phase Overvoltage start signal				
350	VTS Fast Block	Software	PSL Input	No response
This DDB signal is an instantaneously blocking output from the VTS which can block other functions				
380	All Poles Dead	Software	PSL Input	No response
This DDB signal indicates that all poles are dead				

Ordinal	Signal Name	Source	Type	Response
Description				
616	V>3 Start	Software	PSL Input	Protection event
This DDB signal is the third stage three-phase or any-phase Phase Overvoltage start signal				
617	V>3 Start A/AB	Software	PSL Input	Protection event
This DDB signal is the third stage A-phase Phase Overvoltage start signal				
618	V>3 Start B/BC	Software	PSL Input	Protection event
This DDB signal is the third stage B-phase Phase Overvoltage start signal				
619	V>3 Start C/CA	Software	PSL Input	Protection event
This DDB signal is the third stage C-phase Phase Overvoltage start signal				
620	V>3 Trip	Software	PSL Input	Protection event
This DDB signal is the first stage three-phase or any-phase Phase Overvoltage trip signal				
621	V>3 Trip A/AB	Software	PSL Input	Protection event
This DDB signal is the first stage A-phase Phase Overvoltage trip signal				
622	V>3 Trip B/BC	Software	PSL Input	Protection event
This DDB signal is the first stage B-phase Phase Overvoltage trip signal				
623	V>3 Trip C/CA	Software	PSL Input	Protection event
This DDB signal is the first stage C-phase Phase Overvoltage trip signal				
625	V>3 Timer Block	Programmable Scheme Logic	PSL Output	No response
This DDB signal blocks the third stage Phase Overvoltage time delay				

3.4 OVERVOLTAGE SETTINGS

Menu Text	Col	Row	Default Setting	Available Options
Description				
GROUP 1 VOLT PROTECTION	42	00		
This column contains settings for Voltage protection				
OVERVOLTAGE	42	12		
The settings under this sub-heading relate to Overvoltage				
V> Measur't Mode	42	13	Phase-Phase	0=Phase-Phase 1=Phase-Neutral
This set determines the voltage input mode - phase-to-phase or phase-to-neutral.				
V> Operate Mode	42	14	Any Phase	0=Any Phase 1=Three Phase
This setting determines whether any one of the phases or all three of the phases has to satisfy the overvoltage criteria before a decision is made.				
V>1 Function	42	15	DT	0 = Disabled, 1 = DT, 2 = IDMT, 3= User Curve 1, 4= User Curve 2, 5= User Curve 3, 6= User Curve 4
This setting determines the tripping characteristic for the first stage overvoltage element.				
V>1 Voltage Set	42	16	130	From 40*V1 to 185*V1 step 1*V1
This setting sets the pick-up threshold for the first stage overvoltage element.				
V>1 Time Delay	42	17	10	From 0s to 100s step 0.01s

Menu Text	Col	Row	Default Setting	Available Options
Description				
This setting sets the DT time delay for the first stage overvoltage element.				
V>1 TMS	42	18	1	From 0.5 to 100 step 0.5
This is the Time Multiplier Setting to adjust the operate time of IEC IDMT curves.				
V>2 Status	42	19	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the second stage overvoltage element. There is no choice of curves because this stage is DT only.				
V>2 Voltage Set	42	1A	150	From 40*V1 to 185*V1 step 1*V1
This setting sets the pick-up threshold for the second stage overvoltage element.				
V>2 Time Delay	42	1B	0.5	From 0s to 100s step 0.01s
This setting sets the DT time delay for the second stage overvoltage element.				
V>3 Function	42	1C	DT	0 = Disabled, 1 = DT, 2 = IDMT, 3= User Curve 1, 4= User Curve 2, 5= User Curve 3, 6= User Curve 4
This setting determines the tripping characteristic for the third stage overvoltage element.				
V>3 Voltage Set	42	1D	130	From 40*V1 to 185*V1 step 1*V1
This setting sets the pick-up threshold for the third stage overvoltage element.				
V>3 Time Delay	42	1E	10	From 0s to 100s step 0.01s
This setting sets the DT time delay for the third stage overvoltage element.				
V>3 TMS	42	1F	1	From 0.5 to 100 step 0.5
This is the Time Multiplier Setting to adjust the operate time of IEC IDMT curves.				

3.5 APPLICATION NOTES

3.5.1 OVERVOLTAGE SETTING GUIDELINES

The provision of the two stages and their respective operateing characteristics allows for a number of possible applications:

- Definite Time can be used for both stages to provide the required alarm and trip stages
- Use of the IDMT characteristic allows grading of the time delay according to the severity of the overvoltage. As the voltage settings for both of the stages are independent, the second stage could then be set lower than the first to provide a time-delayed alarm stage.
- If only one stage of overvoltage protection is required, or if the element is required to provide an alarm only, the remaining stage may be disabled.

This type of protection must be co-ordinated with any other overvoltage devices at other locations on the system.

4 RATE OF CHANGE OF VOLTAGE PROTECTION

Where there are very large loads, imbalances may occur, which could result in rapid decline in system voltage. The situation could be so bad that shedding one or two stages of load would be unlikely to stop this rapid voltage decline. In such a situation, standard undervoltage protection will normally have to be supplemented with protection that responds to the rate of change of voltage. An element is therefore required, which identifies the high rate of decline of voltage and adapts the load shedding scheme accordingly.

Such protection can identify voltage variations occurring close to nominal voltage thereby providing early warning of a developing voltage problem. The element can also be used as an alarm to warn operators of unusually high system voltage variations.

Rate of Change of Voltage protection is also known as dv/dt protection.

4.1 RATE OF CHANGE OF VOLTAGE PROTECTION IMPLEMENTATION

The dv/dt protection functions can be found in the the VOLT PROTECTION column under the sub-heading dv/dt PROTECTION. The dv/dt protection consists of four independent stages, which can be configured as either 'phase-to-phase' or 'phase-to-neutral' using the **dv/dt Meas mode** cell.

4.2 RATE OF CHANGE OF VOLTAGE LOGIC

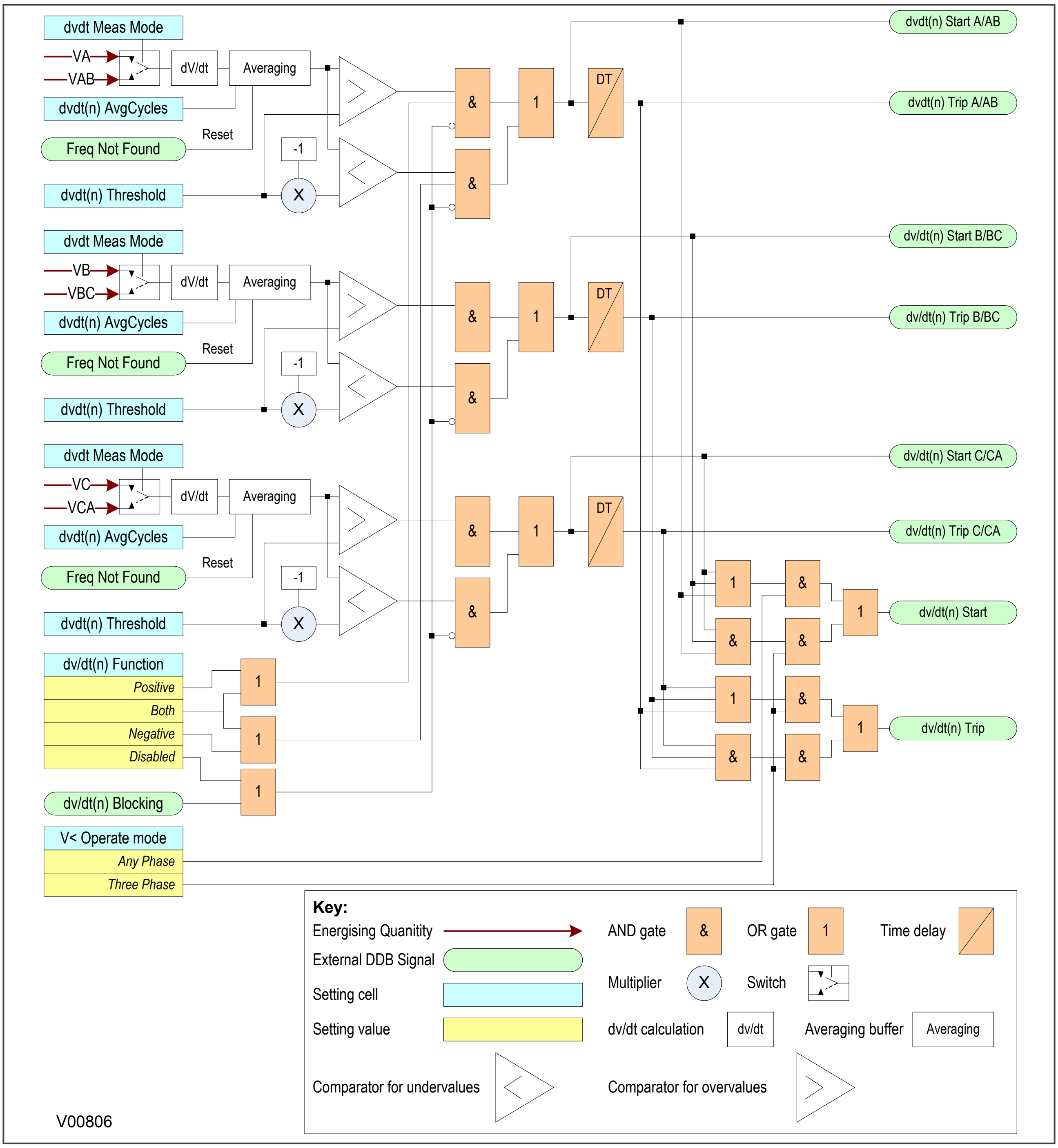


Figure 70: Rate of Change of Voltage protection logic

The dv/dt logic works by differentiating the RMS value of each phase voltage input, which can be with respect to neutral, or respect to another phase depending on the selected measurement mode. This differentiated value is then averaged over a number of cycles, determined by the setting **dv/dt(n)AvgCycles** and comparing this with a threshold (**dv/dt(n)Threshold**) in both the positive and negative directions. A start signal is produced depending on the selected direction (positive, negative or both), set by the setting **dv/dt(n)Function,** which can also disable the function on a per stage basis. Each stage can also be blocked by the DDB signal **dvV/dt(n)Blocking**. The trip signal is produced by passing the Start signal through a DT timer.

The function also produces three-phase Start and Trip signals, which can be set to 'Any Phase' (where any of the phases can trigger the start) or 'Three Phase' (where all three phases are required to trigger the start). The averaging buffer is reset either when the stage is disabled or no frequency is found (**Freq Not Found** DDB signal).

4.3 DV/DT DDB SIGNALS

Ordinal	Signal Name	Source	Type	Response
Description				
411	Freq Not Found	Software	PSL Input	No response
This DDB signal indicates that no frequency has been found				
545	dv/dt1 StartA/AB	Software	PSL Input	Protection event
This DDB signal is the first stage dv/dt start signal for phase A-N or A-B				
546	dv/dt1 StartB/BC	Software	PSL Input	Protection event
This DDB signal is the first stage dv/dt start signal for phase B-N or B-C				
547	dv/dt1 StartC/CA	Software	PSL Input	Protection event
This DDB signal is the first stage dv/dt start signal for phase C-N or C-A				
548	dv/dt1 Start	Software	PSL Input	Protection event
This DDB signal is the first stage dv/dt start signal for any phase or three-phase (select with setting).				
549	dv/dt2 StartA/AB	Software	PSL Input	Protection event
This DDB signal is the second stage dv/dt start signal for phase A-N or A-B				
550	dv/dt2 StartB/BC	Software	PSL Input	Protection event
This DDB signal is the second stage dv/dt start signal for phase B-N or B-C				
551	dv/dt2 StartC/CA	Software	PSL Input	Protection event
This DDB signal is the second stage dv/dt start signal for phase C-N or C-A				
552	dv/dt2 Start	Software	PSL Input	Protection event
This DDB signal is the second stage dv/dt start signal for any phase or three-phase (select with setting).				
553	dv/dt1 Trip A/AB	Software	PSL Input	Protection event
This DDB signal is the first stage dv/dt trip signal for phase A-N or A-B				
554	dv/dt1 Trip B/BC	Software	PSL Input	Protection event
This DDB signal is the first stage dv/dt trip signal for phase B-N or B-C				
555	dv/dt1 Trip C/CA	Software	PSL Input	Protection event
This DDB signal is the first stage dv/dt trip signal for phase C-N or C-A				
556	dv/dt1 Trip	Software	PSL Input	Protection event
This DDB signal is the first stage dv/dt trip signal for any phase or three-phase (select with setting).				
557	dv/dt2 Trip A/AB	Software	PSL Input	Protection event
This DDB signal is the second stage dv/dt trip signal for phase A-N or A-B				
558	dv/dt2 Trip B/BC	Software	PSL Input	Protection event
This DDB signal is the second stage dv/dt trip signal for phase B-N or B-C				
559	dv/dt2 Trip C/CA	Software	PSL Input	Protection event
This DDB signal is the second stage dv/dt trip signal for phase C-N or C-A				
560	dv/dt2 Trip	Software	PSL Input	Protection event
This DDB signal is the second stage dv/dt trip signal for any phase or three-phase (select with setting).				
561	dv/dt1 Blocking	Programmable Scheme Logic	PSL Output	Protection event
This DDB signal blocks the first stage dv/dt protection.				

Ordinal	Signal Name	Source	Type	Response
Description				
562	dv/dt2 Blocking	Programmable Scheme Logic	PSL Output	Protection event
This DDB signal blocks the second stage dv/dt protection.				

4.4 DV/DT SETTINGS

Menu Text	Col	Row	Default Setting	Available Options
Description				
GROUP 1 VOLT PROTECTION	42	00		
This column contains settings for Voltage protection				
dv/dt PROTECTION	42	20		
The settings under this sub-heading relate to rate of change of voltage				
dv/dt Meas Mode	42	21	Phase-Phase	0=Phase-Phase 1=Phase-Neutral
This set determines the voltage input mode - phase-to-phase or phase-to-neutral.				
dv/dt1 Function	42	22	Disabled	0=Disabled 1=Negative 2=Positive 3=Both
This setting determines the tripping direction for the first stage of dv/dt element - either disabled, for a rising voltage (positive), or a falling voltage (negative).				
dv/dt1 Function	42	22	Disabled	0=Disabled 1=Negative 2=Positive 3=Both
This setting determines the tripping direction for the first stage of dv/dt element - either disabled, for a rising voltage (positive), or a falling voltage (negative).				
dv/dt1 Oper Mode	42	23	Any Phase	0=Any Phase 1=Three Phase
This setting determines whether any one of the phases or all three of the phases has to satisfy the dv/dt criteria before a decision is made.				
dv/dt1 AvgCycles	42	24	10	From 5 to 50 step 1
This setting sets the number of averaging cycles for the first stage dv/dt element.				
dv/dt1 Threshold	42	25	10	From 0.5 V/s to 200 V/s step 0.5 V/s
This setting sets the voltage threshold for the first stage dv/dt element.				
dv/dt1 TimeDelay	42	26	0.5	From 0s to 100s step 0.01s
This setting sets the DT time delay for the first stage dv/dt element.				
dv/dt1 tRESET	42	27	0.03	From 0s to 100s step 0.01s
This setting determines the Reset time for the Definite Time Reset characteristic				
dv/dt2 Function	42	28	Disabled	0=Disabled 1=Negative 2=Positive 3=Both
This setting determines the tripping direction for the second stage of dv/dt element - either disabled, for a rising voltage (positive), or a falling voltage (negative).				
dv/dt2 Function	42	28	Disabled	0=Disabled 1=Negative 2=Positive 3=Both

Menu Text	Col	Row	Default Setting	Available Options
Description				
This setting determines the tripping direction for the second stage of dv/dt element - either disabled, for a rising voltage (positive), or a falling voltage (negative).				
dv/dt2 Oper Mode	42	29	Any Phase	0=Any Phase 1=Three Phase
This setting determines whether any one of the phases or all three of the phases has to satisfy the dv/dt criteria before a decision is made.				
dv/dt2 AvgCycles	42	2A	5	From 5 to 50 step 1
This setting sets the number of averaging cycles for the second stage dv/dt element.				
dv/dt2 Threshold	42	2B	50	From 0.5 V/s to 200 V/s step 0.5 V/s
This setting sets the voltage threshold for the second stage dv/dt element.				
dv/dt2 TimeDelay	42	2C	0.3	From 0s to 100s step 0.01s
This setting sets the DT time delay for the second stage dv/dt element.				
dv/dt2 tRESET	42	2D	0.03	From 0s to 100s step 0.01s
This setting determines the Reset time for the Definite Time Reset characteristic				
dv/dt3 Function	42	2E	Disabled	0=Disabled 1=Negative 2=Positive 3=Both
This setting determines the tripping direction for the third stage of dv/dt element - either disabled, for a rising voltage (positive), or a falling voltage (negative).				
dv/dt3 Function	42	2E	Disabled	0=Disabled 1=Negative 2=Positive 3=Both
This setting determines the tripping direction for the third stage of dv/dt element - either disabled, for a rising voltage (positive), or a falling voltage (negative).				
dv/dt3 Oper Mode	42	2F	Any Phase	0=Any Phase 1=Three Phase
This setting determines whether any one of the phases or all three of the phases has to satisfy the dv/dt criteria before a decision is made.				
dv/dt3 AvgCycles	42	30	10	From 5 to 50 step 1
This setting sets the number of averaging cycles for the third stage dv/dt element.				
dv/dt3 Threshold	42	31	10	From 0.5 V/s to 200 V/s step 0.5 V/s
This setting sets the voltage threshold for the third stage dv/dt element.				
dv/dt3 TimeDelay	42	32	0.5	From 0s to 100s step 0.01s
This setting sets the DT time delay for the third stage dv/dt element.				
dv/dt3 tRESET	42	33	0.03	From 0s to 100s step 0.01s
This setting determines the Reset time for the Definite Time Reset characteristic				
dv/dt4 Function	42	34	Disabled	0=Disabled 1=Negative 2=Positive 3=Both
This setting determines the tripping direction for the fourth stage of dv/dt element - either disabled, for a rising voltage (positive), or a falling voltage (negative).				
dv/dt4 Function	42	34	Disabled	0=Disabled 1=Negative 2=Positive 3=Both
This setting determines the tripping direction for the fourth stage of dv/dt element - either disabled, for a rising voltage (positive), or a falling voltage (negative).				

Menu Text	Col	Row	Default Setting	Available Options
Description				
dv/dt4 Oper Mode	42	35	Any Phase	0=Any Phase 1=Three Phase
This setting determines whether any one of the phases or all three of the phases has to satisfy the dv/dt criteria before a decision is made.				
dv/dt4 AvgCycles	42	36	5	From 5 to 50 step 1
This setting sets the number of averaging cycles for the fourth stage dv/dt element.				
dv/dt4 Threshold	42	37	50	From 0.5 V/s to 200 V/s step 0.5 V/s
This setting sets the voltage threshold for the fourth stage dv/dt element.				
dv/dt4 TimeDelay	42	38	0.3	From 0s to 100s step 0.01s
This setting sets the DT time delay for the fourth stage dv/dt element.				
dv/dt4 tRESET	42	39	0.03	From 0s to 100s step 0.01s
This setting determines the Reset time for the Definite Time Reset characteristic				

5 RESIDUAL OVERVOLTAGE PROTECTION

On a healthy three-phase power system, the sum of the three-phase to earth voltages is nominally zero, as it is the vector sum of three balanced vectors displaced from each other by 120°. However, when an earth fault occurs on the primary system, this balance is upset and a residual voltage is produced. This condition causes a rise in the neutral voltage with respect to earth. Consequently this type of protection is also commonly referred to as 'Neutral Voltage Displacement' or NVD for short.

This residual voltage may be derived (from the phase voltages) or measured (from a measurement class open delta VT). Derived values will normally only be used where the model does not support measured functionality (a dedicated measurement class VT). If a measurement class VT is used to produce a measured Residual Voltage, it cannot be used for other features such as Check Synchronisation.

This offers an alternative means of earth fault detection, which does not require any measurement of current. This may be particularly advantageous in high impedance earthed or insulated systems, where the provision of core balanced current transformers on each feeder may be either impractical, or uneconomic, or for providing earth fault protection for devices with no current transformers.

5.1 RESIDUAL OVERVOLTAGE PROTECTION IMPLEMENTATION

Residual Overvoltage Protection is implemented in the RESIDUAL O/V NVD column of the relevant settings group.

Some applications require more than one stage. For example an insulated system may require an alarm stage and a trip stage. It is common in such a case for the system to be designed to withstand the associated healthy phase overvoltages for a number of hours following an earth fault. In such applications, an alarm is generated soon after the condition is detected, which serves to indicate the presence of an earth fault on the system. This gives time for system operators to locate and isolate the fault. The second stage of the protection can issue a trip signal if the fault condition persists.

The product provides three stages of Residual Overvoltage protection with independent time delay characteristics.

Stages 1 and 3 provide a choice of operate characteristics, where you can select between:

- An IDMT characteristic
- DT (Definite Time)

The IDMT characteristic is defined by the following formula:

$$t = K/(M - 1)$$

where:

- K= Time multiplier setting
- t = Operating time in seconds
- M = Derived residual voltage setting voltage (**VN> Voltage Set**)

You set this using the **VN>1 Function** and **VN>3 Function** cells depending on the stage.

Stages 1 and 3 also provide a Timer Hold facility as described in Timer Hold facility (on page 88)

Stage 2 can have definite time characteristics only. This is set in the **VN>2** status cell

The device derives the residual voltage internally from the three-phase voltage inputs supplied from either a 5-limb VT or three single-phase VTs. These types of VT design provide a path for the residual flux and consequently permit the device to derive the required residual voltage. In addition, the primary star point of the VT must be earthed. Three-limb VTs have no path for residual flux and are therefore unsuitable for this type of protection.

5.2 RESIDUAL OVERVOLTAGE LOGIC

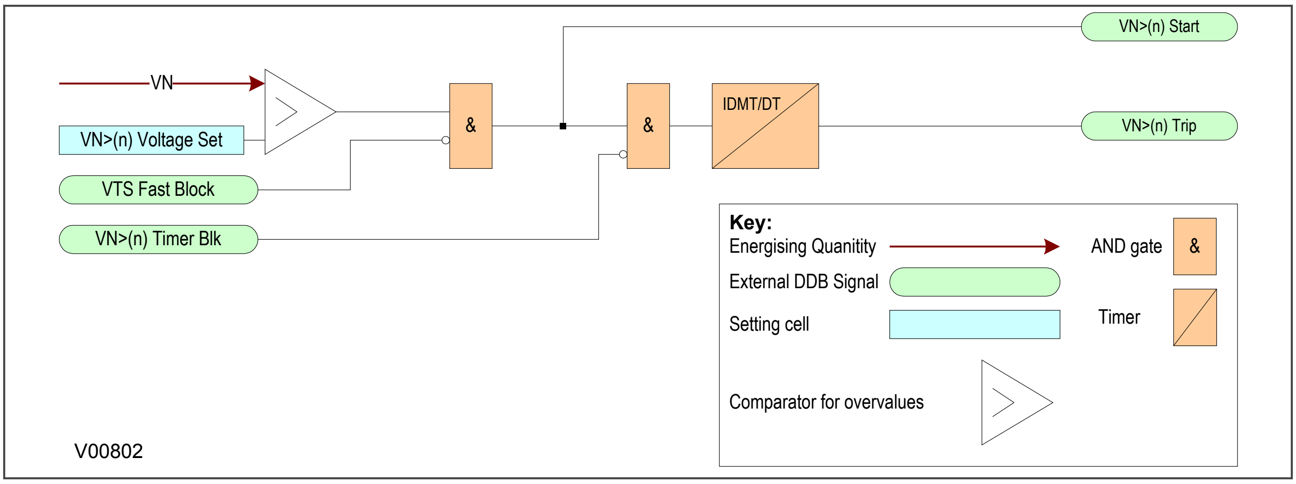


Figure 71: Residual overvoltage logic

The Residual Overvoltage module (VN>) is a level detector that detects when the voltage magnitude exceeds a set threshold, for each stage. When this happens, the comparator output produces a **Start** signal (**VN>(n) Start**), which signifies the "Start of protection". This can be blocked by a **VTS Fast block** signal. This **Start** signal is applied to the timer module. The output of the timer module is the **VN> (n) Trip** signal which is used to drive the tripping output relay.

5.3 RESIDUAL OVERVOLTAGE DDB SIGNALS

Ordinal	Signal Name	Source	Type	Response
Description				
220	VN>1 Timer Blk	Programmable Scheme Logic	PSL Output	No response
This DDB signal blocks the first stage Residual Overvoltage time delay				
221	VN>2 Timer Blk	Programmable Scheme Logic	PSL Output	No response
This DDB signal blocks the second stage Residual Overvoltage time delay				
274	VN>1 Trip	Software	PSL Input	Protection event
This DDB signal is the first stage Residual Overvoltage trip signal				
275	VN>2 Trip	Software	PSL Input	Protection event
This DDB signal is the second stage Residual Overvoltage trip signal				
327	VN>1 Start	Software	PSL Input	Protection event
This DDB signal is the first stage Residual Overvoltage start signal				
328	VN>2 Start	Software	PSL Input	Protection event
This DDB signal is the second stage Residual Overvoltage start signal				
350	VTS Fast Block	Software	PSL Input	No response
This DDB signal is an instantaneously blocking output from the VTS which can block other functions				
605	VN>3 Start	Software	PSL Input	Protection event
This DDB signal is the third stage Residual Overvoltage start signal				
606	VN>3 Trip	Software	PSL Input	Protection event
This DDB signal is the third stage Residual Overvoltage trip signal				
607	VN>3 Timer Blk	Programmable Scheme Logic	PSL Output	No response
This DDB signal blocks the third stage Residual Overvoltage time delay				

5.4 RESIDUAL OVERVOLTAGE SETTINGS

Menu Text	Col	Row	Default Setting	Available Options
Description				
GROUP 1 RESIDUAL O/V NVD	3B	00		
This column contains settings for Residual Overvoltage (Neutral Voltage Displacement)				
VN Input	3B	01	Derived	Not Settable
This cell indicates that VN Input is always derived from the 3 phase voltages				
VN Input	3B	01	Measured	Not Settable
This cell indicates that VN Input is always measured				
VN>1 Function	3B	02	DT	0 = Disabled 1 = DT 2 = IDMT 3= User Curve 1 4= User Curve 2 5= User Curve 3 6= User Curve 4
This setting determines the tripping characteristic for the first stage residual overvoltage element.				
VN>1 Voltage Set	3B	03	5	1V to 80V step 1V
This setting sets the pick-up threshold for the first stage.				
VN>1 Time Delay	3B	04	5	From 0s to 100s step 0.01s
This setting sets the operate time delay for the first stage.				
VN>1 TMS	3B	05	1	0.5 to 100 step 0.5
This setting sets the time multiplier setting for the IDMT characteristic.				
VN>1 tReset	3B	06	0	From 0s to 100s step 0.01s
This setting sets the DT reset time.				
VN>2 Status	3B	07	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the second stage SEF element. There is no choice of curves because this stage is DT only.				
VN>2 Voltage Set	3B	08	10	1V to 80V step 1V
This setting sets the pick-up threshold for the second stage.				
VN>2 Time Delay	3B	09	10	From 0s to 100s step 0.01s
This setting sets the operate time delay for the second stage.				
VN>3 Function	3B	0A	DT	0 = Disabled 1 = DT 2 = IDMT 3= User Curve 1 4= User Curve 2 5= User Curve 3 6= User Curve 4
This setting determines the tripping characteristic for the third stage residual overvoltage element.				
VN>3 Voltage Set	3B	0B	5	1V to 80V step 1V
This setting sets the pick-up threshold for the third stage.				
VN>3 Time Delay	3B	0C	5	From 0s to 100s step 0.01s
This setting sets the operate time delay for the third stage.				
VN>3 TMS	3B	0D	1	0.5 to 100 step 0.5
This setting sets the time multiplier setting for the IDMT characteristic.				
VN>3 tReset	3B	0E	0	From 0s to 100s step 0.01s

Menu Text	Col	Row	Default Setting	Available Options
Description				
This setting sets the DT reset time.				

5.5 APPLICATION NOTES

5.5.1 CALCULATION FOR SOLIDLY EARTHED SYSTEMS

Consider a phase A to Earth fault on a simple radial system.

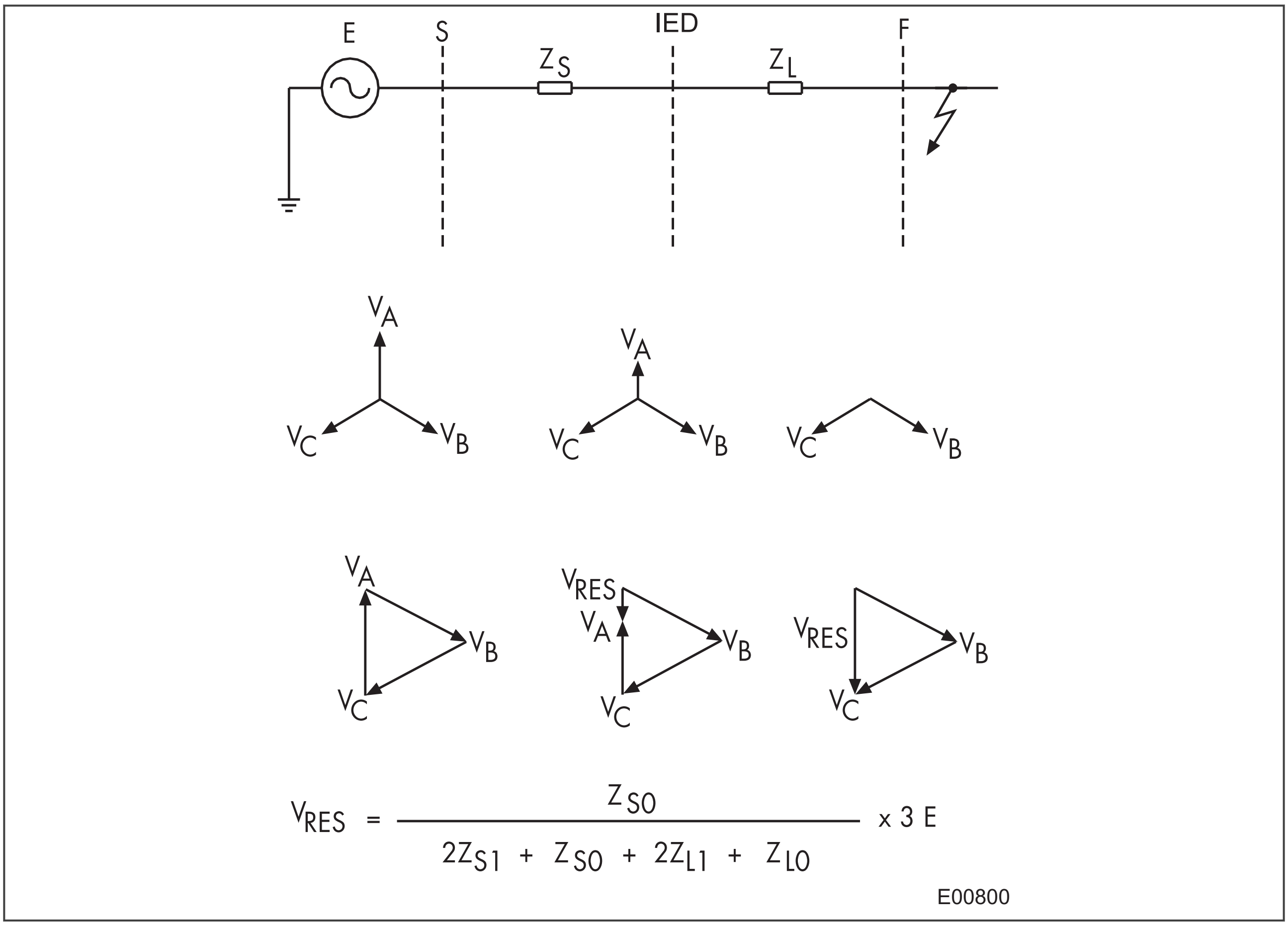


Figure 72: Residual voltage for a solidly earthed system

As can be seen from the above diagram, the residual voltage measured on a solidly earthed system is solely dependent on the ratio of source impedance behind the IED to the line impedance in front of the IED, up to the point of fault. For a remote fault far away, the Z_S/Z_L: ratio will be small, resulting in a correspondingly small residual voltage. Therefore, the protection only operates for faults up to a certain distance along the system. The maximum distance depends on the device setting.

5.5.2 CALCULATION FOR IMPEDANCE EARTHED SYSTEMS

Consider a phase A to Earth fault on a simple radial system.

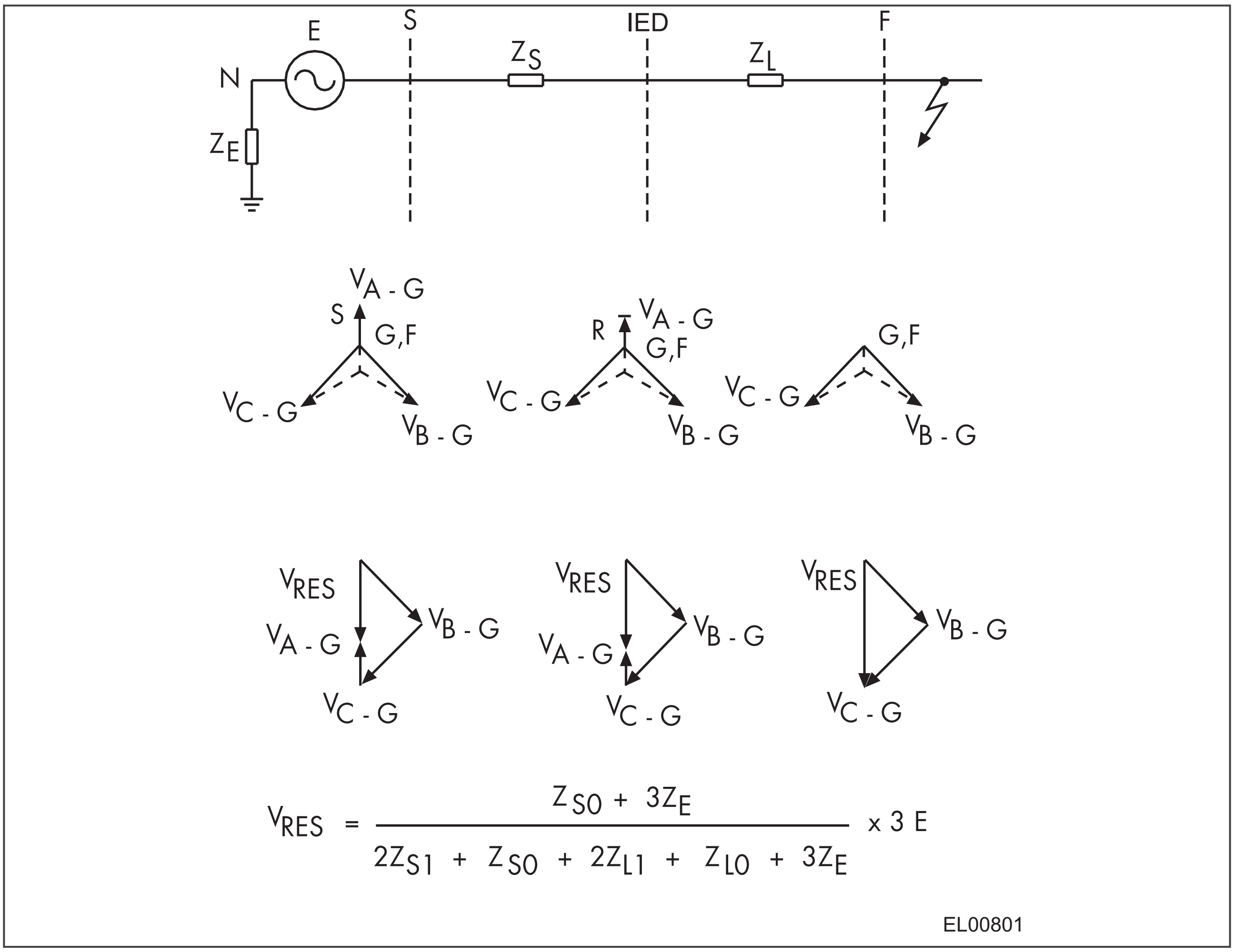


Figure 73: Residual voltage for an impedance earthed system

An impedance earthed system will always generate a relatively large degree of residual voltage, as the zero sequence source impedance now includes the earthing impedance. It follows then that the residual voltage generated by an earth fault on an insulated system will be the highest possible value (3 x phase-neutral voltage), as the zero sequence source impedance is infinite.

5.5.3 CALCULATION FOR IMPEDANCE EARTHED SYSTEMS

The voltage setting applied to the elements is dependent on the magnitude of residual voltage that is expected to occur during the earth fault condition. This in turn is dependent upon the method of system earthing employed.

Also, you must ensure that the IED setting is set above any standing level of residual voltage that is present on the system.

6 NEGATIVE SEQUENCE OVERVOLTAGE PROTECTION

Where an incoming feeder is supplying rotating plant equipment such as an induction motor, correct phasing and balance of the supply is essential. Incorrect phase rotation will result in connected motors rotating in the wrong direction. For directionally sensitive applications, such as elevators and conveyor belts, it is unacceptable to allow this to happen.

Imbalances on the incoming supply cause negative phase sequence voltage components. In the event of incorrect phase rotation, the supply voltage would effectively consist of 100% negative phase sequence voltage only.

6.1 NEGATIVE SEQUENCE OVERVOLTAGE IMPLEMENTATION

Negative Sequence Overvoltage Protection is implemented in the NEG SEQUENCE O/V column of the relevant settings group.

The device includes one Negative Phase Sequence Overvoltage element with a single stage. Only Definite time is possible.

This element monitors the input voltage rotation and magnitude (normally from a bus connected voltage transformer) and may be interlocked with the motor contactor or circuit breaker to prevent the motor from being energised whilst incorrect phase rotation exists.

The element is enabled using the **V2> status** cell.

6.2 NEGATIVE SEQUENCE OVERVOLTAGE LOGIC

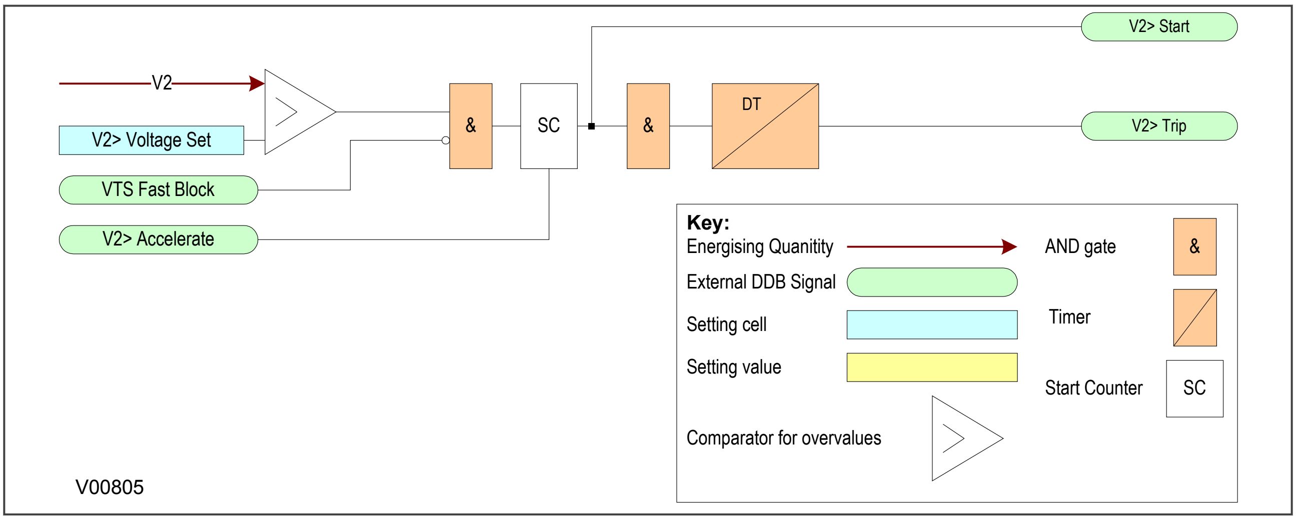


Figure 74: Negative Sequence Overvoltage logic

The Negative Voltage Sequence Overvoltage module (**V2>**) is a level detector that detects when the voltage magnitude exceeds a set threshold. When this happens, the comparator output Overvoltage Module produces a **Start** signal (**V2> Start**), which signifies the "Start of protection". This can be blocked by a **VTS Fast block** signal. This **Start** signal is applied to the DT timer module. The output of the DT timer module is the **V2> Trip** signal which is used to drive the tripping output relay.

The **V2> Accelerate** signal accelerates the operating time of the function, by reducing the number of cyles needed to start the function from 4 cycles to 2 cycles. At 50 hz, this means the protection start is reduced from 80 ms to 40 ms.

6.3 NEGATIVE SEQUENCE OVERVOLTAGE DDB SIGNALS

Ordinal	Signal Name	Source	Type	Response
Description				
277	V2> Trip	Software	PSL Input	Protection event
This DDB signal is the negative Sequence Overvoltage trip signal				
330	V2> Start	Software	PSL Input	Protection event
This DDB signal is the Negative Sequence Overvoltage start signal				
350	VTS Fast Block	Software	PSL Input	No response
This DDB signal is an instantaneously blocking output from the VTS which can block other functions				
517	V2> Accelerate	Programmable Scheme Logic	PSL Output	No response
This DDB reduces the pickup delay of the negative sequence overvoltage function.				

6.4 NEGATIVE SEQUENCE OVERVOLTAGE SETTINGS

Menu Text	Col	Row	Default Setting	Available Options
Description				
GROUP 1 NEG SEQUENCE O/V	3D	00		
This column contains settings for Negative Sequence Over Voltage protection (NPSOV)				
V2> Status	3D	01	Enabled	0 = Disabled, 1 = Enabled
This setting enables or disables NPSOV.				
V2> Voltage Set	3D	02	15	From 1*V1 to 110*V1 step 1*V1
This setting sets the pick-up threshold for the NPSOV protection element.				
V2> Time Delay	3D	03	5	From 0s to 100s step 0.01s
This setting sets the operate time-delay for the NPSOV protection element.				

6.5 APPLICATION NOTES

6.5.1 SETTING GUIDELINES

The primary concern is usually the detection of incorrect phase rotation (rather than small imbalances), therefore a sensitive setting is not required. The setting must be higher than any standing NPS voltage, which may be present due to imbalances in the measuring VT, device tolerances etc.

A setting of approximately 15% of rated voltage may be typical.

> *Note:*
> *Standing levels of NPS voltage (V2) are displayed in the **V2 Magnitude** cell of the MEASUREMENTS 1 column.*

The operation time of the element is highly dependent on the application. A typical setting would be in the region of 5 seconds.

7 FREQUENCY PROTECTION OVERVIEW

Power generation and utilisation needs to be well balanced in any industrial, distribution or transmission network. These electrical networks are dynamic entities, with continually varying loads and supplies, which are continually affecting the system frequency. Increased loading reduces the system frequency and generation needs to be increased to maintain the frequency of the supply. Conversely decreased loading increases the system frequency and generation needs to be reduced. Sudden fluctuations in load can cause rapid changes in frequency, which need to be dealt with quickly.

Unless corrective measures are taken at the appropriate time, frequency decay can go beyond the point of no return and cause widespread network collapse, which has dire consequences.

Protection devices capable of detecting low frequency conditions are generally used to disconnect unimportant loads in order to re-establish the generation-to-load balance. However, with such devices, the action is initiated only after the event and this form of corrective action may not be effective enough to cope with sudden load increases that cause large frequency decays in very short times. In such cases a device that can anticipate the severity of frequency decay and act to disconnect loads before the frequency reaches dangerously low levels, are very effective in containing damage. This is called instantaneous rate of change of frequency protection.

During severe disturbances, the frequency of the system oscillates as various generators try to synchronise to a common frequency. The measurement of instantaneous rate of change of frequency can be misleading during such a disturbance. The frequency decay needs to be monitored over a longer period of time to make the correct decision for load shedding. This is called average rate of dchange of frequency protection.

Normally, generators are rated for a particular band of frequency. Operation outside this band can cause mechanical damage to the turbine blades. Protection against such contingencies is required when frequency does not improve even after load shedding steps have been taken. This type of protection can be used for operator alarms or turbine trips in case of severe frequency decay.

Clearly a range of methods is required to ensure system frequency stability. The Alstom Grid frequency devices provides several protection means:

- Underfrequency Protection: abbreviated to f+t<
- Overfrequency Protection: abbreviated to f+t>
- Independent Rate of Change of Frequency Protection: abbreviated to Independent R.O.C.O.F, or df/dt +t
- Frequency-supervised Rate of Change of Frequency Protection: abbreviated to Frequency-supervised R.O.C.O.F, or f+df/dt
- Average Rate of Change of Frequency Protection: abbreviated to Average R.O.C.O.F, or f+Df/Dt (note the uppercase 'D')
- Load Shedding and Restoration

7.1 FREQUENCY PROTECTION IMPLEMENTATION

Frequency Protection is implemented in the FREQ PROTECTION column of the relevant settings group.

The device includes 9 stages for all the frequency protection methods (f+t<, f+t>, df/dt+t, f+df/dt, f+Df/Dt) to facilitate load shedding and subsequent restoration.

Each stage can be disabled or enabled with the **Stage (n)** setting. The frequency protection can also be blocked by an undervoltage condition if required.

8 UNDERFREQUENCY PROTECTION

A reduced system frequency implies that the net load is in excess of the available generation. Such a condition can arise, when an interconnected system splits, and the load left connected to one of the subsystems is in excess of the capacity of the generators in that particular subsystem. Industrial plants that are dependent on utilities to supply part of their loads will experience underfrequency conditions when the incoming lines are lost.

Many types of industrial loads have limited tolerances on the operating frequency and running speeds (e.g. synchronous motors). Sustained underfrequency has implications on the stability of the system, whereby any subsequent disturbance may damage equipment and even lead to blackouts. It is therefore essential to provide protection for underfrequency conditions.

8.1 UNDERFREQUENCY PROTECTION IMPLEMENTATION

The following settings are relevant for underfrequency:

- **Stg (n) f+t Status**: determines whether the stage is underfrequency, overfrequency, or disabled
- **Stg (n) f+t Freq**: defines the frequency pickup setting
- **Stg (n) f+t Time**: sets the time delay

8.2 UNDERFREQUENCY PROTECTION LOGIC

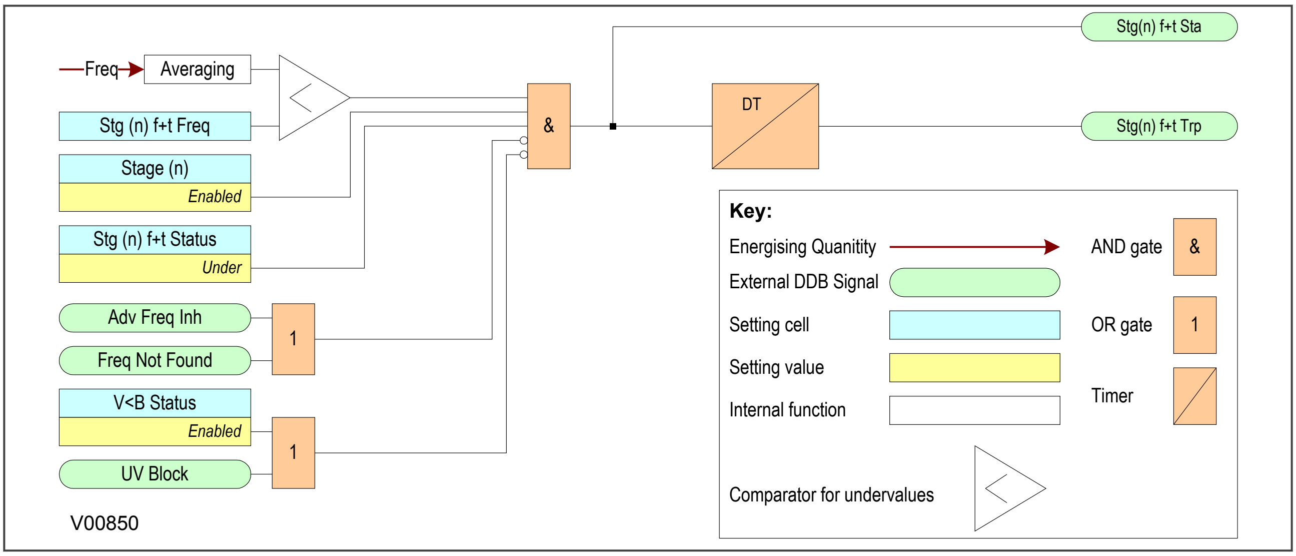


Figure 75: Underfrequency logic (single stage)

If the frequency is below the setting and not blocked the DT timer is started. If the frequency cannot be determined, the function is blocked.

8.3 APPLICATION NOTES

8.3.1 SETTING GUIDELINES

In order to minimise the effects of underfrequency, a multi-stage load shedding scheme may be used with the plant loads prioritised and grouped. During an underfrequency condition, the load groups are disconnected sequentially, with the highest priority group being the last one to be disconnected.

The effectiveness of each load shedding stage depends on the proportion of power deficiency it represents. If the load shedding stage is too small compared with the prevailing generation deficiency, then there may be no improvement in the frequency. This should be taken into account when forming the load groups.

Time delays should be sufficient to override any transient dips in frequency, as well as to provide time for the frequency controls in the system to respond. These should not be excessive as this could jeopardize system stability. Time delay settings of 5 - 20 s are typical.

An example of a four-stage load shedding scheme for 50 Hz systems is shown below:

Stage	Element	Frequency Setting (Hz)	Time Setting (Sec)
1	Stage 1(f+t)	49.0	20 s
2	Stage 2(f+t)	48.6	20 s
3	Stage 3(f+t)	48.2	10 s
4	Stage 4(f+t)	47.8	10 s

The relatively long time delays are intended to provide sufficient time for the system controls to respond. This will work well in a situation where the decline of system frequency is slow. For situations where rapid decline of frequency is expected, this load shedding scheme should be supplemented by rate of change of frequency protection elements.

9 OVERFREQUENCY PROTECTION

An increased system frequency arises when the mechanical power input to a generator exceeds the electrical power output. This could happen, for instance, when there is a sudden loss of load due to tripping of an outgoing feeder from the plant to a load centre. Under such conditions, the governor would normally respond quickly to obtain a balance between the mechanical input and electrical output, thereby restoring normal frequency. Overfrequency protection is required as a backup to cater for cases where the reaction of the control equipment is too slow.

9.1 OVERFREQUENCY PROTECTION IMPLEMENTATION

The following settings are relevant for overfrequency:

- **Stg (n) f+t Status**: determines whether the stage is underfrequency, overfrequency, or disabled
- **Stg (n) f+t Freq**: defines the frequency pickup setting
- **Stg (n) f+t Time**: sets the time delay

9.2 OVERFREQUENCY PROTECTION LOGIC

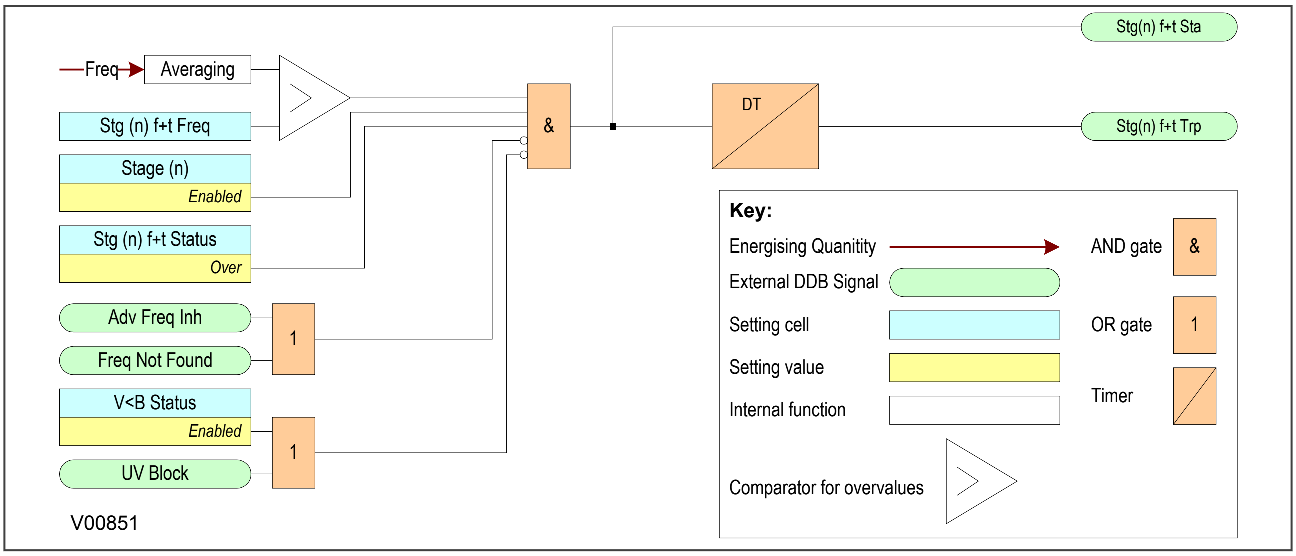


Figure 76: Overfrequency logic (single stage)

If the frequency is above the setting and not blocked, the DT timer is started and after this has timed out, the trip is produced. If the frequency cannot be determined, the function is blocked.

9.3 APPLICATION NOTES

9.3.1 SETTING GUIDELINES

Following changes on the network caused by faults or other operational requirements, it is possible that various subsystems will be formed within the power network. It is likely that these subsystems will suffer from a generation/load imbalance. The "islands" where generation exceeds the existing load will be subject to overfrequency conditions. Severe over frequency conditions may be unacceptable to many industrial loads, since running speeds of motors will be affected. The overfrequency element can be suitably set to sense this contingency.

An example of two-stage overfrequency protection is shown below using stages 5 and 6 of the f+t elements. However, settings for a real system will depend upon the maximum frequency that equipment can tolerate for a given period of time.

Stage	Element	Frequency Setting (Hz)	Time Setting (Sec.)
1	Stage 5(f+t)	50.5	30
2	Stage 6(f+t)	51.0	20

The relatively long time delays are intended to provide time for the system controls to respond and will work well in a situation where the increase of system frequency is slow.

For situations where rapid increase of frequency is expected, the protection scheme above could be supplemented by rate of change of frequency protection elements.

In the system shown below, the generation in the MV bus is sized according to the loads on that bus, whereas the generators linked to the HV bus produce energy for export to utility. If the links to the grid are lost, the IPP generation will cause the system frequency to rise. This rate of rise could be used to isolate the MV bus from the HV system.

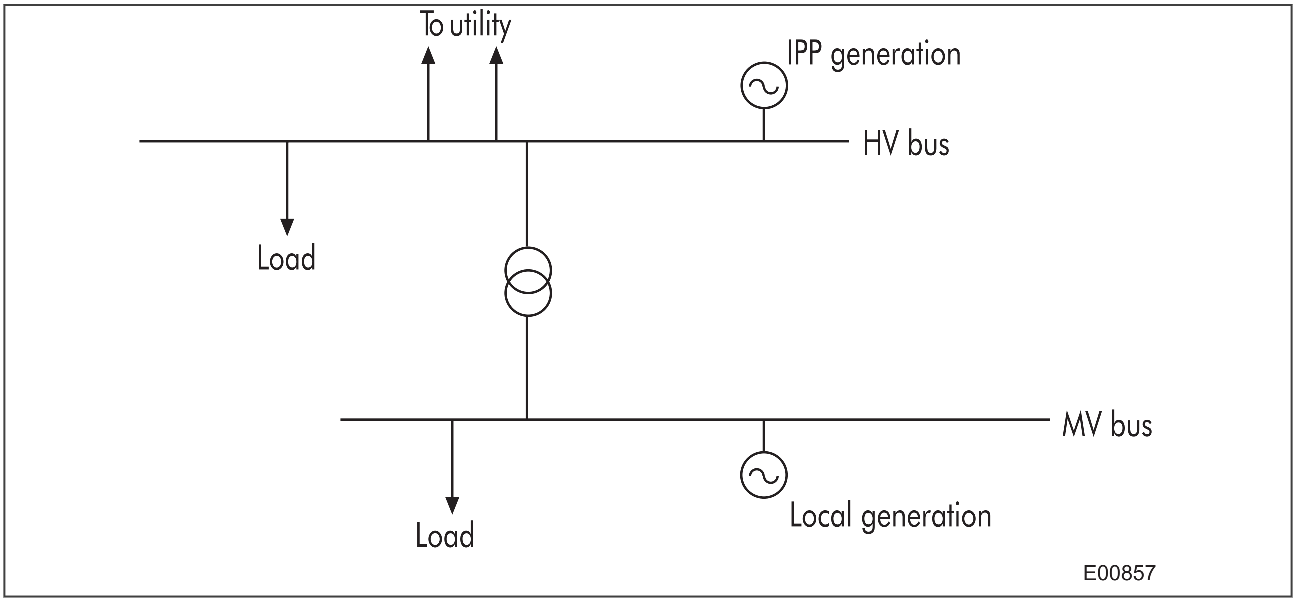


Figure 77: Power system segregation based upon frequency measurements

10 INDEPENDENT R.O.C.O.F PROTECTION

Where there are very large loads imbalances may occur that result in rapid decline in system frequency. The situation could be so bad that shedding one or two stages of load is unlikely to stop this rapid frequency decline. In such a situation, standard underfrequency protection will normally have to be supplemented with protection that responds to the rate of change of frequency. An element is therefore required which identifies the high rate of decline of frequency, and adapts the load shedding scheme accordingly.

Such protection can identify frequency variations occurring close to nominal frequency thereby providing early warning of a developing frequency problem. The element can also be used as an alarm to warn operators of unusually high system frequency variations.

Independent Rate of Change of Frequency protection is also known as df/dt+t protection.

10.1 INDEPENENT R.O.C.O.F PROTECTION IMPLEMENTATION

The device provides nine independent stages of protection. Each stage can respond to either rising or falling frequency conditions. This depends on whether the frequency threshold is set above or below the system nominal frequency. For example, if the frequency threshold is set above nominal frequency, the rate of change of frequency setting is considered as positive and the element will operate for rising frequency conditions. If the frequency threshold is set below nominal frequency, the setting is considered as negative and the element will operate for falling frequency conditions.

The following settings are relevant for df/dt+t protection:

- **df/dt+t (n) Status**: determines whether the stage is for falling or rising frequency conditions
- **df/dt+t (n) Set**: defines the rate of change of frequency pickup setting
- **df/dt+t (n) Time**: sets the time delay

10.2 INDEPENDENT R.O.C.O.F PROTECTION LOGIC

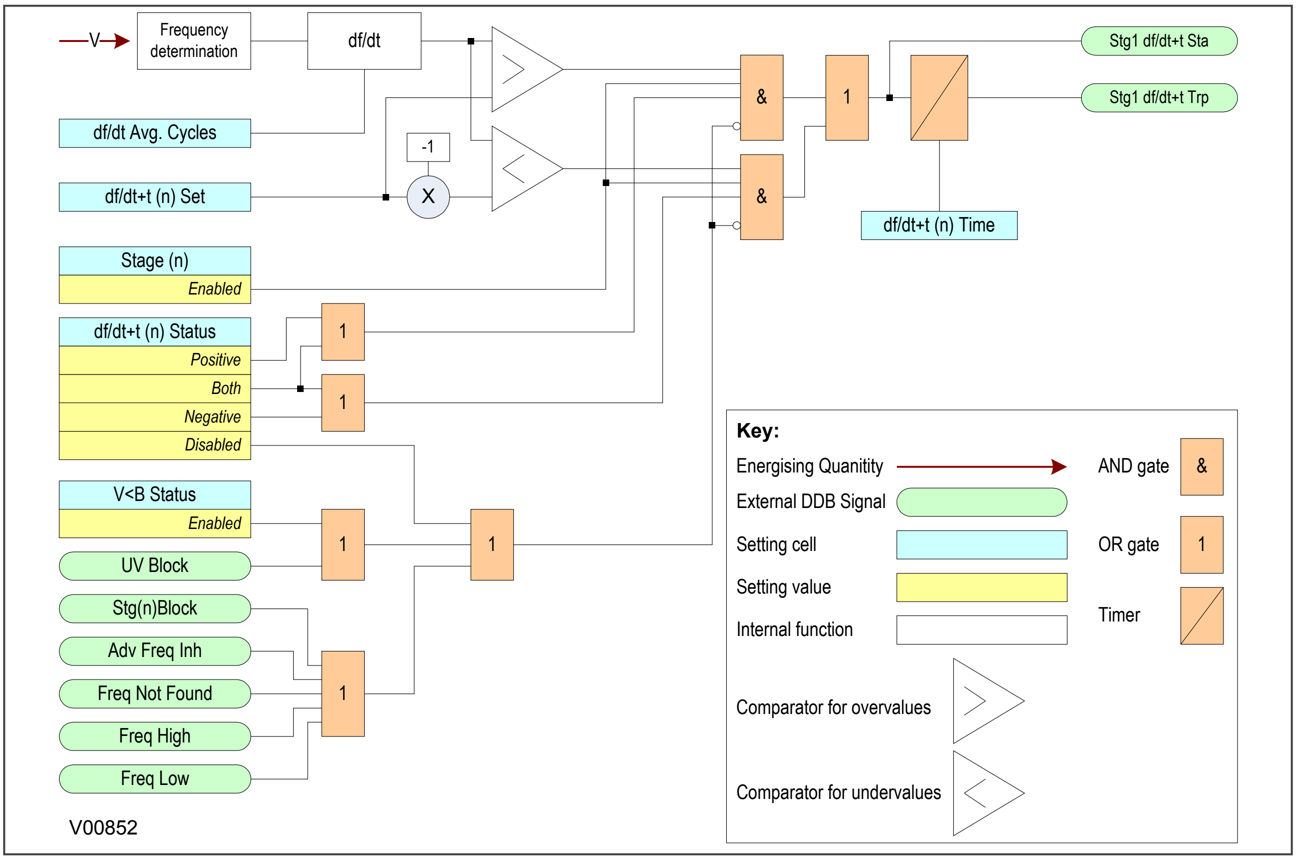


Figure 78: Independent rate of change of frequency logic (single stage)

10.3 APPLICATION NOTES

10.3.1 SETTING GUIDELINES

Considerable care should be taken when setting this element because it is not supervised by a frequency setting. Setting of the time delay or increasing the number of df/dt averaging cycles will improve stability but this is traded against reduced tripping times.

It is likely that this element would be used in conjunction with other frequency based protection elements to provide a scheme that accounts for severe frequency fluctuations. An example scheme is shown below:

	Frequency "f+t [81U/81O]" Elements		Frequency Supervised Rate of Change of Frequency "f +df/dt [81RF]" Elements	
Stage	Frequency Setting (Hz)	Time Setting (Sec.)	Frequency Setting (Hz)	Rate of Change of Frequency Setting (Hz/Sec.)
1	49	20	49.2	1.0
2	48.6	20	48.8	1.0
3	48.2	10	48.4	1.0
4	47.8	10	48.0	1.0
5	-	-	-	-

Stage	Rate of Change of Frequency "df/dt+t [81R]" Elements	
	Rate of Change of Frequency Setting (Hz/Sec.)	Time Setting (Sec.)
1	-	-
2	-	-
3	-3.0	0.5
4	-3.0	0.5
5	-3.0	0.1

In this scheme, tripping of the last two stages is accelerated by using the independent rate of change of frequency element. If the frequency starts falling at a high rate (> 3 Hz/s in this example), then stages 3 & 4 are shed at around 48.5 Hz, with the objective of improving system stability. Stage 5 serves as an alarm and gives operators advance warning that the situation is critical.

11 FREQUENCY-SUPERVISED R.O.C.O.F PROTECTION

Frequency-supervised Rate of Change of Frequency protection works in a similar way to Independent Rate of change of Frequency Protection. The only difference is that with frequency supervision, the actual frequency itself is monitored and the protection operates when both the rate of change of frequency AND the frequency itself go outside the set limits.

Frequency-supervised Rate of Change of Frequency protection is also known asf+df/dt protection.

11.1 FREQUENCY-SUPERVISED R.O.C.O.F IMPLEMENTATION

The device provides nine independent stages of protection. Each stage can respond to either rising or falling frequency conditions. This depends on whether the frequency threshold is set above or below the system nominal frequency. For example, if the frequency threshold is set above nominal frequency, the rate of change of frequency setting is considered as positive and the element will operate for rising frequency conditions. If the frequency threshold is set below nominal frequency, the setting is considered as negative and the element will operate for falling frequency conditions.

The following settings are relevant for f+ df/dt protection:

- **f+df/dt 1 Status**: determines whether the stage is for falling or rising frequency conditions
- **f+df/dt 1 freq**: defines the frequency pickup setting
- **f+df/dt 1 df/dt**: defines the rate of change of frequency pickup setting

The device will also indicate when an incorrect setting has been applied if the frequency threshold is set to the nominal system frequency. There is no intentional time delay associated with this element, but time delays could be applied using the PSL if required.

11.2 FREQUENCY-SUPERVISED R.O.C.O.F LOGIC

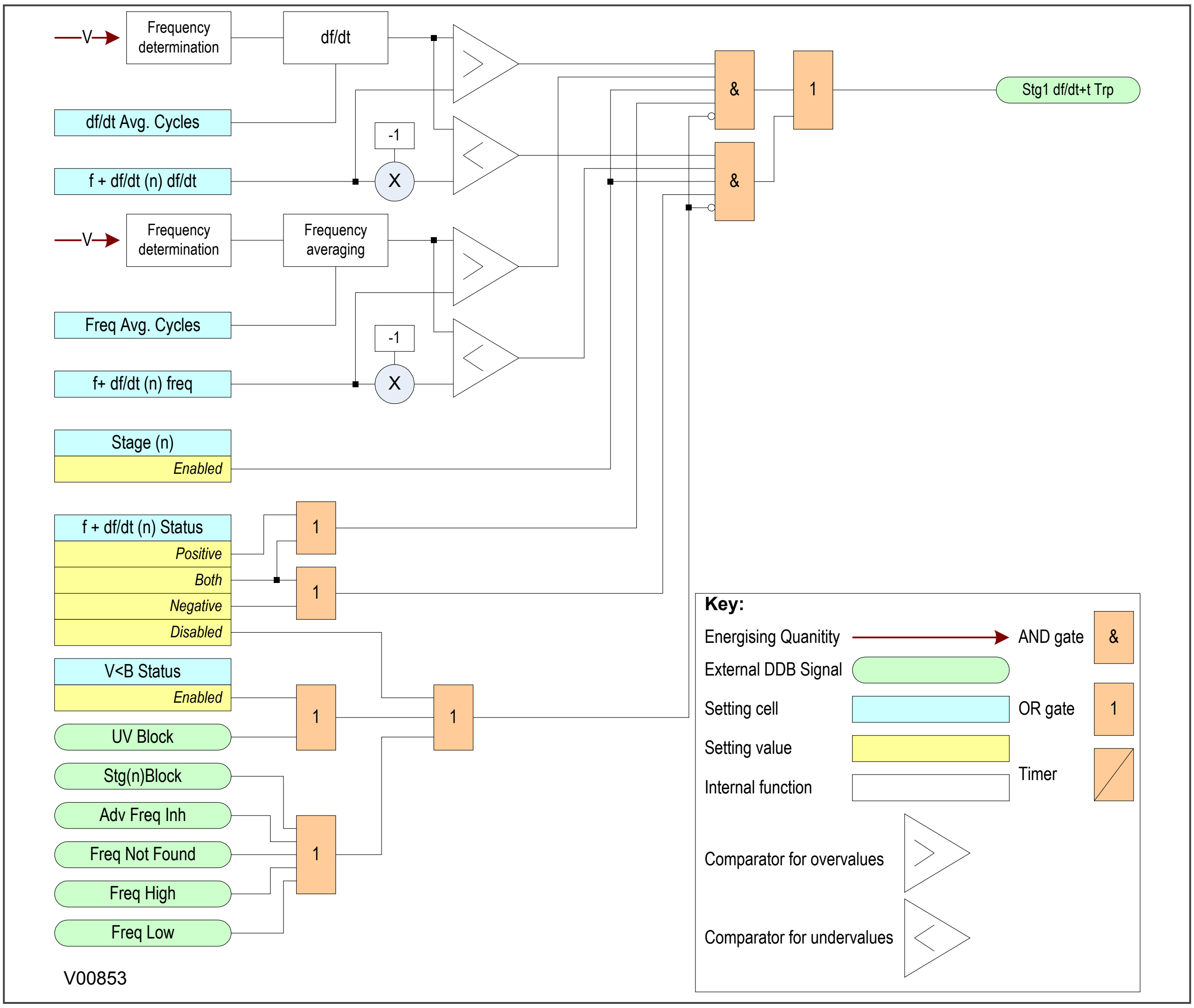


Figure 79: Frequency-supervised rate of change of frequency logic (single stage)

11.3 APPLICATION NOTES

11.3.1 APPLICATION EXAMPLE

In the load shedding scheme below, we assume that for falling frequency conditions, the system can be stabilised at frequency f2 by shedding a stage of load. For slow rates of decay, this can be achieved using the underfrequency protection element set at frequency f1 with a suitable time delay. However, if the generation deficit is substantial, the frequency will rapidly decrease and it is possible that the time delay imposed by the underfrequency protection will not allow for frequency stabilisation. In this case, the chance of system recovery will be enhanced by disconnecting the load stage based on a measurement of rate of change of frequency and bypassing the time delay.

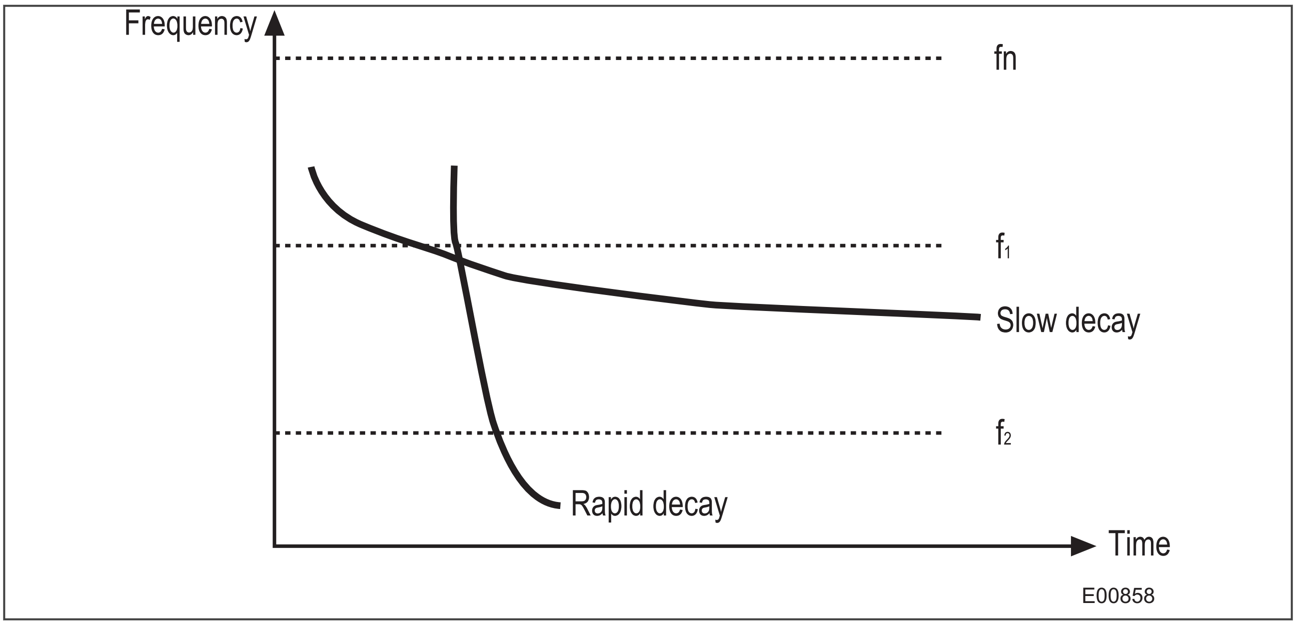


Figure 80: Frequency supervised rate of change of frequency protection

11.3.2 SETTING GUIDELINES

We recommend that the frequency supervised rate of change of frequency protection (f+df/dt) element be used in conjunction with the time delayed frequency protection (f+t) elements.

A four stage high speed load shedding scheme may be configured as indicated below, noting that in each stage, both the "f+t" and the "f+df/dt" elements are enabled.

	Frequency "f+t [81U/81O]" Elements		Frequency Supervised Rate of Change of Frequency "f+df/dt [81RF]" Elements	
Stage	Frequency Setting (Hz)	Time Setting (Sec.)	Frequency Setting (Hz)	Rate of Change of Frequency Setting (Hz/sec.)
1	49	20	49	1.0
2	48.6	20	48.6	1.0
3	48.2	10	48.2	1.0
4	47.8	10	47.8	1.0

It may be possible to further improve the speed of load shedding by changing the frequency setting on the f +df/dt element. In the settings outlined below, the frequency settings for this element have been set slightly higher than the frequency settings for the f+t element. This difference will allow for the measuring time, and will result in the tripping of the two elements at approximately the same frequency value. Therefore, the slow frequency decline and fast frequency decline scenarios are independently monitored and optimised without sacrificing system security.

	Frequency "f+t [81U/81O]" Elements		Frequency Supervised Rate of Change of Frequency "f +df/dt [81RF]" Elements	
Stage	Frequency Setting (Hz)	Time Setting (Sec.)	Frequency Setting (Hz)	Rate of Change of Frequency Setting (Hz/sec.)
1	49	20	49.2	1.0
2	48.6	20	48.8	1.0
3	48.2	10	48.4	1.0
4	47.8	10	48.0	1.0

12 AVERAGE RATE OF CHANGE OF FREQUENCY PROTECTION

Owing to the complex dynamics of power systems, variations in frequency during times of generation-to-load imbalance are highly non-linear. Oscillations will occur as the system seeks to address the imbalance, resulting in frequency oscillations typically in the order of 0.1 Hz to 1 Hz, in addition to the basic change in frequency.

The independent and frequency-supervised rate of change of frequency elements use an instantaneous measurement of the rate of change of frequency, based on a 3-cycle, filtered, rolling average technique. Due to the oscillatory nature of frequency excursions, this instantaneous value can sometimes be misleading, either causing unexpected operation or excessive instability. For this reason, the device also provides an element for monitoring the longer term frequency trend, thereby reducing the effects of non-linearity in the system.

Average Rate of Change of Frequency protection is also known as f+Df/Dt protection (note the upper-case "D").

12.1 AVERAGE R.O.C.O.F PROTECTION IMPLEMENTATION

The device provides nine independent stages of protection. Each stage can respond to either rising or falling frequency conditions. This depends on whether the frequency threshold is set above or below the system nominal frequency. For example, if the frequency threshold is set above nominal frequency, the rate of change of frequency setting is considered as positive and the element will operate for rising frequency conditions. If the frequency threshold is set below nominal frequency, the setting is considered as negative and the element will operate for falling frequency conditions.

When the measured frequency crosses the supervising frequency threshold, a timer is initiated. At the end of this time period, the frequency difference is evaluated and if this exceeds the setting, a trip output is given.

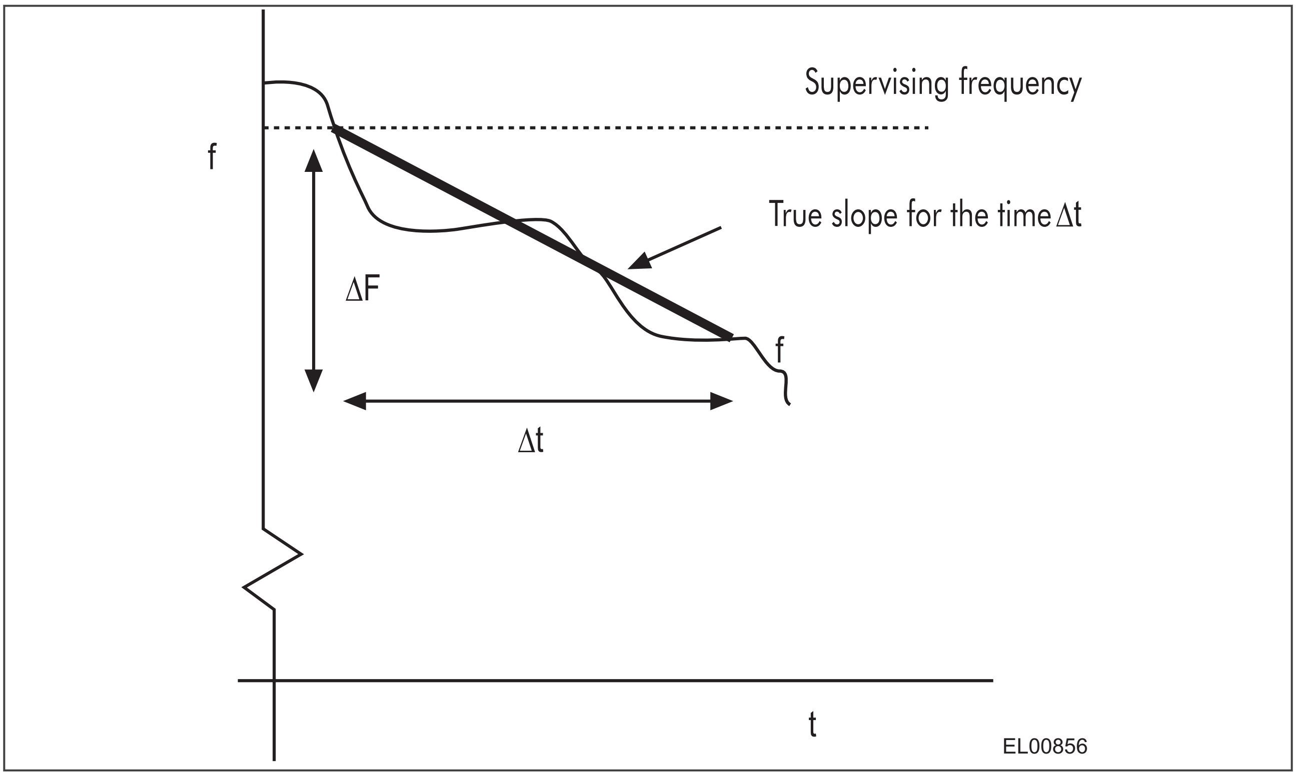


Figure 81: Average rate of change of frequency characteristic

After time Δt, the element is blocked from further operation until the frequency recovers to a value above the supervising frequency threshold. If the element has operated, the trip DDB signal will be ON until the frequency recovers to a value above the supervising frequency threshold.

The average rate of change of frequency is then measured based on the frequency difference, Δf over the settable time period, Δt.

The following settings are relevant for Df/Dt protection:

- **f+Df/Dt (n) Status**: determines whether the stage is for falling or rising frequency conditions
- **f+Df/Dt (n) Freq**: defines the frequency pickup setting
- **f+Df/Dt (n) Dfreq**: defines the change in frequency that must be measured in a set time period
- **f+Df/Dt (n) Dtime**: sets the time period over which the frequency is monitiored

12.2 AVERAGE R.O.C.O.F LOGIC

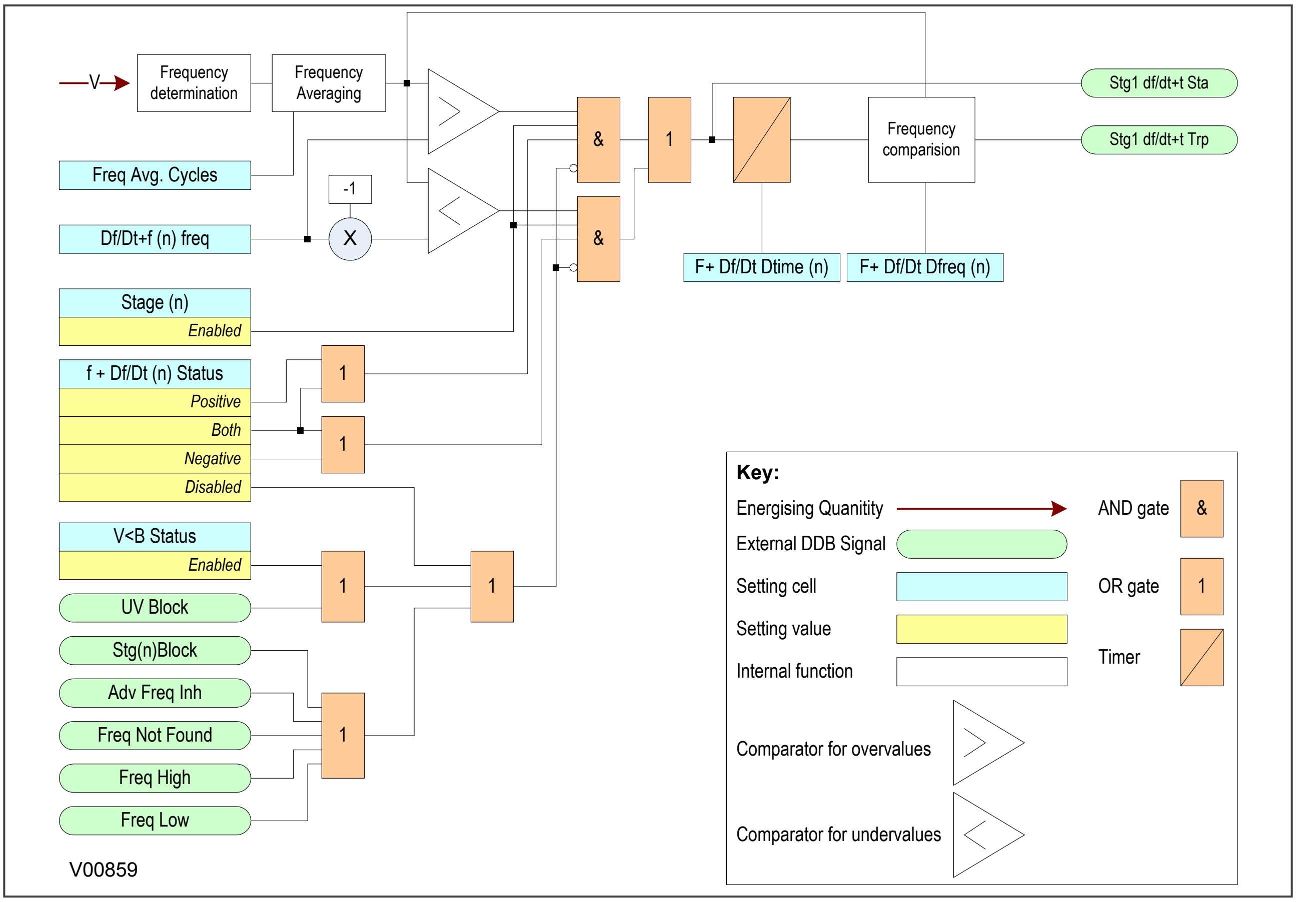


Figure 82: Average rate of change of frequency logic (single stage)

12.3 APPLICATION NOTES

12.3.1 SETTING GUIDELINES

The average rate of change of frequency element can be set to measure the rate of change over a short period as low as 20 ms (1 cycle @ 50 Hz) or a relatively long period up to 2 s (100 cycles @ 50 Hz). With a time setting, Dt, towards the lower end of this range, the element becomes similar to the frequency supervised rate of change function, "f+df/dt". With high Dt settings, the element acts as a frequency trend monitor.

Although the element has a wide range of setting possibilities we recommend that the Dt setting is set greater than 100 ms to ensure the accuracy of the element.

A possible four stage load shedding scheme using the average rate of change frequency element is shown in the following table:

	Frequency "f+t [81U/81O]" Elements		Average Rate of Change of Frequency "f+Df/Dt [81RAV]" Elements		
Stage	**(f+t) f Frequency Setting (Hz)**	**(f+t) t Time Setting (Sec.)**	**(f+Df/Dt) f Frequency Setting (Hz)**	**(f+Df/Dt) Df Frequency Diff Setting, (Hz)**	**(f+Df/Dt) Dt Time Period, (Sec.)**
1	49	20	49	0.5	0.5
2	48.6	20	48.6	0.5	0.5
3	48.2	10	48.2	0.5	0.5
4	47.8	10	47.8	0.5	0.5

In the above scheme, the faster load shed decisions are made by monitoring the frequency change over 500 ms. Therefore tripping takes place more slowly than in schemes employing frequency-supervised df/dt, but the difference is not very much at this setting. If the delay jeopardises system stability, then the scheme can be improved by increasing the independent "f" setting. Depending on how much this value is increased, the frequency at which the "f+Df/Dt" element will trip also increases and so reduces the time delay under more severe frequency fluctuations. For example, with the settings shown below, the first stage of load shedding would be tripped approximately 300 msecs after 49.0 Hz is reached and at a frequency of approximately 48.7 Hz.

	Frequency "f+t [81U/81O]" Elements		Average Rate of Change of Frequency "f+Df/Dt [81RAV]" Elements		
Stage	**(f+t) f Frequency Setting (Hz)**	**(f+t) t Time Setting (Sec)**	**(f+Df/Dt) f Frequency Setting (Hz)**	**(f+Df/Dt) Df Frequency Diff Setting (Hz)**	**(f+Df/Dt) Dt Time Period, (Sec.)**
1	49	20	49.2	0.5	0.5 s
2	48.6	20	48.8	0.5	0.5 s
3	48.2	10	48.4	0.5	0.5 s
4	47.8	10	48.0	0.5	0.5 s

13 LOAD SHEDDING AND RESTORATION

The goal of load shedding is to stabilise a falling system frequency. As the system stabilises and the generation capability improves, the system frequency will recover to near normal levels and after some time delay it is possible to consider the restoration of load onto the healthy system. However, load restoration needs to be performed carefully and systematically so that system stability is not jeopardized again.

In the case of industrial plants with captive generation, load restoration should be linked to the available generation since connecting additional load when the generation is still inadequate, will only result in declining frequency and more load shedding. If the in-plant generation is insufficient to meet the load requirements, then load restoration should be interlocked with recovery of the utility supply.

Whilst load shedding leads to an improvement in the system frequency, the disconnected loads need to be reconnected after the system is stable again. Loads should only be restored if the frequency remains stable for some period of time (minor frequency excursions can be ignored during this time period). The number of load restoration steps is normally less than the load shedding steps to reduce repeated disturbances while restoring load.

13.1 LOAD RESTORATION IMPLEMENTATION

The device uses the measurement of system frequency as the main criteria for load restoration. For each stage of load restoration, it is necessary that the same stage of load shedding has occurred previously and that no elements within that stage are configured for overfrequency or rising frequency conditions. If load shedding has not previously occurred, the load restoration for that stage is inactive.

The device provides nine independent stages of Load Restoration. It is implemented in the FREQ PROTECTION column of the relevant settings group. The following settings are relevant for Load Restoration:

- **Restore(n) Status**: determines whether the stage is disabled or enabled
- **Restore(n) Freq**: defines the frequency pickup setting
- **Restore(n) Time**: Timer period for which the measured frequency must be higher than the stage restoration.
- **Holding Timer**: Sets the holding timer value

13.2 HOLDING BAND

Load restoration for a given stage begins when the system frequency rises above the **Restore(n) Freq** setting for that stage and the stage restoration timer **Restore(n) Time** is initiated. If the system frequency remains above the frequency setting for the set time delay, load restoration of that stage will be triggered.

Unfortunately, frequency recovery profiles are highly non-linear and it would be reasonably common for the system frequency to fall transiently below the restoration frequency threshold. If the restoration timer immediately reset whenever a frequency dip occurred, it is likely that load restoration would never be successful. For this reason, the IED has a "holding band". This holding band is a region defined by the restoration frequency and the highest frequency setting used in the load shedding elements for that stage. The difference between these two settings must always be greater than 0.02 Hz, otherwise a **Wrong Setting** alarm will be generated. Whenever the system frequency dips into the holding band, operation of the stage restoration timer is suspended until the frequency rises above the restoration frequency setting, at which point timing will continue. If the system frequency dip is sufficiently large to cause any frequency element to start or trip in this stage, i.e. if the frequency falls below the lower limit of the holding band, the restoration timer will immediately be reset. This is demonstrated below.

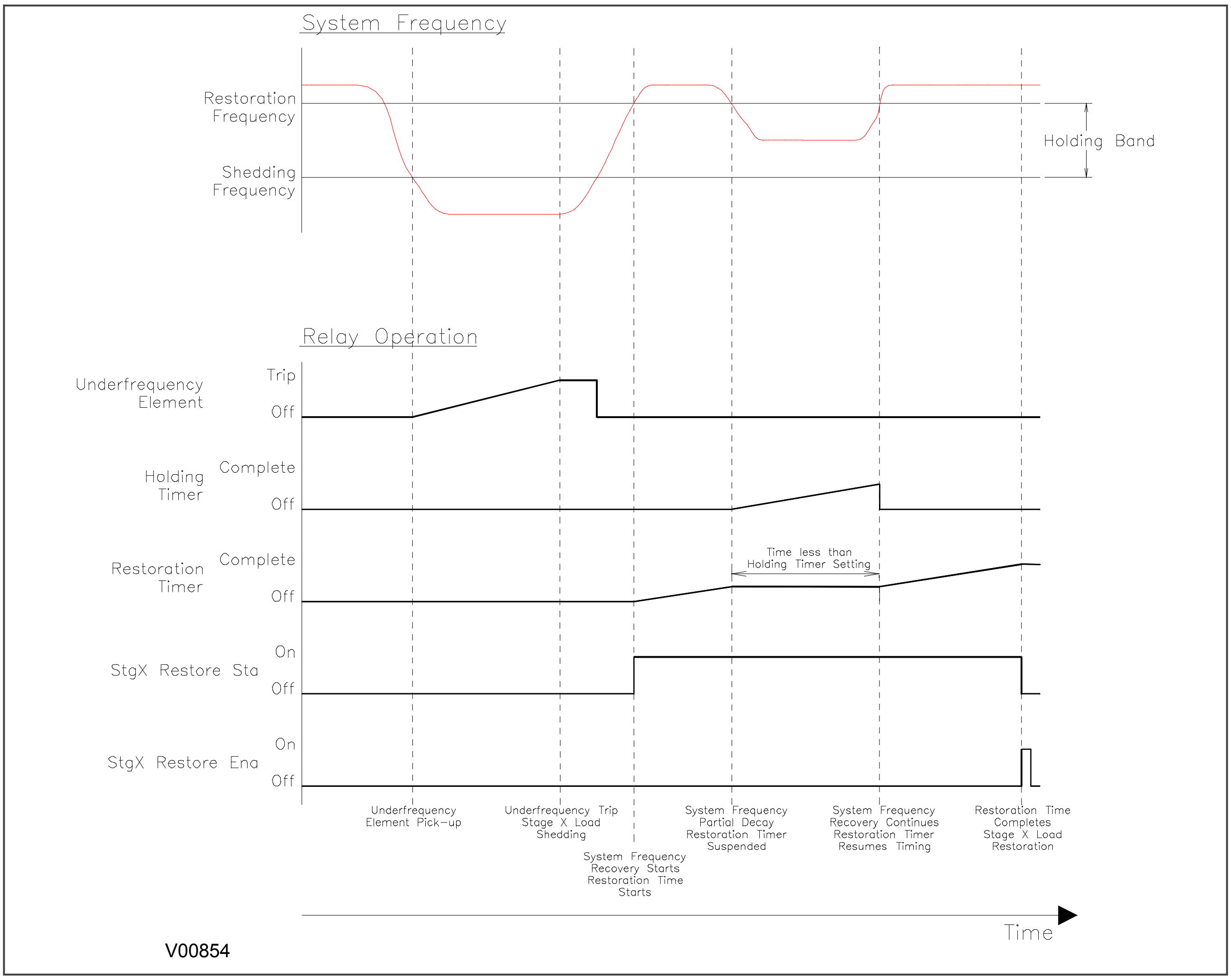


Figure 83: Load restoration with short deviation into holding band

If the system frequency remains in the holding band for too long it is likely that other system frequency problems are occurring and it would be prudent to reset the restoration timer for that stage. For this reason, as soon as the system frequency is measured to be within the holding band, the "Holding Timer" is initiated. If the system frequency doesn't leave the holding band before the holding timer setting has been exceeded, the load restoration time delay for that stage is immediately reset.

Note:
The holding timer has a common setting for all stages of load restoration.

An example of the case when the time in the holding band is excessive is shown below.

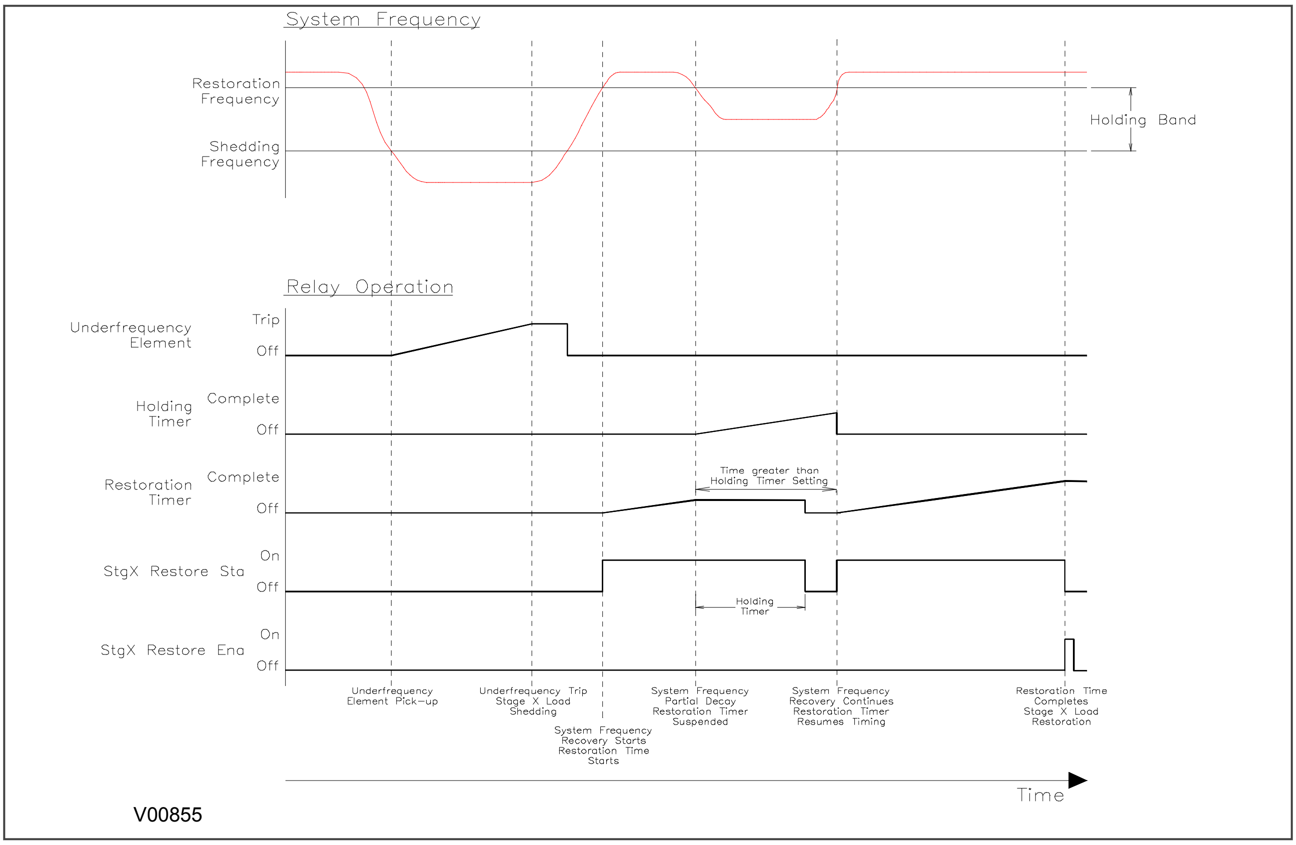


Figure 84: Load restoration with long deviation into holding band

13.3 LOAD RESTORATION LOGIC

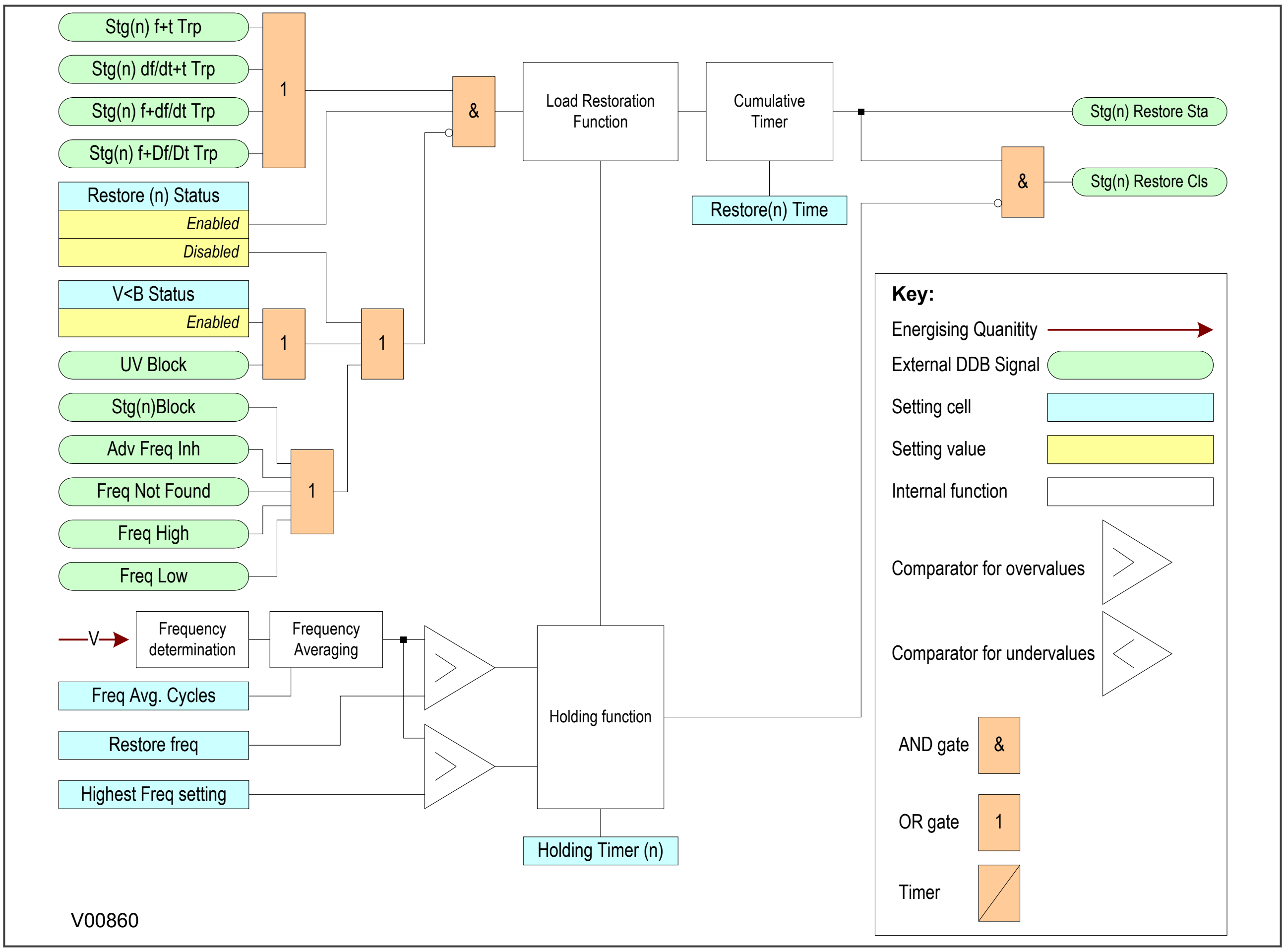


Figure 85: Load Restoration logic

13.4 APPLICATION NOTES

13.4.1 SETTING GUIDELINES

A four stage, single frequency load restoration scheme is shown below. The frequency setting has been chosen such that there is sufficient separation between the highest load shed frequency and the restoration frequency to prevent any possible hunting. A restoration frequency setting closer to nominal frequency may be chosen if an operating frequency of 49.3 Hz is unacceptable.

Stage	Restoration Frequency Setting (Hz)	Restoration Time Delay (secs)	Holding Time Delay (secs)
1	49.3 Hz	240 sec	20 sec
2	49.3 Hz	180 sec	20 sec
3	49.3 Hz	120 sec	20 sec
4	49.3 Hz	60 sec	20 sec

In this scheme, the time delays ensure that the most critical loads are reconnected (assuming that the higher stages refer to more important loads). By restoring the load sequentially, system stability should normally be maintained. These time settings are system dependent; higher or lower settings may be required depending on the particular application.

It is possible to set up restoration schemes involving multiple frequencies. This allows faster restoration of loads, but there is the possibility of continuous system operation at frequencies far removed from the nominal. A typical scheme using two frequencies is illustrated below:

Stage	Restore Freq. Restoration Frequency Setting (Hz)	Restore DelayRestoration Time Delay (S)	Holding Time Delay (S)
1	49.5 Hz	120 sec	20 sec
2	49.5 Hz	60 sec	20 sec
3	49.0 Hz	120 sec	20 sec
4	49.0 Hz	60 sec	20 sec

Staggered time settings may be used in this scheme as well, but the time separation among the restoration of stages will be a function of the frequency recovery pattern. Time coordinated restoration can only be guaranteed for those stages with a common restoration frequency setting.

14 FREQUENCY PROTECTION DDB SIGNALS

Within the Programmable Scheme Logic (PSL), signals are available to indicate the start and trip of each frequency stage.

The DDB signal states can be be viewed by setting the **Monitor Bit** cells in the COMMISSION TESTS column.

The complete set of frequency-related DDB signals is detailed as follows:

Ordinal	Signal Name	Source	Type	Response
Description				
167	UV Block	Software	PSL Input	Alarm latched event
This DDB blocks the undervoltage element				
411	Freq Not Found	Software	PSL Input	No response
This DDB signal indicates that no frequency has been found				
1280	Adv Freq Inh	Programmable Scheme Logic	PSL Output	No response
This DDB inhibits frequency protection				
1281	Stg1 f+t Sta	Software	PSL Input	Protection event
This DDB signal is the start signal for the first stage Frequency protection element.				
1282	Stg1 f+t Trp	Software	PSL Input	Protection event
This DDB signal is the trip signal for the first stage Frequency protection element.				
1283	Stg1 f+df/dt Trp	Software	PSL Input	Protection event
This DDB signal is the trip signal for the first stage Frequency-Supervised Rate-of-Change-of-Frequency protection element.				
1284	Stg1 df/dt+t Sta	Software	PSL Input	Protection event
This DDB signal is the start signal for the first stage Independent Rate-of-Change-of-Frequency protection element.				
1285	Stg1 df/dt+t Trp	Software	PSL Input	Protection event
This DDB signal is the trip signal for the first stage Independent Rate-of-Change-of-Frequency protection element.				
1286	Stg1 f+Df/Dt Sta	Software	PSL Input	Protection event
This DDB signal is the start signal for the first stage Average Rate-of-Change-of-Frequency protection element.				
1287	Stg1 f+Df/Dt Trp	Software	PSL Input	Protection event
This DDB signal is the trip signal for the first stage Average Rate-of-Change-of-Frequency protection element.				
1288	Stg1 Block	Programmable Scheme Logic	PSL Output	No response
This DDB signal blocks all first stage Frequency protection elements				
1291	Stg1 Restore Cls	Software	PSL Input	Protection event
This DDB signal closes the first stage Load Restoration				
1292	Stg1 Restore Sta	Software	PSL Input	Protection event
This DDB signal starts the first stage Load Restoration				
1295	Stg2 f+t Sta	Software	PSL Input	Protection event
This DDB signal is the start signal for the second stage Frequency protection element.				
1296	Stg2 f+t Trp	Software	PSL Input	Protection event
This DDB signal is the trip signal for the second stage Frequency protection element.				
1297	Stg2 f+df/dt Trp	Software	PSL Input	Protection event
This DDB signal is the trip signal for the second stage Frequency-Supervised Rate-of-Change-of-Frequency protection element.				
1298	Stg2 df/dt+t Sta	Software	PSL Input	Protection event
This DDB signal is the start signal for the second stage Independent Rate-of-Change-of-Frequency protection element.				
1299	Stg2 df/dt+t Trp	Software	PSL Input	Protection event

Ordinal	Signal Name	Source	Type	Response
Description				
This DDB signal is the trip signal for the second stage Independent Rate-of-Change-of-Frequency protection element.				
1300	Stg2 f+Df/Dt Sta	Software	PSL Input	Protection event
This DDB signal is the start signal for the second stage Average Rate-of-Change-of-Frequency protection element.				
1301	Stg2 f+Df/Dt Trp	Software	PSL Input	Protection event
This DDB signal is the trip signal for the second stage Average Rate-of-Change-of-Frequency protection element.				
1302	Stg2 Block	Programmable Scheme Logic	PSL Output	No response
This DDB signal blocks all second stage Frequency protection elements				
1305	Stg2 Restore Cls	Software	PSL Input	Protection event
This DDB signal closes the second stage Load Restoration				
1306	Stg2 Restore Sta	Software	PSL Input	Protection event
This DDB signal starts the second stage Load Restoration				
1309	Stg3 f+t Sta	Software	PSL Input	Protection event
This DDB signal is the start signal for the third stage Frequency protection element.				
1310	Stg3 f+t Trp	Software	PSL Input	Protection event
This DDB signal is the trip signal for the third stage Frequency protection element.				
1311	Stg3 f+df/dt Trp	Software	PSL Input	Protection event
This DDB signal is the trip signal for the third stage Frequency-Supervised Rate-of-Change-of-Frequency protection element.				
1312	Stg3 df/dt+t Sta	Software	PSL Input	Protection event
This DDB signal is the start signal for the third stage Independent Rate-of-Change-of-Frequency protection element.				
1313	Stg3 df/dt+t Trp	Software	PSL Input	Protection event
This DDB signal is the trip signal for the third stage Independent Rate-of-Change-of-Frequency protection element.				
1314	Stg3 f+Df/Dt Sta	Software	PSL Input	Protection event
This DDB signal is the start signal for the third stage Average Rate-of-Change-of-Frequency protection element.				
1315	Stg3 f+Df/Dt Trp	Software	PSL Input	Protection event
This DDB signal is the trip signal for the third stage Average Rate-of-Change-of-Frequency protection element.				
1316	Stg3 Block	Programmable Scheme Logic	PSL Output	No response
This DDB signal blocks all third stage Frequency protection elements				
1319	Stg3 Restore Cls	Software	PSL Input	Protection event
This DDB signal closes the third stage Load Restoration				
1320	Stg3 Restore Sta	Software	PSL Input	Protection event
This DDB signal starts the third stage Load Restoration				
1323	Stg4 f+t Sta	Software	PSL Input	Protection event
This DDB signal is the start signal for the fourth stage Frequency protection element.				
1324	Stg4 f+t Trp	Software	PSL Input	Protection event
This DDB signal is the trip signal for the fourth stage Frequency protection element.				
1325	Stg4 f+df/dt Trp	Software	PSL Input	Protection event
This DDB signal is the trip signal for the fourth stage Frequency-Supervised Rate-of-Change-of-Frequency protection element.				
1326	Stg4 df/dt+t Sta	Software	PSL Input	Protection event
This DDB signal is the start signal for the fourth stage Independent Rate-of-Change-of-Frequency protection element.				
1327	Stg4 df/dt+t Trp	Software	PSL Input	Protection event
This DDB signal is the trip signal for the fourth stage Independent Rate-of-Change-of-Frequency protection element.				
1328	Stg4 f+Df/Dt Sta	Software	PSL Input	Protection event

Ordinal	Signal Name	Source	Type	Response
Description				
This DDB signal is the start signal for the fourth stage Average Rate-of-Change-of-Frequency protection element.				
1329	Stg4 f+Df/Dt Trp	Software	PSL Input	Protection event
This DDB signal is the trip signal for the fourth stage Average Rate-of-Change-of-Frequency protection element.				
1330	Stg4 Block	Programmable Scheme Logic	PSL Output	No response
This DDB signal blocks all fourth stage Frequency protection elements				
1333	Stg4 Restore Cls	Software	PSL Input	Protection event
This DDB signal closes the fourth stage Load Restoration				
1334	Stg4 Restore Sta	Software	PSL Input	Protection event
This DDB signal starts the fourth stage Load Restoration				
1337	Stg5 f+t Sta	Software	PSL Input	Protection event
This DDB signal is the start signal for the fifth stage Frequency protection element.				
1338	Stg5 f+t Trp	Software	PSL Input	Protection event
This DDB signal is the trip signal for the fifth stage Frequency protection element.				
1339	Stg5 f+df/dt Trp	Software	PSL Input	Protection event
This DDB signal is the trip signal for the fifth stage Frequency-Supervised Rate-of-Change-of-Frequency protection element.				
1340	Stg5 df/dt+t Sta	Software	PSL Input	Protection event
This DDB signal is the start signal for the fifth stage Independent Rate-of-Change-of-Frequency protection element.				
1341	Stg5 df/dt+t Trp	Software	PSL Input	Protection event
This DDB signal is the trip signal for the fifth stage Independent Rate-of-Change-of-Frequency protection element.				
1342	Stg5 f+Df/Dt Sta	Software	PSL Input	Protection event
This DDB signal is the start signal for the fifth stage Average Rate-of-Change-of-Frequency protection element.				
1343	Stg5 f+Df/Dt Trp	Software	PSL Input	Protection event
This DDB signal is the trip signal for the fifth stage Average Rate-of-Change-of-Frequency protection element.				
1344	Stg5 Block	Programmable Scheme Logic	PSL Output	No response
This DDB signal blocks all fifth stage Frequency protection elements				
1347	Stg5 Restore Cls	Software	PSL Input	Protection event
This DDB signal closes the fifth stage Load Restoration				
1348	Stg5 Restore Sta	Software	PSL Input	Protection event
This DDB signal starts the fifth stage Load Restoration				
1351	Stg6 f+t Sta	Software	PSL Input	Protection event
This DDB signal is the start signal for the sixth stage Frequency protection element.				
1352	Stg6 f+t Trp	Software	PSL Input	Protection event
This DDB signal is the trip signal for the sixth stage Frequency protection element.				
1353	Stg6 f+df/dt Trp	Software	PSL Input	Protection event
This DDB signal is the trip signal for the sixth stage Frequency-Supervised Rate-of-Change-of-Frequency protection element.				
1354	Stg6 df/dt+t Sta	Software	PSL Input	Protection event
This DDB signal is the start signal for the sixth stage Independent Rate-of-Change-of-Frequency protection element.				
1355	Stg6 df/dt+t Trp	Software	PSL Input	Protection event
This DDB signal is the trip signal for the sixth stage Independent Rate-of-Change-of-Frequency protection element.				
1356	Stg6 f+Df/Dt Sta	Software	PSL Input	Protection event
This DDB signal is the start signal for the sixth stage Average Rate-of-Change-of-Frequency protection element.				
1357	Stg6 f+Df/Dt Trp	Software	PSL Input	Protection event

Ordinal	Signal Name	Source	Type	Response
Description				
This DDB signal is the trip signal for the sixth stage Average Rate-of-Change-of-Frequency protection element.				
1358	Stg6 Block	Programmable Scheme Logic	PSL Output	No response
This DDB signal blocks all sixth stage Frequency protection elements				
1361	Stg6 Restore Cls	Software	PSL Input	Protection event
This DDB signal closes the sixth stage Load Restoration				
1362	Stg6 Restore Sta	Software	PSL Input	Protection event
This DDB signal starts the sixth stage Load Restoration				
1365	Stg7 f+t Sta	Software	PSL Input	Protection event
This DDB signal is the start signal for the seventh stage Frequency protection element.				
1366	Stg7 f+t Trp	Software	PSL Input	Protection event
This DDB signal is the trip signal for the seventh stage Frequency protection element.				
1367	Stg7 f+df/dt Trp	Software	PSL Input	Protection event
This DDB signal is the trip signal for the seventh stage Frequency-Supervised Rate-of-Change-of-Frequency protection element.				
1368	Stg7 df/dt+t Sta	Software	PSL Input	Protection event
This DDB signal is the start signal for the seventh stage Independent Rate-of-Change-of-Frequency protection element.				
1369	Stg7 df/dt+t Trp	Software	PSL Input	Protection event
This DDB signal is the trip signal for the seventh stage Independent Rate-of-Change-of-Frequency protection element.				
1370	Stg7 f+Df/Dt Sta	Software	PSL Input	Protection event
This DDB signal is the start signal for the seventh stage Average Rate-of-Change-of-Frequency protection element.				
1371	Stg7 f+Df/Dt Trp	Software	PSL Input	Protection event
This DDB signal is the trip signal for the seventh stage Average Rate-of-Change-of-Frequency protection element.				
1372	Stg7 Block	Programmable Scheme Logic	PSL Output	No response
This DDB signal blocks all seventh stage Frequency protection elements				
1375	Stg7 Restore Cls	Software	PSL Input	Protection event
This DDB signal closes the seventh stage Load Restoration				
1376	Stg7 Restore Sta	Software	PSL Input	Protection event
This DDB signal starts the seventh stage Load Restoration				
1379	Stg8 f+t Sta	Software	PSL Input	Protection event
This DDB signal is the start signal for the eighth stage Frequency protection element.				
1380	Stg8 f+t Trp	Software	PSL Input	Protection event
This DDB signal is the trip signal for the eighth stage Frequency protection element.				
1381	Stg8 f+df/dt Trp	Software	PSL Input	Protection event
This DDB signal is the trip signal for the eighth stage Frequency-Supervised Rate-of-Change-of-Frequency protection element.				
1382	Stg8 df/dt+t Sta	Software	PSL Input	Protection event
This DDB signal is the start signal for the eighth stage Independent Rate-of-Change-of-Frequency protection element.				
1383	Stg8 df/dt+t Trp	Software	PSL Input	Protection event
This DDB signal is the trip signal for the eighth stage Independent Rate-of-Change-of-Frequency protection element.				
1384	Stg8 f+Df/Dt Sta	Software	PSL Input	Protection event
This DDB signal is the start signal for the eighth stage Average Rate-of-Change-of-Frequency protection element.				
1385	Stg8 f+Df/Dt Trp	Software	PSL Input	Protection event
This DDB signal is the trip signal for the eighth stage Average Rate-of-Change-of-Frequency protection element.				
1386	Stg8 Block	Programmable Scheme Logic	PSL Output	No response

Ordinal	Signal Name	Source	Type	Response
Description				
This DDB signal blocks all eighth stage Frequency protection elements				
1389	Stg8 Restore Cls	Software	PSL Input	Protection event
This DDB signal closes the eighth stage Load Restoration				
1390	Stg8 Restore Sta	Software	PSL Input	Protection event
This DDB signal starts the eighth stage Load Restoration				
1393	Stg9 f+t Sta	Software	PSL Input	Protection event
This DDB signal is the start signal for the ninth stage Frequency protection element.				
1394	Stg9 f+t Trp	Software	PSL Input	Protection event
This DDB signal is the trip signal for the ninth stage Frequency protection element.				
1395	Stg9 f+df/dt Trp	Software	PSL Input	Protection event
This DDB signal is the trip signal for the ninth stage Frequency-Supervised Rate-of-Change-of-Frequency protection element.				
1396	Stg9 df/dt+t Sta	Software	PSL Input	Protection event
This DDB signal is the start signal for the ninth stage Independent Rate-of-Change-of-Frequency protection element.				
1397	Stg9 df/dt+t Trp	Software	PSL Input	Protection event
This DDB signal is the trip signal for the ninth stage Independent Rate-of-Change-of-Frequency protection element.				
1398	Stg9 f+Df/Dt Sta	Software	PSL Input	Protection event
This DDB signal is the start signal for the ninth stage Average Rate-of-Change-of-Frequency protection element.				
1399	Stg9 f+Df/Dt Trp	Software	PSL Input	Protection event
This DDB signal is the trip signal for the ninth stage Average Rate-of-Change-of-Frequency protection element.				
1400	Stg9 Block	Programmable Scheme Logic	PSL Output	No response
This DDB signal blocks all ninth stage Frequency protection elements				
1403	Stg9 Restore Cls	Software	PSL Input	Protection event
This DDB signal closes the ninth stage Load Restoration				
1404	Stg9 Restore Sta	Software	PSL Input	Protection event
This DDB signal starts the ninth stage Load Restoration				
1405	Restore Reset	Programmable Scheme Logic	PSL Output	No response
This DDB signal resets all Load Restoration stages				
1406	Reset Stats	Programmable Scheme Logic	PSL Output	No response
This DDB signal resets all statistics counters				

15 FREQUENCY PROTECTION SETTINGS

Menu Text	Col	Row	Default Setting	Available Options
Description				
FREQ PROTECTION	4D	00		
This column contains settings for frequency protection.				
Freq Avg.Cycles	4D	01	5	From 0 to 48 step 1
This setting sets the number of power system cycles that are used to average the frequency measurement.				
df/dt Avg.Cycles	4D	02	5	From 0 to 48 step 1
This setting sets the number of power system cycles that are used to average the rate of change of frequency measurement.				
V<B Status	4D	03	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the undervoltage blocking of the frequency protection elements.				
V<B Voltage Set	4D	04	25*V1	From 10*V1 to 120*V1 step 1*V1
This setting sets the pick-up threshold for the undervoltage blocking element.				
V<B Measur Mode	4D	05	Phase-Phase	0=Phase-Phase 1=Phase-Neutral
This set determines the mode for the measured input voltage that will be used for the under voltage blocking: phase-to-phase or phase-to-neutral.				
V<B Operate Mode	4D	06	Three Phase	0=Any Phase 1=Three Phase
This setting determines whether any one of the phases or all three of the phases has to satisfy the undervoltage criteria before a decision is made.				
Stage 1	4D	07	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the first stage of frequency protection.				
Stg 1 f+t Status	4D	08	Disabled	0=Disabled 1=Under 2=Over
This setting selects either underfrequency or overfrequency protection, or disables it for this stage.				
Stg 1 f+t Freq	4D	09	49	From 40.1Hz to 69.9Hz step 0.01Hz
This setting sets the pick-up threshold for the first stage frequency protection element.				
Stg 1 f+t Time	4D	0A	2	From 0s to 100s step 0.01s
This setting sets the operating time delay for the first stage frequency protection element.				
df/dt+t 1 Status	4D	0B	Disabled	0=Disabled 1=Negative 2=Positive 3=Both
This setting disables or determines the tripping direction for the first stage independent rate of change of frequency protection (df/dt+t).				
df/dt+t 1 Set	4D	0C	2	From 0.01Hz/s to 10Hz/s step 0.01Hz/s
This setting sets the rate of change of frequency threshold for the first stage.				
df/dt+t 1 Time	4D	0D	0.5	From 0s to 100s step 0.01s
This setting sets the operating time delay for the first stage rate of change of frequency protection element.				
f+df/dt 1 Status	4D	0E	Negative	0=Disabled 1=Negative 2=Positive 3=Both
This setting disables or determines the tripping direction for the first stage frequency-supervised rate of change of frequency protection (f+df/dt).				
f+df/dt 1 Status	4D	0E	Disabled	0=Disabled
This setting disables or determines the tripping direction for the first stage frequency-supervised rate of change of frequency protection (f+df/dt).				

Menu Text	Col	Row	Default Setting	Available Options
Description				
f+df/dt 1 freq	4D	0F	49	From 40.1Hz to 69.9Hz step 0.01Hz
This setting sets the pick-up threshold for the first stage frequency-supervised rate of change of frequency protection element.				
f+df/dt 1 df/dt	4D	10	1	From 0.01Hz/s to 10Hz/s step 0.01Hz/s
This setting sets the df/dt threshold for the first stage frequency-supervised rate of change of frequency.				
f+Df/Dt 1 Status	4D	11	Disabled	0=Disabled 1=Under 2=Over
This setting selects either underfrequency or overfrequency protection for the average rate of change of frequency (Df/Dt)y, or disables it for this stage.				
f+Df/Dt 1 Status	4D	11	Disabled	0=Disabled
This setting selects either underfrequency or overfrequency protection for the average rate of change of frequency (Df/Dt)y, or disables it for this stage.				
f+Df/Dt 1 freq	4D	12	49	From 40.1Hz to 69.9Hz step 0.01Hz
This setting sets the pick-up trheshold for the first stage average rate of change of frequency protection element.				
f+Df/Dt 1 Dfreq	4D	13	1	From 0.1Hz to 10Hz step 0.01Hz
This setting sets the change in frequency that must be measured in the set time for the first stage average rate of change of frequency protection element.				
f+Df/Dt 1 Dtime	4D	14	0.5	From 0.02s to 100s step 0.01s
This setting sets the time period in which an excessive change in frequency must be measured for the first stage average rate of change of frequency protection element.				
Restore1 Status	4D	15	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the first stage of load restoration.				
Restore1 Status	4D	15	Disabled	0=Disabled
This setting enables or disables the first stage of load restoration.				
Restore1 Freq	4D	16	49.5	From 40.1Hz to 69.9Hz step 0.01Hz
This setting sets the pick-up trheshold for the first stage of load restoration, above which the associated load restoration time can start.				
Restore1 Time	4D	17	240	From 0s to 7200s step 0.25s
This setting sets the time period for which the measured frequency must be higher than the first stage restoration frequency setting to permit load restoration.				
Holding Timer 1	4D	18	5	From 1s to 7200s step 1s
This setting sets the holding time of the first stage load restoration.				
Stg 1 UV Block	4D	19	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the undervoltage blocking of the first stage load restoration element.				
Stage 2	4D	1A	Enabled	0 = Disabled or 1 = Enabled
This setting enables or disables the second stage of frequency protection.				
Stg 2 f+t Status	4D	1B	Under	0=Disabled 1=Under 2=Over
This setting selects either underfrequency or overfrequency protection, or disables it for this stage.				
Stg 2 f+t Freq	4D	1C	48.6	From 40.1Hz to 69.9Hz step 0.01Hz
This setting sets the pick-up threshold for the second stage frequency protection element.				
Stg 2 f+t Time	4D	1D	2	From 0s to 100s step 0.01s
This setting sets the operating time delay for the second stage frequency protection element.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
df/dt+t 2 Status	4D	1E	Negative	0=Disabled 1=Negative 2=Positive 3=Both
This setting disables or determines the tripping direction for the second stage independent rate of change of frequency protection (df/dt+t).				
df/dt+t 2 Set	4D	1F	2	From 0.01Hz/s to 10Hz/s step 0.01Hz/s
This setting sets the rate of change of frequency threshold for the second stage.				
df/dt+t 2 Time	4D	20	0.5	From 0s to 100s step 0.01s
This setting sets the operating time delay for the second stage rate of change of frequency protection element.				
f+df/dt 2 Status	4D	21	Negative	0=Disabled 1=Negative 2=Positive 3=Both
This setting disables or determines the tripping direction for the second stage frequency-supervised rate of change of frequency protection (f+df/dt).				
f+df/dt 2 Status	4D	21	Disabled	0=Disabled
This setting disables or determines the tripping direction for the second stage frequency-supervised rate of change of frequency protection (f+df/dt).				
f+df/dt 2 freq	4D	22	48.6	From 40.1Hz to 69.9Hz step 0.01Hz
This setting sets the pick-up threshold for the second stage frequency-supervised rate of change of frequency protection element.				
f+df/dt 2 df/dt	4D	23	1	From 0.01Hz/s to 10Hz/s step 0.01Hz/s
This setting sets the df/dt threshold for the second stage frequency-supervised rate of change of frequency.				
f+Df/Dt 2 Status	4D	24	Disabled	0=Disabled 1=Under 2=Over
This setting selects either underfrequency or overfrequency protection for the average rate of change of frequency (Df/Dt), or disables it for this stage.				
f+Df/Dt 2 Status	4D	24	Disabled	0=Disabled
This setting selects either underfrequency or overfrequency protection for the average rate of change of frequency (Df/Dt), or disables it for this stage.				
f+Df/Dt 2 freq	4D	25	49	From 40.1Hz to 69.9Hz step 0.01Hz
This setting sets the pick-up trheshold for the second stage average rate of change of frequency protection element.				
f+Df/Dt 2 Dfreq	4D	26	1	From 0.1Hz to 10Hz step 0.01Hz
This setting sets the change in frequency that must be measured in the set time for the second stage average rate of change of frequency protection element.				
f+Df/Dt 2 Dtime	4D	27	0.5	From 0.02s to 100s step 0.01s
This setting sets the time period in which an excessive change in frequency must be measured for the second stage average rate of change of frequency protection element.				
Restore2 Status	4D	28	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the second stage of load restoration.				
Restore2 Status	4D	28	Disabled	0=Disabled
This setting enables or disables the second stage of load restoration.				
Restore2 Freq	4D	29	49.5	From 40.1Hz to 69.9Hz step 0.01Hz
This setting sets the pick-up trheshold for the second stage of load restoration, above which the associated load restoration time can start.				
Restore2 Time	4D	2A	180	From 0s to 7200s step 0.25s
This setting sets the time period for which the measured frequency must be higher than the second stage restoration frequency setting to permit load restoration.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
Holding Timer 2	4D	2B	5	From 1s to 7200s step 1s
This setting sets the holding time of the second stage load restoration.				
Stg 2 UV Block	4D	2C	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the undervoltage blocking of the second stage load restoration element.				
Stage 3	4D	2D	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the third stage of frequency protection.				
Stg 3 f+t Status	4D	2E	Disabled	0=Disabled 1=Under 2=Over
This setting selects either underfrequency or overfrequency protection, or disables it for this stage.				
Stg 3 f+t Freq	4D	2F	48.2	From 40.1Hz to 69.9Hz step 0.01Hz
This setting sets the pick-up threshold for the third stage frequency protection element.				
Stg 3 f+t Time	4D	30	2	From 0s to 100s step 0.01s
This setting sets the operating time delay for the third stage frequency protection element.				
df/dt+t 3 Status	4D	31	Disabled	0=Disabled 1=Negative 2=Positive 3=Both
This setting disables or determines the tripping direction for the third stage independent rate of change of frequency protection (df/dt+t).				
df/dt+t 3 Set	4D	32	2	From 0.01Hz/s to 10Hz/s step 0.01Hz/s
This setting sets the rate of change of frequency threshold for the third stage.				
df/dt+t 3 Time	4D	33	0.5	From 0s to 100s step 0.01s
This setting sets the operating time delay for the third stage rate of change of frequency protection element.				
f+df/dt 3 Status	4D	34	Disabled	0=Disabled 1=Negative 2=Positive 3=Both
This setting disables or determines the tripping direction for the third stage frequency-supervised rate of change of frequency protection (f+df/dt).				
f+df/dt 3 Status	4D	34	Disabled	0=Disabled
This setting disables or determines the tripping direction for the third stage frequency-supervised rate of change of frequency protection (f+df/dt).				
f+df/dt 3 freq	4D	35	49	From 40.1Hz to 69.9Hz step 0.01Hz
This setting sets the pick-up threshold for the third stage frequency-supervised rate of change of frequency protection element.				
f+df/dt 3 df/dt	4D	36	1	From 0.01Hz/s to 10Hz/s step 0.01Hz/s
This setting sets the df/dt threshold for the third stage frequency-supervised rate of change of frequency.				
f+Df/Dt 3 Status	4D	37	Disabled	0=Disabled 1=Under 2=Over
This setting selects either underfrequency or overfrequency protection for the average rate of change of frequency (Df/Dt)y, or disables it for this stage.				
f+Df/Dt 3 Status	4D	37	Disabled	0=Disabled
This setting selects either underfrequency or overfrequency protection for the average rate of change of frequency (Df/Dt)y, or disables it for this stage.				
f+Df/Dt 3 freq	4D	38	48.5	From 40.1Hz to 69.9Hz step 0.01Hz
This setting sets the pick-up trheshold for the third stage average rate of change of frequency protection element.				
f+Df/Dt 3 Dfreq	4D	39	1	From 0.1Hz to 10Hz step 0.01Hz

Menu Text	Col	Row	Default Setting	Available Options
Description				
This setting sets the change in frequency that must be measured in the set time for the third stage average rate of change of frequency protection element.				
f+Df/Dt 3 Dtime	4D	3A	0.5	From 0.02s to 100s step 0.01s
This setting sets the time period in which an excessive change in frequency must be measured for the third stage average rate of change of frequency protection element.				
Restore3 Status	4D	3B	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the third stage of load restoration.				
Restore3 Status	4D	3B	Disabled	0=Disabled
This setting enables or disables the third stage of load restoration.				
Restore3 Freq	4D	3C	49.5	From 40.1Hz to 69.9Hz step 0.01Hz
This setting sets the pick-up trheshold for the third stage of load restoration, above which the associated load restoration time can start.				
Restore3 Time	4D	3D	120	From 0s to 7200s step 0.25s
This setting sets the time period for which the measured frequency must be higher than the third stage restoration frequency setting to permit load restoration.				
Holding Timer 3	4D	3E	5	From 1s to 7200s step 1s
This setting sets the holding time of the third stage load restoration.				
Stg 3 UV Block	4D	3F	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the undervoltage blocking of the third stage load restoration element.				
Stage 4	4D	40	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the fourth stage of frequency protection.				
Stg 4 f+t Status	4D	41	Disabled	0=Disabled 1=Under 2=Over
This setting selects either underfrequency or overfrequency protection, or disables it for this stage.				
Stg 4 f+t Freq	4D	42	47.8	From 40.1Hz to 69.9Hz step 0.01Hz
This setting sets the pick-up threshold for the fourth stage frequency protection element.				
Stg 4 f+t Time	4D	43	2	From 0s to 100s step 0.01s
This setting sets the operating time delay for the fourth stage frequency protection element.				
df/dt+t 4 Status	4D	44	Disabled	0=Disabled 1=Negative 2=Positive 3=Both
This setting disables or determines the tripping direction for the fourth stage independent rate of change of frequency protection (df/dt+t).				
df/dt+t 4 Set	4D	45	2	From 0.01Hz/s to 10Hz/s step 0.01Hz/s
This setting sets the rate of change of frequency threshold for the fourth stage.				
df/dt+t 4 Time	4D	46	0.5	From 0s to 100s step 0.01s
This setting sets the operating time delay for the fourth stage rate of change of frequency protection element.				
f+df/dt 4 Status	4D	47	Disabled	0=Disabled 1=Negative 2=Positive 3=Both
This setting disables or determines the tripping direction for the fourth stage frequency-supervised rate of change of frequency protection (f+df/dt).				
f+df/dt 4 Status	4D	47	Disabled	0=Disabled
This setting disables or determines the tripping direction for the fourth stage frequency-supervised rate of change of frequency protection (f+df/dt).				
f+df/dt 4 freq	4D	48	47.8	From 40.1Hz to 69.9Hz step 0.01Hz
This setting sets the pick-up threshold for the fourth stage frequency-supervised rate of change of frequency protection element.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
f+df/dt 4 df/dt	4D	49	1	From 0.01Hz/s to 10Hz/s step 0.01Hz/s
This setting sets the df/dt threshold for the fourth stage frequency-supervised rate of change of frequency.				
f+Df/Dt 4 Status	4D	4A	Disabled	0=Disabled 1=Under 2=Over
This setting selects either underfrequency or overfrequency protection for the average rate of change of frequency (Df/Dt)y, or disables it for this stage.				
f+Df/Dt 4 Status	4D	4A	Disabled	0=Disabled
This setting selects either underfrequency or overfrequency protection for the average rate of change of frequency (Df/Dt)y, or disables it for this stage.				
f+Df/Dt 4 freq	4D	4B	48.5	From 40.1Hz to 69.9Hz step 0.01Hz
This setting sets the pick-up trheshold for the fourth stage average rate of change of frequency protection element.				
f+Df/Dt 4 Dfreq	4D	4C	1	From 0.1Hz to 10Hz step 0.01Hz
This setting sets the change in frequency that must be measured in the set time for the fourth stage average rate of change of frequency protection element.				
f+Df/Dt 4 Dtime	4D	4D	0.5	From 0.02s to 100s step 0.01s
This setting sets the time period in which an excessive change in frequency must be measured for the fourth stage average rate of change of frequency protection element.				
Restore4 Status	4D	4E	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the fourth stage of load restoration.				
Restore4 Status	4D	4E	Disabled	0=Disabled
This setting enables or disables the fourth stage of load restoration.				
Restore4 Freq	4D	4F	49	From 40.1Hz to 69.9Hz step 0.01Hz
This setting sets the pick-up threshold for the fourth stage of load restoration, above which the associated load restoration time can start.				
Restore4 Time	4D	50	240	From 0s to 7200s step 0.25s
This setting sets the time period for which the measured frequency must be higher than the fourth stage restoration frequency setting to permit load restoration.				
Holding Timer 4	4D	51	5	From 1s to 7200s step 1s
This setting sets the holding time of the fourth stage load restoration.				
Stg 4 UV Block	4D	52	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the undervoltage blocking of the fourth stage load restoration element.				
Stage 5	4D	53	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the fifth stage of frequency protection.				
Stg 5 f+t Status	4D	54	Disabled	0=Disabled 1=Under 2=Over
This setting selects either underfrequency or overfrequency protection, or disables it for this stage.				
Stg 5 f+t Freq	4D	55	47.4	From 40.1Hz to 69.9Hz step 0.01Hz
This setting sets the pick-up threshold for the fifth stage frequency protection element.				
Stg 5 f+t Time	4D	56	2	From 0s to 100s step 0.01s
This setting sets the operating time delay for the fifth stage frequency protection element.				
df/dt+t 5 Status	4D	57	Disabled	0=Disabled 1=Negative 2=Positive 3=Both
This setting disables or determines the tripping direction for the fifth stage independent rate of change of frequency protection (df/dt+t).				

Menu Text	Col	Row	Default Setting	Available Options
Description				
df/dt+t 5 Set	4D	58	2	From 0.01Hz/s to 10Hz/s step 0.01Hz/s
This setting sets the rate of change of frequency threshold for the fifth stage.				
df/dt+t 5 Time	4D	59	0.5	From 0s to 100s step 0.01s
This setting sets the operating time delay for the fifth stage rate of change of frequency protection element.				
f+df/dt 5 Status	4D	5A	Disabled	0=Disabled 1=Negative 2=Positive 3=Both
This setting disables or determines the tripping direction for the fifth stage frequency-supervised rate of change of frequency protection (f+df/dt).				
f+df/dt 5 Status	4D	5A	Disabled	0=Disabled
This setting disables or determines the tripping direction for the fifth stage frequency-supervised rate of change of frequency protection (f+df/dt).				
f+df/dt 5 freq	4D	5B	47.4	From 40.1Hz to 69.9Hz step 0.01Hz
This setting sets the pick-up threshold for the fifth stage frequency-supervised rate of change of frequency protection element.				
f+df/dt 5 df/dt	4D	5C	1	From 0.01Hz/s to 10Hz/s step 0.01Hz/s
This setting sets the df/dt threshold for the fifth stage frequency-supervised rate of change of frequency.				
f+Df/Dt 5 Status	4D	5D	Disabled	0=Disabled 1=Under 2=Over
This setting selects either underfrequency or overfrequency protection for the average rate of change of frequency (Df/Dt)y, or disables it for this stage.				
f+Df/Dt 5 Status	4D	5D	Disabled	0=Disabled
This setting selects either underfrequency or overfrequency protection for the average rate of change of frequency (Df/Dt)y, or disables it for this stage.				
f+Df/Dt 5 freq	4D	5E	48	From 40.1Hz to 69.9Hz step 0.01Hz
This setting sets the pick-up trheshold for the fifth stage average rate of change of frequency protection element.				
f+Df/Dt 5 Dfreq	4D	5F	1	From 0.1Hz to 10Hz step 0.01Hz
This setting sets the change in frequency that must be measured in the set time for the fifth stage average rate of change of frequency protection element.				
f+Df/Dt 5 Dtime	4D	60	0.5	From 0.02s to 100s step 0.01s
This setting sets the time period in which an excessive change in frequency must be measured for the fifth stage average rate of change of frequency protection element.				
Restore5 Status	4D	61	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the fifth stage of load restoration.				
Restore5 Status	4D	61	Disabled	0=Disabled
This setting enables or disables the fifth stage of load restoration.				
Restore5 Freq	4D	62	49	From 40.1Hz to 69.9Hz step 0.01Hz
This setting sets the pick-up trheshold for the fifth stage of load restoration, above which the associated load restoration time can start.				
Restore5 Time	4D	63	180	From 0s to 7200s step 0.25s
This setting sets the time period for which the measured frequency must be higher than the fifth stage restoration frequency setting to permit load restoration.				
Holding Timer 5	4D	64	5	From 1s to 7200s step 1s
This setting sets the holding time of the fifth stage load restoration.				
Stg 5 UV Block	4D	65	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the undervoltage blocking of the fifth stage load restoration element.				
Stage 6	4D	66	Disabled	0 = Disabled or 1 = Enabled

Menu Text	Col	Row	Default Setting	Available Options
Description				
This setting enables or disables the sixth stage of frequency protection.				
Stg 6 f+t Status	4D	67	Disabled	0=Disabled 1=Under 2=Over
This setting selects either underfrequency or overfrequency protection, or disables it for this stage.				
Stg 6 f+t Freq	4D	68	47	From 40.1Hz to 69.9Hz step 0.01Hz
This setting sets the pick-up threshold for the sixth stage frequency protection element.				
Stg 6 f+t Time	4D	69	2	From 0s to 100s step 0.01s
This setting sets the operating time delay for the sixth stage frequency protection element.				
df/dt+t 6 Status	4D	6A	Disabled	0=Disabled 1=Negative 2=Positive 3=Both
This setting determines the tripping direction for the sixth stage of dv/dt element - either disabled, for a rising frequency (positive), or a falling frequency (negative) for the sixth stage independent rate of change of frequency protection (df/dt+t).				
df/dt+t 6 Set	4D	6B	2	From 0.01Hz/s to 10Hz/s step 0.01Hz/s
This setting sets the rate of change of frequency threshold for the sixth stage.				
df/dt+t 6 Time	4D	6C	0.5	From 0s to 100s step 0.01s
This setting sets the operating time delay for the sixth stage rate of change of frequency protection element.				
f+df/dt 6 Status	4D	6D	Disabled	0=Disabled 1=Negative 2=Positive 3=Both
This setting disables or determines the tripping direction for the sixth stage independent rate of change of frequency protection (df/dt+t).				
f+df/dt 6 Status	4D	6D	Disabled	0=Disabled
This setting sets the rate of change of frequency threshold for the sixth stage.				
f+df/dt 6 freq	4D	6E	49	From 40.1Hz to 69.9Hz step 0.01Hz
This setting sets the operating time delay for the sixth stage rate of change of frequency protection element.				
f+df/dt 6 df/dt	4D	6F	1	From 0.01Hz/s to 10Hz/s step 0.01Hz/s
This setting disables or determines the tripping direction for the sixth stage frequency-supervised rate of change of frequency protection (f+df/dt).				
f+Df/Dt 6 Status	4D	70	Disabled	0=Disabled 1=Under 2=Over
This setting disables or determines the tripping direction for the sixth stage frequency-supervised rate of change of frequency protection (f+df/dt).				
f+Df/Dt 6 Status	4D	70	Disabled	0=Disabled
This setting selects either underfrequency or overfrequency protection for the average rate of change of frequency (Df/Dt)y, or disables it for this stage.				
f+Df/Dt 6 freq	4D	71	48	From 40.1Hz to 69.9Hz step 0.01Hz
This setting sets the pick-up trheshold for the sixth stage average rate of change of frequency protection element.				
f+Df/Dt 6 Dfreq	4D	72	1	From 0.1Hz to 10Hz step 0.01Hz
This setting sets the change in frequency that must be measured in the set time for the sixth stage average rate of change of frequency protection element.				
f+Df/Dt 6 Dtime	4D	73	0.5	From 0.02s to 100s step 0.01s
This setting sets the time period in which an excessive change in frequency must be measured for the sixth stage average rate of change of frequency protection element.				
Restore6 Status	4D	74	Disabled	0 = Disabled or 1 = Enabled

Menu Text	Col	Row	Default Setting	Available Options
Description				
This setting enables or disables the sixth stage of load restoration.				
Restore6 Status	4D	74	Disabled	0=Disabled
This setting enables or disables the sixth stage of load restoration.				
Restore6 Freq	4D	75	49	From 40.1Hz to 69.9Hz step 0.01Hz
This setting sets the pick-up trheshold for the sixth stage of load restoration, above which the associated load restoration time can start.				
Restore6 Time	4D	76	120	From 0s to 7200s step 0.25s
This setting sets the time period for which the measured frequency must be higher than the sixth stage restoration frequency setting to permit load restoration.				
Holding Timer 6	4D	77	5	From 1s to 7200s step 1s
This setting sets the holding time of the sixth stage load restoration.				
Stg 6 UV Block	4D	78	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the undervoltage blocking of the sixth stage load restoration element.				
Stage 7	4D	79	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the seventh stage of frequency protection.				
Stg 7 f+t Status	4D	7A	Disabled	0=Disabled 1=Under 2=Over
This setting selects either underfrequency or overfrequency protection, or disables it for this stage.				
Stg 7 f+t Freq	4D	7B	46.6	From 40.1Hz to 69.9Hz step 0.01Hz
This setting sets the pick-up threshold for the seventh stage frequency protection element.				
Stg 7 f+t Time	4D	7C	2	From 0s to 100s step 0.01s
This setting sets the operating time delay for the seventh stage frequency protection element.				
df/dt+t 7 Status	4D	7D	Disabled	0=Disabled 1=Negative 2=Positive 3=Both
This setting disables or determines the tripping direction for the seventh stage independent rate of change of frequency protection (df/dt+t).				
df/dt+t 7 Set	4D	7E	2	From 0.01Hz/s to 10Hz/s step 0.01Hz/s
This setting sets the rate of change of frequency threshold for the seventh stage.				
df/dt+t 7 Time	4D	7F	0.5	From 0s to 100s step 0.01s
This setting sets the operating time delay for the seventh stage rate of change of frequency protection element.				
f+df/dt 7 Status	4D	80	Disabled	0=Disabled 1=Negative 2=Positive 3=Both
This setting disables or determines the tripping direction for the seventh stage frequency-supervised rate of change of frequency protection (f+df/dt).				
f+df/dt 7 Status	4D	80	Disabled	0=Disabled
This setting disables or determines the tripping direction for the seventh stage frequency-supervised rate of change of frequency protection (f+df/dt).				
f+df/dt 7 freq	4D	81	46.6	From 40.1Hz to 69.9Hz step 0.01Hz
This setting sets the pick-up threshold for the seventh stage frequency-supervised rate of change of frequency protection element.				
f+df/dt 7 df/dt	4D	82	1	From 0.01Hz/s to 10Hz/s step 0.01Hz/s
This setting sets the df/dt threshold for the seventh stage frequency-supervised rate of change of frequency.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
f+Df/Dt 7 Status	4D	83	Disabled	0=Disabled 1=Under 2=Over
This setting selects either underfrequency or overfrequency protection for the average rate of change of frequency (Df/Dt)y, or disables it for this stage.				
f+Df/Dt 7 Status	4D	83	Disabled	0=Disabled
This setting selects either underfrequency or overfrequency protection for the average rate of change of frequency (Df/Dt)y, or disables it for this stage.				
f+Df/Dt 7 freq	4D	84	47.5	From 40.1Hz to 69.9Hz step 0.01Hz
This setting sets the pick-up trheshold for the seventh stage average rate of change of frequency protection element.				
f+Df/Dt 7 Dfreq	4D	85	1	From 0.1Hz to 10Hz step 0.01Hz
This setting sets the change in frequency that must be measured in the set time for the seventh stage average rate of change of frequency protection element.				
f+Df/Dt 7 Dtime	4D	86	0.5	From 0.02s to 100s step 0.01s
This setting sets the time period in which an excessive change in frequency must be measured for the seventh stage average rate of change of frequency protection element.				
Restore7 Status	4D	87	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the seventh stage of load restoration.				
Restore7 Status	4D	87	Disabled	0=Disabled
This setting enables or disables the seventh stage of load restoration.				
Restore7 Freq	4D	88	49	From 40.1Hz to 69.9Hz step 0.01Hz
This setting sets the pick-up trheshold for the seventh stage of load restoration, above which the associated load restoration time can start.				
Restore7 Time	4D	89	100	From 0s to 7200s step 0.25s
This setting sets the time period for which the measured frequency must be higher than the seventh stage restoration frequency setting to permit load restoration.				
Holding Timer 7	4D	8A	5	From 1s to 7200s step 1s
This setting sets the holding time of the seventh stage load restoration.				
Stg 7 UV Block	4D	8B	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the undervoltage blocking of the seventh stage load restoration element.				
Stage 8	4D	8C	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the eighth stage of frequency protection.				
Stg 8 f+t Status	4D	8D	Disabled	0=Disabled 1=Under 2=Over
This setting selects either underfrequency or overfrequency protection, or disables it for this stage.				
Stg 8 f+t Freq	4D	8E	50.5	From 40.1Hz to 69.9Hz step 0.01Hz
This setting sets the pick-up threshold for the eighth stage frequency protection element.				
Stg 8 f+t Time	4D	8F	2	From 0s to 100s step 0.01s
This setting sets the operating time delay for the eighth stage frequency protection element.				
df/dt+t 8 Status	4D	90	Disabled	0=Disabled 1=Negative 2=Positive 3=Both
This setting disables or determines the tripping direction for the eighth stage independent rate of change of frequency protection (df/dt+t).				
df/dt+t 8 Set	4D	91	2	From 0.01Hz/s to 10Hz/s step 0.01Hz/s
This setting sets the rate of change of frequency threshold for the eighth stage.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
df/dt+t 8 Time	4D	92	0.5	From 0s to 100s step 0.01s
This setting sets the operating time delay for the eighth stage rate of change of frequency protection element.				
f+df/dt 8 Status	4D	93	Disabled	0=Disabled 1=Negative 2=Positive 3=Both
This setting disables or determines the tripping direction for the eighth stage frequency-supervised rate of change of frequency protection (f+df/dt).				
f+df/dt 8 Status	4D	93	Disabled	0=Disabled
This setting disables or determines the tripping direction for the eighth stage frequency-supervised rate of change of frequency protection (f+df/dt).				
f+df/dt 8 freq	4D	94	50.5	From 40.1Hz to 69.9Hz step 0.01Hz
This setting sets the pick-up threshold for the eighth stage frequency-supervised rate of change of frequency protection element.				
f+df/dt 8 df/dt	4D	95	1	From 0.01Hz/s to 10Hz/s step 0.01Hz/s
This setting sets the df/dt threshold for the eighth stage frequency-supervised rate of change of frequency.				
f+Df/Dt 8 Status	4D	96	Disabled	0=Disabled 1=Under 2=Over
This setting selects either underfrequency or overfrequency protection for the average rate of change of frequency (Df/Dt)y, or disables it for this stage.				
f+Df/Dt 8 Status	4D	96	Disabled	0=Disabled
This setting selects either underfrequency or overfrequency protection for the average rate of change of frequency (Df/Dt)y, or disables it for this stage.				
f+Df/Dt 8 freq	4D	97	50.5	From 40.1Hz to 69.9Hz step 0.01Hz
This setting sets the pick-up trheshold for the eighth stage average rate of change of frequency protection element.				
f+Df/Dt 8 Dfreq	4D	98	1	From 0.1Hz to 10Hz step 0.01Hz
This setting sets the change in frequency that must be measured in the set time for the eighth stage average rate of change of frequency protection element.				
f+Df/Dt 8 Dtime	4D	99	0.5	From 0.02s to 100s step 0.01s
This setting sets the time period in which an excessive change in frequency must be measured for the eighth stage average rate of change of frequency protection element.				
Restore8 Status	4D	9A	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the eighth stage of load restoration.				
Restore8 Status	4D	9A	Disabled	0=Disabled
This setting enables or disables the eighth stage of load restoration.				
Restore8 Freq	4D	9B	49	From 40.1Hz to 69.9Hz step 0.01Hz
This setting sets the pick-up trheshold for the eighth stage of load restoration, above which the associated load restoration time can start.				
Restore8 Time	4D	9C	80	From 0s to 7200s step 0.25s
This setting sets the time period for which the measured frequency must be higher than the eighth stage restoration frequency setting to permit load restoration.				
Holding Timer 8	4D	9D	5	From 1s to 7200s step 1s
This setting sets the holding time of the eighth stage load restoration.				
Stg 8 UV Block	4D	9E	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the undervoltage blocking of the eighth stage load restoration element.				
Stage 9	4D	9F	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the ninth stage of frequency protection.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
Stg 9 f+t Status	4D	A0	Disabled	0=Disabled 1=Under 2=Over
This setting selects either underfrequency or overfrequency protection, or disables it for this stage.				
Stg 9 f+t Freq	4D	A1	51	From 40.1Hz to 69.9Hz step 0.01Hz
This setting sets the pick-up threshold for the ninth stage frequency protection element.				
Stg 9 f+t Time	4D	A2	2	From 0s to 100s step 0.01s
This setting sets the operating time delay for the ninth stage frequency protection element.				
df/dt+t 9 Status	4D	A3	Disabled	0=Disabled 1=Negative 2=Positive 3=Both
This setting disables or determines the tripping direction for the ninth stage independent rate of change of frequency protection (df/dt+t).				
df/dt+t 9 Set	4D	A4	2	From 0.01Hz/s to 10Hz/s step 0.01Hz/s
This setting sets the rate of change of frequency threshold for the ninth stage.				
df/dt+t 9 Time	4D	A5	0.5	From 0s to 100s step 0.01s
This setting sets the operating time delay for the ninth stage rate of change of frequency protection element.				
f+df/dt 9 Status	4D	A6	Disabled	0=Disabled 1=Negative 2=Positive 3=Both
This setting disables or determines the tripping direction for the ninth stage frequency-supervised rate of change of frequency protection (f+df/dt).				
f+df/dt 9 Status	4D	A6	Disabled	0=Disabled
This setting disables or determines the tripping direction for the ninth stage frequency-supervised rate of change of frequency protection (f+df/dt).				
f+df/dt 9 freq	4D	A7	51	From 40.1Hz to 69.9Hz step 0.01Hz
This setting sets the pick-up threshold for the ninth stage frequency-supervised rate of change of frequency protection element.				
f+df/dt 9 df/dt	4D	A8	1	From 0.01Hz/s to 10Hz/s step 0.01Hz/s
This setting sets the df/dt threshold for the ninth stage frequency-supervised rate of change of frequency.				
f+Df/Dt 9 Status	4D	A9	Disabled	0=Disabled 1=Under 2=Over
This setting selects either underfrequency or overfrequency protection for the average rate of change of frequency (Df/Dt)y, or disables it for this stage.				
f+Df/Dt 9 Status	4D	A9	Disabled	0=Disabled
This setting selects either underfrequency or overfrequency protection for the average rate of change of frequency (Df/Dt)y, or disables it for this stage.				
f+Df/Dt 9 freq	4D	AA	51	From 40.1Hz to 69.9Hz step 0.01Hz
This setting sets the pick-up trheshold for the ninth stage average rate of change of frequency protection element.				
f+Df/Dt 9 Dfreq	4D	AB	1	From 0.1Hz to 10Hz step 0.01Hz
This setting sets the change in frequency that must be measured in the set time for the ninth stage average rate of change of frequency protection element.				
f+Df/Dt 9 Dtime	4D	AC	0.5	From 0.02s to 100s step 0.01s
This setting sets the time period in which an excessive change in frequency must be measured for the ninth stage average rate of change of frequency protection element.				
Restore9 Status	4D	AD	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the ninth stage of load restoration.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
Restore9 Status	4D	AD	Disabled	0 = Disabled
This setting enables or disables the ninth stage of load restoration.				
Restore9 Freq	4D	AE	49	From 40.1Hz to 69.9Hz step 0.01Hz
This setting sets the pick-up trheshold for the ninth stage of load restoration, above which the associated load restoration time can start.				
Restore9 Time	4D	AF	60	From 0s to 7200s step 0.25s
This setting sets the time period for which the measured frequency must be higher than the ninth stage restoration frequency setting to permit load restoration.				
Holding Timer 9	4D	B0	5	From 1s to 7200s step 1s
This setting sets the holding time of the ninth stage load restoration.				
Stg 9 UV Block	4D	B1	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the undervoltage blocking of the ninth stage load restoration element.				

16 FREQUENCY STATISTICS

Menu Text	Col	Row	Default Setting	Available Options
Description				
FREQUENCY STAT	05	00		
This column contains frequency protection statistical parameters				
Stg1 f+t Sta	05	01		Not Settable
Number of f+t starts for Stage 1				
Stg1 f+t Trp	05	02		Not Settable
Number of f+t trips for Stage 1				
Stg1 f+df/dt Trp	05	03		Not Settable
Number of f+df/dt trips for Stage 1				
Stg1 df/dt+t Sta	05	04		Not Settable
Number of df/dt+t starts for Stage 1				
Stg1 df/dt+t Trp	05	05		Not Settable
Number of df/dt trips for Stage 1				
Stg1 f+Df/Dt Sta	05	06		Not Settable
Number of f+DF/DT starts for Stage 1				
Stg1 f+Df/Dt Trp	05	07		Not Settable
Number of f+DF/DT trips for Stage 1				
Stg1 Revn Date	05	08		Not Settable
Stage 1 Revision Date				
Stg2 f+t Sta	05	0A		Not Settable
Number of f+t starts for Stage 2				
Stg2 f+t Trp	05	0B		Not Settable
Number of f+t trips for Stage 2				
Stg2 f+df/dt Trp	05	0C		Not Settable
Number of f+df/dt trips for Stage 2				
Stg2 df/dt+t Sta	05	0D		Not Settable
Number of df/dt+t starts for Stage 2				
Stg2 df/dt+t Trp	05	0E		Not Settable
Number of df/dt trips for Stage 2				
Stg2 f+Df/Dt Sta	05	0F		Not Settable
Number of f+DF/DT starts for Stage 2				
Stg2 f+Df/Dt Trp	05	10		Not Settable
Number of f+DF/DT trips for Stage 2				
Stg2 Revn Date	05	11		Not Settable
Stage 2 Revision Date				
Stg3 f+t Sta	05	13		Not Settable
Number of f+t starts for Stage 3				
Stg3 f+t Trp	05	14		Not Settable
Number of f+t trips for Stage 3				
Stg3 f+df/dt Trp	05	15		Not Settable
Number of f+df/dt trips for Stage 3				

Menu Text	Col	Row	Default Setting	Available Options
Description				
Stg3 df/dt+t Sta	05	16		Not Settable
Number of df/dt+t starts for Stage 3				
Stg3 df/dt+t Trp	05	17		Not Settable
Number of df/dt trips for Stage 3				
Stg3 f+Df/Dt Sta	05	18		Not Settable
Number of f+DF/DT starts for Stage 3				
Stg3 f+Df/Dt Trp	05	19		Not Settable
Number of f+DF/DT trips for Stage 3				
Stg3 Revn Date	05	1A		Not Settable
Stage 3 Revision Date				
Stg4 f+t Sta	05	1C		Not Settable
Number of f+t starts for Stage 4				
Stg4 f+t Trp	05	1D		Not Settable
Number of f+t trips for Stage 4				
Stg4 f+df/dt Trp	05	1E		Not Settable
Number of f+df/dt trips for Stage 4				
Stg4 df/dt+t Sta	05	1F		Not Settable
Number of df/dt+t starts for Stage 4				
Stg4 df/dt+t Trp	05	20		Not Settable
Number of df/dt trips for Stage 4				
Stg4 f+Df/Dt Sta	05	21		Not Settable
Number of f+DF/DT starts for Stage 4				
Stg4 f+Df/Dt Trp	05	22		Not Settable
Number of f+DF/DT trips for Stage 4				
Stg4 Revn Date	05	23		Not Settable
Stage 4 Revision Date				
Stg5 f+t Sta	05	25		Not Settable
Number of f+t starts for Stage 5				
Stg5 f+t Trp	05	26		Not Settable
Number of f+t trips for Stage 5				
Stg5 f+df/dt Trp	05	27		Not Settable
Number of f+df/dt trips for Stage 5				
Stg5 df/dt+t Sta	05	28		Not Settable
Number of df/dt+t starts for Stage 5				
Stg5 df/dt+t Trp	05	29		Not Settable
Number of df/dt trips for Stage 5				
Stg5 f+Df/Dt Sta	05	2A		Not Settable
Number of f+DF/DT starts for Stage 5				
Stg5 f+Df/Dt Trp	05	2B		Not Settable
Number of f+DF/DT trips for Stage 5				
Stg5 Revn Date	05	2C		Not Settable
Stage 5 Revision Date				

Menu Text	Col	Row	Default Setting	Available Options
Description				
Stg6 f+t Sta	05	2E		Not Settable
Number of f+t starts for Stage 6				
Stg6 f+t Trp	05	2F		Not Settable
Number of f+t trips for Stage 6				
Stg6 f+df/dt Trp	05	30		Not Settable
Number of f+df/dt trips for Stage 6				
Stg6 df/dt+t Sta	05	31		Not Settable
Number of df/dt+t starts for Stage 6				
Stg6 df/dt+t Trp	05	32		Not Settable
Number of df/dt trips for Stage 6				
Stg6 f+Df/Dt Sta	05	33		Not Settable
Number of f+DF/DT starts for Stage 6				
Stg6 f+Df/Dt Trp	05	34		Not Settable
Number of f+DF/DT trips for Stage 6				
Stg6 Revn Date	05	35		Not Settable
Stage 6 Revision Date				
Stg7 f+t Sta	05	37		Not Settable
Number of f+t starts for Stage 7				
Stg7 f+t Trp	05	38		Not Settable
Number of f+t trips for Stage 7				
Stg7 f+df/dt Trp	05	39		Not Settable
Number of f+df/dt trips for Stage 7				
Stg7 df/dt+t Sta	05	3A		Not Settable
Number of df/dt+t starts for Stage 7				
Stg7 df/dt+t Trp	05	3B		Not Settable
Number of df/dt trips for Stage 7				
Stg7 f+Df/Dt Sta	05	3C		Not Settable
Number of f+DF/DT starts for Stage 7				
Stg7 f+Df/Dt Trp	05	3D		Not Settable
Number of f+DF/DT trips for Stage 7				
Stg7 Revn Date	05	3E		Not Settable
Stage 7 Revision Date				
Stg8 f+t Sta	05	40		Not Settable
Number of f+t starts for Stage 8				
Stg8 f+t Trp	05	41		Not Settable
Number of f+t trips for Stage 8				
Stg8 f+df/dt Trp	05	42		Not Settable
Number of f+df/dt trips for Stage 8				
Stg8 df/dt+t Sta	05	43		Not Settable
Number of df/dt+t starts for Stage 8				
Stg8 df/dt+t Trp	05	44		Not Settable
Number of df/dt trips for Stage 8				

Menu Text	Col	Row	Default Setting	Available Options
Description				
Stg8 f+Df/Dt Sta	05	45		Not Settable
Number of f+DF/DT starts for Stage 8				
Stg8 f+Df/Dt Trp	05	46		Not Settable
Number of f+DF/DT trips for Stage 8				
Stg8 Revn Date	05	47		Not Settable
Stage 8 Revision Date				
Stg9 f+t Sta	05	49		Not Settable
Number of f+t starts for Stage 9				
Stg9 f+t Trp	05	4A		Not Settable
Number of f+t trips for Stage 9				
Stg9 f+df/dt Trp	05	4B		Not Settable
Number of f+df/dt trips for Stage 9				
Stg9 df/dt+t Sta	05	4C		Not Settable
Number of df/dt+t starts for Stage 9				
Stg9 df/dt+t Trp	05	4D		Not Settable
Number of df/dt trips for Stage 9				
Stg9 f+Df/Dt Sta	05	4E		Not Settable
Number of f+DF/DT starts for Stage 9				
Stg9 f+Df/Dt Trp	05	4F		Not Settable
Number of f+DF/DT trips for Stage 9				
Stg9 Revn Date	05	50		Not Settable
Stage 9 Revision Date				
Reset Statistics	05	52	No Operation	0=No Operation 1=All 2=Stage 1 3=Stage 2 4=Stage 3 5=Stage 4 6=Stage 5 7=Stage 6 8=Stage 7 9=Stage 8 10=Stage 9
This command resets the statistics on a stage by stage basis or for all stages at once				

POWER PROTECTION FUNCTIONS

CHAPTER 7

1 CHAPTER OVERVIEW

Power protection is used for protecting generators. The described product provides basic power protection for small distributed generators, typically less than 2 MW.

This chapter contains the following sections:

2 OVERPOWER PROTECTION

With Overpower, we should consider two distinct conditions: Forward Overpower and Reverse Overpower.

A forward overpower condition occurs when the system load becomes excessive. A generator is rated to supply a certain amount of power and if it attempts to supply power to the system greater than its rated capacity, it could be damaged. Therefore overpower protection in the forward direction can be used as an overload indication. It can also be used as back-up protection for failure of governor and control equipment. Generally the Overpower protection element would be set above the maximum power rating of the machine.

A reverse overpower condition occurs if the generator prime mover fails. When this happens, the power system may supply power to the generator, causing it to motor. This reversal of power flow due to loss of prime mover can be very damaging and it is important to be able to detect this with a Reverse Overpower element.

2.1 OVERPOWER PROTECTION IMPLEMENTATION

Overpower Protection is implemented in the POWER PROTECTION column of the relevant settings group, under the sub-heading OVERPOWER.

The Overpower Protection element provides 2 stages of directional overpower for both active and reactive power. The directional element can be configured as forward or reverse and can activate single-phase or three-phase trips.

The elements use three-phase power and single phase power measurements as the energising quantities. A Start condition occurs when two consecutive measurements exceed the setting threshold. A trip condition occurs if the Start condition is present for the set time delay. This can be inhibited by the VTS Slow Block and Pole Dead logic if desired.

The Start and Trip timer resets if the power falls below the drop-off level or if an inhibit condition occurs. The reset mechanism is similar to the overcurrent functionality for a pecking fault condition, where the percentage of elapsed time for the operate timer is memorised for a set reset time delay. If the Start condition returns before the reset timer has timed out, the operate time initialises from the memorised travel value. Otherwise the memorised value is reset to zero after the reset time times out.

2.2 OVERPOWER LOGIC

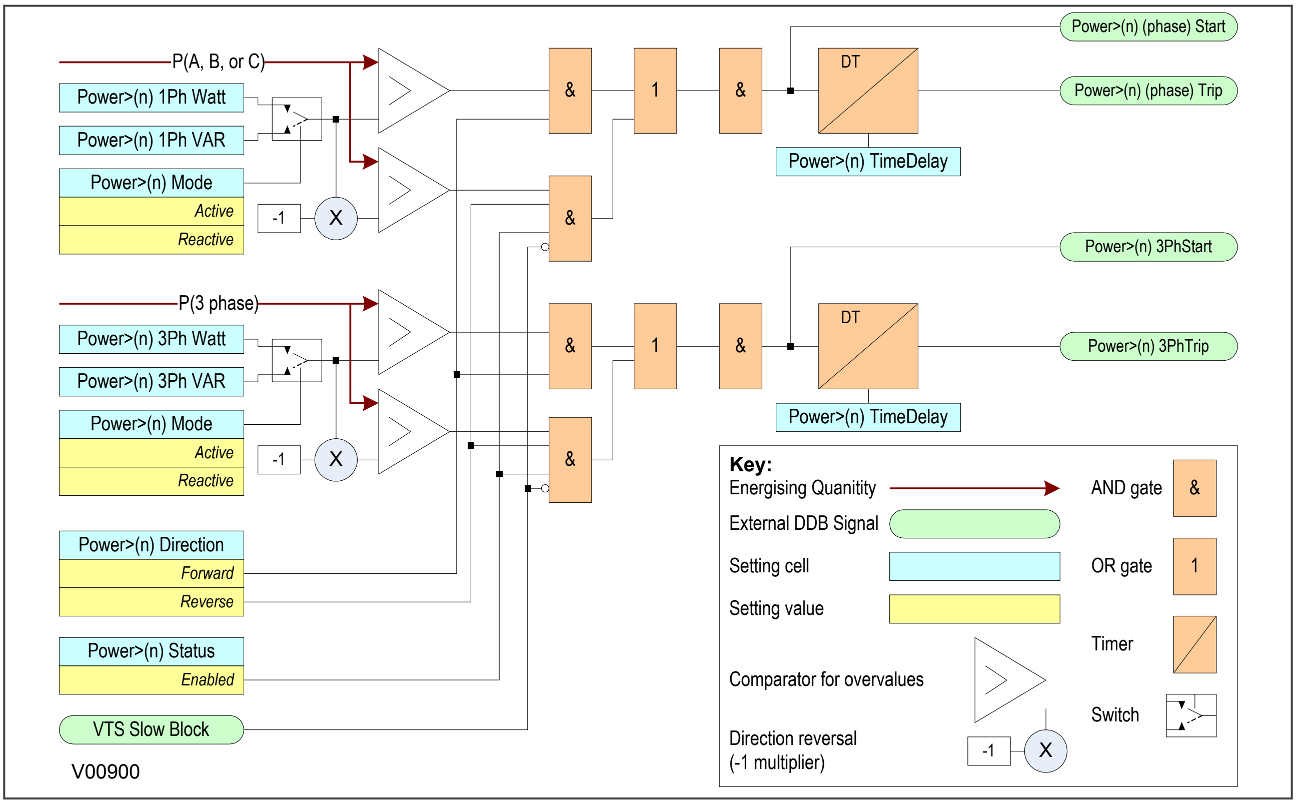


Figure 86: Overpower logic

2.3 OVERPOWER DDB SIGNALS

Ordinal	Signal Name	Source	Type	Response
Description				
351	VTS Slow Block	Software	PSL Input	No response
This DDB signal is a purposely delayed output from the VTS which can block other functions				
722	Power>1 3PhStart	Software	PSL Input	Protection event
This DDB signal is the first stage three-phase Phase Overpower start signal				
723	Power>1 A Start	Software	PSL Input	Protection event
This DDB signal is the first stage A-phase Phase Overpower start signal				
724	Power>1 B Start	Software	PSL Input	Protection event
This DDB signal is the first stage B-phase Phase Overpower start signal				
725	Power>1 C Start	Software	PSL Input	Protection event
This DDB signal is the first stage C-phase Phase Overpower start signal				
726	Power>2 3PhStart	Software	PSL Input	Protection event
This DDB signal is the second stage three-phase Phase Overpower start signal				
727	Power>2 A Start	Software	PSL Input	Protection event
This DDB signal is the second stage A-phase Phase Overpower start signal				
728	Power>2 B Start	Software	PSL Input	Protection event
This DDB signal is the second stage B-phase Phase Overpower start signal				

Ordinal	Signal Name	Source	Type	Response
Description				
729	Power>2 C Start	Software	PSL Input	Protection event
This DDB signal is the second stage C-phase Phase Overpower start signal				
738	Power>1 3Ph Trip	Software	PSL Input	Protection event
This DDB signal is the first stage three-phase Phase Overpower trip signal				
739	Power>1 A Trip	Software	PSL Input	Protection event
This DDB signal is the first stage A-phase Phase Overpower trip signal				
740	Power>1 B Trip	Software	PSL Input	Protection event
This DDB signal is the first stage B-phase Phase Overpower trip signal				
741	Power>1 C Trip	Software	PSL Input	Protection event
This DDB signal is the first stage C-phase Phase Overpower trip signal				
742	Power>2 3Ph Trip	Software	PSL Input	Protection event
This DDB signal is the second stage three-phase Phase Overpower trip signal				
743	Power>2 A Trip	Software	PSL Input	Protection event
This DDB signal is the second stage A-phase Phase Overpower trip signal				
744	Power>2 B Trip	Software	PSL Input	Protection event
This DDB signal is the second stage B-phase Phase Overpower trip signal				
745	Power>2 C Trip	Software	PSL Input	Protection event
This DDB signal is the second stage C-phase Phase Overpower trip signal				
754	Power>1 Block	Programmable Scheme Logic	PSL Output	Protection event
This DDB signal blocks the first stage Overpower protection				
755	Power>2 Block	Programmable Scheme Logic	PSL Output	Protection event
This DDB signal blocks the second stage Overpower protection				

2.4 OVERPOWER SETTINGS

Menu Text	Col	Row	Default Setting	Available Options
Description				
GROUP 1 POWER PROTECTION	41	00		
This column contains settings for Power protection				
OVER POWER	41	01		
The settings under this sub-heading relate to Overpower				
Power>1 Status	41	02	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the first stage Overpower protection.				
Power>1Direction	41	03	Forward	0=Reverse 1=Forward
This setting determines the direction of the first stage Overpower element.				
Power>1 Mode	41	04	Active	0=Active 1=Reactive
There are two operation modes; Active or Reactive. This setting determines which mode is to be used for the first stage Overpower element.				
Power>1TimeDelay	41	05	1	From 0s to 100s step 0.01s
This setting sets the operate time delay setting for the first stage Overpower element.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
Power>1 tRESET	41	06	0	From 0s to 100s step 0.01s
This setting sets the time delay for the first stage Overpower element.				
Power>1 1Ph Watt	41	07	40	From 1 to 325 step 1
This setting sets the pick-up threshold for the single-phase Overpower element for the 'Active' mode.				
Power>1 1Ph VAr	41	08	24	From 1 to 325 step 1
This setting sets the pick-up threshold of the single-phase Overpower element for the 'Reactive' mode.				
Power>1 3Ph Watt	41	09	120	From 1 to 325 step 1
This setting sets the pick-up threshold for the three-phase Overpower element for the 'Active' mode.				
Power>1 3Ph VAr	41	0A	72	From 1 to 325 step 1
This setting sets the pick-up threshold of the three-phase Overpower element for the 'Reactive' mode.				
Power>2 Status	41	0B	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the second stage Overpower protection.				
Power>2Direction	41	0C	Forward	0=Reverse 1=Forward
This setting determines the direction of the second stage Overpower element.				
Power>2 Mode	41	0D	Active	0=Active 1=Reactive
There are two operation modes; Active or Reactive. This setting determines which mode is to be used for the second stage Overpower element.				
Power>2TimeDelay	41	0E	1	From 0s to 100s step 0.01s
This setting sets the operate time delay setting for the second stage Overpower element.				
Power>2 tRESET	41	0F	0	From 0s to 100s step 0.01s
This setting sets the time delay for the second stage Overpower element.				
Power>2 1Ph Watt	41	10	40	From 1 to 325 step 1
This setting sets the pick-up threshold for the single-phase Overpower element for the 'Active' mode.				
Power>2 1Ph VAr	41	11	24	From 1 to 325 step 1
This setting sets the pick-up threshold of the single-phase Overpower element for the 'Reactive' mode.				
Power>2 3Ph Watt	41	12	120	From 1 to 325 step 1
This setting sets the pick-up threshold for the three-phase Overpower element for the 'Active' mode.				
Power>2 3Ph VAr	41	13	72	From 1 to 325 step 1
This setting sets the pick-up threshold of the three-phase Overpower element for the 'Reactive' mode.				

2.5 APPLICATION NOTES

2.5.1 FORWARD OVERPOWER SETTING GUIDELINES

The relevant power threshold settings should be set greater than the machine full load rated power.

The operating mode should be set to Forward.

A time delay setting (**Power>(n) TimeDelay**) should be applied. This setting is dependant on the application, but would typically be around 5 seconds. The delay on the reset timer (**Power>(n) tRESET**), would normally be set to zero.

2.5.2 REVERSE POWER CONSIDERATIONS

A generator is expected to supply power to the connected system in normal operation. If the generator prime mover fails, it will begin to motor (if the power system to which it is connected has other generating sources).

The consequences of generator motoring and the level of power drawn from the power system will be dependent on the type of prime mover.

Typical levels of motoring power and possible motoring damage that could occur for various types of generating plant are given in the following table.

<table>
<tr><th>Prime mover</th><th>Motoring power</th><th>Possible damage (percentage rating)</th></tr>
<tr><td>Diesel Engine</td><td>5% - 25%</td><td>Risk of fire or explosion from unburned fuel</td></tr>
<tr><td colspan="3">Motoring level depends on compression ratio and cylinder bore stiffness. Rapid disconnection is required to limit power loss and risk of damage.</td></tr>
<tr><td>Gas Turbine</td><td>10% - 15% (Split-shaft)
>50% (Single-shaft)</td><td>With some gear-driven sets, damage may arise due to reverse torque on gear teeth.</td></tr>
<tr><td colspan="3">Compressor load on single shaft machines leads to a high motoring power compared to split-shaft machines. Rapid disconnection is required to limit power loss or damage.</td></tr>
<tr><td>Hydraulic Turbines</td><td>0.2 - >2% (Blades out of water)
>2.0% (Blades in water)</td><td>Blade and runner damage may occur with a long period of motoring</td></tr>
<tr><td colspan="3">Power is low when blades are above tail-race water level. Hydraulic flow detection devices are often the main means of detecting loss of drive. Automatic disconnection is recommended for unattended operation.</td></tr>
<tr><td>Steam Turbines</td><td>0.5% - 3% (Condensing sets)
3% - 6% (Non-condensing sets)</td><td>Thermal stress damage may be inflicted on low-pressure turbine blades when steam flow is not available to dissipate losses due to air resistance.</td></tr>
<tr><td colspan="3">Damage may occur rapidly with non-condensing sets or when vacuum is lost with condensing sets. Reverse power protection may be used as a secondary method of detection and might only be used to raise an alarm.</td></tr>
</table>

In some applications, the level of reverse power in the case of prime mover failure may fluctuate. This may be the case for a failed diesel engine. To prevent cyclic initiation and reset of the main trip timer, an adjustable reset time delay is provided. You will need to set this time delay longer than the period for which the reverse power could fall below the power setting. This setting needs to be taken into account when setting the main trip time delay.

Note:
A delay in excess of half the period of any system power swings could result in operation of the reverse power protection during swings.

2.5.3 REVERSE OVERPOWER SETTING GUIDELINES

Each stage of power protection can be selected to operate as a reverse power stage by selecting the **Power>(n) Direction** cell to 'Reverse'.

The relevant power threshold settings should be set to less than 50% of the motoring power.

The operating mode should be set to Reverse.

The reverse power protection function should be time-delayed to prevent false trips or alarms being given during power system disturbances or following synchronisation.

A time delay setting, of approximately 5 s would be typically applied.

The delay on the reset timer, **Power>1 tRESET** or **Power>2 tRESET**, would normally be set to zero.

When settings of greater than zero are used for the reset time delay, the pick-up time delay setting may need to be increased to ensure that false tripping does not result in the event of a stable power swinging event.

Reverse overpower protection can also be used for loss of mains applications. If the distributed generator is connected to the grid but not allowed to export power to the grid, it is possible to use reverse power detection to switch off the generator. In this case, the threshold setting should be set to a sensitive value, typically less than 2% of the rated power. It should also be time-delayed to prevent false trips or alarms being given during power system disturbances, or following synchronisation. A typical time delay is 5 seconds.

3 UNDERPOWER PROTECTION

Although the Underpower protection is directional and can be configured as forward or reverse, the most common application is for Low Forward Power protection.

When a machine is generating and the circuit breaker connecting the generator to the system is tripped, the electrical load on the generator is cut off. This could lead to overspeeding of the generator if the mechanical input power is not reduced quickly. Large turbo-alternators, with low-inertia rotor designs, do not have a high over speed tolerance. Trapped steam in a turbine, downstream of a valve that has just closed, can rapidly lead to over speed. To reduce the risk of over speed damage, it may be desirable to interlock tripping of the circuit breaker and the mechanical input with a low forward power check. This ensures that the generator circuit breaker is opened only after the mechanical input to the prime mover has been removed, and the output power has reduced enough such that overspeeding is unlikely. This delay in tripping the circuit breaker may be acceptable for non-urgent protection trips (e.g. stator earth fault protection for a high impedance earthed generator). For urgent trips however (e.g. stator current differential protection), this Low Forward Power interlock should not be used.

3.1 UNDERPOWER PROTECTION IMPLEMENTATION

Underpower Protection is implemented in the POWER PROTECTION column of the relevant settings group, under the sub-heading UNDERPOWER.

The UNDERPOWER Protection element provides 2 stages of directional underpower for both active and reactive power. The directional element can be configured as forward or reverse and can activate single-phase or three-phase trips.

The elements use three-phase power and single phase power measurements as the energising quantity. A start condition occurs when two consecutive measurements fall below the setting threshold. A trip condition occurs if the start condition is present for the set trip time. This can be inhibited by the VTS slow block and pole dead logic if desired.

The Start and Trip timer resets if the power exceeds the drop-off level or if an inhibit condition occurs. The reset mechanism is similar to the overcurrent functionality for a pecking fault condition, where the percentage of elapsed time for the operate timer is memorised for a set reset time delay. If the Start condition returns before the reset timer has timed out, the operate time initialises from the memorised travel value. Otherwise the memorised value is reset to zero after the reset time times out.

3.2 UNDERPOWER LOGIC

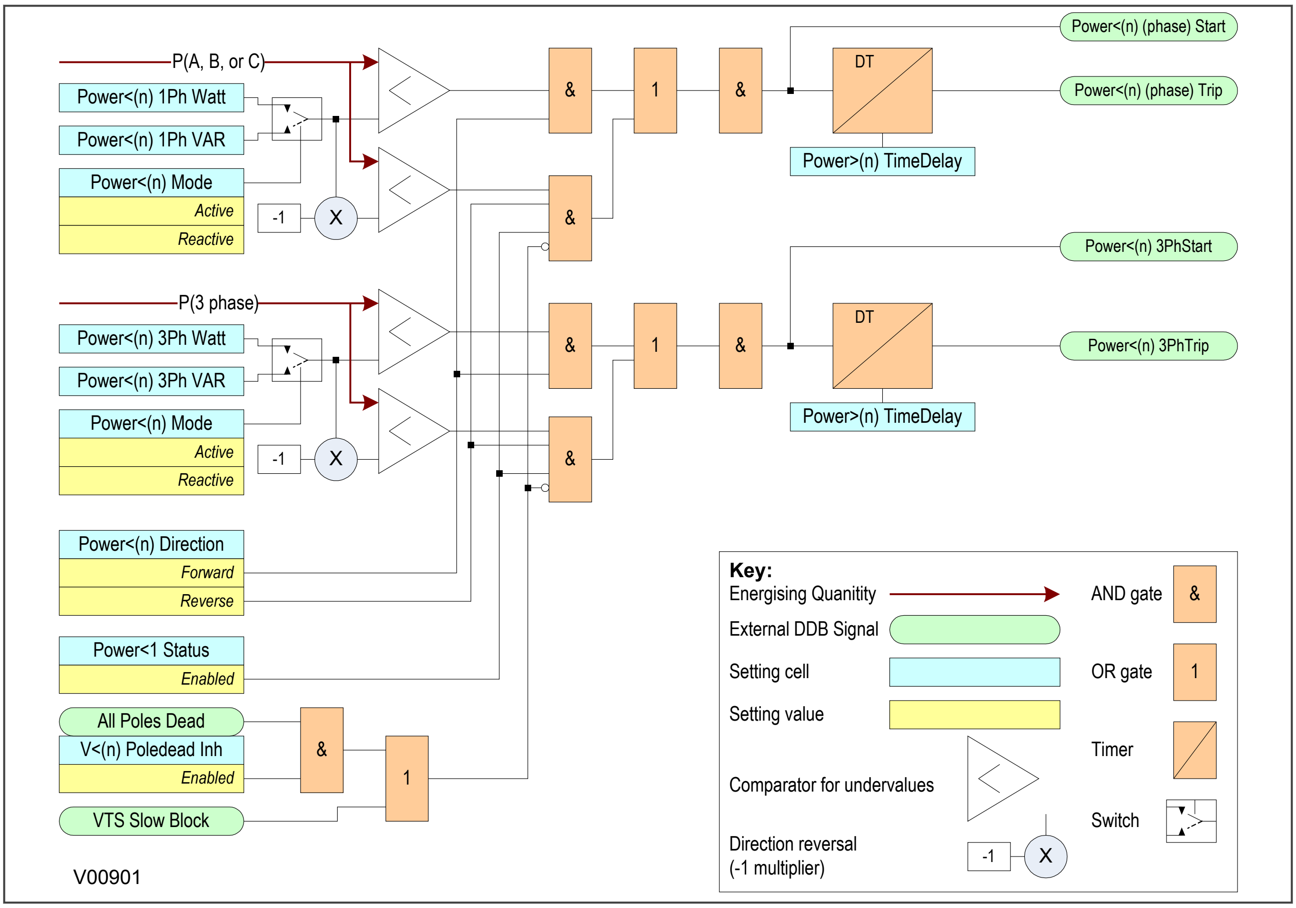


Figure 87: Underpower logic

3.3 UNDERPOWER DDB SIGNALS

Ordinal	Signal Name	Source	Type	Response
Description				
351	VTS Slow Block	Software	PSL Input	No response
This DDB signal is a purposely delayed output from the VTS which can block other functions				
380	All Poles Dead	Software	PSL Input	No response
This DDB signal indicates that all poles are dead				
730	Power<1 3PhStart	Software	PSL Input	Protection event
This DDB signal is the first stage three-phase Phase Underpower start signal				
731	Power<1 A Start	Software	PSL Input	Protection event
This DDB signal is the first stage A-phase Phase Underpower start signal				
732	Power<1 B Start	Software	PSL Input	Protection event
This DDB signal is the first stage B-phase Phase Underpower start signal				
733	Power<1 C Start	Software	PSL Input	Protection event
This DDB signal is the first stage C-phase Phase Underpower start signal				
734	Power<2 3PhStart	Software	PSL Input	Protection event
This DDB signal is the second stage three-phase Phase Underpower start signal				

Ordinal	Signal Name	Source	Type	Response
Description				
735	Power<2 A Start	Software	PSL Input	Protection event
This DDB signal is the second stage A-phase Phase Underpower start signal				
736	Power<2 B Start	Software	PSL Input	Protection event
This DDB signal is the second stage B-phase Phase Underpower start signal				
737	Power<2 C Start	Software	PSL Input	Protection event
This DDB signal is the second stage C-phase Phase Underpower start signal				
746	Power<1 3Ph Trip	Software	PSL Input	Protection event
This DDB signal is the first stage three-phase Phase Underpower trip signal				
747	Power<1 A Trip	Software	PSL Input	Protection event
This DDB signal is the first stage A-phase Phase Underpower trip signal				
748	Power<1 B Trip	Software	PSL Input	Protection event
This DDB signal is the first stage B-phase Phase Underpower trip signal				
749	Power<1 C Trip	Software	PSL Input	Protection event
This DDB signal is the first stage C-phase Phase Underpower trip signal				
750	Power<2 3Ph Trip	Software	PSL Input	Protection event
This DDB signal is the second stage three-phase Phase Underpower trip signal				
751	Power<2 A Trip	Software	PSL Input	Protection event
This DDB signal is the second stage A-phase Phase Underpower trip signal				
752	Power<2 B Trip	Software	PSL Input	Protection event
This DDB signal is the second stage B-phase Phase Underpower trip signal				
753	Power<2 C Trip	Software	PSL Input	Protection event
This DDB signal is the second stage C-phase Phase Underpower trip signal				
756	Power<1 Block	Programmable Scheme Logic	PSL Output	Protection event
This DDB signal blocks the first stage Underpower protection				
757	Power<2 Block	Programmable Scheme Logic	PSL Output	Protection event
This DDB signal blocks the second stage Underpower protection				

3.4 UNDERPOWER SETTINGS

Menu Text	Col	Row	Default Setting	Available Options
Description				
GROUP 1 POWER PROTECTION	41	00		
This column contains settings for Power protection				
UNDER POWER	41	14		
The settings under this sub-heading relate to Underpower				
Power<1 Status	41	15	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the first stage Underpower protection.				
Power<1Direction	41	16	Forward	0=Reverse 1=Forward
This setting determines the direction of the first stage Underpower element.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
Power<1 Mode	41	17	Active	0=Active 1=Reactive
There are two operation modes; Active or Reactive. This setting determines which mode is to be used for the first stage Underpower element.				
Power<1TimeDelay	41	18	1	From 0s to 100s step 0.01s
This setting sets the operate time delay setting for the first stage Underpower element.				
Power<1 tRESET	41	19	0	From 0s to 100s step 0.01s
This setting sets the time delay for the first stage Underpower element.				
Power<1 1Ph Watt	41	1A	10	From 1 to 325 step 1
This setting sets the pick-up threshold for the single-phase Underpower element for the 'Active' mode.				
Power<1 1Ph VAr	41	1B	6	From 1 to 325 step 1
This setting sets the pick-up threshold of the single-phase Underpower element for the 'Reactive' mode.				
Power<1 3Ph Watt	41	1C	30	From 1 to 325 step 1
This setting sets the pick-up threshold for the three-phase Underpower element for the 'Active' mode.				
Power<1 3Ph VAr	41	1D	18	From 1 to 325 step 1
This setting sets the pick-up threshold of the three-phase Underpower element for the 'Reactive' mode.				
Power<2 Status	41	1E	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the second stage Underpower protection.				
Power<2Direction	41	1F	Forward	0=Reverse 1=Forward
Thc setting determines the direction of the second stage Underpower element.				
Power<2 Mode	41	20	Active	0=Active 1=Reactive
There are two operation modes; Active or Reactive. This setting determines which mode is to be used for the second stage Underpower element.				
Power<2TimeDelay	41	21	1	From 0s to 100s step 0.01s
This setting sets the operate time delay setting for the second stage Underpower element.				
Power<2 tRESET	41	22	0	From 0s to 100s step 0.01s
This setting sets the time delay for the second stage Underpower element.				
Power<2 1Ph Watt	41	23	10	From 1 to 325 step 1
This setting sets the pick-up threshold for the single-phase Underpower element for the 'Active' mode.				
Power<2 1Ph VAr	41	24	6	From 1 to 325 step 1
This setting sets the pick-up threshold of the single-phase Underpower element for the 'Reactive' mode.				
Power<2 3Ph Watt	41	25	30	From 1 to 325 step 1
This setting sets the pick-up threshold for the three-phase Underpower element for the 'Active' mode.				
Power<2 3Ph VAr	41	26	18	From 1 to 325 step 1
This setting sets the pick-up threshold of the three-phase Underpower element for the 'Reactive' mode.				
Power Blocking	41	27	0x3	Bit 0=Poledead Blocks Power<1 Bit 1=Poledead Blocks Power<2
This setting is a 2 bit binary (Data type G402), whereby you can activate the Poledead Blocking for the Underpower and Overpower elements.				

3.5 APPLICATION NOTES

3.5.1 LOW FORWARD POWER CONSIDERATIONS

The Low Forward Power protection can be arranged to interlock ‘non-urgent’ protection tripping using the programmable scheme logic. It can also be arranged to provide a contact for external interlocking of manual tripping. To prevent unwanted alarms and flags, a Low Forward Power protection element can be disabled when the circuit breaker is opened via ‘Pole Dead’ logic.

The Low Forward Power protection can also be used to provide loss of load protection when a machine is motoring. It can be used for example to protect a machine which is pumping from becoming unprimed, or to stop a motor in the event of a failure in the mechanical transmission.

A typical application would be for pump storage generators operating in the motoring mode, where there is a need to prevent the machine becoming unprimed which can cause blade and runner damage. During motoring conditions, it is typical for the IED to switch to another setting group with the low forward power enabled and correctly set and the protection operating mode set to 'Reverse'.

A low forward power element may also be used to detect a loss of mains or loss of grid condition for applications where the distributed generator is not allowed to export power to the system.

3.5.2 LOW FORWARD POWER SETTING GUIDELINES

Each stage of power protection can be selected to operate as a forward power stage by selecting the **Power<(n) Direction** cell to 'Forward'.

When required for interlocking of non-urgent tripping applications, the threshold setting of the low forward power protection function should be less than 50% of the power level that could result in a dangerous overspeed condition on loss of electrical loading.

When required for loss of load applications, the threshold setting of the low forward power protection function, is system dependent, however, it is typically set to 10 - 20% below the minimum load. The operating mode should be set to 'Reverse' for this application.

For interlocking non-urgent trip applications the time delay associated with the low forward power protection function could be set to zero. However, some delay is desirable so that permission for a non-urgent electrical trip is not given in the event of power fluctuations arising from sudden steam valve/throttle closure. A typical time delay is 2 seconds.

For loss of load applications the pick-up time delay is application dependent but is normally set in excess of the time between motor starting and the load being established. Where rated power cannot be reached during starting (for example where the motor is started with no load connected) and the required protection operating time is less than the time for load to be established then it will be necessary to inhibit the power protection during this period. This can be done in the PSL using AND logic and a pulse timer triggered from the motor starting to block the power protection for the required time.

When required for loss of mains or loss of grid applications where the distributed generator is not allowed to export power to the system, the threshold setting of the reverse power protection function, should be set to a sensitive value, typically <2% of the rated power.

The low forward power protection function should be time-delayed to prevent false trips or alarms being given during power system disturbances or following synchronisation. A time delay setting, of 5s should be applied typically.

The delay on the reset timers would normally be set to zero.

To prevent unwanted alarms and flags, the protection element can be disabled when the circuit breaker is open via Pole Dead logic.

4 SENSITIVE POWER PROTECTION

In some applications, it is necessary to have very high accuracy when applying power protection. For such applications it is possible to use metering class CTs and separate Sensitive Power elements.

The Sensitive Power protection is a single-phase power element using phase A current and voltage. It provides two independent stages of Low Forward Power, Reverse Power and Over Power protection with timer and pole-dead blocking.

> *Note:*
> *Sensitive Power Protection is only available for models equipped with a SEF transformer.*

4.1 SENSITIVE POWER PROTECTION IMPLEMENTATION

Sensitive Power Protection is implemented in the POWER PROTECTION column of the relevant settings group, under the sub-heading SENSITIVE POWER. It is a single phase power element using the A-phase current and voltage.

There are two stages of Sensitive Power protection, which can be independently selected as Low Forward Power, Reverse Power and Overpower.

> *Note:*
> *When the sensitive power function is used, the SEF CT must be connected to Phase A current, making the measured power ISEF x VA.*

4.2 SENSITIVE POWER MEASUREMENTS

Three sensitive power related measurements are added to the Measurements column, the visibility of which will depend on the protection configuration.

- A-Phase Sensitive Active Power in Watts (**APh Sen Watts**)
- A-Phase Sensitive Re-active Power in VArs (**APh Sen VARs**)
- A-Phase Sensitive Power Angle (**APh Power Angle**)

4.3 SENSITIVE POWER LOGIC

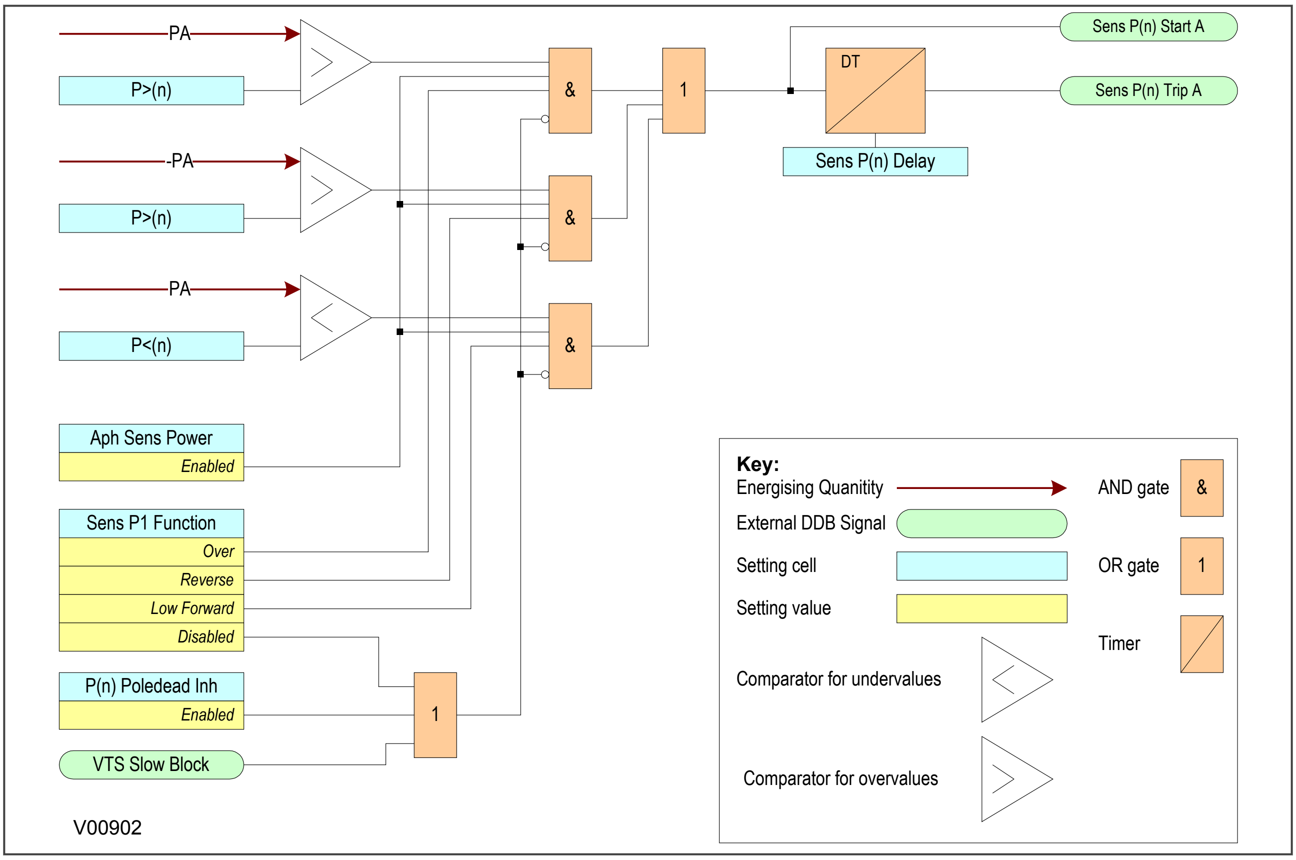


Figure 88: Sensitive Power logic diagram

4.4 SENSITIVE POWER DDB SIGNALS

Ordinal	Signal Name	Source	Type	Response
Description				
351	VTS Slow Block	Software	PSL Input	No response
This DDB signal is a purposely delayed output from the VTS which can block other functions				
758	SensP1 Start A	Software	PSL Input	Protection event
This DDB signal is the first stage Sensitive Power protection start signal				
759	SensP2 Start A	Software	PSL Input	Protection event
This DDB signal is the second stage Sensitive Power protection start signal				
760	SensP1 Trip A	Software	PSL Input	Protection event
This DDB signal is the first stage Sensitive Power protection trip signal				
761	SensP2 Trip A	Software	PSL Input	Protection event
This DDB signal is the second stage Sensitive Power protection trip signal				

4.5 SENSITIVE POWER SETTINGS

Menu Text	Col	Row	Default Setting	Available Options
Description				
GROUP 1 POWER PROTECTION	41	00		
This column contains settings for Power protection				
SENSITIVE POWER	41	28		
The settings under this sub-heading relate to Sensitive Power protection				
Aph Sens Power	41	29	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables Sensitive Power protection (A-phase only)				
Comp Angle	41	2A	0	From -5 to 5 step 0.1
This setting sets the CT compensating angle.				
Sens P1 Function	41	2B	Reverse	0=Disabled 1=Reverse 2=Low Forward 3=Over
This setting determines the type of Sensitive Power protection is used for this stage.				
Sens -P>1Setting	41	2C	0.5*V1*I3	From 0.3*V1*I3 to 100*V1*I3 step 0.1*V1*I3
This setting sets the pick-up threshold for the first stage Sensitive Reverse Power element.				
Sens P<1 Setting	41	2D	0.5*V1*I3	From 0.3*V1*I3 to 100*V1*I3 step 0.1*V1*I3
This setting sets the pick-up threshold for the first stage Low Forward Power element.				
Sens P>1 Setting	41	2E	50*V1*I3	From 0.3*V1*I3 to 100*V1*I3 step 0.1*V1*I3
This setting sets the pick-up threshold for the first stage Overpower element.				
Sens P1 Delay	41	2F	5	From 0s to 100s step 0.01s
This setting sets the operate time delay setting for the first stage Sensitive Power element.				
Sens P1 tRESET	41	30	0	From 0s to 100s step 0.01s
This setting sets the reset time delay for the first stage Sensitive Power element.				
P1 Poledead Inh	41	31	Enabled	0 = Disabled or 1 = Enabled
This setting enables or disables the first stage Pole Dead inhibit signal.				
Sens P2 Function	41	32	Low Forward	0=Disabled 1=Reverse 2=Low Forward 3=Over
This setting determines the type of Sensitive Power protection is used for this stage.				
Sens -P>2Setting	41	33	0.5*V1*I3	From 0.3*V1*I3 to 100*V1*I3 step 0.1*V1*I3
This setting sets the pick-up threshold for the second stage Sensitive Reverse Power element.				
Sens P<2 Setting	41	34	0.5*V1*I3	From 0.3*V1*I3 to 100*V1*I3 step 0.1*V1*I3
This setting sets the pick-up threshold for the second stage Low Forward Power element.				
Sens P>2 Setting	41	35	50*V1*I3	From 0.3*V1*I3 to 100*V1*I3 step 0.1*V1*I3
This setting sets the pick-up threshold for the second stage Overpower element.				
Sens P2 Delay	41	36	2	From 0s to 100s step 0.01s
This setting sets the operate time delay setting for the second stage Sensitive Power element.				
Sens P2 tRESET	41	37	0	From 0s to 100s step 0.01s
This setting sets the reset time delay for the second stage Sensitive Power element.				
P2 Poledead Inh	41	38	Enabled	0 = Disabled or 1 = Enabled

Menu Text	Col	Row	Default Setting	Available Options
Description				
This setting enables or disables the second stage Pole Dead inhibit signal.				

4.6 APPLICATION NOTES

4.6.1 SENSITIVE POWER CALCULATION

Input Quantities

Sensitive power is calculated from VA Ph-N voltage and I sensitive current input (connected to phase A).

The calculation for active power with the correction angle is:

$$P_A = I_{AS} V_A \cos(\varphi - \theta_C)$$

Where:

- V_A = A-phase voltage
- I_{AS} = A-phase sensitive current
- Φ= the angle of I_{AS} with respect to V_A
- θ_C = the CT correction angle

Calculations within the device are based upon quadrature components obtained from the Fourier analysis of the input signals. The quadrature values for V_A and I_{AS} are used for the sensitive power calculation as shown:

$$\bar{V}_A = V_{Ar} + jV_{Ai}$$

$$\bar{I}_{AS} = I_{ASr} + jI_{ASi}$$

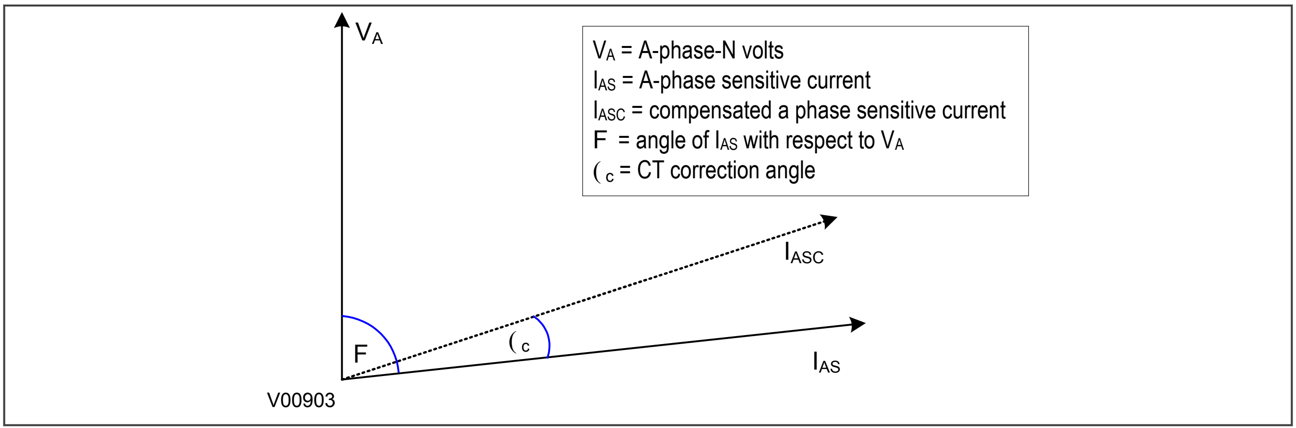


Figure 89: Sensitive Power input vectors

CT Correction

The CT correction rotates the I_{AS} vector by the correction angle. This correction is performed before the power calculation and can be achieved with the use of a rotation matrix:

$$\begin{bmatrix} \cos\theta_C & -\sin\theta_C \\ \sin\theta_C & \cos\theta_C \end{bmatrix}$$

The corrected phase-A sensitive current I_{ASC} is thus:

$$\overline{I}_{ASC} = \begin{bmatrix} I_{ASCr} \\ I_{ASCi} \end{bmatrix} = \overline{I}_{AS} = \begin{bmatrix} I_{ASr} \\ I_{ASi} \end{bmatrix} \begin{bmatrix} cos\,\theta_C & -sin\,\theta_C \\ sin\,\theta_C & cos\,\theta_C \end{bmatrix} = \begin{bmatrix} I_{ASr}\,cos\,\theta_C - I_{ASi}\,sin\,\theta_C \\ I_{ASr}\,sin\,\theta_C + I_{ASi}\,cos\,\theta_C \end{bmatrix}$$

therefore:

$$I_{ASCr} = I_{ASr}\,cos\,\theta_C - I_{ASi}\,sin\,\theta_C$$

and

$$I_{ASCi} = I_{ASr}\,sin\,\theta_C + I_{ASi}\,cos\,\theta_C$$

These values will be stored and only calculated when the compensation angle setting is changed. The stored values can then be used to calculate I_{ASC} and I_{ASC}

Active Power Calculation

The corrected A-phase sensitive current vector can now be used to calculate the sensitive A-Phase active power P_{AS}.

Using the equation

$$P_{AS} = Re\,\overline{V}_A \overline{I}^*_{ASC}$$

$$P_{AS} = Re\left(V_{Ar} + jV_{Ai}\right)\left(I_{ASCr} + jI_{ASCi}\right)$$

$$= Re\left(V_{Ar} + jV_{Ai}\right)\left(I_{ASCr} - jI_{ASCi}\right) = Re\left(V_{Ar}I_{ASCr} + V_{Ai}I_{ASCi}\right) + j\left(V_{Ai}I_{ASCr} - V_{Ar}I_{ASCi}\right)$$

$$= V_{Ar}I_{ASCr} + V_{Ai}I_{ASCi}$$

4.6.2 SENSITIVE POWER SETTING GUIDELINES

For reverse and low forward power protection, if settings greater than 3% Pn are used, the phase angle errors of suitable protection class current transformers will not result in any risk of maloperation. If settings of less than 3% are used, however, we recommend that the current input is driven by a correctly loaded metering class current transformer.

The sensitive power protection has a minimum setting accuracy of 0.5% Pn. It uses the In sensitive CT to calculate single-phase active power. It also provides phase compensation to remove errors introduced by the primary input transformers.

AUTORECLOSE

CHAPTER 8

1 CHAPTER OVERVIEW

Selected models of this product provide sophisticated Autoreclose (AR) functionality. The purpose of this chapter is to describe the operation of this functionality including the principles, logic diagrams and applications.

This chapter contains the following sections:

2 INTRODUCTION TO 3-PHASE AUTORECLOSE

It is known that approximately 80 - 90% of faults are transient in nature. This means that most faults do not last long and are self-clearing. A common example of a transient fault is an insulator flashover, which may be caused for example by lightning, clashing conductors or wind-blown debris.

A transient fault, such as an insulator flashover, is a self-clearing ‘non-damage’ fault. The flashover will cause one or more circuit breakers to trip, but it may also have the effect of clearing the fault. If the fault clears itself, the fault does not recur when the line is re-energised.

The remaining 10 – 20% of faults are either semi-permanent or permanent. A small tree branch falling on the line could cause a semi-permanent fault. Here the cause of the fault would not be removed by the immediate tripping of the circuit, but could be burnt away during a time-delayed trip. Permanent faults could be broken conductors, transformer faults, cable faults or machine faults, which must be located and repaired before the supply can be restored.

In the majority of fault incidents, if the faulty line is immediately tripped out, and time is allowed for the fault arc to deionise, reclosure of the circuit breakers will result in the line being successfully re-energised.

Autoreclose schemes are used to automatically reclose a circuit breaker a set time after it has been opened due to operation of a protection element.

On HV/MV distribution networks, autoreclosing is applied mainly to radial feeders, where system stability problems do not generally arise. The main advantages of using Autoreclose are:

- Minimal interruption in supply to the consumer
- Reduction of operating costs - fewer man hours in repairing fault damage and the possibility of running unattended substations
- With Autoreclose, instantaneous protection can be used which means shorter fault durations. This in turn means less fault damage and fewer permanent faults

Autoreclosing provides an important benefit on circuits using time-graded protection, in that it allows the use of instantaneous protection to provide a high speed first trip. With fast tripping, the duration of the power arc resulting from an overhead line fault is reduced to a minimum. This lessens the chance of damage to the line, which might otherwise cause a transient fault to develop into a permanent fault. Using instantaneous protection also prevents blowing of fuses in teed feeders, as well as reducing circuit breaker maintenance by eliminating pre-arc heating.

When instantaneous protection is used with autoreclosing, the scheme is normally arranged to block the instantaneous protection after the first trip. Therefore, if the fault persists after re-closure, the time-graded protection will provide discriminative tripping resulting in the isolation of the faulted section. However, for certain applications, where the majority of the faults are likely to be transient, it is common practise to allow more than one instantaneous trip before the instantaneous protection is blocked.

Some schemes allow a number of re-closures and time-graded trips after the first instantaneous trip, which may result in the burning out and clearance of semi-permanent faults. Such a scheme may also be used to allow fuses to operate in teed feeders where the fault current is low.

When considering feeders that are partly overhead line and partly underground cable, any decision to install auto-reclosing should be subject to analysis of the data (knowledge of the frequency of transient faults). This is because this type of arrangement probably has a greater proportion of semi-permanent and permanent faults than for purely overhead feeders. In this case, the advantages of autoreclosing are small. It can even be disadvantageous because re-closing on to a faulty cable is likely to exacerbate the damage.

3 IMPLEMENTATION

Autoreclose functionality is a software option, which is selected when ordering the device, so this description only applies to models with this option.

Autoreclose works for phase overcurrent (POC) earth fault (EF) and sensitive earth fault (SEF) protection. It is implemented in the AUTORECLOSE column of the relevant settings group. In addition to the settings contained in this column, you will also need to make some settings in the blocking cells of the relevant protection columns.

The Autoreclose function can be set to perform a single-shot, two-shot, three-shot or four-shot cycle. You select this by the **Number of Shots** cell in the AUTORECLOSE column. You can also initiate a separate Autoreclose cycle for the SEF protection, with a different number of shots, selected by the **Number of SEF Shots** cell. Dead times for all shots can be adjusted independently.

An Autoreclose cycle can be initiated internally by operation of a protection element, or externally by a separate protection device. The dead time starts in one of two cases; when the circuit breaker has tripped, or when the protection has reset. You select this using the **Start Dead t On** cell.

At the end of the relevant dead time, a **CB close 3ph** signal is given, providing it is safe for the circuit breaker to close. This is determined by checking that certain system conditions are met as specified by the **System Checks** functionality.

It is safe to close the circuit breaker providing that:

- only one side of the circuit breaker is live (either dead line / live bus, or live line / dead bus), or
- if both bus and line sides of the circuit breaker are live, the system voltages are synchronised.

In addition, the energy source powering the circuit breaker (for example the closing spring) must be fully charged. This is indicated from the **CB Healthy** DDB input.

When the CB has closed, the reclaim time starts. If the circuit breaker does not trip again, the Autoreclose function resets at the end of the set reclaim time. If the protection operates during the reclaim time the device either advances to the next shot in the Autoreclose cycle, or if all reclose attempts have been made, goes to lockout.

CB Status signals must also be available, so the default setting for **CB Status Input** should be modified according to the application. The default PSL requires 52A, 52B and CB Healthy logic inputs, so a setting of both **52A and 52B** is required for the **CB Status Input**.

4 AUTORECLOSE FUNCTION INPUTS

The Autoreclose function has several logic inputs, which can be mapped to any of the opto-inputs or to one or more of the DDB output signals generated by the PSL. The functions of these inputs are described below.

4.1 CB HEALTHY

It is necessary to establish if there is sufficient energy in the circuit breaker (spring charged, gas pressure healthy, etc.) before the CB can be re-closed. This **CB Healthy** input is used to ensure this before initiating a **CB closed 3ph** command. If on completion of the dead time, the **CB Healthy** input is low, and remains low for a period given by the **CB Healthy Time** timer, lockout will result and the circuit breaker will remain open.

The majority of circuit breakers are only capable of providing a single trip-close-trip cycle, in which case the **CB Healthy** signal would stay low after one Autoreclose shot, resulting in lockout.

This check can be disabled by not allocating an opto-input for the **CB Healthy** signal, whereby the signal defaults to a High state.

4.2 BLOCK AR

The **Block AR** input blocks the Autoreclose function and causes a lockout. It can be used when protection operation without Autoreclose is required. A typical example is on a transformer feeder, where Autoreclose may be initiated by the feeder protection but blocked by the transformer protection.

4.3 RESET LOCKOUT

The **Reset Lockout** input can be used to reset the Autoreclose function following lockout. It also resets any Autoreclose alarms, provided that the signals that initiated the lockout have been removed.

4.4 AR AUTO MODE

The **AR Auto Mode** input is used to select the Auto operating mode. In this mode, the Autoreclose function is in service.

4.5 AR LIVE LINE MODE

The **AR Live Line Mode** input is used to select the Live Line operating mode when Autoreclose is out of service and all blocking of instantaneous protection by Autoreclose is disabled. This operating mode takes precedence over all other operating modes for safety reasons, as it indicates that utility personnel are working near live equipment.

4.6 TELECONTROL MODE

The **Telecontrol** input is used to select the Telecontrol operating mode so that the Auto and Non-auto modes of operation can be selected remotely.

4.7 LIVE/DEAD CCTS OK (LIVE/DEAD CIRCUITS OK)

The **Live/Dead Ccts OK** signal is a signal indicating the status of the Live Line / Dead Bus or Live Bus / Dead Line system conditions (High = OK, Low = Not OK). The logic required can be derived in the PSL from the Live Line, Dead Line, Live Bus and Dead Bus signals in the System Check logic, or it can come from an external source depending on the application.

4.8 AR SYS CHECKS (AR SYSTEM CHECKS)

The **AR Sys Checks** signal can be mapped from the system checks output **SysChksInactive**, to enable auto-reclosing without any system checks, providing the **System Checks** setting in the CONFIGURATION column is disabled. This mapping is not essential, because the **No System Checks** setting in the AUTORECLOSE column can be enabled to achieve the same effect.

This DDB can also be mapped to an opto-input, to allow the IED to receive a signal from an external system monitoring device, indicating that the system conditions are suitable for CB closing. This should not normally be necessary, since the IED has comprehensive built in system check functionality.

4.9 EXT AR PROT TRIP (EXTERNAL AR PROTECTION TRIP)

The **Ext AR Prot** signal allows Autoreclose initiation by a Trip from a separate protection device.

4.10 EXT AR PROT START(EXTERNAL AR PROTECTION START)

The **Ext AR Prot** signal allows Autoreclose initiation by a Start from a separate protection device.

4.11 DAR COMPLETE (DELAYED AUTORECLOSE COMPLETE)

Some utilities require Delayed Autoreclose (DAR) functionality.

The **DAR Complete** signal can, if required, be mapped in PSL to provide a short pulse when a CB Close command is given at the end of the dead time. If **DAR Complete** is activated during an Autoreclose cycle, output **DAR in Progress** resets, even though the reclaim time may still be running, and **AR in Progress** remains set until the end of the reclaim time.

For most applications, **DAR complete** can be ignored (not mapped in PSL). In such cases, output **DAR in Progress** operates and resets in parallel with **AR in Progress**.

4.12 CB IN SERVICE (CIRCUIT BREAKER IN SERVICE)

This signal must be high until the instant of protection operation for an Autoreclose cycle to be initiated. For most applications, this DDB can be mapped simply from **CB Closed 3ph**. More complex PSL mapping can be programmed if required, for example where it is necessary to confirm not only that the CB is closed but also that the line and/or bus VT is actually live up to the instant of protection operation.

4.13 AR RESTART

In some applications, it is sometimes necessary to initiate an Autoreclose cycle by means of connecting an external signal to an opto-input. This would be when the normal interlock conditions are not all satisfied, i.e. when the CB is open and the associated feeder is dead. If the **AR Restart** input is mapped to an opto-input, activation of that opto-input will initiate an Autoreclose cycle irrespective of the status of the **CB in Service** input, provided the other interlock conditions, are still satisfied.

4.14 DT OK TO START (DEAD TIME OK TO START)

This is an optional extra interlock in the dead time initiation logic. In addition to the CB being open and the protection reset, **DT OK To Start** has to be set high to allow the dead time function to be primed after an AR cycle has started. Once the dead time function is primed, this signal has no further affect – the dead time function stays primed even if the signal subsequently goes low. A typical PSL mapping for this input is from the **Dead Line** signal from the System Check logic. This would enable dead time priming only when the feeder has gone dead after CB tripping. If this extra dead time priming interlock is not required, **DT OK To Start** can be left unmapped, and it will default to a high state.

4.15 DEAD TIME ENABLED

This is another optional interlock in the dead time logic. This signal has to be high to allow the dead time to run. If this signal goes low, the dead time stops and resets, but stays primed, and will restart from zero when it goes high again. A typical PSL mapping is from the **CB Healthy** input or from selected signals from the System Check logic. It could also be mapped to an opto-input to provide a 'hold off' function for the follower CB in a 'master/follower' application with 2 CBs. If this optional interlock is not required, **Dead Time Enabled** can be left unmapped, and it will default to a high state.

4.16 AR INIT TRIP TEST (INITIATE TRIP TEST)

If **AR Init TripTest** is mapped to an opto-input, and that input is activated momentarily, the IED generates a CB trip output via **AR Trip Test**. The default PSL then maps this to output to the trip output relay and initiates an Autoreclose cycle.

4.17 AR SKIP SHOT 1

If **AR Skip Shot 1** is mapped to an opto-input, and that input is activated momentarily, the IED logic will cause the Autoreclose sequence counter to increment by 1. This will decrease the available number of reclose shots and will lockout the re-closer.

4.18 INH RECLAIM TIME (INHIBIT RECLAIM TIME)

If **Inh Reclaim Time** is mapped to an opto-input, and that input is active at the start of the reclaim time, the IED logic will cause the reclaim timers to be blocked.

5 AUTORECLOSE FUNCTION OUTPUTS

The Autoreclose function has several logic outputs, which can be assigned to output relay contacts, monitor bits in the COMMISSIONING TESTS column, or the PSL. The functions of these outputs are described below.

5.1 AR IN PROGRESS

This signal is present during the complete re-close cycle from the start of protection to the end of the reclaim time or lockout.

5.2 DAR IN PROGRESS

This operates together with the **AR In Progress** signal at the start of Autoreclose. If **DAR Complete** does not operate, **DAR in Progress** remains operated until **AR In Progress** resets at the end of the cycle. If **DAR Complete** goes high during the Autoreclose cycle, **DAR in Progress** resets.

5.3 SEQUENCE COUNTER STATUS DDB SIGNALS

During each Autoreclose cycle a sequence Counter increments by 1 after each fault trip and resets to zero at the end of the cycle.

- **Seq. Counter** = 0 is set when the counter is at zero
- **Seq. Counter** = 1 is set when the counter is at 1
- **Seq. Counter** = 2 is set when the counter is at 2
- **Seq. Counter** = 3 is set when the counter is at 3
- **Seq. Counter** = 4 is set when the counter is at 4

5.4 SUCCESSFUL CLOSE

The **Successful Close** output indicates that an Autoreclose cycle has been successfully completed. A successful Autoreclose signal is given after the protection has tripped the CB and it has reclosed successfully. The successful Autoreclose output is reset at the next CB trip or from one of the reset lockout methods.

5.5 AR IN SERVICE

The **AR In Service** output indicates whether the Autoreclose is in or out of service. Autoreclose is In Service when the device is in **Auto** mode and Out of Service when in the **Non-Auto** and **Live Line** modes.

5.6 AR BLK MAIN PROT (BLOCK MAIN PROTECTION)

The **AR Blk Main Prot** signal blocks the DT-only stages (instantaneous stages) of the main current protection elements. These are **I>3, I>4, I>6, IN1>3, IN1>4, IN2>3,** and **IN2>4**. You block the instantaneous stages for each trip of the Autoreclose cycle using the Overcurrent and Earth Fault 1 and 2 settings, **I> Blocking, IN1> Blocking, IN2> Blocking** and the **Trip 1/2/3/4/5 Main** settings.

5.7 AR BLK SEF PROT (BLOCK SEF PROTECTION)

The **AR Blk SEF Prot** signal blocks the DT-only stages (instantaneous stages) of the SEF protection elements. These are **ISEF>3**, and **ISEF>4**. You block the instantaneous SEF stages for each trip of the Autoreclose cycle using the SEF PROTECTION setting **ISEF> Blocking**, and the **Trip 1/2/3/4/5 SEF** settings.

5.8 RECLOSE CHECKS

The **Reclose Checks** output indicates that the AR System Checks are in progress.

5.9 DEADTIME IN PROG

The **DeadTime in Prog** output indicates that the dead time is in progress. This signal is set when **Reclose Checks** is set AND input **Dead TimeEnabled** is high. This may be useful during commissioning to check the operation of the Autoreclose cycle.

5.10 DT COMPLETE (DEAD TIME COMPLETE)

DT Complete (Dead time complete) operates at the end of the set dead time, and remains operated until either the scheme resets at the end of the reclaim time or a further protection operation or Autoreclose initiation occurs. It can be applied purely as an indication, or included in PSL mapping to logic input **DAR Complete**.

5.11 AR SYNC CHECK (AR SYNCHRONISATION CHECK)

AR Sync Check indicates that the Autoreclose Synchronism checks are satisfactory. This is when either of the synchronisation check modules (CS1 or CS2), confirms an In-Synchronism condition.

5.12 AR SYSCHECKS OK (AR SYSTEM CHECKS OK)

AR SysChecks OK indicates that the Autoreclose System checks are satisfactory. This is when any selected system check condition (synchronism check, live bus/dead line etc.) is confirmed.

5.13 AUTO CLOSE

The **Auto Close** output indicates that the Autoreclose logic has issued a 'Close' signal to the CB. This output feeds a signal to the control close pulse timer and remains on until the CB has closed. This signal may be useful during commissioning to check the operation of the Autoreclose cycle.

5.14 PROTECTION LOCKT (PROTECTION LOCKOUT)

Protection Lockt (Protection Lockout) operates if **AR lockout** is triggered by protection operation either during the inhibit period following a manual CB close or when the device is in **Non-auto** or **Live Line** mode.

5.15 RESET LCKOUT ALM (RESET LOCKOUT ALARM)

Reset Lckout Alm operates when the device is in **Non-auto** mode, if the **Reset Lockout** setting is set to 'Select Non Auto'.

5.16 RECLAIM IN PROG

Reclaim in Prog output indicates that a reclaim timer is in progress and will drop-off once the reclaim timer resets.

5.17 RECLAIM COMPLETE

Reclaim Complete operates at the end of the set reclaim time and is a fast reset. To maintain the output indication a dwell timer has to be implemented in PSL.

6 AUTORECLOSE FUNCTION ALARMS

The following DDB signals will produce an alarm. These are described below.

6.1 AR NO SYS CHECK

The **AR No Sys Check** alarm indicates that the system voltages are not suitable for autoreclosing at the end of the system check time (setting **Sys Check Time**), leading to a lockout condition. This alarm is latched and must be reset manually.

6.2 AR CB UNHEALTHY

The **AR CB Unhealthy** alarm indicates that the **CB Healthy** input was not energised at the end of the 'CB Healthy Time', leading to a lockout condition. This alarm is latched and must be reset manually.

6.3 AR LOCKOUT

The **AR Lockout** alarm indicates that the device is in a lockout status and that further re-close attempts will not be made. This alarm can configured to reset automatically (self-reset) or manually as determined by the setting **Reset Lockout by** in the CB CONTROL column.

7 AUTORECLOSE OPERATION

7.1 OPERATING MODES

The Autoreclose function has three operating modes:

- Auto Mode: Autoreclose is in service
- Non-auto Mode: Autoreclose is out of service AND the chosen protection functions are blocked if setting **AR Deselected** = 'Block Inst Prot.'
- Live Line Mode: Autoreclose is out of service, but protection functions are NOT blocked, even if setting **AR Deselected** = 'Block Inst Prot.'

> *Note:*
> *Live Line Mode provides extra security for live line working on the protected feeder.*

The Autoreclose function must first be enabled in the CONFIGURATION column. You can then select the operating mode according to application requirements. The basic method of mode selection is determined by the setting **AR Mode Select** in the AUTORECLOSE column, as summarised in the following table:

AR Mode Select Setting	Description
Command Mode	Auto or Non-auto mode selection is determined by the command cell **Autoreclose Mode** in the CB CONTROL column.
Opto Set Mode	Auto or Non-auto mode selection is determined by an opto-input mapped to **AR Auto Mode** If the **AR Auto Mode** input is high, Auto operating mode is selected. If the **AR Auto Mode** input is low, Non-Auto operating mode is selected.
User Set Mode	Auto or Non-auto mode selection is controlled by the **Telecontrol Mode** input. If the **Telecontrol Mode** input is high, the setting **Autoreclose Mode** in the CB CONTROL column is used to select Auto or Non Auto operating mode. If the **Telecontrol Mode** input is low, it behaves as for the 'Opto Set Mode' setting.
Pulse Set Mode	Auto or Non-auto mode selection is determined by the falling edge of **Telecontrol**. If the **Telecontrol** input is high, the operating mode is toggled between Auto and Non Auto Mode on the falling edge as it goes low. The Auto Mode pulses are produced by the SCADA system. If the **Telecontrol** input is low, it behaves as for the 'Opto Set Mode' setting.

The Live Line Mode is controlled by **AR Live Line** Mode. If this is high, the scheme is forced into Live Line Mode irrespective of the other signals.

7.1.1 FOUR-POSITION SELECTOR SWITCH IMPLEMENTATION

It is quite common for some utilities to apply a four position selector switch to control the mode of operation. This application can be implemented using the DDB signals **AR Live Line Mode**, **AR Auto Mode** and **Telecontrol Mode**. This is demonstrated in the following diagram.

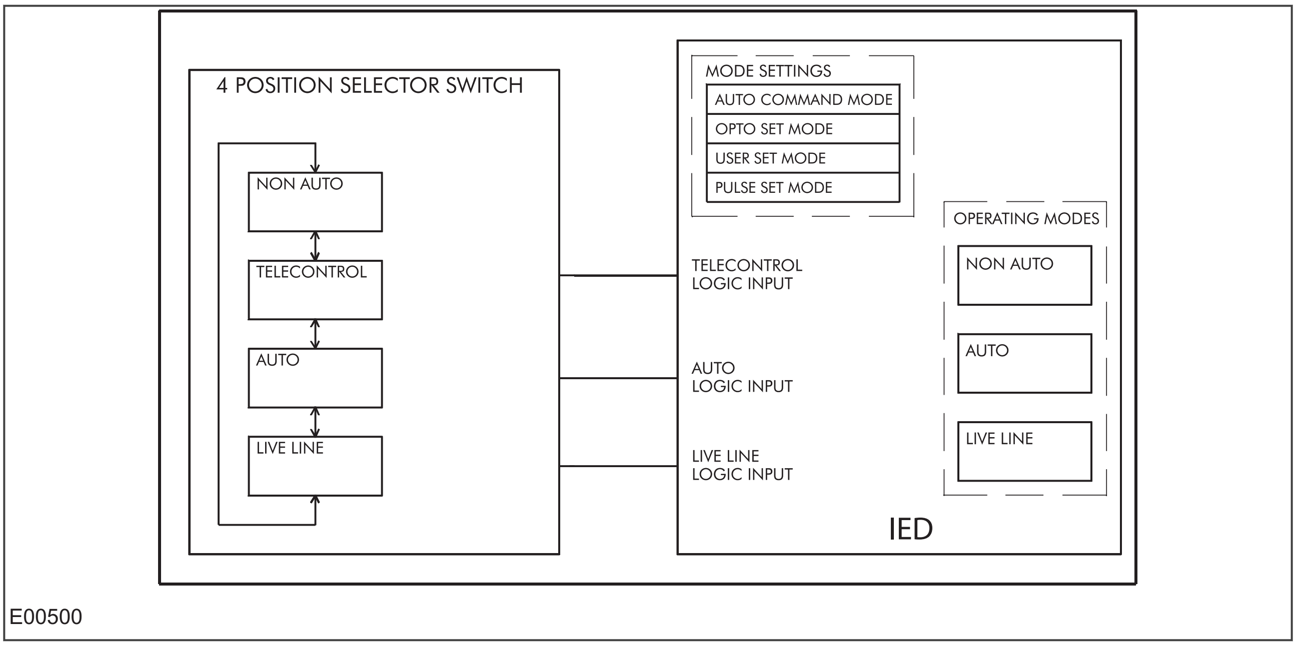


Figure 90: Four-position selector switch implementation

The required logic truth table for this arrangement is as follows:

Switch position	AR Auto Mode	Telecontrol Mode	AR Live Line Mode
Non-auto	0	0	0
Telecontrol	0 or SCADA pulse	1	0
Auto	1	0	0
Live Line	0	0	1

7.1.2 OPERATING MODE SELECTION LOGIC

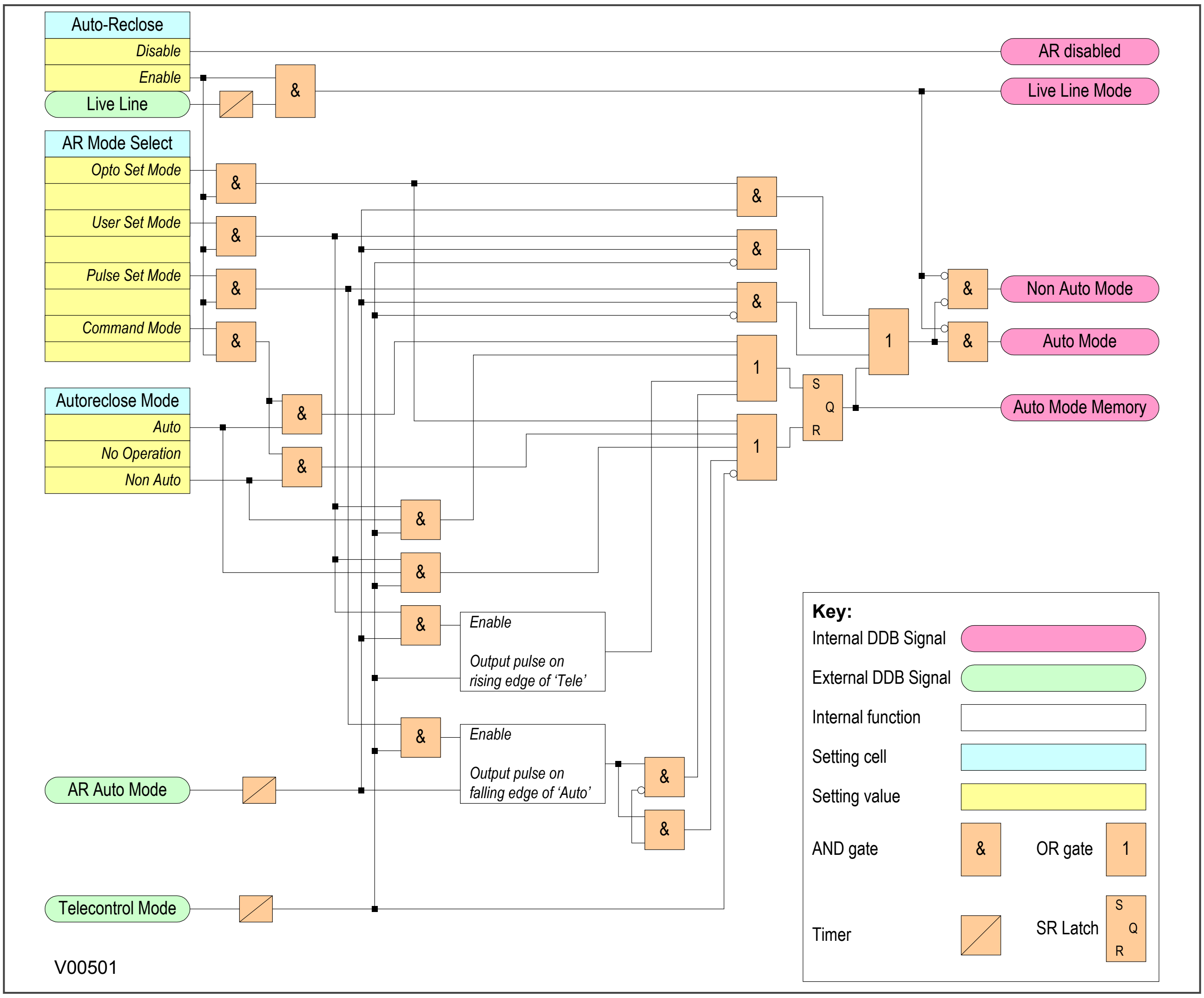


Figure 91: Autoreclose mode select logic

The mode selection logic includes a 100 ms delay **Auto Mode**, **Telecontrol** and **Live Line** logic inputs, to ensure a predictable change of operating modes. This is of particular importance for the case when the four position switch does not have 'make-before-break' contacts. The logic also ensures that when the switch is moved from Auto or Non-Auto position to Telecontrol, the scheme remains in the previously selected mode (Auto or Non-Auto) until a different mode is selected by remote control.

For applications where live line operating mode and remote selection of Auto/Non-auto modes are not required, a simple two position switch can be arranged to activate **Auto Mode** input. In this case, the **Live Line** and **Telecontrol** inputs would be unused.

7.2 AUTORECLOSE INITIATION

Autoreclose is usually initiated from the IED's internal protection function. Different stages of phase overcurrent and earth fault protection can be programmed to initiate or block the main Autoreclose function. The stages of sensitive earth fault protection can also be programmed to initiate or block both the Main Autoreclose function or the SEF Autoreclose function.

The associated settings are found in the AUTORECLOSE column under the sub-heading AR INITIATION.

For example:

If **I>1 AR** is set to 'Initiate Main AR', operation of the **I>1** protection stage will initiate Autoreclose

If **ISEF>1 AR** is set to 'No Action', operation of the **ISEF>1** protection stage will lead to a CB trip but no reclose.

> *Note:*
> *A selection must be made for each protection stage that is enabled.*

A separate protection device may also initiate Autoreclose. The Autoreclose can be initiated from a protection Trip, or when sequence coordination is required from a protection Start. If external triggering of Autoreclose is required, the following DDB signals should be mapped to opto-inputs:

- **Ext AR Prot Trip**
- **Ext AR Prot Strt** (if applicable)

In addition, the setting **Ext Prot** should be set to 'Initiate Main AR'.

Although a protection start and a protection trip can initiate an AR cycle, several checks still have to be performed before the initialisation signal is given. Some of the checks are listed below:

- **Auto Mode** has been selected
- **Live line mode** is disabled
- The number of main protection and SEF shots have not been reached
- Sequence co-ordination is enabled (for protection start to initiate AR. This is not necessary if a protection trip is doing the initiating)
- The **CB Ops Lockout** DDB signal is not set
- The **CB in Service** DDB signal is high

> *Note:*
> *The relevant protection trip must be mapped to the **Trip Command In** DDB.*

7.2.1 START SIGNAL LOGIC

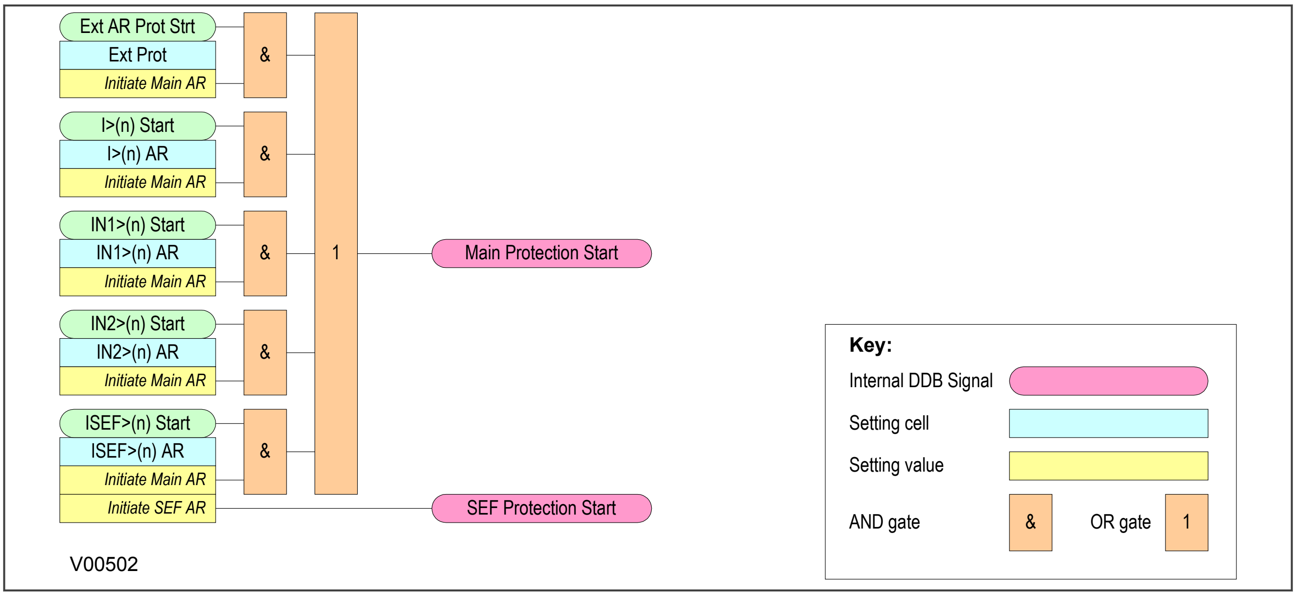


Figure 92: Start signal logic

7.2.2 TRIP SIGNAL LOGIC

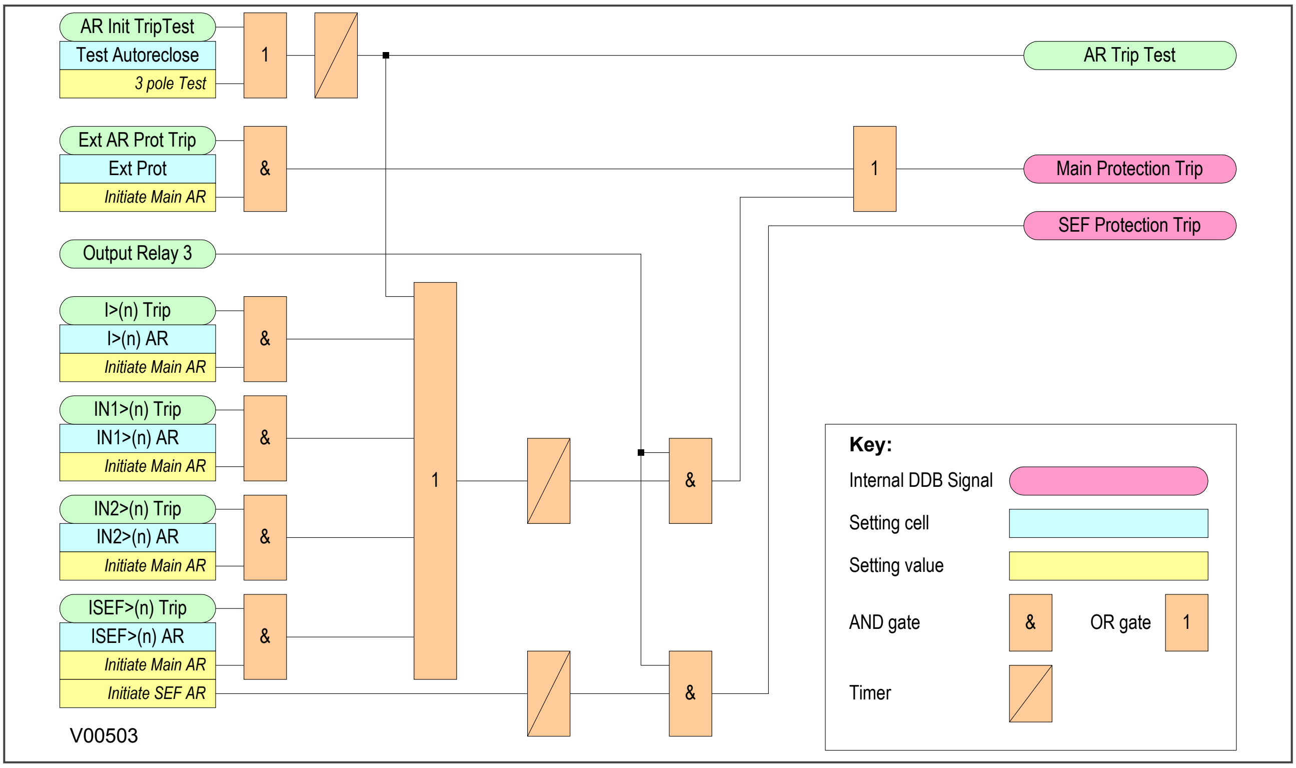


Figure 93: Trip signal logic

7.2.3 BLOCKING SIGNAL LOGIC

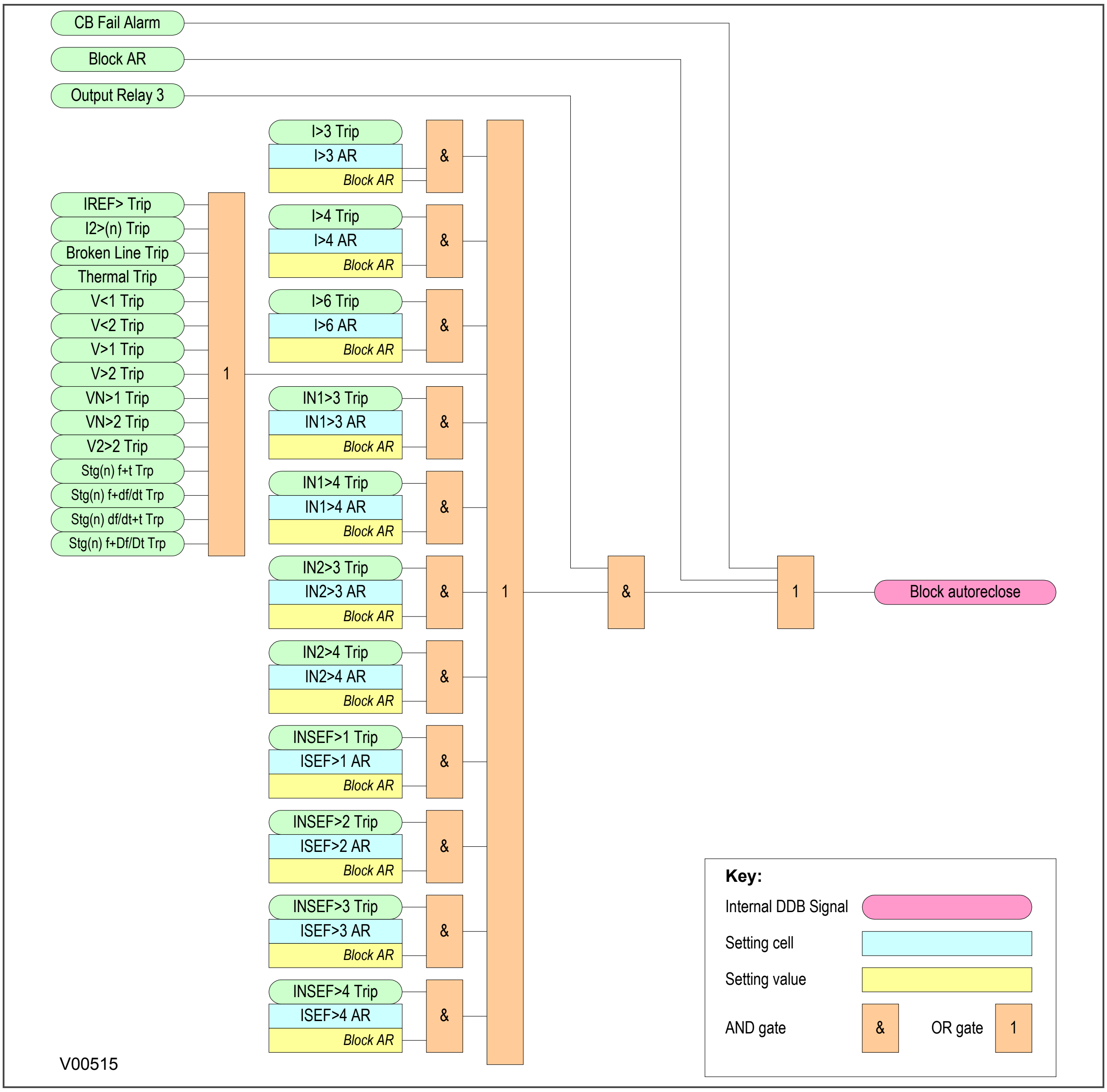


Figure 94: Blocking signal logic

7.2.4 SHOTS EXCEEDED LOGIC

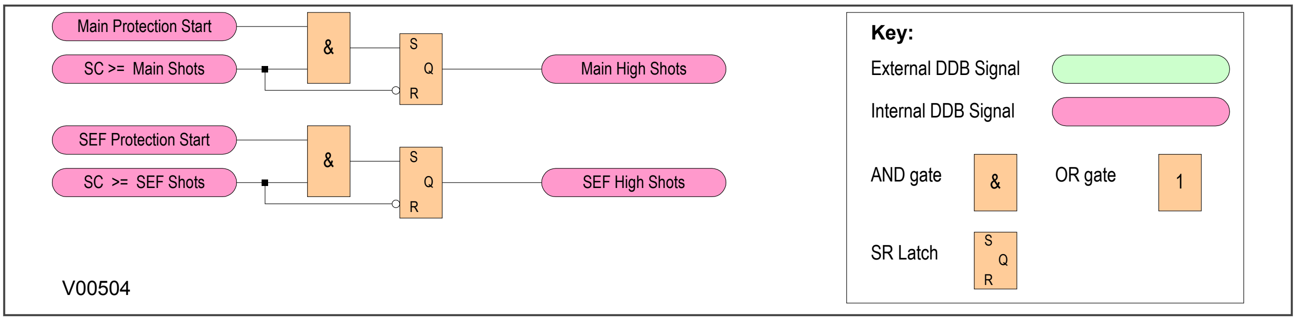


Figure 95: Shots Exceeded logic

7.2.5 AR INITIATION LOGIC

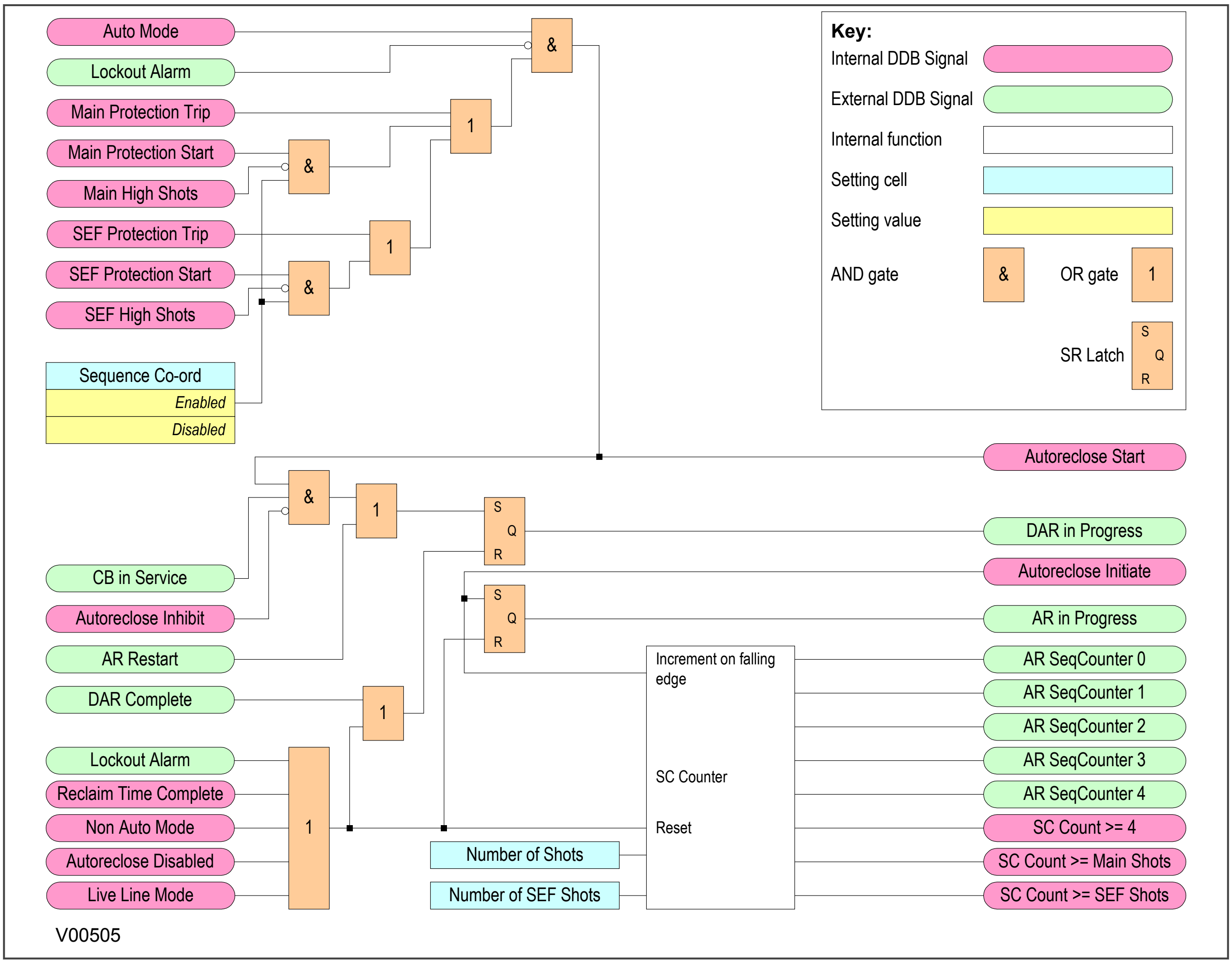


Figure 96: AR initiation logic

7.3 BLOCKING INSTANTANEOUS PROTECTION FOR SELECTED TRIPS

Instantaneous protection may be blocked or not blocked for each trip in an Autoreclose cycle. This is selected using the **Trip (n) Main** and **Trip (n) SEF** settings, where n is the number of the trip in the autoreclose cycle. These allow the instantaneous elements of phase, earth fault and SEF protection to be selectively blocked for a CB trip sequence. For example, if **Trip 1 Main** is set to 'No Block' and **Trip 2 Main** is set to 'Block Inst Prot', the instantaneous elements of the phase and earth fault protection will be available for the first trip but blocked afterwards for the second trip during the Autoreclose cycle. The logic for this is shown below.

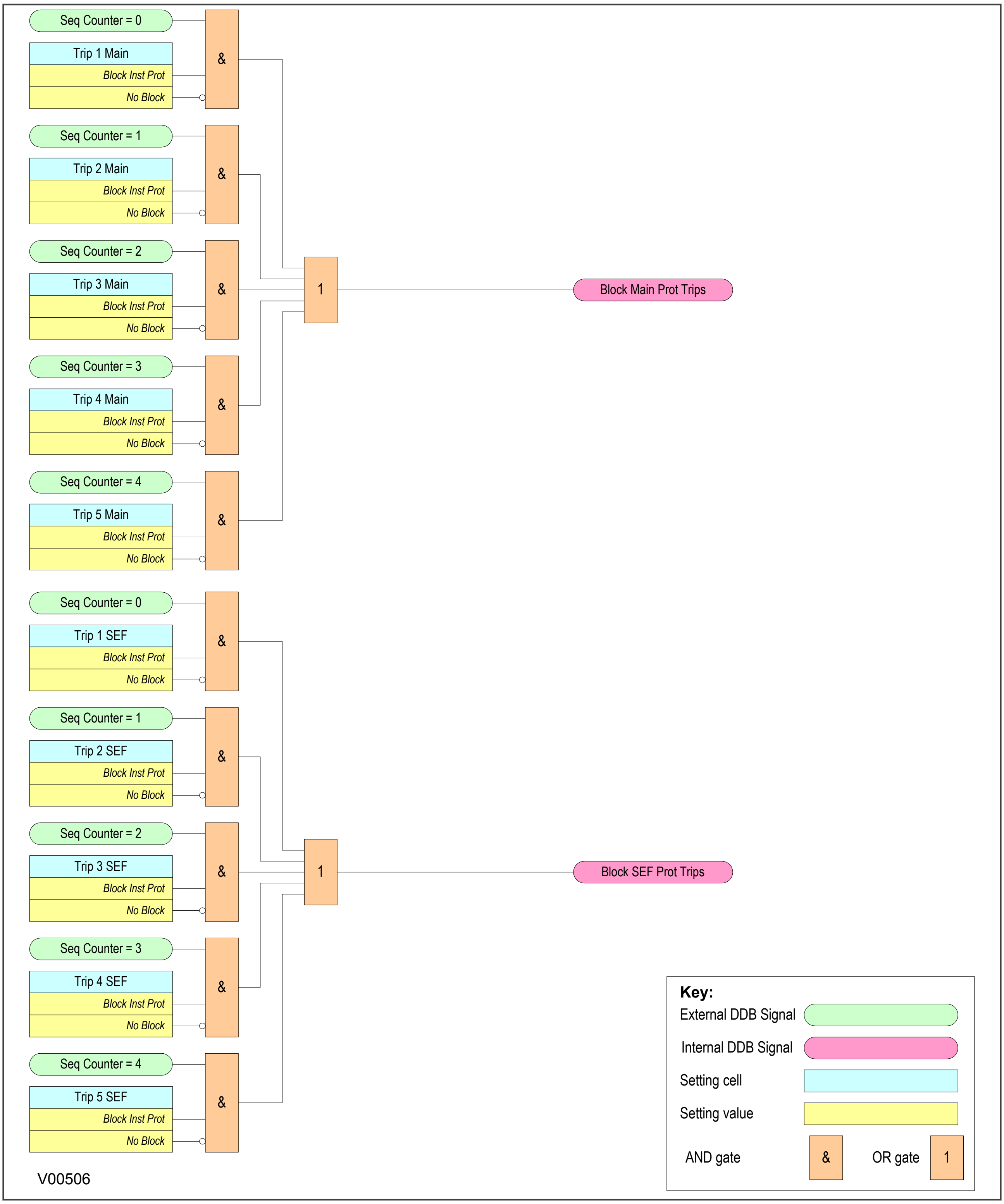


Figure 97: Blocking instantaneous protection for selected trips

7.4 BLOCKING INSTANTANEOUS PROTECTION FOR LOCKOUTS

Instantaneous protection can also be blocked for certain lockout conditions:

It is blocked when the CB maintenance lockout counter or excessive fault frequency lockout has reached its penultimate value.

For example, if the setting **No. CB Ops Lock** in the CB MONITOR SETUP column is set to 100 and the **No. CB Ops Maint** = '99', the instantaneous protection can be blocked to ensure that the last CB trip before lockout will be due to discriminative protection operation. This is controlled using the **EFF Maint Lock** setting (Excessive Fault Frequency maintenance lockout). If this is set to 'Block Inst Prot', the instantaneous protection will be blocked for the last CB Trip before lockout occurs.

Instantaneous protection can also be blocked when the IED is locked out, using the **AR Lockout** setting. It can also be blocked after a manual close using the **Manual Close** setting. When the IED is in the Non-auto mode it can be blocked by using the **AR Deselected** setting. The logic for these features is shown below.

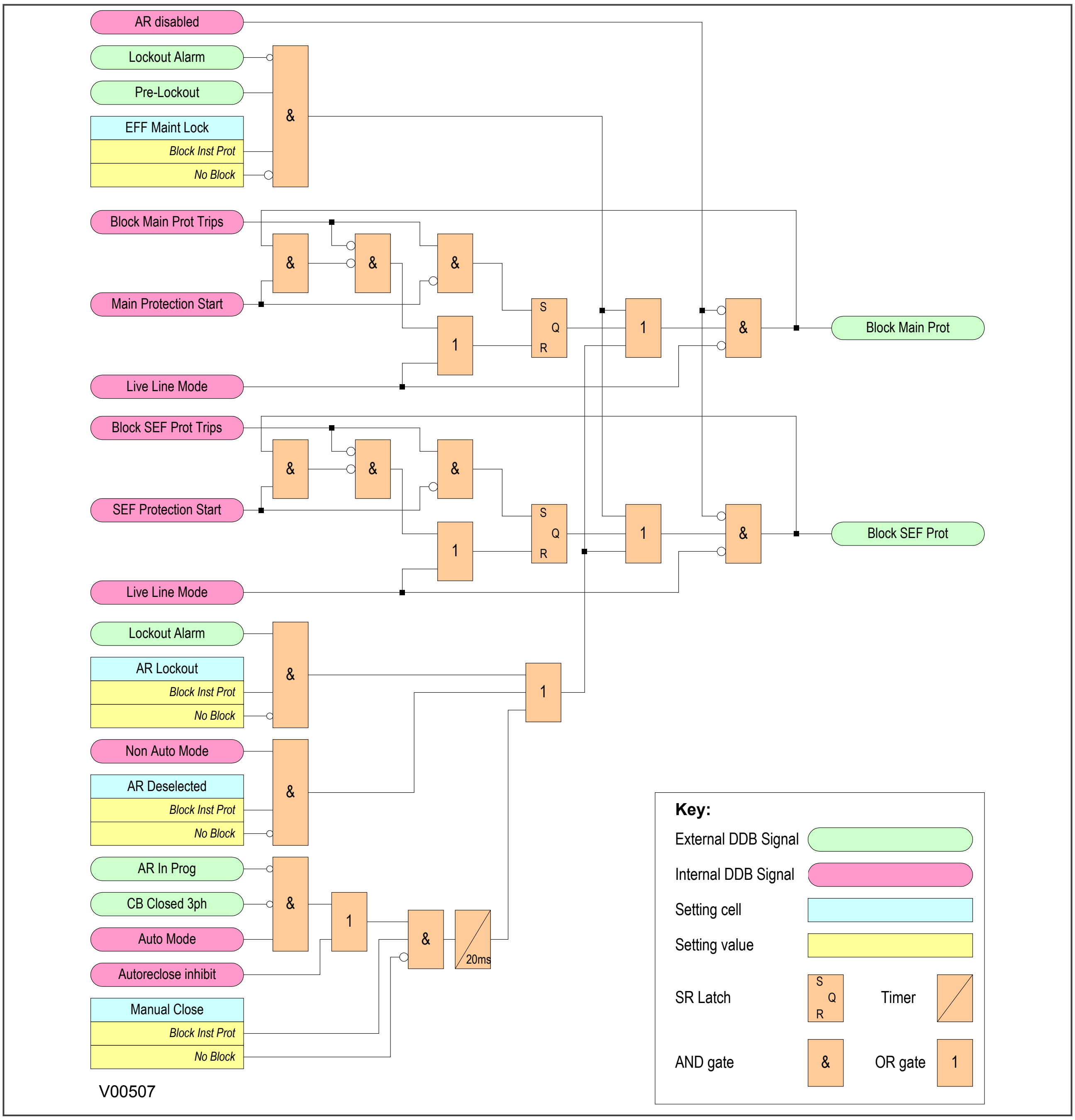


Figure 98: Blocking instantaneous protection for lockouts

7.5 DEAD TIME CONTROL

When the setting **CS AR Immediate** is enabled, immediate re-closure of the circuit breaker is allowed providing that both sides of the circuit breaker are live and in synchronism at any time after the dead time has started. This allows for quicker load restoration, as it is not necessary to wait for the full dead time to expire.

If **CS AR Immediate** is disabled, or neither Line nor Bus are live, the dead timer will continue to run, if the **Dead Time Enabled** signal is high. The **Dead Time Enabled** function could be mapped to an opto-input to indicate that the circuit breaker is healthy. Mapping the **Dead Time Enabled** function in PSL increases the flexibility by allowing it to be triggered by other conditions such as Live Line/Dead Bus. If **Dead Time Enabled** is not mapped in PSL, it defaults to high, so the dead time can run.

The dead time control logic is shown below.

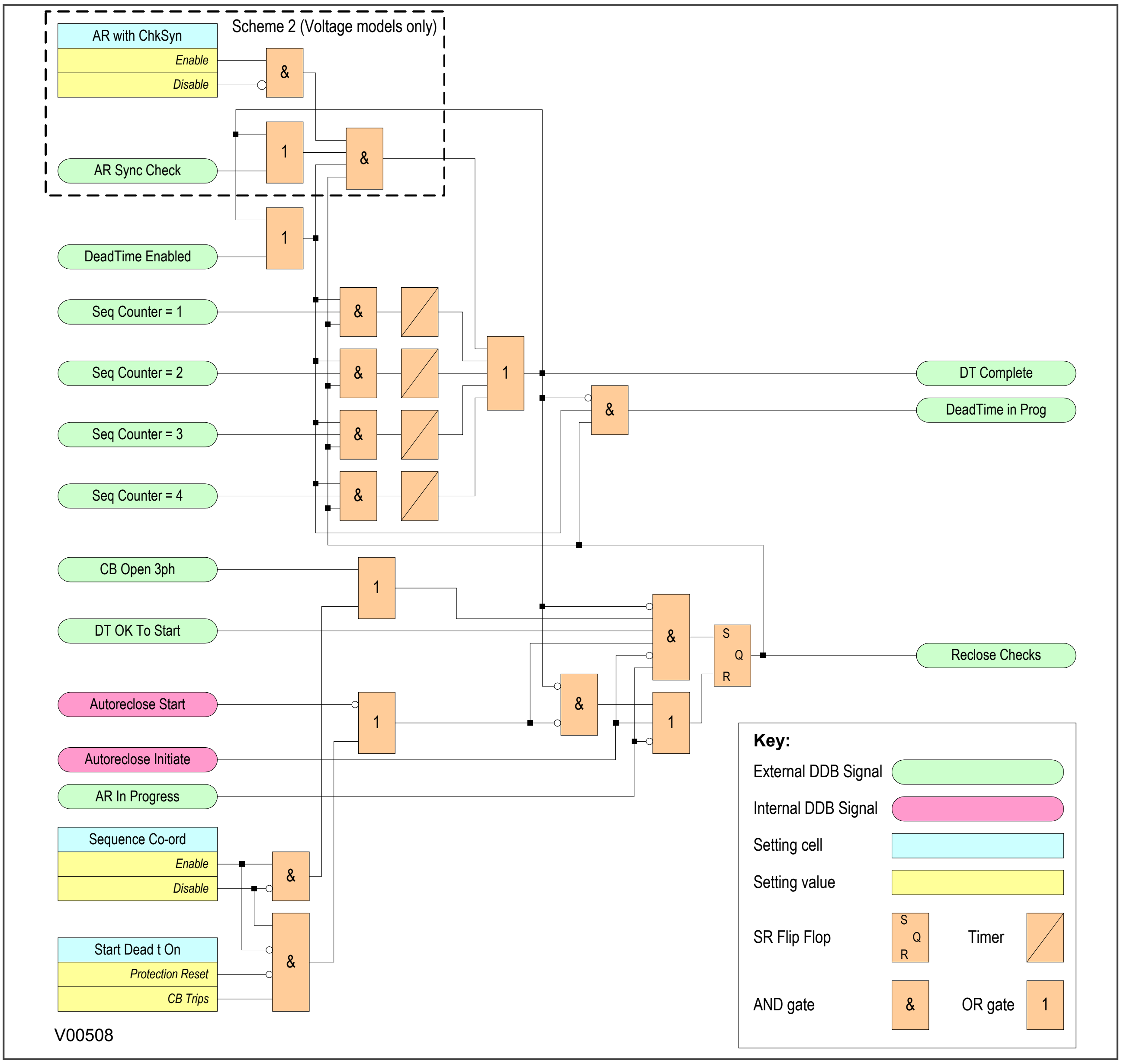


Figure 99: Dead Time Control logic

7.5.1 AR CB CLOSE CONTROL

Once the dead time is completed or a synchronism check is confirmed, the **Auto Close** signal is given, provided both the **CB Healthy** and the **System Checks** are satisfied. The **Auto Close** signal triggers a CB Close command via the CB Control functionality.

The AR CB Close Control Logic is shown below.

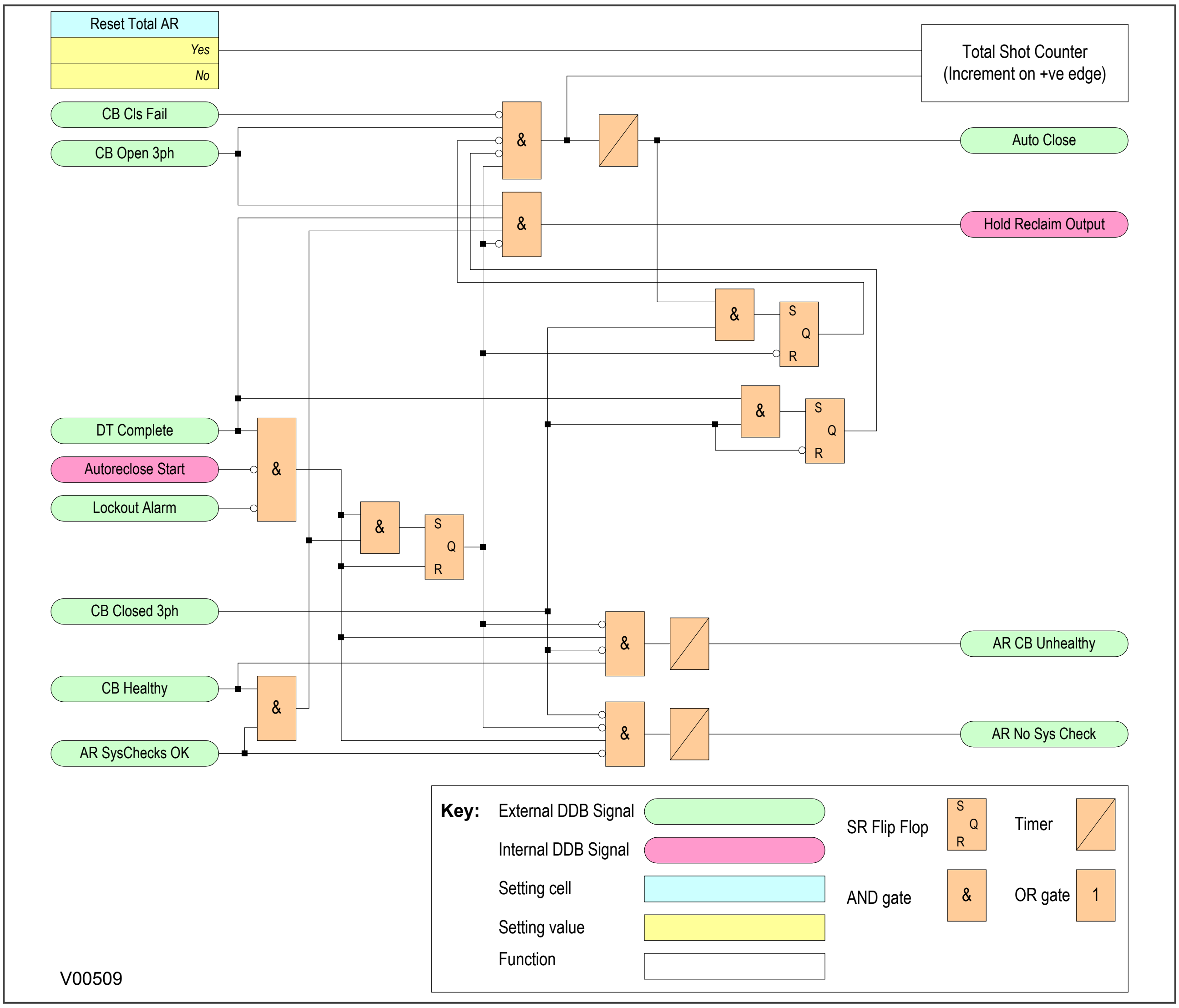


Figure 100: AR CB Close Control logic

7.6 AR SYSTEM CHECKS

The permission to initiate an Autoreclose depends on the following AR system check settings. These are found in the AUTORECLOSE column under the AR SYSTEM CHECKS sub-heading and are not to be confused with the main system check settings in the SYSTEM CHECKS column.

The AR SYSTEM CHECKS are as follows:

- **Live/Dead Ccts**: When enabled this setting will give an **AR Check OK** signal when the **LiveDead Ccts OK** signal is high. This logic input DDB would normally be mapped in PSL to appropriate combinations of Line Live, Line Dead, Bus Live and Bus Dead DDB signals.
- **No System Checks**: When enabled this setting completely disables system checks thus allowing Autoreclose initiation under any system conditions.
- **SysChk on Shot 1**: Can be used to disable system checks on the first AR shot.
- **AR with ChkSync**: Only allows Autoreclose when the system satisfies the Check Sync Stage 1 (CS1) settings in the main SYSTEM CHECKS menu.
- **AR with SysSync**: Only allows Autoreclose when the system satisfies the Check Sync Stage 2 (CS2) settings in the main SYSTEM CHECKS menu.

The AR System Check logic is as follows:

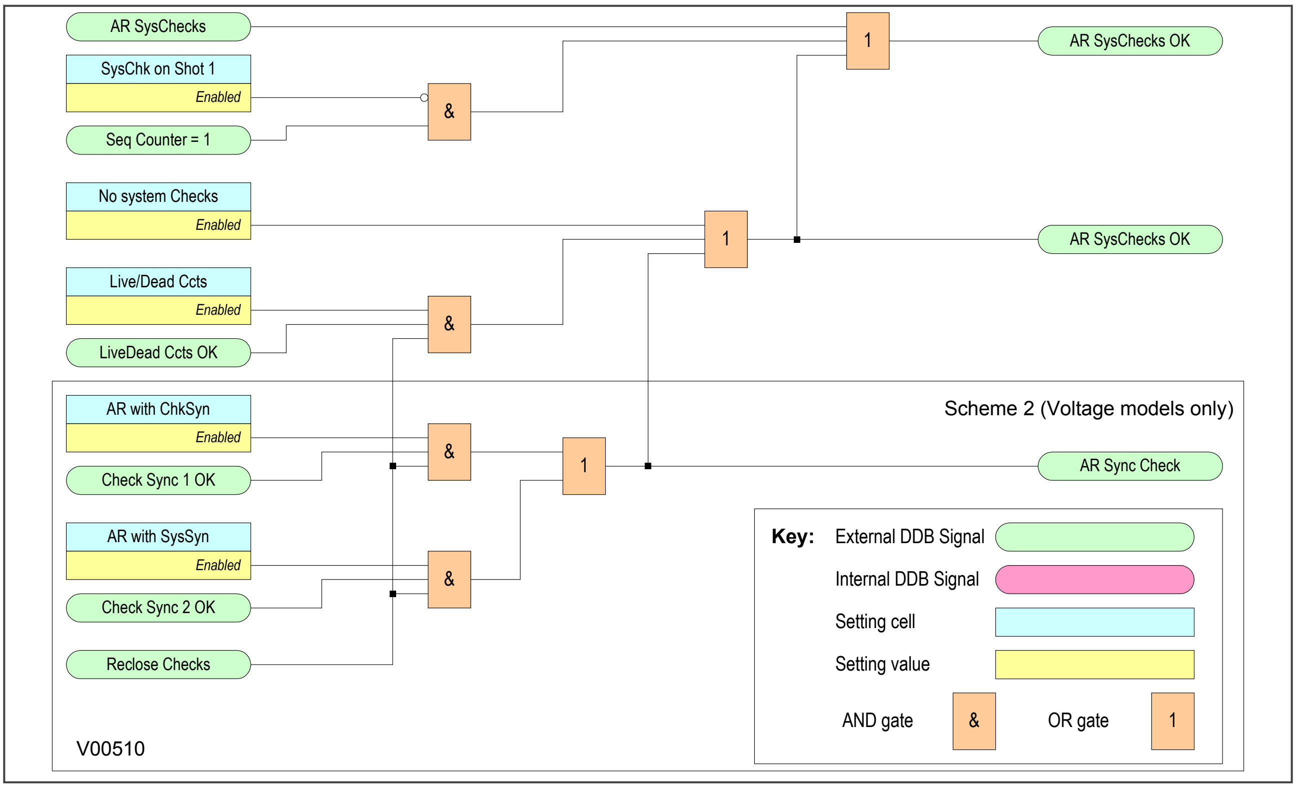


Figure 101: AR System Check logic

7.7 RECLAIM TIMER INITIATION

The **tReclaim** Extend setting allows you to control whether the timer is suspended from the protection start contacts or not. When a setting of 'No Operation' is used, the reclaim timer operates from the instant the CB is closed and will continue until the timer expires. The **Reclaim Time** must therefore be set in excess of the time-delayed protection operating time, to ensure that the protection can operate before the Autoreclose function is reset.

For certain applications it is advantageous to set **tReclaim Extend** to 'On Prot Start'. This facility allows the operation of the reclaim timer to be suspended after CB re-closure by a signal from the main protection start or SEF protection start signals. This feature ensures that the reclaim time cannot time out and reset the Autoreclose before the time delayed protection has operated.

Since the reclaim timer will be suspended, it is unnecessary to use a timer setting in excess of the protection operating time, therefore a short reclaim time can be used. Short reclaim time settings can help to prevent unnecessary lockout for a succession of transient faults in a short period, for example during a thunderstorm.

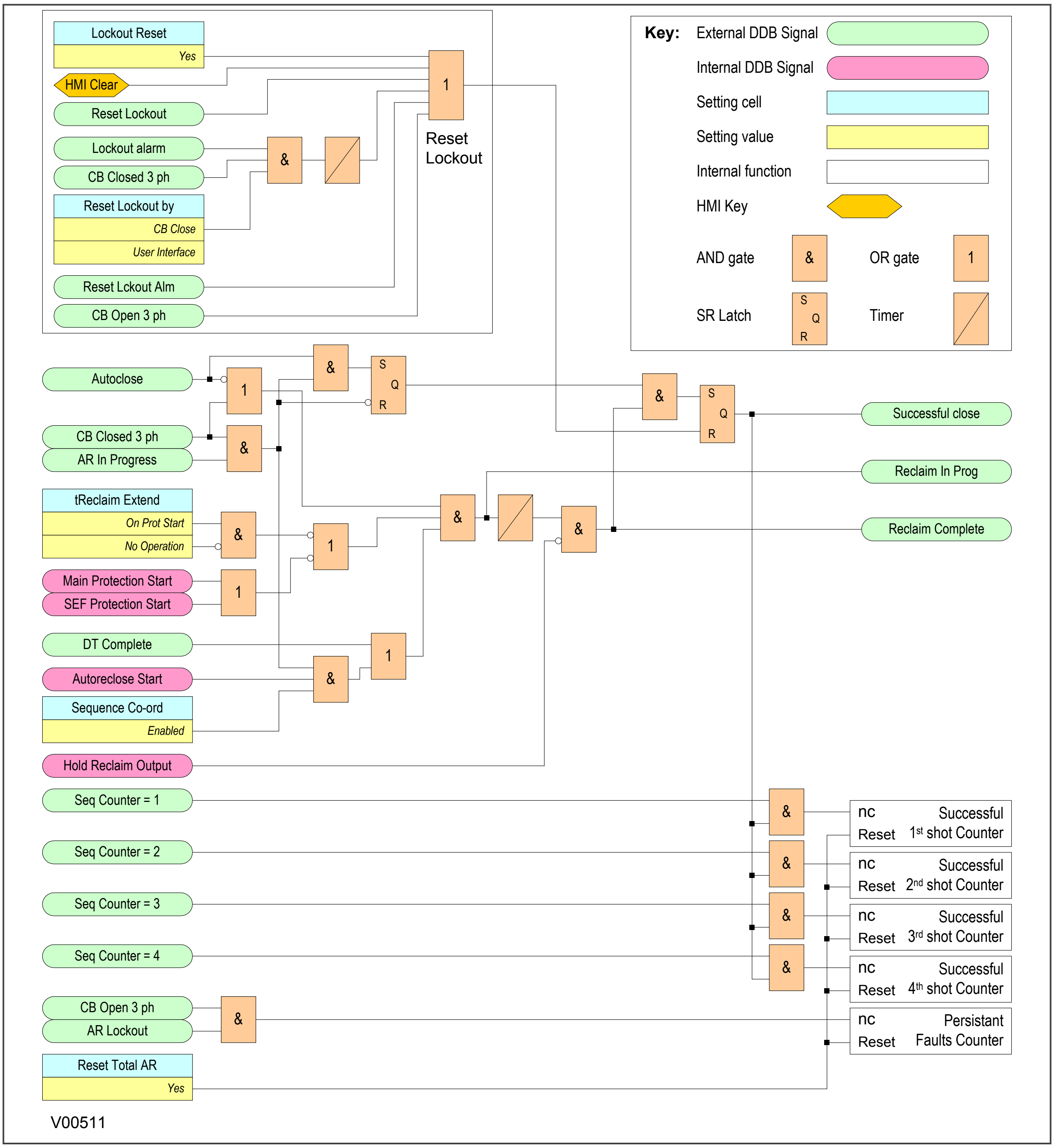


Figure 102: Reclaim Time logic

7.8 AUTORECLOSE INHIBIT

To ensure that autoreclosing is not initiated for a manual CB closure on to a pre-existing fault (switch on to fault), the **AR on Man Close** setting can be set to Inhibited. With this setting, Autoreclose initiation is inhibited for a period equal to setting **AR Inhibit Time** following a manual CB closure. The logic for AR Inhibit is as follows:

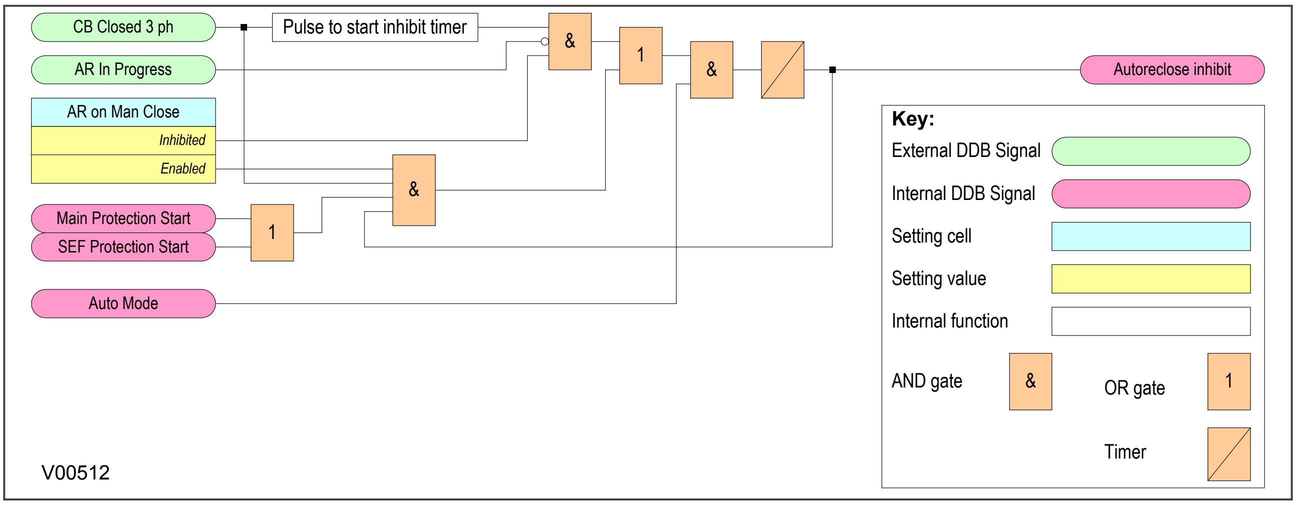


Figure 103: AR Initiation inhibit

If a protection operation occurs during the inhibit period, Autoreclose is not initiated. A further option is provided by setting **Man Close on Flt**. If this is set to 'Lockout', Autoreclose is locked out (**AR Lockout**) for a fault during the inhibit period following manual CB closure. If **Man Close on Flt** is set to 'No Lockout, the CB trips without reclosure, but Autoreclose is not locked out.

You may need to block selected fast non-discriminating protection in order to obtain fully discriminative tripping during the AR initiation inhibit period following CB manual close. You can do this by setting **Manual Close** to 'Block Inst Prot'. A 'No Block setting will enable all protection elements immediately on CB closure.

If setting **AR on Man Close** is set to 'Enabled, Autoreclose can be initiated immediately on CB closure, and settings **AR Inhibit Time**, **Man Close on Flt** and **Manual Close** are irrelevant.

7.9 AUTORECLOSE LOCKOUT

If protection operates during the reclaim time following the final reclose attempt, the IED is driven to lockout and the Autoreclose function is disabled until the lockout condition is reset. This produces the alarm, **AR Lockout**. The **Block AR** input blocks Autoreclose and causes a lockout if Autoreclose is in progress.

Autoreclose lockout can also be caused by the CB failing to close due to an unhealthy circuit breaker (CB springs not charged or low gas pressure) or if there is no synchronisation between the system voltages. These two conditions are indicated by the alarms **CB Unhealthy** and **AR No Check Sync**. This is shown in the AR Lockout logic diagram as follows:

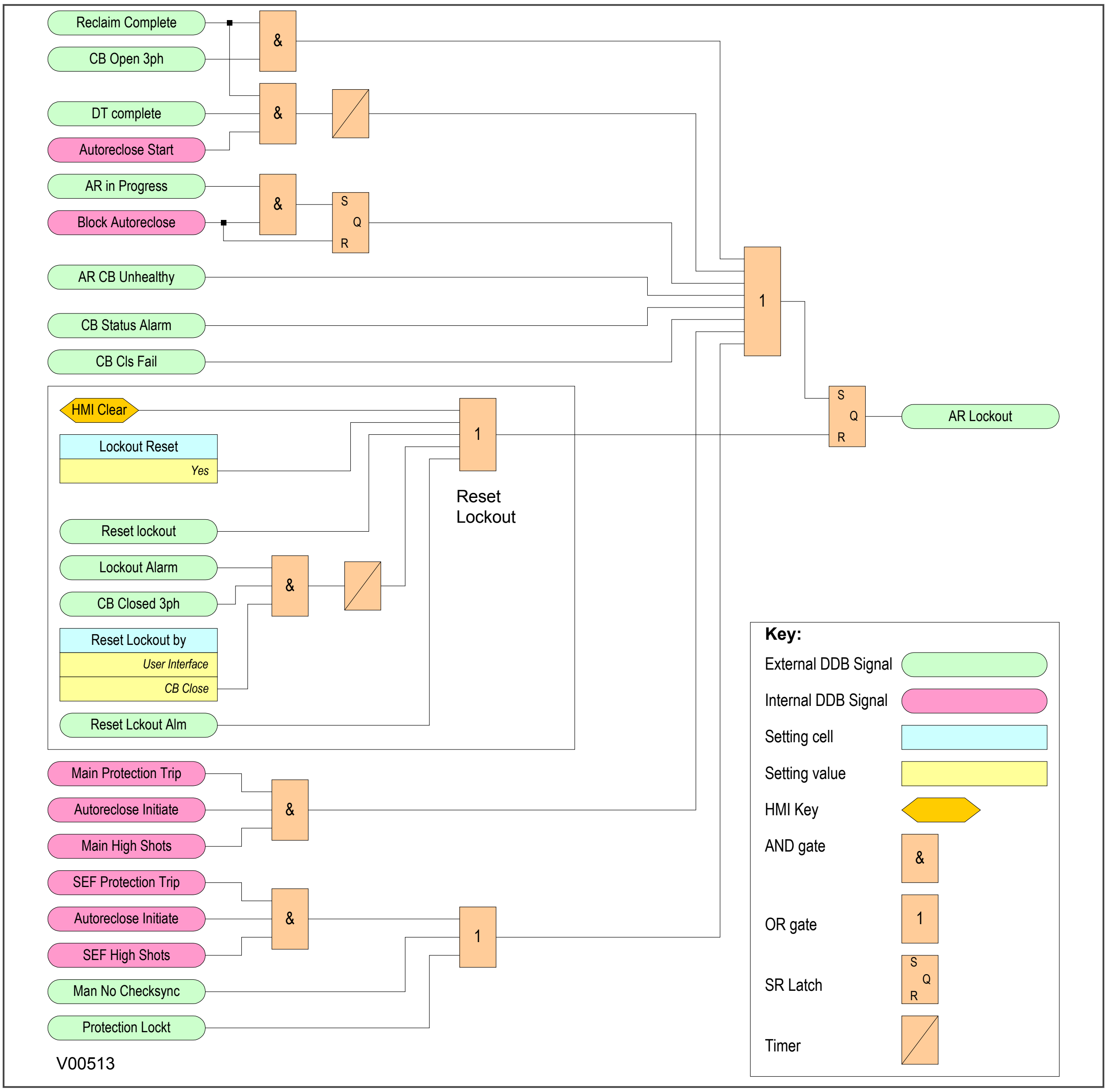


Figure 104: Overall Lockout logic

AR lockout may also be due to a protection operation when the IED is in the Live Line or Non-auto modes when the setting **Trip AR Inactive** is set to 'Lockout'. Autoreclose lockout can also be caused by a protection operation after manual closing during the **AR Inhibit Time** when the **Manual Close on Flt** setting is set to 'Lockout'. This is shown as follows:

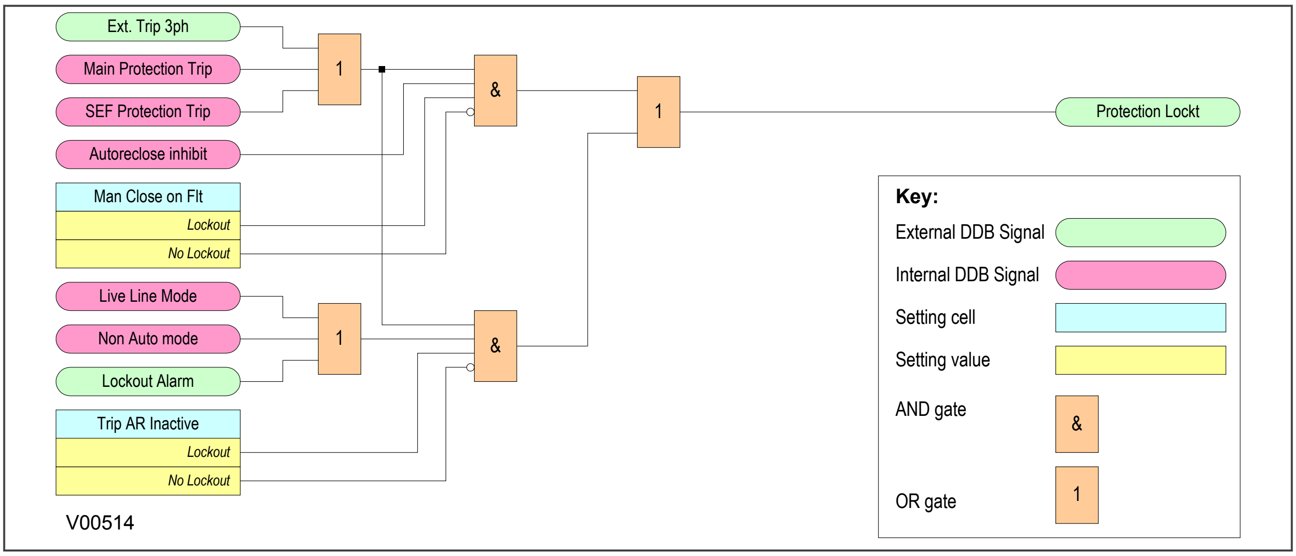


Figure 105: Lockout for protection trip when AR is not available

> *Note:*
> *Lockout can also be caused by the CB condition monitoring functions in the CB MONITOR SETUP column.*

The **Reset Lockout** input can be used to reset the Autoreclose function following lockout and reset any Autoreclose alarms, provided that the signals that initiated the lockout have been removed. Lockout can also be reset from the clear key or the command **Lockout Reset** from the CB CONTROL column.

There are two different **Reset Lockout by** settings. One in the CB CONTROL column and one in the AUTORECLOSE column.

The **Reset Lockout by** setting in the CB CONTROL column is used to enable or disable reset of lockout automatically from a manual close after the manual close time **Man Close Rst Dly**.

The **Reset Lockout by** setting in the AUTORECLOSE column is used to enable/disable the resetting of lockout when the IED is in the Non-auto operating mode. The reset lockout methods are summarised in the following table:

Reset Lockout Method	When Available?
User Interface via the Clear key. Note: This will also reset all other protection flags	Always
User interface via CB CONTROL command Lockout Reset	Always
Opto-input Reset lockout	Always
Following a successful manual close if CB CONTROL setting Reset Lockout by is set to 'CB Close'	Only when set
By selecting Non-Auto mode, provided AUTORECLOSE setting Reset Lockout by is set to 'Select NonAuto'	Only when set

7.10 SEQUENCE CO-ORDINATION

The **Sequence Co-ord** setting in the AUTORECLOSE menu allows sequence co-ordination with other protection devices, such as downstream pole-mounted reclosers.

The main protection start or SEF protection start signals indicate when fault current is present, advance the sequence count by one and start the dead time, whether the CB is open or closed. When the dead time is complete and the protection start inputs are low, the reclaim timer is initiated.

You should program both the upstream and downstream Autoreclose IEDs with the same number of shots to lockout and number of instantaneous trips before instantaneous protection is blocked. This will ensure that for a persistent downstream fault, both Autoreclose IEDs will be on the same sequence count and will block instantaneous protection at the same time. When sequence co-ordination is disabled, the circuit breaker has to be tripped to start the dead time, and the sequence count is advanced by one.

When using sequence co-ordination for some applications such as downstream pole-mounted reclosers, it may be desirable to re-enable instantaneous protection when the recloser has locked out. When the downstream recloser has locked out there is no need for discrimination. This allows you to have instantaneous, then IDMT, then instantaneous trips again during an Autoreclose cycle. Instantaneous protection may be blocked or not blocked for each trip in an Autoreclose cycle using the **Trip (n) Main** and **Trip (n) SEF** settings, where n is the number of the trip in the autoreclose cycle.

7.11 SYSTEM CHECKS FOR FIRST RECLOSE

The **Sys Chk on Shot 1** setting in the SYSTEM CHECKS sub menu of the AUTORECLOSE column is used to enable or disable system checks for the first reclose attempt in an Autoreclose cycle. This may be preferred when high speed Autoreclose is applied, to avoid the extra time for a synchronism check. Subsequent reclose attempts in a multi-shot cycle will, however, still require a synchronism check.

8 DDB SIGNALS

Ordinal	Signal Name	Source	Type	Response
Description				
163	AR Lockout	Software	PSL Input	Alarm self reset event
This DDB signal indicates that the AR did not result in successful reclosure and locks out further reclose attempts				
164	AR CB Unhealthy	Software	PSL Input	Alarm latched event
The scheme has waited for the "CB HEALTHY" signal for the HEALTHY WINDOW time.				
165	AR No Sys Check	Software	PSL Input	Alarm latched event
The scheme has waited for the "SYSTEM OK TO CLOSE" input for the SYSTEM CHECK WINDOW time				
230	CB Healthy	Programmable Scheme Logic	PSL Output	No response
This DDB signal indicates that the CB is healthy.				
237	Reset Lockout	Programmable Scheme Logic	PSL Output	No response
This DDB Resets a lockout condition				
239	Block AR	Programmable Scheme Logic	PSL Output	No response
This DDB signal blocks the Autoreclose function				
240	AR LiveLine Mode	Programmable Scheme Logic	PSL Output	No response
This DB indicates that the autoreclose function is in Live Line mode				
241	AR Auto Mode	Programmable Scheme Logic	PSL Output	No response
This DB indicates that the autoreclose function is in Auto mode				
242	Telecontrol Mode	Programmable Scheme Logic	PSL Output	No response
This DB indicates that the autoreclose function is in Telecontrol mode				
358	AR Blk Main Prot	Software	PSL Input	Protection event
This DDB signal, generated by the Autoreclose function, blocks the Main Protection elements (POC, EF1, EF2, NPSOC)				
359	AR Blk SEF Prot	Software	PSL Input	Protection event
This DDB signal, generated by the Autoreclose function, blocks the SEF Protection element (POC, EF1, EF2, NPSOC)				
360	AR In Progress	Software	PSL Input	Protection event
This DDB signal indicates that three-pole Autoreclose is in progress				
361	AR In Service	Software	PSL Input	Protection event
This DDB signal indicates that Autoreclose is in or out of service (auto, or non-auto mode)				
362	AR SeqCounter 0	Software	PSL Input	No response
This DDB signal indicates that the AR has not been initiated				
363	AR SeqCounter 1	Software	PSL Input	Protection event
This DDB signal indicates that the AR function is in its first shot				
364	AR SeqCounter 2	Software	PSL Input	Protection event
This DDB signal indicates that the AR function is in its second shot				
365	AR SeqCounter 3	Software	PSL Input	Protection event
This DDB signal indicates that the AR function is in its third shot				
366	AR SeqCounter 4	Software	PSL Input	Protection event
This DDB signal indicates that the AR function is in its fourth shot				
367	Successful Close	Software	PSL Input	Protection event
This DDB signal indicates a successful reclosure				
368	DeadTime in Prog	Software	PSL Input	Protection event
This DDB signal indicates that the Autoreclose dead time is in progress				

Ordinal	Signal Name	Source	Type	Response
Description				
369	Protection Lockt	Software	PSL Input	Protection event
This DB signal locks out the Autoreclose function				
370	Reset Lckout Alm	Software	PSL Input	Protection event
This DDB signal indicates that a lockout has been reset.				
371	Auto Close	Software	PSL Input	Protection event
This DDB signal tells the CB to close, originating from Autoreclose only. This DDB signal has a fixed reset time.				
372	AR Trip Test	Software	PSL Input	Protection event
This DDB signal is used to test the Autoreclose function trip test				
403	AR Sys Checks	Programmable Scheme Logic	PSL Output	No response
This DDB signal tells the the Autoreclose that the system checks are satisfied.				
439	Ext AR Prot Trip	Programmable Scheme Logic	PSL Output	No response
This DDB can initiate an Autoreclose sequence from an external trip				
440	Ext AR Prot Strt	Programmable Scheme Logic	PSL Output	No response
This DDB informs the Autoreclose function of an external start				
453	DAR Complete	Programmable Scheme Logic	PSL Output	No response
This DDB signal resets the AR in Progress 1 signal				
454	CB in Service	Programmable Scheme Logic	PSL Output	No response
This DDB signal indicates that the Circuit Breaker is in service				
455	AR Restart	Programmable Scheme Logic	PSL Output	No response
This DDB signal triggers a Restart of the Autoreclose initiation process				
456	DAR In Progress	Software	PSL Input	No response
This DDB signal indicates that delayed Auto-Reclose is in progress				
457	DeadTime Enabled	Programmable Scheme Logic	PSL Output	No response
This DDB signal enables the Dead Time timers				
458	DT OK To Start	Programmable Scheme Logic	PSL Output	No response
This DDB signal tells the AR that it is OK to start the Autoreclose Dead Timer.				
459	DT Complete	Software	PSL Input	No response
This DDB signal indicates that the Autoreclose Dead Time is complete				
460	Reclose Checks	Software	PSL Input	No response
This DDB signal indicates that Autoreclose system checks are in progress				
461	LiveDead Ccts OK	Programmable Scheme Logic	PSL Output	No response
This DDB informs the AR function that there is a Live/Dead circuit condition				
462	AR Sync Check	Software	PSL Input	No response
This DDB signal indicates that the Autoreclose Synchronisation Check is OK				
463	AR SysChecks OK	Software	PSL Input	No response
This DDB signal indicates that the Autoreclose System Checks are is OK				
464	AR Init TripTest	Programmable Scheme Logic	PSL Output	No response
This DDB signal initiates an Autoreclose trip test.				
530	AR Skip Shot 1	Programmable Scheme Logic	PSL Output	No response
This DDB signal forces the Autoreclose function to skip shot 1 of a reclose sequence.				
532	Inh Reclaim Time	Programmable Scheme Logic	PSL Output	No response
This DDB signal inhibits the Autoreclose Reclaim Timer				

Ordinal	Signal Name	Source	Type	Response
Description				
533	Reclaim In Prog	Software	PSL Input	No response
This DDB signal indicates that the Autoreclose Reclaim Time is in progress				
534	Reclaim Complete	Software	PSL Input	No response
This DDB signal indicates that the Autoreclose Reclaim Time is complete				

9 SETTINGS

Menu Text	Col	Row	Default Setting	Available Options
Description				
GROUP 1 AUTORECLOSE	49	00		
This column contains settings for Autoreclose (AR)				
AR Mode Select	49	01	Command Mode	0=Command Mode 1=Opto Set Mode 2=User Set Mode 3=Pulse Set Mode
This setting determines the Autoreclose mode.				
Number of Shots	49	02	1	From 1 to 4 step 1
This setting sets the required number of autoreclose cycles for Overcurrent trips.				
Number SEF Shots	49	03	0	From 0 to 4 step 1
This setting sets the number of required autoreclose cycles for SEF trips.				
Sequence Co-ord	49	04	Disabled	0 = Disabled or 1 = Enabled
This setting enables the sequence co-ordination function to ensure the correct protection grading between an upstream and downstream re-closing device.				
CS AR Immediate	49	05	Disabled	0 = Disabled or 1 = Enabled
This setting allows immediate re-closure of the circuit breaker provided both sides of the circuit breaker are live and in synchronism at any time after the dead time has started.				
Dead Time 1	49	06	10	From 0.01s to 300s step 0.01s
This setting sets the dead time for the first autoreclose cycle.				
Dead Time 2	49	07	60	From 0.01s to 300s step 0.01s
This setting sets the dead time for the second autoreclose cycle.				
Dead Time 3	49	08	180	From 0.01s to 9999s step 0.01s
This setting sets the dead time for the third autoreclose cycle.				
Dead Time 4	49	09	180	From 0.01s to 9999s step 0.01s
This setting sets the dead time for the fourth autoreclose cycle.				
CB Healthy Time	49	0A	5	From 0.01s to 9999s step 0.01s
This setting defines the CB lockout time				
Start Dead t On	49	0B	Protection Reset	0=Protection Reset 1=CB Trips
This setting determines whether the dead time has started when the circuit breaker trips or when the protection trip resets.				
tReclaim Extend	49	0C	No Operation	0=On Prot Start 1=No Operation
This setting allows the user to control whether the reclaim timer is suspended by the protection start contacts or not (i.e. whether the IED is permitted to reclaim if a fault condition is present and will be cleared in a long time-scale).				
Reclaim Time 1	49	0D	180	From 1s to 600s step 0.01s
Sets the autoreclose reclaim time for the first autoreclose cycle.				
Reclaim Time 2	49	0E	180	From 1s to 600s step 0.01s
Sets the autoreclose reclaim time for the second autoreclose cycle.				
Reclaim Time 3	49	0F	180	From 1s to 600s step 0.01s
Sets the autoreclose reclaim time for the third autoreclose cycle.				
Reclaim Time 4	49	10	180	From 1s to 600s step 0.01s

Menu Text	Col	Row	Default Setting	Available Options
Description				
Sets the autoreclose reclaim time for the fourth autoreclose cycle.				
AR Inhibit Time	49	11	5	From 0.01s to 600s step 0.01s
This setting defines the inhibit time before Autoreclose is initiated following a manual CB closure.				
AR Lockout	49	12	No Block	0=No Block 1=Block Inst Prot
This setting is used to block instantaneous protection if the IED has undergone Autoreclose Lockout.				
EFF Maint Lock	49	13	No Block	0=No Block 1=Block Inst Prot
This setting is used to block instantaneous protection for the last circuit breaker trip before lockout occurs.				
AR Deselected	49	14	No Block	0=No Block 1=Block Inst Prot
This setting allows the instantaneous protection to be blocked when autoreclose is in non-auto mode of operation.				
Manual Close	49	15	No Block	0=No Block 1=Block Inst Prot
This setting is used to block instantaneous protection when the circuit breaker is closed manually whilst there is no auto-reclose sequence in progress or autoreclose is inhibited.				
Trip 1 Main	49	16	No Block	0=No Block 1=Block Inst Prot
The Trip (n) Main settings are used to selectively block the instantaneous elements of phase and earth fault protection elements for a circuit breaker trip sequence.				
Trip 2 Main	49	17	Block Inst Prot	0=No Block 1=Block Inst Prot
The Trip (n) Main settings are used to selectively block the instantaneous elements of phase and earth fault protection elements for a circuit breaker trip sequence.				
Trip 3 Main	49	18	Block Inst Prot	0=No Block 1=Block Inst Prot
The Trip (n) Main settings are used to selectively block the instantaneous elements of phase and earth fault protection elements for a circuit breaker trip sequence.				
Trip 4 Main	49	19	Block Inst Prot	0=No Block 1=Block Inst Prot
The Trip (n) Main settings are used to selectively block the instantaneous elements of phase and earth fault protection elements for a circuit breaker trip sequence.				
Trip 5 Main	49	1A	Block Inst Prot	0=No Block 1=Block Inst Prot
The Trip (n) Main settings are used to selectively block the instantaneous elements of phase and earth fault protection elements for a circuit breaker trip sequence.				
Trip 1 SEF	49	1B	Block Inst Prot	0=No Block 1=Block Inst Prot
The Trip (n) SEF settings are used to selectively block the instantaneous elements of sensitive earth fault protection elements for a circuit breaker trip sequence.				
Trip 2 SEF	49	1C	Block Inst Prot	0=No Block 1=Block Inst Prot
The Trip (n) SEF settings are used to selectively block the instantaneous elements of sensitive earth fault protection elements for a circuit breaker trip sequence.				
Trip 3 SEF	49	1D	Block Inst Prot	0=No Block 1=Block Inst Prot
The Trip (n) SEF settings are used to selectively block the instantaneous elements of sensitive earth fault protection elements for a circuit breaker trip sequence.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
Trip 4 SEF	49	1E	Block Inst Prot	0=No Block 1=Block Inst Prot
The Trip (n) SEF settings are used to selectively block the instantaneous elements of sensitive earth fault protection elements for a circuit breaker trip sequence.				
Trip 5 SEF	49	1F	Block Inst Prot	0=No Block 1=Block Inst Prot
The Trip (n) SEF settings are used to selectively block the instantaneous elements of sensitive earth fault protection elements for a circuit breaker trip sequence.				
Man Close on Flt	49	20	Lockout	0=No Lockout 1=Lockout
This setting decides whether the the AR should lockout or not after a Manual Close on Fault operation.				
Trip AR Inactive	49	21	No Lockout	0=No Lockout 1=Lockout
When AR is inactive (Non-auto, or Live Line mode), this setting determines whether The AR should be locked out or not.				
Reset Lockout by	49	22	User Interface	0=User Interface 1=Select NonAuto
This setting is used to determine the method by which the Lockout is reset.				
AR on Man Close	49	24	Inhibited	0=Enabled 1=Inhibited
If this is set to 'Enabled', autoreclosing can be initiated immediately on circuit breaker closure, overriding the settings AR Inhibit Time, Man Close on Flt and Manual Close.				
Sys Check Time	49	25	5	From 0.01s to 9999s step 0.01s
This setting sets the amount of time set for System Checks for Autoreclose operation.				
AR Skip Shot 1	49	26	Disabled	0 = Disabled or 1 = Enabled
When enabled this setting allows the autoreclose sequence counter to be incremented by one via a DDB input signal. This will therefore decrease the number of available re-close shots.				
AR INITIATION	49	28		
The settings under this sub-heading relate to Autoreclose initiation				
I>1 AR	49	29	Initiate Main AR	0=No Action 1=Initiate Main AR
This setting determines impact of the first stage overcurrent protection on AR operation.				
I>2 AR	49	2A	Initiate Main AR	0=No Action 1=Initiate Main AR
This setting determines impact of the second stage overcurrent protection on AR operation.				
I>3 AR	49	2B	Initiate Main AR	0=No Action 1=Initiate Main AR 2=Block AR
This setting determines impact of the third stage overcurrent protection on AR operation.				
I>4 AR	49	2C	Initiate Main AR	0=No Action 1=Initiate Main AR 2=Block AR
This setting determines impact of the fourth stage overcurrent protection on AR operation.				
IN1>1 AR	49	2D	Initiate Main AR	0=No Action 1=Initiate Main AR
This setting determines impact of the first stage measured earth fault overcurrent protection on AR operation.				
IN1>2 AR	49	2E	Initiate Main AR	0=No Action 1=Initiate Main AR
This setting determines impact of the second stage measured earth fault overcurrent protection on AR operation.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
IN1>3 AR	49	2F	Initiate Main AR	0=No Action 1=Initiate Main AR 2=Block AR
This setting determines impact of the third stage measured earth fault overcurrent protection on AR operation.				
IN1>4 AR	49	30	Initiate Main AR	0=No Action 1=Initiate Main AR 2=Block AR
This setting determines impact of the fourth stage measured earth fault overcurrent protection on AR operation.				
IN2>1 AR	49	31	No Action	0=No Action 1=Initiate Main AR
This setting determines impact of the first stage derived earth fault overcurrent protection on AR operation.				
IN2>2 AR	49	32	No Action	0=No Action 1=Initiate Main AR
This setting determines impact of the second stage derived earth fault overcurrent protection on AR operation.				
IN2>3 AR	49	33	No Action	0=No Action 1=Initiate Main AR 2=Block AR
This setting determines impact of the third stage derived earth fault overcurrent protection on AR operation.				
IN2>4 AR	49	34	No Action	0=No Action 1=Initiate Main AR 2=Block AR
This setting determines impact of the fourth stage derived earth fault overcurrent protection on AR operation.				
ISEF>1 AR	49	35	No Action	0=No Action 1=Initiate Main AR 2=Initiate SEF AR 3=Block AR
This setting determines impact of the first stage sensitive earth fault overcurrent protection on AR operation.				
ISEF>2 AR	49	36	No Action	0=No Action 1=Initiate Main AR 2=Initiate SEF AR 3=Block AR
This setting determines impact of the second stage sensitive earth fault overcurrent protection on AR operation.				
ISEF>3 AR	49	37	No Action	0=No Action 1=Initiate Main AR 2=Initiate SEF AR 3=Block AR
This setting determines impact of the third stage sensitive earth fault overcurrent protection on AR operation.				
ISEF>4 AR	49	38	No Action	0=No Action 1=Initiate Main AR 2=Initiate SEF AR 3=Block AR
This setting determines impact of the fourth stage sensitive earth fault overcurrent protection on AR operation.				
Ext Prot	49	3C	No Action	0=No Action 1=Initiate Main AR
This setting determines if external protection inputs initiates auto-reclose. This must be mapped in programmable scheme logic.				
I>5 AR	49	3D	Initiate Main AR	0=No Action 1=Initiate Main AR
This setting determines impact of the fifth stage overcurrent protection on AR operation.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
I>6 AR	49	3E	Initiate Main AR	0=No Action 1=Initiate Main AR 2=Block AR
This setting determines impact of the sixth stage overcurrent protection on AR operation.				
SYSTEM CHECKS	49	40		
The settings under this sub-heading relate to Autoreclose system checks				
AR with ChkSyn	49	41	Disabled	0 = Disabled or 1 = Enabled
This setting enables/disables autoreclose with check synchronisation for Check Sync stage 1 (CS1)				
AR with SysSyn	49	42	Disabled	0 = Disabled or 1 = Enabled
This setting enables/disables autoreclose with check synchronisation for Check Sync stage 2 (CS2)				
Live/Dead Ccts	49	43	Disabled	0 = Disabled or 1 = Enabled
When enabled, this setting will produce an "AR Check Ok" DDB signal when the Live/Dead Ccts DDB signal is high.				
No System Checks	49	44	Enabled	0 = Disabled or 1 = Enabled
When enabled this setting completely disables system checks thus allowing autoreclose initiation without system checks.				
SysChk on Shot 1	49	45	Enabled	0 = Disabled or 1 = Enabled
This setting is used to enable/disable system checks for the first auto-reclose shot.				

10 SETTING GUIDELINES

10.1 NUMBER OF SHOTS

There are no clear cut rules for defining the number of shots for a particular application. Generally medium voltage systems use only two or three shot Autoreclose schemes. However, in certain countries, for specific applications, a four-shot scheme is not uncommon. A four-shot scheme has the advantage that the final dead time can be set sufficiently long to allow any thunderstorms to pass before reclosing for the final time. This arrangement prevents unnecessary lockout for consecutive transient faults.

Typically, the first trip, and sometimes the second, will result from instantaneous protection. Since most faults are transient, the subsequent trips will be time delayed, all with increasing dead times to clear semi-permanent faults.

An important consideration is the ability of the circuit breaker to perform several trip-close operations in quick succession and the affect of these operations on the circuit maintenance period.

On EHV transmission circuits with high fault levels, only one re-closure is normally applied, because of the damage that could be caused by multiple re-closures.

10.2 DEAD TIMER SETTING

The choice of dead time is dependent on the system. The main factors that can influence the choice of dead time are:

- Stability and synchronism requirements
- Operational convenience
- Load
- The type of circuit breaker
- Fault deionising time
- The protection reset time

10.2.1 STABILITY AND SYNCHRONISM REQUIREMENTS

It may be that the power transfer level on a specific feeder is such that the systems at either end of the feeder could quickly fall out of synchronism if the feeder is opened. If this is the case, it is usually necessary to reclose the feeder as quickly as possible to prevent loss of synchronism. This is called high speed autoreclosing (HSAR). In this situation, the dead time setting should be adjusted to the minimum time necessary. This time setting should comply with the minimum dead time limitations imposed by the circuit breaker and associated protection, which should be enough to allow complete deionisation of the fault path and restoration of the full voltage withstand level. Typical HSAR dead time values are between 0.3 and 0.5 seconds.

On a closely interconnected transmission system, where alternative power transfer paths usually hold the overall system in synchronism even when a specific feeder opens, or on a radial supply system where there are no stability implications, it is often preferred to leave a feeder open for a few seconds after fault clearance. This allows the system to stabilise, and reduces the shock to the system on re-closure. This is called slow or delayed auto-reclosing (DAR). The dead time setting for DAR is usually selected for operational convenience.

10.2.2 OPERATIONAL CONVENIENCE

When HSAR is not required, the dead time chosen for the first re-closure following a fault trip is not critical. It should be long enough to allow any resulting transients resulting to decay, but not so long as to cause major inconvenience to consumers who are affected by the loss of the feeder. The setting chosen often depends on service experience with the specific feeder.

Typical first shot dead time settings on 11 kV distribution systems are 5 to 10 seconds. In situations where two parallel circuits from one substation are carried on the same towers, it is often arranged for the dead times on the two circuits to be staggered, e.g. one at 5 seconds and the other at 10 seconds, so that the two circuit breakers do not reclose simultaneously following a fault affecting both circuits.

For multi-shot Autoreclose cycles, the second and subsequent shot dead times are usually longer than the first shot, to allow time for semi-permanent faults to burn clear, and for the CB to recharge. Typical second and third shot dead time settings are 30 seconds and 60 seconds respectively.

10.2.3 LOAD REQUIREMENTS

Some types of electrical load might have specific requirements for minimum and/or maximum dead time, to prevent damage and minimise disruption. For example, synchronous motors are only capable of tolerating extremely short supply interruptions without losing synchronism. In practise it is desirable to disconnect the motor from the supply in the event of a fault; the dead time would normally be sufficient to allow a controlled shutdown. Induction motors, on the other hand, can withstand supply interruptions up to typically 0.5 seconds and re-accelerate successfully.

10.2.4 CIRCUIT BREAKER

For HSAR, the minimum dead time of the power system will depend on the minimum time delays imposed by the circuit breaker during a tripping and reclose operation.

After tripping, time must be allowed for the mechanism to reset before applying a closing pulse, otherwise the circuit breaker might fail to close correctly. This resetting time will vary depending on the circuit breaker, but is typically 0.1 seconds.

Once the mechanism has reset, a CB Close signal can be applied. The time interval between energising the closing mechanism and making the contacts is called the closing time. A solenoid closing mechanism may take up to 0.3 seconds. A spring-operated breaker, on the other hand, can close in less than 0.1 seconds.

Where HSAR is required, for the majority of medium voltage applications, the circuit breaker mechanism reset time itself dictates the minimum dead time. This would be the mechanism reset time plus the CB closing time. A solenoid mechanism is not suitable for high speed Autoreclose as the closing time is generally too long.

For most circuit breakers, after one re-closure, it is necessary to recharge the closing mechanism energy source before a further re-closure can take place. Therefore the dead time for second and subsequent shots in a multi-shot sequence must be set longer than the spring or gas pressure recharge time.

10.2.5 FAULT DEIONISATION TIME

For HSAR, the fault deionising time may be the most important factor when considering the dead time. This is the time required for ionised air to disperse around the fault position so that the insulation level of the air is restored. You cannot accurately predict this, but you can obtain an approximation from the following formula:

Deionising time = (10.5 + ((system voltage in kV)/34.5))/frequency

Examples:

At 66 kV 50 Hz, the deionising time is approximately 0.25 s

At 132 kV 60 Hz, the deionising time is approximately 0.29 s

10.2.6 PROTECTION RESET TIME

It is essential that any time-graded protection fully resets during the dead time, so that correct time discrimination will be maintained after reclosing on to a fault. For HSAR, instantaneous reset of protection is required. However at distribution level, where the protection is predominantly made up of overcurrent and earth fault devices, the protection reset time may not be instantaneous. In the event that the circuit breaker recloses on to a fault and the protection has not fully reset, discrimination may be lost with the downstream protection. To avoid this condition the dead time must be set in excess of the slowest reset time of either the local device or any downstream protection.

Typical 11/33 kV dead time settings in the UK are as follows:

1st dead time = 5 - 10 seconds

2nd dead time = 30 seconds

3rd dead time = 60 - 180 seconds

4th dead time = 1 - 30 minutes

> *Note:*
> *A 4th dead time is uncommon in the UK, however this may be common in other countries such as South Africa.*

10.3 RECLAIM TIMER SETTING

A number of factors influence the choice of the reclaim timer:

- Supply continuity: Large reclaim times can result in unnecessary lockout for transient faults.
- Fault incidence/Past experience: Small reclaim times may be required where there is a high incidence of lightning strikes to prevent unnecessary lockout for transient faults.
- Spring charging time: For HSAR the reclaim time may be set longer than the spring charging time to ensure there is sufficient energy in the circuit breaker to perform a trip-close-trip cycle. For delayed Autoreclose there is no need as the dead time can be extended by an extra CB healthy check window time if there is insufficient energy in the CB. If there is insufficient energy after the check window time the IED will lockout.
- Switchgear maintenance: Excessive operation resulting from short reclaim times can mean shorter maintenance periods. A minimum reclaim time of more than 5 seconds may be needed to allow the circuit breaker time to recover after a trip and close before it can perform another trip-close-trip cycle. This time will depend on the circuit breaker's duty rating.

The reclaim time must be long enough to allow any time-delayed protection initiating Autoreclose to operate. Failure to do so would result in premature resetting of the Autoreclose scheme and re-enabling of instantaneous protection. If this condition arose, a permanent fault would effectively look like a number of transient faults, resulting in continuous autoreclosing, unless additional measures are taken such as excessive fault frequency lockout protection.

Sensitive earth fault protection is applied to detect high resistance earth faults and usually has a long time delay, typically 10 - 15 seconds. This longer time may have to be taken into consideration, if autoreclosing from SEF protection. High resistance earth faults are rarely transient and may be a danger to the public. It is therefore common practise to block Autoreclose by operation of sensitive earth fault protection and lockout the circuit breaker.

A typical 11/33 kV reclaim time in the UK is 5 - 10 seconds. This prevents unnecessary lockout during thunderstorms. However, reclaim times of up to 60 - 180 seconds may be used elsewhere in the world.

MONITORING AND CONTROL

CHAPTER 9

1 CHAPTER OVERVIEW

As well as providing a range of protection functions, the product includes comprehensive monitoring and control functionality.

This chapter contains the following sections:

2 RECORDS

The IED logs three different types of record. These are Event, Fault and Maintenance records, which are stored in the IED's non-volatile memory. It is important to log records because this allows you to establish the sequence of events that occurred, for example following a particular power system condition.

The device is capable of storing up to:

- 2048 event records
- 10 Fault records
- 10 maintenance records

When the available space is exhausted, the oldest record is automatically overwritten by the new one. The IED's internal clock provides a time tag for each event, to a resolution of 1 ms.

The VIEW RECORDS column contains details of these Event, Fault and Maintenance records, which can be displayed on the IED's front panel, although it is far easier to view them using the settings application software.

2.1 EVENT RECORDS

Event records are generated when certain events happen. A change in any digital input signal or protection element output signal causes an event record to be created. These events are generated by the protection software and immediately time stamped. They are then transferred to non-volatile memory for storage. In extreme cases, it is possible for the buffer to overflow under avalanche conditions. If this occurs, a maintenance record is generated to indicate this loss of information.

You can control which events cause an event record to be logged in the RECORD CONTROL column. The following table provides details of this control for all event types.

Menu Text	Col	Row	Default Setting	Available Options
Description				
RECORD CONTROL	0B	00		
This column contains settings for Record Controls.				
Alarm Event	0B	04	Enabled	0 = Disabled or 1 = Enabled
This setting enables or disables the generation of an event on alarm. Disabling this setting means that no event is generated for alarms.				
Relay O/P Event	0B	05	Enabled	0 = Disabled or 1 = Enabled
This setting enables or disables the generation of an event for a change of state of output relay contact. Disabling this setting means that no event will be generated for any change in logic output state.				
Opto Input Event	0B	06	Enabled	0 = Disabled or 1 = Enabled
This setting enables or disables the generation of an event for a change of state of opto-input. Disabling this setting means that no event will be generated for any change in logic input state.				
General Event	0B	07	Enabled	0 = Disabled or 1 = Enabled
This setting enables or disables the generation of general events. Disabling this setting means that no general events are generated.				
Fault Rec Event	0B	08	Enabled	0 = Disabled or 1 = Enabled
This setting enables or disables the generation of fault record events. Disabling this setting means that no event will be generated for any fault that produces a fault record.				
Maint Rec Event	0B	09	Enabled	0 = Disabled or 1 = Enabled
This setting enables or disables the generation of maintenance record events. Disabling this setting means that no event will be generated for any occurrence that produces a maintenance record.				
Protection Event	0B	0A	Enabled	0 = Disabled or 1 = Enabled
This setting enables or disables the generation of protection events. Disabling this setting means that any operation of protection elements will not be logged as an event.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
DDB 31 - 0	0B	40	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 63 - 32	0B	41	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 95 - 64	0B	42	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 127 - 96	0B	43	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 159 - 128	0B	44	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 191 - 160	0B	45	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 223 - 192	0B	46	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 255 - 224	0B	47	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 287 - 256	0B	48	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 319 - 288	0B	49	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 351 - 320	0B	4A	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 383 - 352	0B	4B	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				

Menu Text	Col	Row	Default Setting	Available Options
Description				
DDB 415 - 384	0B	4C	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 447 - 416	0B	4D	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 479 - 448	0B	4E	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 511 - 480	0B	4F	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 543 - 512	0B	50	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 575 - 544	0B	51	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 607 - 576	0B	52	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 639 - 608	0B	53	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 671 - 640	0B	54	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 703 - 672	0B	55	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 735 - 704	0B	56	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 767 - 736	0B	57	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				

Menu Text	Col	Row	Default Setting	Available Options
Description				
DDB 799 - 768	0B	58	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 831 - 800	0B	59	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 863 - 832	0B	5A	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 895 - 864	0B	5B	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 927 - 896	0B	5C	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 959 - 928	0B	5D	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 991 - 960	0B	5E	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 1023 - 992	0B	5F	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 1055 - 1024	0B	60	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 1087 - 1056	0B	61	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 1119 - 1088	0B	62	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 1151 - 1120	0B	63	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				

Menu Text	Col	Row	Default Setting	Available Options
Description				
DDB 1183 - 1152	0B	64	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 1215 - 1184	0B	65	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 1247 - 1216	0B	66	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 1279 - 1248	0B	67	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 1311 - 1280	0B	68	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 1343 - 1312	0B	69	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 1375 - 1344	0B	6A	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 1407 - 1376	0B	6B	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 1439 - 1408	0B	6C	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 1471 - 1440	0B	6D	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 1503 - 1472	0B	6E	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 1535 - 1504	0B	6F	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				

Menu Text	Col	Row	Default Setting	Available Options
Description				
DDB 1567 - 1536	0B	70	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 1599 - 1568	0B	71	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 1631 - 1600	0B	72	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 1663 - 1632	0B	73	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 1695 - 1664	0B	74	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 1727 - 1696	0B	75	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 1759- 1728	0B	76	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 1791- 1760	0B	77	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 1823 - 1792	0B	78	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 1855 - 1824	0B	79	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 1887 - 1856	0B	7A	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 1919 - 1888	0B	7B	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				

Menu Text	Col	Row	Default Setting	Available Options
Description				
DDB 1951 - 1920	0B	7C	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 1983 - 1952	0B	7D	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 2015 - 1984	0B	7E	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				
DDB 2047 - 2016	0B	7F	0xFFFFFFFF	32-bit binary flag (data type G27) 1 = event recording Enabled 0 = event recording Disabled
These signals can be included or excluded from being stored as a Courier event record (assuming the DDB is capable of creating an event)				

You can view the event records using the settings application software or with the front panel HMI. You select the event to be viewed on the LCD with the Select Event cell in the VIEW RECORDS column. A value of '0' corresponds to the latest event, '1' the next latest and so on. The following subsequent cells display details pertaining to the chosen event. Not all cells are relevant in all cases. The cells displayed depend on the type of event.

- **Menu Cell Ref**: indicates the event type
- **Time & Date**: indicates the time and date the event occurred
- **Record Text**: displays the event description (2 lines of 16 characters)
- **Record Value**: displays a 32 bit binary number representing the event
- **Evt Iface Source**: displays the interface on which the event was logged
- **Evt Access Level**: records the access level of the interface that initiated the event. This access level is displayed in this cell.
- **Evt Extra Info**: provides supporting information for the event and can vary between the different event types.
- **Evt Unique ID**: displays the unique event ID associated with the event.
- **Reset indication**: resets the trip LED indications provided that the relevant protection element has reset.

2.2 EVENT TYPES

There are several different types of event:

- Opto-input events (Change of state of opto-input)
- Contact events (Change of state of output relay contact)
- Alarm events
- Protection events (starts and trips)
- Fault record notifications
- Maintenance report notifications
- Security Events
- Platform Events

2.2.1 OPTO-INPUT EVENTS

If one or more of the opto-inputs has changed state since the last time the protection algorithm ran, the new logical state is logged as an event. Details of the event are displayed in the VIEW RECORDS column.

A Time and Date stamp is always associated with the event in question and this is always displayed first.

The event type description shown in the **Record Text** cell for this type of event is always 'Logic Inputs #' where # is the batch number of the opto-inputs. This is '1', for the first batch of 32 opto-inputs and '2' for the second batch of 32 opto-inputs (if applicable).

The event value shown in the **Record Value** cell for this type of event is a binary string of data type G8 depicting their logical states, whereby the LSB (on the right) corresponds to the first opto-input.

The same information is also shown in the **Opto I/P Status** cell in the SYSTEM DATA column.

2.2.2 CONTACT EVENTS

If one or more of the output relays has changed state since the last time the protection algorithm ran, the new logical state is logged as an event. Details of the event are displayed in the VIEW RECORDS column,

A Time and Date stamp is always associated with the event in question and this is always displayed first

The event type description shown in the **Record Text** cell for this type of event is always 'Output Contacts #' where # is the batch number of the relay output contacts. This is '1', for the first batch of 32 output contacts and '2' for the second batch of 32 output contacts (if applicable).

The event value shown in the **Record Value** cell for this type of event is a binary string of data type G9 depicting their logical states, whereby the LSB (on the right) corresponds to the first output contact.

The same information is also shown in the **Relay O/P Status** cell in the SYSTEM DATA column.

2.2.3 ALARM EVENTS

The IED logs any alarm conditions it generates as individual events. Details of the event are displayed in the VIEW RECORDS column.

A Time and Date stamp is always associated with the event in question and this is always displayed first

The event type description shown in the **Record Text** cell for this type of event is dependent on the alarm type of which there are many. These are defined in data types G96-1, G96-2 and G228 as shown below:

The same information is also shown in the **Alarm Status 1**, **Alarm Status 2** and **Alarm Status 3** cells in the SYSTEM DATA column.

Note:
Alarm Status 1 is duplicated in cells 22 and 50.

The event value is not shown in the **Record Value** cell for this type of event. It is intended for use by the extraction software.

Data Type G96-1: Product Alarm Status 1

Bit Number	Event Text	Description
Bit 1	Product Alarm Status 1 (2 Registers)	Unused
Bit 2	Unused	Unused
Bit 3	Unused	Setting group via opto invalid
Bit 4	SG-opto Invalid ON/OFF	Protection Disabled
Bit 5	Prot'n Disabled ON/OFF	Frequency out of range
Bit 6	F out of Range ON/OFF	VTS Alarm

Bit Number	Event Text	Description
Bit 7	VT Fail Alarm ON/OFF	CTS Alarm
Bit 8	CT Fail Alarm ON/OFF	CB Trip Fail Protection
Bit 9	CB Fail Alarm ON/OFF	Broken current Maintenance Alarm
Bit 10	I^ Maint Alarm ON/OFF	Broken current Lockout Alarm
Bit 11	I^ Lockout Alarm ON/OFF	No of CB Ops Maintenance Alarm
Bit 12	CB Ops Maint ON/OFF	No of CB Ops Lockout Alarm
Bit 13	CB Ops Lockout ON/OFF	CB Op Time Maintenance Alarm
Bit 14	CB Op Time Maint ON/OFF	CB Op Time Lockout Alarm
Bit 15	CB Op Time Lock ON/OFF	Excessive Fault Frequency Lockout Alarm
Bit 16	Fault Freq Lock ON/OFF	CB Status Alarm
Bit 17	CB Status Alarm ON/OFF	CB Fail Trip Control
Bit 18	Man CB Trip Fail ON/OFF	CB Fail Close Control
Bit 19	Man CB Cls Fail ON/OFF	No Healthy Control Close
Bit 20	Man CB Unhealthy ON/OFF	No C/S control close
Bit 21	Man No Checksync ON/OFF	A/R Lockout
Bit 22	A/R Lockout ON/OFF	A/R CB Not healthy
Bit 23	A/R CB Unhealthy ON/OFF	A/R No Checksync
Bit 24	A/R No Checksync ON/OFF	System Split
Bit 25	System Split ON/OFF	UV Block
Bit 26	UV Block ON/OFF	User Definable Alarm 1 (Self Reset)
Bit 27	SR User Alarm 1 ON/OFF	User Definable Alarm 2 (Self Reset)
Bit 28	SR User Alarm 2 ON/OFF	User Definable Alarm 3 (Self Reset)
Bit 29	SR User Alarm 3 ON/OFF	User Definable Alarm 4 (Self Reset)
Bit 30	SR User Alarm 4 ON/OFF	User Definable Alarm 5 (Self Reset)
Bit 31	SR User Alarm 5 ON/OFF	User Definable Alarm 6 (Self Reset)
Bit 32	SR User Alarm 6 ON/OFF	User Definable Alarm 7 (Self Reset)

Data Type G96-2: Product Alarm Status 2

Bit Number	Event Text	Description
Bit 1	Unused	Unused
Bit 2	Unused	Unused
Bit 3	Unused	Unused
Bit 4	Unused	Unused
Bit 5	SR User Alarm 8 ON/OFF	User Definable Alarm 8 (Self Reset)
Bit 6	SR User Alarm 9 ON/OFF	User Definable Alarm 9 (Self Reset)
Bit 7	SR User Alarm 10 ON/OFF	User Definable Alarm 10 (Self Reset)
Bit 8	SR User Alarm 11 ON/OFF	User Definable Alarm 11 (Self Reset)
Bit 9	SR User Alarm 12 ON/OFF	User Definable Alarm 12 (Self Reset)
Bit 10	SR User Alarm 13 ON/OFF	User Definable Alarm 13 (Self Reset)
Bit 11	SR User Alarm 14 ON/OFF	User Definable Alarm 14 (Self Reset)
Bit 12	SR User Alarm 15 ON/OFF	User Definable Alarm 15 (Self Reset)
Bit 13	SR User Alarm 16 ON/OFF	User Definable Alarm 16 (Self Reset)
Bit 14	SR User Alarm 17 ON/OFF	User Definable Alarm 17 (Self Reset)

Bit Number	Event Text	Description
Bit 15	MR User Alarm 18 ON/OFF	User Definable Alarm 18 (Latched)
Bit 16	MR User Alarm 19 ON/OFF	User Definable Alarm 19 (Latched)
Bit 17	MR User Alarm 20 ON/OFF	User Definable Alarm 20 (Latched)
Bit 18	MR User Alarm 21 ON/OFF	User Definable Alarm 21 (Latched)
Bit 19	MR User Alarm 22 ON/OFF	User Definable Alarm 22 (Latched)
Bit 20	MR User Alarm 23 ON/OFF	User Definable Alarm 23 (Latched)
Bit 21	MR User Alarm 24 ON/OFF	User Definable Alarm 24 (Latched)
Bit 22	MR User Alarm 25 ON/OFF	User Definable Alarm 25 (Latched)
Bit 23	MR User Alarm 26 ON/OFF	User Definable Alarm 26 (Latched)
Bit 24	MR User Alarm 27 ON/OFF	User Definable Alarm 27 (Latched)
Bit 25	MR User Alarm 28 ON/OFF	User Definable Alarm 28 (Latched)
Bit 26	MR User Alarm 29 ON/OFF	User Definable Alarm 29 (Latched)
Bit 27	MR User Alarm 30 ON/OFF	User Definable Alarm 30 (Latched)
Bit 28	MR User Alarm 31 ON/OFF	User Definable Alarm 31 (Latched)
Bit 29	MR User Alarm 32 ON/OFF	User Definable Alarm 32 (Latched)
Bit 30	MR User Alarm 33 ON/OFF	User Definable Alarm 33 (Latched)
Bit 31	MR User Alarm 34 ON/OFF	User Definable Alarm 34 (Latched)
Bit 32	MR User Alarm 35 ON/OFF	User Definable Alarm 35 (Latched)

Data Type G228: Product Alarm Status 3

Bit Number	Event Text	Description
Bit 1	Unused	Unused
Bit 2	Unused	Unused
Bit 3	Unused	Unused
Bit 4	GOOSE IED Absent	GOOSE IED Absent
Bit 5	NIC Not Fitted	NIC Not Fitted
Bit 6	NIC No Response	NIC No Response
Bit 7	NIC Fatal Error	NIC Fatal Error
Bit 8	Unused	Unused
Bit 9	Bad TCP/IP Cfg.	Bad TCP/IP Cfg.
Bit 10	Unused	Unused
Bit 11	NIC Link Fail	NIC Link Fail
Bit 12	NIC SW Mis-Match	NIC SW Mis-Match
Bit 13	IP Addr Conflict	IP Addr Conflict
Bit 14	Unused	Unused
Bit 15	Unused	Unused
Bit 16	Unused	Unused
Bit 17	Unused	Unused
Bit 18	Unused	Unused
Bit 19	Bad DNP Settings	Bad DNP Settings
Bit 20	Unused	Unused
Bit 21	Unused	Unused
Bit 22	Unused	Unused

Bit Number	Event Text	Description
Bit 23	Unused	Unused
Bit 24	Unused	Unused
Bit 25	Unused	Unused
Bit 26	Unused	Unused
Bit 27	Unused	Unused
Bit 28	Unused	Unused
Bit 29	Unused	Unused
Bit 30	Unused	Unused
Bit 31	Unused	Unused
Bit 32	Unused	Unused

2.2.4 PROTECTION EVENTS

The IED logs protection starts and trips as individual events. Details of the event are displayed in the VIEW RECORDS column.

A Time and Date stamp is always associated with the event in question and this is always displayed first.

The event type description shown in the **Record Text** cell for this type of event is dependent on the protection event that occurred. Each time a protection event occurs, a DDB signal changes state. It is the name of this DDB signal followed by 'ON' or 'OFF' that appears in the **Record Text** cell.

The event value is not shown in the **Record Value** cell for this type of event. It is intended for use by the extraction software. However, the binary strings can be viewed in the COMMISSION TESTS column in the relevant DDB batch cells.

2.2.5 FAULT RECORD EVENTS

An event record is created each time a fault record is generated. This event record is different from the Fault Record itself. The event record simply states that a fault record was generated, but contains no details of the fault.

Details of the event are displayed in the VIEW RECORDS column.

A Time and Date stamp is always associated with the event in question and this is always displayed first.

The event type description shown in the **Record Text** cell for this type of event is just 'Fault Record'.

2.2.6 MAINTENANCE EVENTS

Internal failures detected by the self-monitoring circuitry are logged as maintenance records. An event record is created each time this happens. Details of the event are displayed in the VIEW RECORDS column.

A Time and Date stamp is always associated with the event in question and this is always displayed first

The event type description shown in the **Record Text** cell for this type of event is always 'Maint Recorded.'

The Record Value cell also provides a unique binary code, which should be noted.

2.2.7 SECURITY EVENTS

An event record is generated each time a setting is executed, which requires an access level.

A Time and Date stamp is always associated with the event in question and this is always displayed first.

The event type description shown in the **Record Text** cell displays the type of change. These are as follows:

Event Value	Event Text	Description
0	User Logged In	A user has logged in
1	User Logged Out	A user has logged out
2	P/Word Set Blank	A blank password has been set
3	P/Word Not NERC	The password is not NERC compliant
4	Password Changed	The password has changed
5	Password Blocked	The password has been blocked
6	P/Word Unblocked	The password has been unblocked
7	P/W Ent When Blk	The password has been entered while it is blocked
8	Inval PW Entered	An invalid password has been entered
9	P/Word Timed Out	The password has timed out
10	Rcvy P/W Entered	The recovery password has been entered
11	IED Sec Code Rd	The IED security code has been read
12	IED Sec Code Exp	The IED security code timer has expired
13	Port Disabled	A port has been disabled
14	Port Enabled	A port has been enabled
15	Def Dsp Not NERC	The default display is not NERC compliant
16	PSL Stng D/Load	PSL settings have been downloaded to the IED
17	DNP Stng D/Load	DNP settings have been downloaded to the IED
18	Trace Dat D/Load	Trace Data has been downloaded to the IED
19	IED Confg D/Load	A configuration file has been downloaded to the IED
20	User Crv D/Load	A user curve has been downloaded to the IED
21	Setng Grp D/Load	A settings group has been downloaded to the IED
22	DR Settng D/Load	A Disturbance Recorder setting has been downloaded to the IED
23	PSL Stng Upload	PSL settings have been uploaded from the IED
24	DNP Stng Upload	DNP settings have been uploaded from the IED
25	Trace Dat Upload	Trace Data has been uploaded from the IED
26	IED Confg Upload	A configuration file has been uploaded from the IED
27	User Crv Upload	A user curve has been uploaded from the IED
28	PSL Confg Upload	A PSL configuration has been uploaded from the IED
29	Settings Upload	Settings have been uploaded from the IED
30	Events Extracted	Events have been extracted
31	Actv. Grp Desel. By "Interface"	The active group has been deselected by an interface
32	Actv. Grp Select By "Interface"	The active group has been selected by an interface
33	Actv. Grp Desel. By Opto	The active group has been deselected by a digital input
34	Actv. Grp Select By Opto	The active group has been selected by a digital input
35	C & S Changed	A control and support setting has changed
36	DR Changed	A Disturbance Recorder setting has changed
37	Settings Changed	Settings have been changed
38	Def Set Restored	The default setting has been restored
39	Def Crv Restored	The default curve has been restored
40	Power On	The power has been switched on
41	App Downloaded	An application has been downloaded to the IED
42	IRIG-B Set None	IRIG-B interface has been set to "None"

Event Value	Event Text	Description
43	IRIG-B Set Port1	IRIG-B interface has been set to "RP1"
44	IRIG-B Set Port2	IRIG-B interface has been set to "RP2"

2.2.8 PLATFORM EVENTS

There is a group of events that come under the classification "General Events".

A Time and Date stamp is always associated with the event in question and this is always displayed first.

The event type description shown in the **Record Text** cell displays the type of change. These are as follows:

Event Value	Event Text	Description
0	Alarms Cleared	The alarm log has been cleared
1	Events Cleared	The events log has been cleared
2	Faults Cleared	The fault log has been cleared
3	Maint Cleared	The maintenance log has been cleared
4	IRIG-B Active	IRIG-B is active
5	IRIG-B Inactive	IRIG-B is inactive
6	Time Synch	The time has been synchronised
7	Indication Reset	The LED indications have been reset
14	NIC Link Fail	The Network Interface Card has failed
15	Dist Rec Cleared	The disturbance records have been cleared
16	IO Upgrade OK	The I/O has been upgraded successfully

2.3 FAULT RECORDS

A fault record is triggered by the **Fault REC TRIG** signal DDB, which is assigned in the PSL. If there are any fault records, these will appear automatically in the VIEW RECORDS column. You can select the fault record in the **Select Fault** cell in the VIEW RECORDS column. A value of '0' corresponds to the latest fault record. Information about the fault follows in the subsequent cells. The time stamp assigned to the fault record itself is more accurate than the corresponding stamp of the event record, because the event is logged some time after the actual fault record is generated. The fault measurements in the fault record are given at the time of the protection Start. The fault recorder does not stop recording until the Start or Trip resets.

Note:
We recommend that you set the triggering contact to ‘self reset’ and not 'latching'. This is because if you use a latching contact, the fault record would not be generated until the contact has been fully reset.

2.4 MAINTENANCE RECORDS

Internal failures detected by the self-monitoring circuitry, such as watchdog failure are logged as maintenance records. If there are any maintenance records, these will appear automatically in the VIEW RECORDS column. You can select the maintenance record in the **Select Maint** cell in the VIEW RECORDS column. A value of '0' corresponds to the latest maintenance record. The subsequent cells **Maint Text**, **Maint Type**, and **Maint Data** display details pertaining to the chosen maintenance record, whereby:

Maint Text: displays a description of the maintenance record

Maint Type: indicates the type of maintenance record

Event Value	Event Text	Description
6	FPGA Health Err	There is a Field Programmable Gate Array error

Event Value	Event Text	Description
7	IO Card Error	There is an I/O card error
9	Code Verify Fail	There is a code verification failure
14	Software Failure	There is a general software failure
15	H/W Verify Fail	There is a hardware verification failure
16	Non Standard	There is a non-standard error
17	Ana. Sample Fail	There is a failure with the analogue signal sampling
18	NIC Soft Error	There is a Network Interface Card error
22	PSL Latch Reset	A PSL latch has been reset
23	Control IP Reset	A control input has been reset
24	Fn Keys Reset	A function key has been reset
25	SR Gates Reset	An SR gate has been reset
26	System Error	There is a system error
27	Solicited Reboot	The device has ben requested to reboot.
28	Unrec'ble Error	There is an unrecoverable internal error. The device will reboot after the maintenance record has been created
29	Lockout Request	A lockout has been requested. This is generated whenever maintenance access is gained through the USB port
30	IO Upgrade Fail	There has been an I/O upgrade failure. This can be caused by a faulty I/O card, or the boot loader enable bit on the micro-controller being disabled.
31	Application Fail	An application has failed
32	System Restart	Not used
33	Unknown Error	There is an unknown error
34	FPGA Failure	The Field Programmable Gate Array has failed
35	Upgrade Mode Req	Upgrade mode has been requested. This is generated whenever maintenance access is gained through the USB port
36	Invalid MAC Addr	The device has an invalid MAC address

Maint Data: displays the error code of the maintenance record

The maintenance records are as follows:

2.5 VIEW RECORDS COLUMN

Menu Text	Col	Row	Default Setting	Available Options
Description				
VIEW RECORDS	01	00		
This column contains information about records. Most of these cells are not editable.				
Select Event [0...n]	01	01	0	From 0 to 2048 step 1
This setting selects the required event record. A value of 0 corresponds to the latest event, 1 the second latest and so on.				
Menu Cell Ref	01	02	(From Record)	<Event type>
This cell indicates the type of event				
Time & Date	01	03	(From Record)	<Date and time of the event>
This cell shows the Time & Date of the event, given by the internal Real Time Clock.				
Record Text	01	04		Not Settable
This cell shows the description of the event - up to 32 Characters over 2 lines.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
Record Value	01	05		Not Settable
This cell displays a 32 bit binary Flag representing the event.				
Select Fault [0...n]	01	06	0	From 0 to 9 step 1
This setting selects the required fault record from those stored. A value of 0 corresponds to the latest fault and so on.				
Faulted Phase	01	07		<Faulted phase>
This cell displays the faulted phase.				
Start Elements 1	01	08		<Start signal status>
This cell displays the status of the first set of 32 start signals.				
Start Elements 2	01	09		<Start signal status>
This cell displays the status of the second set of 32 start signals.				
Start Elements 3	01	0A		<Start signal status>
This cell displays the status of the third set of 32 start signals.				
Start Elements 4	01	0B		<Start signal status>
This cell displays the status of the fourth set of 32 start signals.				
Trip Elements 1	01	0C		<Start signal status>
This cell displays the status of the first set of 32 trip signals.				
Trip Elements 2	01	0D		<Start signal status>
This cell displays the status of the second set of 32 trip signals.				
Trip Elements 3	01	0E		<Start signal status>
This cell displays the status of the third set of 32 trip signals.				
Trip Elements 4	01	0F		<Start signal status>
This cell displays the status of the fourth set of 32 trip signals.				
Fault Alarms	01	10		<Faultt alarm signal status>
This cell displays the status of the fault alarm signals.				
Fault Time	01	11		<Fault date and time>
This cell displays the time and date of the fault				
Active Group	01	12		<Active settings group>
This cell displays the active settings group				
System Frequency	01	13		<System frequency>
This cell displays the system frequency				
Fault Duration	01	14		<Fault duration>
This cell displays the duration of the fault time				
CB Operate Time	01	15		<CB operate time>
This cell displays the CB operate time				
IED Trip Time	01	16		<Trip time>
This cell displays the time from protection start to protection trip				
Fault Location	01	17		<Fault location in metres>
This cell displays the fault location in metres.				
Fault Location	01	18		<Fault location in miles>
This cell displays the fault location in miles.				
Fault Location	01	19		<Fault location in ohms>
This cell displays the fault location in ohms.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
Fault Location	01	1A		<Fault location in percentage>
This cell displays the fault location in percentage.				
IA	01	1B		<IA>
This cell displays the phase A current				
IB	01	1C		<IB>
This cell displays the phase B current				
IC	01	1D		<IC>
This cell displays the phase C current				
VAB	01	1E		<VAB>
This cell displays VA with respect to VB				
VBC	01	1F		<VBC>
This cell displays VB with respect to VC				
VCA	01	20		<VCA>
This cell displays VC with respect to VA				
IN Measured	01	21		<IN Measured>
This cell displays the value of measured neutral current				
IN Derived	01	22		<IN Derived>
This cell displays the value of derived neutral current				
IN Sensitive	01	23		<IN Sensitive>
This cell displays the value of sensitive neutral current				
IREF Diff	01	24		<IREF Diff>
This cell displays the value of Restricted Earth Fault differential current				
IREF Bias	01	25		<IREF Bias>
This cell displays the value of Restricted Earth Fault bias current				
VAN	01	26		<VAN>
This cell displays VA with respect to Neutral				
VBN	01	27		<VBN>
This cell displays VB with respect to Neutral				
VCN	01	28		<VCN>
This cell displays VC with respect to Neutral				
VN Derived	01	29		Not Settable
This cell displays the derived Earth fault voltage				
VN Measured	01	29		Not Settable
This cell displays the measured Earth fault voltage				
DC Supply Mag	01	30		Not Settable
This cell displays the Auxiliary Supply Voltage level				
Select Maint [0...n]	01	F0	Manual override to select a fault record.	From 0 to 9 step 1
This setting selects the required maintenance report from those stored. A value of 0 corresponds to the latest report.				
Maint Text	01	F1		<Maintenance record description>
This cell displays the description of the maintenance record				
Maint Type	01	F2		Not Settable
This is the type of maintenance record				

Menu Text	Col	Row	Default Setting	Available Options
Description				
Maint Data	01	F3		Not Settable
This is the maintenance record data (error code)				
Evt Iface Source	01	FA		<Interface source of the event>
This cell displays the interface on which the event was logged				
Evt Access Level	01	FB		<Event access level>
Any security event that indicates that it came from an interface action, such as disabling a port, will also record the access level of the interface that initiated the event. This access level is displayed in this cell.				
Evt Extra Info	01	FC		<Extra event information>
This cell provides supporting information for the event and can vary between the different event types.				
Evt Unique Id	01	FE		<Event ID>
This cell displays the unique event ID associated with the event.				
Reset Indication	01	FF	No	0=No 1=Yes
This command resets the trip LED indications provided that the relevant protection element has reset.				

3 DISTURBANCE RECORDER

The disturbance recorder can record the waveforms of the calibrated analogue channels, plus the values of the digital signals. The disturbance recorder is supplied with data once per cycle, and collates the received data into a disturbance record. The disturbance records can be extracted using application software or the SCADA system, which can also store the data in COMTRADE format, allowing the use of other packages to view the recorded data.

The integral disturbance recorder has an area of memory specifically set aside for storing disturbance records. The number of records that can be stored is dependent on the recording duration. The maximum total recording time is 94.5 seconds, whereby the minimum duration is 0.1 s and the maximum duration is 10.5 s.

When the available memory is exhausted, the oldest records are overwritten by the newest ones.

The disturbance recorder stores the samples that are taken at a rate of 24 samples per cycle.

Each disturbance record consists of 8 analogue data channels and 32 digital data channels. The relevant CT and VT ratios for the analogue channels are also extracted to enable scaling to primary quantities.

Note:
If a CT ratio is set less than unity, the device will choose a scaling factor of zero for the appropriate channel.

The DISTURBANCE RECORDER menu column is summarised in the following table:

Menu Text	Col	Row	Default Setting	Available Options
Description				
DISTURB RECORDER	0C	00		
This column contains settings for the Disturbance Recorder				
Duration	0C	01	1.5	0.1s to 10.5s step 0.01s
This setting sets the overall recording time.				
Trigger Position	0C	02	33.3	0 to 100 step 0.1
This setting sets the trigger point as a percentage of the duration. For example, the default setting, which is set to 33.3% (of 1.5s) gives 0.5s pre-fault and 1s post fault recording times.				
Trigger Mode	0C	03	Single	0 = Single or 1 = Extended
When set to single mode, if a further trigger occurs whilst a recording is taking place, the recorder will ignore the trigger. However, if this has been set to Extended, the post trigger timer will be reset to zero, thereby extending the recording time.				
Analog Channel 1 to 9	0C	04 to 0C	VA	0=VA 1=VB 2=VC 3=V Checksync or VN 4=IA 5=IB 6=IC 7=IN-ISEF 8=Frequency 9=Unused
This setting selects any available analogue input to be assigned to this channel.				
Digital Input 1 to 32	0C	0D to 4B (even)	Relay 1	See Data Types - G32
The digital channels may monitor any of the opto-inputs, output relay contacts and other internal digital signals, such as protection starts, LEDs etc. This setting assigns the digital channel to any one of these.				
Input 1 to 32 Trigger	0C	0E to 4C (odd)	No Trigger	0 = No Trigger, 1 = Trigger L/H, 2 = Trigger H/L
This setting defines whether the digital input is triggered and if so, the trigger polarity (low to high or high to low).				

The fault recording times are set by a combination of the **Duration** and **Trigger Position** cells. The **Duration** cell sets the overall recording time and the **Trigger Position** cell sets the trigger point as a percentage of the duration. For example, the default settings show that the overall recording time is set to 1.5 s with the trigger point being at 33.3% of this, giving 0.5 s pre-fault and 1 s post fault recording times.

With the **Trigger Mode** set to 'Single', if further triggers occurs whilst a recording is taking place, the recorder will ignore the trigger. However, with the **Trigger Mode** set to 'Extended', the post trigger timer will be reset to zero, thereby extending the recording time.

You can select any of the IED's analogue inputs as analogue channels to be recorded. You can also map any of the opto-inputs output contacts to the digital channels. In addition, you may also map a number of internal DDB signals such as Starts and LEDs to digital channels.

You may choose any of the digital channels to trigger the disturbance recorder on either a low to high or a high to low transition, via the **Input Trigger** cell. The default settings are such that any dedicated trip output contacts will trigger the recorder.

It is not possible to view the disturbance records locally via the front panel LCD. You must extract these using suitable software such as MiCOM S1 Agile.

4 MEASUREMENTS

4.1 MEASURED QUANTITIES

The device measures directly and calculates a number of system quantities, which are updated every second. You can view these values in the MEASUREMENTS columns or with the MiCOM S1 Agile Measurement Viewer. Depending on the model, the device may measure and display some or more of the following quantities:

- Measured currents and calculated sequence and RMS currents
- Measured voltages and calculated sequence and RMS voltages
- Power and energy quantities
- Peak, fixed and rolling demand values
- Frequency measurements
- Others measurements

4.1.1 MEASURED AND CALCULATED CURRENTS

The device measures phase-to-phase and phase-to-neutral current values. The values are produced by sampling the analogue input quantities, converting them to digital quantities and using special algorithms to present the magnitude and phase values. Sequence quantities are produced by processing the measured values. These are also displayed as magnitude and phase angle values. RMS phase voltage and current values are calculated using the sum of the samples squared over a cycle of sampled data

These measurements are contained in the MEASUREMENTS 1 column.

4.1.2 MEASURED AND CALCULATED VOLTAGES

The device measures phase-to-phase and phase-to-neutral voltage values. The values are produced by sampling the analogue input quantities, converting them to digital quantities and using special algorithms to present the magnitude and phase values. Sequence quantities are produced by processing the measured values. These are also displayed as magnitude and phase angle values. RMS phase voltage and current values are calculated using the sum of the samples squared over a cycle of sampled data.

These measurements are contained in the MEASUREMENTS 1 column.

4.1.3 POWER AND ENERGY QUANTITIES

Using the measured voltages and currents the device calculates the apparent, real and reactive power quantities. These are produced on a phase by phase basis together with three-phase values based on the sum of the three individual phase values. The signing of the real and reactive power measurements can be controlled using the measurement mode setting. The four options are defined in the table below:

Measurement Mode	Parameter	Signing
0 (Default)	Export Power Import Power Lagging Vars Leading VArs	+ – + –
1	Export Power Import Power Lagging Vars Leading VArs	– + + –
2	Export Power Import Power Lagging Vars Leading VArs	+ – – +

Measurement Mode	Parameter	Signing
3	Export Power Import Power Lagging Vars Leading VArs	– + – +

The device also calculates the per-phase and three-phase power factors.

These power values are also used to increment the total real and reactive energy measurements. Separate energy measurements are maintained for the total exported and imported energy. The energy measurements are incremented up to maximum values of 1000 GWhr or 1000 GVARhr at which point they will reset to zero, it is also possible to reset these values using the menu or remote interfaces using the **R**eset demand cell.

These measurements are contained in the MEASUREMENTS 2 column.

4.1.4 DEMAND VALUES

The device produces fixed, rolling and peak demand values. It is possible to reset these quantities using the **Reset demand** cell.

The fixed demand value is the average value of a quantity over the specified interval. Values are produced for each phase current and for three phase real and reactive power. The fixed demand values displayed are those for the previous interval. The values are updated at the end of the fixed demand period.

The rolling demand values are similar to the fixed demand values, the difference being that a sliding window is used. The rolling demand window consists of a number of smaller sub-periods. The resolution of the sliding window is the sub-period length, with the displayed values being updated at the end of each of the sub-periods.

Peak demand values are produced for each phase current and the real and reactive power quantities. These display the maximum value of the measured quantity since the last reset of the demand values.

These measurements are contained in the MEASUREMENTS 2 column.

4.1.5 FREQUENCY MEASUREMENTS

The device produces a range of frequency statistics and measurements relating to the Frequency Protection function. These include Check synchronisation and Slip frequency measurements found in the MEASUREMENTS 1 column, Rate of Change of Frequency measurements found in the MEASUREMENTS 3 column, and Frequency Protection statistics found in the FREQ STAT column.

The device produces the slip frequency measurement by measuring the rate of change of phase angle between the bus and line voltages, over a one-cycle period. The slip frequency measurement assumes the bus voltage to be the reference phasor.

4.1.6 OTHER MEASUREMENTS

Depending on the model, the device produces a range of other measurements such as 2nd harmonic, thermal, SEF power, impedance and additional frequency measurements.

These measurements are contained in the MEASUREMENTS 3 column.

4.2 MEASUREMENT SETUP

You can define the way measurements are set up and displayed using the MEASURE'T SETUP column, as shown below:

Menu Text	Col	Row	Default Setting	Available Options
Description				
MEASURE'T SETUP	0D	00		
This column contains settings for the measurement setup				
Default Display	0D	01	User Banner	0 = User Banner, 1 = 3Ph + N Current, 2 = 3Ph Voltage, 3 = Power, 4 = Date and Time, 5 = Description, 6 = Plant Reference, 7 = Frequency, 8 = Access Level 9 = DC Supply Mag
This setting is used to select the default display from a range of options.				
Local Values	0D	02	Primary	0 = Primary or 1 = Secondary
This setting controls whether local measured values (via HMI or front port) are displayed as primary or secondary quantities.				
Remote Values	0D	03	Primary	0 = Primary or 1 = Secondary
This setting controls whether remote measured values (via rear comms ports) are displayed as primary or secondary quantities.				
Measurement Ref	0D	04	VA	0 = VA, 1 = VB, 2 = VC, 3 = IA, 4 = IB, 5 = IC
This setting sets the phase reference for all angular measurements (for Measurements 1 only).				
Measurement Mode	0D	05	0	from 0 to 3 in steps of 1
This setting is used to control the signing of the real and reactive power quantities.				
Fix Dem Period	0D	06	30	From 1m to 99m step 1m
This setting defines the length of the fixed demand window in minutes				
Roll Sub Period	0D	07	30	From 1m to 99m step 1m
This setting is used to set the length of the window used for the calculation of rolling demand quantities (in minutes).				
Num Sub Periods	0D	08	1	1 to 15 step 1
This setting is used to set the resolution of the rolling sub window.				
Distance Unit	0D	09	Miles	0 = Kilometres or 1 = Miles
This setting is used to select the unit of distance for fault location purposes.				
Fault Location	0D	0A	Distance	0 = Distance, 1 = Ohms, 2 = % of Line
This setting sets the way the fault location is displayed - in terms of distance, impedance, or percentage of line length.				
Remote 2 Values	0D	0B	Primary	0 = Primary or 1 = Secondary
The setting defines whether the values measured via the Second Rear Communication port are displayed in primary or secondary terms.				

4.3 MEASUREMENT TABLES

Menu Text	Col	Row	Default Setting	Available Options
Description				
MEASUREMENTS 1	02	00		
This column contains measurement parameters				
IA Magnitude	02	01		Not Settable

Menu Text	Col	Row	Default Setting	Available Options
Description				
IA Magnitude				
IA Phase Angle	02	02		Not Settable
IA Phase Angle				
IB Magnitude	02	03		Not Settable
IB Magnitude				
IB Phase Angle	02	04		Not Settable
IB Phase Angle				
IC Magnitude	02	05		Not Settable
IC Magnitude				
IC Phase Angle	02	06		Not Settable
IC Phase Angle				
IN Measured Mag	02	07		Not Settable
IN Measured Magnitude				
IN Measured Ang	02	08		Not Settable
IN Measured Phase Angle				
IN Derived Mag	02	09		Not Settable
IN Derived Magnitude				
IN Derived Angle	02	0A		Not Settable
IN Derived Phase Angle				
ISEF Magnitude	02	0B		Not Settable
ISEF Magnitude				
ISEF Angle	02	0C		Not Settable
ISEF Phase Angle				
I1 Magnitude	02	0D		Not Settable
I1 Magnitude				
I2 Magnitude	02	0E		Not Settable
I2 Magnitude				
I0 Magnitude	02	0F		Not Settable
I0 Magnitude				
IA RMS	02	10		Not Settable
IA RMS				
IB RMS	02	11		Not Settable
IB RMS				
IC RMS	02	12		Not Settable
IC RMS				
VAB Magnitude	02	14		Not Settable
VAB Magnitude				
VAB Phase Angle	02	15		Not Settable
VAB Phase Angle				
VBC Magnitude	02	16		Not Settable
VBC Magnitude				
VBC Phase Angle	02	17		Not Settable

Menu Text	Col	Row	Default Setting	Available Options
Description				
VBC Phase Angle				
VCA Magnitude	02	18		Not Settable
VCA Magnitude				
VCA Phase Angle	02	19		Not Settable
VCA Phase Angle				
VAN Magnitude	02	1A		Not Settable
VAN Magnitude				
VAN Phase Angle	02	1B		Not Settable
VAN Phase Angle				
VBN Magnitude	02	1C		Not Settable
VBN Magnitude				
VBN Phase Angle	02	1D		Not Settable
VBN Phase Angle				
VCN Magnitude	02	1E		Not Settable
VCN Magnitude				
VCN Phase Angle	02	1F		Not Settable
VCN Phase Angle				
VN Derived Mag	02	22		Not Settable
VN Derived Magnitude				
VN Measured Mag	02	22		Not Settable
VN Measured Magnitide				
VN Derived Ang	02	23		Not Settable
VN Derived Phase Angle				
VN Measured Ang	02	23		Not Settable
VN Measured Phase Angle				
V1 Magnitude	02	24		Not Settable
V1 Magnitude				
V2 Magnitude	02	25		Not Settable
V2 Magnitude				
V0 Magnitude	02	26		Not Settable
V0 Magnitude				
V0 Magnitude	02	26		Not Settable
V0 Magnitude				
VAN RMS	02	27		Not Settable
VAN RMS				
VBN RMS	02	28		Not Settable
VBN RMS				
VCN RMS	02	29		Not Settable
VCN RMS				
Frequency	02	2D		Not Settable
Frequency				
C/S Voltage Mag	02	2E		Not Settable

Menu Text	Col	Row	Default Setting	Available Options
Description				
Check Synchronisation Voltage Magnitude				
C/S Voltage Ang	02	2F		Not Settable
Check Synchronisation Voltage Phase Angle				
C/S Bus-Line Ang	02	30		Not Settable
Check Synchronisation Bus-to-Line Phase Angle				
Slip Frequency	02	31		Not Settable
Slip Frequency				
I1 Magnitude	02	40		Not Settable
I1 Magnitude				
I1 Phase Angle	02	41		Not Settable
I1 Phase Angle				
I2 Magnitude	02	42		Not Settable
I2 Magnitude				
I2 Phase Angle	02	43		Not Settable
I2 Phase Angle				
I0 Magnitude	02	44		Not Settable
I0 Magnitude				
I0 Phase Angle	02	45		Not Settable
I0 Phase Angle				
V1 Magnitude	02	46		Not Settable
V1 Magnitude				
V1 Phase Angle	02	47		Not Settable
V1 Phase Angle				
V2 Magnitude	02	48		Not Settable
V2 Magnitude				
V2 Phase Angle	02	49		Not Settable
V2 Phase Angle				
V0 Magnitude	02	4A		Not Settable
V0 Magnitude				
V0 Magnitude	02	4A		Not Settable
V0 Magnitude				
V0 Phase Angle	02	4B		Not Settable
V0 Phase Angle				

4.4 MEASUREMENT TABLE 2

Menu Text	Col	Row	Default Setting	Available Options
Description				
MEASUREMENTS 2	03	00		
This column contains measurement parameters				
A Phase Watts	03	01		Not Settable
A Phase Watts				

Menu Text	Col	Row	Default Setting	Available Options
Description				
B Phase Watts	03	02		Not Settable
B Phase Watts				
C Phase Watts	03	03		Not Settable
C Phase Watts				
A Phase VArs	03	04		Not Settable
A Phase VArs				
B Phase VArs	03	05		Not Settable
B Phase VArs				
C Phase VArs	03	06		Not Settable
C Phase VArs				
A Phase VA	03	07		Not Settable
A Phase VA				
B Phase VA	03	08		Not Settable
B Phase VA				
C Phase VA	03	09		Not Settable
C Phase VA				
3 Phase Watts	03	0A		Not Settable
3 Phase Watts				
3 Phase VArs	03	0B		Not Settable
3 Phase VArs				
3 Phase VA	03	0C		Not Settable
3 Phase VA				
3Ph Power Factor	03	0E		Not Settable
3 Phase Power Factor				
APh Power Factor	03	0F		Not Settable
A Phase Power Factor				
BPh Power Factor	03	10		Not Settable
B Phase Power Factor				
CPh Power Factor	03	11		Not Settable
C Phase Power Factor				
3Ph WHours Fwd	03	12		Not Settable
3 Phase Watt Hours Forward				
3Ph WHours Rev	03	13		Not Settable
3 Phase Watt Hours Reverse				
3Ph VArHours Fwd	03	14		Not Settable
3 Phase VAr Hours Forward				
3Ph VArHours Rev	03	15		Not Settable
3 Phase VAr Hours Reverse				
3Ph W Fix Demand	03	16		Not Settable
3 Phase Watts Fixed Demand				
3Ph VArs Fix Dem	03	17		Not Settable
3 Phase VArs Fixed Demand				

Menu Text	Col	Row	Default Setting	Available Options
Description				
IA Fixed Demand	03	18		Not Settable
IA Fixed Demand				
IB Fixed Demand	03	19		Not Settable
IB Fixed Demand				
IC Fixed Demand	03	1A		Not Settable
IC Fixed Demand				
3 Ph W Roll Dem	03	1B		Not Settable
3 Phase Watts Rolling Demand				
3Ph VArs RollDem	03	1C		Not Settable
3 Phase VArs Rolling Demand				
IA Roll Demand	03	1D		Not Settable
IA Rolling Demand				
IB Roll Demand	03	1E		Not Settable
IB Rolling Demand				
IC Roll Demand	03	1F		Not Settable
IC Rolling Demand				
3Ph W Peak Dem	03	20		Not Settable
3 Phase Watts Peak Demand				
3Ph VAr Peak Dem	03	21		Not Settable
3 Phase VArs Peak Demand				
IA Peak Demand	03	22		Not Settable
IA Peak Demand				
IB Peak Demand	03	23		Not Settable
IB Peak Demand				
IC Peak Demand	03	24		Not Settable
IC Peak Demand				
Reset Demand	03	25	No	0 = No or 1 = Yes
This command resets all the demand cells				

4.5 MEASUREMENT TABLE 3

Menu Text	Col	Row	Default Setting	Available Options
Description				
MEASUREMENTS 3	04	00		
This column contains measurement parameters				
Highest Phase I	04	01		Not Settable
Highest Phase current				
Thermal State	04	02		Not Settable
Thermal State				
Reset Thermal	04	03	No	0 = No or 1 = Yes
This command resets the Thermal State				
IREF Diff	04	04		Not Settable

Menu Text	Col	Row	Default Setting	Available Options
Description				
Retricted Earth Fault differential curent				
IREF Bias	04	05		Not Settable
Retricted Earth Fault bias curent				
I2/I1 Ratio	04	0C		Not Settable
I2/I1 Ratio				
SEF Power	04	0D		Not Settable
Sensitive Earth Fault power				
SEF Power	04	0D		Not Settable
Sensitive Earth Fault power				
df/dt	04	0E		Not Settable
Rate of change of frequency				
IA 2ndHarm	04	0F		Not Settable
IA 2nd Harmonic				
IB 2ndHarm	04	10		Not Settable
IB 2nd Harmonic				
IC 2ndHarm	04	11		Not Settable
IC 2nd Harmonic				
APh Sen Watts	04	12		Not Settable
A Phse Sensitive Watts				
APh Sen Vars	04	13		Not Settable
A Phase Sensitive VArs				
APh Power Angle	04	14		Not Settable
A Phase Power Angle				
Z1 Mag	04	15		Not Settable
Positive Sequence Impedance Magnitude				
Z1 Ang	04	16		Not Settable
Positive Sequence Impedance Angle				
ZA Mag	04	17		Not Settable
Phase A Impedance Magnitude				
ZA Ang	04	18		Not Settable
Phase A Impedance Angle				
ZB Mag	04	19		Not Settable
Phase B Impedance Magnitude				
ZB Ang	04	1A		Not Settable
Phase B Impedance Angle				
ZC Mag	04	1B		Not Settable
Phase C Impedance Magnitude				
ZC Ang	04	1C		Not Settable
Phase C Impedance Angle				
DC Supply Mag	04	20		Not Settable
Auxiliary Supply Voltage level				

5 I/O FUNCTIONS

5.1 FUNCTION KEYS

On models housed in 30TE cases or larger, a number of programmable function keys are available. This allows you to assign function keys to control functionality via the programmable scheme logic (PSL). Each function key is associated with a programmable tri-colour LED, which you can program to give the desired indication on activation of the function key.

These function keys can be used to trigger any function that they are connected to as part of the PSL. The function key commands can be found in the FUNCTION KEYS column.

Each function key is associated with a DDB signal as shown in the DDB table. You can map these DDB signals to any function available in the PSL.

The **Fn Key Status** cell displays the status (energised or de-energised) of the function keys by means of a binary string, where each bit represents a function key starting with bit 0 for function key 1.

Each function key has three settings associated with it, as shown:

- **Fn Key (n) Mode**, which allows you to configure the key as toggled or normal
- **Fn Key (n)**, which enables or disables the function key
- **Fn Key (n) label**, which allows you to define the function key text that is displayed

When the **Fn Key (n) Mode** cell is set to ‘Toggle’, the function key DDB signal output will remain in the set state until a reset command is given. In the ‘Normal’ mode, the function key DDB signal will remain energised for as long as the function key is pressed and will then reset automatically. In this mode, a minimum pulse duration can be programmed by adding a minimum pulse timer to the function key DDB output signal.

The **Fn Key (n)** cell is used to enable (unlock) or disable the function key signals in PSL. The Lock setting has been provided to prevent further activation on subsequent key presses. This allows function keys that are set to ‘Toggled’ mode and their DDB signal active ‘high’, to be locked in their active state thus preventing any further key presses from deactivating the associated function. Locking a function key that is set to the “Normal” mode causes the associated DDB signals to be permanently off. This safety feature prevents any inadvertent function key presses from activating or deactivating critical functions.

The **Fn Key Label** cell makes it possible to change the text associated with each individual function key. This text will be displayed when a function key is accessed in the function key menu, or it can be displayed in the PSL.

The status of all function keys are recorded in non-volatile memory, in case of auxiliary supply interruption.

Note:
The device only recognises a single function key press at a time.

Note:
A key press duration of at least 200 ms is required before it is recognised in PSL. This deglitching feature avoids accidental double presses.

5.1.1 FUNCTION KEY DDB SIGNALS

Ordinal	Signal Name	Source	Type	Response
Description				
712	Function Key 1	Software	Function Key	Protection event

Ordinal	Signal Name	Source	Type	Response
Description				
DDB signal indicates that Function key 1 is active				
713	Function Key 2	Software	Function Key	Protection event
DDB signal indicates that Function key 2 is active				
714	Function Key 3	Software	Function Key	Protection event
DDB signal indicates that Function key 3 is active				

5.1.2 FUNCTION KEY SETTINGS

Menu Text	Col	Row	Default Setting	Available Options
Description				
FUNCTION KEYS	17	00		
This column contains the function key definitions (only available for 30TE case).				
Fn Key Status	17	01	0	Binary flag: 0 = energised 1 = de-energised
This cell displays the status of each function key				
Fn Key 1	17	02	Unlocked	0 = Disabled 1 = Unlocked 2 = Locked
This setting activates function key 1. The 'Lock' setting allows a function key, which is in toggle mode, to be locked in its current active state.				
Fn Key 1 Mode	17	03	Toggled	0 = Normal or 1 = Toggled
This setting sets the function key mode. In 'Toggle' mode, a single key press set sand latches the function key output to 'high' or 'low' in the PSL. In 'Normal' mode the function key output remains high as long as key is pressed.				
Fn Key 1 Label	17	04	Function Key 1	ASCII text (characters 32 to 163 inclusive)
This setting lets you change the function key text to something more suitable for the application.				
Fn Key 2	17	05	Unlocked	0 = Disabled 1 = Unlocked 2 = Locked
This setting activates function key 2. The 'Lock' setting allows a function key, which is in toggle mode, to be locked in its current active state.				
Fn Key 2 Mode	17	06	Normal	0 = Normal or 1 = Toggled
This setting sets the function key mode. In 'Toggle' mode, a single key press set sand latches the function key output to 'high' or 'low' in the PSL. In 'Normal' mode the function key output remains high as long as key is pressed.				
Fn Key 2 Label	17	07	Function Key 2	ASCII text (characters 32 to 163 inclusive)
This setting lets you change the function key text to something more suitable for the application.				
Fn Key 3	17	08	Unlocked	0 = Disabled 1 = Unlocked 2 = Locked
This setting activates function key 3. The 'Lock' setting allows a function key, which is in toggle mode, to be locked in its current active state.				
Fn Key 3 Mode	17	09	Normal	0 = Normal or 1 = Toggled
This setting sets the function key mode. In 'Toggle' mode, a single key press set sand latches the function key output to 'high' or 'low' in the PSL. In 'Normal' mode the function key output remains high as long as key is pressed.				
Fn Key 3 Label	17	0A	Function Key 3	ASCII text (characters 32 to 163 inclusive)
This setting lets you change the function key text to something more suitable for the application.				

5.2 LEDS

Depending on the model, a number of LEDs are used. Some are fixed function LEDs, some are programmable, and for devices with function keys there are LEDs associated with each function key.

5.2.1 FIXED FUNCTION LEDS

Four fixed-function LEDs on the left-hand side of the front panel indicate the following conditions.

- Trip (Red) switches ON when the IED issues a trip signal. It is reset when the associated fault record is cleared from the front display. Also the trip LED can be configured as self-resetting.
- Alarm (Yellow) flashes when the IED registers an alarm. This may be triggered by a fault, event or maintenance record. The LED flashes until the alarms have been accepted (read), then changes to constantly ON. When the alarms are cleared, the LED switches OFF.
- Out of service (Yellow) is ON when the IED's protection is unavailable.
- Healthy (Green) is ON when the IED is in correct working order, and should be ON at all times. It goes OFF if the unit’s self-tests show there is an error in the hardware or software. The state of the healthy LED is reflected by the watchdog contacts at the back of the unit.

5.2.2 PROGRAMABLE LEDS

The device has a number of programmable LEDs. All of the programmable LEDs on the unit are tri-colour and can be set to RED, YELLOW or GREEN.

In the 20TE case, four programmable LEDs are available. In 30TE, eight are available.

5.2.3 FUNCTION KEY LEDS

Adjacent to the function keys are programmable tri-colour LEDs. These should be associated with their respective function keys.

5.2.4 TRIP LED LOGIC

When a trip occurs, the trip LED is illuminated. It is possible to reset this with a number of ways:

- Directly with a reset command (by pressing the Clear Key)
- With a reset logic input
- With self-resetting logic

You enable the automatic self-resetting with the **Sys Fn Links** cell in the SYSTEM DATA column. A '0' disables self resetting and a '1' enables self resetting.

The reset occurs when the circuit is reclosed and the **Any Pole Dead** signal has been reset for three seconds providing the **Any Start** signal is inactive. The reset is prevented if the **Any Start** signal is active after the breaker closes. This is useful when used in conjunction with the Autoreclose logic, as it will prevent unwanted trip flags being displayed after a successful reclosure of the breaker.

The Trip LED logic is as follows:

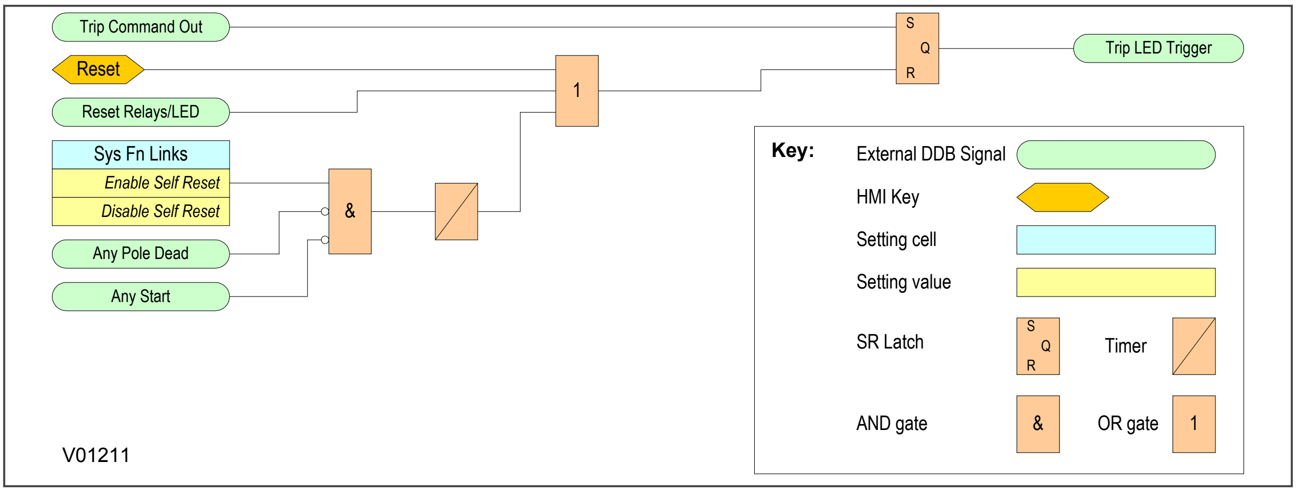


Figure 106: Trip LED logic

5.2.5 LED DDB SIGNALS

Ordinal	Signal Name	Source	Type	Response
Description				
640	LED1 Red	Software	Tri-colour LED	No response
DDB signal indicates that the red LED is active				
641	LED1 Grn	Software	Tri-colour LED	No response
DDB signal indicates that the green LED is active				
642	LED2 Red	Software	Tri-colour LED	No response
DDB signal indicates that the red LED is active				
643	LED2 Grn	Software	Tri-colour LED	No response
DDB signal indicates that the green LED is active				
644	LED3 Red	Software	Tri-colour LED	No response
DDB signal indicates that the red LED is active				
645	LED3 Grn	Software	Tri-colour LED	No response
DDB signal indicates that the green LED is active				
646	LED4 Red	Software	Tri-colour LED	No response
DDB signal indicates that the red LED is active				
647	LED4 Grn	Software	Tri-colour LED	No response
DDB signal indicates that the green LED is active				
648	LED5 Red(30TE)	Software	Tri-colour LED	No response
DDB signal indicates that the red LED is active				
649	LED5 Grn(30TE)	Software	Tri-colour LED	No response
DDB signal indicates that the green LED is active				
650	LED6 Red(30TE)	Software	Tri-colour LED	No response
DDB signal indicates that the red LED is active				
651	LED6 Grn(30TE)	Software	Tri-colour LED	No response
DDB signal indicates that the green LED is active				
652	LED7 Red(30TE)	Software	Tri-colour LED	No response
DDB signal indicates that the red LED is active				

Ordinal	Signal Name	Source	Type	Response
Description				
653	LED7 Grn(30TE)	Software	Tri-colour LED	No response
DDB signal indicates that the green LED is active				
654	LED8 Red(30TE)	Software	Tri-colour LED	No response
DDB signal indicates that the red LED is active				
655	LED8 Grn(30TE)	Software	Tri-colour LED	No response
DDB signal indicates that the green LED is active				
656	FnKey LED1 Red	Software	Tri-colour LED	No response
DDB signal indicates that the red Function Key LED is active				
657	FnKey LED1 Grn	Software	Tri-colour LED	No response
DDB signal indicates that the green Function Key LED is active				
658	FnKey LED2 Red	Software	Tri-colour LED	No response
DDB signal indicates that the red Function Key LED is active				
659	FnKey LED2 Grn	Software	Tri-colour LED	No response
DDB signal indicates that the green Function Key LED is active				
660	FnKey LED3 Red	Software	Tri-colour LED	No response
DDB signal indicates that the red Function Key LED is active				
661	FnKey LED3 Grn	Software	Tri-colour LED	No response
DDB signal indicates that the green Function Key LED is active				

5.2.6 LED CONDITIONERS

When driving an LED, the driving signal has to first be conditioned. We need to define certain properties such as whether it should be latched or not. This is defined in the PSL Editor (on page 502), which is described in the Setting Applications Software chapter.

A different set of DDB signals is provided for the purposes of connecting signals such as trips, starts and alarms, if these signals are to drive the LEDs. The names of these DDB signals are shown below.

Ordinal	Signal Name	Source	Type	Response
Description				
676	LED1 Con R	Programmable Scheme Logic	Tri-colour LED Conditioner	No response
This DDB signal drives the red LED Conditioner 1				
677	LED1 Con G	Programmable Scheme Logic	Tri-colour LED Conditioner	No response
This DDB signal drives the green LED Conditioner 1				
678	LED2 Con R	Programmable Scheme Logic	Tri-colour LED Conditioner	No response
This DDB signal drives the red LED Conditioner 2				
679	LED2 Con G	Programmable Scheme Logic	Tri-colour LED Conditioner	No response
This DDB signal drives the green LED Conditioner 2				
680	LED3 Con R	Programmable Scheme Logic	Tri-colour LED Conditioner	No response
This DDB signal drives the red LED Conditioner 3				
681	LED3 Con G	Programmable Scheme Logic	Tri-colour LED Conditioner	No response
This DDB signal drives the green LED Conditioner 3				
682	LED4 Con R	Programmable Scheme Logic	Tri-colour LED Conditioner	No response
This DDB signal drives the red LED Conditioner 4				
683	LED4 Con G	Programmable Scheme Logic	Tri-colour LED Conditioner	No response

Ordinal	Signal Name	Source	Type	Response
Description				
This DDB signal drives the green LED Conditioner 4				
684	LED5 Con R(30TE)	Programmable Scheme Logic	Tri-colour LED Conditioner	No response
This DDB signal drives the red LED Conditioner 5				
685	LED5 Con G(30TE)	Programmable Scheme Logic	Tri-colour LED Conditioner	No response
This DDB signal drives the green LED Conditioner 5				
686	LED6 Con R(30TE)	Programmable Scheme Logic	Tri-colour LED Conditioner	No response
This DDB signal drives the red LED Conditioner 6				
687	LED6 Con G(30TE)	Programmable Scheme Logic	Tri-colour LED Conditioner	No response
This DDB signal drives the green LED Conditioner 6				
688	LED7 Con R(30TE)	Programmable Scheme Logic	Tri-colour LED Conditioner	No response
This DDB signal drives the red LED Conditioner 7				
689	LED7 Con G(30TE)	Programmable Scheme Logic	Tri-colour LED Conditioner	No response
This DDB signal drives the green LED Conditioner 7				
690	LED8 Con R(30TE)	Programmable Scheme Logic	Tri-colour LED Conditioner	No response
This DDB signal drives the red LED Conditioner 8				
691	LED8 Con G(30TE)	Programmable Scheme Logic	Tri-colour LED Conditioner	No response
This DDB signal drives the green LED Conditioner 8				
692	FnKey LED1 ConR	Programmable Scheme Logic	Tri-colour LED Conditioner	No response
This DDB signal drives the red Function Key LED Conditioner 1				
693	FnKey LED1 ConG	Programmable Scheme Logic	Tri-colour LED Conditioner	No response
This DDB signal drives the green Function Key LED Conditioner 1				
694	FnKey LED2 ConR	Programmable Scheme Logic	Tri-colour LED Conditioner	No response
This DDB signal drives the red Function Key LED Conditioner 2				
695	FnKey LED2 ConG	Programmable Scheme Logic	Tri-colour LED Conditioner	No response
This DDB signal drives the green Function Key LED Conditioner 2				
696	FnKey LED3 ConR	Programmable Scheme Logic	Tri-colour LED Conditioner	No response
This DDB signal drives the red Function Key LED Conditioner 3				
697	FnKey LED3 ConG	Programmable Scheme Logic	Tri-colour LED Conditioner	No response
This DDB signal drives the red Function Key LED Conditioner 3				

5.3 OPTO-INPUTS

Depending on the model, a number of opto-inputs are available. The use of these opto-inputs depends on the application. There are a number of settings associated with the opto-inputs.

5.3.1 OPTO-INPUT CONFIGURATION

Menu Text	Col	Row	Default Setting	Available Options
Description				
OPTO CONFIG	11	00		
This column contains opto-input configuration settings				
Global Nominal V	11	01	48/54V	0 = 24-27V, 1 = 30-34V, 2 = 48-54V, 3 = 110-125V, 4 = 220-250V or 5 = Custom
This setting sets the nominal DC voltage for all opto-inputs. The Custom setting allows you to set each opto-input to any voltage value individually.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
Opto Input 1	11	02	48/54V	0 = 24/27V, 1 = 30/34V, 2 = 48/54V, 3 = 110/125V or 4 = 220/250V
This cell sets the nominal voltage for opto-input 1				
Opto Input 2	11	03	48/54V	0 = 24/27V, 1 = 30/34V, 2 = 48/54V, 3 = 110/125V or 4 = 220/250V
This cell sets the nominal voltage for opto-input 2				
Opto Input 3	11	04	48/54V	0 = 24/27V, 1 = 30/34V, 2 = 48/54V, 3 = 110/125V or 4 = 220/250V
This cell sets the nominal voltage for opto-input 3				
Opto Input 4	11	05	48/54V	0 = 24/27V, 1 = 30/34V, 2 = 48/54V, 3 = 110/125V or 4 = 220/250V
This cell sets the nominal voltage for opto-input 4				
Opto Input 5	11	06	48/54V	0 = 24/27V, 1 = 30/34V, 2 = 48/54V, 3 = 110/125V or 4 = 220/250V
This cell sets the nominal voltage for opto-input 5				
Opto Input 6	11	07	48/54V	0 = 24/27V, 1 = 30/34V, 2 = 48/54V, 3 = 110/125V or 4 = 220/250V
This cell sets the nominal voltage for opto-input 6				
Opto Input 7	11	08	48/54V	0 = 24/27V, 1 = 30/34V, 2 = 48/54V, 3 = 110/125V or 4 = 220/250V
This cell sets the nominal voltage for opto-input 7				
Opto Input 8	11	09	48/54V	0 = 24/27V, 1 = 30/34V, 2 = 48/54V, 3 = 110/125V or 4 = 220/250V
This cell sets the nominal voltage for opto-input 8				
Opto Input 9	11	0A	48/54V	0 = 24/27V, 1 = 30/34V, 2 = 48/54V, 3 = 110/125V or 4 = 220/250V
This cell sets the nominal voltage for opto-input 9				
Opto Input 10	11	0B	48/54V	0 = 24/27V, 1 = 30/34V, 2 = 48/54V, 3 = 110/125V or 4 = 220/250V
This cell sets the nominal voltage for opto-input 10				
Opto Input 11	11	0C	48/54V	0 = 24/27V, 1 = 30/34V, 2 = 48/54V, 3 = 110/125V or 4 = 220/250V
This cell sets the nominal voltage for opto-input 11				
Opto Input 12	11	0D	48/54V	0 = 24/27V, 1 = 30/34V, 2 = 48/54V, 3 = 110/125V or 4 = 220/250V
This cell sets the nominal voltage for opto-input 12				
Opto Input 13	11	0E	48/54V	0 = 24/27V, 1 = 30/34V, 2 = 48/54V, 3 = 110/125V or 4 = 220/250V
This cell sets the nominal voltage for opto-input 13				
Opto Filter Cntl	11	50	0xFFFFFFFF	Binary flag (data type G9): 0 = Off, 1 = Energised
This setting determines whether the in-built noise filter is off or on for each opto-input.				
Characteristic	11	80	Standard 60%-80%	0 = Standard 60% to 80% or 1 = 50% to 70%
This setting selects the opto-inputs' pick-up and drop-off characteristics.				
Opto 9 Mode	11	90	Normal	0 = Normal, 1 = TCS
This setting selects the opto-input's mode of operation; either normal opto or Trip Circuit Supervision (TCS). Valid for I/O option C only.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
Opto 10 Mode	11	91	Normal	0 = Normal, 1 = TCS
This setting selects the opto-input's mode of operation; either normal opto or Trip Circuit Supervision (TCS). Valid for I/O option C only.				
Opto 11 Mode	11	92	Normal	0 = Normal, 1 = TCS
This setting selects the opto-input's mode of operation; either normal opto or Trip Circuit Supervision (TCS). Valid for I/O option C only.				

5.3.2 OPTO-INPUT LABELS

Menu Text	Col	Row	Default Setting	Available Options
Description				
GROUP 1 INPUT LABELS	4A	00		
This column contains settings for the opto-input Labels				
Opto Input 1	4A	01	Input L1	ASCII text
This setting defines the label for opto-input 1				
Opto Input 2	4A	02	Input L2	ASCII text
This setting defines the label for opto-input 2				
Opto Input 3	4A	03	Input L3	ASCII text
This setting defines the label for opto-input 3				
Opto Input 4	4A	04	Input L4	ASCII text
This setting defines the label for opto-input 4				
Opto Input 5	4A	05	Input L5	ASCII text
This setting defines the label for opto-input 5				
Opto Input 6	4A	06	Input L6	ASCII text
This setting defines the label for opto-input 6				
Opto Input 7	4A	07	Input L7	ASCII text
This setting defines the label for opto-input 7				
Opto Input 8	4A	08	Input L8	ASCII text
This setting defines the label for opto-input 8				
Opto Input 9	4A	09	Input L9	ASCII text
This setting defines the label for opto-input 9				
Opto Input 10	4A	0A	Input L10	ASCII text
This setting defines the label for opto-input 10				
Opto Input 11	4A	0B	Input L11	ASCII text
This setting defines the label for opto-input 11				
Opto Input 12	4A	0C	Input L12	ASCII text
This setting defines the label for opto-input 12				
Opto Input 13	4A	0D	Input L13	ASCII text
This setting defines the label for opto-input 13				

5.3.3 OPTO-INPUT DDB SIGNALS

Depending on the model there are up to 13 opto-inputs available. These are connected to DDB signals starting with DDB 32 as follows. The default names are provided, but note that these can be configured in the I/P LABELS column.

Ordinal	Signal Name	Source	Type	Response
Description				
32	Input L1	Software	Opto-input	Opto-input change event
DDB signal connected to opto-input 1				
33	Input L2	Software	Opto-input	Opto-input change event
DDB signal connected to opto-input 2				
34	Input L3	Software	Opto-input	Opto-input change event
DDB signal connected to opto-input 3				
35	Input L4	Software	Opto-input	Opto-input change event
DDB signal connected to opto-input 4				
36	Input L5	Software	Opto-input	Opto-input change event
DDB signal connected to opto-input 5				
37	Input L6	Software	Opto-input	Opto-input change event
DDB signal connected to opto-input 6				
38	Input L7	Software	Opto-input	Opto-input change event
DDB signal connected to opto-input 7				
39	Input L8	Software	Opto-input	Opto-input change event
DDB signal connected to opto-input 8				
40	Input L9	Software	Opto-input	Opto-input change event
DDB signal connected to opto-input 9				
41	Input L10	Software	Opto-input	Opto-input change event
DDB signal connected to opto-input 10				
42	Input L11	Software	Opto-input	Opto-input change event
DDB signal connected to opto-input 11				
43	Input L12	Software	Opto-input	Opto-input change event
DDB signal connected to opto-input 12				
44	Input L13	Software	Opto-input	Opto-input change event
DDB signal connected to opto-input 13				

5.3.4 ENHANCED TIME STAMPING

Each opto-input sample is time stamped within a tolerance of +/- 1 ms with respect to the Real Time Clock. These time stamps are used for the opto event logs and for the disturbance recording. The device needs to be synchronised accurately to an external clock source such as an IRIG-B signal or a master clock signal provided in the relevant data protocol.

For both the filtered and unfiltered opto-inputs, the time stamp of an opto-input change event is the sampling time at which the change of state occurred. If a mixture of filtered and unfiltered opto-inputs change state at the same sampling interval, these state changes are reported as a single event. The enhanced opto-input event time stamping is consistent across all the implemented protocols. The GOOSE messages are published in a timely manner and are not delayed by any event filtering mechanisms.

5.4 OUTPUT RELAYS

Depending on the model, a number of relay outputs are available. The use of these relay outputs depend on the application. There are a number of settings associated with the relay outputs.

5.4.1 OUTPUT RELAY LABELS

In the O/P LABELS column, you can define the DDB signal names for the output relays.

Menu Text	Col	Row	Default Setting	Available Options
Description				
GROUP 1 OUTPUT LABELS	4B	00		
This column contains settings for the output relay labels				
Relay 1	4B	01	Output R1	ASCII text
This setting defines the label for output relay 1				
Relay 2	4B	02	Output R2	ASCII text
This setting defines the label for output relay 2				
Relay 3	4B	03	Output R3	ASCII text
This setting defines the label for output relay 3				
Relay 4	4B	04	Output R4	ASCII text
This setting defines the label for output relay 4				
Relay 5	4B	05	Output R5	ASCII text
This setting defines the label for output relay 5				
Relay 6	4B	06	Output R6	ASCII text
This setting defines the label for output relay 6				
Relay 7	4B	07	Output R7	ASCII text
This setting defines the label for output relay 7				
Relay 8	4B	08	Output R8	ASCII text
This setting defines the label for output relay 8				
Relay 9	4B	09	Output R9	ASCII text
This setting defines the label for output relay 9				
Relay 10	4B	0A	Output R10	ASCII text
This setting defines the label for output relay 10				
Relay 11	4B	0B	Output R11	ASCII text
This setting defines the label for output relay 11				
Relay 12	4B	0C	Output R12	ASCII text
This setting defines the label for output relay 12				

5.4.2 OUTPUT RELAY DDB SIGNALS

Depending on the model there are up to 12 output relays available. These are connected to DDB signals starting with number 0 as follows. The default names are provided, but note that these can be configured in the O/P LABELS column.

Ordinal	Signal Name	Source	Type	Response
Description				
0	Output R1	Software	Output Relay	Output relay change event
DDB signal connected to output relay contact 1				
1	Output R2	Software	Output Relay	Output relay change event
DDB signal connected to output relay contact 2				
2	Output R3	Software	Output Relay	Output relay change event
DDB signal connected to output relay contact 3				
3	Output R4	Software	Output Relay	Output relay change event
DDB signal connected to output relay contact 4				
4	Output R5	Software	Output Relay	Output relay change event

Ordinal	Signal Name	Source	Type	Response
Description				
DDB signal connected to output relay contact 5				
5	Output R6	Software	Output Relay	Output relay change event
DDB signal connected to output relay contact 6				
6	Output R7	Software	Output Relay	Output relay change event
DDB signal connected to output relay contact 7				
7	Output R8	Software	Output Relay	Output relay change event
DDB signal connected to output relay contact 8				
8	Output R9	Software	Output Relay	Output relay change event
DDB signal connected to output relay contact 9				
9	Output R10	Software	Output Relay	Output relay change event
DDB signal connected to output relay contact 10				
10	Output R11	Software	Output Relay	Output relay change event
DDB signal connected to output relay contact 11				
11	Output R12	Software	Output Relay	Output relay change event
DDB signal connected to output relay contact 12				

5.4.3 OUTPUT RELAY CONDITIONERS

When driving an output relay, the driving signal has to first be conditioned. We need to define certain properties such as, pickup time, dropoff time, dwell and whether it is a pulsed or latched output. This is all defined in the PSL Editor, which is described in the Setting Applications Software (on page 493) chapter.

A different set of DDB signals is provided for the purposes of connecting signals such as trip and start commands and alarms, if these signals are to drive the output relays. The names of these DDB signals are shown below.

Ordinal	Signal Name	Source	Type	Response
Description				
72	Relay Cond 1	Programmable Scheme Logic	Output Conditioner	No response
DDB signal connected to output relay conditioner 1				
73	Relay Cond 2	Programmable Scheme Logic	Output Conditioner	No response
DDB signal connected to output relay conditioner 2				
74	Relay Cond 3	Programmable Scheme Logic	Output Conditioner	No response
DDB signal connected to output relay conditioner 3				
75	Relay Cond 4	Programmable Scheme Logic	Output Conditioner	No response
DDB signal connected to output relay conditioner 4				
76	Relay Cond 5	Programmable Scheme Logic	Output Conditioner	No response
DDB signal connected to output relay conditioner 5				
77	Relay Cond 6	Programmable Scheme Logic	Output Conditioner	No response
DDB signal connected to output relay conditioner 6				
78	Relay Cond 7	Programmable Scheme Logic	Output Conditioner	No response
DDB signal connected to output relay conditioner 7				
79	Relay Cond 8	Programmable Scheme Logic	Output Conditioner	No response
DDB signal connected to output relay conditioner 8				
80	Relay Cond 9	Programmable Scheme Logic	Output Conditioner	No response
DDB signal connected to output relay conditioner 9				

Ordinal	Signal Name	Source	Type	Response
Description				
81	Relay Cond 10	Programmable Scheme Logic	Output Conditioner	No response
DDB signal connected to output relay conditioner 10				
82	Relay Cond 11	Programmable Scheme Logic	Output Conditioner	No response
DDB signal connected to output relay conditioner 11				
83	Relay Cond 12	Programmable Scheme Logic	Output Conditioner	No response
DDB signal connected to output relay conditioner 12				

5.5 CONTROL INPUTS

The control inputs are software switches, which can be set or reset locally or remotely. These inputs can be used to trigger any PSL function to which they are connected. There are three setting columns associated with the control inputs.

5.5.1 CONTROL INPUT SETTINGS

Menu Text	Col	Row	Default Setting	Available Options
Description				
CONTROL INPUTS	12	00		
This column contains settings for the type of control input				
Ctrl I/P Status 1	12	01	0x00000000	Binary flag (data type G202): 0 = Reset, 1 = Set
This cell sets or resets the first batch of 32 Control Inputs by scrolling and changing the status of selected bits. Alternatively, each of the 32 Control inputs can be set and reset using the individual Control Input cells.				
Ctrl I/P Status 2	12	02	0x00000000	Binary flag (data type G262): 0 = Reset, 1 = Set
This cell sets or resets the first batch of 32 Control Inputs by scrolling and changing the status of selected bits. Alternatively, each of the 32 Control inputs can be set and reset using the individual Control Input cells.				
Control Inputs 1 to 64	12	10 to 4F	No Operation	0 = No Operation, 1 = Set , 2 = Reset
These commands set or reset Control Inputs 1 to 64				

5.5.2 CONTROL INPUT CONFIGURATION

Menu Text	Col	Row	Default Setting	Available Options
Description				
CTRL I/P CONFIG	13	00		
This column contains configuration settings for the control inputs.				
Hotkey Enabled 1	13	01	0xFFFFFFFF	Binary flag (data type G233): 0 = not assigned, 1 = assigned
This setting allows the control inputs to be individually assigned to the Hotkey menu. The hotkey menu allows the control inputs to be set, reset or pulsed without the need to enter the CONTROL INPUTS column.				
Hotkey Enabled 2	13	02	0xFFFFFFFF	Binary flag (data type G263): 0 = not assigned, 1 = assigned
This setting allows the control inputs to be individually assigned to the Hotkey menu. The hotkey menu allows the control inputs to be set, reset or pulsed without the need to enter the CONTROL INPUTS column.				
Control Inputs 1 to 64	13	10 to ED (evens)	Latched	0 = Latched or 1 = Pulsed

Menu Text	Col	Row	Default Setting	Available Options
Description				
This setting configures the control input as either ‘latched’ or ‘pulsed’.				
Ctrl Commands 1 to 64	13	11 to EE (odds)	SET/RESET	0 = On/Off, 1 = Set/Reset, 2 = In/Out, 3 = Enabled/Disabled
This setting allows you to select the text to be displayed on the hotkey menu.				

5.5.3 CONTROL INPUT LABELS

In the CTRL I/P LABELS column, you can define the DDB signal names for the control inputs.

Menu Text	Col	Row	Default Setting	Available Options
Description				
CTRL I/P LABELS	29	00		
This column contains settings for the Control Input Labels				
Control Inputs 1 to 64	29	01 to 40	Control Input (n)	Extended ASCII text (characters 32 to 234 inclusive)
In this cell you can enter a text label to describe the control input. This text is displayed when a control input is accessed by the hotkey menu and in the programmable scheme logic description of the control input.				

5.5.4 CONTROL INPUT DDB SIGNALS

There are 64 control inputs available. These are connected to DDB signals starting with number 800 and 1233 as follows. The default names are provided, but note that these can be configured in the CTRL I/P LABELS column.

Ordinal	Signal Name	Source	Type	Response
Description				
800 to 831	Control Input (n)	Software	Control	Protection event
This DDB signal is a control input signal				
1233 to 1264	Control Input (n)	Software	Control	Protection event
This DDB signal is a control input signal				

6 CB CONDITION MONITORING

The device records various statistics related to each circuit breaker trip operation, allowing an accurate assessment of the circuit breaker condition to be determined. The circuit breaker condition monitoring counters are incremented every time the device issues a trip command.

These statistics are available in the CB CONDITION column and are shown below. The menu cells shown are counter values only, and cannot be set directly. The counters may be reset, however, during maintenance. This is achieved with the setting **Reset CB Data**.

> *Note:*
> *When in Commissioning test mode the CB condition monitoring counters are not updated.*

6.1 CB CONDITION MEASUREMENTS

Menu Text	Col	Row	Default Setting	Available Options
Description				
CB CONDITION	06	00		
This column contains CB condition monitoring measured parameters				
CB Operations	06	01		Not Settable
This cell displays the number of CB Operations				
Total IA Broken	06	02		Not Settable
This cell displays the total broken IA since the last maintenance procedure				
Total IB Broken	06	03		Not Settable
This cell displays the total broken IB since the last maintenance procedure				
Total IC Broken	06	04		Not Settable
This cell displays the total broken IC since the last maintenance procedure				
CB Operate Time	06	05		Not Settable
This cell displays the CB Operate Time				
Reset CB Data	06	06	No	0 = No or 1 = Yes
This cell resets the CB condition monitoring data				

6.2 CB MONITOR SETUP

Menu Text	Col	Row	Default Setting	Available Options
Description				
CB MONITOR SETUP	10	00		
This column contains Circuit Breaker monitoring parameters				
Broken I^	10	01	2	1 to 2 step 0.1
This setting sets the factor to be used for the cumulative brokent current counter calculation. This factor is set according to the type of Circuit Breaker used.				
I^ Maintenance	10	02	Alarm Disabled	0 = Alarm Disabled or 1 = Alarm Enabled
This setting determines whether an alarm is raised or not when the cumulative broken current maintenance counter threshold is exceeded.				
I^ Maintenance	10	03	1000	From 1 * NM1 to 25000 * NM1 step 1 * NM1
This setting determines the threshold for the cumulative broken current maintenance counter.				
I^ Lockout	10	04	Alarm Disabled	0 = Alarm Disabled or 1 = Alarm Enabled

Menu Text	Col	Row	Default Setting	Available Options
Description				
This setting determines whether an alarm will be raised or not when the cumulative broken current lockout counter threshold is exceeded.				
I^ Lockout	10	05	2000	From 1 * NM1 to 25000 * NM1 step 1 * NM1
This setting determines the threshold for the cumulative broken current lockout counter.				
No. CB Ops Maint	10	06	Alarm Disabled	0 = Alarm Disabled or 1 = Alarm Enabled
This setting activates the 'number of CB operations' maintenance alarm.				
No. CB Ops Maint	10	07	10	1 to 10000 step 1
This setting sets the threshold for the 'Number of CB operations' alarm.				
No. CB Ops Lock	10	08	Alarm Disabled	0 = Alarm Disabled or 1 = Alarm Enabled
This setting activates the 'number of CB operations' lockout alarm.				
No. CB Ops Lock	10	09	20	1 to 10000 step 1
This setting sets the threshold for the 'number of CB operations' lockout. Note: The IED can be set to lockout the autoreclose function on reaching a second operations threshold.				
CB Time Maint	10	0A	Alarm Disabled	0 = Alarm Disabled or 1 = Alarm Enabled
This setting activates the 'CB operate time' maintenance alarm.				
CB Time Maint	10	0B	0.1	From 0.005s to 0.5s step 0.001s
This setting sets the threshold for the allowable accumulated CB interruption time before maintenance should be carried out				
CB Time Lockout	10	0C	Alarm Disabled	0 = Alarm Disabled or 1 = Alarm Enabled
This setting activates the 'CB operate time' lockout alarm.				
CB Time Lockout	10	0D	0.2	From 0.005s to 0.5s step 0.001s
This setting sets the threshold for the allowable accumulated CB interruption time before lockout.				
Fault Freq Lock	10	0E	Alarm Disabled	0 = Alarm Disabled or 1 = Alarm Enabled
This setting enables or disables the 'excessive fault frequency' alarm.				
Fault Freq Count	10	0F	10	From 1 to 9999 step 1
This setting sets a 'CB frequent operations' counter that monitors the number of operations over a set time period.				
Fault Freq Time	10	10	3600	From 0s to 9999s step 1s
This setting sets the time period over which the CB operations are to be monitored. Should the set number of trip operations be accumulated within this time period, an alarm can be raised.				

6.3 APPLICATION NOTES

6.3.1 SETTING THE THRESHOLDS FOR THE TOTAL BROKEN CURRENT

Where power lines are protected by oil circuit breakers (OCBs), changing of the oil accounts for a significant proportion of the switchgear maintenance costs. Often, oil changes are performed after a fixed number of CB fault operations. However, this may result in premature maintenance where fault currents tend to be low, because oil degradation may be slower than would normally be expected. The Total Current Accumulator (I^ counter) cumulatively stores the total value of the current broken by the circuit breaker providing a more accurate assessment of the circuit breaker condition.

The dielectric withstand of the oil generally decreases as a function of I^2t, where ‘I’ is the broken fault current and ‘t’ is the arcing time within the interrupter tank. The arcing time cannot be determined accurately, but is generally dependent on the type of circuit breaker being used. Instead, you set a factor (**Broken I^**) with a value between 1 and 2, depending on the circuit breaker.

Most circuit breakers would have this value set to '2', but for some types of circuit breaker, especially those operating on higher voltage systems, a value of 2 may be too high. In such applications **Broken I^** may be set lower, typically 1.4 or 1.5.

The setting range for **Broken I^** is variable between 1.0 and 2.0 in 0.1 steps.

> *Note:*
> *Any maintenance program must be fully compliant with the switchgear manufacturer's instructions.*

6.3.2 SETTING THE THRESHOLDS FOR THE NUMBER OF OPERATIONS

Every circuit breaker operation results in some degree of wear for its components. Therefore routine maintenance, such as oiling of mechanisms, may be based on the number of operations. Suitable setting of the maintenance threshold will allow an alarm to be raised, indicating when preventative maintenance is due. Should maintenance not be carried out, the device can be set to lockout the autoreclose function on reaching a second operations threshold (**No. CB ops Lock**). This prevents further reclosure when the circuit breaker has not been maintained to the standard demanded by the switchgear manufacturer's maintenance instructions.

Some circuit breakers, such as oil circuit breakers (OCBs) can only perform a certain number of fault interruptions before requiring maintenance attention. This is because each fault interruption causes carbonising of the oil, degrading its dielectric properties. The maintenance alarm threshold (setting **No. CB Ops. Maint**) may be set to indicate the requirement for oil dielectric testing, or for more comprehensive maintenance. Again, the lockout threshold **No. CB Ops Lock** may be set to disable autoreclosure when repeated further fault interruptions could not be guaranteed. This minimises the risk of oil fires or explosion.

6.3.3 SETTING THE THRESHOLDS FOR THE OPERATING TIME

Slow CB operation indicates the need for mechanism maintenance. Alarm and lockout thresholds (**CB Time Maint** and **CB Time Lockout**) are provided to enforce this. They can be set in the range of 5 to 500 ms. This time relates to the interrupting time of the circuit breaker.

6.3.4 SETTING THE THRESHOLDS FOR EXCESSSIVE FAULT FREQUENCY

Persistent faults will generally cause autoreclose lockout, with subsequent maintenance attention. Intermittent faults such as clashing vegetation may repeat outside of any reclaim time, and the common cause might never be investigated. For this reason it is possible to set a frequent operations counter, which allows the number of operations **Fault Freq Count** over a set time period **Fault Freq Time** to be monitored. A separate alarm and lockout threshold can be set.

7 CIRCUIT BREAKER CONTROL

There are several types of circuit breaker;

- CBs with no auxiliary contacts
- CBs with 52A contacts (where the auxiliary contact follows the state of the CB)
- CBs with 52B contacts (where the auxiliary contact is in the opposite state the state of the CB)
- CBs with both 52A and 52B contacts

Circuit Breaker control is only possible if the circuit breaker in question provides auxiliary contacts. The **CB Status Input** cell in the CB CONTROL column must be set to the type of circuit breaker. If no CB auxiliary contacts are available then this cell should be set to 'None', and no CB control will be possible.

For local control, the **CB control by** cell should be set accordingly.

The output contact can be set to operate following a time delay defined by the setting **Man Close Delay**. One reason for this delay is to give personnel time to safely move away from the circuit breaker following a **CB close** command.

The length of the trip and close control pulses can be set via the **Trip Pulse Time** and **Close Pulse Time** settings respectively. These should be set long enough to ensure the breaker has completed its open or close cycle before the pulse has elapsed.

If an attempt to close the breaker is being made, and a protection trip signal is generated, the protection trip command overrides the close command.

The **Reset Lockout by** setting is used to enable or disable the resetting of lockout automatically from a manual close after the time set by **Man Close RstDly**.

If the CB fails to respond to the control command (indicated by no change in the state of CB Status inputs) a **CB Failed to Trip** or **CB Failed to Close** alarm is generated after the relevant trip or close pulses have expired. These alarms can be viewed on the LCD display, remotely, or can be assigned to output contacts using the programmable scheme logic (PSL).

> *Note:*
> *The **CB Healthy Time** and **Sys Check time** set under this menu section are applicable to manual circuit breaker operations only. These settings are duplicated in the AUTORECLOSE menu for autoreclose applications.*

The **Lockout Reset** and **Reset Lockout by** settings are applicable to CB Lockouts associated with manual circuit breaker closure, CB Condition monitoring (Number of circuit breaker operations, for example) and autoreclose lockouts.

The device includes the following options for control of a single circuit breaker:

- Local control using the IED menu
- Local control using the Hotkeys
- Local control using the function keys
- Local control using opto-inputs
- Remote control using remote communication

7.1 LOCAL CONTROL USING THE IED MENU

You can control manual trips and closes with the **CB Trip/Close** command in the SYSTEM DATA column. This can be set to 'No Operation', 'Trip', or 'Close' accordingly.

For this to work you have to set the **CB control by** cell to option 1 'Local', option 5 'Opto+Local', or option 7 'Opto+Local+Remote' in the CB CONTROL column.

7.2 LOCAL CONTROL USING THE DIRECT ACCESS KEYS

The hotkeys allow you to manually trip and close the CB without the need to enter the SYSTEM DATA column. For this to work you have to set the **CB control by** cell to option 1 'Local', option 5 'Opto+Local', or option 7 'Opto+Local+Remote' in the CB CONTROL column.

CB control using the hotkey is achieved by pressing the right-hand button directly below LCD screen. This button is only enabled if:

- The **CB Control by** setting is set to one of the options where local control is possible (option 1,3,5, or 7)
- The **CB Status Input** is set to '52A', '52B', or 'Both 52A and 52B'

If the CB is currently closed, the command text on the bottom right of the LCD screen will read 'Trip'. Conversely, if the CB is currently open, the command text will read 'Close'

If you execute a 'Trip', a screen with the CB status will be displayed once the command has been completed. If you execute a 'Close', a screen with a timing bar will appear while the command is being executed. This screen also gives you the option to cancel or restart the close procedure. The time delay is determined by the **Man Close Delay** setting in the CB CONTROL menu. When the command has been executed, a screen confirming the present status of the circuit breaker is displayed. You are then prompted to select the next appropriate command or exit.

If no keys are pressed for a period of 25 seconds while waiting for the command confirmation, the device will revert to showing the CB Status. If no key presses are made for a period of 25 seconds while displaying the CB status screen, the device will revert to the default screen.

To avoid accidental operation of the trip and close functionality, the hotkey CB control commands are disabled for 10 seconds after exiting the hotkey menu.

The direct access functionality is summarised graphically below:

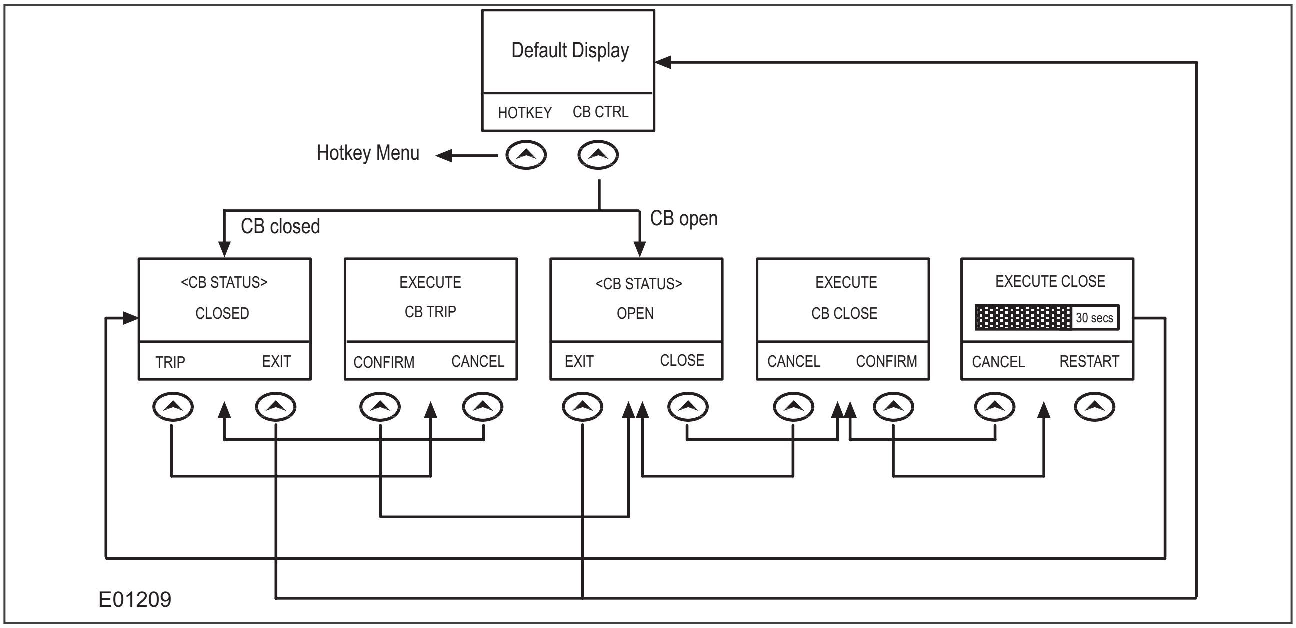


Figure 107: Direct Access menu navigation

7.3 LOCAL CONTROL USING THE FUNCTION KEYS

You can also use the function keys to allow direct control of the circuit breaker. This has the advantage over hotkeys, that the LEDs associated with the function keys can indicate the status of the CB. The default PSL is set up such that Function key 2 initiates a trip and Function key 3 initiates a close. For this to work you have to set the CB control by cell to option 5 'Opto+Local', or option 7 'Opto+Local+Remote' in the CB CONTROL column.

The default PSL logic for the function key mappings is shown below. As you can see, function keys 2 and 3 have already been assigned to CB control in the default PSL.

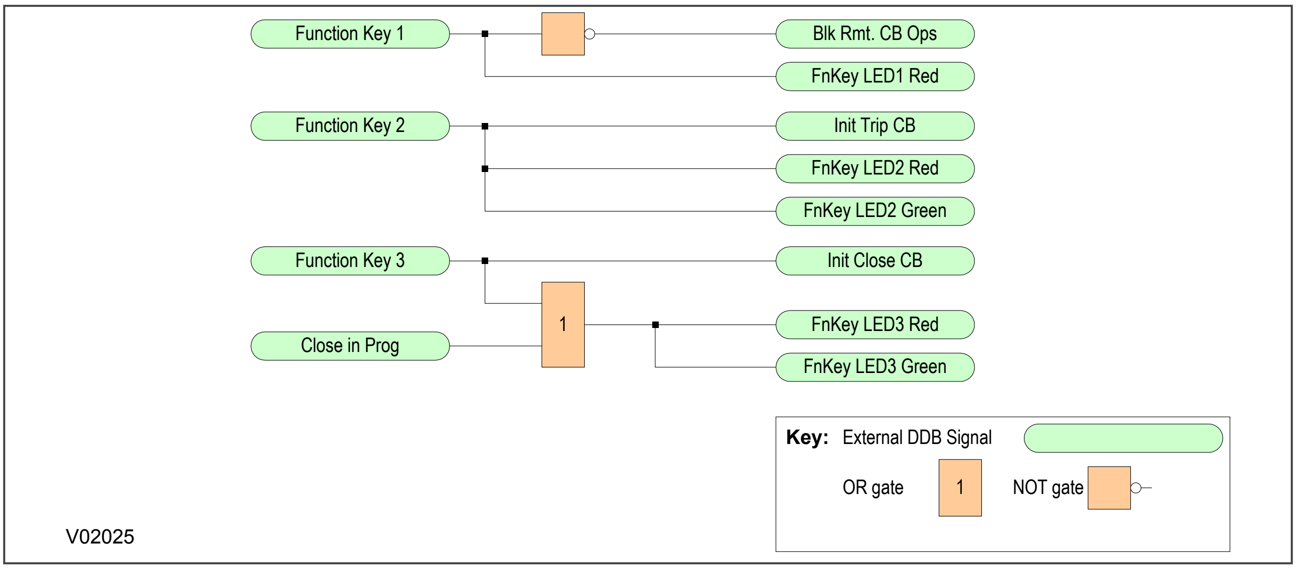


Figure 108: Default function key PSL

The programmable function key LEDs have been mapped such that they will indicate yellow whilst the keys are activated.

7.4 LOCAL CONTROL USING THE OPTO-INPUTS

Certain applications may require the use of push buttons or other external signals to control the various CB control operations. It is possible to connect such push buttons and signals to opto-inputs and map these to the relevant DDB signals.

For this to work, you have to set the **CB control by** cell to option 2 'Remote', option 4 'opto', option 5 'Opto +Local', option 6 'Opto+Remote', or option 7 'Opto+Local+Remote' in the CB CONTROL column.

The following DDB signals would be used for such purposes:

Ordinal	English Text	Source	Type	Response Function
Description				
232	Init Trip CB	Programmable Scheme Logic	PSL Output	No response
This DDB signals the circuit breaker to open				
233	Init Close CB	Programmable Scheme Logic	PSL Output	No response
This DDB signals the circuit breaker to open				
234	Reset Close Dly	Programmable Scheme Logic	PSL Output	No response
This DDB signal resets the Manual CB Close Time Delay				

7.5 REMOTE CONTROL

Remote CB control can be achieved by setting the **CB Trip/Close** cell in the SYSTEM DATA column to trip or close by using a Courier command to the rear interface RP1.

For this to work, you have to set the **CB control by** cell to option 2 'Remote', option 3 'Local+Remote', option 6 ' Opto+remote', or option 7 'Opto+Local+Remote' in the CB CONTROL column.

We recommend that you allocate separate relay output contacts for remote CB control and protection tripping. This allows you to select the control outputs using a simple local/remote selector switch as shown below. Where this feature is not required the same output contact(s) can be used for both protection and remote tripping.

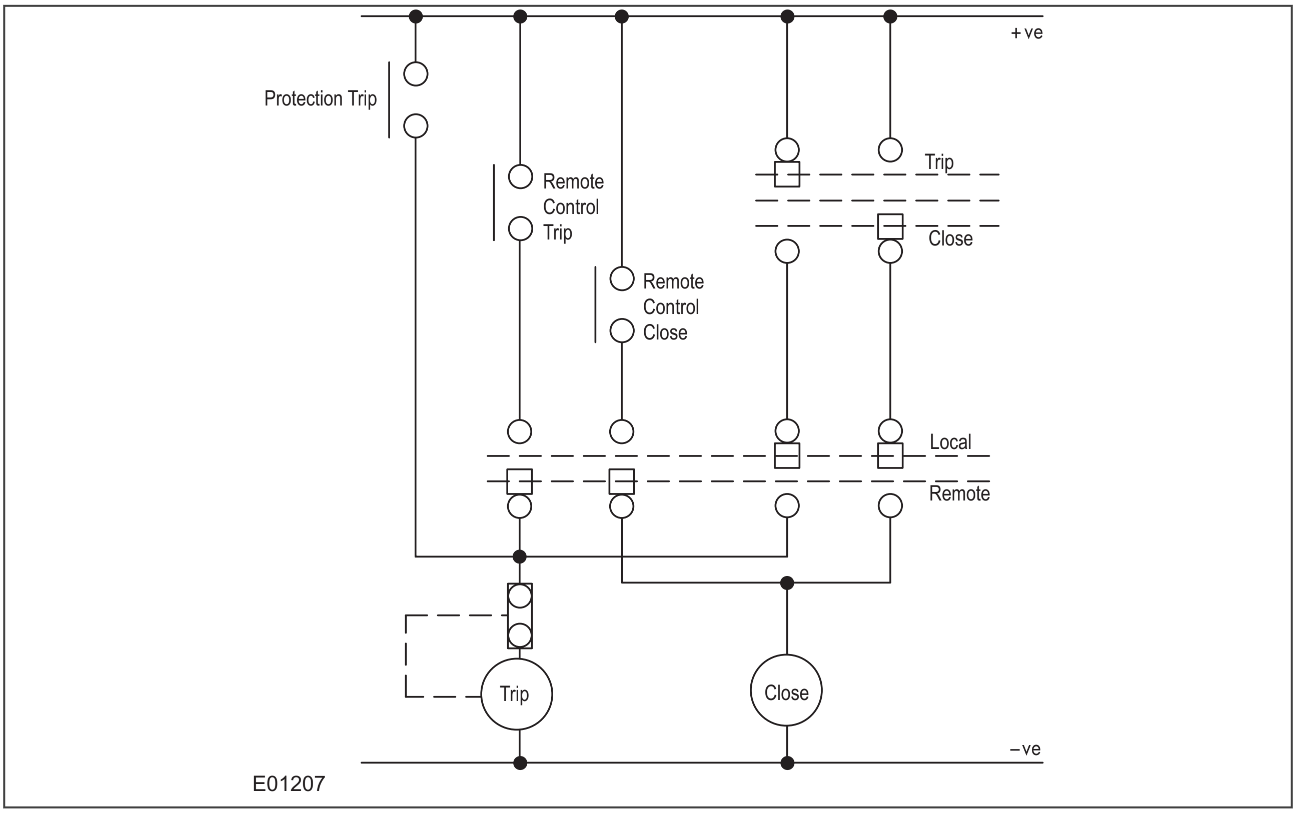


Figure 109: Remote Control of Circuit Breaker

7.6 SYNCHRONISATION CHECK

Where the check synchronism function is set, this can be enabled to supervise manual circuit breaker Close commands. A circuit breaker Close command will only be issued if the Check Synchronisation criteria are satisfied. A time delay can be set with the setting **Sys Check time**. If the Check Synchronisation criteria are not satisfied within the time period following a Close command the device will lockout and alarm.

7.7 CB HEALTHY CHECK

A CB Healthy check is also available if required. This facility accepts an input to one of the opto-inputs to indicate that the breaker is capable of closing (e.g. that it is fully charged). A time delay can be set with the setting **CB Healthy Time**. If the CB does not indicate a healthy condition within the time period following a Close command, the device will lockout and alarm.

7.8 CB CONTROL LOGIC

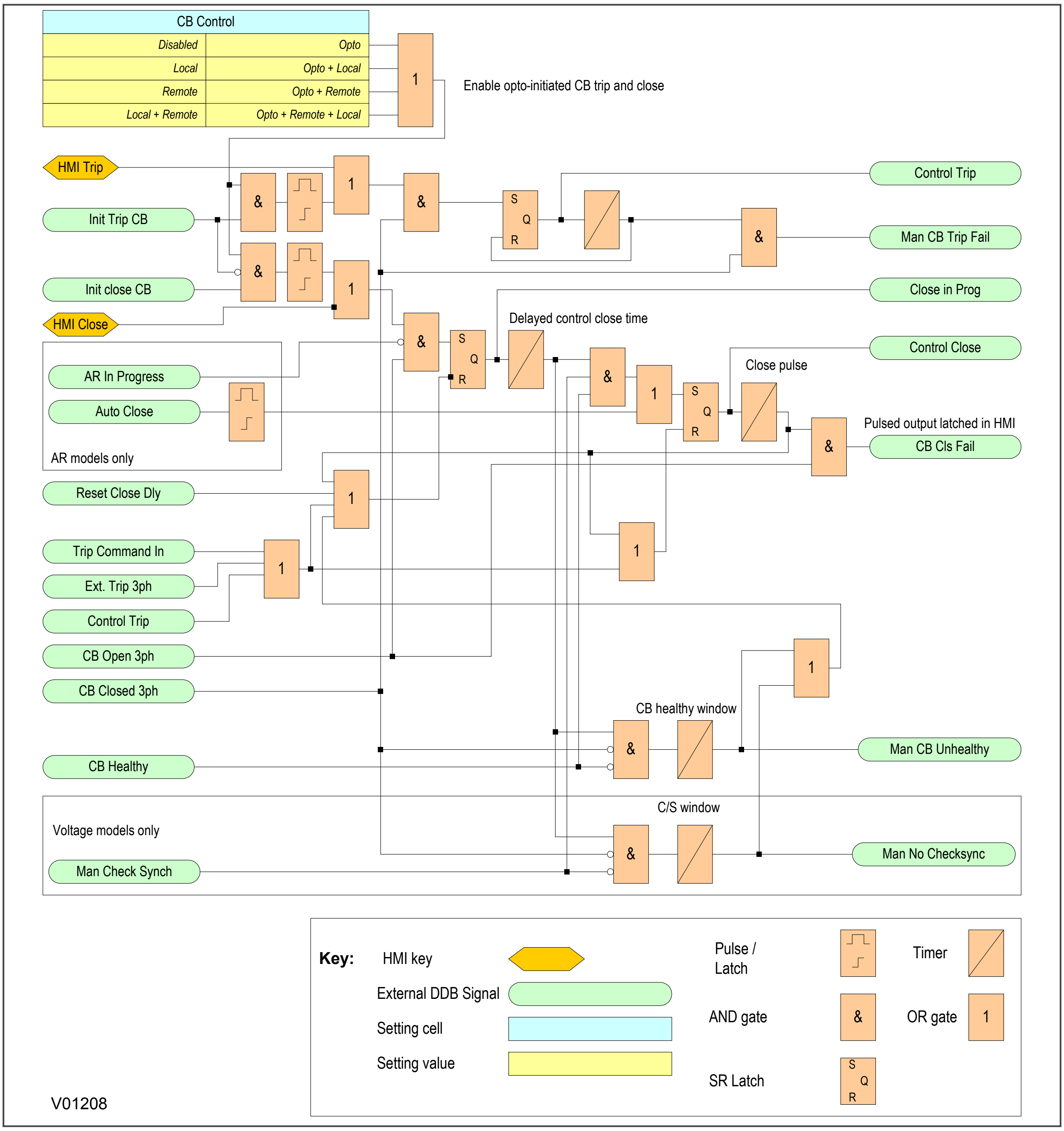


Figure 110: CB Control logic

7.9 CB CONTROL SETTINGS

Menu Text	Col	Row	Default Setting	Available Options
Description				
CB CONTROL	07	00		
This column controls the circuit Breaker Control configuration				

Menu Text	Col	Row	Default Setting	Available Options
Description				
CB Control by	07	01	Disabled	0=Disabled 1=Local 2=Remote 3=Local+Remote 4=Opto 5=Opto+local 6=Opto+Remote 7=Opto+Remote+local
This setting selects the type of circuit breaker control to be used				
Close Pulse Time	07	02	0.5	From 0.1s to 50s step 0.01s
This setting defines the duration of the close pulse within which the CB should close when a close command is issued.				
Trip Pulse Time	07	03	0.5	From 0.1s to 5s step 0.01s
This setting defines the duration of the trip pulse within which the CB should trip when a manual or protection trip command is issued.				
Man Close Delay	07	05	10	From 0.01s to 600s step 0.01s
This setting defines the delay time before the close pulse is executed.				
CB Healthy Time	07	06	5	From 0.01s to 9999s step 0.01s
This setting defines the time period in which a CB needs to indicate a healthy condition before it closes. If the CB does not indicate a healthy condition in this time period following a close command then the IED will lockout and alarm.				
Sys Check Time	07	07	5	From 0.01s to 9999s step 0.01s
This setting sets a time delay for manual closure with System Check Synchronizing. If the System Check Synchronizing criteria are not satisfied in this time period following a close command, the IED will lockout and produce an alarm.				
Lockout Reset	07	08	No	0 = No or 1 = Yes
This command resets the AutoReclose Lockout.				
Reset Lockout by	07	09	CB Close	0=User Interface 1=CB Close
This setting defines whether the AutoReclose Lockout signal is to be reset by the user interface or a CB Closed signal.				
Man Close RstDly	07	0A	5	From 0.1s to 600s step 0.01s
This setting sets the time delay before the Lockout state can be reset following a manual closure.				
Autoreclose Mode	07	0B	No Operation	0=No Operation 1=Auto 2=Non Auto
This command changes the Autoreclose mode				
AR Status	07	0E		<Autoreclose state>
This cell displays the Autoreclose - In Service or Out of Service				
Total Reclosures	07	0F		<Number of successful reclosures>
This cell displays the number of successful reclosures.				
Reset Total AR	07	10	No	0 = No or 1 = Yes
This command allows you to to reset the autoreclose counters.				
CB Status Input	07	11	None	0=None 1=52A 2=52B 3=Both 52A and 52B
Setting to define the type of circuit breaker contacts that will be used for the circuit breaker control logic. Form A contacts match the status of the circuit breaker primary contacts, form B are opposite to the breaker status.				
1 Shot Clearance	07	12		Not Settable
This cell displays the total number of successful clearances after 1 shot				
2 Shot Clearance	07	13		Not Settable

Menu Text	Col	Row	Default Setting	Available Options
Description				
This cell displays the total number of successful clearances after 2 shots				
3 Shot Clearance	07	14		Not Settable
This cell displays the total number of successful clearances after 3 shots				
4 Shot Clearance	07	15		Not Settable
This cell displays the total number of successful clearances after 4 shots				
Persistent Fault	07	16		Not Settable
This cell displays the total number of unsuccessful clearances after which the Autorclose went into lockout.				
Shot1 Recloses	07	20		Not Settable
This cell displays the total number of single-shot shot reclose attempts				
Shot234 Recloses	07	21		Not Settable
This cell displays the total number of multi-shot reclose attempts				

8 CB STATE MONITORING

CB State monitoring is used to verify the open or closed state of a circuit breaker. Most circuit breakers have auxiliary contacts through which they transmit their status (open or closed) to control equipment such as IEDs. These auxiliary contacts are known as:

- 52A for contacts that follow the state of the CB
- 52B for contacts that are in opposition to the state of the CB

All our devices can be set to monitor both of these types of circuit breaker. If the state is unknown for some reason, an alarm can be raised.

Some CBs provide both sets of contacts. If this is the case, these contacts will normally be in opposite states. Should both sets of contacts be open, this would indicate one of the following conditions:

- Auxiliary contacts/wiring defective
- Circuit Breaker (CB) is defective
- CB is in isolated position

Should both sets of contacts be closed, only one of the following two conditions would apply:

- Auxiliary contacts/wiring defective
- Circuit Breaker (CB) is defective

If any of the above conditions exist, an alarm will be issued after a 5 s time delay. An output contact can be assigned to this function via the programmable scheme logic (PSL). The time delay is set to avoid unwanted operation during normal switching duties.

In the CB CONTROL column there is a setting called **CB Status Input**. This cell can be set at one of the following four options:

- None
- 52A
- 52B
- Both 52A and 52B

Where ‘None’ is selected no CB status is available. Where only 52A is used on its own then the device will assume a 52B signal from the absence of the 52A signal. Circuit breaker status information will be available in this case but no discrepancy alarm will be available. The above is also true where only a 52B is used. If both 52A and 52B are used then status information will be available and in addition a discrepancy alarm will be possible, according to the following table:

Auxiliary Contact Position		CB State Detected	Action
52A	52B		
Open	Closed	Breaker open	Circuit breaker healthy
Closed	Open	Breaker closed	Circuit breaker healthy
Closed	Closed	CB failure	Alarm raised if the condition persists for greater than 5s
Open	Open	State unknown	Alarm raised if the condition persists for greater than 5s

8.1 CB STATE MONITORING LOGIC

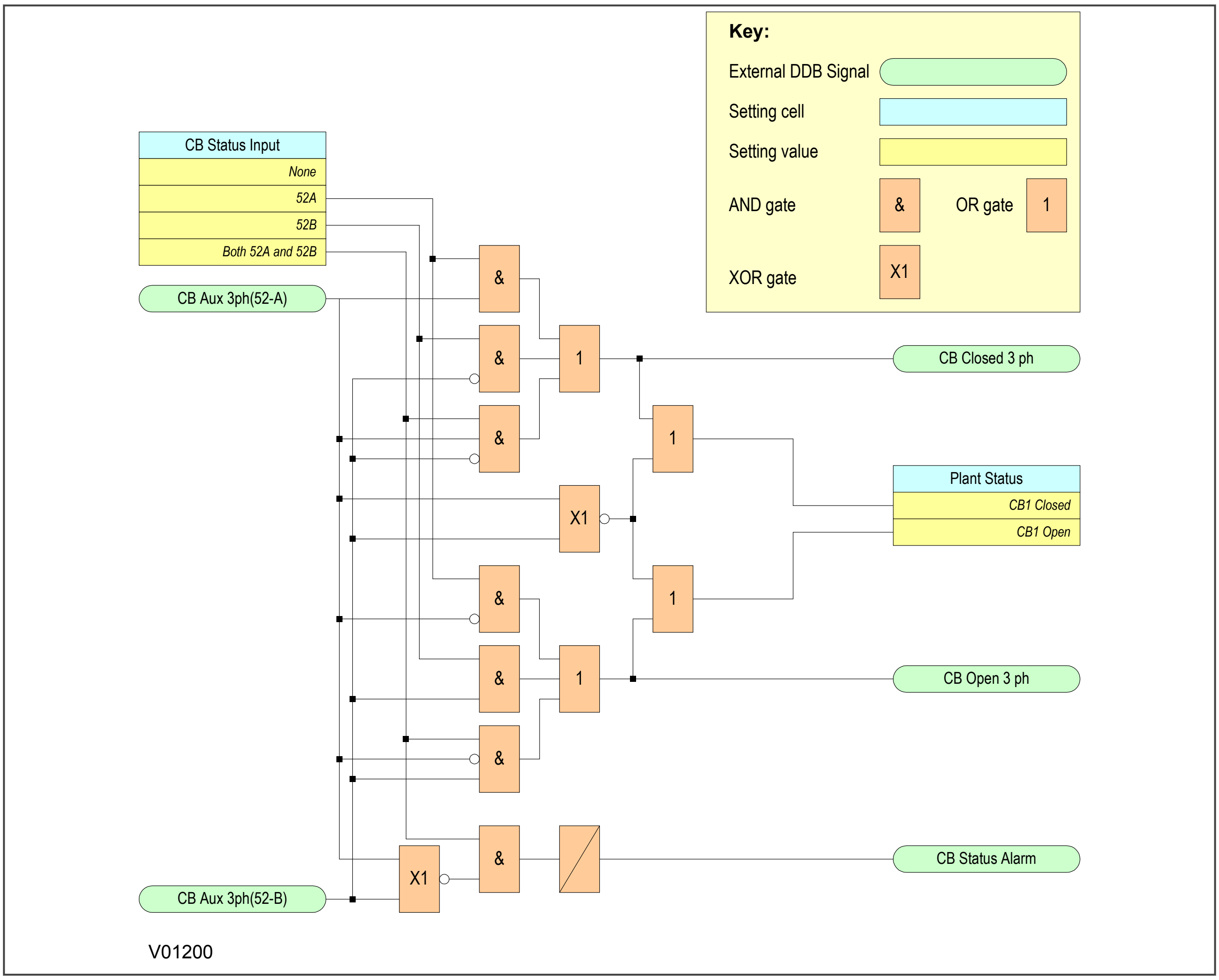


Figure 111: CB State Monitoring logic

9 VOLTAGE TRANSFORMER SUPERVISION

The Voltage Transformer Supervision (VTS) function is used to detect failure of the AC voltage inputs to the IED. This may be caused by internal voltage transformer faults, overloading, or faults on the wiring, which usually results in one or more of the Voltage Transformer (VT) fuses blowing. If there is a failure of the AC voltage input, the IED could misinterpret this as a failure of the actual phase voltages on the power system, which could result in unnecessary tripping of a circuit breaker.

The VTS logic is designed to prevent such a situation by detecting voltage input failures, which are not caused by power system phase voltage failure, and automatically adjusting the configuration of associated protection elements. A time-delayed alarm output is also available.

The following scenarios should be considered regarding the failure of the VT inputs.

- Loss of one or two-phase voltages
- Loss of all three-phase voltages under load conditions
- Absence of three-phase voltages upon line energisation

9.1 LOSS OF ONE ORTWO PHASE VOLTAGES

If the power system voltages are healthy, no Negative Phase Sequence current will be present. If however, one or two of the AC voltage inputs are missing, there will be Negative Phase Sequence voltage present, even if the actual power system phase voltages are healthy. VTS works by using these criteria; that is by detecting Negative Phase Sequence (NPS) voltage without the presence of Negative Phase Sequence current. This, however, works only for the case when one or two voltage inputs are lost.

VTS cannot operate during system fault conditions because of the presence of NPS current.

9.2 LOSS OF ALL THREE PHASE VOLTAGES

If all three voltage inputs are lost, there will be no Negative Phase Sequence quantities present to operate the VTS function. However, under such circumstances, the collapse of all three of the system phase voltages would be apparent, because this would be accompanied by a change in the phase currents. If loss of the three voltage inputs is detected *without* a corresponding change in any of the phase currents, then a VTS condition will be raised.

Any changes in phase currents are detected by comparing the present value with that of one cycle previously.

9.3 ABSENCE OF ALL THREE PHASE VOLTAGES ON LINE ENERGISATION

On line energisation there will be a change in the phase currents as a result of loading or line charging current for example. Under this condition we need an alternative method of detecting three-phase VT failure.

The absence of measured voltage on all three phases on line energization can be as a result of two conditions:

- A three-phase VT failure
- A close-up three-phase fault.

The first condition would require VTS to block the voltage-dependent function and the second would require tripping. To differentiate between these two conditions an overcurrent level detector is used. This will prevent a VTS block from being issued in case of a genuine fault. This element should be set in excess of any non-fault based currents on line energization (load, line charging current, transformer inrush current if applicable), but below the level of current produced by a close-up three-phase fault. If the line is now closed where a three-phase VT failure is present, the overcurrent detector will not operate and a VTS block will be applied. Closing onto a three-phase fault will result in operation of the overcurrent detector and prevent a VTS block being applied.

9.4 VTS IMPLEMENTATION

VTS is implemented in the SUPERVISION column of the relevant settings group, under the sub-heading VT SUPERVISION.

The following settings are relevant for VT Supervision:

- **VTS Status**: determines whether the VTS Operate output will be a blocking output or an alarm indication only
- **VTS PickupThresh**: determines the threshold at which the phase voltage detectors pick up
- **VTS Reset Mode**: determines whether the Reset is to be manual or automatic
- **VTS Time delay**: determines the operating time delay
- **VTS I> Inhibit**: inhibits VTS operation in the case of a phase overcurrent fault
- **VTS I2> Inhibit**: inhibits VTS operation in the case of a negative sequence overcurrent fault

9.5 VTS LOGIC

This logic will only be enabled during a live line condition (as indicated by the pole dead logic) to prevent operation under dead system conditions (i.e. where no voltage will be present and the **VTS I> Inhibit** overcurrent element will not be picked up).

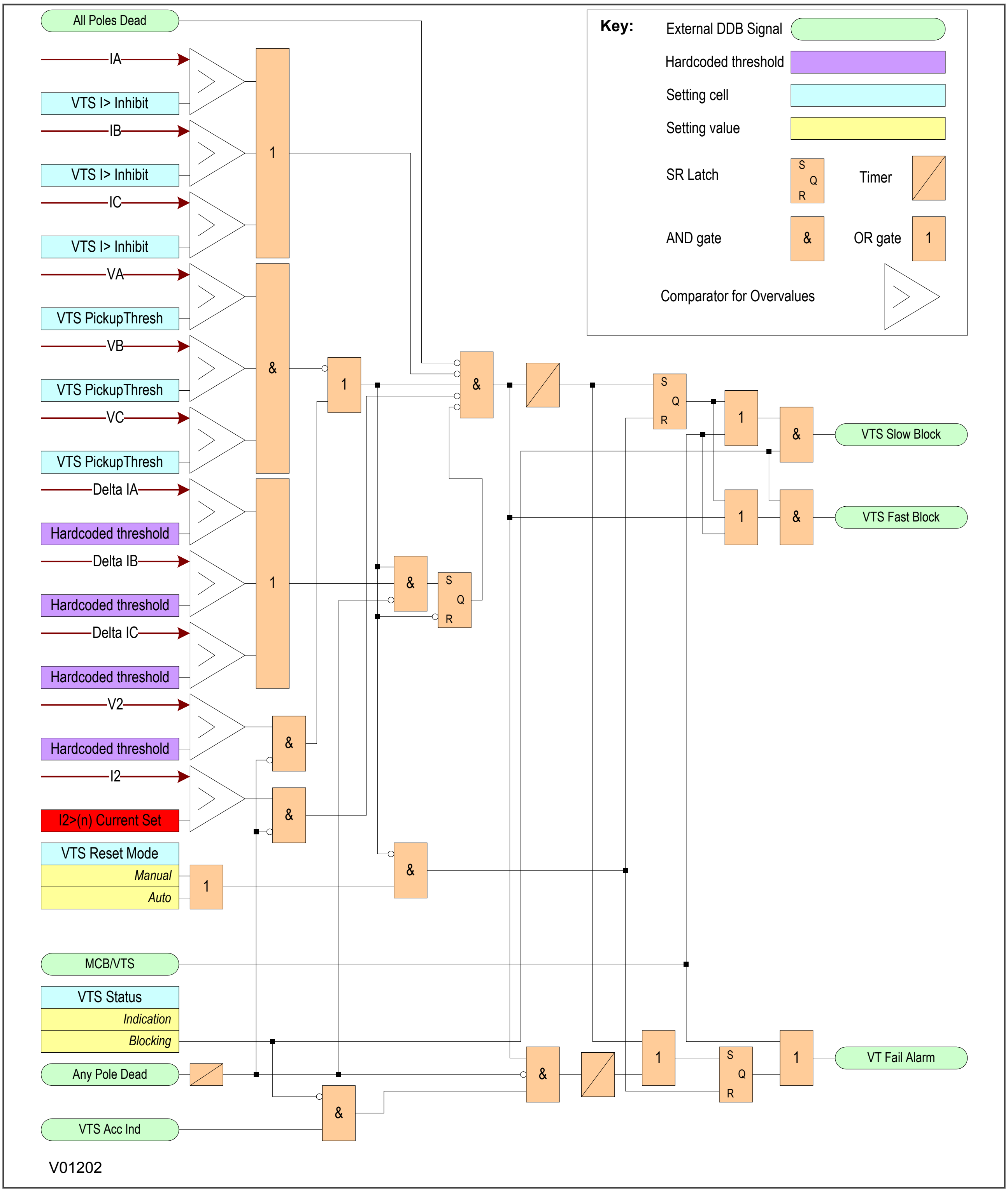


Figure 112: VTS logic

As can be seen from the diagram, the VTS function is inhibited if:

- An All Poles Dead DDB signal is present
- A phase overcurrent condition exists
- A Negative Phase Sequence current exists
- If the phase current changes over the period of 1 cycle

The VTS will operate if:

- All three of the input voltages are lower than the VTS Pickup threshold AND the function is not inhibited by any of the above criteria
- Negative Sequence Voltage is present AND the function is not inhibited by any of the above criteria

The NPS voltage and current detection criteria (used for the case when one or two voltage inputs are lost) is inhibited if an Any Pole Dead signal is present.

9.6 VTS DDB SIGNALS

Ordinal	English Text	Source	Type	Response Function
Description				
380	All Poles Dead	Software	PSL Input	No response
This DDB signal indicates that all poles are dead				
381	Any Pole Dead	Software	PSL Input	No response
This DDB signal indicates that one or more of the poles is dead.				
231	MCB/VTS	Programmable Scheme Logic	PSL Output	No response
This DDB signal initiates a VTS condition from a 3phase miniature circuit breaker				
385	VTS Acc Ind	Fixed Scheme Logic	Hidden	No response
This DDB signal indicates that the VTS accelerate function is active				
350	VTS Fast Block	Software	PSL Input	No response
This DDB signal is an instantaneously blocking output from the VTS which can block other functions				
351	VTS Slow Block	Software	PSL Input	No response
This DDB signal is a purposely delayed output from the VTS which can block other functions				
148	VT Fail Alarm	Software	PSL Input	Alarm self reset event
This DDB signal indicates a Voltage Transformer Fail condition				

9.7 VTS SETTINGS

Menu Text	Col	Row	Default Setting	Available Options
Description				
GROUP 1 SUPERVISION	46	00		
This column contains settings for Supervision.				
VT SUPERVISION	46	01		
The setings under this sub-heading relate to Voltage Transformer Supervision (VTS).				
VTS Status	46	02	Blocking	0=Blocking 1=Indication
This setting determines which operations will occur upon VTS detection. • VTS provides alarm indication only. • VTS provides blocking of voltage dependent protection elements.				
VTS Reset Mode	46	03	Manual	0=Manual 1=Auto
There are two reset methods; Manual reset (via the front panel or remote communications), or Automatic reset (providing the VTS condition has been removed and the 3 phase voltages have been restored for more than 240ms.				
VTS Time Delay	46	04	5	From 1s to 10s step 0.1s
This setting that determines the operate time-delay upon detection of a VTS condition.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
VTS I> Inhibit	46	05	10	From 0.08*I1 to 32*I1 step 0.01*I1
The setting is used to override a VTS blocking signal in the event of a phase fault occurring on the system that could trigger VTS logic.				
VTS I2> Inhibit	46	06	0.05	From 0.05*I1 to 0.5*I1 step 0.01*I1
The setting is used to override a voltage supervision block in the event of a fault occurring on the system with negative sequence current above this setting which could trigger the voltage supervision logic.				
VTS PickupThresh	46	0C	30	From 20*V1 to 120*V1 step 1*V1
This setting sets the threshold for the VTS element.				

10 CURRENT TRANSFORMER SUPERVISION

The Current Transformer Supervision function (CTS) is used to detect failure of the AC current inputs to the IED.

This may be caused by internal current transformer faults, overloading, or faults on the wiring. If there is a failure of the AC current input, the IED could misinterpret this as a failure of the actual phase currents on the power system, which could result in unnecessary tripping of a circuit breaker. Also, interruption in the AC current circuits can cause dangerous CT secondary voltages to be generated.

10.1 CTS IMPLEMENTATION

If the power system currents are healthy, no zero sequence voltage could be derived. If, however, one or more of the AC current inputs are missing, a zero sequence current would be derived, even if the actual power system phase currents are healthy. CTS works by using these criteria; that is by detecting a derived zero sequence current in the absence of a corresponding derived zero sequence voltage.

The voltage transformer connection used must be able to refer zero sequence voltages from the primary to the secondary side. Therefore, this element should only be enabled where the VT is of a five-limb construction, or comprises three single-phase units with the primary star point earthed.

The CTS function is implemented in the SUPERVISION column of the relevant settings group, under the sub-heading CT SUPERVISION.

The following settings are relevant for CT Supervision:

- **CTS Status**: to disable or enable CTS
- **CTS VN< Inhibit**: inhibits CTS if the zero sequence voltage exceeds this setting
- **CTS IN> Set**: determines the level of zero sequence current
- **CTS Time delay**: determines the operating time delay

10.2 CTS LOGIC

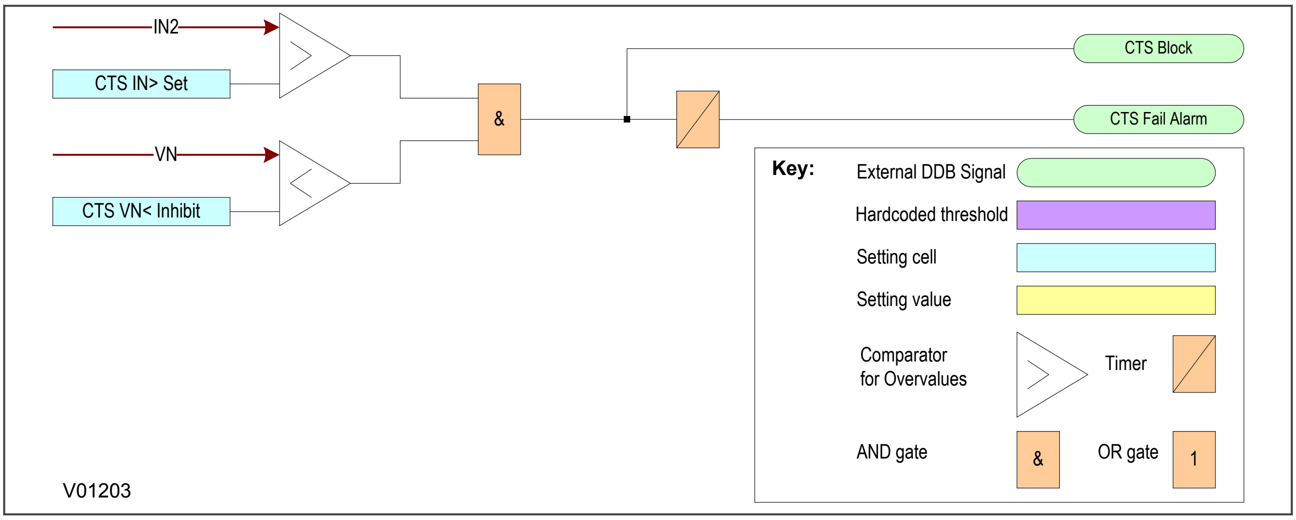


Figure 113: CTS logic diagram

If the derived earth fault current (zero sequence current) exceeds the threshold set by **CTS IN> Set**, a CTS block DDB signal is produced, provided it is not inhibited. the signal is inhibited if the residual voltage is less than the threshold set by **CTS VN< Inhibit**. A CTS alarm is generated after a short time delay defined by the setting **CTS Time Delay**.

10.3 CTS DDB SIGNALS

Ordinal	Signal Name	Source	Type	Response
Description				
149	CT Fail Alarm	Software	PSL Input	Alarm self reset event
This DDB signal indicates a Current Transformer Fail condition				
352	CTS Block	Software	PSL Input	No response
This DDB signal is an instantaneously blocking output from the CTS which can block other functions				

10.4 CTS SETTINGS

Menu Text	Col	Row	Default Setting	Available Options
Description				
GROUP 1 SUPERVISION	46	00		
This column contains settings for Supervision.				
CT SUPERVISION	46	07		
The setings under this sub-heading relate to Current Transformer Supervision (CTS).				
CTS Status	46	08	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables CT Supervision.				
CTS VN< Inhibit	46	09	5	0.5V to 22V step 0.5V
This setting is used to inhibit the CTS element should the zero sequence voltage exceed this threshold. The setting is only visible if CTS Mode is not disabled.				
CTS IN> Set	46	0A	0.1	From 0.08*I1 to 4*I1 step 0.01*I1
This setting determines the level of zero sequence current that must be present for a valid current transformer supervision condition. The setting is visible if CTS Mode is not disabled				
CTS Time Delay	46	0B	5	From 0s to 10s step 1s
This setting sets the operate time delay for the CTS element.				
VTS PickupThresh	46	0C	30	From 20*V1 to 120*V1 step 1*V1
This setting sets the threshold for the VTS element.				

10.5 APPLICATION NOTES

10.5.1 SETTING GUIDELINES

The residual voltage setting, **CTS VN< Inhibit** and the residual current setting, **CTS IN> Set**, should be set to avoid unwanted operation during healthy system conditions. For example:

- **CTS VN< Inhibit** should be set to 120% of the maximum steady state residual voltage.
- **CTS IN> Set** will typically be set below minimum load current.
- **CTS Time Delay** is generally set to 5 seconds.

Where the magnitude of residual voltage during an earth fault is unpredictable, the element can be disabled to prevent protection elements being blocked during fault conditions.

11 POLE DEAD FUNCTION

The Pole Dead Logic is used to indicate that one or more phases of the line are dead. It can also be used to block operation of underfrequency and undervoltage elements where applicable.

A Pole Dead condition is determined by measuring the line currents and/or voltages or by monitoring the status of the circuit breaker auxiliary contacts.

11.1 POLE DEAD LOGIC

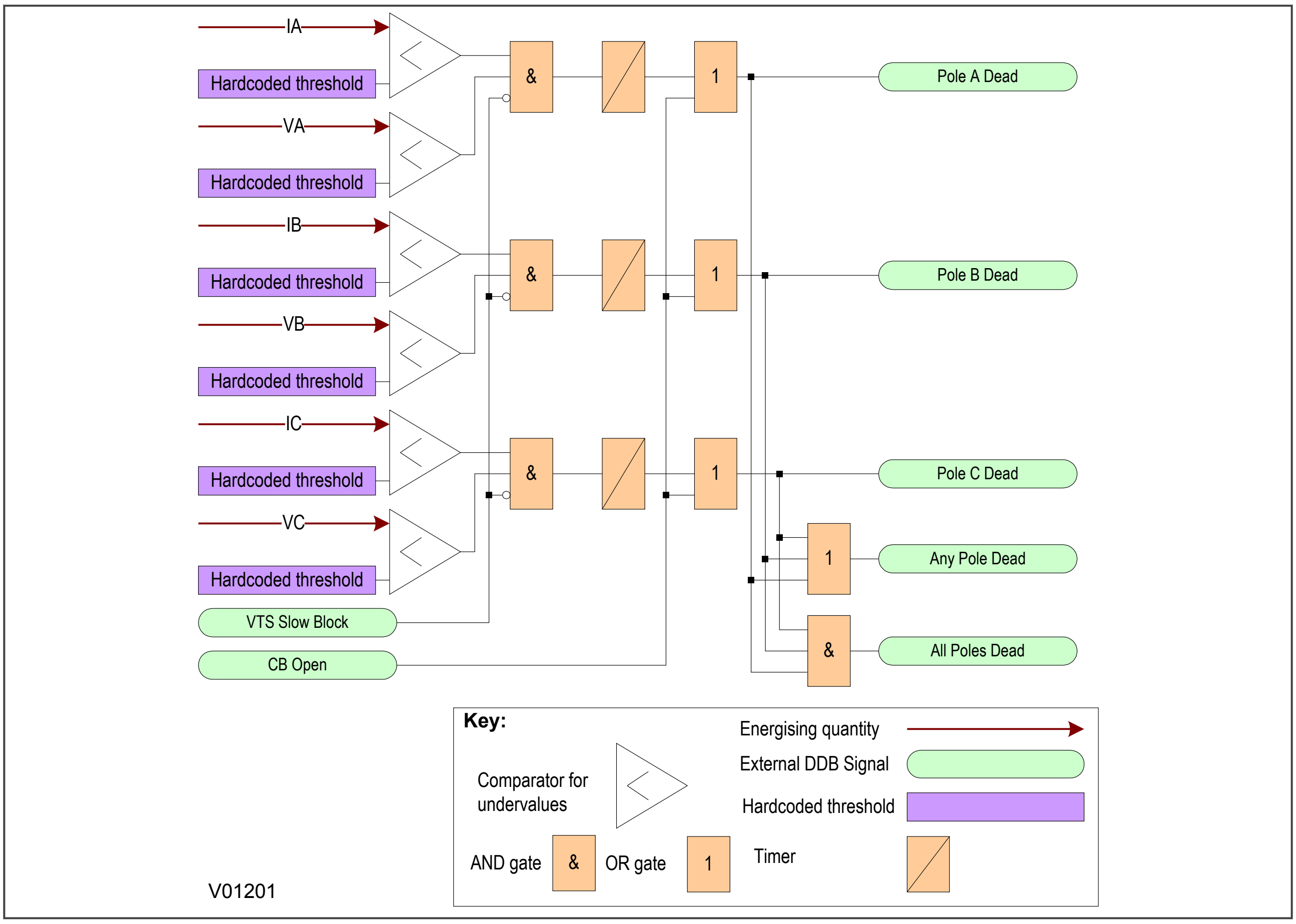


Figure 114: Pole Dead logic

If both the line current and voltage fall below a certain threshold the device will initiate a Pole Dead condition. The undervoltage (V<) and undercurrent (I<) thresholds are hardcoded internally.

If one or more poles are dead, the device will indicate which phase is dead and will also assert the **Any Pole Dead** DDB signal. If all phases are dead the **Any Pole Dead** signal would be accompanied by the **All Poles Dead** signal.

If the VT fails, a **VTS Slow Block** signal is taken from the VTS logic to block the Pole Dead indications that would be generated by the undervoltage and undercurrent thresholds. However, the VTS logic will not block the Pole Dead indications if they are initiated by a **CB Open 3ph** signal. A **CB Open 3ph** signal automatically initiates a Pole Dead condition regardless of the current and voltage measurement.

11.2 POLE DEAD DDB SIGNALS

Ordinal	Signal Name	Source	Type	Response
Description				
378	CB Open 3 ph	Software	PSL Input	Protection event
This DDB signal indicates that the CB is open on all 3 phases				
380	All Poles Dead	Software	PSL Input	No response
This DDB signal indicates that all poles are dead				
381	Any Pole Dead	Software	PSL Input	No response
This DDB signal indicates that one or more of the poles is dead.				
382	Pole Dead A	Software	PSL Input	No response
This DDB signal indicates that the A-phase pole is dead.				
383	Pole Dead B	Software	PSL Input	No response
This DDB signal indicates that the B-phase pole is dead.				
384	Pole Dead C	Software	PSL Input	No response
This DDB signal indicates that the C-phase pole is dead.				

12 DC SUPPLY MONITOR

DC supply monitoring can be a very desirable feature for some applications. The nominal DC Station supply is 48 V DC, which is provided by a very large battery. It is sometimes possible for this nominal supply to fall below or rise above acceptable operational limits. An excessive supply voltage may for example be indicative of overcharging and too low a voltage supply may indicate that the battery is failing. In such cases it is very useful to have DC supply monitoring functionality on some devices, which are being driven by the supply. The P40 Agile products provide such functionality by measuring the auxiliary DC supply fed into the device and processing this information using settings to define certain limits. In addition, the DC Auxiliary Supply value can be displayed on the front panel LCD to a resolution of 0.1 V DC. The measuring range is from 19 V DC to 300 V DC.

12.1 DC SUPPLY MONITOR IMPLEMENTATION

The P40Agile products provide three DC supply monitoring zones; zone 1, zone 2, and zone 3. This allows you to have multiple monitoring criteria. Each zone must be configured to correspond to either an overvoltage condition or an undervoltage condition. A single zone cannot be configured to provide an alarm for both undervoltage and overvoltage conditions. Typically, you would configure zones 1 and 2 for undervoltage conditions, whereby the lowest limit is set very low, and zone 3 for an overvoltage condition whereby the upper limit is very high.

This is best illustrated diagrammatically:

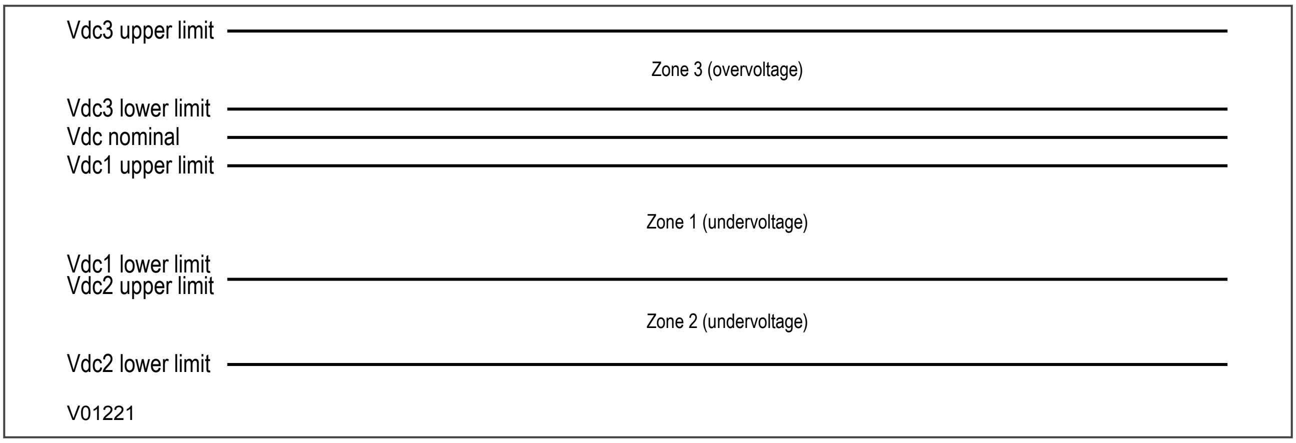


Figure 115: DC Supply Monitor zones

It is possible to have overlapping zones whereby zone 2 upper limit is lower than zone 1 lower limit in the above example.

The DC Supply Monitoring function is implemented using settings in the DC SUP. MONITOR column. There are three sets of settings; one for each of the zones. The settings allow you to:

- Enable or disable the function for each zone
- Set a lower voltage limit for each zone
- Set an upper voltage limit for each zone
- Set a time delay for each zone

12.2 DC SUPPLY MONITOR LOGIC

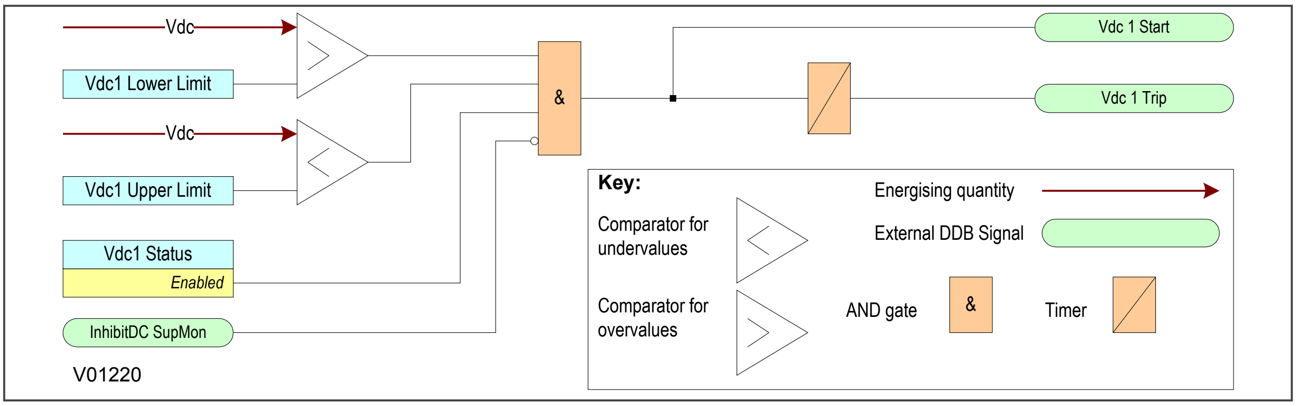


Figure 116: DC Supply Monitor logic

The diagram shows the DC Supply Monitoring logic for stage 1 only. Stages 2 and 3 are identical in principle.

The logic function will work when the setting the **Vdc1 status** cell to enabled and the DC Supply Monitoring inhibit signal (**InhibitDC SupMon**) is low.

If the auxiliary supply voltage (Vdc) exceeds the lower limit AND falls below the upper limit, the voltage is in the unhealthy zone and a Start signal is generated.

12.3 DC SUPPLY MONITOR SETTINGS

Menu Text	Col	Row	Default Setting	Available Options
Description				
DC SUP. MONITOR	2A	00		
This column contains settings for DC Voltage Supply Supervision				
DC ZONE ONE	2A	01		
The settings under this sub-heading apply to zone 1				
Vdc1 Status	2A	02	Enabled	0 = Disabled or 1 = Enabled
This setting enables or disables the DC Supply Monitoring supervision function for zone 1				
Vdc1 Lower Limit	2A	03	88	From 19 to 300 step 1
This setting set the lower threshold for the ZONE setting.				
Vdc1 Upper Limit	2A	04	99	From 19 to 300 step 1
This setting sets the upper threshold for the ZONE setting.				
Vdc1 Timer	2A	05	0.4	From 0s to 7200s step 0.1s
This setting sets the pickup/dropoff for the trip signal of the ZONE Supply Monitoring.				
DC ZONE TWO	2A	11		
The settings under this sub-heading apply to zone 2				
Vdc2 Status	2A	12	Enabled	0 = Disabled or 1 = Enabled
This setting enables or disables the DC Supply Monitoring supervision function for zone 2				
Vdc2 Lower Limit	2A	13	77	From 19 to 300 step 1
This setting set the lower threshold for the ZONE setting.				
Vdc2 Upper Limit	2A	14	88	From 19 to 300 step 1
This setting sets the upper threshold for the ZONE setting.				
Vdc2 Timer	2A	15	0.4	From 0s to 7200s step 0.1s

Menu Text	Col	Row	Default Setting	Available Options
Description				
This setting sets the pickup/dropoff for the trip signal of the ZONE Supply Monitoring.				
DC ZONE THREE	2A	21		
The settings under this sub-heading apply to zone 3				
Vdc3 Status	2A	22	Enabled	0 = Disabled or 1 = Enabled
This setting enables or disables the DC Supply Monitoring supervision function for zone 3				
Vdc3 Lower Limit	2A	23	121	From 19 to 300 step 1
This setting set the lower threshold for the ZONE setting.				
Vdc3 Upper Limit	2A	24	238	From 19 to 300 step 1
This setting sets the upper threshold for the ZONE setting.				
Vdc3 Time Delay	2A	25	0.4	From 0s to 7200s step 0.1s
This setting sets the pickup/dropoff for the trip signal of the ZONE Supply Monitoring.				

12.4 DC SUPPLY MONITOR DDB SIGNALS

Ordinal	Signal Name	Source	Type	Response
Description				
762	Vdc1 Start	Software	PSL Input	Protection event
This DDB signal is the DC Supply Monitoring Zone 1 Start signal				
763	Vdc2 Start	Software	PSL Input	Protection event
This DDB signal is the DC Supply Monitoring Zone 2 Start signal				
764	Vdc3 Start	Software	PSL Input	Protection event
This DDB signal is the DC Supply Monitoring Zone 3 Start signal				
765	Vdc1 Trip	Software	PSL Input	Protection event
This DDB signal is the DC Supply Monitoring Zone 1 Trip signal				
766	Vdc2 Trip	Software	PSL Input	Protection event
This DDB signal is the DC Supply Monitoring Zone 2 Trip signal				
767	Vdc3 Trip	Software	PSL Input	Protection event
This DDB signal is the DC Supply Monitoring Zone 3 Trip signal				
768	InhibitDC SupMon	Programmable Scheme Logic	PSL Input	Protection event
This DDB signal is the DC Supply Monitoring Inhibit Signal				
769	DC Supply Fail	Software	PSL Input	Protection event
This DDB signal is the DC Supply Monitoring Alarm Signal				

13 FAULT LOCATOR

Some models provide fault location functionality. It is possible to identify the fault location by measuring the fault voltage and current magnitude and phases and presenting this information to a Fault Locator function. The fault locator is triggered whenever a fault record is generated, and the subsequent fault location data is included as part of the fault record. This information is also displayed in the **Fault Location** cell in the VIEW RECORDS column. This cell will display the fault location in metres, miles ohms or percentage, depending on the chosen units in the **Fault Location** cell of the MEASURE'T SETUP column.

The Fault Locator uses 12 cycles of the analogue input signals to calculate the fault location. The result is included it in the fault record. The pre-fault and post-fault voltages are also presented in the fault record. The settings associated with the Fault Locator can be found in the FAULT LOCATOR column.

13.1 FAULT LOCATOR SETTINGS

Menu Text	Col	Row	Default Setting	Available Options
Description				
GROUP 1 FAULT LOCATOR	47	00		
This column contains settings for Fault locator				
Line Length	47	01	16000	From 10 to 1000000 step 1
This setting sets the line length in metres.				
Line Length	47	02	10	From 0.005 to 621 step 0.005
This setting sets the line length in miles.				
Line Impedance	47	03	6	From 0.1*V1/I1 to 250*V1/I1 step 0.01*V1/I1
This setting sets the positive sequence line impedance in ohms				
Line Angle	47	04	70	From 20 to 85 step 1
This setting sets the positive sequence line impedance angle in degrees				
KZN Residual	47	05	1	From 0 to 7 step 0.01
This setting sets the residual compensating factor.				
KZN Res Angle	47	06	0	From -90 to 90 step 1
This setting sets the residual compensating factor angle.				

13.2 FAULT LOCATOR SETTINGS EXAMPLE

Assuming the following data for the protected line:

Parameter	Value
CT Ratio	1200/5
VT Ratio	230000/115
Line Length	10 km
Positive sequence line impedance ZL1 (per km|)	0.089+j0.476 Ohms/km
Zero sequence line impedance ZL0	0.34+j1.03 ohms/km
Zero sequence mutual impedance ZM0	0.1068+j0.5712 Ohms/km

The line impedance magnitude and angle settings are calculated as follows:

- Ratio of secondary to primary impedance = CT ratio/VT ratio = 0.12
- Positive sequence line impedance ZL1 (total) = 0.12 x 10(0.484∠79.4°) = 0.58 ∠79.4°
- Therefore set line length = 0.58
- Line angle = 79°

The residual impedance compensation magnitude and angle are calculated using the following formula:

$$KZn = \frac{ZL0 - ZL1}{3ZL1} = \frac{(0.34 + j1.03) - (0.089 + j0.476)}{3(0.484\angle 79.4^\circ)} = \frac{0.6\angle 65.2^\circ}{1.45\angle 79.4^\circ} = 0.41\angle -14.2^\circ$$

Therefore the settings are:

- KZN Residual = 0.41
- KZN Res Angle = -14

14 SYSTEM CHECKS

In some situations it is possible for both "bus" and "line" sides of a circuit breaker to be live when the circuit breaker is open - for example at the ends of a feeder that has a power source at each end. Therefore, it is normally necessary to check that the network conditions on both sides are suitable, before closing the circuit breaker. This applies to both manual circuit breaker closing and autoreclosing. If a circuit breaker were to be closed when the line and bus voltages are both live, with a large phase angle, frequency or magnitude difference between them, the system could be subjected to an unacceptable shock, resulting in loss of stability, and possible damage to connected machines.

The System Checks functionality involves monitoring the voltages on both sides of a circuit breaker, and if both sides are live, performing a synchronisation check to determine whether any differences in voltage magnitude, phase angle or frequency are within permitted limits.

The pre-closing system conditions for a given circuit breaker depend on the system configuration, and for autoreclosing, on the selected autoreclose program. For example, on a feeder with delayed autoreclosing, the circuit breakers at the two line ends are normally arranged to close at different times. The first line end to close usually has a live bus and a dead line immediately before reclosing. The second line end circuit breaker now sees a live bus and a live line.

If there is a parallel connection between the ends of the tripped feeder the frequencies will be the same, but any increased impedance could cause the phase angle between the two voltages to increase. Therefore just before closing the second circuit breaker, it may be necessary to perform a synchronisation check, to ensure that the phase angle between the two voltages has not increased to a level that would cause unacceptable shock to the system when the circuit breaker closes.

If there are no parallel interconnections between the ends of the tripped feeder, the two systems could lose synchronism altogether and the frequency at one end could "slip" relative to the other end. In this situation, the second line end would require a synchronism check comprising both phase angle and slip frequency checks.

If the second line-end busbar has no power source other than the feeder that has tripped; the circuit breaker will see a live line and dead bus assuming the first circuit breaker has re-closed. When the second line end circuit breaker closes the bus will charge from the live line (dead bus charge).

14.1 SYSTEM CHECKS IMPLEMENTATION

The System Checks function is enabled or disabled by the **System Checks** setting in the CONFIGURATION column. If **System Checks** is disabled, the SYSTEM CHECKS menu becomes invisible, and a **SysChks Inactive** DDB signal is set.

The System Checks function provides *Live/Dead Voltage Monitoring*, two stages of *Check Synchronisation* and *System Split* indication.

14.1.1 VOLTAGE MONITORING

The P40Agile voltage products have four voltage transformer inputs; three for a three-phase “Main VT” input and a measurement VT which can be used for System Check purposes.

Depending on the primary system arrangement, the main three-phase VT may be located on either the busbar side or the line side of the circuit breaker, with the measurement VT being located on the other side. Therefore, the device has to be told the location of the main VT. This is done with the **Main VT Location** setting in the TRANS. RATIOS menu. The default setting is 'Line'.

The measurement VT may be connected to either a phase-to-phase or phase to neutral voltage. The C/S Input setting in the TRANS. RATIOS menu should be set as appropriate.

The settings in the VOLTAGE MONITORS sub-heading allow you to define the threshold at which a voltage is considered live, and a threshold at which the voltage is considered dead. These thresholds apply to both line and bus sides. If the measured voltage falls below the **Dead Voltage** setting, a DDB signal is generated

(**Dead Bus**, or **Dead Line**, depending on which side is being measured). If the measured voltage exceeds the **Live Voltage** setting, a DDB signal is generated (**Live Bus**, or **Live Line**, depending on which side is being measured).

14.1.2 CHECK SYNCHRONISATION

The device provides two stages of Check Synchronisation. The first stage (CS1) is designed for general use, whereby the frequencies and phase angles of both sides are compared and if the difference is within set limits, the circuit breaker is allowed to close. The second stage (CS2) is similar to stage, but has an additional adaptive setting. CS2 is used for cases where the two sides are out of synchronism and one frequency is slipping continuously with respect to another. If the closing time of the Circuit breaker is known, the close command can be issued at a definite point in the cycle such that the CB closes at the point when both sides are in phase.

The settings specific to Check Synchronisation are found under the sub-heading CHECK SYNC in the SYSTEM CHECKS column. The only difference between the CS1 settings and the CS2 settings is that **CS2 Slip Control** setting has an option for predictive closure of CB ('Freq + CB Comp').

14.1.3 SYSTEM SPLIT

If the line side and bus side are of the same frequency (i.e. in synchronism) but have a large phase angle between them (180° +/- the set limits), the system is said to be 'Split'. If this is the case, the device will detect this and issue an alarm signal indicating this.

The settings specific to System Split functionality are found under the sub-heading SYSTEM SPLIT in the SYSTEM CHECKS column.

14.2 SYSTEM CHECK LOGIC

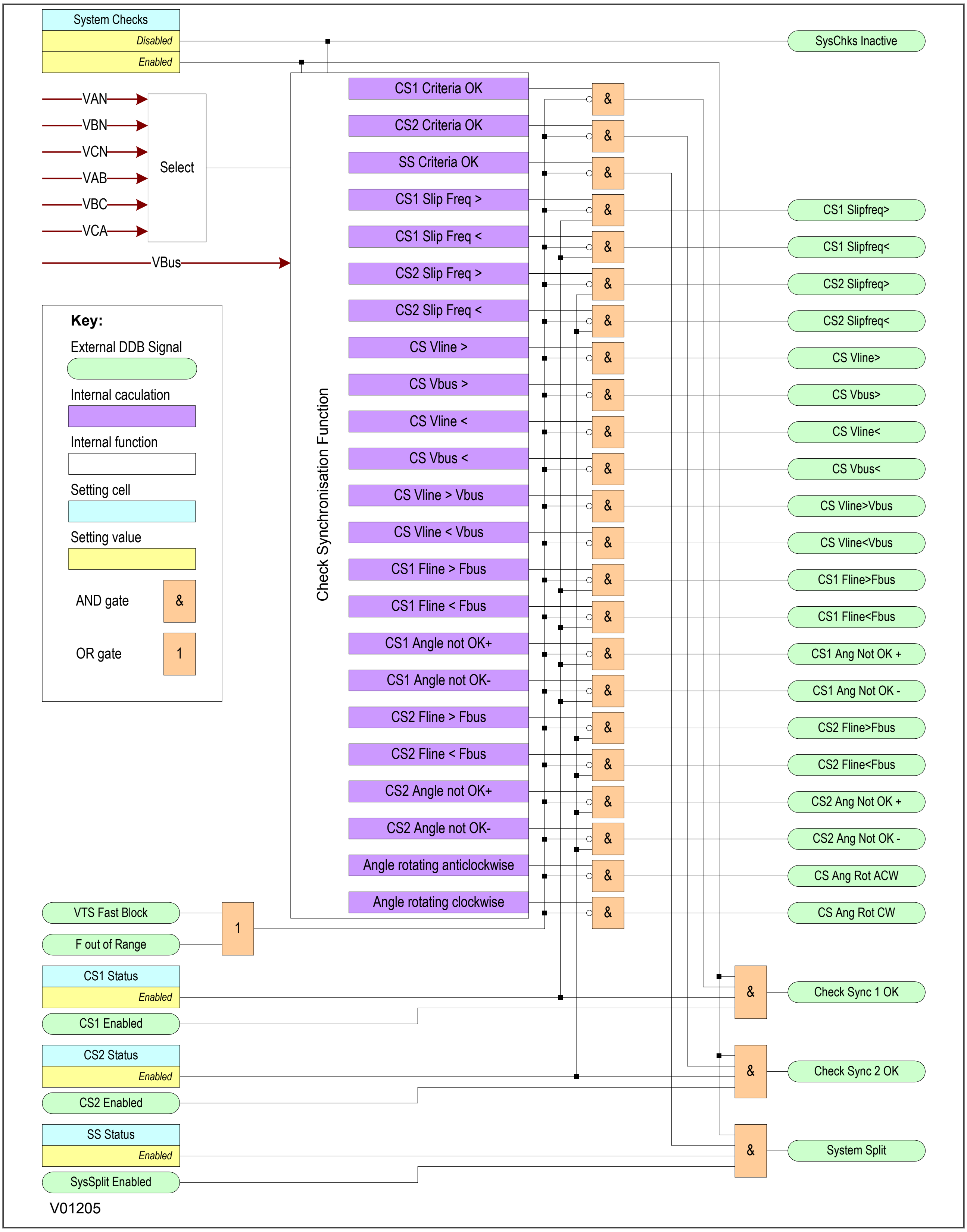


Figure 117: System Check logic

14.3 SYSTEM CHECK PSL

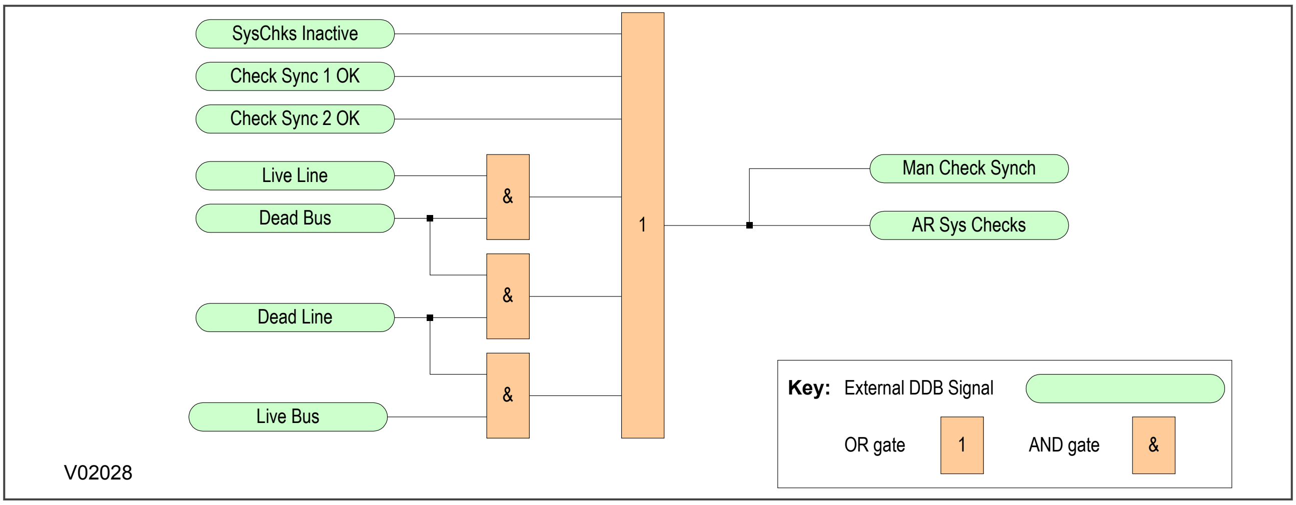


Figure 118: System Check PSL

14.4 SYSTEM CHECK SETTINGS

Menu Text	Col	Row	Default Setting	Available Options
Description				
GROUP 1 SYSTEM CHECKS	48	00		
This column contains settings for the Voltage Monitors and the Check Synchronism function.				
VOLTAGE MONITORS	48	14		
The settings under this sub-heading relate to Voltage Monitors				
Live Voltage	48	15	32	From 1*V1 to 132*V1 step 0.5*V1
This setting sets the minimum voltage threshold above which a line or bus is considered 'Live'.				
Dead Voltage	48	16	13	From 1*V1 to 132*V1 step 0.5*V1
This setting sets the maximum voltage threshold below which a line or bus is considered 'Dead'.				
CHECK SYNC.	48	17		
The settings under this sub-heading relate to Check Synchronism.				
CS1 Status	48	18	Enabled	0 = Disabled or 1 = Enabled
This setting enables or disables the first stage Check Synchronism element.				
CS1 Phase Angle	48	19	20	From 5 to 90 step 1
This setting sets the maximum phase angle difference between the line and bus voltage for the first stage Phase Angle check to be satisfactory.				
CS1 Slip Control	48	1A	Frequency	0=None 1=Timer 2=Frequency 3=Both
This setting determines whether the first stage Slip Control is by slip frequency, by timer, or a combination of both.				
CS1 Slip Freq	48	1B	0.05	From 0.01Hz to 1Hz step 0.01Hz
This seting sets the maximum frequency difference between the line and bus voltage for the for the first stage Slip Frequency check to be satisfactory.				
CS1 Slip Timer	48	1C	1	From 0s to 99s step 0.01s
This setting sets the minimum operate time delay for the first stage Check Syncrhonism element.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
CS2 Status	48	1D	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the second stage Check Synchronism element.				
CS2 Phase Angle	48	1E	20	From 5 to 90 step 1
This setting sets the maximum phase angle difference between the line and bus voltage for the second stage Phase Angle check to be satisfactory.				
CS2 Slip Control	48	1F	Frequency	0=None 1=Timer 2=Frequency 3=Timer + Freq 4=Freq + CB Comp
This setting determines whether the second stage Slip Control is by slip frequency, by timer, or a combination of both.				
CS2 Slip Freq	48	20	0.05	From 0.01Hz to 1Hz step 0.01Hz
This seting sets the maximum frequency difference between the line and bus voltage for the for the second stage Slip Frequency check to be satisfactory.				
CS2 Slip Timer	48	21	1	From 0s to 99s step 0.01s
This setting sets the minimum operate time delay for the second stage Check Syncrhonism element.				
CS Undervoltage	48	22	54	From 10 to 132 step 0.5
This setting sets the check sync undervoltage threshold				
CS Overvoltage	48	23	130	From 40 to 185 step 0.5
This setting sets the check sync overvoltage threshold				
CS Diff Voltage	48	24	6.5	From 1 to 132 step 0.5
This setting sets the maximum voltage magnitude difference between the line and bus, which is allowed for the check to be satisfactory.				
CS Voltage Block	48	25	V<	0=None 1=V< 2=V> 3=Vdiff> 4=V< and V> 5=V< and Vdiff> 6=V> and Vdiff> 7=V< V> and Vdiff
This settng determines which condition or conditions must be satisfied in order for the Check Synchrnism condition to be satisfactory. The setting is an 8-bit binary string (data type G41).				
SYSTEM SPLIT	48	26		
The settins under this sub-headin relate to System Split condition (System Split is where a line and bus are detected, which are not possible to synchronise).				
SS Status	48	27	Enabled	0 = Disabled or 1 = Enabled
This setting enables or disables the System Split function.				
SS Phase Angle	48	28	120	From 90 to 175 step 1
This setting sets the maximum phase angle difference between the line and bus voltage, which must be exceeded for the System Split condition to be satisfied.				
SS Under V Block	48	29	Enabled	0 = Disabled or 1 = Enabled
This setting activates the Undervoltage blocking.				
SS Undervoltage	48	2A	54	From 10 to 132 step 0.5
This setting sets an Undervoltage threshold above which the line and bus voltage must be, to satisfy the System Split condition.				
SS Timer	48	2B	1	From 0s to 99s step 0.01s
The System Split output remains set for as long as the System Split criteria are true, or for a minimum period equal to the System Split Timer setting, whichever is longer.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
CB Close Time	48	2F	0.05	From 0s to 0.5s step 0.001s
This setting sets the CB closing time, from receipt of a CB close command until the main contacts touch.				

14.5 SYSTEM CHECK DDB SIGNALS

Ordinal	Signal Name	Source	Type	Response
Description				
166	System Split	Software	PSL Input	Alarm self reset event
This DDB signal is the System Split alarm				
443	Live Line	Software	PSL Input	No response
This DDB signal indicates a Live Line				
444	Dead Line	Software	PSL Input	No response
This DDB signal indicates a Dead Line				
445	Live Bus	Software	PSL Input	No response
This DDB signal indicates a Live Bus				
446	Dead Bus	Software	PSL Input	No response
This DDB signal indicates a Dead Bus				
447	Check Sync 1 OK	Software	PSL Input	No response
This DDB signal indicates that Check Synchronism stage 1 (CS1) is OK				
448	Check Sync 2 OK	Software	PSL Input	No response
This DDB signal indicates that Check Synchronism stage 2 (CS2) is OK				
449	SysChks Inactive	Software	PSL Input	No response
This DDB signal indicates that all System Checks are inactive				
450	CS1 Enabled	Programmable Scheme Logic	PSL Output	No response
This DDB signal enables CS1				
451	CS2 Enabled	Programmable Scheme Logic	PSL Output	No response
This DDB signal enables CS2				
452	SysSplit Enabled	Programmable Scheme Logic	PSL Output	No response
This DDB signal enables System Split				
471	CS1 Slipfreq>	Software	PSL Input	Protection event
This DDB signal indicates that the CS1 Slip frequency is above the set threshold				
472	CS1 Slipfreq<	Software	PSL Input	No response
This DDB signal indicates that the CS1 Slip frequency is below the set threshold				
473	CS2 Slipfreq>	Software	PSL Input	Protection event
This DDB signal indicates that the CS2 Slip frequency is above the set threshold				
474	CS2 Slipfreq<	Software	PSL Input	No response
This DDB signal indicates that the CS2 Slip frequency is below the set threshold				
489	CS Vline<	Software	PSL Input	No response
This DDB signal indicates that the line voltage is less than the Check Synchronism Undervoltage threshold				
490	CS Vbus<	Software	PSL Input	No response
This DDB signal indicates that the bus voltage is less than the Check Synchronism Undervoltage threshold				
491	CS Vline>	Software	PSL Input	No response

Ordinal	Signal Name	Source	Type	Response
Description				
This DDB signal indicates that the line voltage is more than the Check Synchronism Overvoltage threshold				
492	CS Vbus>	Software	PSL Input	No response
This DDB signal indicates that the bus voltage is more than the Check Synchronism Overvoltage threshold				
493	CS Vline>Vbus	Software	PSL Input	No response
This DDB signal indicates that the line voltage is greater than the bus voltage + the CS diff voltage setting				
494	CS Vline<Vbus	Software	PSL Input	No response
This DDB signal indicates that the bus voltage is greater than the line voltage + the CS diff voltage setting				
495	CS1 Fline>Fbus	Software	PSL Input	No response
This DDB signal indicates that the line frequency is greater than the bus frequency + the CS1 slip frequency setting				
496	CS1 Fline<Fbus	Software	PSL Input	No response
This DDB signal indicates that the bus frequency is greater than the line frequency + the CS1 slip frequency setting				
497	CS1 Ang Not OK +	Software	PSL Input	No response
This DDB signal indicates that the line angle has crossed 0 degrees into the 0 to 180 quadrant.				
498	CS1 Ang Not OK -	Software	PSL Input	No response
This DDB signal indicates that the line angle has crossed 0 degrees into the 0 to -180 quadrant.				
519	CS2 Fline>Fbus	Software	PSL Input	No response
This DDB signal indicates that the line frequency is greater than the bus frequency + the CS2 slip frequency setting				
520	CS2 Fline<Fbus	Software	PSL Input	No response
This DDB signal indicates that the bus frequency is greater than the line frequency + the CS2 slip frequency setting				
521	CS2 Ang Not OK +	Software	PSL Input	No response
This DDB signal indicates that the line angle has crossed 0 degrees into the 0 to 180 quadrant.				
522	CS2 Ang Not OK -	Software	PSL Input	No response
This DDB signal indicates that the line angle has crossed 0 degrees into the 0 to -180 quadrant.				
523	CS Ang Rot ACW	Software	PSL Input	No response
This DDB signal indicates that the Line/Bus phase angle is rotating anti-clockwise				
524	CS Ang Rot CW	Software	PSL Input	No response
This DDB signal indicates that the Line/Bus phase angle is rotating clockwise				

14.6 APPLICATION NOTES

14.6.1 USE OF CHECK SYNC 2 AND SYSTEM SPLIT

Check Sync 2 (CS2) and System Split functions are included for situations where the maximum permitted slip frequency and phase angle for synchronism checks can change due to adverse system conditions. A typical application is on a closely interconnected system, where synchronism is normally retained when a feeder is tripped. But under some circumstances, with parallel interconnections out of service, the feeder ends can drift out of synchronism when the feeder is tripped. Depending on the system and machine characteristics, the conditions for safe circuit breaker closing could be, for example:

Condition 1: For synchronized systems, with zero or very small slip:

- Slip˛50 mHz; phase angle <30°

Condition 2: For unsynchronized systems, with significant slip:

- Slip˛250 mHz; phase angle <10° and decreasing

By enabling both CS1 and CS2, the device can be configured to allow CB closure if either of the two conditions is detected.

For manual circuit breaker closing with synchronism check, some utilities might prefer to arrange the logic to check initially for condition 1 only. However, if a System Split is detected before the condition 1 parameters are satisfied, the device will switch to checking for condition 2 parameters instead, based on the assumption that a significant degree of slip must be present when system split conditions are detected. This can be arranged by suitable PSL logic, using the System Check DDB signals.

14.6.2 SLIP CONTROL

Slip control can be achieved by timer, by frequency or by both. The settings CS1 Slip Control and CS2 Slip Control are used to determine which type of slip control is to be used. As the device supports direct measurement of frequency, you would normally use frequency only.

If you are using Slip Control by Timer, the combination of Phase Angle and Timer settings determines an effective maximum slip frequency, calculated as:

$$2A/360T - \text{for CS1}$$

$$A/360T - \text{for CS2}$$

where:

- A = Phase Angle setting in degrees
- T = Slip Timer setting in seconds

Examples

For CS1, where the Phase Angle setting is 30° and the Timer setting is 3.3 s, the “slipping” vector has to remain within +/- 30° of the reference vector for at least 3.3 seconds. Therefore a synchronisation check output will not be given if the slip is greater than 2 x 30° in 3.3 seconds.

Therefore, the maximum slip frequency = 2x30/360x3.3 = 0.0505 hz.

For CS2, where the Phase Angle setting is 10° and the Timer setting is 0.1 sec., the slipping vector has to remain within 10° of the reference vector, with the angle decreasing, for 0.1 sec. When the angle passes through zero and starts to increase, the synchronisation check output is blocked. Therefore an output will not be given if the slip is greater than 10° in 0.1 second.

Therefore, the maximum slip frequency = 10/360x0.1 = 0.278 Hz.

Slip control by Timer is not practical for “large slip/small phase angle” applications, because the timer settings required are very small, sometimes less than 0.1 seconds. For these situations, slip control by frequency is better.

If Slip Control by Frequency + Timer is selected, for an output to be given, the slip frequency must be less than BOTH the set Slip Freq. value and the value determined by the Phase Angle and Timer settings.

14.6.3 PREDICTIVE CLOSURE OF CIRCUIT BREAKER

The setting **CS2 Slip Control** setting contains an option for compensating the time taken to close the CB. When set to provide CB Close Time compensation, a predictive approach is used to close the circuit breaker ensuring that closing occurs at close to 0º therefore minimising the impact to the power system. The actual closing angle is subject to the constraints of the existing product architecture, i.e. the protection task runs twice per power system cycle, based on frequency tracking over the frequency range of 40 Hz to 70 Hz.

14.6.4 VOLTAGE AND PHASE ANGLE CORRECTION

For the Check Synchronisation function, the device needs to convert measured secondary voltages into primary voltages. In some applications, VTs either side of the circuit breaker may have different VT Ratios. In such cases, a magnitude correction factor is required.

There are some applications where the main VT is on the HV side of a transformer and the Check Sync VT is on the LV side, or vice-versa. If the vector group of the transformer is not "0", the voltages are not in phase, so phase correction is also necessary.

The correction factors are as follows and are located in the TRANS. RATIOS column:

- C/S V kSM, where kSM is the voltage correction factor.
- C/S Phase kSA, where kSA is the angle correction factor.

Assuming C/S input setting is A-N, then:

The line and bus voltage magnitudes are matched if $V_{a\ sec} = V_{cs\ sec}$ x C/S V kSA

The line and bus voltage angles are matched if $\angle V_{a\ sec} = \angle V_{cs\ sec}$ + C/S Phase kSA

> *Note:*
> *Setting the correct VT ratios will not adjust the k factors and will have no impact on the Check Synchronisation functionality. The Check Synchronisation only takes into account the k factors setting.*

> *Note:*
> *The VT ratios have impacts on the presentation of the related measurements or settings in terms of primary or secondary values.*

> *Note:*
> *The CS voltage settings in the SYSTEM CHECKS column are all referenced by the Main VT ratios.*

> *Note:*
> *The* ***C/S Bus-Line Ang*** *measurement takes into account the* ***C/S Phase kSA*** *setting.*

The following application scenarios show where the voltage and angular correction factors are applied to match different VT ratios:

Scenario	Physical Ratios (ph-N Values)				Setting Ratios				CS Correction Factors	
	Main VT Ratio		CS VT Ratio		Main VT Ratio (ph-ph) Always		CS VT Ratio		kSM	kSA
	Pri (kV)	Sec (V)	Pri (kV)	Sec (V)	Pri (kV)	Sec (V)	Pri (kV)	Sec (V)		
1	220/√3	110/√3	132/√3	100/√3	220	110	132	100	1.1	30º
2	220/√3	110/√3	220/√3	110	220	110	127	110	0.577	0º
3	220/√3	110/√3	220/√3	110/3	220	110	381	110	1.732	0º

15 TRIP CIRCUIT SUPERVISION

In most protection schemes, the trip circuit extends beyond the IED enclosure and passes through components such as links, relay contacts, auxiliary switches and other terminal boards. Such complex arrangements may require dedicated schemes for their supervision.

There are two distinctly separate parts to the trip circuit; the trip path, and the trip coil. The trip path is the path between the IED enclosure and the CB cubicle. This path contains ancillary components such as cables, fuses and connectors. A break in this path is possible, so it is desirable to supervise this trip path and to raise an alarm if a break should appear in this path.

The trip coil itself is also part of the overall trip circuit, and it is also possible for the trip coil to develop an open-circuit fault.

15.1 TRIP CIRCUIT SUPERVISION SCHEME 1

This scheme provides supervision of the trip coil with the CB open or closed, however, it does not provide supervision of the trip path whilst the breaker is open. Also, the CB status can be monitored when a self-reset trip contact is used. However, this scheme is incompatible with latched trip contacts, as a latched contact will short out the opto-input for a time exceeding the recommended Delayed Drop-off (DDO) timer setting of 400 ms, and therefore does not support CB status monitoring. If you require CB status monitoring, further opto-inputs must be used.

Note:
A 52a CB auxiliary contact follows the CB position. A 52b auxiliary contact is the opposite.

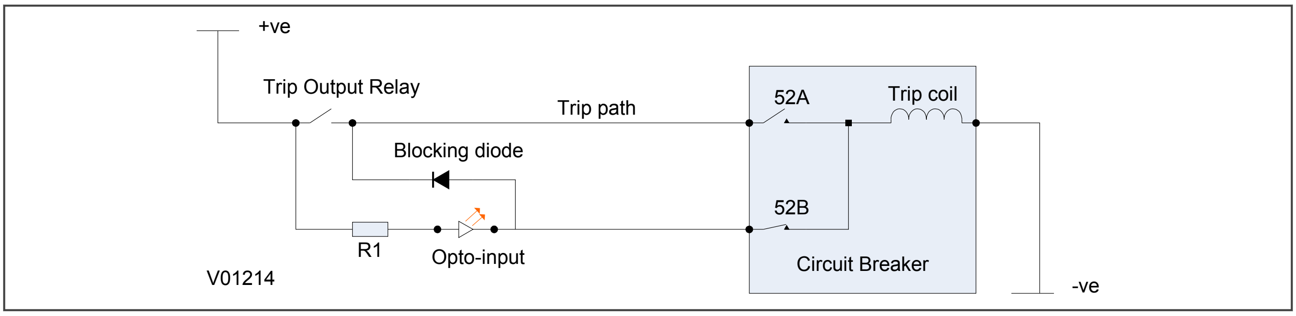


Figure 119: TCS Scheme 1

When the CB is closed, supervision current passes through the opto-input, blocking diode and trip coil. When the CB is open, supervision current flows through the opto-input and into the trip coil via the 52b auxiliary contact. This means that *Trip Coil* supervision is provided when the CB is either closed or open, however *Trip Path* supervision is only provided when the CB is closed. No supervision of the trip path is provided whilst the CB is open (pre-closing supervision). Any fault in the trip path will only be detected on CB closing, after a 400 ms delay.

15.1.1 RESISTOR VALUES

The supervision current is a lot less than the current required by the trip coil to trip a CB. The opto-input limits this supervision current to less than 10 mA. If the opto-input were to be short-circuited however, it could be possible for the supervision current to reach a level that could trip the CB. For this reason, a resistor R1 is often used to limit the current in the event of a short-circuited opto-input. This limits the current to less than 60 mA. The table below shows the appropriate resistor value and voltage setting for this scheme.

Trip Circuit Voltage	Resistor R1 (ohms)
24/27	620

Trip Circuit Voltage	Resistor R1 (ohms)
30/34	820
48/54	1.2 k
110/125	2.7 k
220/250	5.2 k

Warning:
If your IED has Opto Mode settings (Opto 9 Mode, Opto 10 Mode, Opto 11 Mode) in the OPTO CONFIG column, these settings MUST be set to 'TCS'.

15.1.2 PSL FOR TCS SCHEME 1

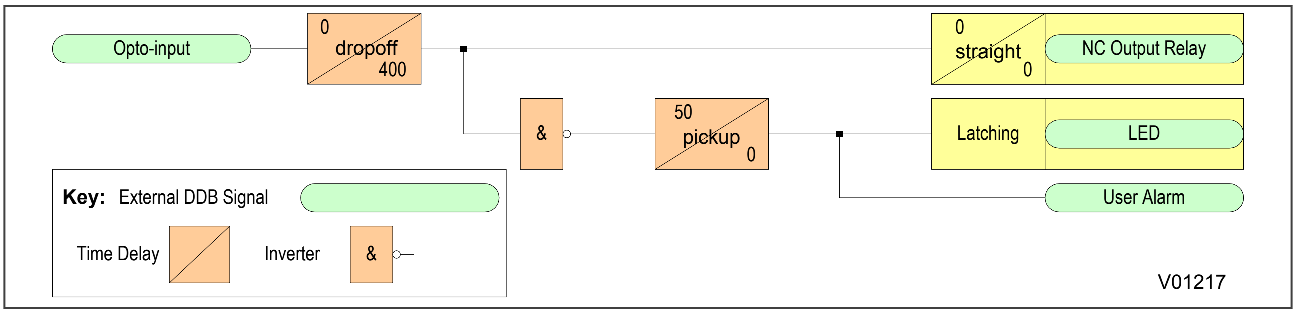


Figure 120: PSL for TCS Scheme 1

The opto-input can be used to drive a Normally Closed Output Relay, which in turn can be used to drive alarm equipment. The signal can also be inverted to drive a latching programmable LED and a user alarm DDB signal.

The DDO timer operates as soon as the opto-input is energised, but will take 400 ms to drop off/reset in the event of a trip circuit failure. The 400 ms delay prevents a false alarm due to voltage dips caused by faults in other circuits or during normal tripping operation when the opto-input is shorted by a self-reset trip contact. When the timer is operated the NC (normally closed) output relay opens and the LED and user alarms are reset.

The 50 ms delay on pick-up timer prevents false LED and user alarm indications during the power up time, following a voltage supply interruption.

15.2 TRIP CIRCUIT SUPERVISION SCHEME 2

Much like TCS scheme 1, this scheme provides supervision of the trip coil with the breaker open or closed but does not provide pre-closing supervision of the trip path. However, using two opto-inputs allows the IED to correctly monitor the circuit breaker status since they are connected in series with the CB auxiliary contacts. This is achieved by assigning Opto-input 1 to the 52a contact and Opto-input 2 to the 52b contact. Provided the **Circuit Breaker Status** setting in the CB CONTROL column is set to '52a and 52b', the IED will correctly monitor the status of the breaker. This scheme is also fully compatible with latched contacts as the supervision current will be maintained through the 52b contact when the trip contact is closed.

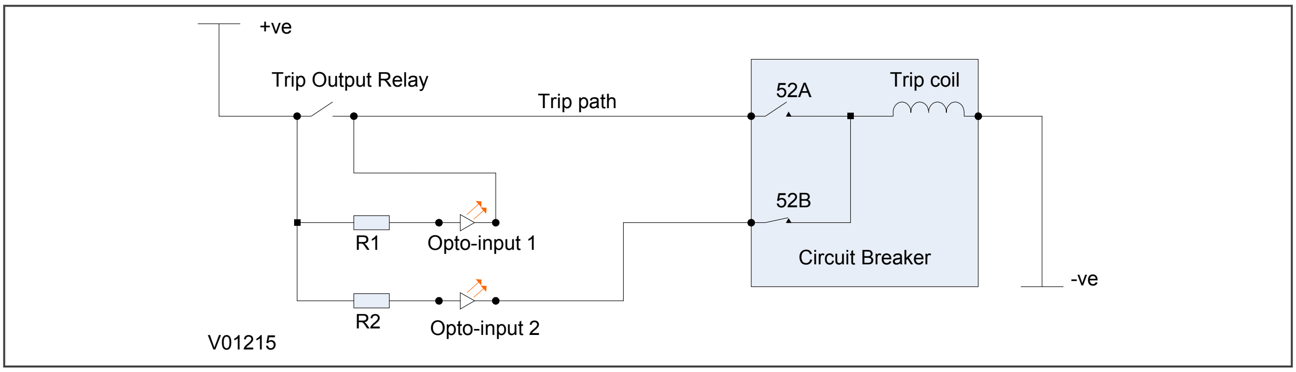


Figure 121: TCS Scheme 2

When the breaker is closed, supervision current passes through opto input 1 and the trip coil. When the breaker is open current flows through opto input 2 and the trip coil. As with scheme 1, no supervision of the trip path is provided whilst the breaker is open. Any fault in the trip path will only be detected on CB closing, after a 400 ms delay.

15.2.1 RESISTOR VALUES

As with scheme 1, optional resistors R1 and R2 can be added to prevent tripping of the CB if either opto-input is shorted. The table below shows the appropriate resistor value and voltage setting for this scheme.

Trip Circuit Voltage	Resistor R1 and R2 (ohms)
24/27	620
30/34	820
48/54	1.2 k
110/125	2.7 k
220/250	5.2 k

Warning:
If your IED has Opto Mode settings (Opto 9 Mode, Opto 10 Mode, Opto 11 Mode) in the OPTO CONFIG column, these settings MUST be set to 'TCS'.

15.2.2 PSL FOR TCS SCHEME 2

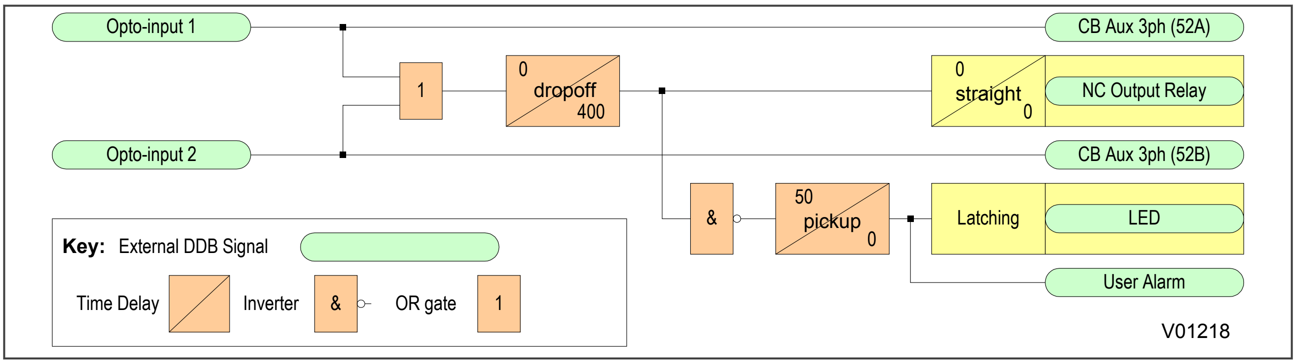


Figure 122: PSL for TCS Scheme 2

The PSL for this TCS scheme 2 is practically the same as that of TCS scheme 1. The main difference is that both opto-inputs must be low before a trip circuit fail alarm is given.

15.3 TRIP CIRCUIT SUPERVISION SCHEME 3

TCS Scheme 3 is designed to provide supervision of the trip coil with the breaker open or closed, but unlike TCS schemes 1 and 2, it also provides pre-closing supervision of the trip path. Since only one opto-input is used, this scheme is not compatible with latched trip contacts. If you require CB status monitoring, further opto-inputs must be used.

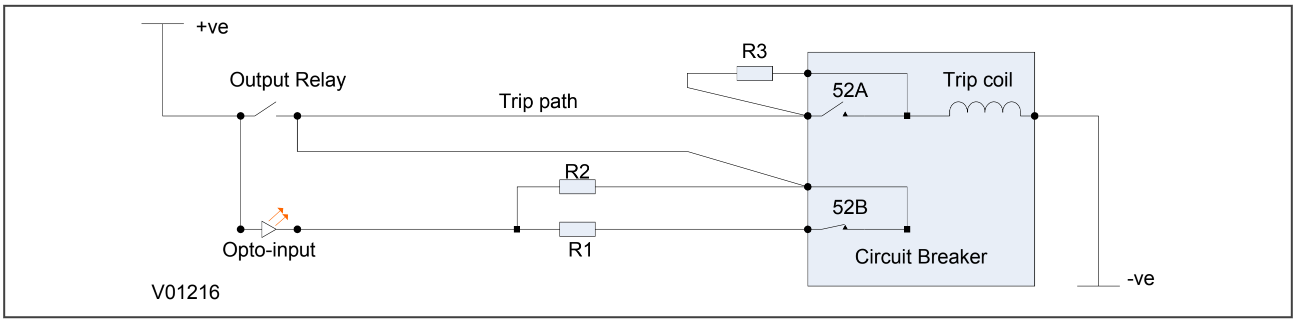


Figure 123: TCS Scheme 3

When the CB is closed, supervision current passes through the opto-input, resistor R2 and the trip coil. When the CB is open, current flows through the opto-input, resistors R1 and R2 (in parallel), resistor R3 and the trip coil. Unlike schemes 1 and 2, supervision current is maintained through the trip path with the breaker in either state, therefore providing pre-closing supervision.

15.3.1 RESISTOR VALUES

As with TCS schemes 1 and 2, resistors R1 and R2 are used to prevent false tripping, if the opto-input is accidentally shorted. However, unlike the other two schemes, this scheme is dependent on the position and value of these resistors. Removing them would result in incomplete trip circuit monitoring. The table below shows the resistor values and voltage settings required for satisfactory operation.

Trip Circuit Voltage	Resistor R1 and R2 (ohms)	Resistor R3
24/27	620	330
30/34	820	430
48/54	1.2 k	620
110/125	2.7 k	1.5 k
220/250	5.2 k	2.7 k

Warning:
If your IED has Opto Mode settings (Opto 9 Mode, Opto 10 Mode, Opto 11 Mode) in the OPTO CONFIG column, these settings MUST be set to 'TCS'.

15.3.2 PSL FOR TCS SCHEME 3

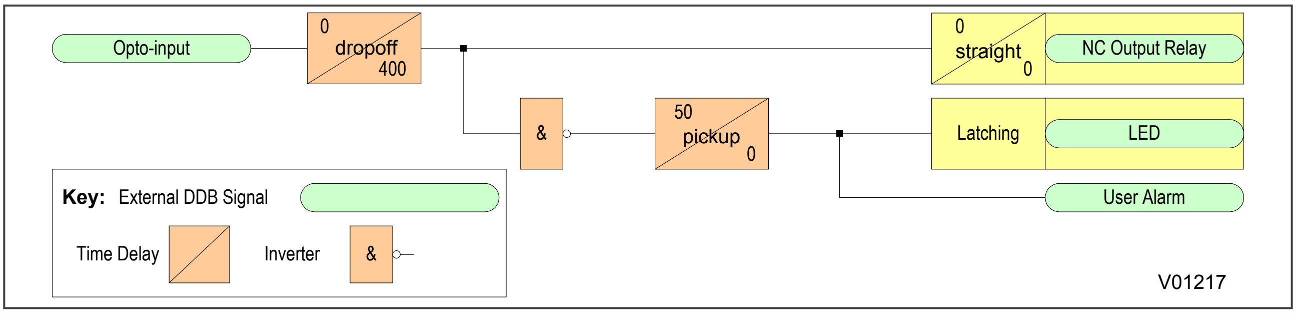


Figure 124: PSL for TCS Scheme 3

15.4 TRIP CIRCUIT SUPERVISION SCHEME 4

Scheme 4 is identical to that offered by MVAX31 (a Trip Circuit Supervision relay) and consequently is fully compliant with ENA Specification H7. To achieve this compliance, there are three settings in the OPTO CONFIG column. These settings (**Opto 9 Mode**, **Opto 10 Mode** and **Opto 11 Mode**) must be set to 'TCS' before the scheme can be used. Typically only two of these three opto-inputs would be used.

In the diagram below, Opto-input 1 and Opto-input 2 would correlate to one of the above-mentioned opto-inputs.

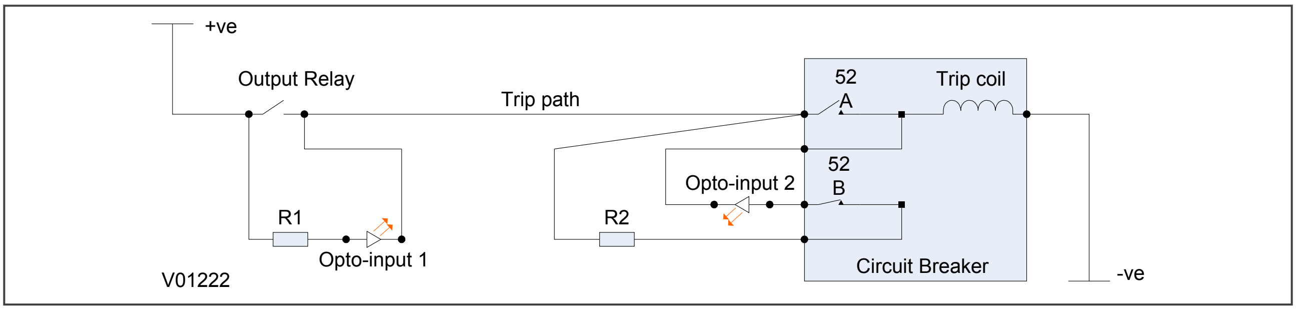


Figure 125: TCS Scheme 4

Under normal non-fault conditions, a current of 2 mA flows through one of the following paths:

a) Post Close Supervision: When the CB is in a closed state, the current flows through R1, Opto-input 1, Contact 52A and the trip coil.

b) Pre-close Supervision: When the CB is in an open state, the current flows through R1, Opto-input 1, Contact 52B, Opto-input 2 and the trip coil.

c) Momentary Tripping with Self-reset Contact: When a self-reset trip contact is in a closed state, the current flows through the trip contact, contact 52A and the trip coil.

d) Tripping with Latched Contact: When a latched trip contact is used and when it is in a closed state, the current flows through the trip contact, Contact 52A, the trip coil, then changing to the path trip contact, R2, Contact 52B, Opto-input 2 and the trip coil.

A current of 2 mA through the Trip Coil is insufficient to cause operation of the Trip Contact, but large enough to energise the opto-inputs. Under this condition both of the opto-inputs will output logic 1, so the output relay (TCS health) will be closed and the User Alarm will be off. If a break occurs in the trip circuit, the current ceases to flow, resulting in both opto-inputs outputting logic 0. This will open the output relay and energise the user alarm.

15.4.1 RESISTOR VALUES

The TCS opto-inputs sink a constant current of 2 mA.The values of external resistors R1 and R2 are chosen to limit the current to a maximum of 60 mA in the event that an opto-input becomes shorted. The values of these resistors depend on the trip circuit voltage. To achieve compliance with ENA Specification H7, we have carried out extensive testing and we recommended the following resistors values.

Trip Circuit Voltage	Resistor R1 and R2 (ohms)
24/27	620
30/34	820
48/54	1.2 k
110/125	2.7 k
220/250	5.2 k

For the momentary tripping condition, none of the opto-inputs are energised. To tide over this normal CB operation, a drop-off time delay of about 400 ms is added in the PSL.

Warning:
If your IED has Opto Mode settings (Opto 9 Mode, Opto 10 Mode, Opto 11 Mode) in the OPTO CONFIG column, these settings MUST be set to 'TCS'.

15.4.2 PSL FOR TCS SCHEME 4

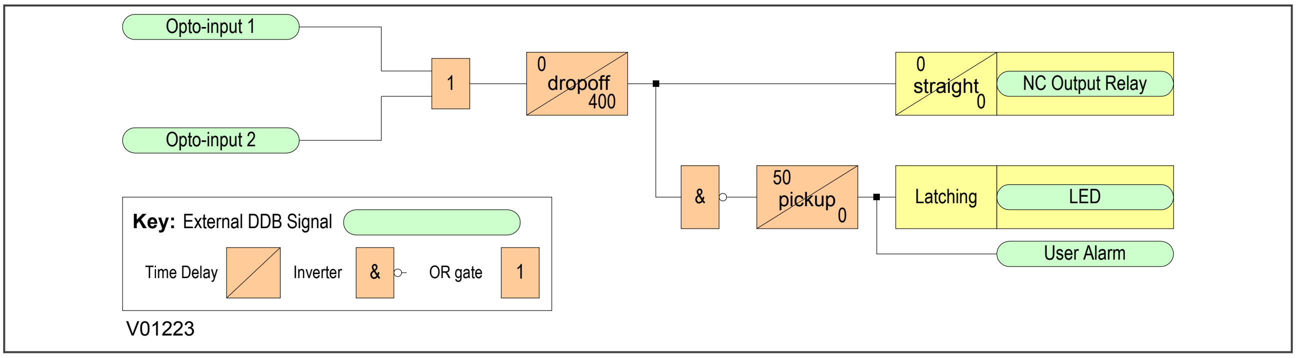


Figure 126: PSL for TCS Scheme 4

SCADA COMMUNICATIONS

CHAPTER 10

1 CHAPTER OVERVIEW

The MiCOM products support substation automation system and SCADA communications based on two communications technologies; serial and Ethernet. Serial communications has been around for a long time, and there are many substations still wired up this way. Ethernet is a more modern medium and all modern substation communications is based on this technology. Alstom Grid's MiCOM products support both of these communication technologies.

This chapter contains the following sections:

2 COMMUNICATION INTERFACES

The MiCOM P40 Agile products have a number of standard and optional communication interfaces. The standard and optional hardware and protocols are summarised below:

Port	Availability	Physical Layer	Use	Data Protocols
Front	Standard	USB	Local settings Firmware download	Courier
Rear serial port 1	Standard	RS485 / K-Bus	SCADA Remote settings IRIG-B	Courier, MODBUS, IEC 60870-5-103, DNP3.0
Rear serial port 2 (order option)	Optional	RS485	SCADA Remote settings IRIG-B	Courier
Rear Ethernet port	Optional	Ethernet/copper	SCADA Remote settings	Courier, DNP3.0 over Ethernet, IEC 61850 (order option)
Rear Ethernet port	Optional	Ethernet/fibre	SCADA Remote settings	Courier or DNP3.0 over Ethernet (order option)

Note:
Optional communication boards are always fitted into slot C and only slot C.
It is only possible to fit one optional communications board, therefore Serial and Ethernet communications are mutually exclusive.

3 SERIAL COMMUNICATION

The physical layer standards that are used for serial communications for SCADA purposes are:

- Universal Serial Bus (USB)
- EIA(RS)485 (often abbreviated to RS485)
- K-Bus (a proprietary customization of RS485)

USB is a relatively new standard, which replaces EIA(RS232) for local communication with the IED (for transferring settings and downloading firmware updates)

RS485 is similar to RS232 but for longer distances and it allows daisy-chaining and multi-dropping of IEDs.

K-Bus is a proprietary protocol quite similar to RS485, but it cannot be mixed on the same link as RS485. Unlike RS485, K-Bus signals applied across two terminals are not polarised.

It is important to note that these are not data protocols. They only describe the physical characteristics required for two devices to communicate with each other.

For a description of the K-Bus standard see K-Bus (on page 428) and Alstom Grid's K-Bus interface guide reference R6509.

A full description of the RS485 is available in the published standard.

3.1 UNIVERSAL SERIAL BUS

The USB port is used for connecting computers locally for the purposes of transferring settings, measurements and records to/from the computer to the IED and to download firmware updates from a local computer to the IED.

3.2 EIA(RS)485 BUS

The RS485 two-wire connection provides a half-duplex, fully isolated serial connection to the IED. The connection is polarized but there is no agreed definition of which terminal is which. If the master is unable to communicate with the product, and the communication parameters match, then it is possible that the two-wire connection is reversed.

The RS485 bus must be terminated at each end with 120 Ω 0.5 W terminating resistors between the signal wires.

The RS485 standard requires that each device be directly connected to the actual bus. Stubs and tees are forbidden. Loop bus and Star topologies are not part of the RS485 standard and are also forbidden.

Two-core screened twisted pair cable should be used. The final cable specification is dependent on the application, although a multi-strand 0.5 mm^2 per core is normally adequate. The total cable length must not exceed 1000 m. It is important to avoid circulating currents, which can cause noise and interference, especially when the cable runs between buildings. For this reason, the screen should be continuous and connected to ground at one end only, normally at the master connection point.

The RS485 signal is a differential signal and there is no signal ground connection. If a signal ground connection is present in the bus cable then it must be ignored. At no stage should this be connected to the cable's screen or to the product’s chassis. This is for both safety and noise reasons.

It may be necessary to bias the signal wires to prevent jabber. Jabber occurs when the signal level has an indeterminate state because the bus is not being actively driven. This can occur when all the slaves are in receive mode and the master is slow to turn from receive mode to transmit mode. This may be because the master is waiting in receive mode, in a high impedance state, until it has something to transmit. Jabber causes the receiving device(s) to miss the first bits of the first character in the packet, which results in the slave rejecting the message and consequently not responding. Symptoms of this are; poor response times (due to retries), increasing message error counts, erratic communications, and in the worst case, complete failure to communicate.

3.2.1 EIA(RS)485 BIASING REQUIREMENTS

Biasing requires that the signal lines be weakly pulled to a defined voltage level of about 1 V. There should only be one bias point on the bus, which is best situated at the master connection point. The DC source used for the bias must be clean to prevent noise being injected.

Note:
Some devices may be able to provide the bus bias, in which case external components would not be required.

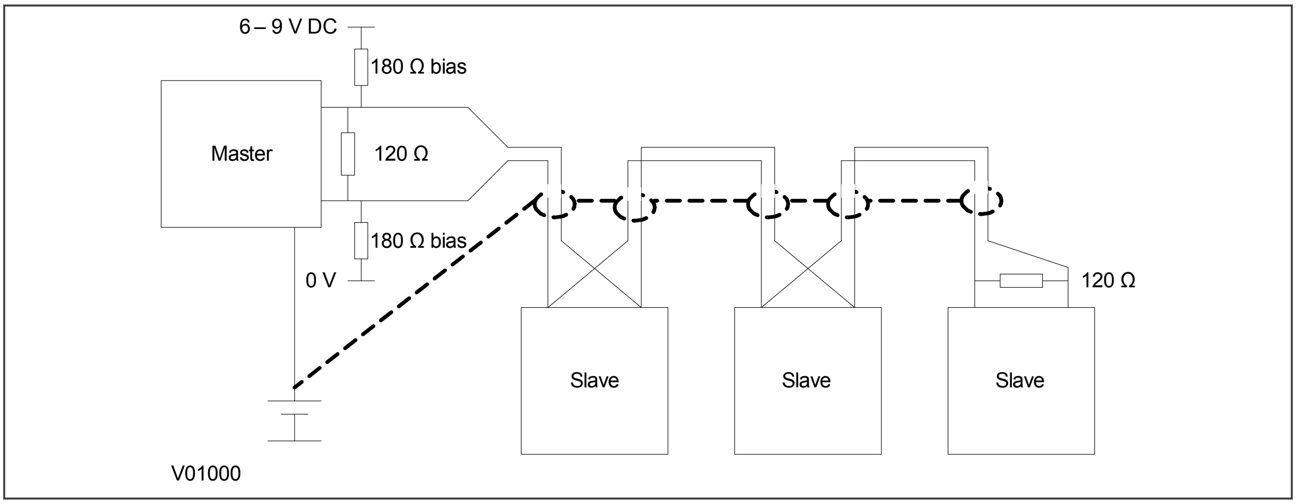


Figure 127: RS485 biasing circuit

Warning:
It is extremely important that the 120 Ω termination resistors are fitted. Otherwise the bias voltage may be excessive and may damage the devices connected to the bus.
As the field voltage is much higher than that required, Alstom Grid cannot assume responsibility for any damage that may occur to a device connected to the network as a result of incorrect application of this voltage.
Ensure the field voltage is not used for other purposes, such as powering logic inputs, because noise may be passed to the communication network.

3.3 K-BUS

K-Bus is a robust signalling method based on RS485 voltage levels. K-Bus incorporates message framing, based on a 64 kbps synchronous HDLC protocol with FM0 modulation to increase speed and security.

The rear interface is used to provide a permanent connection for K-Bus, which allows multi-drop connection.

A K-Bus spur consists of up to 32 IEDs connected together in a multi-drop arrangement using twisted pair wiring. The K-Bus twisted pair connection is non-polarised.

Two-core screened twisted pair cable should be used. The final cable specification is dependent on the application, although a multi-strand 0.5 mm^2 per core is normally adequate. The total cable length must not exceed 1000 m. It is important to avoid circulating currents, which can cause noise and interference, especially when the cable runs between buildings. For this reason, the screen should be continuous and connected to ground at one end only, normally at the master connection point.

The K-Bus signal is a differential signal and there is no signal ground connection. If a signal ground connection is present in the bus cable then it must be ignored. At no stage should this be connected to the cable's screen or to the product’s chassis. This is for both safety and noise reasons.

It is not possible to use a standard EIA(RS)232 to EIA(RS)485 converter to convert IEC 60870-5 FT1.2 frames to K-Bus. A protocol converter, namely the KITZ101, KITZ102 or KITZ201, must be used for this purpose. Please consult Alstom Grid for information regarding the specification and supply of KITZ devices. The following figure demonstrates a typical K-Bus connection.

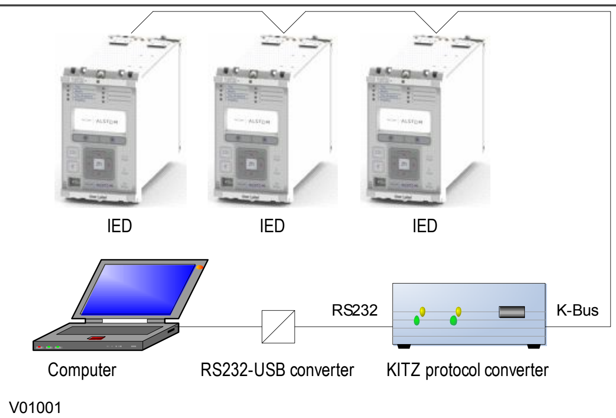


Figure 128: Remote communication using K-Bus

> *Note:*
> *An RS232-USB converter is only needed if the local computer does not provide an RS232 port.*

Further information about K-Bus is available in the publication R6509: K-Bus Interface Guide, which is available on request.

4 STANDARD ETHERNET COMMUNICATION

The Ethernet interface is required for either IEC 61850 or DNP3 over Ethernet (protocol must be selected at time of order). With either of these protocols, the Ethernet interface also offers communication with MiCOM S1 Studio for remote configuration and record extraction.

Fibre optic connection is recommended for use in permanent connections in a substation environment, as it offers advantages in terms of noise rejection. The fibre optic port provides 100 Mbps communication and uses type LC connectors.

The device can also be connected to either a 10Base-T or a 100Base-TX Ethernet hub or switch using the RJ45 port. The port automatically senses which type of hub is connected. Due to noise and interference reasons, this connection type is only recommended for short-term connections over a short distance.

The pins on the RJ45connector are as follows:

Pin	Signal name	Signal definition
1	TXP	Transmit (positive)
2	TXN	Transmit (negative)
3	RXP	Receive (positive)
4	-	Not used
5	-	Not used
6	RXN	Receive (negative)
7	-	Not used
8	-	Not used

5 OVERVIEW OF DATA PROTOCOLS

The products supports a wide range of protocols to make them applicable to many industries and applications. The exact data protocols supported by a particular product depend on its chosen application, but the following table gives a list of the data protocols that are typically available.

SCADA data protocols

Data Protocol	Layer 1 protocol	Description
Courier	K-Bus, RS485, Ethernet, USB	Standard for SCADA communications developed by Alstom Grid.
MODBUS	RS485	Standard for SCADA communications developed by Modicon.
IEC 60870-5-103	RS485	IEC standard for SCADA communications
DNP 3.0	RS485, Ethernet	Standard for SCADA communications developed by Harris. Used mainly in North America.
IEC 61850	Ethernet	IEC standard for substation automation. Facilitates interoperability.

The relationship of these protocols to the lower level physical layer protocols are as follows:

<table>
<tr><td>Data Protocols</td><td>IEC 60870-5-103
MODBUS
DNP3.0
Courier</td><td>IEC61850
DNP3.0
Courier</td><td>Courier</td><td>Courier</td></tr>
<tr><td>Data Link Layer</td><td>EIA(RS)485</td><td>Ethernet</td><td>USB</td><td>K-Bus</td></tr>
<tr><td>Physical Layer</td><td colspan="4">Copper or Optical Fibre</td></tr>
</table>

6 COURIER

This section should provide sufficient detail to enable understanding of the Courier protocol at a level required by most users. For situations where the level of information contained in this manual is insufficient, further publications (R6511 and R6512) containing in-depth details about the protocol and its use, are available on request.

Courier is an Alstom Grid proprietary communication protocol. Courier uses a standard set of commands to access a database of settings and data in the IED. This allows a master to communicate with a number of slave devices. The application-specific elements are contained in the database rather than in the commands used to interrogate it, meaning that the master station does not need to be preconfigured. Courier also provides a sequence of event (SOE) and disturbance record extraction mechanism.

6.1 PHYSICAL CONNECTION AND LINK LAYER

In the P40 Agile products, Courier can be used with three physical layer protocols: K-Bus, EIA(RS)485 and USB.

Three connection options are available for Courier:

- The front USB port - for connection to Settings application software on, for example, a laptop
- Rear serial port 1 - for permanent SCADA connection via RS485 or K-Bus
- The optional rear serial port 2 - for permanent SCADA connection via RS485 or K-Bus

The IED address and baud rate can be selected using the front panel menu or by a suitable application such as MiCOM S1 Agile.

6.2 COURIER DATABASE

The Courier database is two-dimensional and resembles a table. Each cell in the database is referenced by a row and column address. Both the column and the row can take a range from 0 to 255 (0000 to FFFF Hexadecimal. Addresses in the database are specified as hexadecimal values, for example, 0A02 is column 0A row 02. Associated settings or data are part of the same column. Row zero of the column has a text string to identify the contents of the column and to act as a column heading.

The product-specific menu databases contain the complete database definition. This information is also presented in the Settings chapter.

6.3 SETTINGS CATEGORIES

There are two main categories of settings in protection IEDs:

- Control and support settings
- Protection settings

With the exception of the Disturbance Recorder settings, changes made to the control and support settings are implemented immediately and stored in non-volatile memory. Changes made to the Protection settings and the Disturbance Recorder settings are stored in ‘scratchpad’ memory and are not immediately implemented. These need to be committed by writing to the **Save Changes** cell in the CONFIGURATION column.

6.4 SETTING CHANGES

Courier provides two mechanisms for making setting changes. Either method can be used for editing any of the settings in the database.

Method 1

This uses a combination of three commands to perform a settings change:

First, enter Setting mode: This checks that the cell is settable and returns the limits.

1. Preload Setting: This places a new value into the cell. This value is echoed to ensure that setting corruption has not taken place. The validity of the setting is not checked by this action.
2. Execute Setting: This confirms the setting change. If the change is valid, a positive response is returned. If the setting change fails, an error response is returned.
3. Abort Setting: This command can be used to abandon the setting change.

This is the most secure method. It is ideally suited to on-line editors because the setting limits are extracted before the setting change is made. However, this method can be slow if many settings are being changed because three commands are required for each change.

Method 2

The Set Value command can be used to change a setting directly. The response to this command is either a positive confirm or an error code to indicate the nature of a failure. This command can be used to implement a setting more rapidly than the previous method, however the limits are not extracted. This method is therefore most suitable for off-line setting editors such as MiCOM S1 Agile, or for issuing preconfigured control commands.

6.5 SETTINGS TRANSFER

To transfer the settings to or from the IED, use the settings application software.

6.6 EVENT EXTRACTION

You can extract events either automatically (rear serial port only) or manually (either serial port). For automatic extraction, all events are extracted in sequential order using the standard Courier event mechanism. This includes fault and maintenance data if appropriate. The manual approach allows you to select events, faults, or maintenance data as desired.

6.6.1 AUTOMATIC EVENT RECORD EXTRACTION

This method is intended for continuous extraction of event and fault information as it is produced. It is only supported through the rear Courier port.

When new event information is created, the **Event** bit is set in the **Status** byte. This indicates to the Master device that event information is available. The oldest, non-extracted event can be extracted from the IED using the **Send Event** command. The IED responds with the event data.

Once an event has been extracted, the **Accept Event** command can be used to confirm that the event has been successfully extracted. When all events have been extracted, the **Event** bit is reset. If there are more events still to be extracted, the next event can be accessed using the Send Event command as before.

6.6.2 MANUAL EVENT RECORD EXTRACTION

The VIEW RECORDS column (location 01) is used for manual viewing of event, fault, and maintenance records. The contents of this column depend on the nature of the record selected. You can select events by event number and directly select a fault or maintenance record by number.

Event Record Selection ('Select Event' cell: 0101)

This cell can be set the number of stored events. For simple event records (Type 0), cells 0102 to 0105 contain the event details. A single cell is used to represent each of the event fields. If the event selected is a fault or maintenance record (Type 3), the remainder of the column contains the additional information.

Fault Record Selection ('Select Fault' cell: 0105)

This cell can be used to select a fault record directly, using a value between 0 and 4 to select one of up to five stored fault records. (0 is the most recent fault and 4 is the oldest). The column then contains the details of the fault record selected.

Maintenance Record Selection ('Select Maint' cell: 01F0)

This cell can be used to select a maintenance record using a value between 0 and 4. This cell operates in a similar way to the fault record selection.

If this column is used to extract event information, the number associated with a particular record changes when a new event or fault occurs.

Event Types

The IED generates events under certain circumstances such as:

- Change of state of output contact
- Change of state of opto-input
- Protection element operation
- Alarm condition
- Setting change
- Password entered/timed-out

Event Record Format

The IED returns the following fields when the Send Event command is invoked:

- Cell reference
- Time stamp
- Cell text
- Cell value

The Menu Database contains tables of possible events, and shows how the contents of the above fields are interpreted. Fault and Maintenance records return a Courier Type 3 event, which contains the above fields plus two additional fields:

- Event extraction column
- Event number

These events contain additional information, which is extracted from the IED using the RECORDER EXTRACTION column B4. Row 01 of the RECORDER EXTRACTION column contains a Select Record setting that allows the fault or maintenance record to be selected. This setting should be set to the event number value returned in the record. The extended data can be extracted from the IED by uploading the text and data from the column.

6.7 DISTURBANCE RECORD EXTRACTION

The stored disturbance records are accessible through the Courier interface. The records are extracted using the RECORDER EXTRACTION column (B4).

The **Select Record** cell can be used to select the record to be extracted. Record 0 is the oldest non-extracted record. Older records which have been already been extracted are assigned positive values, while younger records are assigned negative values. To help automatic extraction through the rear port, the IED sets the **Disturbance** bit of the **Status** byte, whenever there are non-extracted disturbance records.

Once a record has been selected, using the above cell, the time and date of the record can be read from the **Trigger Time** cell (B402). The disturbance record can be extracted using the block transfer mechanism from cell B40B and saved in the COMTRADE format. The settings application software software automatically does this.

6.8 PROGRAMMABLE SCHEME LOGIC SETTINGS

The programmable scheme logic (PSL) settings can be uploaded from and downloaded to the IED using the block transfer mechanism.

The following cells are used to perform the extraction:

- **Domain** cell (B204): Used to select either PSL settings (upload or download) or PSL configuration data (upload only)
- **Sub-Domain** cell (B208): Used to select the Protection Setting Group to be uploaded or downloaded.
- **Version** cell (B20C): Used on a download to check the compatibility of the file to be downloaded.
- **Transfer Mode** cell (B21C): Used to set up the transfer process.
- **Data Transfer** cell (B120): Used to perform upload or download.

The PSL settings can be uploaded and downloaded to and from the IED using this mechanism. The settings application software MiCOM S1 Agile must be used to edit the settings. It also performs checks on the validity of the settings before they are transferred to the IED.

6.9 TIME SYNCHRONISATION

The time and date can be set using the time synchronization feature of the Courier protocol. The device will correct for the transmission delay. The time synchronization message may be sent as either a global command or to any individual IED address. If the time synchronization message is sent to an individual address, then the device will respond with a confirm message. If sent as a global command, the (same) command must be sent twice. A time synchronization Courier event will be generated/produced whether the time-synchronization message is sent as a global command or to any individual IED address.

If the clock is being synchronized using the IRIG-B input then it will not be possible to set the device time using the Courier interface. An attempt to set the time using the interface will cause the device to create an event with the current date and time taken from the IRIG-B synchronized internal clock.

6.10 CONFIGURATION

To configure the IED for this protocol, please see the Configuration (on page 45) chapter.

7 IEC 60870-5-103

The specification IEC 60870-5-103 (Telecontrol Equipment and Systems Part 5 Section 103: Transmission Protocols), defines the use of standards IEC 60870-5-1 to IEC 60870-5-5, which were designed for communication with protection equipment

This section describes how the IEC 60870-5-103 standard is applied to the Px40 platform. It is not a description of the standard itself. The level at which this section is written assumes that the reader is already familiar with the IEC 60870-5-103 standard.

This section should provide sufficient detail to enable understanding of the standard at a level required by most users.

The IEC 60870-5-103 interface is a master/slave interface with the device as the slave device. The device conforms to compatibility level 2, as defined in the IEC 60870-5-103.standard.

The following IEC 60870-5-103 facilities are supported by this interface:

- Initialization (reset)
- Time synchronization
- Event record extraction
- General interrogation
- Cyclic measurements
- General commands
- Disturbance record extraction
- Private codes

7.1 PHYSICAL CONNECTION AND LINK LAYER

There is just one option for IEC 60870-5-103:

- Rear serial port 1- for permanent SCADA connection via RS485

The IED address and baud rate can be selected using the front panel menu or by a suitable application such as MiCOM S1 Agile.

7.2 INITIALISATION

Whenever the device has been powered up, or if the communication parameters have been changed a reset command is required to initialize the communications. The device will respond to either of the two reset commands; Reset CU or Reset FCB (Communication Unit or Frame Count Bit). The difference between the two commands is that the Reset CU command will clear any unsent messages in the transmit buffer, whereas the Reset FCB command does not delete any messages.

The device will respond to the reset command with an identification message ASDU 5. The Cause of Transmission (COT) of this response will be either Reset CU or Reset FCB depending on the nature of the reset command. The content of ASDU 5 is described in the IEC 60870-5-103 section of the Menu Database, available from Alstom Grid separately if required.

In addition to the above identification message, it will also produce a power up event.

7.3 TIME SYNCHRONISATION

The time and date can be set using the time synchronization feature of the IEC 60870-5-103 protocol. The device will correct for the transmission delay as specified in IEC 60870-5-103. If the time synchronization message is sent as a send/confirm message then the device will respond with a confirm message. A time synchronization Class 1 event will be generated/produced whether the time-synchronization message is sent as a send confirm or a broadcast (send/no reply) message.

If the clock is being synchronized using the IRIG-B input then it will not be possible to set the device time using the IEC 60870-5-103 interface. An attempt to set the time via the interface will cause the device to create an event with the current date and time taken from the IRIG-B synchronized internal clock.

7.4 SPONTANEOUS EVENTS

Events are categorized using the following information:

- Function type
- Information Number

The IEC 60870-5-103 profile in the Menu Database contains a complete listing of all events produced by the device.

7.5 GENERAL INTERROGATION (GI)

The GI request can be used to read the status of the device, the function numbers, and information numbers that will be returned during the GI cycle. These are shown in the IEC 60870-5-103 profile in the Menu Database.

7.6 CYCLIC MEASUREMENTS

The device will produce measured values using ASDU 9 on a cyclical basis, this can be read from the device using a Class 2 poll (note ADSU 3 is not used). The rate at which the device produces new measured values can be controlled using the measurement period setting. This setting can be edited from the front panel menu or using MiCOM S1 Agile. It is active immediately following a change.

The device transmits its measurands at 2.4 times the rated value of the analogue value.

7.7 COMMANDS

A list of the supported commands is contained in the Menu Database. The device will respond to other commands with an ASDU 1, with a cause of transmission (COT) indicating ‘negative acknowledgement’.

7.8 TEST MODE

It is possible to disable the device output contacts to allow secondary injection testing to be performed using either the front panel menu or the front serial port. The IEC 60870-5-103 standard interprets this as ‘test mode’. An event will be produced to indicate both entry to and exit from test mode. Spontaneous events and cyclic measured data transmitted whilst the device is in test mode will have a COT of ‘test mode’.

7.9 DISTURBANCE RECORDS

The disturbance records are stored in uncompressed format and can be extracted using the standard mechanisms described in IEC 60870-5-103.

> *Note:*
> *IEC 60870-5-103 only supports up to 8 records.*

7.10 COMMAND/MONITOR BLOCKING

The device supports a facility to block messages in the monitor direction (data from the device) and also in the command direction (data to the device). Messages can be blocked in the monitor and command directions using one of the two following methods

- The menu command **RP1 CS103Blocking** in the COMMUNICATIONS column
- The DDB signals Monitor Blocked and Command Blocked

7.11 CONFIGURATION

To configure the IED for this protocol, please see the Configuration (on page 45) chapter.

8 DNP 3.0

This section describes how the DNP 3.0 standard is applied to the Px40 platform. It is not a description of the standard itself. The level at which this section is written assumes that the reader is already familiar with the DNP 3.0 standard.

The descriptions given here are intended to accompany the device profile document that is included in the Menu Database document. The DNP 3.0 protocol is not described here, please refer to the documentation available from the user group. The device profile document specifies the full details of the DNP 3.0 implementation. This is the standard format DNP 3.0 document that specifies which objects; variations and qualifiers are supported. The device profile document also specifies what data is available from the device using DNP 3.0. The IED operates as a DNP 3.0 slave and supports subset level 2, as described in the DNP 3.0 standard, plus some of the features from level 3.

The DNP 3.0 protocol is defined and administered by the DNP Users Group. For further information on DNP 3.0 and the protocol specifications, please see the DNP website (www.dnp.org).

8.1 PHYSICAL CONNECTION AND LINK LAYER

DNP 3.0 can be used with two physical layer protocols: EIA(RS)485, or Ethernet.

Several connection options are available for DNP 3.0

- Rear serial port 1 - for permanent SCADA connection via RS485
- The rear Ethernet RJ45 port on the optional Ethernet board - for permanent SCADA Ethernet connection
- The rear Ethernet fibre port on the optional Ethernet board - for permanent SCADA Ethernet connection

The IED address and baud rate can be selected using the front panel menu or by a suitable application such as MiCOM Agile.

When using a serial interface, the data format is: 1 start bit, 8 data bits, 1 stop bit and optional configurable parity bit.

8.2 OBJECT 1 BINARY INPUTS

Object 1, binary inputs, contains information describing the state of signals in the IED, which mostly form part of the digital data bus (DDB). In general these include the state of the output contacts and opto-inputs, alarm signals, and protection start and trip signals. The ‘DDB number’ column in the device profile document provides the DDB numbers for the DNP 3.0 point data. These can be used to cross-reference to the DDB definition list. See the relevant Menu Database document. The binary input points can also be read as change events using Object 2 and Object 60 for class 1-3 event data.

8.3 OBJECT 10 BINARY OUTPUTS

Object 10, binary outputs, contains commands that can be operated using DNP 3.0. Therefore the points accept commands of type pulse on (null, trip, close) and latch on/off as detailed in the device profile in the relevant Menu Database document, and execute the command once for either command. The other fields are ignored (queue, clear, trip/close, in time and off time).

There is an additional image of the Control Inputs. Described as Alias Control Inputs, they reflect the state of the Control Input, but with a dynamic nature.

- If the Control Input DDB signal is already SET and a new DNP SET command is sent to the Control Input, the Control Input DDB signal goes momentarily to RESET and then back to SET.
- If the Control Input DDB signal is already RESET and a new DNP RESET command is sent to the Control Input, the Control Input DDB signal goes momentarily to SET and then back to RESET.

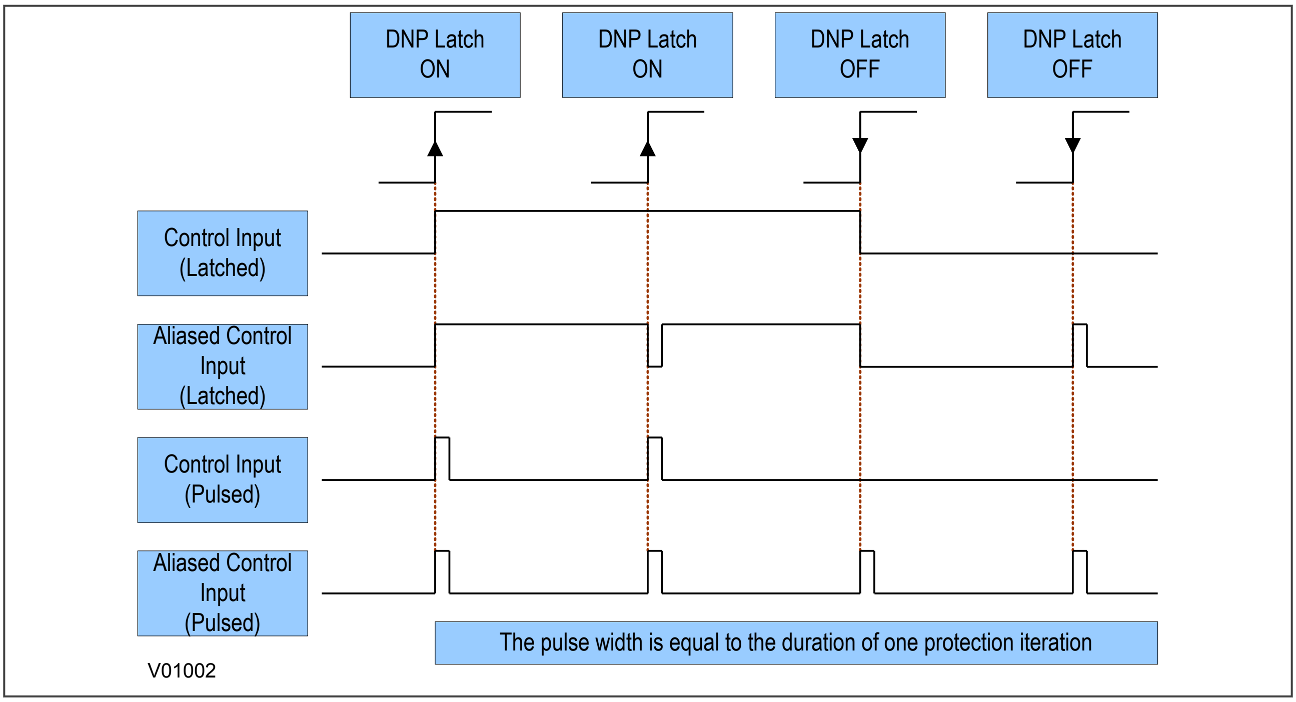


Figure 129: Control input behaviour

Many of the IED's functions are configurable so some of the Object 10 commands described in the following sections may not be available. A read from Object 10 reports the point as off-line and an operate command to Object 12 generates an error response.

Examples of Object 10 points that maybe reported as off-line are:

- Activate setting groups: Ensure setting groups are enabled
- CB trip/close: Ensure remote CB control is enabled
- Reset NPS thermal: Ensure NPS thermal protection is enabled
- Reset thermal O/L: Ensure thermal overload protection is enabled
- Reset RTD flags: Ensure RTD Inputs is enabled
- Control inputs: Ensure control inputs are enabled

8.4 OBJECT 20 BINARY COUNTERS

Object 20, binary counters, contains cumulative counters and measurements. The binary counters can be read as their present 'running' value from Object 20, or as a 'frozen' value from Object 21. The running counters of object 20 accept the read, freeze and clear functions. The freeze function takes the current value of the object 20 running counter and stores it in the corresponding Object 21 frozen counter. The freeze and clear function resets the Object 20 running counter to zero after freezing its value.

Binary counter and frozen counter change event values are available for reporting from Object 22 and Object 23 respectively. Counter change events (Object 22) only report the most recent change, so the maximum number of events supported is the same as the total number of counters. Frozen counter change events (Object 23) are generated whenever a freeze operation is performed and a change has occurred since the previous freeze command. The frozen counter event queues store the points for up to two freeze operations.

8.5 OBJECT 30 ANALOGUE INPUT

Object 30, analogue inputs, contains information from the IED's measurements columns in the menu. All object 30 points can be reported as 16 or 32-bit integer values with flag, 16 or 32-bit integer values without flag, as well as short floating point values.

Analogue values can be reported to the master station as primary, secondary or normalized values (which takes into account the IED's CT and VT ratios), and this is settable in the COMMUNICATIONS column in the IED. Corresponding deadband settings can be displayed in terms of a primary, secondary or normalized value. Deadband point values can be reported and written using Object 34 variations.

The deadband is the setting used to determine whether a change event should be generated for each point. The change events can be read using Object 32 or Object 60. These events are generated for any point which has a value changed by more than the deadband setting since the last time the data value was reported.

Any analogue measurement that is unavailable when it is read is reported as offline. For example, the frequency would be offline if the current and voltage frequency is outside the tracking range of the IED. All Object 30 points are reported as secondary values in DNP 3.0 (with respect to CT and VT ratios).

8.6 OBJECT 40 ANALOGUE OUTPUT

The conversion to fixed-point format requires the use of a scaling factor, which is configurable for the various types of data within the IED such as current, voltage, and phase angle. All Object 40 points report the integer scaling values and Object 41 is available to configure integer scaling quantities.

8.7 OBJECT 50 TIME SYNCHRONISATION

Function codes 1 (read) and 2 (write) are supported for Object 50 (time and date) variation 1. The DNP Need Time function (the duration of time waited before requesting another time sync from the master) is supported, and is configurable in the range 1 - 30 minutes.

If the clock is being synchronized using the IRIG-B input then it will not be possible to set the device time using the Courier interface. An attempt to set the time using the interface will cause the device to create an event with the current date and time taken from the IRIG-B synchronized internal clock.

8.8 CONFIGURATION

To configure the IED for this protocol, please see the Configuration (on page 45) chapter.

9 MODBUS

This section describes how the MODBUS standard is applied to the Px40 platform. It is not a description of the standard itself. The level at which this section is written assumes that the reader is already familiar with the MODBUS standard.

The MODBUS protocol is a master/slave protocol, defined and administered by the MODBUS Organization For further information on MODBUS and the protocol specifications, please seethe Modbus web site (www.modbus.org).

9.1 PHYSICAL CONNECTION AND LINK LAYER

Only one option is available for connecting MODBUS

- Rear serial port 1 - for permanent SCADA connection via EIA(RS)485

The MODBUS interface uses ‘RTU’ mode communication rather than ‘ASCII’ mode as this provides more efficient use of the communication bandwidth. This mode of communication is defined by the MODBUS standard.

The IED address and baud rate can be selected using the front panel menu or by a suitable application such as MiCOM Agile.

When using a serial interface, the data format is: 1 start bit, 8 data bits, 1 parity bit with 1 stop bit, or 2 stop bits (a total of 11 bits per character).

9.2 MODBUS FUNCTIONS

The following MODBUS function codes are supported:

- 01: Read Coil Status
- 02: Read Input Status
- 03: Read Holding Registers
- 04: Read Input Registers
- 06: Preset Single Register
- 08: Diagnostics
- 11: Fetch Communication Event Counter
- 12: Fetch Communication Event Log
- 16: Preset Multiple Registers 127 max

These are interpreted by the MiCOM IED in the following way:

- 01: Read status of output contacts (0xxxx addresses)
- 02: Read status of opto inputs (1xxxx addresses)
- 03: Read setting values (4xxxx addresses)
- 04: Read measured values (3xxxx addresses
- 06: Write single setting value (4xxxx addresses)
- 16: Write multiple setting values (4xxxx addresses)

9.3 RESPONSE CODES

MCode	MODBUS Description	MiCOM Interpretation
01	Illegal Function Code	The function code transmitted is not supported by the slave.

MCode	MODBUS Description	MiCOM Interpretation
02	Illegal Data Address	The start data address in the request is not an allowable value. If any of the addresses in the range cannot be accessed due to password protection then all changes within the request are discarded and this error response will be returned. Note: If the start address is correct but the range includes non–implemented addresses this response is not produced.
03	Illegal Value	A value referenced in the data field transmitted by the master is not within range. Other values transmitted within the same packet will be executed if inside range.
06	Slave Device Busy	The write command cannot be implemented due to the database being locked by another interface. This response is also produced if the software is busy executing a previous request.

9.4 REGISTER MAPPING

The device supports the following memory page references:

- Memory Page: Interpretation
- 0xxxx: Read and write access of the output relays
- 1xxxx: Read only access of the opto inputs
- 3xxxx: Read only access of data
- 4xxxx: Read and write access of settings

where xxxx represents the addresses available in the page (0 to 9999).

A complete map of the MODBUS addresses supported by the device is contained in the relevant menu database, which is available on request.

Note:
The "extended memory file" (6xxxx) is not supported.

Note:
MODBUS convention is to document register addresses as ordinal values whereas the actual protocol addresses are literal values. The MiCOM relays begin their register addresses at zero. Therefore, the first register in a memory page is register address zero. The second register is register address 1 and so on.

Note:
The page number notation is not part of the address.

9.5 EVENT EXTRACTION

The device supports two methods of event extraction providing either automatic or manual extraction of the stored event, fault, and maintenance records.

9.5.1 AUTOMATIC EVENT RECORD EXTRACTION

The automatic extraction facilities allow all types of record to be extracted as they occur. Event records are extracted in sequential order including any fault or maintenance data that may be associated with the event.

The MODBUS master can determine whether the device has any events stored that have not yet been extracted. This is performed by reading the status register 30001 (G26 data type). If the event bit of this register is set then the device has non-extracted events available. To select the next event for sequential extraction, the master station writes a value of 1 to the record selection register 40400 (G18 data type). The event data together with any fault/maintenance data can be read from the registers specified below. Once the data has been read, the event record can be marked as having been read by writing a value of '2' to register 40400.

9.5.2 MANUAL EVENT RECORD EXTRACTION

There are three registers available to manually select stored records and three read-only registers allowing the number of stored records to be determined.

- 40100: Select Event
- 40101: Select Fault
- 40102: Select Maintenance Record

For each of the above registers a value of 0 represents the most recent stored record. The following registers can be read to indicate the numbers of the various types of record stored.

- 30100: Number of stored records
- 30101: Number of stored fault records
- 30102: Number of stored maintenance records

Each fault or maintenance record logged causes an event record to be created. If this event record is selected, the additional registers allowing the fault or maintenance record details will also become populated.

9.5.3 RECORD DATA

The location and format of the registers used to access the record data is the same whether they have been selected using either automatic or manual extraction.

Event Description	MODBUS Address	Length	Comments
Time and Date	30103	4	See G12 data type description
Event Type	30107	1	See G13 data type description
Event Value	30108	2	Nature of value depends on event type. This will contain the status as a binary flag for contact, opto-input, alarm, and protection events.
MODBUS Address	30110	1	This indicates the MODBUS register address where the change occurred. Alarm 30011 Relays 30723 Optos 30725 Protection events – like the relay and opto addresses this will map onto the MODBUS address of the appropriate DDB status register depending on which bit of the DDB the change occurred. These will range from 30727 to 30785. For platform events, fault events and maintenance events the default is 0.
Event Index	30111	1	This register will contain the DDB ordinal for protection events or the bit number for alarm events. The direction of the change will be indicated by the most significant bit; 1 for 0 – 1 change and 0 for 1 – 0 change.
Additional Data Present	30112	1	0 means that there is no additional data. 1 means fault record data can be read from 30113 to 30199 (number of registers depends on the product). 2 means maintenance record data can be read from 30036 to 30039.

If a fault record or maintenance record is directly selected using the manual mechanism then the data can be read from the register ranges specified above. The event record data in registers 30103 to 30111 will not be available.

It is possible using register 40401(G6 data type) to independently clear the stored relay event/fault and maintenance records. This register also provides an option to reset the device indications, which has the same effect on the relay as pressing the clear key within the alarm viewer using the HMI panel menu.

9.6 DISTURBANCE RECORD EXTRACTION

The IED provides facilities for both manual and automatic extraction of disturbance records.

Records extracted over MODBUS from Px40 devices are presented in COMTRADE format. This involves extracting an ASCII text configuration file and then extracting a binary data file.

Each file is extracted by reading a series of data pages from the IED The data page is made up of 127 registers, giving a maximum transfer of 254 bytes per page.

The following set of registers is presented to the master station to support the extraction of uncompressed disturbance records:

MODBUS registers

MODBUS Register	Name	Description
3x00001	Status register	Provides the status of the relay as bit flags: b0: Out of service b1: Minor self test failure b2: Event b3: Time synchronization b4: Disturbance b5: Fault b6: Trip b7: Alarm b8 to b15: Unused A ‘1’ on b4 indicates the presence of a disturbance
3x00800	No of stored disturbances	Indicates the total number of disturbance records currently stored in the relay, both extracted and non-extracted.
3x00801	Unique identifier of the oldest disturbance record	Indicates the unique identifier value for the oldest disturbance record stored in the relay. This is an integer value used in conjunction with the ‘Number of stored disturbances’ value to calculate a value for manually selecting records.
4x00250	Manual disturbance record selection register	This register is used to manually select disturbance records. The values written to this cell are an offset of the unique identifier value for the oldest record. The offset value, which ranges from 0 to the Number of stored disturbances - 1, is added to the identifier of the oldest record to generate the identifier of the required record.
4x00400	Record selection command register	This register is used during the extraction process and has a number of commands. These are: b0: Select next event b1: Accept event b2: Select next disturbance record b3: Accept disturbance record b4: Select next page of disturbance data b5: Select data file
3x00930 - 3x00933	Record time stamp	These registers return the timestamp of the disturbance record.
3x00802	No of registers in data page	This register informs the master station of the number of registers in the data page that are populated.
3x00803 - 3x00929	Data page registers	These 127 registers are used to transfer data from the relay to the master station. They are 16-bit unsigned integers.
3x00934	Disturbance record status register	The disturbance record status register is used during the extraction process to indicate to the master station when data is ready for extraction. See next table.
4x00251	Data file format selection	This is used to select the required data file format. This is reserved for future use.

Note:
Register addresses are provided in reference code + address format. E.g. 4x00001 is reference code 4x, address 1 (which is specified as function code 03, address 0x0000 in the MODBUS specification).

The disturbance record status register will report one of the following values:

Disturbance record states

State	Description
Idle	This will be the state reported when no record is selected; such as after power on or after a record has been marked as extracted.
Busy	The relay is currently processing data.
Page ready	The data page has been populated and the master station can now safely read the data.
Configuration complete	All of the configuration data has been read without error.
Record complete	All of the disturbance data has been extracted.
Disturbance overwritten	An error occurred during the extraction process where the disturbance being extracted was overwritten by a new record.
No non-extracted disturbances	An attempt was made by the master station to automatically select the next oldest non-extracted disturbance when all records have been extracted.
Not a valid disturbance	An attempt was made by the master station to manually select a record that did not exist in the relay.
Command out of sequence	The master station issued a command to the relay that was not expected during the extraction process.

9.6.1 MANUAL EXTRACTION PROCEDURE

The procedure used to extract a disturbance manually is shown below. The manual method of extraction does not allow for the acceptance of disturbance records.

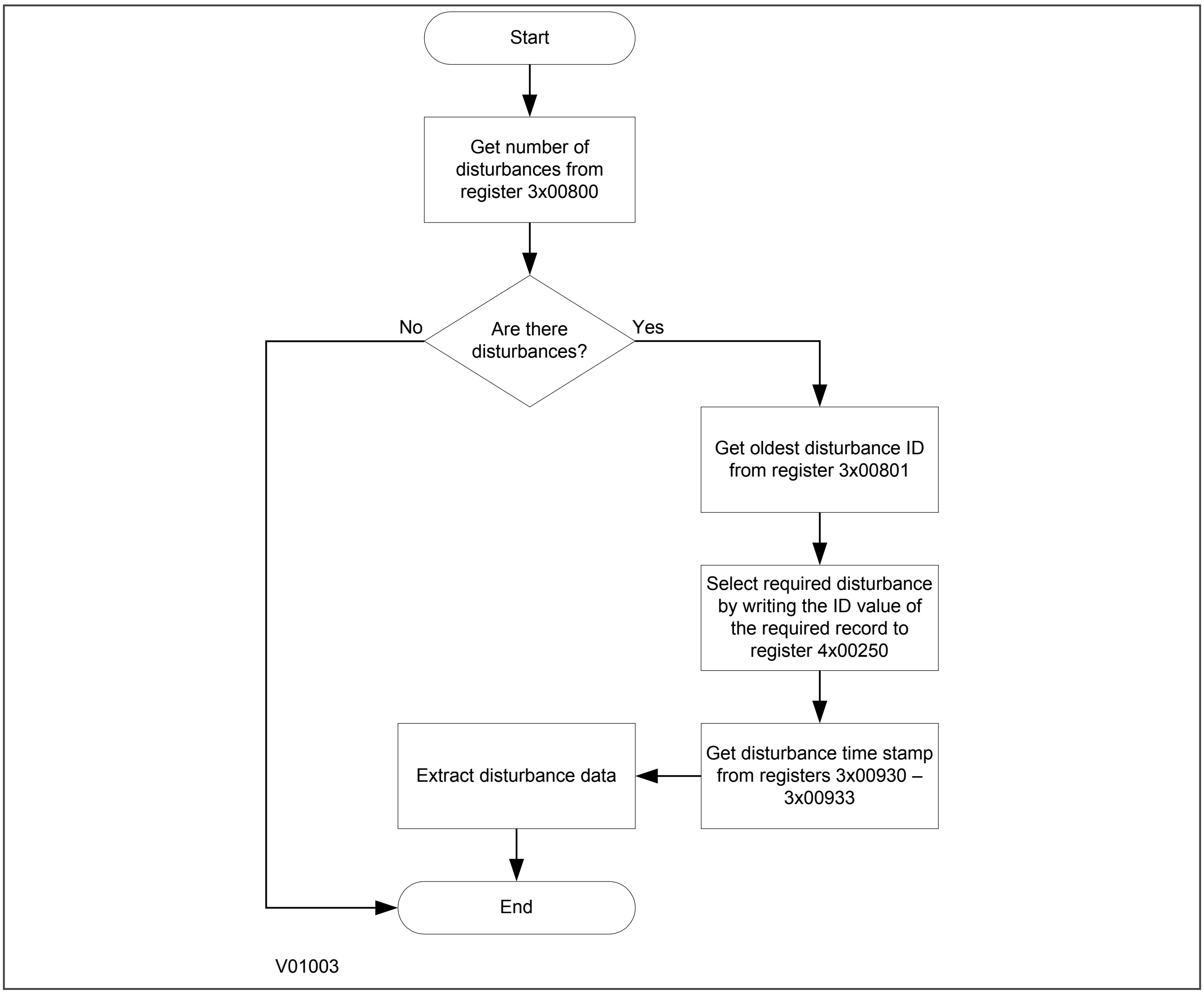


Figure 130: Manual selection of a disturbance record

9.6.2 AUTOMATIC EXTRACTION PROCEDURE

There are two methods that can be used for automatically extracting disturbances:

Method 1

Method 1 is simpler and is better at extracting single disturbance records (when the disturbance recorder is polled regularly).

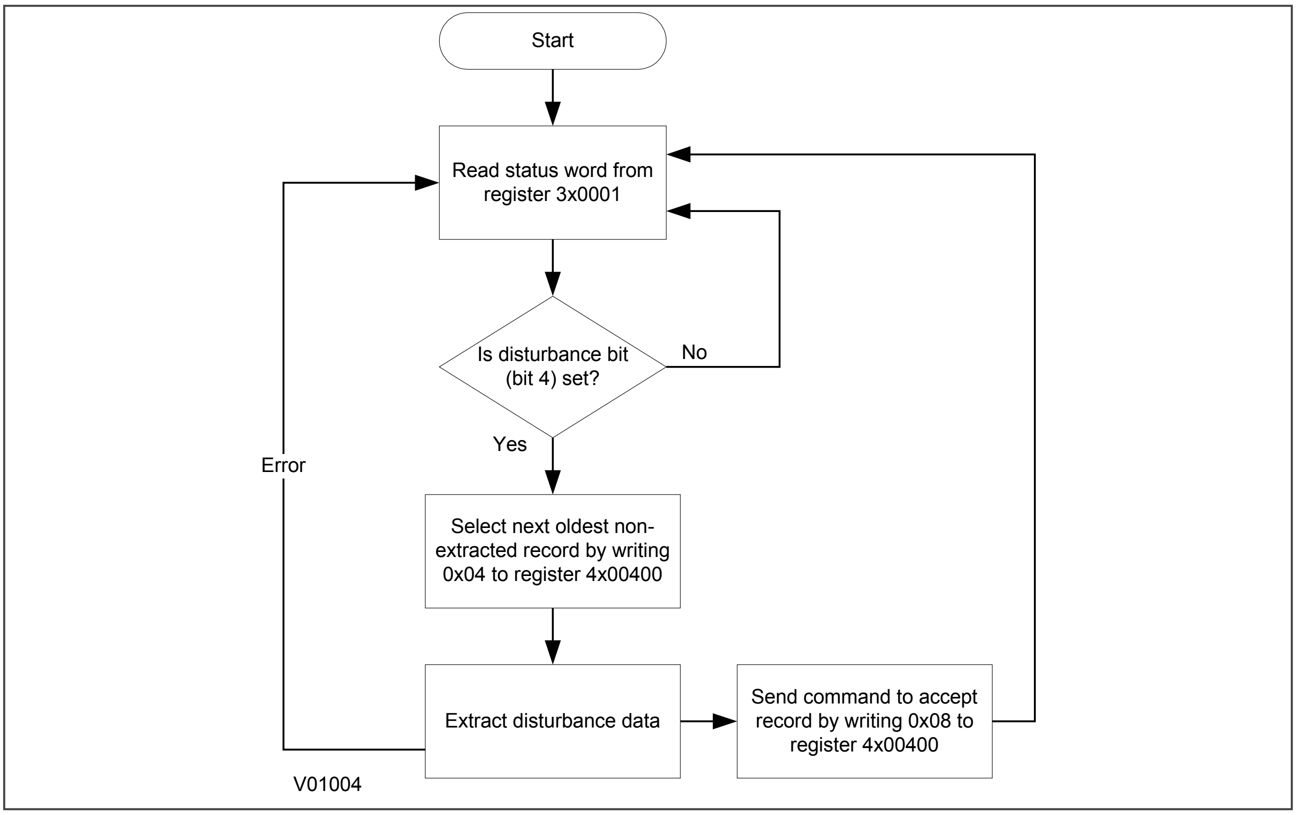


Figure 131: Automatic selection of disturbance record - method 1

Method 2

Method 2 is more complex to implement but is more efficient at extracting large quantities of disturbance records. This may be useful when the disturbance recorder is polled only occasionally and therefore may have many stored records.

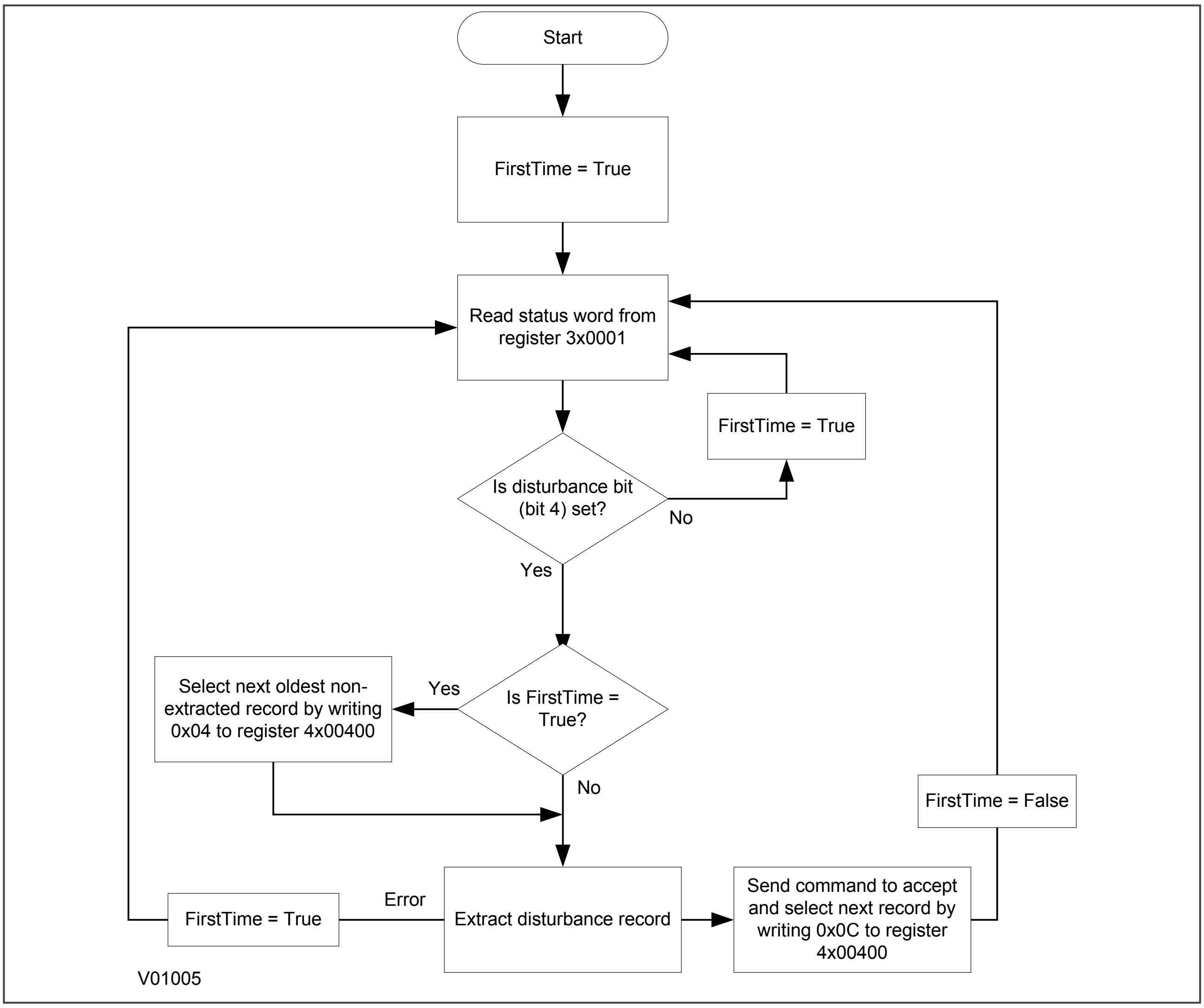


Figure 132: Automatic selection of disturbance record - method 2

9.6.3 EXTRACTING THE DISTURBANCE DATA

The extraction of the disturbance record is a two-stage process that involves extracting the configuration file first and then the data file. first the configuration file must be extracted, followed by the data file:

Extracting the Comtrade configuration file

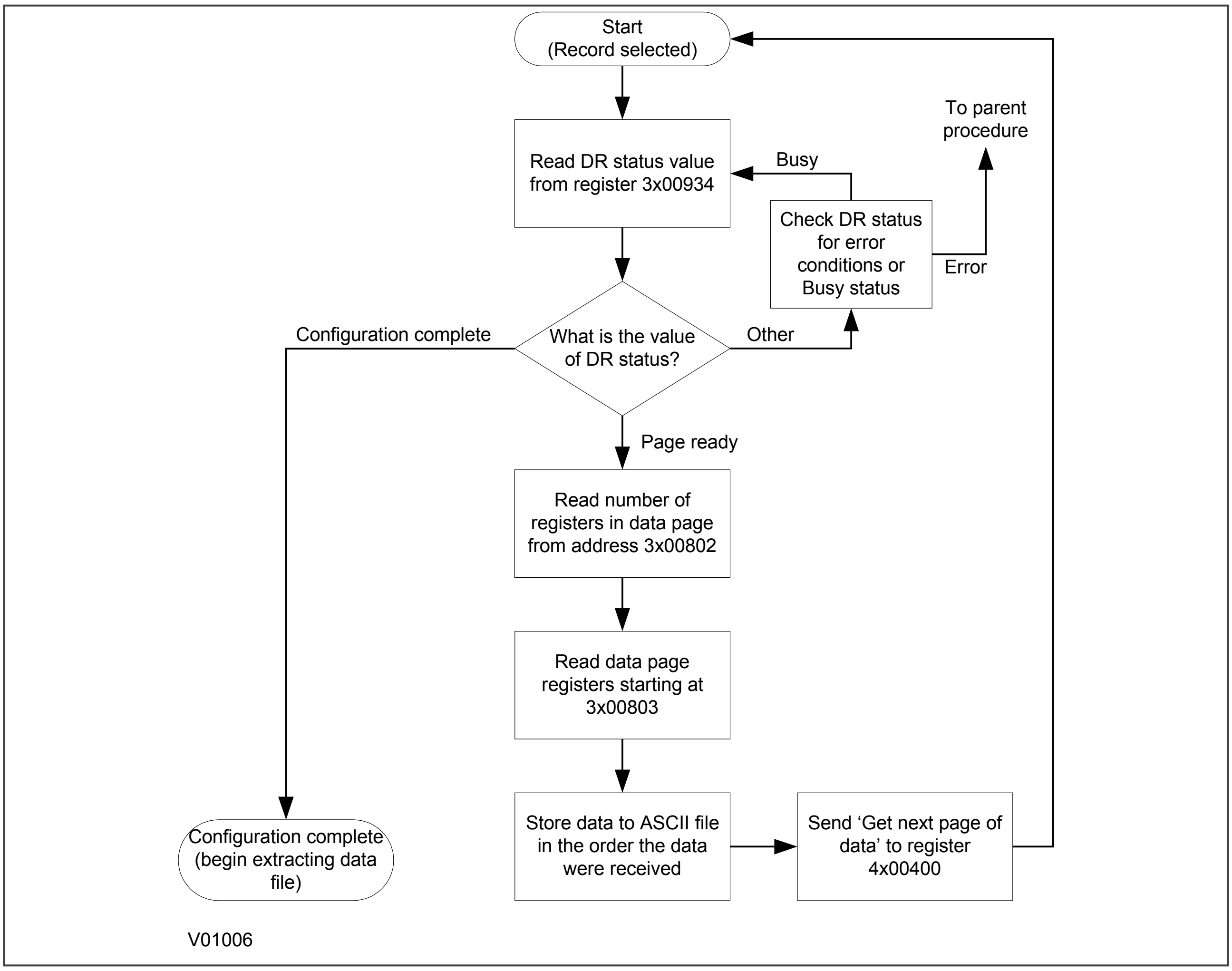


Figure 133: Configuration file extraction

Extracting the comtrade data file

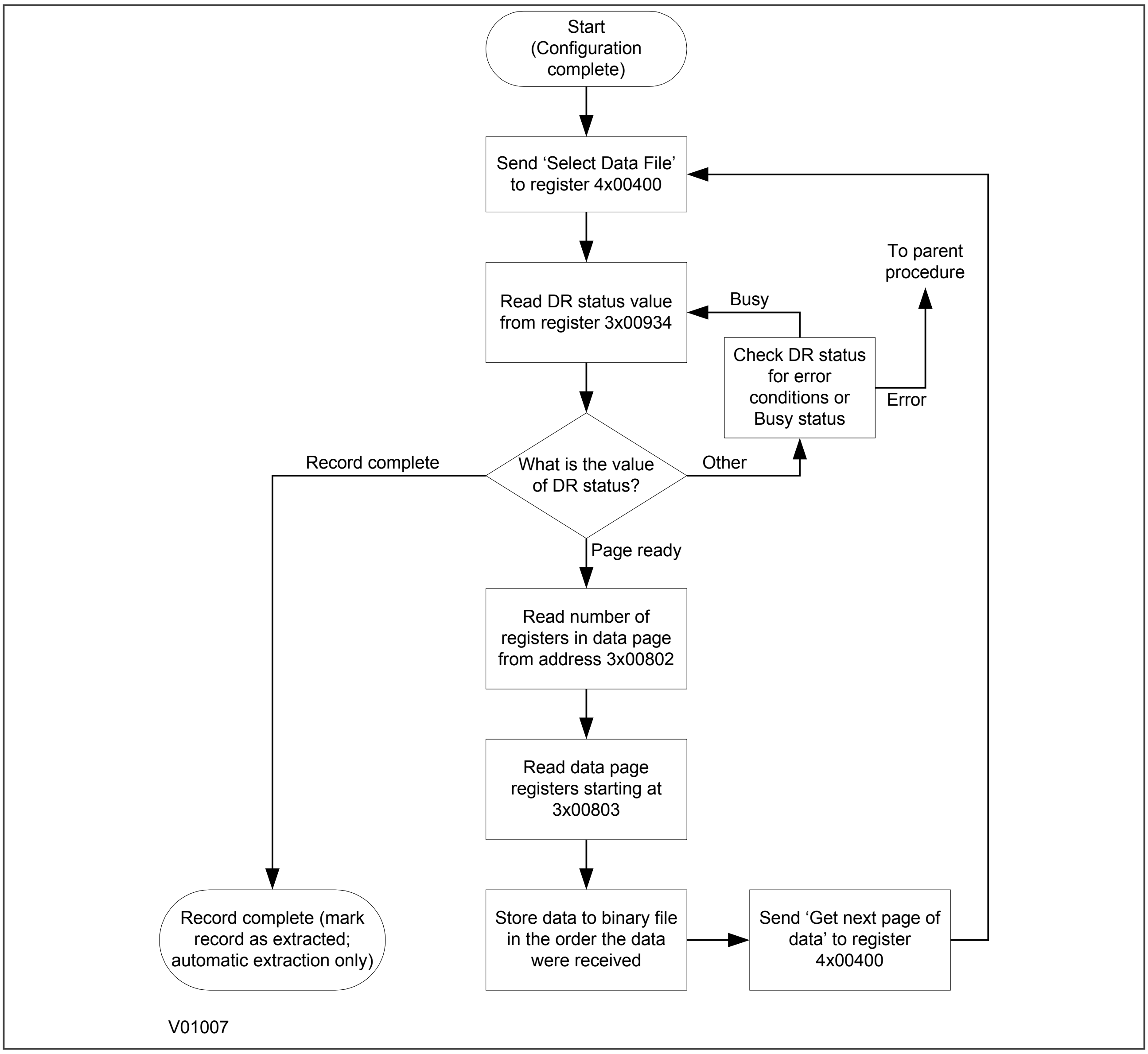


Figure 134: Data file extraction

During the extraction of the COMTRADE files, an error may occur, which will be reported on the DR Status register 3x00934. In this case, you must take action to re-start the record extraction or to abort according to the table below.

Value	State	Description
0	Idle	This will be the state reported when no record is selected; such as after power on or after a record has been marked as extracted.
1	Busy	The relay is currently processing data.
2	Page ready	The data page has been populated and the master station can now safely read the data.
3	Configuration complete	All of the configuration data has been read without error.
4	Record complete	All of the disturbance data has been extracted.
5	Disturbance overwritten	An error occurred during the extraction process where the disturbance being extracted was overwritten by a new record.

Value	State	Description
6	No unextracted disturbances	An attempt was made by the master station to automatically select the next oldest unextracted disturbance when all records have been extracted.
7	Not a valid disturbance	An attempt was made by the master station to manually select a record that did not exist in the relay.
8	Command out of sequence	The master station issued a command to the relay that was not expected during the extraction process.

9.7 SETTING CHANGES

All the IED settings are 4xxxx page addresses. The following points should be noted when changing settings:

- Settings implemented using multiple registers must be written to using a multi-register write operation.
- The first address for a multi-register write must be a valid address. If there are unmapped addresses within the range being written to, the data associated with these addresses will be discarded.
- If a write operation is performed with values that are out of range, the illegal data response will be produced. Valid setting values within the same write operation will be executed.
- If a write operation is performed, which attempts to change registers requiring a higher level of password access than is currently enabled then all setting changes in the write operation will be discarded.

9.8 PASSWORD PROTECTION

The following registers are available to control password protection:

Function	MODBUS Registers
Password entry	4x00001 to 4x00002 and 4x20000 to 4x20003
Setting to change password level 1 (4 character)	4x00023 to 4x00024
Setting to change password level 1 (8 character)	4x20008 to 4x20011
Setting to change password level 2	4x20016 to 4x20019
Setting to change password level 3	4x20024 to 4x20027
Can be read to indicate current access level	3x00010

9.9 PROTECTION AND DISTURBANCE RECORDER SETTINGS

Setting changes to either of these areas are stored in a scratchpad area and will not be used by the IED unless confirmed. Register 40405 can be used either to confirm or abort the setting changes within the scratchpad area.

The IED supports four groups of protection settings. The MODBUS addresses for each of the four groups are repeated within the following address ranges.

- Group 1: 4x1000 - 4x2999
- Group 2: 4x3000 - 4x4999
- Group 3: 4x5000 - 4x6999
- Group 4: 4x7000 - 4x8999

In addition to the basic editing of the protection setting groups, the following functions are provided:

- Default values can be restored to a setting group or to all of the relay settings by writing to register 4x0402.
- It is possible to copy the contents of one setting group to another by writing the source group to register 40406 and the target group to 4x0407.

The setting changes performed by either of the two operations defined above are made to the scratchpad area. These changes must be confirmed by writing to register 4x0405.

The active protection setting groups can be selected by writing to register 40404. An illegal data response will be returned if an attempt is made to set the active group to one that has been disabled.

9.10 TIME SYNCHRONISATION

The date-time data type G12 allows *real* date and time information to be conveyed to a resolution of 1 ms. The structure of the data type is compliant with the IEC 60870-5-4 **Binary Time 2a** format.

The seven bytes of the date/time frame are packed into four 16-bit registers and are transmitted in sequence starting from byte 1. This is followed by a null byte, making eight bytes in total.

Register data is usually transmitted starting with the highest-order byte. Therefore byte 1 will be in the high-order byte position followed by byte 2 in the low-order position for the first register. The last register will contain just byte 7 in the high order position and the low order byte will have a value of zero.

G12 date & time data type structure

	Bit Position							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
1	m7	m6	m5	m4	m3	m2	m1	m0
2	m15	m14	m13	m12	m11	m10	m9	m8
3	IV	R	I5	I4	I3	I2	I1	I0
4	SU	R	R	H4	H3	H2	H1	H0
5	W2	W1	W0	D4	D3	D2	D1	D0
6	R	R	R	R	M3	M2	M1	M0
7	R	Y6	Y5	Y4	Y3	Y2	Y1	Y0

Key to table:

- m = milliseconds: 0 to 59,999
- I = minutes: 0 to 59
- H = hours: 0 to 23
- W = day of the week: 1 to 7 starting from Monday
- D = day of the month: 1 to 31
- M = month of the year: 1 to 12 starting from January
- Y = year of the century: 0 to 99
- R = reserved: 0
- SU = summertime: 0 = GMT, 1 = summertime
- IV = invalid: 0 = invalid value, 1 = valid value

Since the range of the data type is only 100 years, the century must be deduced. The century is calculated as the one that will produce the nearest time value to the current date. For example: 30-12-99 is 30-12-1999 when received in 1999 & 2000, but is 30-12-2099 when received in 2050. This technique allows 2 digit years to be accurately converted to 4 digits in a ±50 year window around the current date.

The invalid bit has two applications:

- It can indicate that the date-time information is considered inaccurate, but is the best information available.
- It can indicate that the date-time information is not available.

The summertime bit is used to indicate that summertime (day light saving) is being used and, more importantly, to resolve the alias and time discontinuity which occurs when summertime starts and ends. This is important for the correct time correlation of time stamped records.

The day of the week field is optional and if not calculated will be set to zero.

The concept of time zone is not catered for by this data type and hence by the relay. It is up to the end user to determine the time zone. Normal practice is to use UTC (universal co-ordinated time).

9.11 POWER AND ENERGY MEASUREMENT DATA FORMATS

The power and energy measurements are available in two data formats:

Data Type G29: an integer format using 3 registers

Data Type G125: a 32 bit floating point format using 2 registers

The G29 registers are listed in the first part of the MEASUREMENTS 2 column of the Courier database. The G125 equivalents appear at the end of the MEASUREMENTS 2 column.

Data type G29

Data type G29 consists of three registers:

The first register is the per unit (or normalised) power or energy measurement. It is a signed 16 bit quantity. This register is of Data Type G28.

The second and third registers contain a multiplier to convert the per unit value to a real value. These are unsigned 32-bit quantities. These two registers together are of Data Type G27.

Thee overall power or energy value conveyed by the G29 data type is therefore G29 = G28 x G27.

The IED calculates the G28 per unit power or energy value as:

G28 = (measured secondary quantity/CT *secondary)(110V/(VT secondary)*.

Since data type G28 is a signed 16-bit integer, its dynamic range is constrained to +/- 32768. You should take this limitation into consideration for the energy measurements, as the G29 value will saturate a long time before the equivalent G125 does.

The associated G27 multiplier is calculated as:

G27 = (CT primary)(VT primary/110V) when primary value measurements are selected

and

G27 = (CT secondary)(VT secondary/110V) when secondary value measurements are selected.

Due to the required truncations from floating point values to integer values in the calculations of the G29 component parts and its limited dynamic range, we only recommend using G29 values when the MODBUS master cannot deal with the G125 IEEE754 floating point equivalents.

> *Note:*
> *The G29 values must be read in whole multiples of three registers. It is not possible to read the G28 and G27 parts with separate read commands.*

Example of Data Type G29

Assuming the CT/VT configurations are as follows:

- Main VT Primary 6.6 kV
- Main VT Secondary 110 V
- Phase CT Primary 3150 A
- Phase CT Secondary 1 A

The Three-phase Active Power displayed on the measurement panel on the front display of the IED would be 21.94 MW

The registers related to the Three-phase Active Power are: 3x00327, 3x00328, 3x00329

Register Address	Data read from these registers	Format of the data
3x00327	116	G28
3x00328	2	G27
3x00329	57928	G27

The Equivalent G27 value = [2^{16} * Value in the address 3x00328 + Value in the address 3x00329] = 216*2 + 57928 = 189000

The Equivalent value of power G29 = G28 * Equivalent G27 =116 * 189000 =21.92 MW

Note:
The above calculated value (21.92 MW) is same as the power value measured on the front panel display.

Data type G125

Data type G125 is a short float IEEE754 floating point format, which occupies 32 bits in two consecutive registers. The high order byte of the format is in the first (low order) register and the low order byte in the second register.

The value of the G125 measurement is as accurate as the IED's ability to resolve the measurement after it has applied the secondary or primary scaling factors. It does not suffer from the truncation errors or dynamic range limitations associated with the G29 data format.

10 IEC 61850

This section describes how the IEC 61850 standard is applied to the Px40 platform. It is not a description of the standard itself. The level at which this section is written assumes that the reader is already familiar with the IEC 61850 standard.

IEC 61850 is the international standard for Ethernet-based communication in substations. It enables integration of all protection, control, measurement and monitoring functions within a substation, and additionally provides the means for interlocking and inter-tripping. It combines the convenience of Ethernet with the security that is so essential in substations today.

10.1 BENEFITS OF IEC 61850

The standard provides:

- Standardized models for IEDs and other equipment within the substation
- Standardized communication services (the methods used to access and exchange data)
- Standardized formats for configuration files
- Peer-to-peer communication

The standard adheres to the requirements laid out by the ISO OSI model and therefore provides complete vendor interoperability and flexibility on the transmission types and protocols used. This includes mapping of data onto Ethernet, which is becoming more and more widely used in substations, in favour of RS485. Using Ethernet in the substation offers many advantages, most significantly including:

- Ethernet allows high-speed data rates (currently 100 Mbps, rather than 10's of kbps or less used by most serial protocols)
- Ethernet provides the possibility to have multiple clients
- Ethernet is an open standard in every-day use
- There is a wide range of Ethernet-compatible products that may be used to supplement the LAN installation (hubs, bridges, switches)

10.2 IEC 61850 INTEROPERABILITY

A major benefit of IEC 61850 is interoperability. IEC 61850 standardizes the data model of substation IEDs, which allows interoperability between products from multiple vendors.

An IEC 61850-compliant device may be interoperable, but this does not mean it is interchangeable. You cannot simply replace a product from one vendor with that of another without reconfiguration. However the terminology is pre-defined and anyone with prior knowledge of IEC 61850 should be able to integrate a new device very quickly without having to map all of the new data. IEC 61850 brings improved substation communications and interoperability to the end user, at a lower cost.

10.3 THE IEC 61850 DATA MODEL

The data model of any IEC 61850 IED can be viewed as a hierarchy of information, whose nomenclature and categorization is defined and standardized in the IEC 61850 specification.

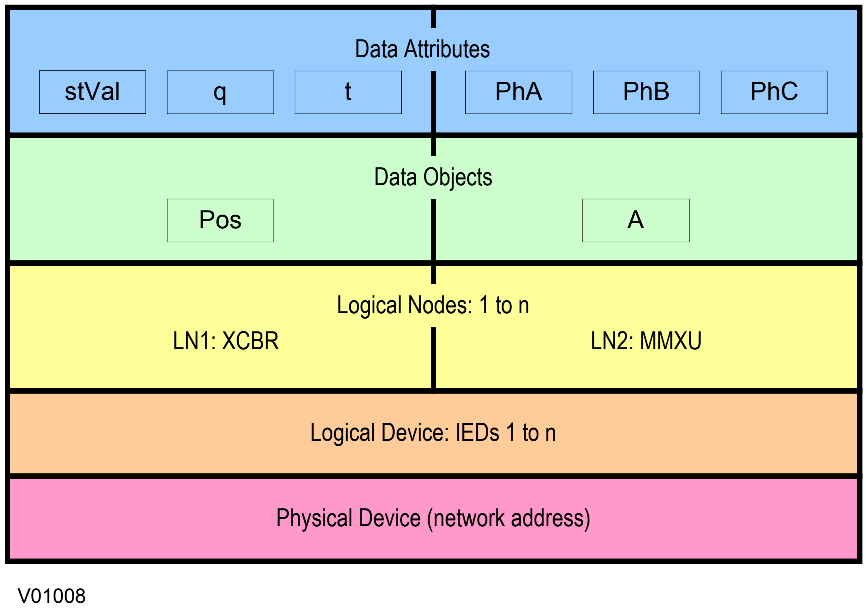


Figure 135: Data model layers in IEC61850

The levels of this hierarchy can be described as follows:

Data Frame format

Layer	Description
Physical Device	Identifies the actual IED within a system. Typically the device's name or IP address can be used (for example Feeder_1 or 10.0.0.2
Logical Device	Identifies groups of related Logical Nodes within the Physical Device. For the MiCOM IEDs, 5 Logical Devices exist: Control, Measurements, Protection, Records, System
Wrapper/Logical Node Instance	Identifies the major functional areas within the IEC 61850 data model. Either 3 or 6 characters are used as a prefix to define the functional group (wrapper) while the actual functionality is identified by a 4 character Logical Node name suffixed by an instance number. For example, XCBR1 (circuit breaker), MMXU1 (measurements), FrqPTOF2 (overfrequency protection, stage 2).
Data Object	This next layer is used to identify the type of data you will be presented with. For example, Pos (position) of Logical Node type XCBR
Data Attribute	This is the actual data (measurement value, status, description, etc.). For example, stVal (status value) indicating actual position of circuit breaker for Data Object type Pos of Logical Node type XCBR

10.4 IEC 61850 IN MICOM IEDS

IEC 61850 is implemented by use of a separate Ethernet card. This Ethernet card manages the majority of the IEC 61850 implementation and data transfer to avoid any impact on the performance of the protection functions.

To communicate with an IEC 61850 IED on Ethernet, it is necessary only to know its IP address. This can then be configured into either:

- An IEC 61850 client (or master), for example a PACiS computer (MiCOM C264)
- An HMI
- An MMS browser, with which the full data model can be retrieved from the IED, without any prior knowledge of the IED

The IEC 61850 compatible interface standard provides capability for the following:

- Read access to measurements
- Refresh of all measurements at the rate of once per second.
- Generation of non-buffered reports on change of status or measurement
- SNTP time synchronization over an Ethernet link. (This is used to synchronize the IED's internal real time clock.
- GOOSE peer-to-peer communication
- Disturbance record extraction by file transfer. The record is extracted as an ASCII format COMTRADE file
- Controls (Direct and Select Before Operate)

> *Note:*
> *Setting changes are not supported in the current IEC 61850 implementation. Currently these setting changes are carried out using MiCOM S1 Agile.*

10.5 IEC 61850 DATA MODEL IMPLEMENTATION

The data model naming adopted in the IEDs has been standardised for consistency. Therefore the Logical Nodes are allocated to one of the five Logical Devices, as appropriate.

The data model is described in the Model Implementation Conformance Statement (MICS) document, which is available as a separate document.

10.6 IEC 61850 COMMUNICATION SERVICES IMPLEMENTATION

The IEC 61850 communication services which are implemented in the IEDs are described in the Protocol Implementation Conformance Statement (PICS) document, which is available as a separate document.

10.7 IEC 61850 PEER-TO-PEER (GSSE) COMMUNICATIONS

The implementation of IEC 61850 Generic Object Oriented Substation Event (GOOSE) enables faster communication between IEDs offering the possibility for a fast and reliable system-wide distribution of input and output data values. The GOOSE model uses multicast services to deliver event information. Multicast messaging means that messages are sent to all the devices on the network, but only those devices that have been appropriately configured will receive the frames. In addition, the receiving devices can specifically accept frames from certain devices and discard frames from the other devices. It is also known as a publisher-subscriber system. When a device detects a change in one of its monitored status points it publishes a new message. Any device that is interested in the information subscribes to the data it contains.

> *Note:*
> *Multicast messages cannot be routed across networks without special equipment.*

Each new message is re-transmitted at configurable intervals, to counter for possible corruption due to interference, and collisions, therefore ensuring delivery. In practice, the parameters controlling the message transmission cannot be calculated. Time must be allocated to the testing of GOOSE schemes before or during commissioning, in just the same way a hardwired scheme must be tested.

10.8 MAPPING GOOSE MESSAGES TO VIRTUAL INPUTS

Each GOOSE signal contained in a subscribed GOOSE message can be mapped to any of the 32 virtual inputs within the PSL. The virtual inputs allow the mapping to internal logic functions for protection control, directly to output contacts or LEDs for monitoring.

An IED can subscribe to all GOOSE messages but only the following data types can be decoded and mapped to a virtual input:

- BOOLEAN
- BSTR2
- INT16
- INT32
- INT8
- UINT16
- UINT32
- UINT8

10.8.1 IEC 61850 GOOSE CONFIGURATION

All GOOSE configuration is performed using the IED Configurator tool available in the MiCOM S1 Agile software application.

All GOOSE publishing configuration can be found under the **GOOSE Publishing** tab in the configuration editor window. All GOOSE subscription configuration parameters are under the **External Binding** tab in the configuration editor window.

Settings to enable GOOSE signalling and to apply Test Mode are available using the HMI.

10.9 ETHERNET FUNCTIONALITY

Settings relating to a failed Ethernet link are available in the COMMUNICATIONS column of the IED's HMI.

10.9.1 ETHERNET DISCONNECTION

IEC 61850 **Associations** are unique and made between the client and server. If Ethernet connectivity is lost for any reason, the associations are lost, and will need to be re-established by the client. The IED has a **TCP_KEEPALIVE** function to monitor each association, and terminate any which are no longer active.

10.9.2 LOSS OF POWER

The IED allows the re-establishment of associations without disruption of its operation, even after its power has been removed. As the IED acts as a server in this process, the client must request the association. Uncommitted settings are cancelled when power is lost, and reports requested by connected clients are reset. The client must re-enable these when it next creates the new association to the IED.

10.10 IEC 61850 CONFIGURATOR SETTINGS

This section contains the table for setting up the IEC61850 Configurator.

Menu Text	Col	Row	Default Setting	Available Options
Description				
IEC61850 CONFIG.	19	00		
This column contains settings for the IEC61850 IED Configurator				

Menu Text	Col	Row	Default Setting	Available Options
Description				
Switch Conf.Bank	19	05	No Action	0 = No Action or 1 = Switch banks
This command allows you to switch between the current configuration, held in the Active Memory Bank to the configuration held in the Inactive Memory Bank.				
Restore MCL	19	0A	No Action	0 = No Action or 1 = Restore MCL
This command lets you restore the MCL (MiCOM Control Language).				
Active Conf.Name	19	10	Not Available	Not Settable
This cell displays the name of the configuration in the Active Memory Bank (usually taken from the SCL file).				
Active Conf.Rev	19	11	Not Available	Not Settable
This cell displays the configuration revision number of the configuration in the Active Memory Bank (usually taken from the SCL file).				
Inact.Conf.Name	19	20	Not Available	Not Settable
This cell displays the name of the configuration in the Inactive Memory Bank (usually taken from the SCL file).				
Inact.Conf.Rev	19	21	Not Available	Not Settable
This cell displays the configuration revision number of the configuration in the Inactive Memory Bank (usually taken from the SCL file).				
IP PARAMETERS	19	30		Not Settable
The data in this sub-heading relates to the IEC61850 IP parameters				
IP Address	19	31	0.0.0.0	Not Settable
This cell displays the IED's IP address.				
Subnet mask	19	32	0.0.0.0	Not Settable
Ths cell displays the subnet mask, which defines the subnet on which the IED is located.				
Gateway	19	33	0.0.0.0	Not Settable
Ths cell displays the gateway address of the LAN on which the IED is located.				
SNTP PARAMETERS	19	40		Not Settable
The data and settings under this sub-heading relate to the IEC61850 SNTP parameters				
SNTP Server 1	19	41	0.0.0.0	Not Settable
This cell displays the IP address of the primary SNTP server.				
SNTP Server 2	19	42	0.0.0.0	Not Settable
This cell displays the IP address of the secondary SNTP server.				
IEC 61850 SCL	19	50		Not Settable
IEC61850 versions only.				
IED Name	19	51	Not Available	Not Settable
This setting displays the unique IED name used on the IEC 61850 network (usually taken from the SCL file).				
IEC 61850 GOOSE	19	60		Not Settable
IEC61850 versions only.				
GoEna	19	70	0x00	Bit 0=gcb01 GoEna Bit 1=gcb02 GoEna Bit 2=gcb03 GoEna Bit 3=gcb04 GoEna Bit 4=gcb05 GoEna Bit 5=gcb06 GoEna Bit 6=gcb07 GoEna Bit 7=gcb08 GoEna
This setting enables the GOOSE publisher settings.				
Test Mode	19	71	0x00	0 = Disabled, 1 = Pass Through, 2 = Forced
This setting allows the test pattern to be sent in the GOOSE message. With 'Pass Through', the data in the GOOSE message is sent as normal. With 'Forced', the data sent in the GOOSE message follows the 'VOP Test Pattern' setting.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
Ignore Test Flag	19	73	No	0 = No or 1 = Yes
This cell allows you to ignore the test flag, if set.				

11 READ ONLY MODE

With IEC 61850 and Ethernet/Internet communication capabilities, security has become an important issue. In view of this, all MiCOM devices comply with the latest Cyber-Security (on page 473) standards. In addition to this, the device provides a facility to allow the user to enable or disable the physical interfaces. This feature is available for products using Courier, IEC 60870-5-103, or IEC 61850.

Note:
For IEC 60870-5-103, Read Only Mode function is different from the existing Command block feature.

11.1 IEC 60870-5-103 PROTOCOL

If Read-Only Mode is enabled for RP1 or RP2 with IEC 60870-5-103, the following commands are blocked at the interface:

- Write parameters (=change setting) (private ASDUs)
- General Commands (ASDU20), namely:
  - INF16 auto-recloser on/off
  - INF19 LED reset
  - Private INFs (for example: CB open/close, Control Inputs)

The following commands are still allowed:

- Poll Class 1 (Read spontaneous events)
- Poll Class 2 (Read measurands)
- GI sequence (ASDU7 'Start GI', Poll Class 1)
- Transmission of Disturbance Records sequence (ASDU24, ASDU25, Poll Class 1)
- Time Synchronisation (ASDU6)
- General Commands (ASDU20), namely:
  - INF23 activate characteristic 1
  - INF24 activate characteristic 2
  - INF25 activate characteristic 3
  - INF26 activate characteristic 4

11.2 COURIER PROTOCOL

If Read-Only Mode is enabled for RP1 or RP2 with Courier, the following commands are blocked at the interface:

- Write settings
- All controls, including:
  - Reset Indication (Trip LED)
  - Operate Control Inputs
  - CB operations
  - Auto-reclose operations
  - Reset demands
  - Clear event/fault/maintenance/disturbance records
  - Test LEDs & contacts

The following commands are still allowed:

• Read settings, statuses, measurands

• Read records (event, fault, disturbance)

• Time Synchronisation

• Change active setting group

11.3 IEC 61850 PROTOCOL

If Read-Only Mode is enabled for the Ethernet interfacing with IEC 61850, the following commands are blocked at the interface:

- All controls, including:
  - Enable/disable protection
  - Operate Control Inputs
  - CB operations (Close/Trip, Lock)
  - Reset LEDs

The following commands are still allowed:

- Read statuses, measurands
- Generate reports
- Extract disturbance records
- Time synchronisation
- Change active setting group

11.4 READ-ONLY SETTINGS

The following settings are available for enabling or disabling Read Only Mode.

- RP1 Read Only
- RP2 Read Only
- NIC Read Only

These settings are not available for MODBUS and DNP3.

11.5 READ-ONLY DDB SIGNALS

The remote read only mode is also available in the PSL using three dedicated DDB signals:

- RP1 Read Only
- RP2 Read Only
- NIC Read Only

Using the PSL, these signals can be activated by opto-inputs, Control Inputs and function keys if required.

12 TIME SYNCHRONISATION

In modern protection schemes it is necessary to synchronise the IED's real time clock so that events from different devices can be time stamped and placed in chronological order. This is achieved in various ways depending on the chosen options and communication protocols.

- Using the IRIG-B input (if fitted)
- Using the SNTP time protocol (for Ethernet IEC61850 versions + DNP3 OE)
- By using the time synchronisation functionality inherent in the data protocols

13 DEMODULATED IRIG-B

IRIG stands for Inter Range instrumentation Group, which is a standards body responsible for standardising different time code formats. There are several different formats starting with IRIG-A, followed by IRIG-B and so on. The letter after the "IRIG" specifies the resolution of the time signal in pulses per second (PPS). IRIG-B, the one which we use has a resolution of 100 PPS. IRIG-B is used when accurate time-stamping is required.

The following diagram shows a typical GPS time-synchronised substation application. The satellite RF signal is picked up by a satellite dish and passed on to receiver. The receiver receives the signal and converts it into time signal suitable for the substation network. IEDs in the substation use this signal to govern their internal clocks and event recorders.

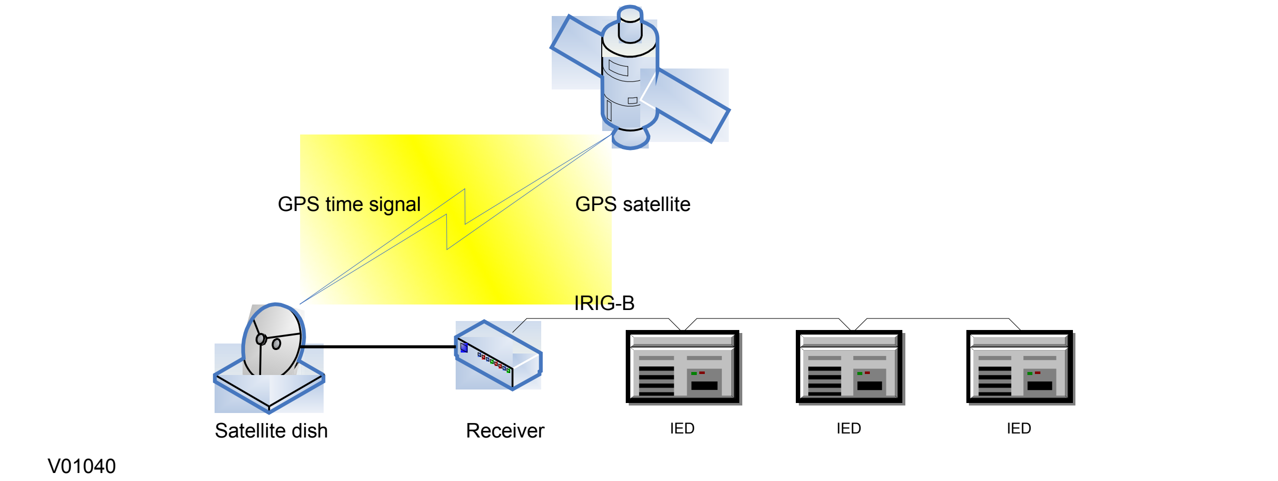


Figure 136: GPS Satellite timing signal

The IRIG-B time code signal is a sequence of one second time frames. Each frame is split up into ten 100 mS slots as follows:

- Time-slot 1: Seconds
- Time-slot 2: Minutes
- Time-slot 3: Hours
- Time-slot 4: Days
- Time-slot 5 and 6: Control functions
- Time-slots 7 to 10: Straight binary time of day

The first four time-slots define the time in BCD (Binary Coded Decimal). Time-slots 5 and 6 are used for control functions, which control deletion commands and allow different data groupings within the synchronisation strings. Time-slots 7-10 define the time in SBS (Straight Binary Second of day).

13.1 DEMODULATED IRIG-B IMPLEMENTATION

All models have the option of accepting a demodulated IRIG-B input. This is a hardware option and it uses the same terminals as the RP1 (or RP2 if applicable) inputs. You cannot have IRIG-B and a serial port in the same slot. This means 20Te models cannot have both IRIG-B time synchronisation and serial communications capability. For 30TE models however, it is possible to have IRIG-B in one slot and a serial port in another, provided this option is ordered.

To set the device to use IRIG-B, use the setting **IRIG-B Sync** cell in the DATE AND TIME column. This can be set to 'None' (for no IRIG-B), 'RP1' (for the option where IRIG-B uses terminals 54 and 56) and 'RP2' (for the option where IRIG-B uses terminals 82 and 84)

The IRIG-B status can be viewed in the **IRIG-B Status** cell in the DATE AND TIME column.

14 SNTP

SNTP is used to synchronise the clocks of computer systems over packet-switched, variable-latency data networks, such as IP. SNTP can be used as the time synchronisation method for models using IEC 61850 over Ethernet.

The device is synchronised by the main SNTP server. This is achieved by entering the IP address of the SNTP server into the IED using the IED Configurator software (on page 510) described in the S1 Agile chapter. A second server is also configured with a different IP address for backup purposes.

The HMI menu does not contain any configurable settings relating to SNTP, as the only way to configure it is using the IEC61850 Configurator. However it is possible to view some parameters in the COMMUNICATIONS column under the sub-heading SNTP parameters. Here you can view the SNTP server addresses and the SNTP poll rate in the cells **SNTP Server** 1, **SNTP Server 2** and **SNTP Poll rate** respectively.

The SNTP time synchronisation status is displayed in the **SNTP Status** cell in the DATE AND TIME column.

15 TIME SYNCHRONSIATION USING THE COMMUNICATION PROTOCOLS

All communication protocols have in-built time synchronisation mechanisms. If neither IRIG-B nor SNTP is used to synchronise the devices, the time synchronisation mechanism within the relevant serial protocol is used. The real time is usually defined in the master station and communicated to the relevant IEDs via one of the rear serial ports using the chosen protocol. It is also possible to define the time locally using settings in the DATE AND TIME column.

The time synchronisation for each protocol is described in the relevant protocol description sections as follows:

- Courier Time Synchronisation (on page 435)
- IEC 60870-5-103 Time synchronisation (on page 436)
- DNP 3 Time Synchronisation (on page 441)
- Modbus time Synchronisation (on page 453)

16 COMMUNICATION SETTINGS

This section contains a complete table of the settings required to set up the device communication.

Menu Text	Col	Row	Default Setting	Available Options
Description				
COMMUNICATIONS	0E	00		
This column contains general communications settings				
RP1 Protocol	0E	01		0 = Courier, 1 = IEC870-5-103, 2 = Modbus, 3 = DNP3.0
This setting sets the address of RP1.				
RP1 Address	0E	02	255	0 to 255 (Courier)
This setting sets the address of RP1.				
RP1 Address	0E	02	247	0 to 247 (Modbus)
This setting sets the address of RP1.				
RP1 Address	0E	02	254	0 to 254 (CS103)
This setting sets the address of RP1.				
RP1 Address	0E	02	255	0 to 65534 (DNP3.0)
This setting sets the address of RP1.				
RP1 InactivTimer	0E	03	15	From 1m to 30m step 1m
This setting defines the period of inactivity on RP1 before the IED reverts to its default state.				
RP1 Baud Rate	0E	04	19200 bits/s	1200, 2400, 4800 9600, 19200, 38400 (dependent on protocol)
This setting sets the communication speed between the IED RP1 port and the master station. It is important that both IED and master station are set at the same speed setting. This cell is applicable for the non-Courier protocols.				
RP1 Parity	0E	05	None	0 = Odd, 1 = Even, 2 = None
This setting controls the parity format used in the data frames of RP1. It is important that both IED and master station are set with the same parity setting.				
RP1 Meas Period	0E	06	15	From 1s to 60s step 1s
This setting controls the time interval that the IED will use between sending measurement data to the master station for IEC60870-5-103 versions.				
RP1 Time Sync	0E	08	Disabled	0 = Disabled or 1 = Enabled
This setting is for DNP3.0 versions only. If set to Enabled the master station can be used to synchronize the time on the IED via RP1. If set to Disabled either the internal free running clock or IRIG-B input are used.				
Modbus IEC Time	0E	09	Standard	0=Standard IEC (Existing format) 1=Reverse IEC (Company agreed format)
When 'Standard IEC' is selected the time format complies with IEC60870-5-4 requirements such that byte 1 of the information is transmitted first, followed by bytes 2 through to 7. If 'Reverse' is selected the transmission of information is reversed.				
RP1 CS103Blcking	0E	0A	Disabled	0 = Disabled, 1 = Monitor Blocking or 2 = Command Blocking
This cell sets the blocking type for IEC60870-5-103. With monitor blocking, reading of the status information and disturbance records is not permitted. When in this mode the IED returns a "termination of general interrogation" message to the master station. With command blocking, all remote commands will be ignored (e.g.CB Trip/Close, change setting group). When in this mode the IED returns a "negative acknowledgement of command" message to the master station.				
RP1 Card Status	0E	0B		0 = K Bus OK 1 = EIA485 OK 2 = IRIG-B
This setting displays the communication type and status of RP1				

Menu Text	Col	Row	Default Setting	Available Options
Description				
RP1 Port Config	0E	0C	EIA485 (RS485)	0 = K-Bus 1 = EIA485 (RS485)
This seting selects the type of physical protocol for RP1 - either K-bus or RS485.				
RP1 Comms Mode	0E	0D	IEC60870 FT1.2	0 = IEC60870 FT1.2 Frame or 1 = 10-bit no parity
This setting determines the serial communication mode.				
RP1 Baud Rate	0E	0E	19200 bits/s	0 = 9600 bits/s, 1 = 19200 bits/s, 2 = 38400 bits/s Courier protocol only
This cell controls the communication speed between IED and master station. It is important that both IED and master station are set at the same speed setting. This cell is applicable for the Courier protocol.				
Meas Scaling	0E	0F	Primary	0 = Normalised, 1 = Primary, 2 = Secondary
This setting determines the scaling type of analogue quantities - in terms of primary, secondary or normalised, for DNP3 models				
Message Gap (ms)	0E	10	0	From 0ms to 50ms step 1ms
This setting allows the master station to have an interframe gap. DNP 3.0 versions only				
DNP Need Time	0E	11	10	From 1ms to 30ms step 1ms
This setting sets the duration of time waited before requesting another time sync from the master. DNP 3.0 versions only.				
DNP App Fragment	0E	12	2048	100 to 2048 step 1
This setting sets the maximum message length (application fragment size) transmitted by the IED for DNP 3.0 versions.				
DNP App Timeout	0E	13	2	From 1s to 120s step 1s
This setting sets the maximum waiting time between sending a message fragment and reciving confirmation from the master. DNP 3.0 versions only.				
DNP SBO Timeout	0E	14	10	From 1s to 10s step 1s
This setting sets the maximum waiting time between receiving (sending?) a select command and awaiting an operate confirmation from the master. DNP 3.0 versions only.				
DNP Link Timeout	0E	15	0	From 0s to 120s step 1s
This setting sets the maximum waiting time for a Data Link Confirm from the master. A value of 0 means data link support disabled. DNP 3.0 versions only.				
NIC Protocol	0E	1F		IEC61850 or DNP3.0 over Ethernet
This cell indicates whether IEC 61850 or DNP 3.0 over Ethernet are used on the rear Ethernet port.				
NIC MAC Address	0E	22	Ethernet MAC Address	<Ethernet MAC address>
This setting displays the MAC address of the rear Ethernet port, if applicable.				
NIC Tunl Timeout	0E	64	5.00 min	From 1ms to 30ms step 1ms
This setting sets the maximum waiting time before an inactive tunnel to the application software is reset. DNP 3.0 over Ethernet versions only.				
NIC Link Report	0E	6A	Alarm	0 = Alarm, 1 = Event, 2 = None
This setting defines how a failed or unfitted network link is reported. DNP 3.0 over Ethernet versions only.				
REAR PORT2 (RP2)	0E	80		
The settings in this sub-menu are for models with a second communications port (RP2).				
RP2 Protocol	0E	81	Courier	Not Settable
This cell displays the communications protocol relevant to main communication port (RP2) of the chosen IED model.				
RP2 Card Status	0E	84		0 = K Bus OK 1 = EIA485 OK 2 = IRIG-B
This setting displays the communication type and status of RP2, if applicable				
RP2 Port Config	0E	88	EIA485 (RS485)	0 = K-Bus 1 = EIA485 (RS485)

Menu Text	Col	Row	Default Setting	Available Options
Description				
This seting selects the type of physical protocol for RP2 - either K-bus or RS485.				
RP2 Comms Mode	0E	8A	IEC60870 FT1.2	0 = IEC60870 FT1.2 Frame or 1 = 10-bit no parity
This setting determines the serial communication mode.				
RP2 Address	0E	90	255	0 to 255 step 1
This setting sets the address of RP2.				
RP2 InactivTimer	0E	92	15	From 1m to 30m step 1m
This setting defines the period of inactivity on RP2 before the IED reverts to its default state.				
RP2 Baud Rate	0E	94	19200 bps	0 = 9600 bps, 1 = 19200 bps, 2 = 38400 bps
This setting sets the communication speed between the IED RP2 port and the master station. It is important that both IED and master station are set at the same speed setting.				
IP Address	0E	A1	0.0.0.0	Not Settable
This cell displays the IED's IP address. DNP over Ethernet versions only.				
Subnet Address	0E	A2	0.0.0.0	Not Settable
This cell displays the the LAN's subnet address on which the IED is located. DNP 3.0 over Ethernet versions only.				
Gateway	0E	A4	0.0.0.0	Not Settable
This cell displays the LAN's gateway address on which the IED is located. DNP 3.0 over Ethernet versions only.				
DNP Time Synch	0E	A5	Disabled	0 = Disabled or 1 = Enabled
If set to ‘Enabled’ the DNP3.0 master station can be used to synchronise the IED's time clock. If set to ‘Disabled’ either the internal free running clock, or IRIG-B input are used. DNP 3.0 over Ethernet versions only.				
Meas Scaling	0E	A6	Primary	0 = Normalised, 1 = Primary, 2 = Secondary
This setting determines the scaling type of analogue quantities - in terms of primary, secondary or normalised, for DNP3 models.				
NIC Tunl Timeout	0E	A7	5	From 1ms to 30ms step 1ms
This setting sets the maximum waiting time before an inactive tunnel to the application software is reset. DNP 3.0 over Ethernet versions only.				
NIC Link Report	0E	A8	Alarm	0 = Alarm, 1 = Event, 2 = None
This setting defines how a failed or unfitted network link is reported. DNP 3.0 over Ethernet versions only.				
NIC Link Timeout	0E	A9	60s	From 0.1ms to 60ms step 0.1ms
This setting determines the duration of time waited, after a failed network link is detected, before communication by an alternative media interface is attempted.				
SNTP PARAMETERS	0E	AA		
The settings in this sub-menu are for models using DNP3 over Ethernet.				
SNTP Server 1	0E	AB	0.0.0.0	Not Settable
This cell indicates the SNTP Server 1 address. DNP 3.0 over Ethernet versions only.				
SNTP Server 2	0E	AC	0.0.0.0	Not Settable
This cell indicates the SNTP Server 2 address. DNP 3.0 over Ethernet versions only.				
SNTP Poll Rate	0E	AD	64s	Not Settable
This cell displays the SNTP poll rate interval in seconds. DNP 3.0 over Ethernet versions only.				
DNP Need Time	0E	B1	10	From 1 to 30 step 1
This setting sets the duration of time waited before requesting another time sync from the master. DNP 3.0 versions only.				
DNP App Fragment	0E	B2	2048	From 100 to 2048 step 1
This setting sets the maximum message length (application fragment size) transmitted by the IED for DNP 3.0 versions.				
DNP App Timeout	0E	B3	2	From 1s to 120s step 1s
This setting sets the maximum waiting time between sending a message fragment and reciving confirmation from the master. DNP 3.0 versions only.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
DNP SBO Timeout	0E	B4	10	From 1s to 10s step 1s
This setting sets the maximum waiting time between receiving (sending?) a select command and awaiting an operate confirmation from the master. DNP 3.0 versions only.				

CYBER-SECURITY

CHAPTER 11

1 OVERVIEW

In the past, substation networks were traditionally isolated and the protocols and data formats used to transfer information between devices were more often than not proprietary.

For these reasons, the substation environment was very secure against cyber-attacks. The terms used for this inherent type of security are:

- Security by isolation (if the substation network is not connected to the outside world, it cannot be accessed from the outside world).
- Security by obscurity (if the formats and protocols are proprietary, it is very difficult to interpret them.

The increasing sophistication of protection schemes coupled with the advancement of technology and the desire for vendor interoperability has resulted in standardisation of networks and data interchange within substations. Today, devices within substations use standardised protocols for communication. Furthermore, substations can be interconnected with open networks, such as the internet or corporate-wide networks, which use standardised protocols for communication. This introduces a major security risk making the grid vulnerable to cyber-attacks, which could in turn lead to major electrical outages.

Clearly, there is now a need to secure communication and equipment within substation environments. This chapter describes the security measures that have been put in place for Alstom Grid 's range of Intelligent Electronic Devices (IEDs).

This chapter contains the following sections:

2 THE NEED FOR CYBER-SECURITY

Cyber-security provides protection against unauthorised disclosure, transfer, modification, or destruction of information or information systems, whether accidental or intentional. To achieve this, there are several security requirements:

- Confidentiality (preventing unauthorized access to information)
- Integrity (preventing unauthorized modification)
- Availability / Authentication (preventing the denial of service and assuring authorized access to information)
- Non-repudiation (preventing the denial of an action that took place)
- Traceability/Detection (monitoring and logging of activity to detect intrusion and analyze incidents)

The threats to cyber-security may be unintentional (e.g. natural disasters, human error), or intentional (e.g. cyber-attacks by hackers).

Good cyber-security can be achieved with a range of measures, such as closing down vulnerability loopholes, implementing adequate security processes and procedures and providing technology to help achieve this.

Examples of vulnerabilities are:

- Indiscretions by personnel (e.g. users keep passwords on their computer)
- Bad practice (users do not change default passwords, or everyone uses the same password to access all substation equipment)
- Bypassing of controls (e.g. users turn off security measures)
- Inadequate technology (e.g. substation is not firewalled)

Examples of availability issues are:

- Equipment overload, resulting in reduced or no performance
- Expiry of a certificate preventing access to equipment

To help tackle these issues, standards organizations have produced various standards, by which compliance significantly reduces the threats associated with lack of cyber-security.

3 STANDARDS

There are several standards, which apply to substation cyber-security. The standards currently applicable to Alstom Grid IEDs are NERC and IEEE1686.

Standard	Country	Description
NERC CIP (North American Electric Reliability Corporation)	USA	Framework for the protection of the grid critical Cyber Assets
BDEW (German Association of Energy and Water Industries)	Germany	Requirements for Secure Control and Telecommunication Systems
ANSI ISA 99	USA	ICS oriented then Relevant for EPU completing existing standard and identifying new topics such as patch management
IEEE 1686	International	International Standard for substation IED cyber-security capabilities
IEC 62351	International	Power system data and Comm. protocol
ISO/IEC 27002	International	Framework for the protection of the grid critical Cyber Assets
NIST SP800-53 (National Institute of Standards and Technology)	USA	Complete framework for SCADA SP800-82and ICS cyber-security
CPNI Guidelines (Centre for the Protection of National Infrastructure)	UK	Clear and valuable good practices for Process Control and SCADA security

3.1 NERC COMPLIANCE

The North American Electric Reliability Corporation (NERC) created a set of standards for the protection of critical infrastructure. These are known as the CIP standards (Critical Infrastructure Protection). These were introduced to ensure the protection of 'Critical Cyber Assets', which control or have an influence on the reliability of North America’s electricity generation and distribution systems.

These standards have been compulsory in the USA for several years now. Compliance auditing started in June 2007, and utilities face extremely heavy fines for non-compliance.

NERC CIP standards

CIP standard	Description
CIP-002-1 Critical Cyber Assets	Define and document the Critical Assets and the Critical Cyber Assets
CIP-003-1 Security Management Controls	Define and document the Security Management Controls required to protect the Critical Cyber Assets
CIP-004-1 Personnel and Training	Define and Document Personnel handling and training required protecting Critical Cyber Assets
CIP-005-1 Electronic Security	Define and document logical security perimeter where Critical Cyber Assets reside and measures to control access points and monitor electronic access
CIP-006-1 Physical Security	Define and document Physical Security Perimeters within which Critical Cyber Assets reside
CIP-007-1 Systems Security Management	Define and document system test procedures, account and password management, security patch management, system vulnerability, system logging, change control and configuration required for all Critical Cyber Assets
CIP-008-1 Incident Reporting and Response Planning	Define and document procedures necessary when Cyber-security Incidents relating to Critical Cyber Assets are identified
CIP-009-1 Recovery Plans	Define and document Recovery plans for Critical Cyber Assets

3.1.1 CIP 002

CIP 002 concerns itself with the identification of:

- Critical assets, such as overhead lines and transformers
- Critical cyber assets, such as IEDs that use routable protocols to communicate outside or inside the Electronic Security Perimeter; or are accessible by dial-up.

Power utility responsibilities:	Alstom Grid's contribution:
Create the list of the assets	We can help the power utilities to create this asset register automatically. We can provide audits to list the Cyber assets

3.1.2 CIP 003

CIP 003 requires the implementation of a cyber-security policy, with associated documentation, which demonstrates the management's commitment and ability to secure its Critical Cyber Assets.

The standard also requires change control practices whereby all entity or vendor-related changes to hardware and software components are documented and maintained.

Power utility responsibilities:	Alstom Grid 's contribution:
To create a Cyber-security Policy	We can help the power utilities to have access control to its critical assets by providing centralized Access control. We can help the customer with its change control by providing a section in the documentation where it describes changes affecting the hardware and software.

3.1.3 CIP 004

CIP 004 requires that personnel having authorized cyber access or authorized physical access to Critical Cyber Assets, (including contractors and service vendors), have an appropriate level of training.

Power utility responsibilities:	Alstom Grid 's contribution:
To provide appropriate training of its personnel	We can provide cyber-security training

3.1.4 CIP 005

CIP 005 requires the establishment of an Electronic Security Perimeter (ESP), which provides:

- The disabling of ports and services that are not required
- Permanent monitoring and access to logs (24x7x365)
- Vulnerability Assessments (yearly at a minimum)
- Documentation of Network Changes

Power utility responsibilities:	Alstom Grid 's contribution:
To monitor access to the ESP To perform the vulnerability assessments To document network changes	To disable all ports not used in the IED To monitor and record all access to the IED

3.1.5 CIP 006

CIP 006 states that Physical Security controls, providing perimeter monitoring and logging along with robust access controls, must be implemented and documented. All cyber assets used for Physical Security are considered critical and should be treated as such:

Power utility responsibilities:	Alstom Grid 's contribution:
Provide physical security controls and perimeter monitoring. Ensure that people who have access to critical cyber assets don't have criminal records.	Alstom Grid cannot provide additional help with this aspect.

3.1.6 CIP 007

CIP 007 covers the following points:

- Test procedures
- Ports and services
- Security patch management
- Antivirus
- Account management
- Monitoring
- An annual vulnerability assessment should be performed

Power utility responsibilities:	Alstom Grid 's contribution:
To provide an incident response team and have appropriate processes in place	Test procedures; We can provide advice and help on testing. Ports and services; Our devices can disable unused ports and services Security patch management; We can provide assistance Antivirus; We can provide advise and assistance Account management; We can provide advice and assistance Monitoring; Our equipment monitors and logs access

3.1.7 CIP 008

CIP 008 requires that an incident response plan be developed, including the definition of an incident response team, their responsibilities and associated procedures.

Power utility responsibilities:	Alstom Grid 's contribution:
To provide an incident response team and have appropriate processes in place.	Alstom Grid cannot provide additional help with this aspect.

3.1.8 CIP 009

CIP 009 states that a disaster recovery plan should be created and tested with annual drills.

Power utility responsibilities:	Alstom Grid 's contribution:
To implement a recovery plan	To provide guidelines on recovery plans and backup/restore documentation

3.2 IEEE 1686-2007

IEEE 1686-2007 is an IEEE Standard for substation IEDs' cyber-security capabilities. It proposes practical and achievable mechanisms to achieve secure operations.

The following features described in this standard apply to Alstom Grid Px4x relays:

- Passwords are 8 characters long and can contain upper-case, lower-case, numeric and special characters.
- Passwords are never displayed or transmitted to a user.

- IED functions and features are assigned to different password levels. The assignment is fixed.
- Record of an audit trail listing events in the order in which they occur, held in a circular buffer.
- Records contain all defined fields from the standard and record all defined function event types where the function is supported.
- No password defeat mechanism exists. Instead a secure recovery password scheme is implemented.
- Unused ports (physical and logical) may be disabled.

4 CYBER-SECURITY IMPLEMENTATION

The Alstom Grid IEDs have always been and will continue to be equipped with state-of-the-art security measures. Due to the ever-evolving communication technology and new threats to security, this requirement is not static. Hardware and software security measures are continuously being developed and implemented to mitigate the associated threats and risks.

This section describes the current implementation of cyber-security, valid for the release of platform software to which this manual pertains. This current cyber-security implementation is known as Cyber-security Phase 1.

At the IED level, these cyber-security measures have been implemented:

- NERC-compliant default display
- Four-level access
- Enhanced password security
- Password recovery procedure
- Disabling of unused physical and logical ports
- Inactivity timer
- Security events management

External to the IEDs, the following cyber-security measures have been implemented:

- Antivirus
- Security patch management

4.1 NERC-COMPLIANT DISPLAY

In order for the IED to be NERC-compliant, it must provide the option for a NERC-compliant default display. The default display that is implemented in Alstom Grid's cyber-security concept contains a warning that the IED can be accessed by authorised users.

```
ACCESS ONLY FOR
AUTHORISED USERS
HOTKEY
```

If you try to change the default display from the NERC-compliant one, a further warning is displayed:

```
DISPLAY NOT NERC
COMPLIANT OK?
```

The default display navigation map shows how NERC-compliance is achieved with the product's default display concept.

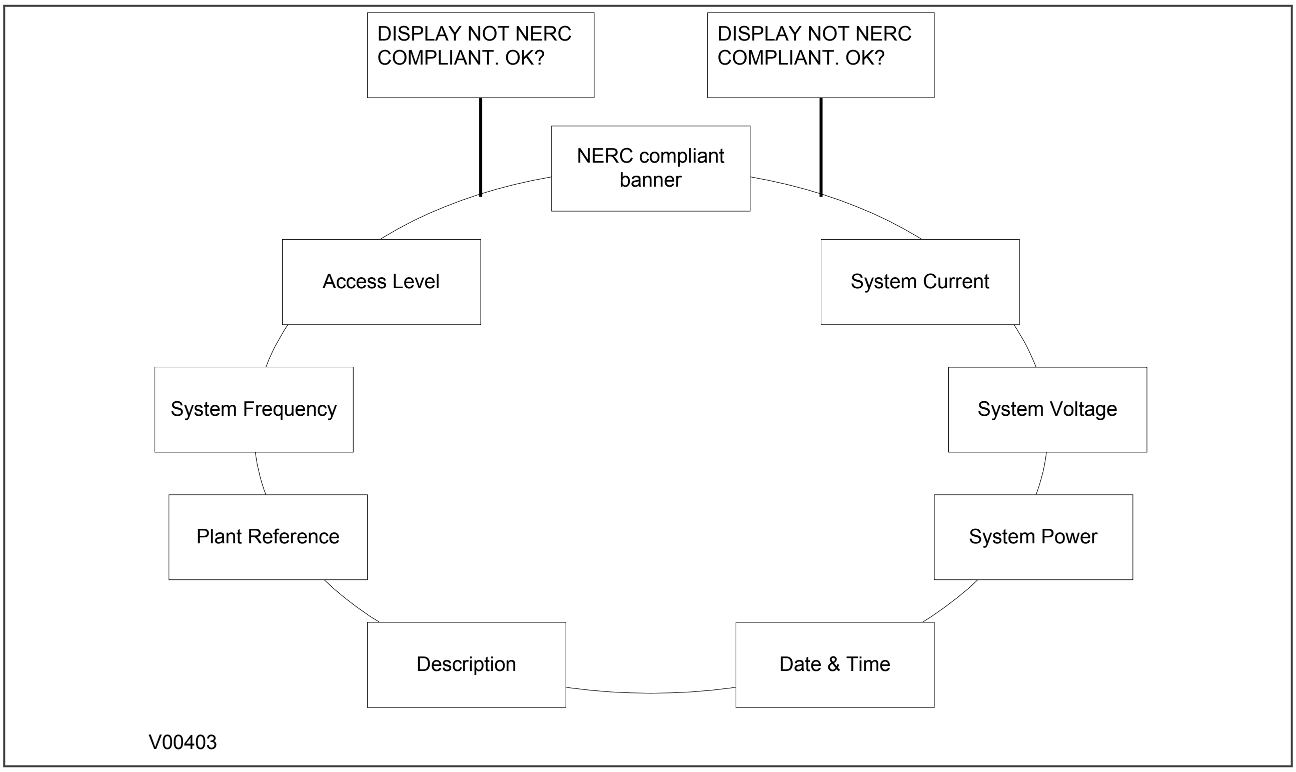


Figure 137: Default display navigation

4.2 FOUR-LEVEL ACCESS

The menu structure contains four levels of access, three of which are password protected.

Password levels

Level	Meaning	Read Operation	Write Operation
0	Read Some Write Minimal	SYSTEM DATA column: Description Plant Reference Model Number Serial Number S/W Ref. Access Level Security Feature SECURITY CONFIG column: User Banner Attempts Remain Blk Time Remain Fallback PW level Security Code (UI only)	Password Entry LCD Contrast (UI only)
1	Read All Write Few	All data and settings are readable. Poll Measurements	All items writeable at level 0. Level 1 Password setting Extract Disturbance Record Select Event, Main and Fault (upload) Extract Events (e.g. via MiCOM S1 Studio)

Level	Meaning	Read Operation	Write Operation
2	Read All Write Some	All data and settings are readable. Poll Measurements	All items writeable at level 1. Setting Cells that change visibility (Visible/Invisible). Setting Values (Primary/Secondary) selector Commands: Reset Indication Reset Demand Reset Statistics Reset CB Data / counters Level 2 Password setting
3	Read All Write All	All data and settings are readable. Poll Measurements	All items writeable at level 2. Change all Setting cells Operations: Extract and download Setting file. Extract and download PSL Extract and download MCL61850 (IED Config - IEC61850) Auto-extraction of Disturbance Recorder Courier/Modbus Accept Event (auto event extraction, e.g. via A2R) Commands: Change Active Group setting Close / Open CB Change Comms device address. Set Date & Time Switch MCL banks / Switch Conf. Bank in UI (IED Config - IEC61850) Enable / Disable Device ports (in SECURITY CONFIG column) Level 3 password setting

4.2.1 BLANK PASSWORDS

A blank password is effectively a zero-length password. Through the front panel it is entered by confirming the password entry without actually entering any password characters. Through a communications port the Courier and Modbus protocols each have a means of writing a blank password to the IED. A blank password disables the need for a password at the level that this password applied.

Blank passwords have a slightly different validation procedure. If a blank password is entered through the front panel, the following text is displayed, after which the procedure is the same as already described:

```
BLANK PASSWORD
ENTERED CONFIRM
```

Blank passwords cannot be configured if lower level password is not blank.

Blank passwords affect fall back level after inactivity timeout or logout.

The ‘fallback level’ is the password level adopted by the IED after an inactivity timeout, or after the user logs out. This will be either the level of the highest level password that is blank, or level 0 if no passwords are blank.

4.2.2 PASSWORD RULES

- Default passwords are blank for Level 1 and AAAA for Levels 2 and 3
- Passwords may be any length between 0 and 8 characters long

- Passwords may or may not be NERC compliant
- Passwords may contain any ASCII character in the range ASCII code 33 (21 Hex) to ASCII code 122 (7A Hex) inclusive
- Only one password is required for all the IED interfaces

4.2.3 ACCESS LEVEL DDBS

In additiona to having the 'Access level' cell in the 'System data' column (address 00D0), the current level of access for each interface is also available for use in the Programming Scheme Logic (PSL) by mapping to these Digital Data Bus (DDB) signals:

- HMI Access Lvl 1
- HMI Access Lvl 2
- FPort AccessLvl1
- FPort AccessLvl2
- RPrt1 AccessLvl1
- RPrt1 AccessLvl2
- RPrt2 AccessLvl1
- RPrt2 AccessLvl2

Each pair of DDB signals indicates the access level as follows:

- Lvl 1 off, Lvl 2 off = 0
- Lvl 1 on, Lvl 2 off = 1
- Lvl 1 off, Lvl 2 on = 2
- Lvl 1 on, Lvl 2 on = 3

Key:

HMI = Human Machine Interface

FPort = Front Port

RPrt = Rear Port

Lvl = Level

4.3 ENHANCED PASSWORD SECURITY

Cyber-security requires strong passwords and validation for NERC compliance.

4.3.1 PASSWORD STRENGTHENING

NERC compliant passwords result in a minimum level of complexity, and include these requirements:

- At least one upper-case alpha character
- At least one lower-case alpha character
- At least one numeric character
- At least one special character (%,$...)
- At least six characters long

4.3.2 PASSWORD VALIDATION

The IED checks for NERC compliance. If the password is entered through the front panel then this is reflected on the panel Liquid Crystal Display (LCD) display.

If the entered password is NERC compliant, the following text is displayed.

```
NERC COMPLIANT
P/WORD WAS SAVED
```

The IED does not enforce NERC compliance. It is the responsibility of the user to ensure that compliance is adhered to as and when necessary. If the password entered is not NERC-compliant, the user is required to actively confirm this, in which case the non-compliance is logged.

If the entered password is not NERC compliant, the following text is displayed:

```
NERC COMPLIANCE
NOT MET CONFIRM?
```

On confirmation, the non-compliant password is stored and the following acknowledgement message is displayed for 2 seconds.

```
NON-NERC P/WORD
SAVED OK
```

If the action is cancelled, the password is rejected and the following message displayed for 2 seconds.

```
NON-NERC P/WORD
NOT SAVE
```

If the password is entered through a communications port using Courier or Modbus protocols the IED will store the password, irrespective of whether it is or isn't NERC-compliant, and then uses appropriate response codes to inform the client that the password was NERC-compliant or not. The client then can choose if he/she wishes to enter a new password that is NERC-compliant or leave the entered one in place.

4.3.3 PASSWORD BLOCKING

You are locked out temporarily, after a defined number of failed password entry attempts. The number of password entry attempts, and the blocking periods are configurable as shown in the table at the end of this section.

Each invalid password entry attempt decrements the 'Attempts Remain' data cell by 1. When the maximum number of attempts has been reached, access is blocked. If the attempts timer expires, or the correct password is entered *before* the 'attempt count' reaches the maximum number, then the 'attempts count' is reset to 0.

An attempt is only counted if the attempted password uses only characters in the valid range, but the attempted password is not correct (does not match the corresponding password in the IED). Any attempt where one or more characters of the attempted password are not in the valid range will not be counted.

Once the password entry is blocked, a 'blocking timer' is initiated. Attempts to access the interface whilst the 'blocking timer' is running results in an error message, irrespective of whether the correct password is entered or not. Only after the 'blocking timer' has expired will access to the interface be unblocked, whereupon the attempts counter is reset to zero.

Attempts to write to the password entry whilst it is blocked results in the following message, which is displayed for 2 seconds.

```
NOT ACCEPTED
ENTRY IS BLOCKED
```

Appropriate responses achieve the same result if the password is written through a communications port.

The attempts count, attempts timer and blocking timer can be configured, as shown in the table.

Password blocking configuration

Setting	Cell col row	Units	Default Setting	Available Setting
Attempts Limit	25 02		3	0 to 3 step 1
Attempts Timer	25 03	Minutes	2	1 to 3 step 1
Blocking Timer	25 04	Minutes	5	1 to 30 step 1

4.4 PASSWORD RECOVERY

Password recovery is the means by which the passwords can be recovered on a device if the customer should mislay the configured passwords. To obtain the recovery password the customer must contact the Alstom Grid Contact Centre and supply two pieces of information from the IED – namely the *Serial Number* and its *Security Code*. The Contact Centre will use these items to generate a Recovery Password which is then provided to the customer.

The security code is a 16-character string of upper case characters. It is a read-only parameter. The IED generates its own security code randomly. A new code is generated under the following conditions:

- On power up
- Whenever settings are set back to default
- On expiry of validity timer (see below)
- When the recovery password is entered

As soon as the security code is displayed on the LCD display, a validity timer is started. This validity timer is set to 72 hours and is not configurable. This provides enough time for the contact centre to manually generate and send a recovery password. The Service Level Agreement (SLA) for recovery password generation is one working day, so 72 hours is sufficient time, even allowing for closure of the contact centre over weekends and bank holidays.

To prevent accidental reading of the IED security code the cell will initially display a warning message:

```
PRESS ENTER TO
READ SEC. CODE
```

The security code will be displayed on confirmation, whereupon the validity timer will be started. The security code can only be read from the front panel.

4.4.1 PASSWORD RECOVERY

The recovery password is intended for recovery only. It is not a replacement password that can be used continually. It can only be used once – for password recovery.

Entry of the recovery password causes the IED to reset all passwords back to default. This is all it is designed to do. After the passwords have been set back to default, it is up to the user to enter new passwords appropriate for the function for which they are intended, ensuring NERC compliance, if required.

On this action, the following message is displayed:

```
PASSWORDS HAVE
BEEN SET TO
DEFAULT
```

The recovery password can be applied through any interface, local or remote. It will achieve the same result irrespective of which interface it is applied through.

4.4.2 PASSWORD ENCRYPTION

The IED supports encryption for passwords entered remotely. The encryption key can be read from the IED through a specific cell available only through communication interfaces, not the front panel. Each time the key is read the IED generates a new key that is valid only for the next password encryption write. Once used, the key is invalidated and a new key must be read for the next encrypted password write. The encryption mechanism is otherwise transparent to the user.

4.5 DISABLING PHYSICAL PORTS

It is possible to disable unused physical ports. A level 3 password is needed to perform this action.

To prevent accidental disabling of a port, a warning message is displayed according to whichever port is required to be disabled. For example if rear port 1 is to be disabled, the following message appears:

```
REAR PORT 1 TO BE
DISABLED.CONFIRM
```

Two to four ports can be disabled, depending on the model.

- Front port
- Rear port 1
- Rear port 2 (not implemented on all models)
- Ethernet port (not implemented on all models)

Note:
Note: It is not possible to disable a port from which the disabling port command originates.

4.6 DISABLING LOGICAL PORTS

It is possible to disable unused logical ports. A level 3 password is needed to perform this action.

Note:
Note: The port disabling setting cells are not provided in the settings file. It is only possible to do this using the HMI front panel.

It is not desirable to disable the Ethernet port as doing this will disable all Ethernet communications. It is more appropriate to disable selected protocols on the Ethernet card and leave the others functioning.

Three protocols can be disabled:

- IEC61850
- DNP3 Over Ethernet
- Courier Tunnelling

> *Note:*
> *Note: If any of these protocols are enabled or disabled, the Ethernet card will reboot.*

4.7 SECURITY EVENTS MANAGEMENT

The implementation of NERC-compliant cyber-security necessitates the generation of a range of Event records, which log security issues such as the entry of a non-NERC-compliant password, or the selection of a non-NERC-compliant default display.

Security event values

Event Value	Display
PASSWORD LEVEL UNLOCKED	USER LOGGED IN ON <int> LEVEL <n>
PASSWORD LEVEL RESET	USER LOGGED OUT ON <int> LEVEL <n>
PASSWORD SET BLANK	P/WORD SET BLANK BY <int> LEVEL <p>
PASSWORD SET NON-COMPLIANT	P/WORD NOT-NERC BY <int> LEVEL <p>
PASSWORD MODIFIED	PASSWORD CHANGED BY <int> LEVEL <p>
PASSWORD ENTRY BLOCKED	PASSWORD BLOCKED ON <int>
PASSWORD ENTRY UNBLOCKED	P/WORD UNBLOCKED ON <int>
INVALID PASSWORD ENTERED	INV P/W ENTERED ON <int>
PASSWORD EXPIRED	P/WORD EXPIRED ON <int>
PASSWORD ENTERED WHILE BLOCKED	P/W ENT WHEN BLK ON <int>
RECOVERY PASSWORD ENTERED	RCVY P/W ENTERED ON <int>
IED SECURITY CODE READ	IED SEC CODE RD ON <int>
IED SECURITY CODE TIMER EXPIRED	IED SEC CODE EXP -
PORT DISABLED	PORT DISABLED BY <int> PORT <prt>
PORT ENABLED	PORT ENABLED BY <int> PORT <prt>
DEF. DISPLAY NOT NERC COMPLIANT	DEF DSP NOT-NERC
PSL SETTINGS DOWNLOADED	PSL STNG D/LOAD BY <int> GROUP <grp>

Event Value	Display
DNP SETTINGS DOWNLOADED	DNP STNG D/LOAD BY <int>
TRACE DATA DOWNLOADED	TRACE DAT D/LOAD BY <int>
IEC61850 CONFIG DOWNLOADED	IED CONFG D/LOAD BY <int>
USER CURVES DOWNLOADED	USER CRV D/LOAD BY <int> GROUP <crv>
PSL CONFIG DOWNLOADED	PSL CONFG D/LOAD BY <int> GROUP <grp>
SETTINGS DOWNLOADED	SETTINGS D/LOAD BY <int> GROUP <grp>
PSL SETTINGS UPLOADED	PSL STNG UPLOAD BY <int> GROUP <grp>
DNP SETTINGS UPLOADED	DNP STNG UPLOAD BY <int>
TRACE DATA UPLOADED	TRACE DAT UPLOAD BY <int>
IEC61850 CONFIG UPLOADED	IED CONFG UPLOAD BY <int>
USER CURVES UPLOADED	USER CRV UPLOAD BY <int> GROUP <crv>
PSL CONFIG UPLOADED	PSL CONFG UPLOAD BY <int> GROUP <grp>
SETTINGS UPLOADED	SETTINGS UPLOAD BY <int> GROUP <grp>
EVENTS HAVE BEEN EXTRACTED	EVENTS EXTRACTED BY <int> <nov> EVNTS
ACTIVE GROUP CHANGED	ACTIVE GRP CHNGE BY <int> GROUP <grp>
CS SETTINGS CHANGED	C & S CHANGED BY <int>
DR SETTINGS CHANGED	DR CHANGED BY <int>
SETTING GROUP CHANGED	SETTINGS CHANGED BY <int> GROUP <grp>
POWER ON	POWER ON -
SOFTWARE_DOWNLOADED	S/W DOWNLOADED -

Where:

- int is the interface definition (UI, FP, RP1, RP2, TNL, TCP)
- prt is the port ID (FP, RP1, RP2, TNL, DNP3, IEC, ETHR)
- grp is the group number (1, 2, 3, 4)
- crv is the Curve group number (1, 2, 3, 4)

- n is the new access level (0, 1, 2, 3)
- p is the password level (1, 2, 3)
- nov is the number of events (1 – nnn)

Each event is identified with a unique number that is incremented for each new event so that it is possible to detect missing events as there will be a ‘gap’ in the sequence of unique identifiers. The unique identifier forms part of the event record that is read or uploaded from the IED.

> *Note:*
> *It is no longer possible to clear Event, Fault, Maintenance, and Disturbance Records*

4.8 LOGGING OUT

If you have been configuring the IED, you should 'log out'. Do this by going up to the top of the menu tree. When you are at the Column Heading level and you press the Up button, you may be prompted to log out with the following display:

```
DO YOU WANT TO
LOG OUT?
```

You will only be asked this question if your password level is higher than the fallback level.

If you confirm, the following message is displayed for 2 seconds:

```
LOGGED OUT
Access Level <x>
```

Where x is the current fallback level.

If you decide not to log out (i.e. you cancel), the following message is displayed for 2 seconds.

```
LOGOUT CANCELLED
Access Level <x>
```

Where x is the current access level.

5 CYBER-SECURITY SETTINGS

The cyber-security settings are contained in the HMI database under the SECURITY CONFIGURATION.

A summary of the relevant settings is shown below.

Security cells summary

Parameter	Cell col row	Default Setting	Available Setting	Interface Applicability	In Setting file?
Password	00 02		ASCII 33 to 122	All	Yes
Access Level	00 D0		0 = Read Some, 1 = Read All, 2 = Read All + Write Some, 3 = Read All + Write All	All	Yes, Not Settable
Password Level 1	00 D2		ASCII 33 to 122	All	Yes
Password Level 2	00 D3		ASCII 33 to 122	All	Yes
Password Level 3	00 D4		ASCII 33 to 122	All	Yes
Security Feature	00 DF		1	All	Yes, Not Settable
SECURITY CONFIG	25 00			All	Yes
Use Banner	25 01	ACCESS ONLY FOR AUTHORISED USERS	ASCII 32 to 163	All	Yes
Attempts Limit	25 02	3	0 to 3 step 1	All	Yes
Attempts Timer	25 03	2	1 to 3 step 1	All	Yes
Blocking Timer	25 04	5	1 to 30 step 1	All	Yes
Front Port	25 05	Enabled	0 = Disabled or 1 = Enabled	All	No
Rear Port 1	25 06	Enabled	0 = Disabled or 1 = Enabled	All	No
Rear Port 2	25 07	Enabled	0 = Disabled or 1 = Enabled	All	No
Ethernet Port*	25 08	Enabled	0 = Disabled or 1 = Enabled	All	No
Courier Tunnel*†	25 09	Enabled	0 = Disabled or 1 = Enabled	All	No
IEC61850*†	25 0A	Enabled	0 = Disabled or 1 = Enabled	All	No
DNP3 OE*†	25 0B	Enabled	0 = Disabled or 1 = Enabled	All	No
Attempts Remain	25 11			All	Yes, Not Settable
Blk Time Remain	25 12			All	Yes, Not Settable
Fallbck PW Level	25 20	0	0 = Password Level 0, 1 = Password Level 1, 2 = Password Level 2, 3 = Password Level 3	All	Yes, Not Settable
Security Code	25 FF			UI Only	No
Evt Unique Id (Normal Extraction)	01 FE			All	No

Parameter	Cell col row	Default Setting	Available Setting	Interface Applicability	In Setting file?
Evt Iface Source ± (Bits 0 – 7 of Event State)	01 FA			All	No
Evt Access Level ± (Bits 15 – 8 of Event State)	01 FB			All	No
Evt Extra Info 1 ± (Bits 23 – 16 of Event State)	01 FC			All	No
Evt Extra Info 2 ±Ω (Bits 31 – 24 of Event State)	01 FD			All	No

Where:

* - These cells will not be present in a non-Ethernet product

†- These cells will be invisible if the Ethernet port is disabled.

± - These cells invisible if event is not a Security event

Ω – This cell is invisible in current phase as it does not contain any data. It is reserved for future use.

SETTINGS APPLICATION SOFTWARE

CHAPTER 12

1 CHAPTER OVERVIEW

The settings application software used in this range of IEDs is called MiCOM S1 Agile. It is a collection of software tools, which is used for managing all aspects of the IEDs. This chapter provides a brief description of each software tool. Further information is available in the Help system.

This chapter contains the following sections:

2 INTRODUCTION

This software allows you to edit device settings and commands for Alstom Grid's range of IEDs. It is compatible with Windows XP, Windows Vista and Windows 7 operating systems.

It also enables you to manage the MiCOM devices in your system. You can build a list of devices and organise them in the same way as they physically exist in a system. Parameters can be created and uploaded for each device, and devices can be supervised directly.

It also includes a Product Selector tool. This is an interactive product catalogue, which makes it easier to choose the right device for each application.

3 USER INTERFACE

3.1 TILE STRUCTURE

Figure 138: Tile structure

3.2 MENU STRUCTURE

Figure 139: Menu structure

4 GETTING STARTED

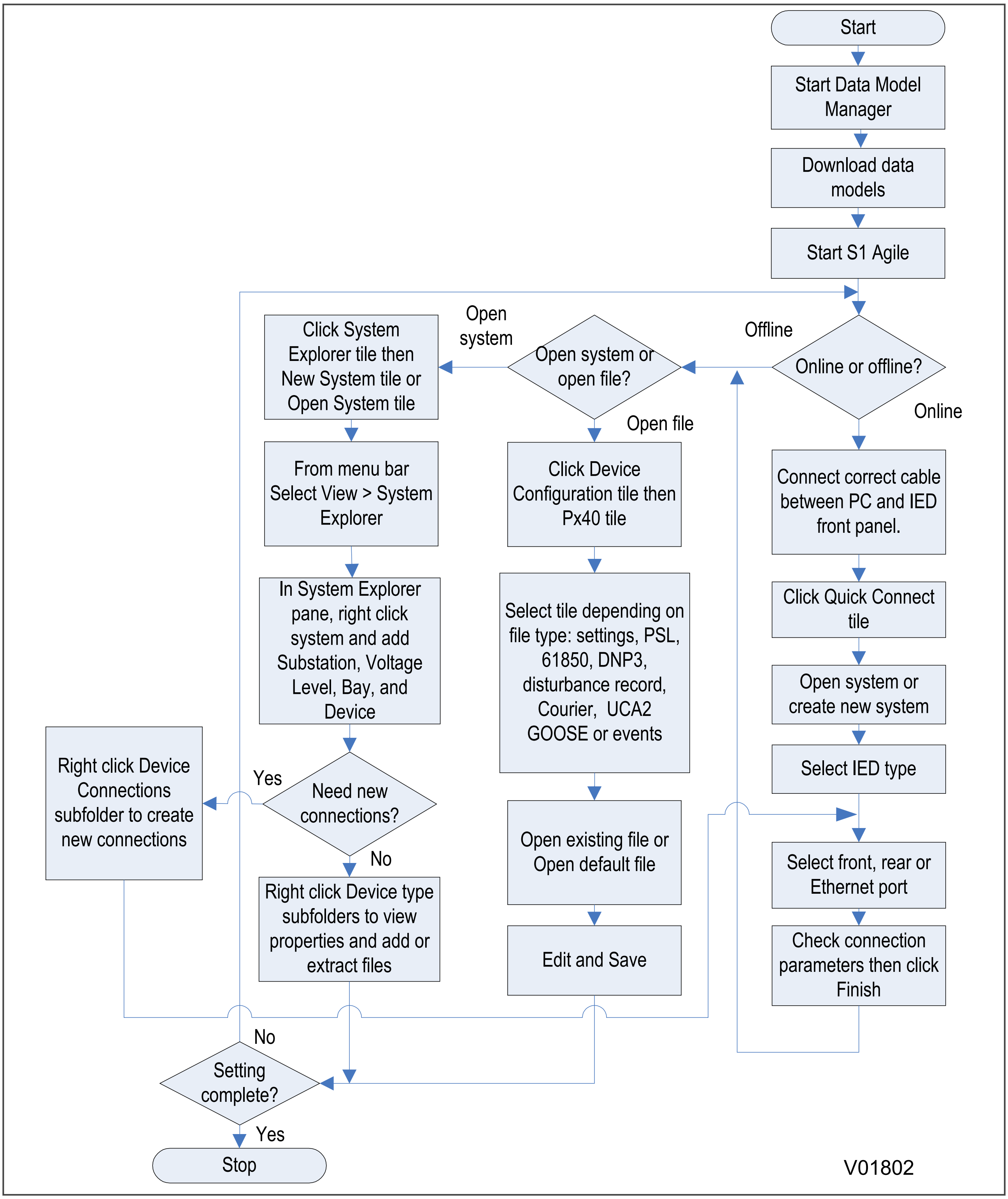


Figure 140: Flowchart showing how S1 Agile can be used to set up and save a protection system offline or online.

4.1 QUICK SYSTEM GUIDE

You can create a system to mimic your real world system of devices. A system provides a root node in the System Explorer from which all subsequent nodes are created. You can add substations, bays, voltage levels and devices to the system.

You can either Create a new system or Open an existing system.

If there is no default system, use Quick Connect to automatically create one.

If a system is no longer needed, right-click it and select Delete to permanently delete it.

Systems are not opened automatically. To change this, select **Options** > **Preferences** then check the checkbox **Reopen last System at start-up**.

4.2 DOWNLOAD DATA MODELS

1. Close S1 Agile and run the Data Model Manager.
2. Follow the on-screen instructions.

4.3 SET UP A SYSTEM

1. Click the System **Explorer** tile then the **New System** tile or **Open System** tile.
2. From the menu bar select **View** > **System Explorer**.
3. In the System Explorer pane, right click **System** and select **New Substation**, **New Voltage Level**, **New Bay**, and **New Device**.
4. Right-click the **Device** subfolders to view properties and add or extract files.

4.4 CONNECTING TO AN IED FRONT PORT

1. Connect the cable between the PC and IED.
2. From the main screen, click **Quick Connect**.
3. Select the product range.
4. Select connection to the **Front Port**.
5. Set the connection parameters and click **Finish**.

4.5 CONNECTING TO AN IED IN A SYSTEM

1. Make sure that the correct serial rear port or Ethernet cables are in place.
2. From the main screen, click **Quick Connect**.
3. Select the product range.
4. Select connection to the **Rear Port** or **Ethernet Port**.
5. Set the connection parameters and click **Finish**.

4.6 SEND SETTINGS TO A DEVICE

To send settings to a device there must be at least one setting file in a settings folder for a device.

1. Right-click the device name in System Explorer and select **Send**.
2. In the **Send To** dialog select the setting files and click **Send**.
3. Click **Close** to close the **Send To** dialog.

4.7 EXTRACT SETTINGS FROM A DEVICE

1. Using System Explorer, find the device.
2. Right-click the device's Settings folder and select **Extract Settings** or **Extract Full Settings**.
3. Once the settings file is retrieved, click **Close**.

4.8 EXTRACT A PSL FILE FROM A DEVICE

1. Using System Explorer, find the Px4x device.
2. Right-click the device's **PSL** folder and select **Extract**.
3. Once the file is retrieved, click **Close**.

Note:
If you extract a PSL file from a device that does not store the position information of the PSL scheme elements, the layout of the scheme may not be the same as originally drawn. Also the Original and Logic Only CRC values may not match the original scheme. However, the scheme will be logically correct.

4.9 EXTRACT A DNP3 FILE FROM A DEVICE

1. Using System Explorer, find the device.
2. Right-click the device's **DNP3** folder and select **Extract**.
3. Once the file is retrieved, click **Close**.

4.10 EXTRACT AN EVENTS FILE FROM A DEVICE

1. Using System Explorer, find the device.
2. Right-click the device's **Events** folder and select **Extract Events**.
3. Once the file is retrieved, click **Close**.

4.11 EXTRACT A DISTURBANCE RECORD FROM A DEVICE

1. Using System Explorer, find the device.
2. Right-click the device's **Disturbance Records** folder and select **Extract Disturbances**.
3. Select a disturbance record to extract.
4. Choose a COMTRADE format, 1991 or 2001.
5. Click **Extract** or **Save**. Save leaves the record in the device, Extract deletes it.
6. Once the disturbance records file is retrieved, click **Close**.

5 PSL EDITOR

The Programmable Scheme Logic (PSL) is a module of programmable logic gates and timers in the IED, which can be used to create customised internal logic. This is done by mapping the IED's digital inputs, combining these inputs with internally generated digital signals using logic gates and timers, and mapping the resultant signals to the IED's digital outputs and LEDs.

The Programmable Scheme Logic (PSL) Editor allows you to create and edit scheme logic diagrams to suit your own particular application.

Before a scheme logic diagram can be created, the Editor must have a ‘template’ configuration that allows it to determine various IED-specific parameters such as the number of opto-inputs and output relays, as well as signal names and types. Because there are many different product variants, it is not possible for the Editor to provide a common default scheme. Instead, you need to load a configuration from a file.

The PSL uses the concept of a digital data bus (DDB). The DDB is a parallel data bus containing all of the digital signals (inputs, outputs, and internal signals), which are available for use in the PSL.

The PSL's software logic gates and timers can be used to combine and condition the DDB signals. The logic gates can be programmed to perform a range of different logic functions and can accept any number of inputs. The timers are used either to create a programmable delay or to condition the logic outputs.

Inputs to the PSL include:

- Optically-isolated digital inputs (opto-inputs)
- IEC 61850 GOOSE inputs
- Control inputs
- Function keys

Outputs from the PSL include:

- Relay outputs
- LEDs
- IEC 61850 GOOSE outputs
- Trigger signals

Internal signals include:

- Inputs to the PSL originating from internal functions. These are signals generated within the device and can be used to affect the operation of the scheme logic.
- Outputs from the PSL. These are signals that can be driven from the PSL to activate specific functions.

An example of an internal input and output are:

- **I>1 Trip**. This is an output from the Stage 1 overcurrent protection function, which can be input into the PSL to create further functionality. This is therefore a **PSL input**.
- **V>1 Trip**. This is an output from the overvoltage protection function, which can be input into the PSL to create further functionality. This is therefore a **PSL input**.
- Reset Relays/LED. This is a **PSL output**, which can be asserted to reset the output relays and LEDs.

The PSL logic is event driven. Only the part of the PSL logic that is affected by the particular input change that has occurred is processed. This reduces the amount of processing time used by the PSL when compared to some competition devices.

The PSL editor lets you:

- Start a new PSL diagram
- Extract a PSL file from an IED

- Download a PSL file to an IED
- Open a diagram from a PSL file
- Add logic components to a PSL file
- Move components in a PSL file
- Edit links in a PSL file
- Add links to a PSL file
- Highlight a path in a PSL file
- Use a conditioner output to control logic
- Print PSL files

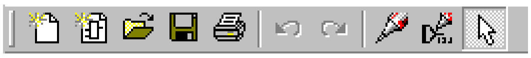
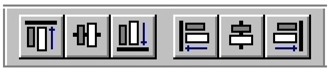
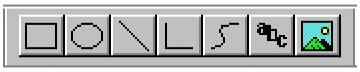
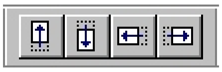
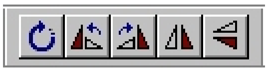
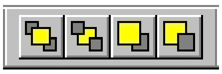
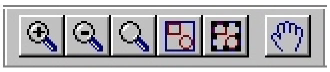
For further information on the PSL editor, see the online help built into the settings application software.

5.1 LOADING SCHEMES FROM FILES

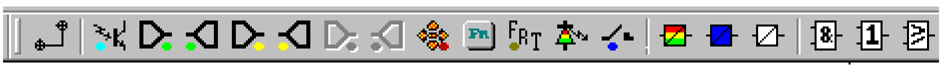
The product is shipped with default scheme files. These can be used as a starting point for changes to a scheme. To create a new blank scheme, select **File > New > 'Blank scheme...** to open the default file for the appropriate IED. This deletes the diagram components from the default file to leave an empty diagram but with the correct configuration information loaded.

5.2 PSL EDITOR TOOLBAR

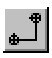
There are a number of toolbars available to help with navigating and editing the PSL.

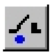
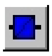
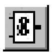
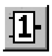
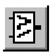
Toolbar	Description
	Standard tools: For file management and printing.
	Alignment tools: To snap logic elements into horizontally or vertically aligned groupings.
	Drawing tools : To add text comments and other annotations, for easier reading of PSL schemes.
	Nudge tools: To move logic elements.
	Rotation tools: Tools to spin, mirror and flip.
	Structure tools: To change the stacking order of logic components.
	Zoom and pan tools: For scaling the displayed screen size, viewing the entire PSL, or zooming to a selection.

5.2.1 LOGIC SYMBOLS



The logic symbol toolbar provides icons to place each type of logic element into the scheme diagram. Not all elements are available in all devices. Icons are only displayed for elements available in the selected device.

Symbol	Function	Explanation
	Link	Create a link between two logic symbols.

Symbol	Function	Explanation
	Opto Signal	Create an opto-input signal.
	Input Signal	Create an input signal.
	Output Signal	Create an output signal.
	GOOSE In	Create an input signal to logic to receive a GOOSE message transmitted from another IED. Used in either UCA2.0 or IEC 61850 GOOSE applications only.
	GOOSE Out	Create an output signal from logic to transmit a GOOSE message to another IED. Used in either UCA2.0 or IEC 61850 GOOSE applications only.
	Control In	Create an input signal to logic that can be operated from an external command.
	InterMiCOM In	Create an input signal to logic to receive an InterMiCOM command transmitted from another IED.
	InterMiCOM Out	Create an output signal from logic to transmit an InterMiCOM command to another IED.
	Function Key	Create a function key input signal.
	Trigger Signal	Create a fault record trigger.
	LED Signal	Create an LED input signal that repeats the status of tri-colour LED.
	Contact Signal	Create a contact signal.
	LED Conditioner	Create an LED conditioner.
	Contact Conditioner	Create a contact conditioner.
	Timer	Create a timer.
	AND Gate	Create an AND Gate.
	OR Gate	Create an OR Gate.
	Programmable Gate	Create a programmable gate.

5.3 LOGIC SIGNAL PROPERTIES

1. Use the logic toolbar to select logic signals. This is enabled by default but to hide or show it, select **View** > **Logic Toolbar**.
2. Zoom in or out of a logic diagram using the toolbar icon or select **View** > **Zoom Percent**.
3. Right-click any logic signal and a context-sensitive menu appears.

Certain logic elements show the **Properties** option. If you select this, a **Component Properties** window appears. The contents of this window and the signals listed will vary according to the logic symbol selected. The actual DDB numbers are dependent on the model.

5.3.1 LINK PROPERTIES

Links form the logical link between the output of a signal, gate or condition and the input to any element. Any link connected to the input of a gate can be inverted. To do this:

1. Right-click the input
2. Select **Properties…**. The Link Properties window appears.
3. Check the box to invert the link. Or uncheck for a non-inverted link

An inverted link is shown with a small circle on the input to a gate. A link must be connected to the input of a gate to be inverted.

Links can only be started from the output of a signal, gate, or conditioner, and must end at an input to any element.

Signals can only be an input or an output. To follow the convention for gates and conditioners, input signals are connected from the left and output signals to the right. The Editor automatically enforces this convention.

A link is refused for the following reasons:

- There has been an attempt to connect to a signal that is already driven. The reason for the refusal may not be obvious because the signal symbol may appear elsewhere in the diagram. In this case you can right-click the link and select Highlight to find the other signal. Click anywhere on the diagram to disable the highlight.
- An attempt has been made to repeat a link between two symbols. The reason for the refusal may not be obvious because the existing link may be represented elsewhere in the diagram.

5.3.2 OPTO SIGNAL PROPERTIES

E02030

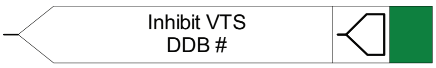
Each opto-input can be selected and used for programming in PSL. Activation of the opto-input drives an associated DDB signal.

5.3.3 INPUT SIGNAL PROPERTIES

E02031

IED logic functions provide logic output signals that can be used for programming in PSL. Depending on the IED functionality, operation of an active IED function drives an associated DDB signal in PSL.

5.3.4 OUTPUT SIGNAL PROPERTIES



E02032

Logic functions provide logic input signals that can be used for programming in PSL. Depending on the functionality of the output relay, when the output signal is activated, it drives an associated DDB signal in PSL. This causes an associated response to the function of the output relay.

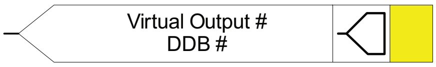
5.3.5 GOOSE INPUT SIGNAL PROPERTIES

E02033

The Programmable Scheme Logic interfaces with the GOOSE Scheme Logic through 32 Virtual Inputs. The Virtual Inputs can be used in much the same way as the opto-input signals.

The logic that drives each of the Virtual Inputs is contained in the GOOSE Scheme Logic file. You can map any number of bit-pairs from any subscribed device using logic gates onto a Virtual Input.

5.3.6 GOOSE OUTPUT SIGNAL PROPERTIES



E02034

The Programmable Scheme Logic interfaces with the GOOSE Scheme Logic through 32 Virtual Outputs.

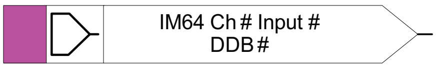
You can map Virtual Outputs to bit-pairs for transmitting to any subscribed devices.

5.3.7 CONTROL INPUT SIGNAL PROPERTIES

E02035

There are 32 control inputs which can be activated using the menu, the hotkeys or through courier communications. Depending on the programmed setting that is latched or pulsed, when a control input is operated an associated DDB signal is activated in PSL.

5.3.8 INTERMICOM INPUT PROPERTIES



E02036

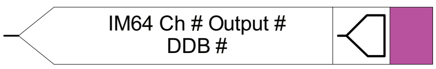
There are 16 InterMiCOM inputs that can be used for teleprotection and remote commands. **InterMiCOM In** is a signal which is received from the remote end. It can be mapped to a selected output relay or logic input.

IED End B

E02037

At end B, InterMiCOM Input 1 is mapped to the command **Clear Statistics**.

5.3.9 INTERMICOM OUTPUT PROPERTIES



E02038

There are 16 InterMiCOM outputs that can be used for teleprotection and remote commands. **InterMiCOM Out** is a send command to a remote end that can be mapped to any logic output or opto-input. This is transmitted to the remote end as a corresponding **InterMiCOM In** command.

IED End A

E02039

At end A, InterMiCOM Output 1 is mapped to the command indication **Clear Statistics** issued at end A.

5.3.10 FUNCTION KEY PROPERTIES

E02040

Each function key can be selected and used for programming in PSL. Activation of the function key drives an associated DDB signal. The DDB signal remains active according to the programmed setting (toggled or normal). Toggled mode means the DDB signal remains in the new state until the function key is pressed again. In Normal mode, the DDB is only active while the key is pressed.

5.3.11 FAULT RECORDER TRIGGER PROPERTIES

E02041

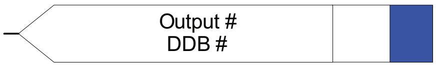
The fault recording facility can be activated by driving the fault recorder trigger DDB signal.

5.3.12 LED SIGNAL PROPERTIES

E02042

All programmable LEDs drive associated DDB signals when the LED is activated.

5.3.13 CONTACT SIGNAL PROPERTIES



E02043

All output relay contacts drive associated DDB signal when the output contact is activated.

5.3.14 LED CONDITIONER PROPERTIES

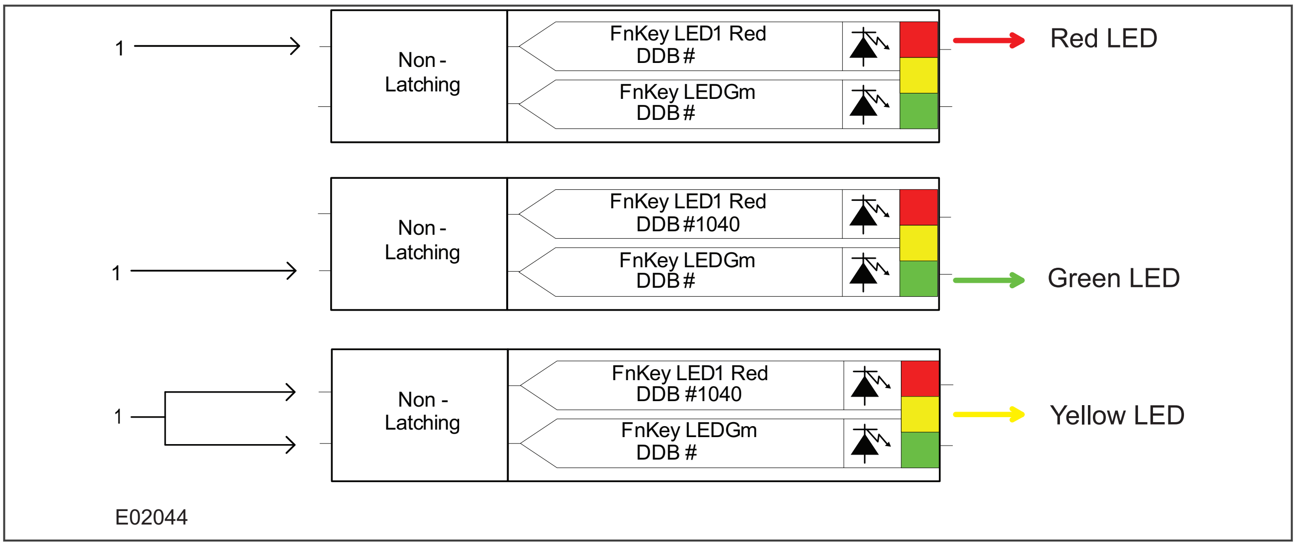


Figure 141: Examples of how to set Red, Green and Yellow LEDs

To set LED conditioner properties,

1. Select the LED name from the list (only shown when inserting a new symbol).
2. Configure the LED output to be Red, Yellow or Green.
3. Configure a Green LED by driving the Green DDB input.
4. Configure a RED LED by driving the RED DDB input.
5. Configure a Yellow LED by driving the RED and GREEN DDB inputs simultaneously.
6. Configure the LED output to be latching or non-latching.

5.3.15 CONTACT CONDITIONER PROPERTIES

Each contact can be conditioned with an associated timer that can be selected for pick up, drop off, dwell, pulse, pick-up/drop-off, straight-through, or latching operation.

Straight-through means it is not conditioned at all whereas **Latching** is used to create a sealed-in or lockout type function.

To set contact properties,

1. Select the contact name from the **Contact Name** list (only shown when inserting a new symbol).
2. Choose the conditioner type required in the **Mode** tick list.
3. Set the **Pick-up Value** (in milliseconds), if required.
4. Set the **Drop-off Value** (in milliseconds), if required.

5.3.16 TIMER PROPERTIES

Each timer can be selected for pick-up, drop-off, dwell, pulse or pick-up/drop-off operation.

To set timer properties,

1. From the **Timer Mode** tick list, choose the mode.
2. Set the **Pick-up Value** (in milliseconds), if required.
3. Set the **Drop-off Value** (in milliseconds), if required.
4. Click **OK**.

5.3.17 GATE PROPERTIES

A gate can be an AND, OR, or programmable gate.

- An **AND Gate** requires that all inputs are TRUE for the output to be TRUE.
- An **OR Gate** requires that one or more input is TRUE for the output to be TRUE.
- A **Programmable Gate** requires that the number of inputs that are TRUE is equal to or greater than its **Inputs to Trigger** setting for the output to be TRUE.

To set gate properties,

1. Select the gate type: **AND Gate**, **OR Gate**, or **Programmable Gate**.
2. If you select **Programmable Gate,** set the number of **Inputs to Trigger**.
3. If you want the output of the gate to be inverted, check the **Invert Output** check box. An inverted output appears as a "bubble" on the gate output.
4. Click **OK**.

5.3.18 SR PROGRAMMABLE GATE PROPERTIES

A Programmable SR gate can be selected to operate with the following three latch properties:

Set	Reset	Q0 (Previous Output State)	Q1 Set Dominant	Q1 Reset Dominant	Q1 No Dominance
0	0	0	0	0	0
0	0	1	1	1	1
0	1	1	0	0	0
0	1	0	0	0	0
1	1	0	1	0	0
1	1	1	1	0	1
1	0	1	1	1	1
1	0	0	1	1	1

Q0 is the previous output state of the latch before the inputs change. Q1 is the output of the latch after the inputs change.

The Set dominant latch ignores the Reset if the Set is on.

The Reset Dominant latch ignores the Set if the Reset is on.

When both Set and Reset are on, the output of the non-dominant latch depends on its previous output Q0. Therefore if Set and Reset are energised simultaneously, the output state does not change.

> *Note:*
> *Use a set or reset dominant latch. Do not use a non-dominant latch unless this type of operation is required.*

SR latch properties

In the Component Properties dialog, you can select S-R latches as **Standard (no input dominant)**, **Set input dominant** or **Reset input dominant**.

If you want the output to be inverted, check the **Invert Output** check box. An inverted output appears as a "bubble" on the gate output.

6 IEC 61850 IED CONFIGURATOR

IEC 61850 is a substation communications standard. It standardizes the way data is transferred to and from IEC 61850 compliant IEDs, making the communication independent of the manufacturer. This makes it easier to connect different manufacturers' products together and simplifies wiring and network changes.

The IEC 61850 IED Configurator tool is used to configure the IEC 61850 settings of MiCOM IEDs, not the protection settings. It also allows you to extract a configuration file so you can view, check and modify the IEC 61850 settings during precommissioning.

6.1 IEC 61850 IED CONFIGURATOR TOOL FEATURES

The IEC 61850 IED configurator allows you to:

- Configure basic IEC 61850 communication parameters of the IED.
- Configure IED time synchronisation using SNTP.
- Define datasets for inclusion in report and GOOSE control blocks.
- Configure GOOSE control blocks for publishing (outgoing) messages.
- Configure virtual inputs, mapping them onto subscribed (incoming) GOOSE messages.
- Configure report control blocks.
- Configure the operation of control objects (circuit breaker trip and close):
  - The control mode (such as Direct, Select Before Operate)
  - Uniqueness of control (to ensure only one control in the system can operate at any one time).
- Configure measurements:
  - Scaling (multiplier unit such as kA, MV).
  - Range (minimum and maximum measurement values).
  - Deadband (percentage change of measurement range for reporting).
- Transfer IEC 61850 configuration information to and from an IED.
- Import SCL files for any IEC 61850 device (including devices from other manufacturers) to simplify configuration of GOOSE messaging between IEDs.
- Generate SCL files to provide IED configuration data to other manufacturers' tools, allowing them to use published GOOSE Messages and reports.

6.2 IEC 61850 IED CONFIGURATOR LANGUAGES

The IEC 61850 IED Configurator uses the following languages.

MiCOM Configuration Language (MCL)

This is a proprietary language file which contains a MiCOM device's IEC 61850 configuration information. This file is used for transferring data to or from a MiCOM IED.

Substation Configuration Language (SCL)

This is an XML-based standard language used to configure IEC 61850 IEDs in substations. It allows common substation files to be exchanged between all devices and between different manufacturers' toolsets. This helps to reduce inconsistencies in system configurations. Users can specify and provide their own SCL files to ensure that IEDs are configured according to their requirements.

SCL also allows IEC 61850 applications to be configured off-line without needing a network connection to the IED. Off-line system development tools can be used to generate the files needed for IED configuration automatically from the power system design. This significantly reduces the cost of IED configuration by eliminating most of the manual configuration tasks.

SCL specifies a hierarchy of configuration files, which enable the various levels of the system to be described: SSD, SCD, ICD, CID and IID files.

6.3 IEC 61850 SUBSTATION CONFIGURATION FILES

These files all use the standard Substation Configuration Language (SCL). They have the same construction but differ depending on the application.

System Specification Description (SSD)

This contains the complete specification of a substation automation system including a single line diagram for the substation and its functionalities, or logical nodes. The SSD contains SCD and ICD files.

Substation Configuration Description (SCD)

This contains information about the substation, all IEDs, data types and communications configuration. When engineering a system from the top down, an SCD file is produced and imported into the IED Configurator. To ensure consistency with the configuration of other IEDs in the system, this SCD file normally should not be edited. If there is no SCD file available, and you need to manually configure a MiCOM IED for precommissioning tests, you can open an ICD file and edit this to suit the IED application. The ICD file can be preinstalled as a template in the IED Configurator and opened directly, or it can be provided separately.

IED Capability Description file (ICD)

This describes the IED's capabilities, including information on its data model (Logical Devices or Logical Node instances) and GOOSE support. The IEC 61850 IED Configurator can be used before commissioning an IED to create a blank configuration ICD file. The IEC 61850 IED Configurator can also extract an ICD file for viewing or modification and error checking a MiCOM IED.

Configured IED Description File (CID) or Individual IED Description File (IID)

This describes a single IED in the system, including communications parameters.

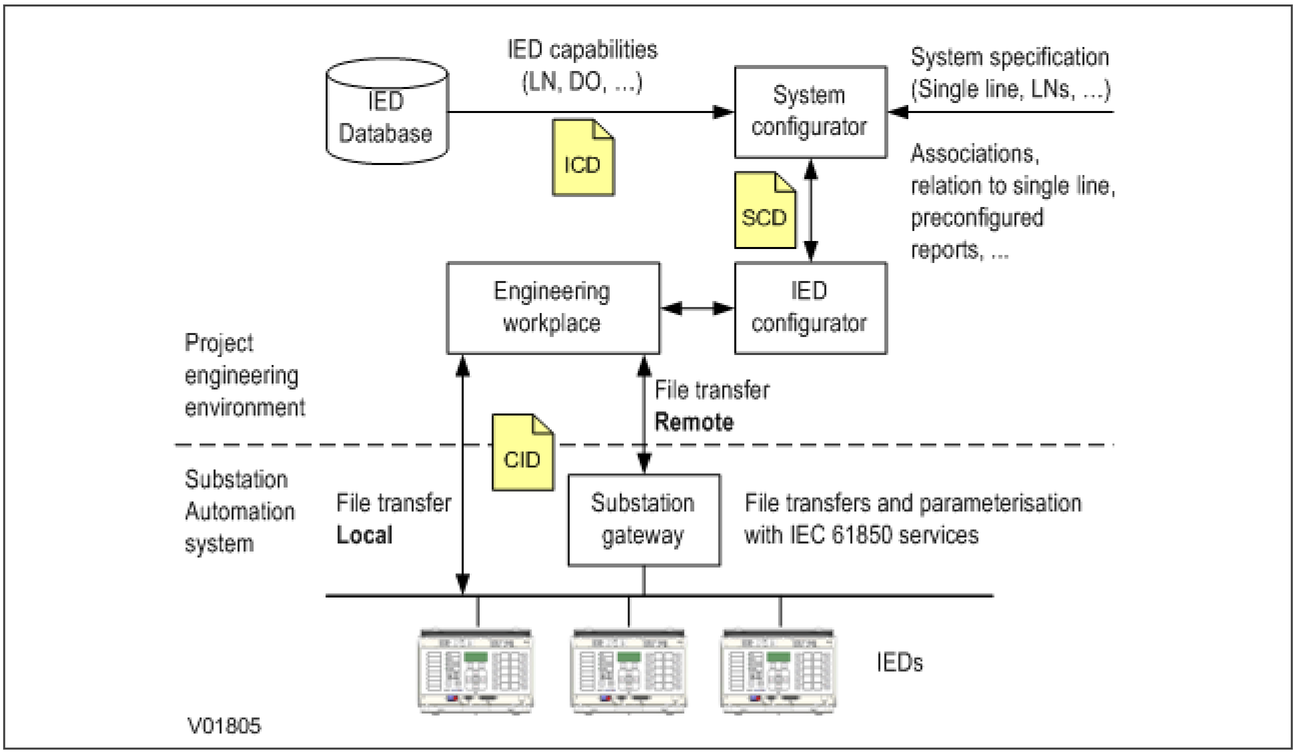


Figure 142: IEC 61850 project configuration

6.4 OPENING A PRECONFIGURED SCL FILE

An SCL configuration file contains the information for the MiCOM IED that is to be configured. To open an SCL configuration file for the system

1. Select **File > Import SCL**. A search dialog box appears.
2. Select the required SCL file and click **Open**.
3. The SCL Explorer window appears, showing an icon for each IED present in the SCL file.

IEDs which can be configured using the IED Configurator are shown in a bold typeface and an icon with a green tick.

IEDs which cannot be configured using the IED Configurator are shown with greyed text and an icon with a red X.

The left hand side of the window shows information on the SCL file and any selected IED tasks that can be performed on the selected IED(s). Alternatively right-click an IED to list tasks that can be performed on that particular IED.

6.5 OPENING A TEMPLATE ICD FILE

If there is no SCD configuration file available, open an ICD template file for the MiCOM IED type that is to be configured.

1. Select **File > New**. The **Template** window appears.
2. Select the IED model number from the list. The list shows information about the IED's associated ICD template file, the SCL header details and the IEC 61850 features supported by the IED.
3. Use the **Model Number** filter at the top of the window to filter product variants.

6.5.1 TEMPLATE INSTALLED FOR REQUIRED IED TYPE

If you can find the IED type or ICD template, highlight it and click the **Select** button. The configuration opens in manual editing mode so it can be customised for the application.

6.5.2 TEMPLATE NOT INSTALLED FOR REQUIRED IED TYPE

1. If there is no installed ICD file for the IED type that is to be configured, but there is one available from your supplier, click **Browse for External**.
2. A search dialog box appears. When you have found the required ICD file, click **Open**.
3. If the selected ICD Template file is already available as an installed template, a message appears and a new IED Configuration is created from the installed file.
4. If the selected ICD Template file has additional supported model numbers, a message appears asking if the additional model numbers should be merged into the installed template.
5. Select **Yes** to merge the new model numbers into the installed ICD Template file. This makes it available the next time the Template window appears.
6. If the selected ICD Template file is not installed, a message asks if it should be added to the application template library.
7. Select **Yes** to copy the selected ICD template file into the application library. This makes it available the next time the Template window appears.

6.6 OPENING AN EXISTING MCL CONFIGURATION FILE

1. Select **File** > **Open**. A search dialog box appears.
2. Select the required MCL file and click **Open**.

3. The IED Configurator tool tries to automatically match the MCL data to an installed ICD Template file and then display the configuration data in a read-only mode.
4. If it cannot automatically match the MCL data to an ICD Template file, the Template window appears. This allows you to manually assign the MCL data to an ICD Template file. If there is no suitable template available, click **Cancel**.
5. A message asks if the configuration is to be opened with Restricted Editing. Select **Yes** to display the configuration data in a read-only mode.

6.7 CONFIGURING A MICOM IED

Working offline:

1. Click the icon **New MiCOM Configuration from an Installed ICD File**.
2. Double-click the product variant.
3. Double-click **TEMPLATE** to expand it.

Or working online:

1. Select **Device** > **Manage IED**.
2. Select the IED type and click **Next**.
3. Select the IED address and click **Next**. The IED 61850 Configurator tool reads information from the IED and shows them in the **Summary** view.

The aspects of a MiCOM IED that can be configured come from its ICD Template file. These are shown in the main area of the IED Configurator tool, in the left hand side of the Editor window. The right hand side of the Editor window shows the configuration page of the selected category.

Each configurable item of the MiCOM IED is categorised into one of the following groups in the Editor window.

IED Details Displays general configuration and data about the IED and the selected ICD template file.

Communications Displays configuration of the communications Subnetwork.

SNTP Displays configuration of the client/server SNTP time synchronisation.

Dataset Definitions Displays dataset definitions used by the IED's GOOSE and report control blocks.

GOOSE Publishing Displays configuration for the GOOSE control blocks and associated messages to be published.

GOOSE Subscribing Displays configuration of virtual inputs that are subscribed to published GOOSE messages.

Report Control Blocks Displays configuration for the report control blocks in the IED data model.

Controls Displays configuration of control objects and uniqueness of control parameters (for larger control systems).

Measurements Displays configuration of measurement objects in the IED data model.

Configurable Data Attributes Displays parameter values for the configurable data attributes in the IED data model.

Each configurable item is either read-only or editable in manual mode. If it is read-only it is always non-editable. If it is editable in manual mode, some items may not be configurable if opened from a configured SCL file.

If a configured SCL file or MCL file was opened, and it is necessary to edit the configuration, select **View** > **Enter Manual Editing Mode** or click the toolbar icon. If an ICD file is opened, these items are automatically displayed in manual editing mode.

6.8 READING OR EDITING IED DETAILS

Working offline:

1. Click the icon **New MiCOM Configuration from an Installed ICD File**.
2. Double-click the product variant.
3. Double-click the **IED Details** item.

Or working online:

1. Select **Device** > **Manage IED**.
2. Select the IED type device number.
3. Select the IED address and click **Next**. The IED 61850 Configurator tool reads information from the IED and shows them in the **Summary** view.
4. Click the **IED Details** tab to show more information and edit the settings.

The following IED details can be edited.

SCL File ID The identification name, taken from the header section of an SCL file. Editable in Manual Editing Mode.

SCL File Version The version number, taken from the header section of an SCL file. Editable in Manual Editing Mode.

Name The IED name, taken from the IED section of an SCL file. This should be unique for all IEDs on the IEC 61850 network and is an Object Reference type so can be up to 65 characters long. However, it is recommended to restrict IED names to 8 characters or less. Editable in Manual Editing Mode.

ICD Template The ICD Template filename associated with the device's IEC 61850 configuration (MCL data). Read-only.

Description A basic description of the MiCOM IED type. It is taken from the IED section of the ICD template file and is not stored in MCL data or sent to the MiCOM IED. Read-only.

Type The MiCOM IED type. It is taken from the IED section of the ICD template file and is not stored in MCL data or sent to the MiCOM IED. Read-only.

Configuration Revision The software version of the target MiCOM IED. It is taken from the IED section of the ICD template file and is not stored in MCL data or sent to the MiCOM IED. Read-only.

Supported Models The specific MiCOM IED models supported by the ICD template file. If an ICD file is opened, these models are supported directly. If a configured SCL file is opened, these models are derived from the ICD file which is used to create a configured SCL file. It is not stored in MCL data nor sent to the MiCOM IED. Read-only.

6.9 COMMUNICATIONS SETUP

Before the IEC 61850 IED Configurator tool can manage an IED's configuration, you must first configure the communication parameters.

Select **Tools** > **Options**, then select the tab according to the protocol used.

IEC 870-5-103 Communications tab. Communication is through a serial connection from a COM port of the PC to the front port of the IED. If supported by the IED, you can also use the rear port. The Ethernet connection is not used, because the MiCOM IED does not have an IP address until it has been configured. This is also used for Px30 products.

Courier Communications tab. Communication is through a serial connection from a COM port of the PC to the front port of the IED. If supported by the IED, you can also use the rear port. The Ethernet connection is not used, because the MiCOM IED does not have an IP address until it has been configured. This is typically used for Px40 products.

1. In the **Default Configurations** field, if using the front port, select **MiCOM P*40 Front Port (COM *)**, if using the rear port, select **Courier (COM *)**.
2. Set the **Connection Values** and **Transaction Parameters** as required or leave them at the default values.
3. Click **OK**.

FTP communications tab. Communication is over Ethernet to the FTP server of a MiCOM IED. The IP Address settings for both the PC and MiCOM IED must be for the same SubNetwork, especially if a direct connection is used with a cross-over network lead. If there is no valid or active IEC 61850 configuration in the IED, configure a default IP Address for the IED. This is also used for Mx70 products.

6.10 EDITING COMMUNICATIONS SETTINGS

Working offline:

1. Click the icon **New MiCOM Configuration from an Installed ICD File**.
2. Double-click the product variant.
3. Double-click the **Communications** item.

Or working online:

1. Select **Device** > **Manage IED**.
2. Select the IED type device number.
3. Select the IED address and click **Next**. The IED 61850 Configurator tool reads information from the IED and shows them in the Summary view.
4. Click the **Communications** tab to read and edit the settings.

The following communications settings can be edited.

Connected Subnetwork This is the subnetwork name to which the IED is connected. It is particularly important for subscribing to GOOSE messages because an IED can only subscribe to publishers that are connected to the same subnetwork. The subnetwork name is taken from the Communications section of an SCL file. Normally editable in Manual Editing Mode, except if opened from a configured SCL file.

Access Point The Access Point (physical port) name for the MiCOM IED. This is taken from the IED Access Point section of the ICD template file. It is not stored in MCL data or sent to the MiCOM IED. Read-only.

IP Address Used to configure the unique network IP address of the MiCOM IED. It is taken from the ConnectedAP Address section of the configured SCL file. Editable in Manual Editing Mode.

SubNet Mask Used to configure the IP subnet mask for the network to which the MiCOM IED will be connected. It is taken from the ConnectedAP Address section of the configured SCL file. Editable in Manual Editing Mode.

Gateway Address Used to configure the IP address of any gateway (proxy) device, to which the MiCOM IED is connected. It is taken from the ConnectedAP Address section of the configured SCL file.

If there is no gateway (proxy) in the system, leave this at its default unconfigured value of 0.0.0.0. Editable in Manual Editing Mode.

Default Media Used to set whether a copper or fibre optic Ethernet interface is used for communication between clients and peers, and the MiCOM IED. It is taken from the ConnectedAP/PhysConn section of the configured SCL file. Editable in Manual Editing Mode.

TCP Keepalive Used to set the frequency at which the MiCOM IED sends a TCP Keepalive message to keep open an association with a connected client. This setting is not taken from SCL. It is specific to MCL with a setting range of 1 to 20 seconds. Editable in Manual Editing Mode.

Database Lock Timeout Used to set how long the MiCOM IED waits without receiving any messages on the active link before it reverts to its default state. This includes resetting any password access that was enabled. It is taken from the IED/AccessPoint/Server section of the configured SCL file and has a valid setting range of 60 to 1800 seconds (1 to 30 minutes). Only applicable to MiCOM IEDs that support setting changes over IEC 61850. Editable in Manual Editing Mode.

6.11 SIMPLE NETWORK TIME PROTOCOL (SNTP)

Simple Network Time Protocol (SNTP) is used to synchronize the clocks of computer systems over packet-switched, variable-latency data networks, such as IP. A jitter buffer is used to reduce the effects of variable latency introduced by queuing, ensuring a continuous data stream over the network.

SNTP is supported by both the IED and the switch in the redundant Ethernet board. Both the IED and the redundant Ethernet board have their own IP address. Using the IP address of each device it can be synchronised to the SNTP server.

For the IED this is done by entering the IP address of the SNTP server into the IED using the IEC 61850 IED Configurator software.

For the redundant Ethernet board, this is done depending on the redundant Ethernet protocol being used. For PRP use the PRP Configurator. For RSTP use the RSTP Configurator. For SHP and DHP use Switch Manager.

6.11.1 CONFIGURING SNTP IN THE IED

These settings allow you to configure a MiCOM IED for SNTP.

Working offline:

1. Click the icon **New MiCOM Configuration from an Installed ICD File**.
2. Double-click the product variant.
3. Double-click the **SNTP** item.

Or working online:

1. Select **Device** > **Manage IED**.
2. Select the IED type device number.
3. Select the IED address and click **Next**. The IED 61850 Configurator tool reads information from the IED and shows them in the **Summary** view.
4. Click the **SNTP** tab. Expand the tab and select **General Config** (configuring the IED for SNTP).

The following settings can be edited.

Poll Rate Use this to configure the interval at which the MiCOM IED requests time synchronisation from the selected SNTP server(s). This setting is not taken from SCL. It is specific to MCL with a setting range of 64 to 1024 seconds and is editable in Manual Editing Mode.

Accepted Stratum level SNTP uses a hierarchical system of clock sources. Each level is known as a stratum and is assigned a layer number starting with zero at the top, which is the reference time signal. The Accepted Stratum level setting specifies the stratum range for all configured SNTP servers. It defines the range MiCOM IEDs need to be able to accept time synchronisation responses. Any server response outside the specified range is discarded. You cannot edit this setting.

Time server This configures whether or not the IED acts as a time server in the system. If this option is enabled, other devices can synchronise their clocks to this IED. The value for this setting is taken from the IED/AccessPoint section of the configured SCL file. This setting is editable in Manual Editing Mode.

6.11.2 CONFIGURING THE SNTP SERVER

These settings allow you to configure external SNTP time servers with which the IED tries to synchronise its clock and connect.

Working offline:

1. Click the icon **New MiCOM Configuration from an Installed ICD File**.
2. Double-click the product variant.
3. Double-click the SNTP item.

Or working online:

1. Select **Device** > **Manage IED**.
2. Select the IED type device number.
3. Select the IED address and click **Next**. The IED 61850 Configurator tool reads information from the IED and shows them in the **Summary** view.
4. Click the **SNTP** tab. Expand the tab and select **External Server** (configuring external SNTP time servers to which the IED connects).

The following details can be edited.

Server Name If opened from a configured SCL file, this shows the name of the device with which the MiCOM IED attempts to synchronise its clock. If you need to change the device, click the drop-down list to see all time-server devices in the configured SCL file. This is Read-only, is not stored in MCL data and is not sent to the MiCOM IED.

Access Point If opened from a configured SCL file, this shows the connected Access Point of the device with which the MiCOM IED attempts to synchronise its clock. This is Read-only, is not stored in MCL data and is not sent to the MiCOM IED.

Sub Network Name If opened from a configured SCL file, this shows the Sub Network name with which the device is connected. This is Read-only, is not stored in MCL data and is not sent to the MiCOM IED.

IP Address This is the IP Address of the device that provides SNTP Time synchronisation services. Devices are assigned to SNTP servers based on the contents of a configured SCL file. The IED/Access Point section of the SCL fil lists devices supporting SNTP time synchronisation. This setting is editable in Manual Editing Mode.

Use Anycast button This button automatically sets the SNTP Server IP address to the broadcast address of the Sub Network to which the MiCOM IED is connected. Using the SubNet broadcast address forces the IED to use the Anycast SNTP Mode of operation. This button is only enabled when the IED has a valid IP Address and SubNet Mask. This setting is editable in Manual Editing Mode.

6.12 EDITING DATASET DEFINITIONS

To edit a dataset definition, working offline:

1. Click the icon **New MiCOM Configuration from an Installed ICD File**.
2. Double-click the product variant.
3. Double-click the **Dataset Definitions** item.

Or working online:

1. Select **Device** > **Manage IED**.
2. Select the IED type device number.
3. Select the IED address and click **Next**. The IED 61850 Configurator tool reads information from the IED and shows them in the **Summary** view.
4. Click the **Dataset Definitions** tab.

If supported by the IED, datasets can be dynamically defined.

1. Right-click the **Dataset Definitions** icon and select **Add New Dataset**.
   or on the **Dataset Definitions Summary** page, in the **Task** pane, click **Add Dataset**.
2. Find the dataset to be specified and click **Set**. A dataset can be created in any logical node of the IED's data model.
3. The **Dataset Definition** appears listing **Name**, **Location**, **Contents** and **GOOSE Capacity**.

The following settings can be edited.

Name The name of the dataset. This value is derived from the Dataset section of the selected logical node location in the configured SCL file. The initial character must be an alphabetic character (a-z, A-Z) while the remainder of the name can be either alphanumeric or the underscore symbol. The dataset name must be unique in the logical node where it is contained. Editable in Manual Editing Mode.

Location The location of the dataset in the IED data model. The location is always read-only. To change the read-only status, click **>>**. Specify a new location for the dataset. Editable in Manual Editing Mode.

Contents This shows the Functionally Constrained Data Attributes (FCDA) contained in the dataset. The ordering of these FCDA items in this list shows how values are seen over MMS communications.

Using the following icons on the toolbar, FCDA items can be moved around, deleted or added.

Toolbar Icon	Definition
Up & down arrows icon	These toolbar buttons move the selected FCDA up and down in the dataset definition.
Plus symbol	This toolbar button launches a dialog that allows you to select multiple FCDA items which can be added to the dataset definition. Items that can be selected have an outline tick symbol. Items that have been selected have a green tick symbol and are shown in the selection summary at the bottom of the dialog.
Minus symbol	This toolbar button removes the selected FCDA items from the dataset definition.
Square dot icon	For convenience a dataset can be defined from a supported Functional Constraint. This toolbar button expands the selected Functional Constraint into a list of Data Objects it contains. A dataset cannot contain both Data Objects and a Functional Constraint.
Rotating arrows icon	If the dataset is assigned to one or more control blocks (GOOSE), clicking this toolbar button automatically increments each control block's Configuration Revision. The Configuration Revision is used to identify changes to data, therefore this toolbar button is only enabled when the dataset definition is modified. If you change the selected configuration page and this toolbar button is enabled, you are asked if associated Configuration Revisions should be updated. Editable in Manual Editing Mode.

GOOSE Capacity. The size (in bytes) of a GOOSE message has an upper restriction. It can not be any larger than the maximum allowable size of an Ethernet frame. This restriction limits the maximum number of items that can be included in a dataset.

The GOOSE Capacity gauge shows how large a dataset definition is with respect to GOOSE. If a dataset that is too large for transmission in a GOOSE message is assigned to a GOOSE Control Block, a validation warning appears. Read-only.

To delete Dataset definitions,

1. Right-click the dataset definition icon.
2. Select **Delete Dataset**.

or

1. In the **Dataset Definitions Summary** page, select a dataset.
2. In the task pane, click **Delete Dataset**.

To delete every dataset definition in the configuration data, click **Delete All Datasets**.

Any references in GOOSE or Reporting Control Blocks to the deleted dataset remain unchanged. However, a validation warning appears stating that the dataset definition does not exist.

6.13 GOOSE PUBLISHING CONFIGURATION

Working offline:

1. Click the icon **New MicOM Configuration from an Installed ICD File**.
2. Double-click the product variant.
3. Double-click the **GOOSE Publishing** item.

Or working online:

1. Select **Device** > **Manage IED**, then select the IED type device number.
2. Select the IED address and click **Next**. The IED 61850 Configurator tool reads information from the IED and shows them in the **Summary** view.
3. Click the **GOOSE Publishing** tab. Then select a GOOSE Control Block (GoCB).

The following details can be edited.

Multicast MAC Address Configures the multicast MAC address to that which the GoCB publishes GOOSE messages. The first four octets (01 – 0C – CD – 01) are defined by the IEC 61850 standard; leave these at their default values. The multicast MAC address is taken from the ConnectedAP/GSE section of the configured SCL file. Editable in Manual Editing Mode.

Application ID Configures the AppID to that which the GoCB publishes GOOSE messages. The AppID is specified as a hexadecimal value with a setting range of 0 to 3FFF and is taken from the ConnectedAP/GSE section of the configured SCL file. Editable in Manual Editing Mode.

VLAN Identifier Configures the VLAN (Virtual LAN) on to which the GOOSE messages are published. The VLAN Identifier has a setting range of 0 to 4095 and is taken from the ConnectedAP/GSE section of the configured SCL file. If no VLAN is used, leave this setting at its default value. Editable in Manual Editing Mode.

VLAN Priority Configures the VLAN Priority of published GOOSE messages on the VLAN. The VLAN priority has a setting range of 0 to 7 and is taken from the ConnectedAP/GSE section of the configured SCL file. If no VLAN is used, leave this setting at its default value. Editable in Manual Editing Mode.

Minimum Cycle Time Configures the Minimum Cycle Time between the first change-driven message being transmitted and its first repeat retransmission. The Minimum Cycle Time has a setting range of 1 to 50 milliseconds and is taken from the ConnectedAP/GSE/MinTime section of the configured SCL file. Editable in Manual Editing Mode.

Maximum Cycle Time Configures the Maximum Cycle Time between repeat message transmissions under a quiescent 'no change' state. The Maximum Cycle Time has a setting range of 1 to 60 seconds and is taken from the ConnectedAP/GSE/MaxTime section of the configured SCL file. Editable in Manual Editing Mode.

Increment Determines the rate at which the repeat message transmission intervals step up from the Minimum Cycle Time to the Maximum Cycle Time. The higher the number, the fewer the repeat messages (and therefore time) it takes to reach the Maximum Cycle Time. This setting is not taken from SCL. It is specific to MCL with a setting range of 0 to 999 and has no units. Editable in Manual Editing Mode.

GOOSE Identifier Configures the 64 character GOOSE Identifier (GoID) of the published GOOSE message that is configured in the SCL file. The initial character must be alphabetic (a to z or A to Z) while the rest of the name can be either alphanumeric or the underscore symbol. The GOOSE Identifier must be unique for the entire system. This setting is taken from the LN0/GSEControl section of the configured SCL file. Editable in Manual Editing Mode.

Dataset Reference Configures the dataset which is to be included in the GoCB's published messages. Only datasets that belong to the same logical node as the GoCB can be selected for inclusion in the GOOSE messages. If the dataset definition does not exist or is too large for publishing in a GOOSE message, a warning appears.

This setting is taken from the LN0/GSEControl section of the configured SCL file. Right-click the Dataset Reference control to perform the following operations:

- Create and assign a new dataset definition. Only if the current dataset assignment is empty.
- Delete the current dataset assignment. Only if there is an assigned dataset.
- Edit the currently assigned datasets definition. Only if there is an assigned dataset.

Editable in Manual Editing Mode.

Configuration Revision Displays the Configuration Revision of the published GOOSE message. If the dataset reference or dataset contents are changed, the Configuration Revision must be incremented to allow other peers listening to the published GOOSE messages to identify the change in configuration. This setting has a range of 0 to 4294967295 and is taken from the LN0/GSEControl section of the configured SCL file. Editable in Manual Editing Mode.

Any other IED in the system that needs to subscribe to the published GOOSE messages of the MiCOM IEDs must use the same value in its GOOSE subscription configuration.

6.14 GOOSE SUBRICRIPTION CONFIGURATION

Working offline:

1. Click the icon **New MiCOM Configuration from an Installed ICD File**.
2. Double-click the product variant.
3. Double-click the **GOOSE Subscribing** item.

Or working online:

1. Select **Device** > **Manage IED**.
2. Select the IED type device number.
3. Select the IED address and click **Next**. The IED 61850 Configurator tool reads information from the IED and shows them in the **Summary** view.
4. Click the **GOOSE Subscribing** tab.

Configuration of the GOOSE Subscription depends on whether the IED configuration has been compiled from a configured SCL file, from an MCL file or manually created.

GOOSE Subscription is also based on two concepts.

Mapped Inputs Applicable in all instances. A Mapped Input is an External Binding between two IEDs that is assigned to a valid Data Attribute in the IED data model (the internal Data Attribute supports binding to an external value).

For example, on a MiCOM Px40 device, a Mapped Input is an External Binding that has been assigned to a Virtual Input for use in Programmable Scheme Logic.

Unmapped Inputs Primarily applicable to configured SCL files. An Unmapped Input is similar to the Mapped Input. It is an External Binding between two IEDs but the binding has not yet been assigned to a supporting Data Attribute in the IED data model.

For example, on a MiCOM Px40 device, an Unmapped Input is an External Binding that has been identified as necessary for the IED configuration but has not yet been assigned to a Virtual Input for use in Programmable Scheme Logic.

6.15 REPORT CONTROL BLOCK CONFIGURATION

Working offline:

1. Click the icon **New MiCOM Configuration from an Installed ICD File**.
2. Double-click the product variant.
3. Double-click the **Report Control Blocks** item.

Or working online:

1. Select **Device** > **Manage IED**.
2. Select the IED type device number.
3. Select the IED address and click **Next**. The IED 61850 Configurator tool reads information from the IED and shows them in the **Summary** view.
4. Click the **Report Control Blocks** tab. Then select a Report Control Block (RCB).

The following details can be edited.

Report Type Displays the type of the selected RCB. Read-only.

Report ID Configures the default Report ID of the RCB. Any clients wanting to use the RCB can override this default value if required. The initial character of the Report ID must be alphabetic (a to z or A to Z) while the rest of the name can be either alphanumeric or the underscore symbol. This setting is taken from the LN(0)/ReportControl section of the required RCB in the configured SCL file. Editable in Manual Editing Mode.

Dataset Reference Configures the dataset which is to be included in the generated reports from the RCB. Only datasets that belong to the same logical node as the RCB can be included in the reports. This setting is taken from the LN(0)/ReportControl section of the required RCB in the configured SCL file. Editable in Manual Editing Mode.

Configuration Revision Displays the Configuration Revision of the RCB. If there are any changes to dataset reference or dataset contents, the Configuration Revision must be incremented to allow clients receiving the reports to identify the change in configuration. This setting is taken from the LN(0)/ReportControl section of the required RCB in the configured SCL file. Editable in Manual Editing Mode.

6.16 CONTROLS CONFIGURATION

Working offline:

1. Click the icon **New MiCOM Configuration from an Installed ICD File**.
2. Double-click the product variant.
3. Double-click the **Control Objects** item.

Or working online:

1. Select **Device** > **Manage IED**.
2. Select the IED type device number.
3. Select the IED address and click **Next**. The IED 61850 Configurator tool reads information from the IED and shows them in the **Summary** view.
4. Click the **Controls** tab.

The following details can be edited.

- **Control Objects** is the configuration of each Cotrol Object (Circuit Breaker Trip/Close control) in the IED's data model, for example its Control Model Direct Operate, Select Before Operate.
  This breaks down into:
  - **ctlModel** This configures the control model (ctlModel) of the Control Object to one of the following predefined options and is is taken from the LN(0)/DOI/DAI/Val section of the ctlModel in the configured SCL file. Editable in Manual Editing Mode.
    Status Only
    DOns (Direct Operate - Normal Security)
    SBOns (Select-Before-Operate - Normal Security)
    DOes (Direct Operate - Enhanced Security)
    SBOes (Select-Before-Operate - Enhanced Security)
  - **sboTimeout** If supported by the Control Object, this configures the Select Before Operate timeout. A client has the configured number of milliseconds to operate the control following the select command. If the Control Object is not operated in this time period, it is reset back to an unselected state. This setting is taken from the LN(0)/DOI/DAI/Val section of sboTimeout in the configured SCL file. Editable in Manual Editing Mode.
- **Uniqueness of Control** This adds a layer of security onto control operations by allowing only one Control Object to operate at any time in the whole system. Uniqueness of Control checks are performed using GOOSE, making it simple and reliable without any server redundancy.

6.17 EDITING MEASUREMENT CONFIGURATIONS

Working offline:

1. Click the icon **New MiCOM Configuration from an Installed ICD File**.
2. Double-click the product variant.
3. Double-click the **Measurements** item.

Or working online:

1. Select **Device** > **Manage IED**.
2. Select the IED type device number.
3. Select the IED address and click **Next**. The IED 61850 Configurator tool reads information from the IED and shows them in the **Summary** view.
4. Click the **Measurements** tab. Then Select a measurement object.

The following details can be edited.

Unit multiplier If supported by the IED, this configures how the measurement value will be scaled when read by or reported to a client. The multiplier is shown in the following table.

Value	Multiplier	Name	Symbol
-24	10^{-24}	Yocto	y
-21	10^{-21}	Zepto	z
-18	10^{-18}	Atto	a
-15	10^{-15}	Femto	f
-12	10^{-12}	Pico	p
-9	10^{-9}	Nano	n
-6	10^{-6}	Micro	?
-3	10^{-3}	Milli	m
-2	10^{-2}	Centi	c

Value	Multiplier	Name	Symbol
-1	10^{-1}	Deci	d
0	1		
1	10	Deca	da
2	10^{2}	Hecto	h
3	10^{3}	Kilo	k
6	10^{6}	Mega	M
9	10^{9}	Giga	G
12	10^{12}	Tera	T
15	10^{15}	Petra	P
18	10^{18}	Exa	E
21	10^{21}	Zetta	Z
24	10^{24}	Yotta	Y

For example, if the phase A current is 1250 amps and the multiplier is kilo (k), the relay measures 1.250 (kA). Editable in Manual Editing Mode.

Scaled Measurement Range Min/Max If supported by the IED, this configures the minimum and maximum values of a measurement object. The min and max values are used with the deadband value to calculate how much a measurement must change to be updated or reported to a client. Editable in Manual Editing Mode.

Deadband This configures the deadband, which is a percentage change based on the measurements range in units of 0.001% (giving a range of 0 to 100000). A deadband of 0 means the measurement is updated instantaneously. To simplify the calculation process, click the **>>** button. Specify the deadband as a percentage change (such as 5%) or as an absolute change (such as 0.1 Hz). Editable in Manual Editing Mode. The deadband can be specified at any level in the Measurements tab. The range, including the multiplier, can only be specified at a level where all measurement objects are of the same type. For example, all phase current measurements.

6.18 EDITING CONFIGURABLE DATA ATTRIBUTES

1. Select **Device** > **Manage IED**.
2. Select the IED type.
3. Select the IED address and click **Next**. The IED 61850 Configurator tool reads information from the IED and shows them in the **Summary** view.
4. Click the **Configurable Data Attributes** tab.
5. Select a Data Attribute.

The following details can be edited.

Data Type This shows the SCL Data type of the Data Attribute. The data type influences the type of control used to represent the Data Attributes value.

- Integer based types use a numeric up-down control to specifiy the value.
- Enumerated types use a combo box to specify the available setting values.
- String types use a text box to allow text entry.

Read-only.

Value This is the value to assign to the Data Attribute and is taken from the LN(0)/DOI/DAI/Val section of the required Data Attribute in the configured SCL file. Editable in Manual Editing Mode.

6.19 FULL VALIDATION OF IED CONFIGURATION

The IED Configurator can be used to validate configured SCL files against the SCL schema when they are opened. It can also validate an IED's MCL configuration at any time.

1. In the SCL Explorer workspace, right-click a MiCOM IED and click **Validate**.
2. The selected MiCOM IED is validated and the results appear in a Validation Log window. The log shows three levels of classification:
   - Information. No actions required.
   - Warning. Some consideration may be required.
   - Error. IED may not function as expected with current configuration.
3. Double-click a warning or error item. The configuration page that generated the log entry appears. Double clicking information entries has no effect.

6.20 VALIDATION SUMMARIES

1. Select **Device** > **Manage IED**.
2. Select the IED type device number.
3. Select the IED address and click **Next**. The IED 61850 Configurator tool reads details from the IED and shows them in the **Summary** view.
4. Select a category tab. A summary of each the configuration appears in the Summary pane. Double-click an item and a list of log entries appears in the Validation Report pane.

The following log entries can be edited.

SNTP Summary. This shows all the server sources available for configuration in the IED. If a server source is configured, it is shown in bold. Also the IP address of the external time synchronisation server is shown. If a server source is unconfigured, it is shown greyed.

Dataset Definitions Summary. This shows all the datasets defined throughout the IED's data model. For each defined dataset, its number of Functionally Constrained Data Attributes is also shown. The summary page includes a common set of tasks to manage the dataset definitions.

GOOSE Publishing Summary. This shows all of the GOOSE Control Blocks (GoCB) available in the IED. If a GoCB is fully configured, it is shown in bold. A partially configured GoCB is shown in normal typeface. If a GoCB is unconfigured, it is shown greyed.

GOOSE Subscribing Summary. This shows all of the Virtual Inputs available in the IED. If a Virtual Input is fully configured, it is shown in bold. A partially configured Virtual Input is shown in normal typeface. If a Virtual Input is unconfigured, it is shown greyed. Any unmapped inputs are listed in an additional summary.

Report Control Block Summary. This shows all of the Report Control Blocks (RCB) available in the IED. If an RCB is fully configured, it is shown in bold. A partially configured RCB is shown using in normal typeface. If an RCB is unconfigured, it is shown greyed.

Control Objects Summary. This shows all of the Control Objects available in the IED's data model, and what their configured control model is (Direct Operate, Select Before Operate).

Uniqueness of Control Summary. This shows all of the Virtual Inputs available in the IED. If a Virtual Input is fully configured, it is shown in bold. A partially configured Virtual Input is shown in normal typeface. If a Virtual Input is unconfigured, it is shown greyed. Any unmapped inputs are listed in an additional summary.

Measurements Summary. The Measurements summary shows all of the Measurement Objects available in the IED's data model, plus their configured range and deadband.

Configurable Data Attributes Summary. The Configurable Data Attribute summary shows all of the Configurable Data Attributes available in the IED's data model, plus their data type and configured value.

6.21 MANAGING SCL SCHEMA VERSIONS

The IEC 61850 IED Configurator supports several versions of the SCL schema. This improves its reliability and correctly validates any version of SCL file. The schema files are not available and are encoded into a proprietary binary format that allows basic version control management by the IEC 61850 IED Configurator tool.

Existing schema versions can be removed or new versions added.

1. Select **Tools** > **Options**.
2. Click the **General** tab.
3. Click the **Manage Schemas** button. New schema versions are provided in a binary distribution file.
4. Click a schema and its details are shown in the left-hand pane.

To add a new SCL Schema:

1. In the left-hand pane, click **Add New SCL Schema** then search for the binary schema distribution file.
2. Click **Open** to import the file. The IEC 61850 IED Configurator merges all schema versions in the distribution file into the application repository. If a schema version is already available in the application repository it is skipped.

To remove an SCL Schema:

1. In the right-hand pane, right-click a schema and select **Remove Schema File**. This removes the selected SCL schema from the application repository. The operation cannot be undone.

6.22 CONFIGURATION BANKS

In the MiCOM IED there are two configuration banks for IEC 61850 configuration. The configuration bank concept is similar to that of setting groups for protection settings, promoting version management and helping to minimise IED down-time during system upgrades and maintenance.

To view an IED's configuration bank details:

1. Establish a connection to the MiCOM IED.
2. Select **Device** > **Manage IED**.
3. If the connection to the MiCOM IED is successful , the Manage IED window appears showing the details of the Active and Inactive configuration banks.

The following configuration banks can be edited.

Switch banks button. This toggles the IED's configuration banks so the Active Bank becomes inactive and the Inactive Bank becomes active. The switching technique used ensures the system down-time is minimised to the start-up time of the new configuration.

Refresh banks button. This forces the IEC 61850 IED Configurator tool to refresh the details displayed for the Active and Inactive configuration banks. It is especially useful if, for example, configuration banks have been toggled directly on the IED.

Extract ICD file button. This button is only enabled for IEDs that hold their own local copy of their ICD template file. Press this button to define where the ICD template file that is contained in the IED should be saved. After the ICD template is extracted, it can be made available as an Installed template.

Extract configuration buttons. These buttons extract the appropriate configuration bank and open it for viewing or editing in a new window.

6.23 TRANSFER OF CONFIGURATIONS

The IED Configurator tool can be used to transfer configurations to and from any supporting MiCOM IED.

If you send a configuration to a supporting MiCOM IED, it is automatically stored in the Inactive configuration bank. It therefore does not immediately affect the current Active configuration.

To send a configuration to a MiCOM IED:

1. Establish a connection to the MiCOM IED.
2. Select **Device** > **Send Configuration**.
3. The IED Configurator tool checks the compatibility of the IED model number. It then transfers the configuration to the IED.

6.24 EXPORTING INSTALLED ICD TEMPLATE FILES

Any installed ICD template file can be exported by the IEC 61850 IED Configurator tool to a user-defined location.

1. Select **Tools** > **Export Installed ICD File**. The Template dialog appears.
2. Select the MiCOM IED type for which the template file is to be exported.
3. Click the **Select** button. Specify the location and filename of the ICD template file being exported.

6.25 EXPORTING CONFIGURED SCL FILES

Any IED configuration in an Editor window can be exported to a configured SCL file, if it has not been opened for restricted editing. To export a configured SCL file, the IED Configurator tool needs the IED's ICD template file.

1. In an Editor window, select **Tools** > **Export Configuration to SCL**.
2. Select the MCL configuration file which is to be exported.
3. Specify the destination filename for the configured SCL file.

Configuration items that are specific to MCL are not exported. This is because the information is not supported by the SCL schema. It is therefore important to save the configuration in an MCL file.

The main reason for exporting configured SCL files is to allow configuration information to be shared between multiple SCL/IED configurator tools. This is for the configuration of, for example, GOOSE message exchange.

7 DNP3 CONFIGURATOR

DNP3 (Distributed Network Protocol) is a master/slave protocol developed for reliable communications between various types of data acquisition and control equipment. It allows interoperability between various SCADA components in substations. It was designed to function with adverse electrical conditions such as electromagnetic distortion, aging components and poor transmission media.

The DNP3 Configurator allows you to retrieve and edit its settings and send the modified file back to a MiCOM IED.

7.1 PREPARING FILES OFFLINE TO SEND TO AN IED

To prepare files, it is not necessary to connect to an IED.

1. Select the IED type.
2. Click the **DNP3 Settings File** tile.
3. Click **Open Default File**.
4. Select the IED from the list and click **Next**.
5. Type or select a model number and click **Finish**. The **Default DNP3 Settings** screen appears.

Or

1. From the main screen, select **File** > **Open File** > **Px40** > **DNP3 Settings File**.
2. Select the IED file from the list and click **Open**.

Then

1. Expand the Explorer view and double click an item.
2. The left-hand column shows a list of available Master Points. Using the buttons, add or remove items from the left-hand column to list of Configured Points in the right-hand column.
3. Right-click any Configured Point in the right-hand column for further settings.
4. Click **OK**.

7.2 SEND SETTINGS TO AN IED

To send settings to a device, connect the PC to the IED and select the communication port. See Getting Started (on page 499). There must be at least one setting file in a settings folder for a device.

1. From the main screen, select **View** > **System Explorer**.
2. Expand the view to see the required device.
3. Right-click the device name and select **Send**.
4. In the **Send to...** dialog, select the setting files and click **Send**.
5. Click **Close**.

7.3 EXTRACT SETTINGS FROM AN IED

1. From the main screen, select **View** > **System Explorer**.
2. Expand the view to see the required device.
3. Right-click the device name and select **Extract Settings**. To exrtract all settings select **Extract Full Settings** then **Yes**.
4. Click **Close**.

7.4 VIEW IED SETTINGS

1. Under System, Substation, Voltage Level, Bay, Device, DNP3, double-click the New System.
2. In the left-hand pane, expand the **DNP3 Over Ethernet** properties.

8 CURVE TOOL

The User Programmable Curve Tool (UPCT) allows you to create user-defined curves and to download and upload these curves to and from the Px4x range of IEDs. You can use this tool to create programmable overcurrent and overfluxing operating and reset curves. Its user-friendly interface lets you easily create and visualize curves either by entering formulae or data points.

8.1 FEATURES

The Curve Tool allows you to:

- Create new configuration curve files or edit existing curve files
- Enter a defined number of curve points or a user-defined formula
- Create and save multiple formulae
- Associate the user-defined curve with a predefined curve template
- Interpolate between curve points
- Save curve formulae in XML format and configure curve points in CSV format, enabling easy data exchange
- Save configured curve data in CRV format, suitable for download into the IED
- Easily upload of the curve data from an IED
- Input constants with user-defined values
- Graphically display curves with zoom, pan, and point-on-curve facilities
- Colour code multiple curves to allow effective comparison
- Print curves or save curves in a range of standard image formats

8.2 SCREEN LAYOUT

The curve selection table and Curve Plot are in the right-hand panes. The Curve Details, Curve Points, Input Table View and Product View are in the left-hand-panes. To change the width of the left- and right-hand panes, drag the vertical border between them.

8.3 CURVE SELECTION PANE

To open an existing curve:

1. Select **File > Open Curve**. You can open several curves and the **Curve Selection** pane has a list of those available. As you import or create more curves, they appear as rows in the table.
2. Check the checkbox to select a curve and the corresponding row is then highlighted. Selecting the curve displays it in the Curve Plot pane and makes it available for upload or download.
3. Select **View > Show Curve Details t**o view the Curve Details.

8.4 CURVE PLOT PANE

The Curve Plot pane displays the curves showing time on the y-axis and Q (multiples of nominal current) on the x-axis. This is the standard method of defining protection IED configuration curves.

Right-click anywhere in the Curve Plot pane to carry out a range of flexible operations on the curves from the context sensitive menu. Operations include copying the image, zooming, panning and printing. Images can be saved as PNG, GIF, JPEG, TIFF or BMP.

Right-click any point on the plot and select **Show Point Values** to show the Q and T values at that point.

8.4.1 ZOOMING AND PANNING

To zoom in, drag a box around the area using the mouse.

To pan, click and hold the left mouse button while holding the shift key and move the mouse in the relevant direction.

To un-zoom or un-pan, right-click the Curve Plot and select **Un-zoom** or **Un-pan**.

To revert to the original view, right-click the Curve Plot and select **Undo All Zoom/Pan**.

8.4.2 SCALES AND GRID LINES

To change the scales:

1. Select **Graph Options**.
2. Select **X-Axis Scale** or **Y-Axis Scale**.
3. Select **logarithmic** or **linear**.

To change the grid lines:

1. Select **Graph Options** > **Grid Lines**.
2. Select **Major Grid Lines** or **Minor Grid Lines** to show the grid lines in a coarse or fine scale.

8.5 CURVE DETAILS PANE

To show further details about the curves, select **View > Show Curve Detail**.

In the **Curve Details** pane you can define the name and description of the user curve. You can enter a string up to 16 standard ASCII characters. If you do not enter a name, the default name New Curve is used.

The formula name and template version are also displayed if applicable.

To close the Curve Detail dialog, click the X in the right-hand corner.

To auto-hide the Curve Detail, click the icon next to the cross. This shows the plot full size and only shows the curve detail when you position the cursor in the marked area in the left-hand margin.

8.6 CURVE POINTS PANE

The Curve Points pane has three columns

Index. Each curve point has a unique index number associated with it, starting at 0, incrementing by 1 and ending with the last curve point.

Q (multiples of setting). Q, in this context stands for Quantity. It is the secondary current Is, expressed in multiples of the nominal current In.

T (Time in secs). T is the imposed delay time, expressed in seconds.

8.6.1 ENTERING VALUES OF Q AND T INTO THE TABLE

To input values for Q and T to define a table:

1. Select **File** > **New** > **Input Table**.
2. Insert the values for **Q** and **T** up to a maximum of 256 curve points (index 0 to 255). The tool instantaneously updates the graph view as points are entered. If fewer points are inserted, the tool automatically interpolates points using linear interpolation.

To copy and paste an entire table from Excel or other compatible table formats:

1. Copy the table to the clipboard.
2. Position the cursor in the top left-hand Q cell and paste.

8.7 INPUT TABLE VIEW

This allows you to show show or hide the user curve and its associated points. It also allows you to choose the colour of the plotted user curve.

8.8 PRODUCT VIEW

This allows you to select a curve template from the Px40 product range. You can choose whether or not to plot the product curve and its points. This pane also allows you to choose the colour of the plotted product curve.

8.9 FORMULA EDITOR

1. To open the Formula Editor select **View** > **Show Formula Editor**.
2. Enter the formula in the **T=** field. The formula is case sensitive, use only uppercase letters.
3. Select the required template from the **Curve Template** dropdown box. The curve you are creating with the formula must be associated with a predefined template. This must match the template of one of the curves stored in the IED. The template defines a curve with a specific spread of points which can be downloaded to the IED.
4. Enter the formula name into the **Formula Name** field. This can be any combination of standard ASCII characters up to 32 characters.
5. If you need a Definite Time characteristic, check the **DMT** (Definite Minimum Time) checkbox. Then enter fixed values for the tripping current multiplier (**Q**) and the delay time (**T**).
6. You can enter any constants into the formula and the first eight letters of the Greek alphabet are included in the formula editor as buttons. Click a button to enter the character in the **Formula** field.
7. Input the formula constants into the **Value** column.
8. To validate the formula, click the **Verify Formula** button at the bottom left corner of the screen. The names of the constants used in the formula are shown in the **Input Constants** table. The formula verifier checks the operators are valid but does not check if the formula is valid or if the results are out of range.
9. Select the **Options** tab, click **Save As** and enter a file name. The file is saved in XML format. Enter up to 16 standard ASCII characters.
10. Once the constants are entered and the file is saved, click the **Generate Curve** button (next to the Verify Formula button) to generate a curve. The curve appears in the Curve Plot pane.

Allowed Formula Editor operators

Operators	Description
+	Plus
-	Minus
*	Multiply
/	Divide
^	Raise to the power of
sqrt()	Square Root
ln()	Natural logarithm
Sin	Sin function
Cos	Cos function
Tan	Tan function

8.10 CURVE TEMPLATE DEFINITIONS

Many protection functions use a graphical curve to define their Operate and Reset characteristics. These are inverse curves with current on the x-axis and time on the y-axis and each curve has 256 points.

In the Phasor tool, the curves created with the formula or points table must match the templates of their respective curves stored in the IED. Each curve is defined by 256 points with a specific spread of the points in different areas of the curve.

The following are examples of Curve Tool templates.

Curve tool templates

Template	Description
Overcurrent Operate	Overcurrent protection IDMT operate curve
Overcurrent Reset	Overcurrent protection IDMT reset curve
Thermal Overload Operate	Thermal overload protection operate (heating) curve
Thermal Overload Reset	Thermal overload protection reset (cooling) curve
Undervoltage Operate	Undervoltage protection operate curve

The curve templates have a clearly defined number of graphical points to define certain portions of the curve. The following tables are examples of template definitions.

Overcurrent operate

Range	Number of points
Range 1: 1x to 3x setting	128
Range 2: 3x to 32x setting	116
Range 3: 32x to 76x setting	12
Overall range	256

Overcurrent reset

Range	Number of points
Range 1: 1x to 0.96x setting	116
Range 2: 0.96x to 0.7x setting	128
Range 3: 0.7x to 0x setting	12
Overall range	256

Thermal overload operate

Range	Number of points
Range 1: 1x to 4x setting	150
Range 2: 4x to 5x setting	68
Range 3: 5x to 10x setting	32
Range 4: 10x to 32x setting	6

Thermal overload reset

Range	Number of points
Range 1: 1x to 0.96x setting	116
Range 2: 0.96x to 0.7x setting	128

Range	Number of points
Range 3: 0.7x to 0x setting	12
Overall range	256

8.11 CONNECTING TO AN IED

Depending on the model, the MiCOM IEDs will have one or more of the following ports to which you can connect to in order to transfer curve files:

- Front USB
- Front serial
- Rear RS485
- Rear Ethernet

The front port is a temporary local connection used to set up the IED. The rear serial port is typically used for multi-drop SCADA. The Ethernet port runs at 10/100 Mbps and is typically used for network SCADA.

To configure the communication settings for downloading and uploading the curves to and from the IED

1. Select **Device** > **Connection Configuration**. The Edit Connection dialog appears.
2. In the Scheme dropdown box, select which port to configure.
3. Click the **Transaction Values** tab. These are the default values. If you make changes and need to revert to the default settings, click the **Restore Defaults** button.

The following is a list of transaction values and their definitions

Busy Hold-off Time (ms). The time interval used by Courier between receiving a BUSY response and sending a subsequent POLL BUFFER command.

Busy Count. The maximum number of BUSY responses that will be accepted for a single Courier transaction before aborting the transaction.

To cope with abnormal situations where a device is not replying correctly to requests, a limit is placed on the number of BUSY responses that should be accepted. Without this limit the link to the device would be stuck in a loop.

Reset Response Time (ms). The maximum time from a sending the last byte of a Courier Reset Remote Link message to receiving the first byte of a response. When that time has elapsed the request is aborted.

Response Time (ms). The maximum time from a sending the last byte of a Courier message to receiving the first byte of a response. When that time has elapsed the request is aborted. The Response Time parameter is used for all messages except Courier Reset Remote Link messages.

Try Count. The number of tries before aborting the request.

Transmit Delay Time (ms). The minimum delay that is put between receiving a response and transmitting the next request. Transmit delay is normally set to zero but can be set to a few milliseconds when using half duplex communication. This gives the other end of the link time to change from transmitting to receiving.

Global Transmit Time (ms). The minimum delay that is put between transmitting a global message and the next transmission.

8.11.1 CONNECTING TO A SERIAL PORT

If you connect to a serial port, the **Serial** tab appears.

1. Click the **Serial** tab. The fields are already populated with the default settings.
2. Enter the **Relay Address**. This is an integer which represents the Courier address of the IED.

8.11.2 CONNECTING TO THE ETHERNET PORT

If you connect to the Ethernet port, the **Ethernet** tab appears.

1. There is no DHCP support so you must know the **IP address** and enter it manually.
2. The TCP port can be dynamic or static. If you need a static TCP port, check the **Use fixed incoming TCP port** checkbox and enter the **Fixed incoming port number**.
3. If the device is attached to a bay unit, click the **Device is attached to a bay unit** checkbox. Then select from the **Bus Address** dropdown box.
4. Enter the **Relay Address**. This is an integer which represents the Courier address of the IED.

8.12 SEND A CURVE TO AN IED

1. To open an existing curve, select **File** > **Open Curve**. You can open several curves and the **Curve Selection** pane has a list of those available. As you import or create more curves, they appear as rows in the table.
2. Check the checkbox to select a curve and the corresponding row is then highlighted. Selecting the curve displays it in the **Curve Plot** pane and makes it available for upload or download.
3. Click the Device tab and select **Send Curve**. The **Send Curve Form** appears.
4. The IED stores several curve characteristics. In the **Curve Characteristic** dropdown box, select which curve you want to overwrite.
5. Click **Send** to send the curve to the IED then click **Get Curve Ref**.
6. Check the **PC Curve Value** is the same as the **Relay Curve Value**. This shows that the send has been successful because it overwrites the existing Relay Curve Value.

8.13 EXTRACT A CURVE FROM AN IED

1. Select **Device** > **Extract Curve**.
2. Select **File** > **Save** > **Input Table View** to save the curve file in CSV format
   or
   select **File** > **Save** > **Product View** to save the curve file in CRV format.

9 S&R COURIER

Settings and Records - Courier enables you to connect to any Courier device, retrieve and edit its settings and send the modified settings back to a Courier device, including DNP 3.0 configuration if supported by the device.

Although each device has different settings, each cell is presented in a uniform style, showing the permissible range and step size allowed.

Settings and Records - Courier also enables you to:

- extract events from a device
- extract disturbance records from a device
- control breakers and isolators
- set date and time on device
- set active group on device
- change the address of a device
- save settings, DNP 3.0 configuration, events and disturbance files to disk

9.1 SET UP IED COMMUNICATION

1. Select **Device** > **Communications Setup**. The Communications Setup dialog appears.
2. If the configuration you want to use already exists, select it from the Scheme drop-down list and click **OK**.
3. If the configuration you want to use does not exist, create a new communications setup.

9.2 CREATE A NEW COMMUNICATION SETUP

1. Select **Device** > **Communications Setup**. The **Communications Setup** dialog box appears.
2. Select the connection: **Serial**, **Modem** or **Internet**.

If using a serial connection,

1. Select the **Serial** tab.
2. In the **COM Port** drop-down list, select the serial port to which the device will be connected.
3. Select the **Baud rate** and **Framing**.

If using a modem,

1. Select the **Modem** tab.
2. Click **Configure…** to enter the phone number.

Then for all connection types,

1. Select the **Transaction Values** tab and complete the fields.
2. Click **Save As**.
3. Enter a name in the **Save Communications Parameters As** field and click **OK**.
4. Click **OK** to configure the communications port.

9.3 OPEN A CONNECTION

1. **Select Device** > **Open Connection**.
2. If known, enter the device address in the **Address** field, otherwise click **Browse** to scan available devices.
3. Click **OK** to open the connection.
4. Enter the password using four alphabetic characters.
5. Click **OK**. If the password is valid, the connection is made and the **On-line** window appears.

> *Note:*
> *If the device is set to the default password, the **Enter Password** dialog is not needed for enhanced DNP 3.0 devices.*

9.4 CREATE A NEW OR DEFAULT IED DNP 3.0 FILE

1. Select **File** > **New**.
2. Select **DNP File**. The **New DNP 3.0 File** dialog appears.
3. Select the required device type from the **Device Type** drop-down list. The model numbers for the device type are displayed.
4. Select the model number from the **Model Number** list or use the **Advanced** button to construct the required model number. If duplicate model numbers exist, the Header details give version numbers and other identifying information. The appropriate language is displayed in the **Language** drop-down list, showing the language of the file.
5. If more than one language type is supported, the **Language** drop-down list shows the languages for the device type.
6. Click **OK**. A new DNP 3.0 file is generated, based on the selected model.

9.5 EXTRACT A SETTINGS FILE FROM A DEVICE

1. **Select Device** > **Open Connection** to open a connection to the required device.
2. In the **Online Device** window, right-click the device name.
3. Select **Send To** > **New Settings File**.
4. The **New Settings File** dialog appears. Select the device model number.
5. Click **OK**.
6. Once the extraction is complete, a window appears showing the settings.

9.6 SAVE A SETTINGS FILE

1. Select **File** > **Save As**.
2. Edit the **File Name** or **Header** fields as required.
3. Click **Save**.

9.7 SEND A SETTINGS FILE TO A DEVICE

1. Open a connection to the required device.
2. Make sure the destination file is in the active window.
3. Select File > Send To
4. Click the appropriate device.

10 AEDR2

AutoExtract Disturbance Records 2 (AEDR2) automatically reads COMTRADE disturbance records from the rear communication ports of both K-Series and MiCOM Px40 devices with the Courier protocol, and from Px40 or Px30 devices with the IEC 60870-5-103 protocol.

AEDR2 is configured with an initialisation file. This file contains all settings, file names and file directories needed for configuration. This file can be created and edited using a standard text editor. Log files are also defined in the initialisation file which are used by AEDR2 to record a history of events and errors.

Once configured, disturbance records are automatically extracted according to a schedule from devices connected in a defined range of addresses. This is done using the Windows® Scheduled Task facility which can be used to execute one or several schedules. All new disturbance records are saved to a user-defined drive and filename.

AEDR2 also has a test function to ensure the initialisation file has been properly configured. The command line is used to execute the test function and validate the initialisation file. The command line can also be used to manually execute the AEDR2 application on demand.

WinAEDR2 is a management facility for AEDR2. It shows the history of all previous extractions and has shortcut buttons to launch WaveWin, Windows Explorer and the Scheduled Task facility. It can also be used to view log files, and edit and test the initialisation file.

10.1 INITIALISATION FILE

First of all you need to create or edit the initialisation file (AEDR2.INI) with a text editor such as Microsoft® Notepad. It needs to be configured for each application and for the communication requirements of the connected devices.

The AEDR2.INI file contains 3 sections: the common section headed [AEDR2], the Courier section headed [Courier] and the IEC 60870-5-103 section headed [IEC-103]. Section entries are only included when non-default values are needed.

10.1.1 COMMON SECTION

Function	Description	Values		Default
ErrorLogFileName	Filename of Error Log	Valid filename	1	Error.log
ExtractionLogFileName	Filename of Extraction Log	Valid filename	1	Extraction.log
StatusLogFileName	Filename of Status Log	Valid filename	1	Status.log
ComtradeName	Used to create Comtrade short filenames	Part of valid filename	2	DR
ComtradeDir	Where to store the resulting Comtrade files	Valid directory	1	empty
ComtradeFormat	Defines Comtrade format	1991 or 1999		1999
ReportMissingDevices	1 indicates that any device not found between MinAddress and MaxAddress is reported as "not found" in the Error Log	0 or 1	3	0
LongFileNames	1 indicates Comtrade long filenames	0 or 1	4	0
LFN_TCode	For long filenames, defines the Time Zone with respect to UTC	Valid time zone		0z
LFN_Substation	For long filenames, the substation name or code where the originating device is located	Part of valid filename		empty

Function	Description	Values		Default
LFN_Company	The company of the specified substation	Part of valid filename		empty

Use full pathnames for files or directories (e.g. "C:\Directory\SubDir"). If relative paths are used, they are assumed to be relative to the directory in which the applications are installed.

Short filenames use the following format:

```
DEV_XX_TIMESTAMP
```

DEV identifies the device – C for Courier or I for IEC 60870-5-103 followed by the 3-digit device address.

For example `061001,231941657,0z,South Park,C001,Stafford Power,,,,.DAT`

XX denotes the value of the ComtradeName key

TIMESTAMP expresses the date and time when the disturbance was recorded, in the format YYYY-MM-DD--HH-MM-SS. For example,

```
C001_DR_2006-10-01--23-19-41.DAT
```

Function	Value	Description
ReportMissingDevices	0	Missing devices are not reported as errors.
	1	Arrange all device addresses consecutively without gaps.
LongFileNames	0	Records are saved using the short file name format.
	1	Records are saved using the long file name format as defined by the IEEE.

10.1.2 COURIER SECTION

Key	Purpose	Values		Default
MinAddress	Minimum device address	1 to 254	1	empty
MaxAddress	Maximum device address	1 to 254	1	empty
CommPort	Which COM port to use	Valid COM port	2	COM1
BaudRate	Baud rate to use	Valid baud rate		9600
ElevenBits	Ten or Eleven bits	0 or 1	3	1
BusyHoldoff	Standard Courier parameter	Integer		50
BusyCount	ditto	Integer		100
ResetResponse	ditto	Integer		100
Response	ditto	Integer		100
TryCount	ditto	Integer		3
TransmitDelay	ditto	Integer		5
GlobalTransmit	ditto	Integer		10
UseModem	Whether to use a Modem	0 or 1		0
TAPI_ModemName	Modem Name	String		empty
TAPI_LineAddress	Line Address	Integer		0
TAPI_NumberToDial	Number to Dial	String		empty
TAPI_UseCountryAndAreaCodes	Whether to use Country/Area codes	Integer		0
API_AreaCode	Area Code to dial	String		empty
TAPI_CountryCode	Country Code to dial	String		empty

Key	Purpose	Values		Default
SecondaryPort	Defines which devices (if any) uses Secondary Port extraction	ALL or NONE or a sequence of numbers e.g. 1,4,77,12	4	NONE

The MinAddress and MaxAddress entries must either be both included or both omitted. If included, MaxAddress must be greater than MinAddress. All Courier addresses between MinAddress and MaxAddress (inclusive) are tried. If omitted, no Courier address is tried.

Both Courier and IEC 60870-5-103 disturbance extraction can use the same COM port. This is because all Courier devices are polled first, each time the AEDR2 application runs, followed by all IEC 60870-5-103 devices.

If ElevenBits = 0, serial data is set to 1 start bit, 8 data bits, no parity and 1 stop bit.

If ElevenBits = 1, serial data is set to 1 start bit, 8 data bits, even parity and 1 stop bit.

Secondary Port Extraction means the disturbance records can be read from the device but not deleted.

Primary Port Extraction means that disturbance records are deleted from the device once read. The value SecondaryPort can be set in one of three ways:

- **NONE** All devices are connected using their primary port.
- **ALL** All devices use the secondary port upload mechanism.
- **<comma separated list of device addresses>** e.g. 11,4,5,23,121

If the value is a list of addresses, the listed addresses use the secondary port upload mechanism. All other addresses between MinAddress and MaxAddress use the standard primary port Courier disturbance record method of extraction.

A device connected to AEDR2 through its primary port, but set using its primary port to free its secondary port, operates as if it were connected to its secondary port. A device connected to AEDR2 through its secondary port, but set using its secondary port to free its primary port, fails to upload records and the same record is uploaded repeatedly.

10.1.3 IEC 60870-5-103 SECTION

Key	Purpose	Possible Values		Default
MinAddress	Minimum device address	0 .. 254	1	empty
MaxAddress	Maximum device address	0 .. 254	1	empty
CommPort	Which COM port to use	Valid COM port		COM1
BaudRate	Baud rate to use	Valid baud rate		9600
ElevenBits	Ten or Eleven bits	0 or 1	2	1
DModDirectory	Defines where the DMod directory is found	Valid directory	3	see note
LeaveInDevice	Defines which devices (if any) have disturbance records left in	ALL or NONE or a sequence of numbers e.g. 1,4,77,12	4	NONE
ComtradeDataFormat	Defines the Comtrade data format	BINARY or ASCII		ASCII

The MinAddress and MaxAddress entries must either be both included or both omitted. If included, MaxAddress must be greater than MinAddress. All IEC 60870-5-103 addresses between MinAddress and MaxAddress (inclusive) are tried. If omitted, no IEC 60870-5-103 address is tried.

If ElevenBits = 0, serial data is set to 1 start bit, 8 data bits, no parity and 1 stop bit.

If ElevenBits = 1, serial data is set to 1 start bit, 8 data bits, even parity and 1 stop bit.

The DModDirectory value defines where the DMod files are. This is used for the descriptions of the signals in the disturbance records.

The default directory is:

C:\Program Files\Alstom Grid\MiCOM S1 Agile\S&R-103\DMod

"Leave in Device" means that the disturbance records can be read from the device but not deleted. Otherwise, disturbance records are deleted from the device once read. The value LeaveInDevice can be set in one of three ways:

- **NONE** (all records are extracted and deleted)
- **ALL** (no records will be deleted from devices)
- **<comma separated list of device addresses>** e.g. 11,4,5,23,121

If the value is a list of addresses, the disturbance records of the listed addresses are left after extraction. For all other addresses between MinAddress and MaxAddress, records are extracted and deleted.

10.1.4 IEC 60870-5-103 SECTION

```
[AEDR2]
ErrorLogFileName = TestError.log
ExtractionLogFileName = TestExtraction.log
StatusLogFileName = TestStatus.log
ComtradeDir = C:\Project\AEDR2\WinAEDR2
ReportMissingDevices = 1
LongFileNames = 1
LFN_Substation = "South Park"
LFN_Company = "Stafford Power"
ComtradeFormat = 1999

[Courier]
CommPort = COM1
BaudRate = 19200
ElevenBits = 1
MinAddress = 1
MaxAddress = 2
SecondaryPort = 1,3,5

[IEC-103]
CommPort = COM1
BaudRate = 115200
ElevenBits = 1
MinAddress = 1
MaxAddress = 2
LeaveInDevice = ALL
DModDirectory = C:\Program Files\Alstom Grid\MiCOM S1 Agile\S&R-103\DMod
ComtradeDataFormat = ASCII
UseModem = 0
TAPI_ModemName = Standard 56000 bps Modem
TAPI_NumberToDial = 01223503445
```

10.2 IEC 60870-5-103 SECTION

The PC running AEDR2 can be connected to either to the Rear Port 1 or the Rear Port 2 (if fitted) of a Courier device. AEDR2 can not be used with the front port of Px40 IEDs. Rear Port 1 allows the disturbance records to be extracted or saved. Rear Port 2 can only save disturbance records. Extracted records are saved to the local PC then deleted from the device. Saved records are copied to the local PC but not deleted from the device. AEDR2 can extract or save disturbance records from IEC 60870-5-103 devices. It maintains a list of previously extracted records so it can only extract such records once. Devices using IEC 60870-5-103 and Courier use a single direct connection to the same or different COM ports. Devices using

Courier can also connect using a modem link. AEDR2 can run on more than one COM port but it needs to be run separately for each, with each port or modem using its own initialisation file.

10.3 OPERATION

AEDR2 scans all the Courier and IEC 60870-5-103 device addresses in a specified range. If it does not find a device at an address it goes to the next address. You only need to specify the lowest and highest addresses, even if there are devices missing in the sequence.

AEDR2 does not keep a list of known devices. Each time it runs, it scans all addresses in the specified range. You can add new devices or remove existing devices and AEDR2 extracts disturbance records from all addresses it finds in the range each time it operates.

If a device is found at an address in the specified range and an error is found while extracting a record, the error is reported to a log file.

When executed directly or by the Scheduled Task facility, the AEDR2 application runs invisibly in the background, without the WinAEDR2 interface running. The only communication between AEDR2 and WinAEDR2 is through three log files written by AEDR2 which are as follows:

Error Log

This contains errors reported by the Courier or IEC 60870-5-103 transfer mechanisms, or errors caused by missing devices. Each entry contains date, time and an error description.

Extraction Log

This has an entry for every record that is uploaded. Each entry contains date, time, communication type, device address, trigger date and time information.

Status Log

This file has one line showing the time and date that AEDR2 was last run. The Status Log is overwritten each time AEDR2 is run.

10.4 DISTURBANCE RECORD FILES

For each disturbance record, a set of two or three files are created in standard COMTRADE format (*.CFG, *.HDR, *.DAT).

Filenames in a set use the following format,

<AAA>_<ComtradeName>_<Date and Time>

<AAA> Is the decimal address of the device, always three digits.

<ComtradeName> Is the name specified by the ComtradeName section entry in the INI file.

<Date and Time> Is the date and time of the extraction in the following format,

YYYY-MM-DD--HH-MM-SS

where (HH) use the 24 hour clock.

Lists of filenames are sorted into chronological order for each device address.

10.5 OPERATION

All errors are output to a log file. Some errors may create more than one error in the log file. The log file name is user settable. See the LogFileName entry in the INI file.

10.6 USING THE SCHEDULED TASKS PROGRAM

1. Select **Start** > **Settings** > **Control Panel**.
2. Double-click **Scheduled Tasks**. The Scheduled Tasks program starts.
3. Double click **Add Scheduled Task**. The Scheduled Tasks Wizard starts. This lets you schedule the program to run at regular intervals from once a day to once a year (inclusive). Once the task has been created, it can be scheduled more frequently than once a day.
4. Double-click **AEDR2**, the **Properties** dialog appears.
5. Select **Schedule** > **Advanced** to configure it to run at intervals which can be as small as one minute.

Note:
The Scheduled Tasks facility can also be run directly from the WinAEDR2 application.

The Scheduled Tasks program is a component that is included with Windows®. It allows programs to be run automatically at predetermined times. Other programs are available from independent companies that provide more comprehensive facilities and these can be used as alternatives to run AEDR2.

10.7 SCHEDULED TASKS PROGRAM TUTORIAL

When creating a scheduled task, test the INI file first. To set the Scheduled Tasks Program to run AEDR2,

1. Select **Start** > **Settings** > **Control Panel**.
2. Double-click the **Scheduled Tasks** icon. The Scheduled Tasks program starts.
3. Double click **Add Scheduled Task**. The Scheduled Tasks Wizard starts.
4. Click **Next**. Ignore the list of programs and click the **Browse** button. Find AEDR2.exe. If you loaded MiCOM P14D at the default location it is at C:\Program Files\Alstom Grid\MiCOM S1 Agile \WinAEDR2\AEDR2.exe.
5. Select **AEDR2.exe** and click the **Open** button.
6. Select **Daily** and click **Next**. If you want it to operate more often than daily you can do this later.
7. Select the **Start Time** and **Start Date** and click **Next**.
8. Enter your **user name** and **password** (twice) and click **Next**.
9. Click **Open advanced properties for this task when I click Finish** then click **Finish**.
10. The **Properties** dialog opens. In this basic tutorial it's only necessary to set how often AEDR2 runs and set which INI file it uses.

To set how often AEDR2 operates,

1. Click the **Schedule** tab, then the **Advanced** button. The **Advanced Schedule Options** dialog appears.
2. Enable **Repeat Task** and select **Every 30 minutes**. This sets Schedule Tasks to operate AEDR2 every 30 minutes.
3. Enable **Duration** and select **24 hour(s)**.
4. Enable **If the task is still running, stop it at this time**.
5. Click **OK**.

To tell the Scheduled Tasks which INI file AEDR2 should use,

1. Click the **Task** tab.
2. In the **Run** edit box, enter **AEDR2.exe** as the program to run.
3. Enter a space after AEDR2.exe then the name of the INI file it uses.
   If the INI file contains spaces, enclose it in in double quotes. Do NOT add the /t option when running automatically.
   For example,
   "C:\Program Files\Alstom Grid\MiCOM S1 Agile\WinAEDR2\AEDR2.exe" " C:\Program Files\Alstom Grid\MiCOM S1 Agile\WinAEDR2\example.ini"
4. Click **OK** to complete setting up.

If you need to modify the settings later, in the **Schedule Tasks** window, double-click the scheduled task and the **Properties** dialog opens.

> *Note:*
> *If you need to use several INI files for Courier devices at various locations, take care over when each one operates. For example, if AEDR2 uses two INI files which use the same COM port at the same time, it will fail. However, if the two INI files use different COM ports at the same time, it will not fail.*

11 WINAEDR2

WinAEDR2 is a management facility for AEDR2. It shows the history of all previous extractions and has shortcut buttons to launch WaveWin, Windows Explorer and the Scheduled Task facility. It can also be used to view log files, and edit and test the initialisation file.

11.1 FUNCTIONS

The main window lists the most recently extracted records in the order of extraction. There are also buttons to launch the following functions.

WaveWin launches the WaveWin COMTRADE viewer application

ExtractionLog launches notepad to view the extraction log

ErrorLog launches notepad to view the error log

Explorer launches Windows Explorer

Scheduler launches the "Scheduled Tasks" application

Edit .INI File launches notepad to edit INI file

Test .INI File tests the INI file for errors and logs any errors

Run AEDR2 launches the AEDR2.exe application

AEDR2 Status shows the run status of AEDR2

12 WAVEWIN

Wavewin is used for viewing and analysing waveforms from disturbance records. It can be used to determine the sequence of events that led to a fault.

Wavewin provides the following functions. For further details please refer to the Wavewin user manual.

- File management
- Query management
- Log management
- Report generation
- Sequence of Events(SOE)
- Conversion of COMTRADE files
- Waveform summary

12.1 FILE MANAGER FEATURES

The File Manager is used to manage files, search the contents of a drive or directory, and edit, plot or draw the contents of a file. This feature is similar to Windows Explorer with application-specific functions tailored for the Power Utility industry.

The functions include automatic event file association, specialized copy or move, intelligent queries, report files, COMTRADE conversion and compression routines, merge and append waveform and load files, event summaries and calibration reports.

The File Manager supports the IEEE long file naming format.

12.2 SAVE AS COMTRADE

Oscillography formats supported by the software can be converted to the COMTRADE ASCII or Binary format. Two Comtrade versions are supported: the older 1991 format and the newer 1999 format. The Comtrade format can be selected from the Data Plotting Window's Properties dialog. The default format is the newer 1999 format.

To create a COMTRADE file,

1. Place the cursor on the event file or mark the desired files
2. Select **Options** > **Save As COMTRADE** (ASCII or Binary).
3. Enter the destination path and filename (do not enter a filename extension).
4. Click **OK**. The .DAT and .CFG files are created automatically. If a path is not defined, the COMTRADE files are saved in the active directory.

If the sample values in the selected file(s) are RMS calibrated and the desired COMTRADE file must have instantaneous values, set the Comtrade Settings fields to automatically convert the RMS data to instantaneous values.

To set the **Comtrade Settings** fields,

1. In the **Analysis** display, open the **Window Properties** dialog.
2. Select the **Comtrade** tab.
3. In the **Convert RMS Calibrated Data to Peak Data** dropdown box, select **Yes**.

To automatically convert the selected file(s) to COMTRADE using the IEEE long filename format,

1. In the **Save As Comtrade** dialog, check the **Use the ComNames Naming Convention to Name the Comtrade File(s)** field
2. Leave the **File Name field** empty.
3. Click **OK**.

All files marked in the table are converted to the selected COMTRADE format and are named using the IEEE long file naming convention.

13 DEVICE (MENU) TEXT EDITOR

The Menu Text Editor enables you to modify and replace the menu texts held in MiCOM Px4x IEDs. For example, you may want to customise an IED so that menus appear in a language other than one of the standard languages.

By loading a copy of the current menu text file in one of the standard languages into the reference column, you can type the appropriate translation of each menu entry into the target column.

This can then be sent to the IED through your PC's parallel port, replacing one of the current standard languages. New menu text files created this way can also be saved to disk for later use or further editing.

13.1 OPEN A CONNECTION

1. Select **Device** > **Open Connection**. The Open Connection dialog appears.
2. Select the Parallel Port to which the device is connected.
3. Select the **Device Timeout** in minutes.
4. Click **OK**. The Password dialog is displayed.
5. Type the Password. This is displayed as asterisks.
6. Click **OK**. A message appears confirming the connection has been opened.

13.2 CHANGE CONNECTION PASSWORD

1. Open a connection with the device.
2. Select **Device** > **Change Password**. The Change Password dialog appears.
3. In the **New Password** box, enter the new password. This is displayed as asterisks.
4. In the **Verify New Password** box, enter the password again.
5. Click **OK** to accept.

13.3 OPEN A MENU TEXT FILE AS A REFERENCE

1. Select the **Reference** column.
2. Select **File** > **Open**. The Open File dialog appears.
3. Select the required menu text file then click the **Open** button.
4. The menu text file appears in the **Reference** column.

13.4 EDIT TEXT FILE OF DEVICE

1. Select File > **New** to create a default menu text file for the required device or select File > **Open** to open an existing file.
2. The menu text file appears in the **Target** column. Select the required text cell in the **Target** tab corresponding to the text in the **Reference** tab. Edit the file as required.
3. Select **File** > **Save As**.
4. Edit the File Name or Header fields as required.
5. Click **Save**.

13.5 SEND EDITED TEXT FILE TO DEVICE

1. Connect a PC with a parallel cable to the required device.
2. Select **Device** > **Open Connection** to open a connection to the required device.

3. Select **Send To Device**.
4. Click **OK**.
5. Once the sending of the text file is complete, the new text appears in the menu on the IED screen.

SCHEME LOGIC

CHAPTER 13

1 CHAPTER OVERVIEW

Alstom Grid products are supplied with pre-loaded Fixed Scheme Logic (FSL) and Programmable Scheme Logic (PSL). The FSL schemes cannot be modified. They have been individually designed to suit the model in question. Each model also provides default PSL schemes, which have also been designed to suit each model. If these schemes suit your requirements, you do not need to take any action. However, if you want to change the input-output mappings, or to implement custom scheme logic, you can change these, or create new PSL schemes using the PSL editor.

This chapter provides details of the in-built FSL schemes and the default PSL schemes.

This chapter contains the following sections:

2 INTRODUCTION TO THE SCHEME LOGIC

The Scheme Logic is a functional module within the IED, through which all mapping of inputs to outputs is handled. The scheme logic can be split into two parts; the Fixed Scheme Logic (FSL) and the Programmable Scheme Logic (PSL).

The FSL Scheme Logic is logic that has been designed and implemented at the factory. It is logic that is necessary for the fundamental workings of the IED. It is fixed and cannot be changed.

The PSL is logic that is user-programmable. The PSL consists of logic gates and timers, which combine and condition the DDB signals. The logic gates can be programmed to perform a range of different logic functions and can accept any number of inputs. The timers are used either to create a programmable delay or to condition the logic outputs. The PSL logic is event driven. Only the part of the PSL logic that is affected by the particular input change that has occurred is processed. This reduces the amount of processing time used by the PSL, when compared to some competition devices. The device is shipped with a selection of default schemes, which should cover basic applications, but you can modify these default schemes to create custom schemes, if desired. You can also create new schemes from scratch, should you wish to do so.

The Scheme Logic module is built around a concept called the digital data bus (DDB). The DDB is a parallel data bus containing all of the digital signals (inputs, outputs, and internal signals), which are available for use in the FSL and PSL

The following diagram shows how the scheme logic interacts with the rest of the IED.

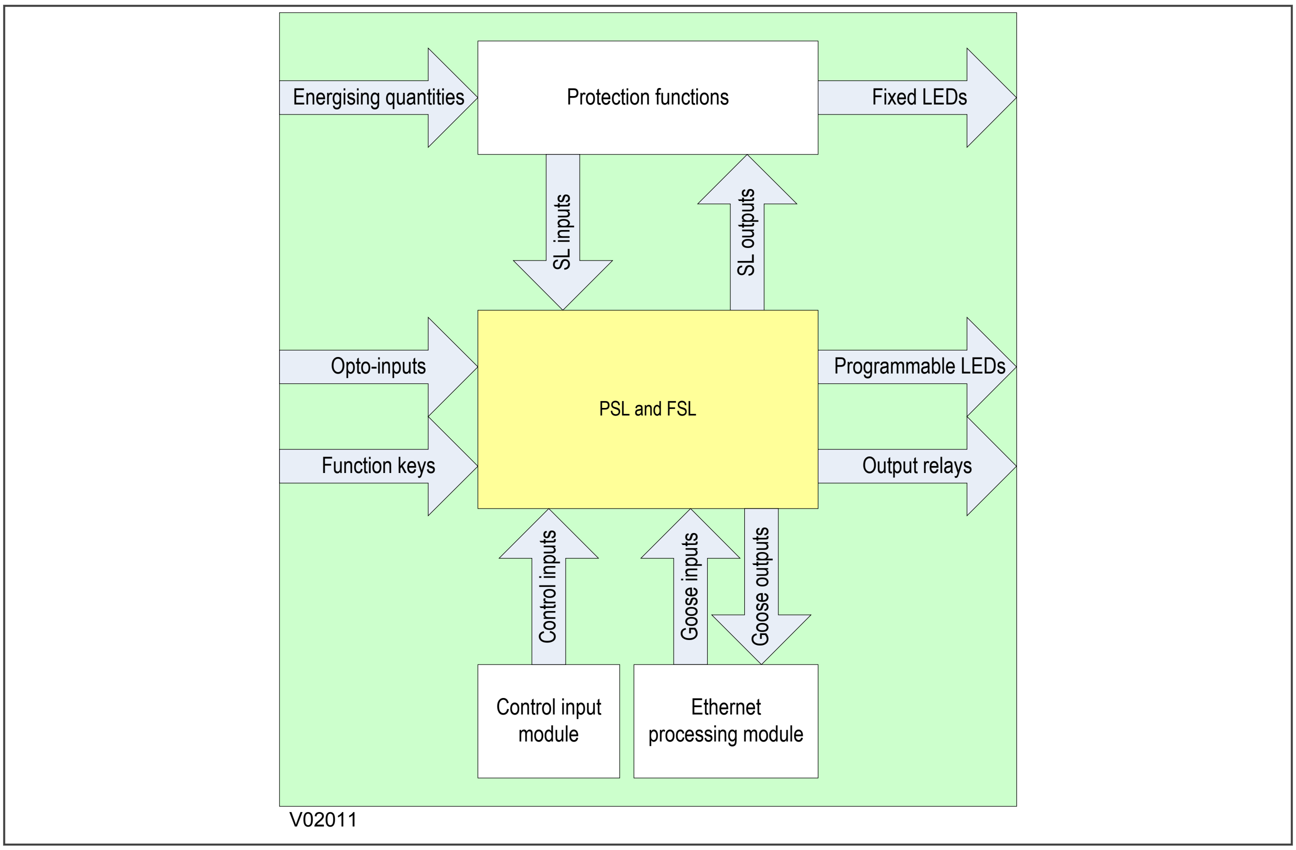


Figure 143: Scheme Logic Interfaces

The inputs to the scheme logic are:

- Opto-inputs: Optically-coupled logic inputs
- Function keys: Keys on the device (not on 20TE models)

- Control inputs: Software inputs for controlling functionality
- Goose inputs: Messages from other devices via the IEC61850 interface (not on all models)
- Scheme Logic inputs: Inputs from the protection functions (SL inputs are protection function outputs)

The outputs from the scheme logic are:

- Programmable LEDs
- Output relays
- Goose outputs: Messages to other devices via the IEC61850 interface (not on all models)
- Scheme Logic outputs: Outputs to the protection functions (SL outputs are protection function inputs)

Examples of internal inputs and outputs include:

- **IN>1 Trip**: This is an output from the Stage 1 Earth Fault protection function, which can be input into the PSL to create further functionality. This is therefore an **SL input**.
- **Thermal Trip**: This is an output from the the thermal protection function, which can be input into the PSL to create further functionality. This is therefore an **SL input**.
- **Reset Relays/LED**: This is an **SL output**, which can be asserted to reset the output relays and LEDs.

The FSL is fixed, but the PSL allows you to create your own scheme logic design. For this, you need a suitable PC support package to facilitate the design of the PSL scheme. This PC support package is provided in the form of the the PSL Editor, which is included as part of the MiCOM S1 Agile engineering tool. The PSL Editor is one of a suite of applications available in the settings application software, but is also available as a standalone package. This tool is described in the Settings Application Software chapter.

3 FIXED SCHEME LOGIC

This section contains logic diagrams of the fixed scheme logic, which covers all of the device models. You must be aware that some models do not contain all the functionality described in this section.

3.1 ANY START LOGIC

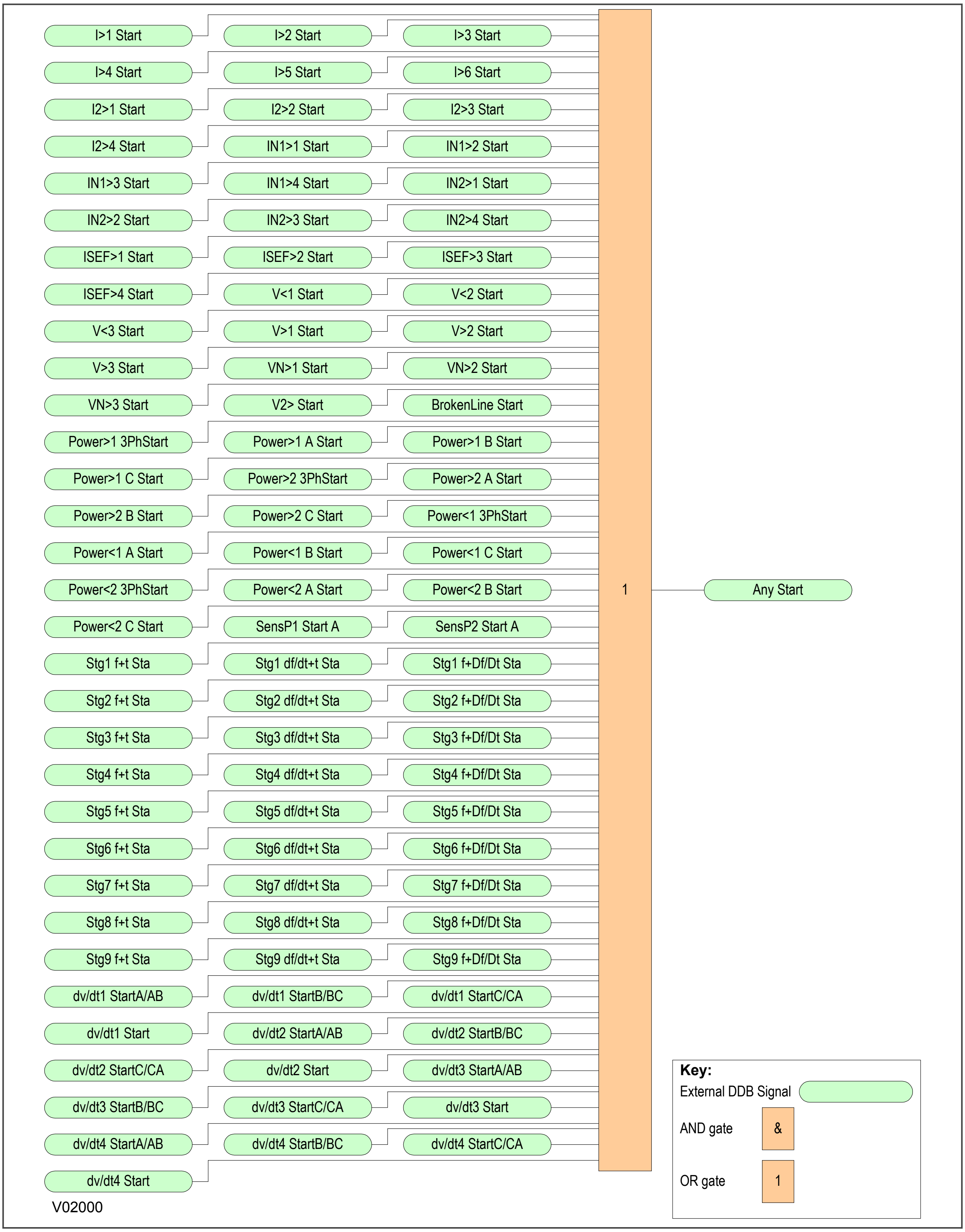


Figure 144: Any Start Logic

3.2 VTS ACCELERATION INDICATION LOGIC

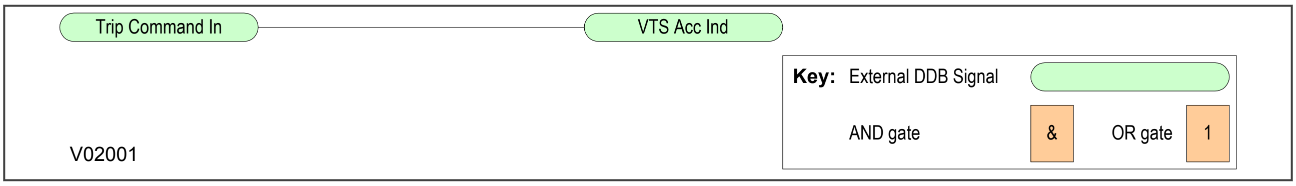


Figure 145: VTS Acceleration Indication Logic

3.3 CB FAIL SEF PROTECTION LOGIC

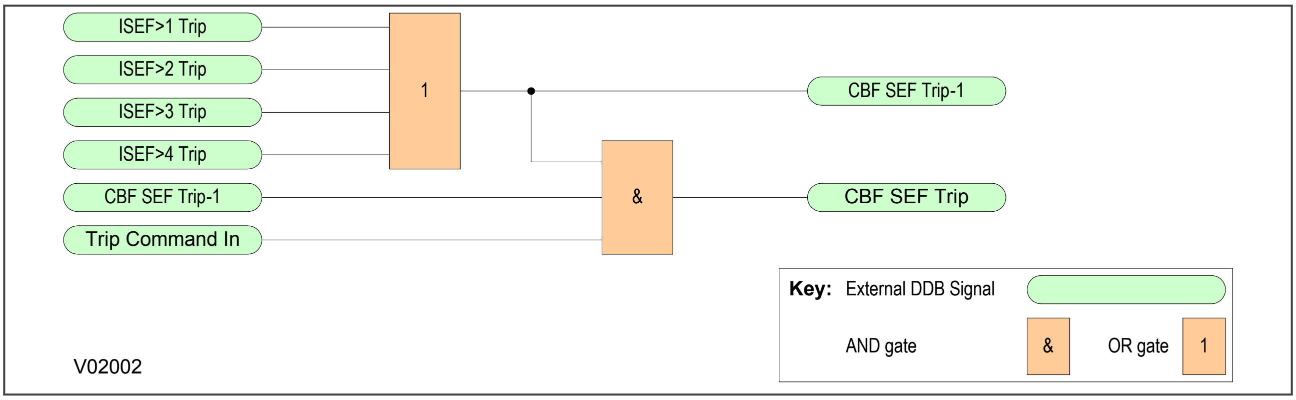


Figure 146: CB Fail SEF Protection Logic

3.4 CB FAIL NON CURRENT PROTECTION LOGIC

Figure 147: CB Fail Non Current Protection Logic

3.5 COMPOSITE EARTH FAULT START LOGIC

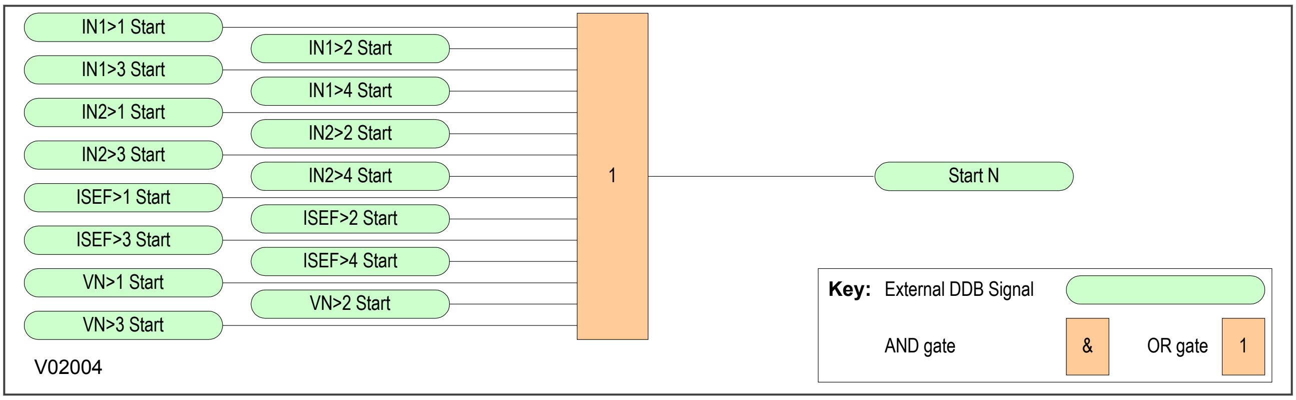


Figure 148: Composite Earth Fault Start Logic

3.6 ANY TRIP LOGIC

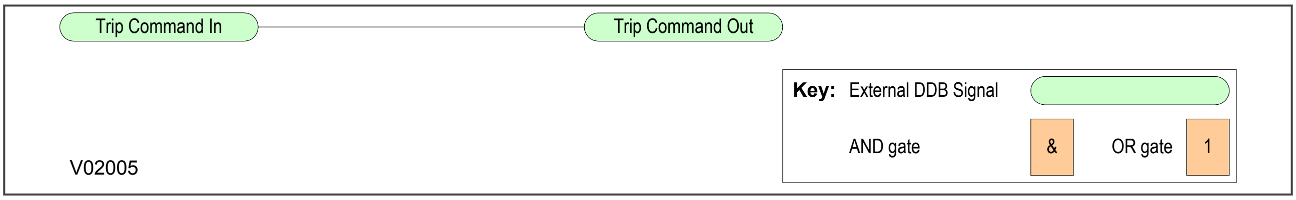


Figure 149: Any Trip Logic

3.7 SEF ANY START LOGIC

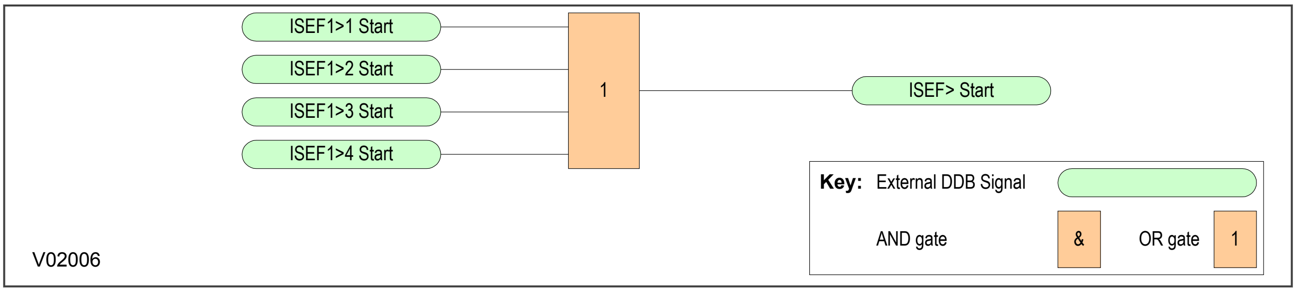


Figure 150: SEF Any Start Logic

4 PROGRAMMABLE SCHEME LOGIC

This section contains logic diagrams of the default programmable scheme logic, which covers all of the device models. You must be aware that some models do not contain all the functionality described in this section.

All these diagrams can be viewed, edited and printed from the PSL Editor.

4.1 TRIP OUTPUT MAPPINGS

Figure 151: Trip Output Mappings

4.2 OPTO-INPUT MAPPINGS

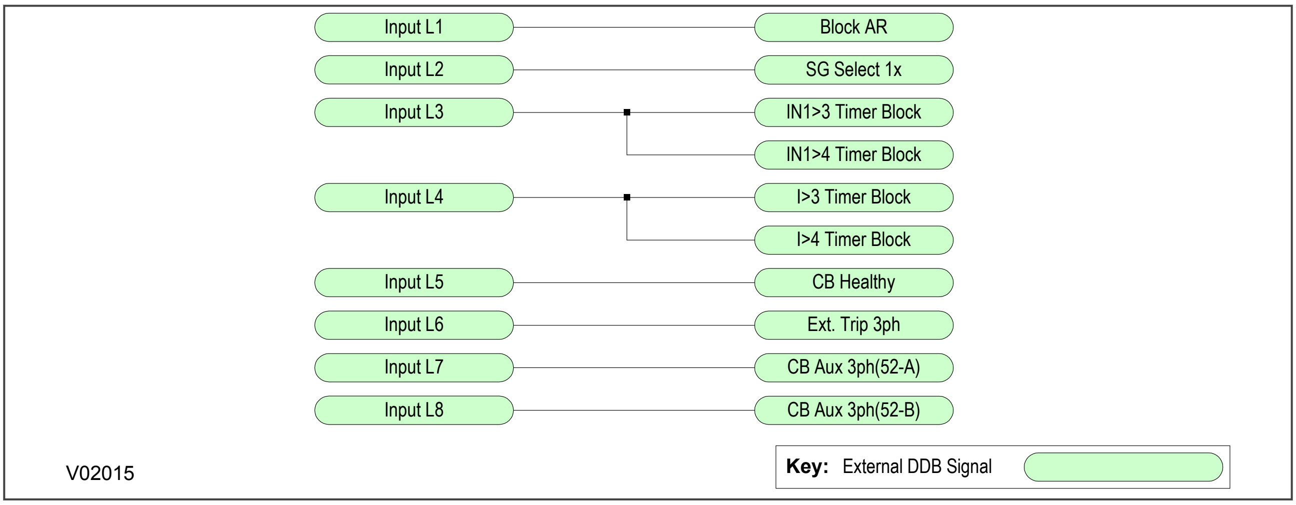


Figure 152: Opto-Input Mappings

4.3 OUTPUT RELAY MAPPINGS

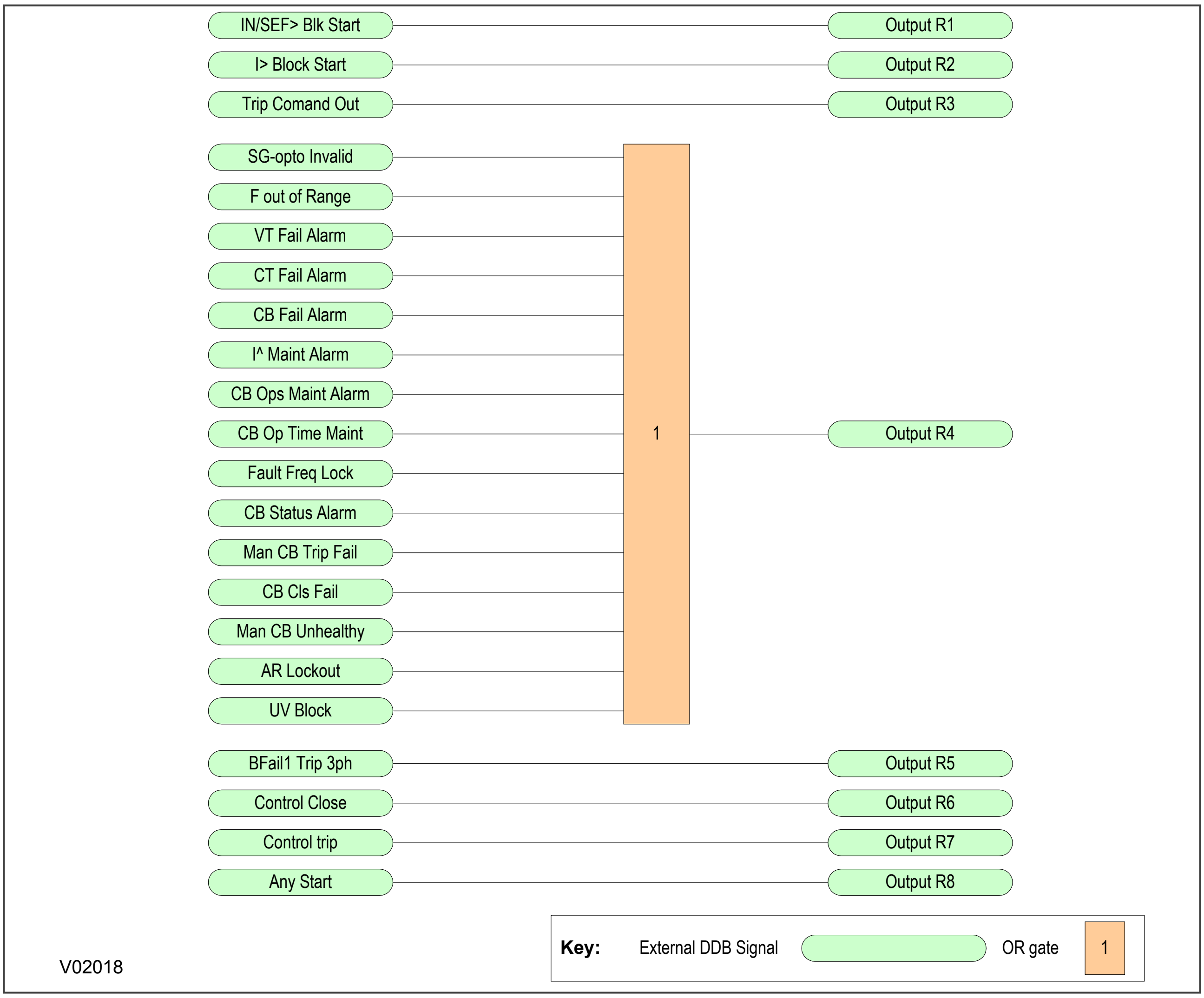


Figure 153: Output Relay Mappings

4.4 LED MAPPINGS

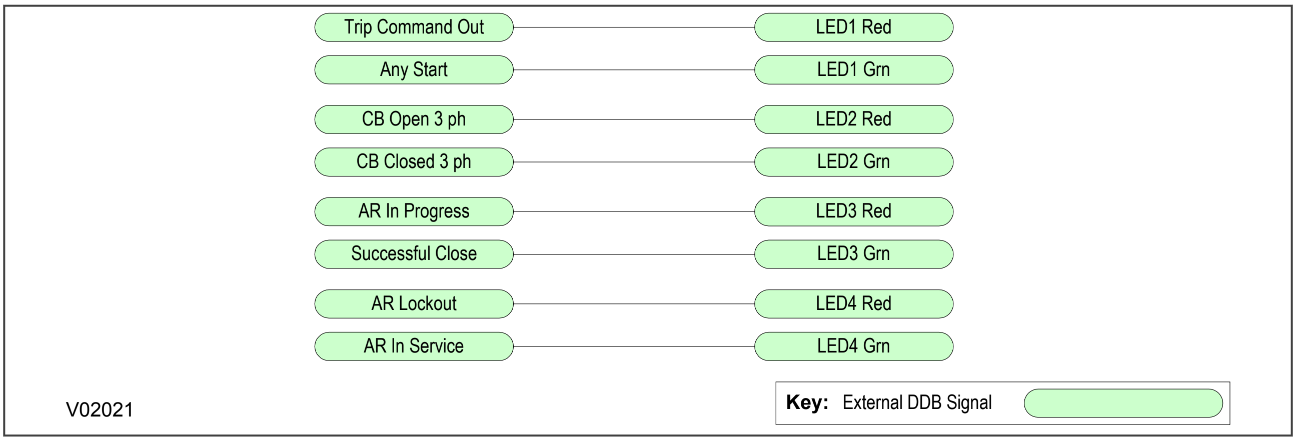


Figure 154: LED Mappings

4.5 CONTROL INPUT MAPPINGS

Figure 155: Control Input Mappings

4.6 FUNCTION KEY MAPPINGS

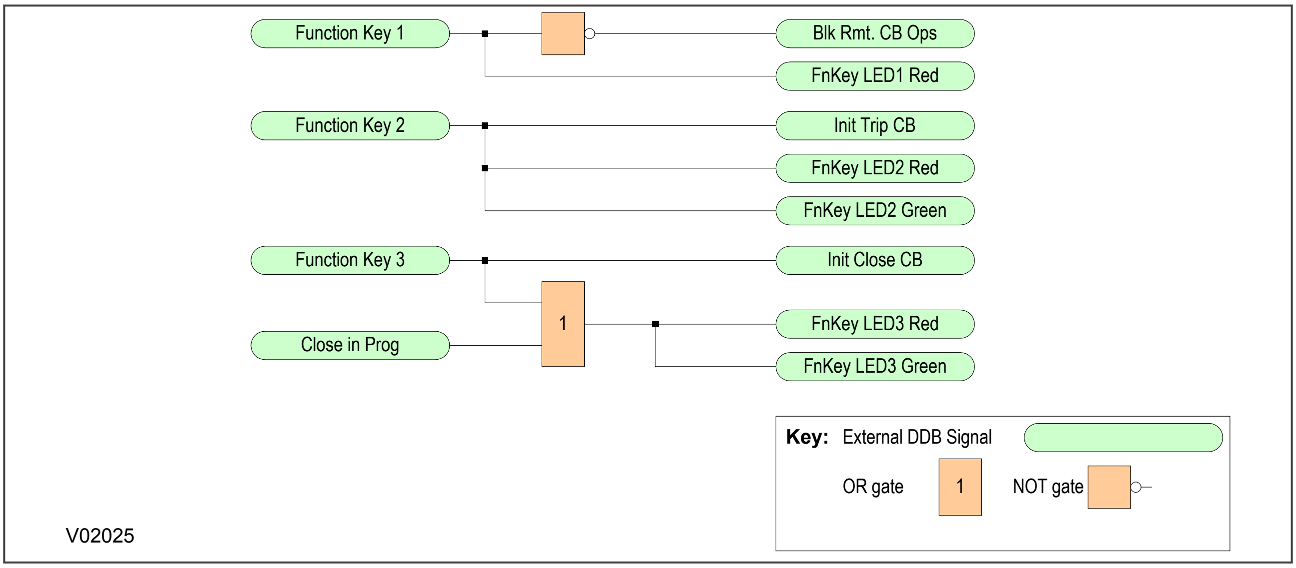


Figure 156: Function Key Mappings

4.7 CIRCUIT BREAKER MAPPING

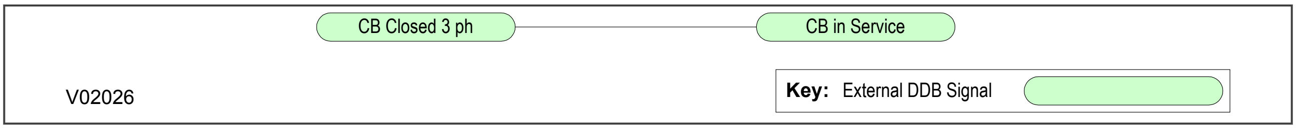


Figure 157: Circuit Breaker mapping

4.8 FAULT RECORD TRIGGER MAPPING

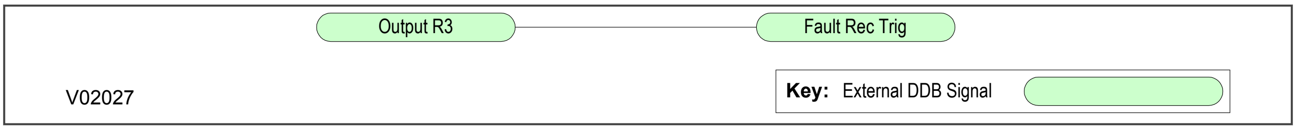


Figure 158: Fault Record Trigger mapping

4.9 HIGH IMPEDEANCE FAULT PROTECTION MAPPINGS

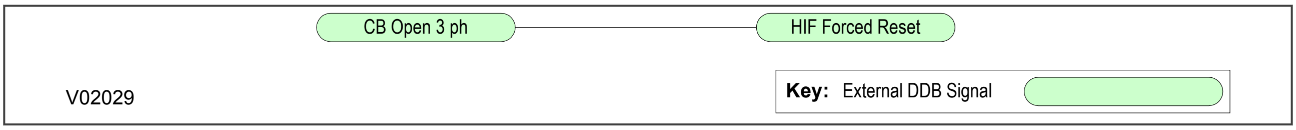


Figure 159: High Impedance Fault Protection Mappings

4.10 CHECK SYNCHRONISATION AND VOLTAGE MONITOR MAPPINGS

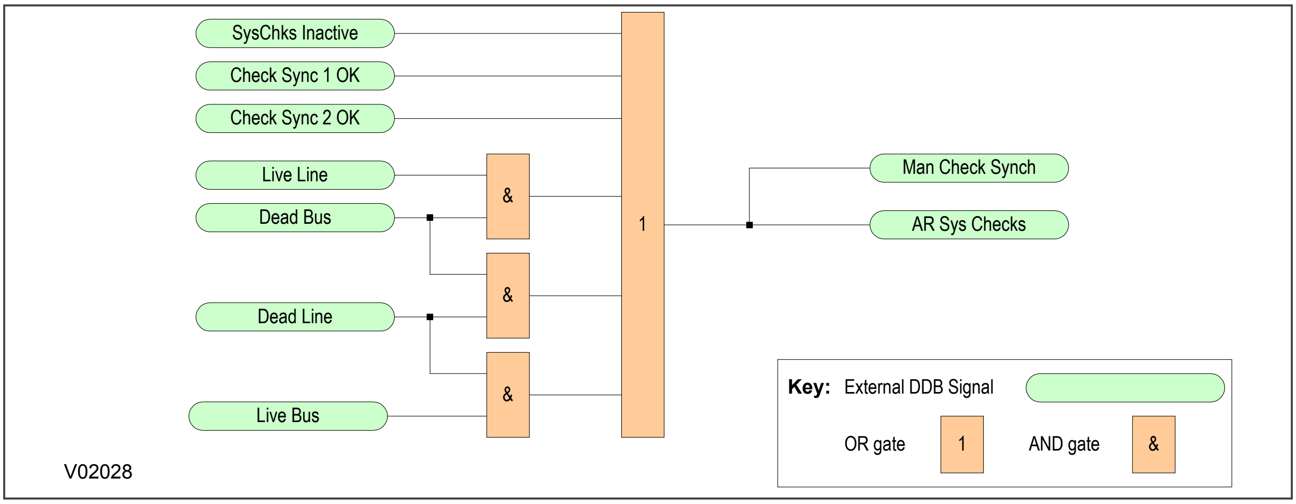


Figure 160: Check Synchronisation and Voltage Monitor mappings

4.11 SETTINGS

The device contains a PSL DATA column, which can be used to track PSL modifications. A total of 12 cells are contained in the PSL DATA column; 3 for each setting group.

Grp(n) PSL Ref: When downloading a PSL scheme to an IED, you will be prompted to enter the relevant group number and a reference identifier. The first 32 characters of the reference identifier are displayed in this cell. The horizontal cursor keys can scroll through the 32 characters as the LCD display only displays 16 characters.

Example:

```
Grp. PSL Ref.
```

Date/time: This cell displays the date and time when the PSL scheme was downloaded to the IED.

Example:

```
18 Nov 2002
08:59:32.047
```

Grp(n) PSL ID: This cell displays a unique ID number for the downloaded PSL scheme.

Example:

```
Grp. 1 PSL
ID - 2062813232
```

The complete Settings table is shown below:

Menu Text	Col	Row	Default Setting	Available Options
Description				
PSL DATA	B7	00		
This column contains information about the Programmable Scheme Logic				
Grp1 PSL Ref	B7	01		Not settable
This setting displays the Group 1 PSL reference				
Date/Time	B7	02		Not settable
This setting displays the date and time the PSL was created				
Grp1 PSL ID	B7	03		Not settable
This setting displays the Group 1 PSL ID				
Grp2 PSL Ref	B7	11		Not settable
This setting displays the Group 2 PSL reference				
Date/Time	B7	12		Not settable
This setting displays the date and time the PSL was created				
Grp2 PSL ID	B7	13		Not settable
This setting displays the Group 2 PSL ID				
Grp3 PSL Ref	B7	21		Not settable
This setting displays the Group 3 PSL reference				
Date/Time	B7	22		Not settable
This setting displays the date and time the PSL was created				
Grp3 PSL ID	B7	23		Not settable
This setting displays the Group 3 PSL ID				
Grp4 PSL Ref	B7	31		Not settable
This setting displays the Group 4 PSL reference				
Date/Time	B7	32		Not settable
This setting displays the date and time the PSL was created				
Grp4 PSL ID	B7	33		Not settable
This setting displays the Group 4 PSL ID				

INSTALLATION

CHAPTER 14

1 CHAPTER OVERVIEW

This chapter provides information about installing the product.

This chapter contains the following sections:

2 HANDLING THE GOODS

Our products are of robust construction but require careful treatment before installation on site. This section discusses the requirements for receiving and unpacking the goods, as well as associated considerations regarding product care and personal safety.

Caution:
Before lifting or moving the equipment you should be familiar with the Safety Information chapter of this manual.

2.1 RECEIPT OF THE GOODS

On receipt, ensure the correct product has been delivered. Unpack the product immediately to ensure there has been no external damage in transit. If the product has been damaged, make a claim to the transport contractor and notify us promptly.

For products not intended for immediate installation, repack them in their original delivery packaging.

2.2 UNPACKING THE GOODS

When unpacking and installing the product, take care not to damage any of the parts and make sure that additional components are not accidentally left in the packing or lost. Do not discard any CDROMs or technical documentation. These should accompany the unit to its destination substation and put in a dedicated place.

The site should be well lit to aid inspection, clean, dry and reasonably free from dust and excessive vibration. This particularly applies where installation is being carried out at the same time as construction work.

2.3 STORING THE GOODS

If the unit is not installed immediately, store it in a place free from dust and moisture in its original packaging. Keep any de-humidifier bags included in the packing. The de-humidifier crystals lose their efficiency if the bag is exposed to ambient conditions. Restore the crystals before replacing it in the carton. Ideally regeneration should be carried out in a ventilating, circulating oven at about 115°C. Bags should be placed on flat racks and spaced to allow circulation around them. The time taken for regeneration will depend on the size of the bag. If a ventilating, circulating oven is not available, when using an ordinary oven, open the door on a regular basis to let out the steam given off by the regenerating silica gel.

On subsequent unpacking, make sure that any dust on the carton does not fall inside. Avoid storing in locations of high humidity. In locations of high humidity the packaging may become impregnated with moisture and the de-humidifier crystals will lose their efficiency.

The device can be stored between –25º to +70ºC (-13ºF to +158ºF).

2.4 DISMANTLING THE GOODS

If you need to dismantle the device, always observe standard ESD (Electrostatic Discharge) precautions. The minimum precautions to be followed are as follows:

- Use an antistatic wrist band earthed to a suitable earthing point.
- Avoid touching the electronic components and PCBs.

3 MOUNTING THE DEVICE

The products are available in the following forms

- For flush panel and rack mounting
- For retrofitting K-series models
- Software only (for upgrades)

3.1 FLUSH PANEL MOUNTING

Panel-mounted devices are flush mounted into panels using M4 SEMS Taptite self-tapping screws with captive 3 mm thick washers (also known as a SEMS unit). These fastenings are available in packs of five (our part number ZA0005 104).

Caution:
Do not use conventional self-tapping screws, because they have larger heads and could damage the faceplate.

Alternatively, you can use tapped holes if the panel has a minimum thickness of 2.5 mm.

For applications where the product needs to be semi-projection or projection mounted, a range of collars are available.

If several products are mounted in a single cut-out in the panel, mechanically group them horizontally or vertically into rigid assemblies before mounting in the panel.

Caution:
Do not fasten products with pop rivets because this makes them difficult to remove if repair becomes necessary.

If the product is mounted on a BS EN60529 IP52 compliant panel, fit a metallic sealing strip between adjoining products (part no GN2044 001) and fit a sealing ring around the complete assembly, according to the following table.

Width	Sealing ring for single tier	Sealing ring for double tier
10TE	GJ9018 002	GJ9018 018
15TE	GJ9018 003	GJ9018 019
20TE	GJ9018 004	GJ9018 020
25TE	GJ9018 005	GJ9018 021
30TE	GJ9018 006	GJ9018 022
35TE	GJ9018 007	GJ9018 023
40TE	GJ9018 008	GJ9018 024
45TE	GJ9018 009	GJ9018 025
50TE	GJ9018 010	GJ9018 026
55TE	GJ9018 011	GJ9018 027
60TE	GJ9018 012	GJ9018 028
65TE	GJ9018 013	GJ9018 029
70TE	GJ9018 014	GJ9018 030
75TE	GJ9018 015	GJ9018 031
80TE	GJ9018 016	GJ9018 032

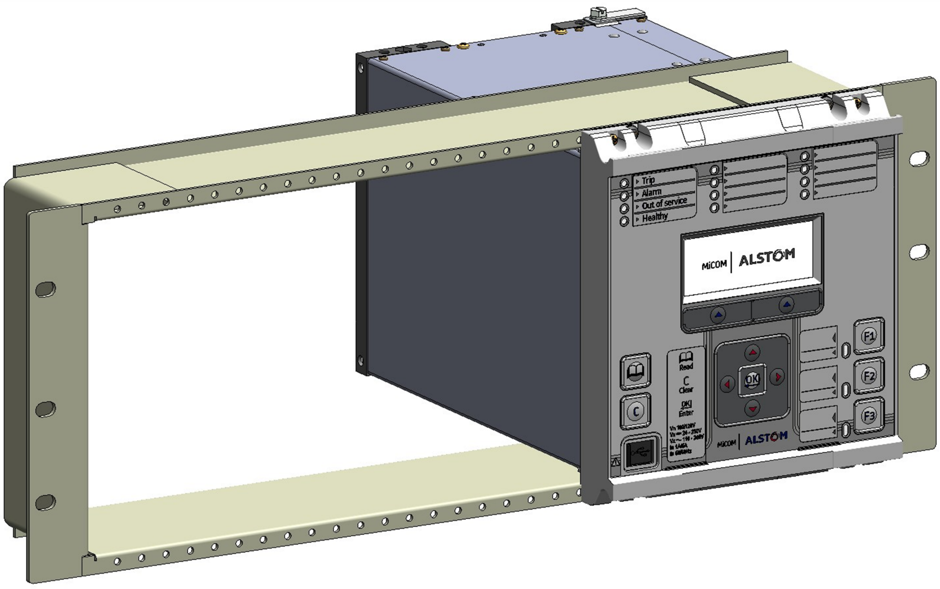
3.1.1 RACK MOUNTING

Panel-mounted variants can also be rack mounted using single-tier rack frames (our part number FX0021 101), as shown in the figure below. These frames are designed with dimensions in accordance with IEC 60297 and are supplied pre-assembled ready to use. On a standard 483 mm (19 inch) rack this enables combinations of case widths up to a total equivalent of size 80TE to be mounted side by side.

The two horizontal rails of the rack frame have holes drilled at approximately 26 mm intervals. Attach the products by their mounting flanges using M4 Taptite self-tapping screws with captive 3 mm thick washers (also known as a SEMS unit). These fastenings are available in packs of five (our part number ZA0005 104).

Caution:
Risk of damage to the front cover molding. Do not use conventional self-tapping screws, including those supplied for mounting MiDOS products because they have slightly larger heads.

Once the tier is complete, the frames are fastened into the racks using mounting angles at each end of the tier.



R01400

Figure 161: Rack mounting of products

Products can be mechanically grouped into single tier (4U) or multi-tier arrangements using the rack frame. This enables schemes using products from different product ranges to be pre-wired together before mounting.

Use blanking plates to fill any empty spaces. The spaces may be used for installing future products or because the total size is less than 80TE on any tier. Blanking plates can also be used to mount ancillary components. The part numbers are as follows:

Case size summation	Blanking plate part number
5TE	GJ2028 101
10TE	GJ2028 102
15TE	GJ2028 103
20TE	GJ2028 104
25TE	GJ2028 105

Case size summation	Blanking plate part number
30TE	GJ2028 106
35TE	GJ2028 107
40TE	GJ2028 108

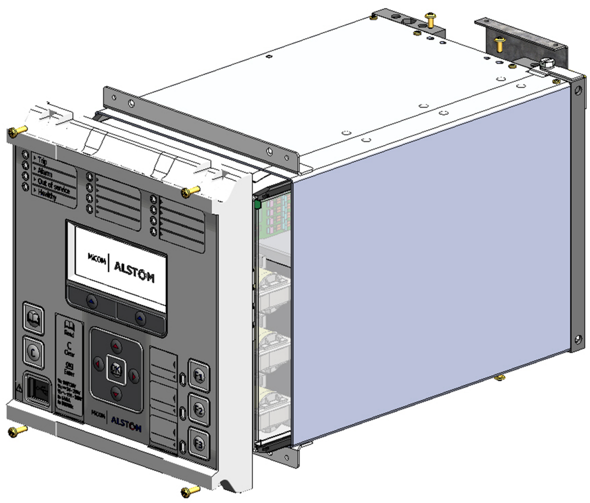
3.2 K-SERIES RETROFIT

A major advantage of the P40 Agile platform is its backward compatibility with the K-series products. The P40 Agile products have been designed such that the case, back panel terminal layout and pin-outs are identical to their K-series predecessors and can be retrofitted without the usual overhead associated with replacing and rewiring devices. This allows easy upgrade of the protection system with minimum impact and minimum shutdown time of the feeder.

The equivalencies of the models are as follows:

Case width (TE)	Case width (mm)	Equivalent K series	Products
20TE	102.4 mm (4 inches)	KCGG140/142	P14N
30TE	154.2 mm (6 inches)	KCEG140/142	P14D

The old K-series products can be removed by sliding the cradle out of the case. The new P40 Agile cradle can then be inserted into the old case as shown below:

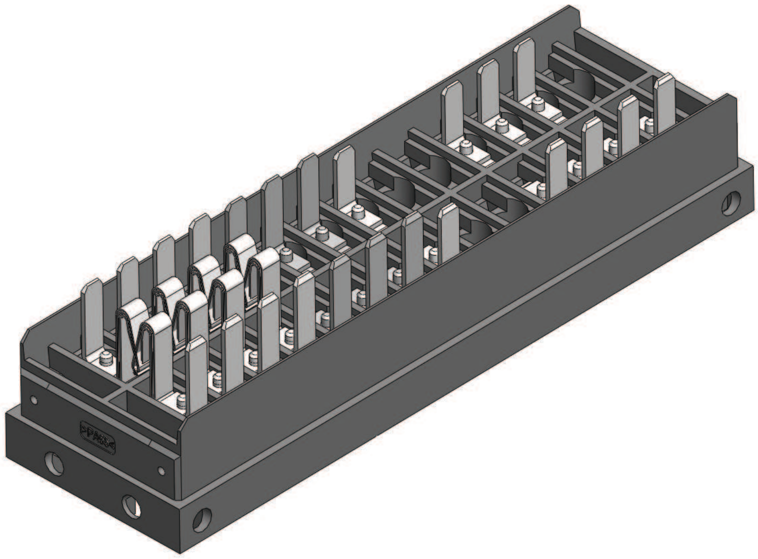


R00201

Figure 162: Inserting cradle into case

Both K-series products and P40 Agile products are equipped with CT shorting links. Depending on the model, your device may or may not be equipped with CTs. If there are CTs present, spring-loaded shorting contacts (see below) ensure that the terminals into which the CTs connect are shorted before the CT contacts are broken, when withdrawing the cradle from the case. This ensures that no voltage is developed between the two terminals on breaking the CT connections.

If no CTs are present, the CT terminals are permanently shorted internally.



E01407

Figure 163: Spring-loaded CT shorting contacts

Before withdrawing the cradle it is important to:

- Check the existing case for any damage
- Check the wiring is in good condition, especially the earth wiring
- Check the continuity of the earth connection to the cublicle earthing bar.

If there is any doubt as to the integrity of any of these aspects, contact your local representative.

Caution:
After removing the K-series product from its case, refit it into the case that came with your device, for storage or reuse in another location.

The difference between a standard device and a K-series retrofit device is that the retrofit device has internal links between terminals 7 and 13, and terminals 8 and 14 respectively. This is so that equipment driven by the K-series field voltage conected to terminals 7 and 8, will continue to be driven indirectly via terminals 13 and 14 when replaced by P40 Agile products.

A K-series device provides a 48V DC field voltage between terminals 7 and 8. This field voltage is intended for driving auxiliary equipment such as opto-inputs. P40 Agile devices DO NOT provide this field voltage. For this reason, P40 Agile retrofit devices have internal shorting links between terminals 7 and 13, and terminals 8 and 14 respectively. The intention of this is to provide the auxiliary supply voltage to terminals 7 and 8 in lieue of the field voltage.

Caution:
The voltage on terminals 7 and 8 mirros that of the auxiliary supply voltage. If the auxiliary supply voltage on terminals 13 and 14 is not 48V DC, then the voltage on terminals 7 and 8 is also not 48V DC. This means that the P40 Agile K-series retrofit models should only be used on sites where the auxiliary supply voltage is 48V DC.

Caution:
When retrofitting a K-series device, ensure the load on terminals 7 and 8 is limited to a maximum of 5A. A jumplead with a 5A ceramic timelag fuse is fitted internally.

3.2.1 CONVENTIONS

The P40 Agile products have different conventions from the K-series products when it comes to numbering some hardware components. It is very important that you are aware of this. This is just a matter of convention and does not affect the terminal compatibility.

The equivalencies are as follows:

Component	P40 Agile products	K-series products
Output relay	RL1	RL0
Output relay	RL2	RL1
Output relay	RL3	RL2
Output relay	RL4	RL3
Output relay	RL5	RL4
Output relay	RL6	RL5
Output relay	RL7	RL6
Output relay	RL8	RL7
Opto-input	L1	L0
Opto-input	L2	L1
Opto-input	L3	L2
Opto-input	L4	L3
Opto-input	L5	L4
Opto-input	L6	L5
Opto-input	L7	L6
Opto-input	L8	L7

3.3 SOFTWARE ONLY

It is possible to upgrade an existing device by purchasing software only (providing the device is already fitted with the requisite hardware).

There are two options for software-only products:

- Your device is sent back to the Alstom factory for upgrade.
- The software is sent to you for upgrade. Please contact your local representative if you wish to procure the services of a commissioning engineer to help you with your device upgrade.

Note:
Software-only products are licensed for use with devices with specific serial numbers.

Caution:
Do not attempt to upgrade an existing device if the software has not been licensed for that speciific device.

4 CABLES AND CONNECTORS

This section describes the type of wiring and connections that should be used when installing the device. For pin-out details please refer to the Hardware Design chapter or the wiring diagrams.

Caution:
Before carrying out any work on the equipment you should be familiar with the Safety Section and the ratings on the equipment's rating label.

4.1 TERMINAL BLOCKS

The P40 Agile devices use MiDOS terminal blocks as shown below.

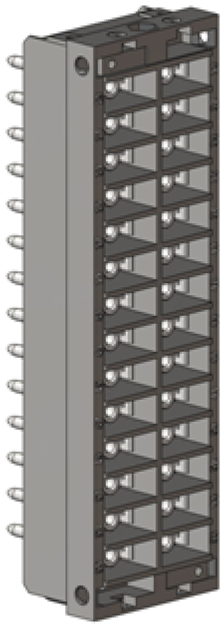


Figure 164: MiDOS terminal block

The MiDOS terminal block consists of up to 28 x M4 screw terminals. The wires should be terminated with rings using 90° ring terminals, with no more than two rings per terminal. The products are supplied with sufficient M4 screws.

M4 90° crimp ring terminals are available in three different sizes depending on the wire size. Each type is available in bags of 100.

Part number	Wire size	Insulation color
ZB9124 901	0.25 - 1.65 mm^2 (22 – 16 AWG)	Red
ZB9124 900	1.04 - 2.63 mm^2 (16 – 14 AWG)	Blue
ZB9124 904	2.53 - 6.64 mm^2 (12 – 10 AWG)	Un-insulated

Caution:
Always fit an insulating sleeve over the ring terminal.

4.2 POWER SUPPLY CONNECTIONS

These should be wired with 1.5 mm PVC insulated multi-stranded copper wire terminated with M4 ring terminals.

The wire should have a minimum voltage rating of 300 V RMS.

Caution:
Protect the auxiliary power supply wiring with a maximum 16 A high rupture capacity (HRC) type NIT or TIA fuse.

4.3 EARTH CONNNECTION

Every device must be connected to the cubicle earthing bar using the M4 earth terminal.

Use a wire size of at least 2.5 mm^2 terminated with a ring terminal.

Due to the physical limitations of the ring terminal, the maximum wire size you can use is 6.0 mm^2 using ring terminals that are not pre-insulated. If using pre insulated ring terminals, the maximum wire size is reduced to 2.63 mm^2 per ring terminal. If you need a greater cross-sectional area, use two wires in parallel, each terminated in a separate ring terminal.

The wire should have a minimum voltage rating of 300 V RMS.

Note:
To prevent any possibility of electrolytic action between brass or copper ground conductors and the rear panel of the product, precautions should be taken to isolate them from one another. This could be achieved in several ways, including placing a nickel-plated or insulating washer between the conductor and the product case, or using tinned ring terminals.

4.4 CURRENT TRANSFORMERS

Current transformers would generally be wired with 2.5 mm^2 PVC insulated multi-stranded copper wire terminated with M4 ring terminals.

Due to the physical limitations of the ring terminal, the maximum wire size you can use is 6.0 mm^2 using ring terminals that are not pre-insulated. If using pre insulated ring terminals, the maximum wire size is reduced to 2.63 mm^2 per ring terminal. If you need a greater cross-sectional area, use two wires in parallel, each terminated in a separate ring terminal.

The wire should have a minimum voltage rating of 300 V RMS.

Caution:
Current transformer circuits must never be fused.

Note:
If there are CTs present, spring-loaded shorting contacts ensure that the terminals into which the CTs connect are shorted before the CT contacts are broken.

Note:
For 5A CT secondaries, we recommend using 2 x 2.5 mm² PVC insulated multi-stranded copper wire.

4.5 VOLTAGE TRANSFORMER CONNECTIONS

Voltage transformers should be wired with 2.5 mm^2 PVC insulated multi-stranded copper wire terminated with M4 ring terminals.

The wire should have a minimum voltage rating of 300 V RMS.

4.6 WATCHDOG CONNECTIONS

These should be wired with 1 mm PVC insulated multi-stranded copper wire terminated with M4 ring terminals.

The wire should have a minimum voltage rating of 300 V RMS.

4.7 EIA(RS)485 AND K-BUS CONNECTIONS

For connecting the EIA(RS485) / K-Bus ports, use 2-core screened cable with a maximum total length of 1000 m or 200 nF total cable capacitance.

A typical cable specification would be:

- Each core: 16/0.2 mm^2 copper conductors, PVC insulated
- Nominal conductor area: 0.5 mm^2 per core
- Screen: Overall braid, PVC sheathed

To guarantee the performance specifications, you must ensure continuity of the screen, when daisy chaining the connections. The device is supplied with an earth link pack (part number ZA0005092) consisting of an earth link and a self-tapping screw to facilitate this requirement.

The earth link is fastened to the Midos block just below terminal number 56 as shown:

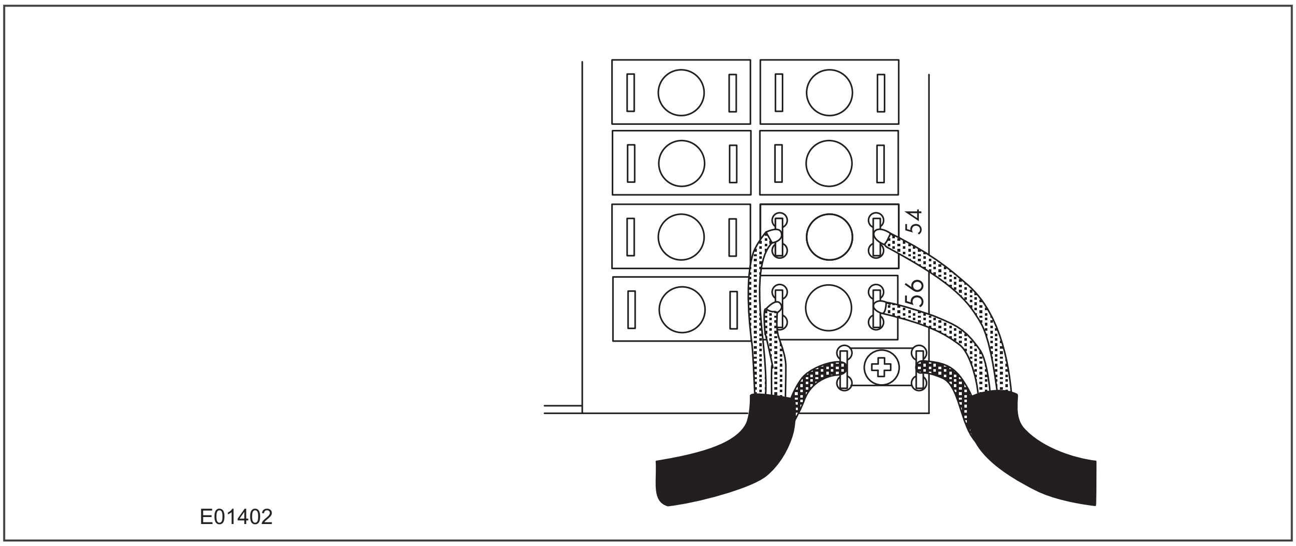


Figure 165: Earth link for cable screen

There is no electrical connection of the cable screen to the device. The link is provided purely to link together the two cable screens.

4.8 IRIG-B CONNECTION

The optional IRIG-B input uses the same terminals as the EIA(RS)485 port RP1. It is therefore apparent that RS485 communications and IRIG-B input are mutually exclusive.

A typical cable specification would be:

- Each core: 16/0.2 mm^2 copper conductors, PVC insulated
- Nominal conductor area: 0.5 mm^2 per core
- Screen: Overall braid, PVC sheathed

4.9 OPTO-INPUT CONNECTIONS

These should be wired with 1 mm^2 PVC insulated multi-stranded copper wire terminated with M4 ring terminals.

Each opto-input has a selectable preset ½ cycle filter. This makes the input immune to noise induced on the wiring. This can, however slow down the response. If you need to switch off the ½ cycle filter, either use double pole switching on the input, or screened twisted cable on the input circuit.

Caution:
Protect the opto-inputs and their wiring with a maximum 16 A high rupture capacity (HRC) type NIT or TIA fuse.

4.10 OUTPUT RELAY CONNECTIONS

These should be wired with 1 mm PVC insulated multi-stranded copper wire terminated with M4 ring terminals.

4.11 ETHERNET METALLIC CONNECTIONS

If the device has a metallic Ethernet connection, it can be connected to either a 10Base-T or a 100Base-TX Ethernet hub. Due to noise sensitivity, we recommend this type of connection only for short distance connections, ideally where the products and hubs are in the same cubicle. For increased noise immunity, CAT 6 (category 6) STP (shielded twisted pair) cable and connectors can be used.

The connector for the Ethernet port is a shielded RJ-45. The pin-out is as follows:

Pin	Signal name	Signal definition
1	TXP	Transmit (positive)
2	TXN	Transmit (negative)
3	RXP	Receive (positive)
4	-	Not used
5	-	Not used
6	RXN	Receive (negative)
7	-	Not used
8	-	Not used

4.12 ETHERNET FIBRE CONNECTIONS

We recommend the use of fibre-optic connections for permanent connections in a substation environment. The 100 Mbps fibre optic port is based on the 100BaseFX standard and uses type LC connectors. They are compatible with 50/125 µm or 62.5/125 µm multimode fibres at 1300 nm wavelength.

4.13 USB CONNECTION

The IED has a type B USB socket on the front panel. A standard USB printer cable (type A one end, type B the other end) can be used to connect a local PC to the IED. This cable is the same as that used for connecting a printer to a PC.

5 CASE DIMENSIONS

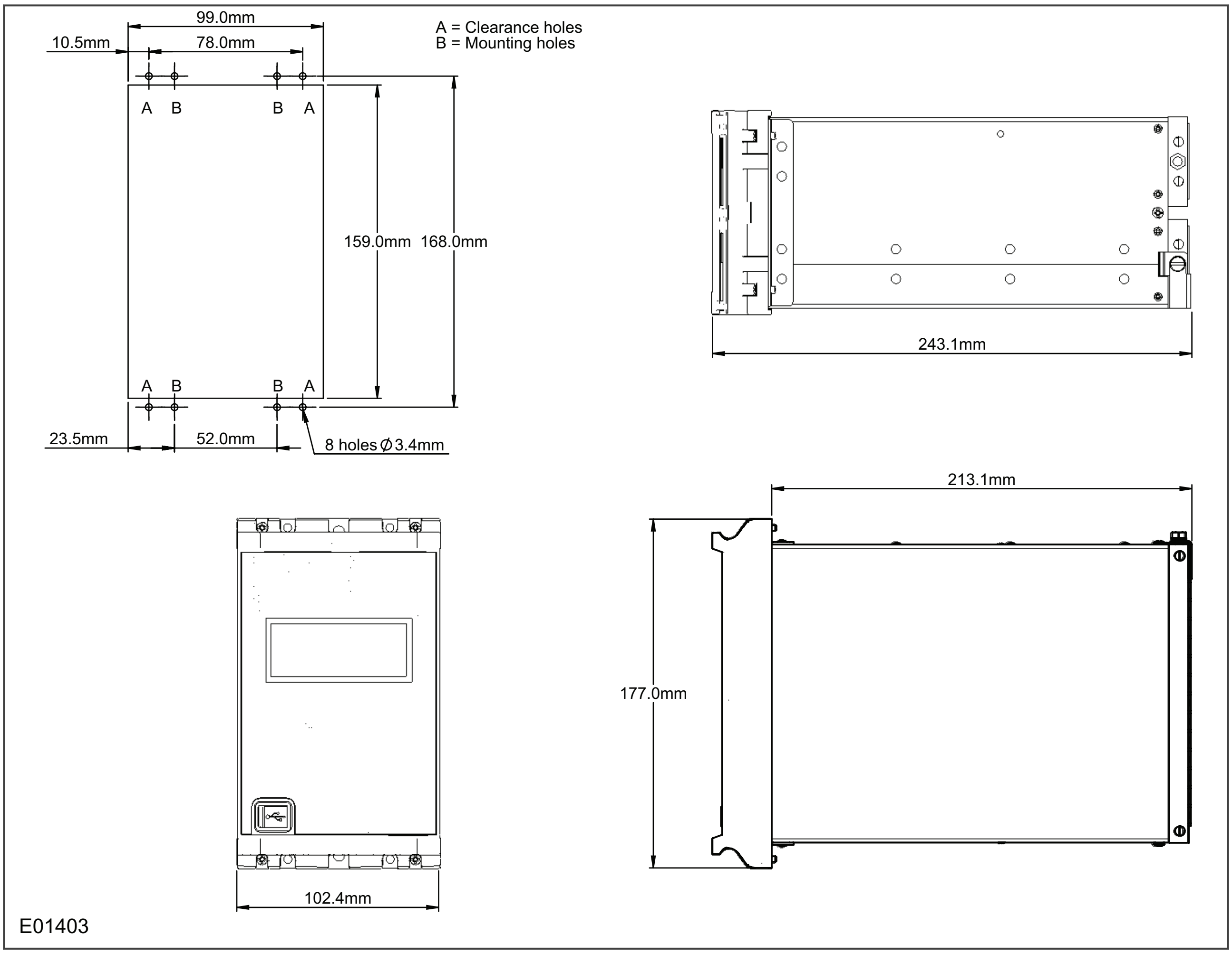


Figure 166: 20TE case dimensions

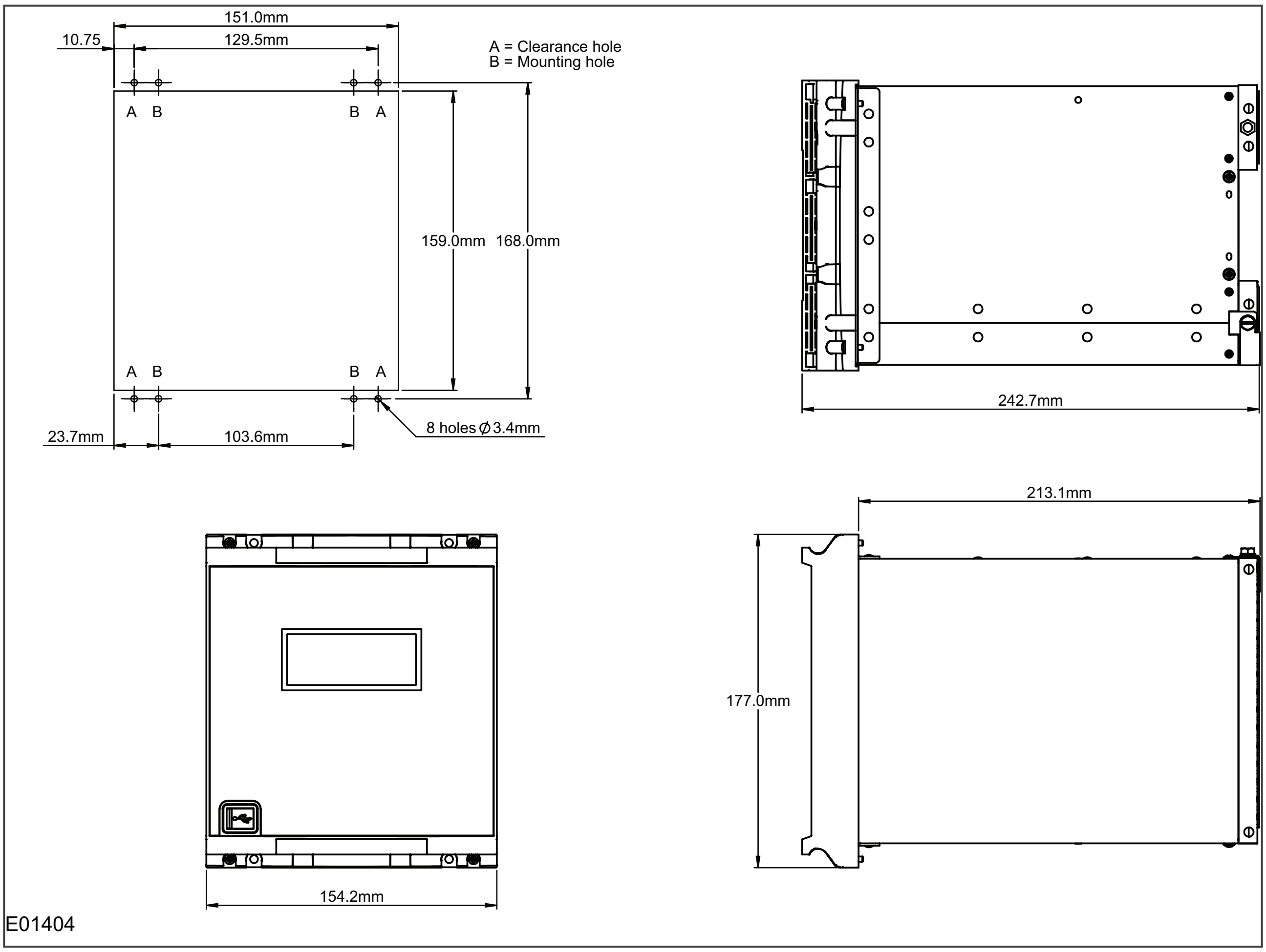


Figure 167: 30TE case dimensions

COMMISSIONING INSTRUCTIONS

CHAPTER 15

1 CHAPTER OVERVIEW

This chapter contains the following sections:

2 GENERAL GUIDELINES

Alstom Grid IEDs are self-checking devices and will raise an alarm in the unlikely event of a failure. This is why the commissioning tests are less extensive than those for non-numeric electronic devices or electro-mechanical relays.

To commission the IEDs, you do not need to test every IED function. You need only verify that the hardware is functioning correctly and that the application-specific software settings have been applied. You can check the settings by extracting them using appropriate setting software, or by means of the front panel interface (HMI panel).

The customer is usually responsible for determining the settings to be applied and for testing any scheme logic.

The menu language is user-selectable, so the Commissioning Engineer can change it for commissioning purposes if required.

Note:
Remember to restore the language setting to the customer's preferred language on completion.

Caution:
Before carrying out any work on the equipment you should be familiar with the contents of the Safety Section or Safety Guide SFTY/4LM as well as the ratings on the equipment's rating label.

Warning:
Do not disassemble the IED in any way during commissioning.

3 COMMISSIONING TEST MENU

The IED provides several test facilities under the COMMISSION TESTS menu heading. There are menu cells that allow you to monitor the status of the opto-inputs, output relay contacts, internal Digital Data Bus (DDB) signals and user-programmable LEDs.

This section describes the commissioning tests available in the IED's Commissioning test menu.

3.1 OPTO I/P STATUS CELL (OPTO-INPUT STATUS)

This cell can be used to monitor the status of the opto-inputs while they are sequentially energised with a suitable DC voltage.

The cell displays the status of the opto-inputs as a binary string, '1' meaning energised, '0' meaning de-energised. If you move the cursor along the binary numbers, the corresponding label text is displayed for each logic input.

3.2 RELAY O/P STATUS CELL (RELAY OUTPUT STATUS)

This cell displays the status of the DDB signals that result in energisation of the output relays as a binary string, a '1' indicating an operated state and '0' a non-operated state. If you move the cursor along the binary numbers the corresponding label text is displayed for each relay output.

The displayed information can be used to indicate the status of the output relays when the IED is in service. You can also check for relay damage by comparing the status of the output contacts with their associated bits.

Note:
When the Test Mode cell is set to Contacts Blocked, this cell continues to indicate which contacts would operate if the IED was in-service. It does not show the actual status of the output relays.

3.3 TEST PORT STATUS CELL

This cell displays the status of the DDB signals that have been allocated in the **Monitor Bit** cells. If you move the cursor along the binary numbers, the corresponding DDB signal text string is displayed for each monitor bit.

By using this cell with suitable monitor bit settings, the state of the DDB signals can be displayed as various operating conditions or sequences are applied to the IED. This allows you to test the Programmable Scheme Logic (PSL).

3.4 MONITOR BIT 1 TO 8 CELLS

The eight Monitor Bit cells allows you to select eight DDB signals that can be observed in the Test Port Status cell.

Each Monitor Bit cell can be assigned to a particular DDB signal. You set it by entering the required DDB signal number from the list of available DDB signals.

3.5 TEST MODE CELL

This cell allows you to perform secondary injection testing. It also lets you test the output contacts directly by applying menu-controlled test signals.

To go into test mode, select the 'Test Mode' option in the **Test Mode** cell. This takes the IED out of service causing an alarm condition to be recorded and the **Out of Service** LED to illuminate. This also freezes any information stored in the CB CONDITION column. In IEC 60870-5-103 versions, it changes the Cause of Transmission (COT) to Test Mode.

In Test Mode, the output contacts are still active. To disable the output contacts you must select the 'Contacts Blocked' option

Once testing is complete, return the device back into service by setting the **Test Mode** Cell back to 'Disabled'.

Caution:
When the cell is in Test Mode, the Scheme Logic still drives the output relays, which could result in tripping of circuit breakers. To avoid this, set the Test Mode cell to 'Contacts Blocked'.

Note:
'Test mode' and 'Contacts Blocked' mode can also be selected by energising an opto-input mapped to the Test Mode signal, and the Contact Block signal respectively.

3.6 TEST PATTERN CELL

The **Test Pattern** cell is used to select the output relay contacts to be tested when the **Contact Test** cell is set to 'Apply Test'. The cell has a binary string with one bit for each user-configurable output contact, which can be set to '1' to operate the output and '0' to not operate it.

3.7 CONTACT TEST CELL

When the 'Apply Test' command in this cell is issued, the contacts set for operation change state. Once the test has been applied, the command text on the LCD will change to **No Operation** and the contacts will remain in the Test state until reset by issuing the 'Remove Test' command. The command text on the LCD will show **No Operation** after the 'Remove Test' command has been issued.

Note:
*When the **Test Mode** cell is set to 'Contacts Blocked' the **Relay O/P Status** cell does not show the current status of the output relays and therefore cannot be used to confirm operation of the output relays. Therefore it will be necessary to monitor the state of each contact in turn.*

3.8 TEST LEDS CELL

When the 'Apply Test' command in this cell is issued, the user-programmable LEDs illuminate for approximately 2 seconds before switching off, and the command text on the LCD reverts to **No Operation**.

3.9 TEST AUTORECLOSE CELL

Where the IED provides an auto-reclose function, this cell will be available for testing the sequence of circuit breaker trip and auto-reclose cycles.

The ‘3 Pole Test’ command causes the device to perform the first three phase trip/reclose cycle so that associated output contacts can be checked for operation at the correct times during the cycle. Once the trip output has operated the command text will revert to 'No Operation' whilst the rest of the auto-reclose cycle is performed. To test subsequent three-phase autoreclose cycles, you repeat the ‘3 Pole Test’ command.

> *Note:*
> *The default settings for the programmable scheme logic has the ‘AR Trip Test’ signals mapped to the ‘Trip Input’ signals. If the programmable scheme logic has been changed, it is essential that these signals retain this mapping for the ‘Test Auto-reclose’ facility to work.*

3.10 RED AND GREEN LED STATUS CELLS

These cells contain binary strings that indicate which of the user-programmable red and green LEDs are illuminated when accessing from a remote location. A '1' indicates that a particular LED is illuminated.

> *Note:*
> *When the status in both Red LED Status and Green LED Status cells is ‘1’, this indicates the LEDs illumination is yellow.*

4 COMMISSIONING EQUIPMENT

4.1 MINIMUM EQUIPMENT REQUIRED

As a minimum, the following equipment is required:

- Multifunctional current and voltage injection test set (where applicable)
- Multimeter with suitable AC current range, and DC voltage ranges of 0 - 440 V and 0 - 250 V respectively
- Continuity tester (if not included in multimeter).
- A portable PC, installed with appropriate software (MiCOM S1 Agile)

4.2 OPTIONAL EQUIPMENT REQUIRED

- Multi-finger test plug:
  - P992 for test block type P991
  - MMLB for test block type MMLG blocks
- Electronic or brushless insulation tester with a DC output not exceeding 500 V
- KITZ K-Bus - EIA(RS)232 protocol converter for testing EIA(RS)485 K-Bus port, if applicable
- EIA(RS)485 to EIA(RS)232 converter for testing EIA(RS)485 Courier/MODBUS/IEC60870-5-103/DNP3 port, if applicable
- A portable printer (for printing a setting record from the portable PC).
- Phase angle meter (where applicable)
- Phase rotation meter
- Fibre optic power meter (where applicable)
- Fibre optic test leads (where applicable)

5 PRODUCT CHECKS

These product checks are designed to ensure that the device has not been physically damaged prior to commissioning, is functioning correctly and that all input quantity measurements are within the stated tolerances.

If the application-specific settings have been applied to the IED prior to commissioning, you should make a copy of the settings. This will allow you to restore them at a later date if necessary. This can be done by:

- Obtaining a setting file from the customer.
- Extracting the settings from the IED itself, using a portable PC with appropriate setting software.

If the customer has changed the password that prevents unauthorised changes to some of the settings, either the revised password should be provided, or the original password restored before testing.

Note:
If the password has been lost, a recovery password can be obtained from Alstom Grid.

5.1 PRODUCT CHECKS WITH THE IED DE-ENERGISED

Warning:
The following group of tests should be carried out without the auxiliary supply being applied to the IED and, if applicable, with the trip circuit isolated.

The current and voltage transformer connections must be isolated from the IED for these checks. If a P991 test block is provided, the required isolation can be achieved by inserting test plug type P992. This open circuits all wiring routed through the test block.

Before inserting the test plug, you should check the scheme diagram to ensure that this will not cause damage or a safety hazard (the test block may, for example, be associated with protection current transformer circuits). The sockets in the test plug, which correspond to the current transformer secondary windings, must be linked before the test plug is inserted into the test block.

Warning:
Never open-circuit the secondary circuit of a current transformer since the high voltage produced may be lethal and could damage insulation.

If a test block is not provided, the voltage transformer supply to the IED should be isolated by means of the panel links or connecting blocks. The line current transformers should be short-circuited and disconnected from the IED terminals. Where means of isolating the auxiliary supply and trip circuit (for example isolation links, fuses and MCB) are provided, these should be used. If this is not possible, the wiring to these circuits must be disconnected and the exposed ends suitably terminated to prevent them from being a safety hazard.

5.1.1 VISUAL INSPECTION

Caution:
Check the rating information provided with the device. Check that the IED being tested is correct for the line or circuit.

Carefully examine the IED to see that no physical damage has occurred since installation.

Ensure that the case earthing connections (bottom left-hand corner at the rear of the IED case) are used to connect the IED to a local earth bar using an adequate conductor.

Check that the current transformer shorting switches in the case are wired into the correct circuit. Ensure that, during withdrawal, they are closed by checking with a continuity tester. The shorting switches are between terminals 21 and 22, 23 and 24, 25 and 26, and 27 and 28.

5.1.2 INSULATION

Insulation resistance tests are only necessary during commissioning if explicitly requested.

Isolate all wiring from the earth and test the insulation with an electronic or brushless insulation tester at a DC voltage not exceeding 500 V. Terminals of the same circuits should be temporarily connected together.

The main groups of IED terminals are:

- Voltage transformer circuits (not all models)
- Current transformer circuits (not all models)
- Supply voltage
- Opto-inputs
- Output Relay contacts
- EIA(RS)485 communication ports
- Ethernet communication ports (not all models)
- Case earth

The insulation resistance should be greater than 100 MΩ at 500 V.

On completion of the insulation resistance tests, ensure all external wiring is correctly reconnected to the IED.

5.1.3 EXTERNAL WIRING

Caution:
Check that the external wiring is correct according to the relevant IED and scheme diagrams. Ensure that phasing/phase rotation appears to be as expected.

If a P991 test block is provided, check the connections against the scheme diagram. We recommend that you make the supply connections to the live side of the test block (coloured orange) and use the odd numbered terminals.

The auxiliary DC voltage supply uses terminals 13 (supply positive) and 14 (supply negative). Unlike the K-series products, the P40Agile series does not provide a field voltage supply. For K-series retrofit applications where pin-to-pin compatibility is required, the equivalent P40 Agile products emulate the field voltage supply by having internal links between pins 7 and 13, and pins 8 and 14, respectively.

5.1.4 WATCHDOG CONTACTS

Using a continuity tester, check that the Watchdog contacts are in the following states:

Terminals	De-energised contact
3 - 5	Closed
4 - 6	Open

5.1.5 POWER SUPPLY

The IED can accept a nominal DC voltage from 24 V DC to 250 V DC, or a nominal AC voltage from 110 V AC to 240 V AC at 50 Hz or 60 Hz. Ensure that the power supply is within this operating range. The power supply must be rated at 12 Watts.

Warning:
Do not energise the IED or interface unit using the battery charger with the battery disconnected as this can irreparably damage the power supply circuitry.

Caution:
Energise the IED only if the auxiliary supply is within the specified operating ranges. If a test block is provided, it may be necessary to link across the front of the test plug to connect the auxiliary supply to the IED.

5.2 PRODUCT CHECKS WITH THE IED ENERGISED

Warning:
The current and voltage transformer connections must remain isolated from the IED for these checks. The trip circuit should also remain isolated to prevent accidental operation of the associated circuit breaker.

The following group of tests verifies that the IED hardware and software is functioning correctly and should be carried out with the supply applied to the IED.

5.2.1 WATCHDOG CONTACTS

Using a continuity tester, check that the Watchdog contacts are in the following states:

Terminals	Energised contact
3 - 5	Open
4 - 6	Closed

5.2.2 TEST LCD

The Liquid Crystal Display (LCD) is designed to operate in a wide range of substation ambient temperatures. For this purpose, the IEDs have an **LCD Contrast** setting. The contrast is factory pre-set, but it may be necessary to adjust the contrast to give the best in-service display.

To change the contrast, you can increment or decrement the **LCD Contrast** cell in the CONFIGURATION column.

Caution:
Before applying a contrast setting, make sure that it will not make the display so light or dark such that menu text becomes unreadable. It is possible to restore the visibility of a display by downloading a setting file, with the LCD Contrast set within the typical range of 7 - 11.

5.2.3 DATE AND TIME

The date and time is stored in non-volatile memory. If the values are not already correct, set them to the correct values. The method of setting will depend on whether accuracy is being maintained by the IRIG-B port or by the IED's internal clock.

When using IRIG-B to maintain the clock, the IED must first be connected to the satellite clock equipment (usually a P594), which should be energised and functioning.

1. Set the IRIG-B Sync cell in the DATE AND TIME column to 'Enabled'.
2. Ensure the IED is receiving the IRIG-B signal by checking that cell IRIG-B Status reads 'Active'.
3. Once the IRIG-B signal is active, adjust the time offset of the universal co coordinated time (satellite clock time) on the satellite clock equipment so that local time is displayed.
4. Check that the time, date and month are correct in the Date/Time cell. The IRIG-B signal does not contain the current year so it will need to be set manually in this cell.
5. Reconnect the IRIG-B signal.

If the time and date is not being maintained by an IRIG-B signal, ensure that the IRIG-B Sync cell in the DATE AND TIME column is set to 'Disabled'.

1. Set the date and time to the correct local time and date using Date/Time cell or using the serial protocol.

5.2.4 TEST LEDS

On power-up, all LEDs should first flash yellow. Following this, the green "Healthy" LED should illuminate indicating that the device is healthy.

The IED's non-volatile memory stores the states of the alarm, the trip, and the user-programmable LED indicators (if configured to latch). These indicators may also illuminate when the auxiliary supply is applied.

If any of these LEDs are ON then they should be reset before proceeding with further testing. If the LEDs successfully reset (the LED goes off), no testing is needed for that LED because it is obviously operational.

> *Note:*
> *In most cases, alarms related to the communications channels will not reset at this stage.*

5.2.5 TEST ALARM AND OUT-OF-SERVICE LEDS

The alarm and out of service LEDs can be tested using the COMMISSION TESTS menu column.

1. Set the **Test Mode** cell to 'Contacts Blocked'.
2. Check that the out of service LED illuminates continuously and the alarm LED flashes.

It is not necessary to return the **Test Mode** cell to 'Disabled' at this stage because the test mode will be required for later tests.

5.2.6 TEST TRIP LED

The trip LED can be tested by initiating a manual circuit breaker trip. However, the trip LED will operate during the setting checks performed later. Therefore no further testing of the trip LED is required at this stage.

5.2.7 TEST USER-PROGRAMMABLE LEDS

To test these LEDs, set the Test LEDs cell to 'Apply Test'. Check that all user-programmable LEDs illuminate.

5.2.8 TEST OPTO-INPUTS

This test checks that all the opto-inputs on the IED are functioning correctly.

The opto-inputs should be energised one at a time. For terminal numbers, please see the external connection diagrams in the "Wiring Diagrams" chapter. Ensuring correct polarity, connect the supply voltage to the appropriate terminals for the input being tested.

The status of each opto-input can be viewed using either the **Opto I/P Status** cell in the SYSTEM DATA column, or the **Opto I/P Status** cell in the COMMISSION TESTS column.

A '1' indicates an energised input and a '0' indicates a de-energised input. When each opto-input is energised, one of the characters on the bottom line of the display changes to indicate the new state of the input.

5.2.9 TEST OUTPUT RELAYS

This test checks that all the output relays are functioning correctly.

1. Ensure that the IED is still in test mode by viewing the Test Mode cell in the COMMISSION TESTS column. Ensure that it is set to 'Blocked'.
2. The output relays should be energised one at a time. To select output relay 1 for testing, set the Test Pattern cell as appropriate.
3. Connect a continuity tester across the terminals corresponding to output relay 1 as shown in the external connection diagram.
4. To operate the output relay set the Contact Test cell to 'Apply Test'.
5. Check the operation with the continuity tester.
6. Measure the resistance of the contacts in the closed state.
7. Reset the output relay by setting the Contact Test cell to 'Remove Test'.
8. Repeat the test for the remaining output relays.
9. Return the IED to service by setting the Test Mode cell in the COMMISSION TESTS menu to 'Disabled'.

5.2.10 TEST SERIAL COMMUNICATION PORT RP1

You need only perform this test if the IED is to be accessed from a remote location. The test will vary depending on the communications protocol used.

It is not the intention of this test to verify the operation of the complete communication link between the IED and the remote location, just the IED's rear communication port and, if applicable, the protocol converter.

5.2.10.1 CHECK PHYSICAL CONNECTIVITY

The rear communication port RP1 is presented on terminals 54 and 56. Screened twisted pair cable is used to make a connection to the port. The cable screen should be connected to the earth link just below pin 56:

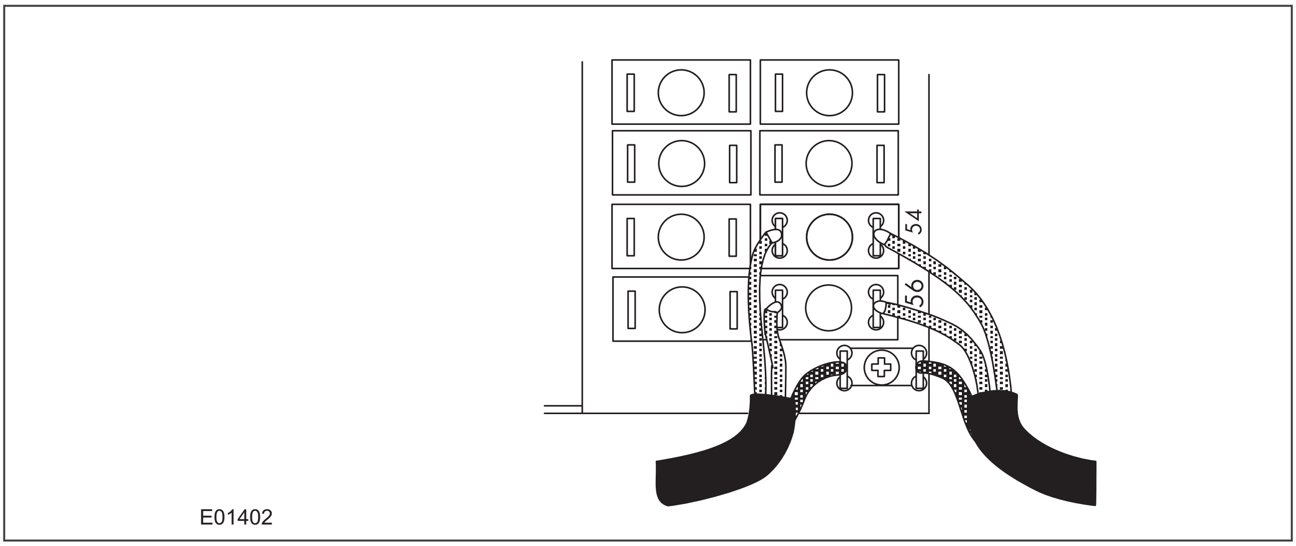


Figure 168: RP1 physical connection

For K-Bus applications, pins 54 and 56 are not polarity sensitive and it does not matter which way round the wires are connected. EIA(RS)485 is polarity sensitive, so you must ensure the wires are connected the correct way round (pin 54 is positive, pin 56 is negative).

If K-Bus is being used, a Kitz protocol converter (KITZ101, KITZ102 OR KITZ201) will have been installed to convert the K-Bus signals into RS232. Likewise, if RS485 is being used, an RS485-RS232 converter will have been installed. In the case where a protocol converter is being used, a laptop PC running appropriate software (such as MiCOM S1 Agile) can be connected to the incoming side of the protocol converter. An example for K-bus to RS232 conversion is shown below. RS485 to RS232 would follow the same principle, only using a RS485-RS232 converter. Most modern laptops have USB ports, so it is likely you will also require a RS232 to USB converter too.

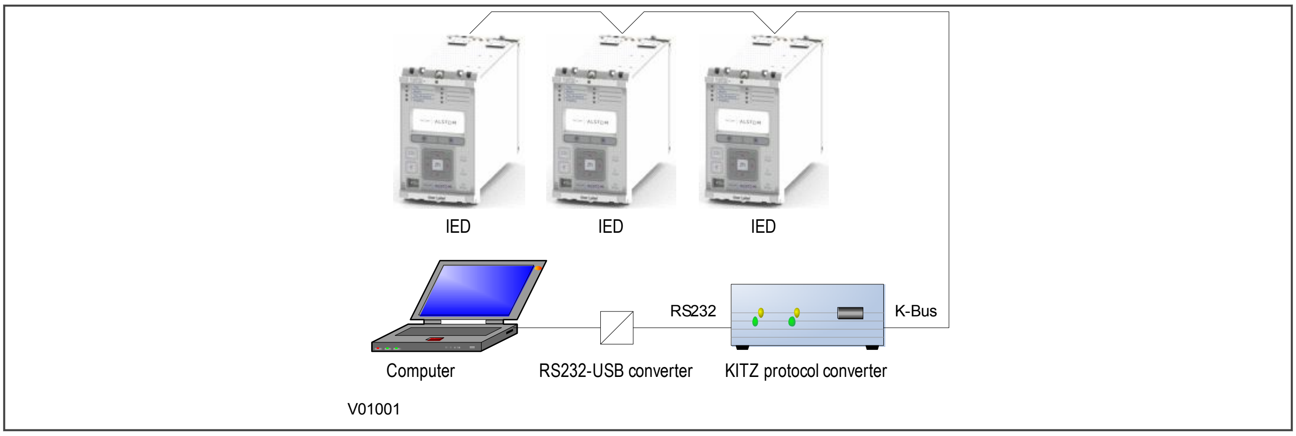


Figure 169: Remote communication using K-bus

5.2.10.2 CHECK LOGICAL CONNECTIVITY

The logical connectivity depends on the chosen data protocol, but the principles of testing remain the same for all protocol variants:

1. Ensure that the communications baud rate and parity settings in the application software are set the same as those on the protocol converter.
2. For Courier models, ensure that you have set the correct RP1 address
3. Check that communications can be established with this IED using the portable PC/Master Station.

5.2.11 TEST SERIAL COMMUNICATION PORT RP2

RP2 is only available on selected models. If applicable, this test is the same as for RP1 only the relevant terminals are 82 and 84.

5.2.12 TEST ETHERNET COMMUNICATION

To test the Ethernet communication:

1. Connect a portable PC running the appropriate IEC 61850 Client Software or MMS browser to the IED's Ethernet port.
2. Configure the IP parameters (IP Address, Subnet Mask, Gateway) and SNTP time synchronisation parameters (SNTP Server 1, SNTP Server 2). You can import the IP parameter configuration from an SCL file or apply them manually using the IED Configurator tool, which is installed as part of MiCOM S1 Agile. These cannot be configured via the IED's HMI on the front panel.
3. Check that communication with this IED can be established.

Note:
If the assigned IP address is duplicated elsewhere on the same network, the remote communications will operate in an indeterminate way. However, the device will check for a conflict on every IP configuration change and at power up. An alarm will be raised if an IP conflict is detected. The device can be configured to accept data from networks other than the local network by using the 'Gateway' setting.

5.2.13 TEST CURRENT INPUTS

This test verifies that the current measurement inputs are configured correctly.

All devices leave the factory set for operation at a system frequency of 50 Hz. If operation at 60 Hz is required then this must be set in the Frequency cell in the SYSTEM DATA column.

1. Apply current equal to the line current transformer secondary winding rating to each current transformer input in turn.
2. Check its magnitude using a multi-meter or test set readout. The corresponding reading can then be checked in the MEASUREMENTS 1 column.
3. Record the displayed value. The measured current values will either be in primary or secondary Amperes. If the Local Values cell in the MEASURE'T SETUP column is set to 'Primary', the values displayed should be equal to the applied current multiplied by the corresponding current transformer ratio (set in the TRANS. RATIOS column), as shown below. If the Local Values cell is set to Secondary, the value displayed should be equal to the applied current.

Note:
If a PC connected to the IED using the rear communications port is being used to display the measured current, the process will be similar. However, the setting of the Remote Values cell in the MEASURE'T SETUP column will determine whether the displayed values are in primary or secondary Amperes.

The measurement accuracy of the IED is ±1%. However, an additional allowance must be made for the accuracy of the test equipment being used.

Cell in MEASUREMENTS 1	Corresponding CT ratio (in TRANS. RATIOS column)
IA magnitude IB magnitude IC magnitude	Phase CT Primary / Phase CT Sec'y
IN measured mag	E/F CT Primary / E/F CT Secondary

Cell in MEASUREMENTS 1	Corresponding CT ratio (in TRANS. RATIOS column)
ISEF magnitude	SEF CT Primary / SEF CT Secondary

5.2.14 TEST VOLTAGE INPUTS

This test verifies that the voltage measurement inputs are configured correctly.

1. Apply rated voltage to each voltage transformer input in turn
2. Check its magnitude using a multimeter or test set readout. The corresponding reading can then be checked in the MEASUREMENTS 1 column.
3. Record the value displayed. The measured voltage values will either be in primary or secondary Volts. If the Local Values cell in the MEASURE'T SETUP column is set to 'Primary', the values displayed should be equal to the applied voltage multiplied by the corresponding voltage transformer ratio (set in the TRANS. RATIOS column) as shown below. If the Local Values cell is set to Secondary, the value displayed should be equal to the applied voltage.

Note:
If a PC connected to the IED using the rear communications port is being used to display the measured current, the process will be similar. However, the setting of the Remote Values cell in the MEASURE'T SETUP column will determine whether the displayed values are in primary or secondary Amperes.

Cell in MEASUREMENTS 1	Corresponding VT ratio (in TRANS. RATIOS column)
VAN magnitude VBN magnitude VCN magnitude	Main VT Primary / Main VT Sec'y
C/S Voltage Mag	C/S VT Primary / C/S VT Secondary

6 SETTING CHECKS

The setting checks ensure that all of the application-specific settings (both the IED's function and programmable scheme logic settings) have been correctly applied.

> *Note:*
> *If applicable, the trip circuit should remain isolated during these checks to prevent accidental operation of the associated circuit breaker.*

6.1 APPLY APPLICATION-SPECIFIC SETTINGS

There are two different methods of applying the settings to the IED

- Transferring settings to the IED from a pre-prepared setting file using MiCOM S1 Agile
- Enter the settings manually using the IED's front panel HMI

6.1.1 TRANSFERRING SETTINGS FROM A SETTINGS FILE

This is the preferred method for transferring function settings as it is much faster, and there is a lower margin for error.

1. Connect a laptop/PC (that is running MiCOM S1 Agile) to the IED's front port (could be serial RS232 or USB depending on the product), or a rear Courier communications port (with a KITZ protocol converter if necessary).
2. Power on the IED
3. Right-click on the appropriate device name in the System Explorer pane and select **Send**
4. In the **Send to** dialog select the setting files and click **Send**

> *Note:*
> *If the device name does not already exist in the System Explorer system, then first perform a Quick Connect to the IED. It will then be necessary to manually add the settings file to the device name in the Studio Explorer system. Refer to the MiCOM S1 Studio help for details of how to do this.*

6.1.2 ENTERING SETTINGS USING THE HMI

It is not possible to change the PSL using the IED's front panel HMI.

1. Starting at the default display, press the Down cursor key to show the first column heading.
2. Use the horizontal cursor keys to select the required column heading.
3. Use the vertical cursor keys to view the setting data in the column.
4. To return to the column header, either press the Up cursor key for a second or so, or press the **Cancel** key once. It is only possible to move across columns at the column heading level.
5. To return to the default display, press the Up cursor key or the Cancel key from any of the column headings. If you use the auto-repeat function of the Up cursor key, you cannot go straight to the default display from one of the column cells because the auto-repeat stops at the column heading.
6. To change the value of a setting, go to the relevant cell in the menu, then press the **Enter** key to change the cell value. A flashing cursor on the LCD shows that the value can be changed. You may be prompted for a password first.
7. To change the setting value, press the vertical cursor keys. If the setting to be changed is a binary value or a text string, select the required bit or character to be changed using the left and right cursor keys.

8. Press the **Enter** key to confirm the new setting value or the **Clear** key to discard it. The new setting is automatically discarded if it is not confirmed within 15 seconds.
9. For protection group settings and disturbance recorder settings, the changes must be confirmed before they are used. When all required changes have been entered, return to the column heading level and press the down cursor key. Before returning to the default display, the following prompt appears.

```
Update settings?
ENTER or CLEAR
```

10. Press the **Enter** key to accept the new settings or press the **Clear** key to discard the new settings.

Note:
If the menu time-out occurs before the setting changes have been confirmed, the setting values are also discarded.
Control and support settings are updated immediately after they are entered, without the Update settings prompt.
It is not possible to change the PSL using the IED's front panel HMI.

Caution:
Where the installation needs application-specific PSL, the relevant .psl files, must be transferred to the IED, for each and every setting group that will be used. If you do not do this, the factory default PSL will still be resident. This may have severe operational and safety consequences.

7 PROTECTION TIMING CHECKS

There is no need to check every protection function. Only one protection function needs to be checked as the purpose is to verify the timing on the processor is functioning correctly.

7.1 OVERCURRENT CHECK

If the overcurrent protection function is being used, test the overcurrent protection for stage 1.

1. Check for any possible dependency conditions and simulate as appropriate.
2. In the CONFIGURATION column, disable all protection elements other than the one being tested.
3. Make a note of which elements need to be re-enabled after testing.
4. Connect the test circuit
5. Perform the test
6. Check the operating time

7.2 CONNECTING THE TEST CIRCUIT

1. Use the PSL to determine which output relay will operate when an overcurrent trip occurs.
2. Use the output relay assigned to **Trip Output A**.
3. Use the PSL to map the protection stage under test directly to an output relay.

> *Note:*
> *If using the default PSL, use output relay 3 as this is already mapped to the DDB signal **Trip Command Out**.*

4. Connect the output relay so that its operation will trip the test set and stop the timer.
5. Connect the current output of the test set to the A-phase current transformer input.

   If the **I>1 Directional** cell in the OVERCURRENT column is set to 'Directional Fwd', the current should flow out of terminal 21. If set to 'Directional Rev', it should flow into terminal 21.

   If the **I>1 Directional** cell in the OVERCURRENT column has been set to 'Directional Fwd' or 'Directional Rev', the rated voltage should be applied to terminals 18 and 19.
6. Ensure that the timer starts when the current is applied.

> *Note:*
> *If the timer does not stop when the current is applied and stage 1 has been set for directional operation, the connections may be incorrect for the direction of operation set. Try again with the current connections reversed.*

7.3 PERFORMING THE TEST

1. Ensure that the timer is reset.
2. Apply a current of twice the setting shown in the **I>1 Current Set** cell in the OVERCURRENT column.
3. Note the time displayed when the timer stops.
4. Check that the red trip LED has illuminated.

7.4 CHECK THE OPERATING TIME

Check that the operating time recorded by the timer is within the range shown below.

For all characteristics, allowance must be made for the accuracy of the test equipment being used.

Characteristic	Operating time at twice current setting and time multiplier/ time dial setting of 1.0	
	Nominal (seconds)	Range (seconds)
DT	I>1 Time Delay] setting	Setting ±2%
IEC S Inverse	10.03	9.53 - 10.53
IEC V Inverse	13.50	12.83 - 14.18
IEC E Inverse	26.67	24.67 - 28.67
UK LT Inverse	120.00	114.00 - 126.00
IEEE M Inverse	3.8	3.61 - 4.0
IEEE V Inverse	7.03	6.68 - 7.38
IEEE E Inverse	9.50	9.02 - 9.97
US Inverse	2.16	2.05 - 2.27
US ST Inverse	12.12	11.51 - 12.73

Note:
With the exception of the definite time characteristic, the operating times given are for a Time Multiplier Setting (TMS) or Time Dial Setting (TDS) of 1. For other values of TMS or TDS, the values need to be modified accordingly.

Note:
For definite time and inverse characteristics there is an additional delay of up to 0.02 second and 0.08 second respectively. You may need to add this the IED's acceptable range of operating times.

Caution:
On completion of the tests, you must restore all settings that were disabled for testing purposes.

8 ONLOAD CHECKS

Onload checks can only be carried out if there are no restrictions preventing the energisation of the plant, and the other devices in the group have already been commissioned.

Remove all test leads and temporary shorting links, then replace any external wiring that has been removed to allow testing.

Warning:
If any external wiring has been disconnected for the commissioning process, replace it in accordance with the relevant external connection or scheme diagram.

8.1 CONFIRM CURRENT CONNECTIONS

1. Measure the current transformer secondary values for each input using a multimeter connected in series with the corresponding current input.
2. Check that the current transformer polarities are correct by measuring the phase angle between the current and voltage, either against a phase meter already installed on site and known to be correct or by determining the direction of power flow by contacting the system control centre.
3. Ensure the current flowing in the neutral circuit of the current transformers is negligible.
4. Compare the values of the secondary phase currents and phase angle with the measured values, which can be found in the MEASUREMENTS 1 column.

If the **Local Values** cell is set to 'Secondary', the values displayed should be equal to the applied secondary voltage. The values should be within 1% of the applied secondary voltages. However, an additional allowance must be made for the accuracy of the test equipment being used.

If the **Local Values** cell is set to 'Primary', the values displayed should be equal to the applied secondary voltage multiplied the corresponding voltage transformer ratio set in the TRANS. RATIOS column. The values should be within 1% of the expected values, plus an additional allowance for the accuracy of the test equipment being used.

8.2 CONFIRM VOLTAGE CONNECTIONS

1. Using a multimeter, measure the voltage transformer secondary voltages to ensure they are correctly rated.
2. Check that the system phase rotation is correct using a phase rotation meter.
3. Compare the values of the secondary phase voltages with the measured values, which can be found in the MEASUREMENTS 1 menu column.

Cell in MEASUREMENTS 1 Column	Corresponding VT ratio in 'TRANS. RATIO column
VAB Magnitude VBC Magnitude VCA Magnitude VAN Magnitude VBN Magnitude VCN Magnitude	Main VT Primary / Main VT Sec'y
C/S Voltage Mag.	CS VT Primary / CS VT Secondary

If the **Local Values** cell is set to 'Secondary', the values displayed should be equal to the applied secondary voltage. The values should be within 1% of the applied secondary voltages. However, an additional allowance must be made for the accuracy of the test equipment being used.

If the **Local Values** cell is set to 'Primary', the values displayed should be equal to the applied secondary voltage multiplied the corresponding voltage transformer ratio set in the TRANS. RATIOS column. The values should be within 1% of the expected values, plus an additional allowance for the accuracy of the test equipment being used.

8.3 ON-LOAD DIRECTIONAL TEST

This test ensures that directional overcurrent and fault locator functions have the correct forward/reverse response to fault and load conditions. For this test you must first know the actual direction of power flow on the system. If you do not already know this you must determine it using adjacent instrumentation or protection already in-service.

- For load current flowing in the Forward direction (power export to the remote line end), the **A Phase Watts** cell in the MEASUREMENTS 2 column should show positive power signing.
- For load current flowing in the Reverse direction (power import from the remote line end), the **A Phase Watts** cell in the MEASUREMENTS 2 column should show negative power signing.

> *Note:*
> *This check applies only for Measurement Modes 0 (default), and 2. This should be checked in the MEASURE'T. SETUP column (**Measurement Mode** = 0 or 2). If measurement modes 1 or 3 are used, the expected power flow signing would be opposite to that shown above.*

In the event of any uncertainty, check the phase angle of the phase currents with respect to their phase voltage.

9 FINAL CHECKS

1. Remove all test leads and temporary shorting leads.
2. If you have had to disconnect any of the external wiring in order to perform the wiring verification tests, replace all wiring, fuses and links in accordance with the relevant external connection or scheme diagram.
3. Ensure that the IED has been restored to service by checking that the **Test Mode** cell in the COMMISSION TESTS column is set to 'Disabled'.
4. The settings applied should be carefully checked against the required application-specific settings to ensure that they are correct, and have not been mistakenly altered during testing.
5. Ensure that all protection elements required have been set to **Enabled** in the CONFIGURATION column
6. If the IED is in a new installation or the circuit breaker has just been maintained, the circuit breaker maintenance and current counters should be zero. These counters can be reset using the **Reset All Values** cell. If the required access level is not active, the device will prompt for a password to be entered so that the setting change can be made.
7. If the menu language has been changed to allow accurate testing it should be restored to the customer's preferred language.
8. If a P991/MMLG test block is installed, remove the P992/MMLB test plug and replace the cover so that the protection is put into service.
9. Ensure that all event records, fault records, disturbance records, alarms and LEDs and communications statistics have been reset.

MAINTENANCE AND TROUBLESHOOTING

CHAPTER 16

1 CHAPTER OVERVIEW

The Maintenance and Troubleshooting chapter provides details of how to maintain and troubleshoot products based on the Px4x and P40Agile platforms. Always follow the warning signs in this chapter Failure to do so may result injury or defective equipment.

Caution:
Before carrying out any work on the equipment you should be familiar with the contents of the Safety Section or the Safety Guide SFTY/4LM and the ratings on the equipment's rating label.

The troubleshooting part of the chapter allows an error condition on the IED to be identified so that appropriate corrective action can be taken.

If the IED develops a fault, it is usually possible to identify which module needs replacing. It is not possible to perform an on-site repair to a faulty module.

If you return a faulty unit or module to the manufacturer or one of their approved service centres, you should include a completed copy of the Repair or Modification Return Authorization (RMA) form.

This chapter contains the following sections:

2 MAINTENANCE

2.1 MAINTENANCE CHECKS

In view of the critical nature of the application, Alstom Grid products should be checked at regular intervals to confirm they are operating correctly. Alstom Grid products are designed for a life in excess of 20 years.

The devices are self-supervising and so require less maintenance than earlier designs of protection devices. Most problems will result in an alarm, indicating that remedial action should be taken. However, some periodic tests should be carried out to ensure that they are functioning correctly and that the external wiring is intact. It is the responsibility of the customer to define the interval between maintenance periods. If your organisation has a Preventative Maintenance Policy, the recommended product checks should be included in the regular program. Maintenance periods depend on many factors, such as:

- The operating environment
- The accessibility of the site
- The amount of available manpower
- The importance of the installation in the power system
- The consequences of failure

Although some functionality checks can be performed from a remote location, these are predominantly restricted to checking that the unit is measuring the applied currents and voltages accurately, and checking the circuit breaker maintenance counters. For this reason, maintenance checks should also be performed locally at the substation.

Caution:
Before carrying out any work on the equipment you should be familiar with the contents of the Safety Section or the Safety Guide SFTY/4LM and the ratings on the equipment's rating label.

2.1.1 ALARMS

First check the alarm status LED to see if any alarm conditions exist. If so, press the Read key repeatedly to step through the alarms.

After dealing with any problems, clear the alarms. This will clear the relevant LEDs.

2.1.2 OPTO-ISOLATORS

Check the opto-inputs by repeating the commissioning test detailed in the Commissioning chapter.

2.1.3 OUTPUT RELAYS

Check the output relays by repeating the commissioning test detailed in the Commissioning chapter.

2.1.4 MEASUREMENT ACCURACY

If the power system is energised, the measured values can be compared with known system values to check that they are in the expected range. If they are within a set range, this indicates that the A/D conversion and the calculations are being performed correctly. Suitable test methods can be found in Commissioning chapter.

Alternatively, the measured values can be checked against known values injected into the device using the test block, (if fitted) or injected directly into the IED's terminals. Suitable test methods can be found in the Commissioning chapter. These tests will prove the calibration accuracy is being maintained.

2.2 REPLACING THE UNIT

If your product should develop a fault while in service, depending on the nature of the fault, the watchdog contacts will change state and an alarm condition will be flagged. In the case of a fault, you should normally replace the cradle which slides easily out of the case. This can be done without disturbing the scheme wiring.

In the unlikely event that the problem lies with the wiring and/or terminals, then you must replace the complete device, rewire and re-commission the device.

Caution:
If the repair is not performed by an approved service centre, the warranty will be invalidated.

Caution:
Before carrying out any work on the equipment, you should be familiar with the contents of the Safety Information section of this guide or the Safety Guide SFTY/4LM, as well as the ratings on the equipment's rating label. This should ensure that no damage is caused by incorrect handling of the electronic components.

Warning:
Before working at the rear of the unit, isolate all voltage and current supplying it.

Note:
The Alstom Grid products have integral current transformer shorting switches which will close, for safety reasons, when the terminal block is removed.

To replace the cradle without disturbing the case and wiring:

1. Remove the faceplate.
2. Carefully withdraw the cradle from the front.
3. To reinstall the unit, follow the above instructions in reverse, ensuring that each terminal block is relocated in the correct position and the chassis ground, IRIG-B and fibre optic connections are replaced. The terminal blocks are labelled alphabetically with 'A' on the left hand side when viewed from the rear.

Once the unit has been reinstalled, it should be re-commissioned as set out in the Commissioning chapter.

2.3 CLEANING

Warning:
Before cleaning the IED, ensure that all AC and DC supplies and transformer connections are isolated, to prevent any chance of an electric shock while cleaning.

Only clean the equipment with a lint-free cloth dampened with clean water. Do not use detergents, solvents or abrasive cleaners as they may damage the product's surfaces and leave a conductive residue.

3 TROUBLESHOOTING

3.1 SELF-DIAGNOSTIC SOFTWARE

The IED includes several self-monitoring functions to check the operation of its hardware and software while in service. If there is a problem with the hardware or software, it should be able to detect and report the problem, and attempt to resolve the problem by performing a reboot. In this case, the device would be out of service for a short time, during which the 'Healthy' LED on the front of the device is switched OFF and the watchdog contact at the rear is ON. If the restart fails to resolve the problem, the unit takes itself permanently out of service; the 'Healthy' LED stays OFF and watchdog contact stays ON.

If a problem is detected by the self-monitoring functions, the device attempts to store a maintenance record to allow the nature of the problem to be communicated to the user.

The self-monitoring is implemented in two stages: firstly a thorough diagnostic check which is performed on boot-up, and secondly a continuous self-checking operation, which checks the operation of the critical functions whilst it is in service.

3.2 POWER-UP ERRORS

If the IED does not appear to power up, use the following checks to determine whether the fault is in the external wiring, auxiliary fuse, IED power supply module or IED front panel.

Test	Check	Action
1	Measure the voltage on terminals 13 and 14. Verify the voltage level and polarity against the rating label	If the auxiliary voltage is correct, go to test 2. Otherwise check the wiring and fuses in the auxiliary supply.
2	Check the LEDs and LCD backlight switch on at power-up. Also check the N/O (normally open) watchdog contact on terminals 4 and 6 to see if they close.	If the LEDs and LCD backlight switch on, or the Watchdog contacts close and no error code is displayed, the error is probably on the main processor board. If the LEDs and LCD backlight do not switch on and the N/O Watchdog contact does not close, the fault is probably in the IED power supply module.

3.3 ERROR MESSAGE OR CODE ON POWER-UP

The IED performs a self-test during power-up. If it detects an error, a message appears on the LCD and the power-up sequence stops. If the error occurs when the IED application software is running, a maintenance record is created and the device reboots.

Test	Check	Action
1	Is an error message or code permanently displayed during power up?	If the IED locks up and displays an error code permanently, go to test 2. If the IED prompts for user input, go to test 3. If the IED reboots automatically, go to test 4.
2	Record displayed error and re-apply IED supply.	Record whether the same error code is displayed when the IED is rebooted, then contact the local service centre stating the error code and product details.
3	The IED displays a message for corrupt settings and prompts for the default values to be restored for the affected settings.	The power-up tests have detected corrupted IED settings. Restore the default settings to allow the power-up to complete, and then reapply the application-specific settings.
4	The IED resets when the power-up is complete. A record error code is displayed.	Programmable scheme logic error due to excessive execution time. Restore the default settings by powering up with both horizontal cursor keys pressed, then confirm restoration of defaults at the prompt using the Enter key. If the IED powers up successfully, check the programmable logic for feedback paths. Other error codes relate to software errors on the main processor board, contact the local service centre.

3.4 OUT OF SERVICE LED ON AT POWER-UP

Test	Check	Action	
1	Using the IED menu, confirm the Commission Test or Test Mode setting is Enabled. If it is not Enabled, go to test 2.	If the setting is Enabled, disable the test mode and make sure the Out of Service LED is OFF.	
2	Select the VIEW RECORDS column then view the last maintenance record from the menu.	Check for the H/W Verify Fail maintenance record. This indicates a discrepancy between the IED model number and the hardware. Examine the **Maint Data**; cell. This indicates the causes of the failure using bit fields: Bit Meaning	
		0	The application 'type' field in the Cortec does not match the software ID
		1	The 'subset' field in the model number does not match the software ID
		2	The 'platform' field in the model number does not match the software ID
		3	The 'product type' field in the model number does not match the software ID
		4	The 'protocol' field in the Cortec does not match the software ID
		5	The 'model' field in the Cortec does not match the software ID
		6	The first 'software version' field in the does not match the software ID
		7	The second 'software version' field in the Cortec does not match the software ID
		8	No VTs are fitted
		9	No CTs are fitted
		10	No Earth CT is fitted
		11	No SEF CT is fitted

3.5 ERROR CODE DURING OPERATION

The IED performs continuous self-checking. If the IED detects an error it displays an error message, logs a maintenance record and after a short delay resets itself. A permanent problem (for example due to a hardware fault) is usually detected in the power-up sequence. In this case the IED displays an error code and halts. If the problem was transient, the IED reboots correctly and continues operation. By examining the maintenance record logged, the nature of the detected fault can be determined.

3.6 MAL-OPERATION DURING TESTING

3.6.1 FAILURE OF OUTPUT CONTACTS

An apparent failure of the relay output contacts can be caused by the configuration. Perform the following tests to identify the real cause of the failure. The self-tests verify that the coils of the output relay contacts have been energized. An error is displayed if there is a fault in the output relay board.

Test	Check	Action
1	Is the Out of Service LED ON?	If this LED is ON, the relay may be in test mode or the protection has been disabled due to a hardware verify error.
2	Examine the Contact status in the Commissioning section of the menu.	If the relevant bits of the contact status are operated, go to test 4; if not, go to test 3.

Test	Check	Action
3	Examine the fault record or use the test port to check the protection element is operating correctly.	If the protection element does not operate, check the test is correctly applied. If the protection element operates, check the programmable logic to make sure the protection element is correctly mapped to the contacts.
4	Using the Commissioning or Test mode function, apply a test pattern to the relevant relay output contacts. Consult the correct external connection diagram and use a continuity tester at the rear of the relay to check the relay output contacts operate.	If the output relay operates, the problem must be in the external wiring to the relay. If the output relay does not operate the output relay contacts may have failed (the self-tests verify that the relay coil is being energized). Ensure the closed resistance is not too high for the continuity tester to detect.

3.6.2 FAILURE OF OPTO-INPUTS

The opto-isolated inputs are mapped onto the IED's internal DDB signals using the programmable scheme logic. If an input is not recognized by the scheme logic, use the **Opto I/P Status** cell in the COMMISSION TESTS column to check whether the problem is in the opto-input itself, or the mapping of its signal to the scheme logic functions.

If the device does not correctly read the opto-input state, test the applied signal. Verify the connections to the opto-input using the wiring diagram and the nominal voltage settings in the OPTO CONFIG column. To do this:

1. Select the nominal battery voltage for all opto-inputs by selecting one of the five standard ratings in the **Global Nominal V** cell.
2. Select 'Custom' to set each opto-input individually to a nominal voltage.
3. Using a voltmeter, check that the voltage on its input terminals is greater than the minimum pick-up level (See the Technical Specifications chapter for opto pick-up levels).

If the signal is correctly applied, this indicates failure of an opto-input, which case, the complete cradle should be replaced.

3.6.3 INCORRECT ANALOGUE SIGNALS

If the measured analogue quantities do not seem correct, use the measurement function to determine the type of problem. The measurements can be configured in primary or secondary terms.

1. Compare the displayed measured values with the actual magnitudes at the terminals.
2. Check the correct terminals are used
3. Check the CT and VT ratios set are correct.
4. Check the phase displacement to confirm the inputs are correctly connected

3.7 PSL EDITOR TROUBLESHOOTING

A failure to open a connection could be due to one or more of the following:

- The IED address is not valid (this address is always 1 for the front port)
- Password in not valid
- Communication set-up (COM port, Baud rate, or Framing) is not correct
- Transaction values are not suitable for the IED or the type of connection
- The connection cable is not wired correctly or broken
- The option switches on any protocol converter used may be incorrectly set

3.7.1 DIAGRAM RECONSTRUCTION

Although a scheme can be extracted from an IED, a facility is provided to recover a scheme if the original file is unobtainable.

A recovered scheme is logically correct but much of the original graphical information is lost. Many signals are drawn in a vertical line down the left side of the canvas. Links are drawn orthogonally using the shortest path from A to B. Any annotation added to the original diagram such as titles and notes are lost.

Sometimes a gate type does not appear as expected. For example, a single-input AND gate in the original scheme appears as an OR gate when uploaded. Programmable gates with an inputs-to-trigger value of 1 also appear as OR gates

3.7.2 PSL VERSION CHECK

The PSL is saved with a version reference, time stamp and CRC check. This gives a visual check whether the default PSL is in place or whether a new application has been downloaded.

3.8 REPAIR AND MODIFICATION PROCEDURE

Please follow these steps to return an Automation product to us:

1. Get the Repair and Modification Return Authorization (RMA) form
   For an electronic version of the RMA form, go to the following url:
   http://www.alstom.com/grid/productrepair/
2. Fill in the RMA form
   Fill in only the white part of the form.
   Please ensure that all fields marked **(M)** are completed such as:
   - Equipment model
   - Model No. and Serial No.
   - Description of failure or modification required (please be specific)
   - Value for customs (in case the product requires export)
   - Delivery and invoice addresses
   - Contact details
3. Send the RMA form to your local contact
   For a list of local service contacts worldwide, go to following url:
   http://www.alstom.com/grid/productrepair/
4. The local service contact provides the shipping information
   Your local service contact provides you with all the information needed to ship the product:
   - Pricing details
   - RMA number
   - Repair centre address

   If required, an acceptance of the quote must be delivered before going to the next stage.
5. Send the product to the repair centre
   - Address the shipment to the repair centre specified by your local contact
   - Make sure all items are packaged in an anti-static bag and foam protection
   - Make sure a copy of the import invoice is attached with the returned unit
   - Make sure a copy of the RMA form is attached with the returned unit
   - E-mail or fax a copy of the import invoice and airway bill document to your local contact.

TECHNICAL SPECIFICATIONS

CHAPTER 17

1 CHAPTER OVERVIEW

This chapter describes the technical specifications of the product.

This chapter contains the following sections:

2 INTERFACES

2.1 FRONT USB PORT

Front USB port	
Use	For local connection to laptop for configuration purposes and firmware downloads
Standard	USB
Connector	USB type B
Isolation	Isolation to ELV level
Protocol	Courier
Constraints	Maximum cable length 5 m

2.2 REAR SERIAL PORT 1

Rear serial port 1	
Use	For SCADA communications (multi-drop)
Standard	EIA(RS)485, K-bus
Terminal type	MiDOS
Connector	General purpose block, M4 screws (2 wire)
Cable	Screened twisted pair (STP)
Supported Protocols	Courier, IEC-60870-5-103, DNP3.0, MODBUS
Isolation	Isolation to SELV level
Constraints	Maximum cable length 1000 m

2.3 REAR SERIAL PORT 2

Rear serial port 2	
Use	For SCADA communications (multi-drop)
Standard	EIA(RS)485, K-bus, EIA(RS)232
Terminal type	MiDOS
Connector	General purpose block, M4 screws (2 wire)
Cable	Screened twisted pair (STP)
Supported Protocols	Courier
Isolation	Isolation to SELV level
Constraints	Maximum cable length 1000 m

2.4 IRIG-B PORT

IRIG-B Interface (De-modulated)	
Use	External clock synchronization signal
Standard	IRIG 200-98 format B00X
Terminal type	MiDOS
Connector	General purpose block, M4 screws (2 wire)
Cable type	Screened twisted pair (STP)

IRIG-B Interface (De-modulated)	
Isolation	Isolation to SELV level
Constraints	Maximum cable length 1000 m
Accuracy	< +/- 1 s per day

2.5 REAR ETHERNET PORT - FIBRE

Rear Ethernet port (fiber)	
Main Use	IEC 61850 or DNP3 SCADA communications
Connector	UNI SONET OC-3 LC (1 each for Tx and Rx)
Standard	IEEE 802.3.u 100 BaseFX
Fibre type	Multimode 50/125 µm or 62.5/125 µm
Supported Protocols	IEC 61850, DNP3.0 / Ethernet
Wavelength	1300 nm

2.5.1 100 BASE FX RECEIVER CHARACTERISTICS

Parameter	Sym	Min.	Typ.	Max.	Unit
Input Optical Power Minimum at Window Edge	PIN Min. (W)		-33.5	–31	dBm avg.
Input Optical Power Minimum at Eye Center	PIN Min. (C)		-34.5	-31.8	Bm avg.
Input Optical Power Maximum	PIN Max.	-14	-11.8		dBm avg.

Conditions: TA = 0°C to 70°C, VCC = 4.75 V to 5.25 V

2.5.2 100 BASE FX TRANSMITTER CHARACTERISTICS

Parameter	Sym	Min.	Typ.	Max.	Unit
Output Optical Power BOL 62.5/125 µm NA = 0.275 Fibre EOL	PO	-19 -20	-16.8	-14	dBm avg.
Output Optical Power BOL 50/125 µm NA = 0.20 Fibre EOL	PO	-22.5 -23.5	-20.3	-14	dBm avg.
Optical Extinction Ratio				10 -10	% dB
Output Optical Power at Logic "0" State	PO			-45	dBm avg.

Conditions: TA = 0°C to 70°C, VCC = 4.75 V to 5.25 V

2.6 REAR ETHERNET PORT COPPER

Rear Ethernet port (copper)	
Main Use	IEC 61850 or DNP3.0 OE SCADA communications
Standard	IEEE 802.3 10BaseT/100BaseTX
Connector	RJ45

Rear Ethernet port (copper)	
Cable type	Screened twisted pair (STP)
Isolation	1 kV
Supported Protocols	IEC 61850, DNP3.0 / Over Ethernet
Constraints	Maximum cable length 10 m

3 CURRENT PROTECTION FUNCTIONS

3.1 THREE-PHASE CURRENTPROTECTION

Accuracy	
DT Pick-up	Setting +/- 5%
Drop-off	0.95 x setting +/- 5%
Minimum trip level for IDMT elements	1.05 x Setting +/-5%
IDMT shape	According to IEC 60255-151:2009
IEEE reset	+/- 5% or 50 ms, whichever is greater
DT Operation	+/- 2% or 70 ms, whichever is greater (1.05 – <2) Is +/- 2% or 50 ms, whichever is greater (2 – 20) Is
DT Reset	+/- 5%
Repeatability	+/- 2.5%
Overshoot of overcurrent elements	<30 ms

3.1.1 DIRECTIONAL PARAMETERS

Accuracy	
Directional boundary accuracy (RCA +/-90%)	+/-2° with hysteresis <3°
DT Operation	+/- 2% or 80 ms, whichever is greater (1.05 – <2) Is +/- 2% or 60 ms, whichever is greater (2 – 20) Is

3.2 EARTH FAULT PROTECTION (MEASURED)

Earth Fault	
DT Pick-up	Setting +/- 5%
Drop-off	0.95 x Setting +/-5%
Minimum IDMT Trip level	1.05 x Setting +/-5%
IDMT shape	According to IEC 60255-151:2009 (Reference conditions TMS = 1, TD = 1 and IN1 > setting of 1 A, operating range 2-20 In)
IEEE reset	+/- 5% or 50 ms, whichever is greater
DT operation	+/- 2% or 70 ms, whichever is greater (1.05 – <2) Is +/- 2% or 50 ms, whichever is greater (2 – 20) Is
DT reset	+/- 5%
Repeatability	+/- 2.5%

3.3 EARTH FAULT PROTECTION (DERIVED)

Earth Fault	
DT Pick-up	Setting +/- 5%
Drop-off	0.95 x Setting +/-5%
Minimum IDMT Trip level	1.05 x Setting +/-5%

Earth Fault	
IDMT shape	According to IEC 60255-151:2009 (Reference conditions TMS = 1, TD = 1 and IN2 > setting of 1 A, operating range 2-20 In)
IEEE reset	+/- 10% or 40 ms, whichever is greater
DT operation	+/- 2% or 70 ms, whichever is greater (1.05 – <2) Is +/- 2% or 50 ms, whichever is greater (1.05 – <2) Is
DT reset	+/- 2% or 50 ms, whichever is greater
Repeatability	+/- 5%

3.4 EARTH FAULT DIRECTIONALISATION

Zero Sequence Polarising	
Operating pick-up	+/-2% of RCA+/-90%
Hysteresis	<3°
VN> pick-up	Setting+/-10%
VN> drop-off	0.9 x Setting +/-10%

Negative Sequence Polarising	
Operating pick-up	+/-2% of RCA+/-90%
Hysteresis	<3°
VN2> pick-up	Setting+/-10%
VN2> drop-off	0.9 x Setting +/-10%
IN2> pick-up	Setting+/-10%
IN2> drop-off	0.9 x Setting +/-10%

3.5 SENSITIVE EARTH FAULT PROTECTION

Sensitive Earth Fault (SEF)	
Pick-up	Setting +/- 5%
Drop-off	0.95 x Setting +/-5%
Minimum IDMT Trip level	1.05 x Setting +/-5%
IDMT shape	According to IEC 60255-151:2009 (Reference conditions TMS = 1, TD = 1 and IN > setting of 100 mA, operating range 2-20 In)
IEEE reset	+/- 7.5% or 60 ms, whichever is greater
IDMT operation	+/- 2% or 70 ms, whichever is greater (1.05 - <2) Is +/- 2% or 50 ms, whichever is greater (2 - 20) Is
DT reset	+/- 5%
Repeatability	+/- 5%
DT Operation	+/- 2% or 80 ms, whichever is greater (1.05 - <2) Is +/- 2% or 60 ms, whichever is greater (2 - 20) Is

Note:
SEF claims apply to SEF input currents of no more than 2 x In. For input ranges above 2 x In, the claim is not supported.

3.5.1 SEF DIRECTIONALISATION

Wattmetric SEF	
Pick-up for P = 0 W	ISEF > +/-5% or 5 mA
Pick-up for P > 0 W	P > +/-5%
Drop-off for P = 0 W	0.95 x ISEF> +/- 5% or 5 mA
Drop-off for P > 0 W	0.9 x P> +/- 5% or 5 mA
Boundary accuracy	+/-5% with hysteresis < 1°
Repeatability	+/- 5%

SEF CosΦ	
Pick-up	Setting +/-5% for angles RCA+/-60°
Drop-off	0.9 x setting
IDMT shape	+/- 5% or 50 ms, whichever is greater (Reference conditions TMS = 1, TD = 1 and IN > setting of 100 mA, operating range 2-0 In)
IEEE reset	+/- 7.5% or 60 ms, whichever is greater
DT operation	+/- 2% or 50 ms, whichever is greater
DT reset	+/- 5%
Repeatability	+/- 2%

SEF SinΦ	
Pick-up	Setting +/-5% for angles RCA+/-60° to RCA+/-90°
Drop-off	0.9 x setting
IDMT shape	+/- 5% or 50 ms, whichever is greater (Reference conditions TMS = 1, TD = 1 and IN > setting of 100 mA, operating range 2-0In)
IEEE reset	+/- 7.5% or 60 ms, whichever is greater
DT operation	+/- 2% or 50 ms, whichever is greater
DT reset	+/- 5%
Repeatability	+/- 2%

3.6 RESTRICTED EARTH FAULT PROTECTION

High Impedance Residual Earth Fault (REF)	
Pick-up	Setting formula +/- 5%
Drop-off	0.8 x Setting formula +/-5%
Operating time	< 60 ms
High pick-up	Setting +/- 10%
High operating time	< 30 ms
Repeatability	< 15%

Low Impedance Residual Earth Fault (REF)	
Pick-up	Setting formula +/- 5%
Drop-off	0.8 x Setting formula +/-5%

Low Impedance Residual Earth Fault (REF)	
Operating time	< 60 ms
High pick-up	Setting +/- 5%
High operating time	< 30 ms
Repeatability	< 15%

3.7 NEGATIVE SEQUNCE OVERCURRENT PROTECTION

Accuracy	
DT Pick-up	Setting +/- 5%
Drop-off	0.95 x Setting +/-5%
Minimum IDMT Trip level	1.05 x Setting +/-5%
IDMT shape	+/- 5% or 40 ms, whichever is greater
IEEE reset	+/- 5% or 50 ms, whichever is greater
DT operation	+/- 2% or 70 ms, whichever is greater (1.05 – <2) Is +/- 2% or 50 ms, whichever is greater (2 – 20) Is
DT Reset	+/- 5%

3.7.1 DIRECTIONAL PARAMETERS

Accuracy	
Directional boundary accuracy	+/- 2% with hysteresis < 1°
DT Operation	+/- 2% or 80 ms, whichever is greater (1.05 – <2) Is +/- 2% or 60 ms, whichever is greater (2 – 20) Is

3.8 CIRCUIT BREAKER FAIL AND UNDERCURRENT PROTECTION

Accuracy	
I< Pick-up	+/- 5% or 20 mA, whichever is greater
I< Drop-off	100% of setting +/- 5% or 20 mA, whichever is greater
Timers	+/- 2% or 50 ms, whichever is greater
Reset time	< 25 ms without DC offset < 35 ms with DC offset

3.9 BROKEN CONDUCTOR PROTECTION

Accuracy	
Pick-up	Setting +/- 2.5%
Drop-off	0.95 x Setting +/- 2.5%
DT operation	+/- 2% or 55 ms, whichever is greater

3.10 THERMAL OVERLOAD PROTECTION

Accuracy	
Thermal alarm pick-up	Calculated trip time +/- 10%

Accuracy	
Thermal overload pick-up	Calculated trip time +/- 10%
Cooling time accuracy	+/- 15% of theoretical
Repeatability	<5%

Operating time measured with applied current of 20% above thermal setting.

3.11 COLD LOAD PICKUP PROTECTION

Accuracy	
I> Pick-up	Setting +/- 1.5%
IN> Pick-up	Setting +/- 1.5%
I> Drop-off	0.95 x Setting +/- 1.5%
IN> Drop-off	0.95 x Setting +/- 1.5%
DT operation	+/- 0.5% or 50 ms, whichever is greater
Repeatability	+/- 1%

3.12 SELECTIVE OVERCURRENT PROTECTION

Accuracy	
Fast Block operation	< 25 ms
Fast Block reset	< 30 ms
Time delay	Setting +/- 2% or 20 ms, whichever is greater

3.13 VOLTAGE DEPENDENT OVERCURRENT PROTECTION

Accuracy	
VCO/VRO threshold pick-up	Setting+/-5%
Overcurrent pick-up	K-factor x setting +/-5%
VCO/VRO threshold drop-off	1.05 x setting +/-5%
Overcurrent drop-off	0.95(K-factor x setting) +/-5%
Operating time	+/- 5% or 60 ms, whichever is greater
Repeatability	+/- 1%

4 VOLTAGE AND FREQUENCY PROTECTION FUNCTIONS

4.1 UNDERVOLTAGE PROTECTION

Accuracy	
DT Pick-up	Setting +/- 5%
IDMT Pick-up	Setting +/- 5%
Drop-off	1.02 x Setting +/-5%
IDMT shape	+/- 3.5% or 40 ms, whichever is greater (<10 V) +/- 5% or 40 ms, whichever is greater (>10 V)
DT operation	+/- 2% or 50 ms, whichever is greater
Reset	< 75 ms
Repeatability	+/- 1%

4.2 OVERVOLTAGE PROTECTION

Accuracy	
DT Pick-up	Setting +/- 1%
IDMT Pick-up	Setting +/- 2%
Drop-off	0.98 x Setting +/-5%
IDMT shape	+/-3.5% or 40 ms, whichever is greater (<10 V) +/- 5% or 40 ms, whichever is greater (>10 V)
DT operation	+/- 2% or 50 ms, whichever is greater
Reset	< 75 ms
Repeatability	+/- 1%

4.3 RESIDUAL OVERVOLTAGE PROTECTION

Derived NVD Accuracy	
DT Pick-up	Setting +/- 5%
IDMT Pick-up	1.05 x Setting +/- 5%
Drop-off	0.95 x Setting +/-5%
IDMT shape	+/- 5% or 65 ms, whichever is greater
DT operation	+/- 2% or 20 ms or whichever is greater
Instantaneous operation	< 55 ms
Reset	< 35 ms
IDMT shape	+/- 60ms or 5%, whichever is greater
Repeatability	<10%

Measured NVD Accuracy	
DT Pick-up	Setting +/- 5%

Measured NVD Accuracy	
IDMT Pick-up	1.05 x Setting +/- 5%
Drop-off	0.95 x Setting +/-5%
IDMT shape	+/- 5% or 65 ms, whichever is greater
DT operation	+/- 2% or 20 ms or whichever is greater
Instantaneous operation	< 55 ms
Reset	< 35 ms
IDMT shape	+/- 60 ms or 5%, whichever is greater
Repeatability	< 10%

4.4 NEGATIVE SEQUENCE VOLTAGE PROTECTION

Accuracy	
Pick-up	Setting +/- 5%
Drop-off	0.95 x Setting +/-5%
DT operation	+/- 2% or 65 ms, whichever is greater (70 Hz - 45 Hz) +/- 5% or 70 ms, whichever is greater (<45 Hz)
Repeatability	+/- 1%

4.5 RATE OF CHANGE OF VOLTAGE PROTECTION

Accuracy for 110V VT	
Tolerance	1% or 0.07, whichever is greater
Pick-up	Setting +/- tolerance
Drop-off for positive direction	(Setting – 0.07)+/- tolerance
Drop-off for negative direction	(Setting + 0.07)+/- tolerance
Operating time at 50Hz	(Average cycle x 20) +60 ms
Reset time at 50Hz	40 ms

4.6 OVERFREQUENCY PROTECTION

Accuracy	
Pick-up	Setting +/- 10 mHz
Drop-off	Setting -20 mHz +/- 10 mHz
Operating timer	+/- 2% or 50 ms, whichever is greater

Operating and Reset time	
Operating time (Fs/Ff ratio less than 2)	<125 ms
Operating time (Fs/Ff ratio between 2 and 30)	<150 ms
Operating time (Fs/Ff ratio greater than 30)	<200 ms
Reset time	<200 ms

Reference conditions: Tested using step changed in frequency with Freq. Av Cycles setting = 0 and no intentional time delay.

Fs = start frequency – frequency setting

Ff = frequency setting – end frequency

4.7 UNDERFREQUENCY PROTECTION

Accuracy	
Pick-up	Setting +/- 10 mHz
Drop-off	Setting + 20 mHz +/- 10 mHz
Operating timer	+/- 2% or 50 ms, whichever is greater

Operating and Reset time	
Operating time (Fs/Ff ratio less than 2)	<100 ms
Operating time (Fs/Ff ratio between 2 and 6)	<160 ms
Operating time (Fs/Ff ratio greater than 6)	<230 ms
Reset time	<200 ms

Reference conditions: Tested using step changed in frequency with Freq. Av Cycles setting = 0 and no intentional time delay.

Fs = start frequency – frequency setting

Ff = frequency setting – end frequency

4.8 SUPERVISED RATE OF CHANGE OF FREQUENCY PROTECTION

Accuracy	
Pick-up (f)	Setting +/- 10 mHz
Pick-up (df/dt)	Setting +/- 3% or +/- 10 mHz/s, whichever is greater
Drop-off (f, underfrequency)	Setting + 20 mHz +/- 10 mHz
Drop-off (f, overfrequency)	Setting - 20 mHz +/- 10 mHz
Drop-off (df/dt, falling, for settings between 10 mHz/s and 100 mHz/s)	Setting + 5 mHz/s +/- 10 mHz/s
Drop-off (df/dt, falling, for settings greater than 100 mHz/s)	Setting + 50 mHz/s +/- 5% or +/- 55 mHz/s, whichever is greater
Drop-off (df/dt, rising, for settings between 10 mHz/s and 100 mHz/s)	Setting - 5 mHz/s +/- 10 mHz/s
Drop-off (df/dt, rising, for settings greater than 100 mHz/s)	Setting - 50 mHz/s +/- 5% or +/- 55 mHz/s, whichever is greater

Operating and Reset time	
Instantaneous operating time (Freq AvCycles setting = 0)	<125 ms
Reset time time (df/dt AvCycles setting = 0)	<400 ms

4.9 INDEPENDENT RATE OF CHANGE OF FREQUENCY PROTECTION

Accuracy	
Pick-up (df/dt)	Setting +/- 3% or +/- 10 mHz/s, whichever is greater

Accuracy	
Drop-off (df/dt, falling, for settings between 10 mHz/s and 100 mHz/s)	Setting + 5 mHz/s +/- 10 mHz/s
Drop-off (df/dt, falling, for settings greater than 100 mHz/s)	Setting + 50 mHz/s +/- 5% or +/- 55 mHz/s, whichever is greater
Drop-off (df/dt, rising, for settings between 10 mHz/s and 100 mHz/s)	Setting - 5 mHz/s +/- 10 mHz/s
Drop-off (df/dt, rising, for settings greater than 100 mHz/s)	Setting - 50 mHz/s +/- 5% or +/- 55 mHz/s, whichever is greater
Operating timer	+/- 2% or 50 ms, whichever is greater

Operating and Reset time	
Operating time (for ramps 2 x seting or greater)	<200 ms
Operating time (for ramps 1.3 x seting or greater)	<300 ms
Reset time time (df/dt AvCycles setting = 0 for df/dt settings greater than 0.1 Hz/s and no intentional time delay)	<250 ms

4.10 AVERAGE RATE OF CHANGE OF FREQUENCY PROTECTION

Accuracy	
Pick-up (f)	Setting +/- 10 mHz
Pick-up (Df/Dt)	Setting +/- 100 mHz/s
Drop-off (falling)	Setting + 20 mHz +/- 10 mHz
Drop-off (rising)	Setting - 20 mHz +/- 10 mHz
Operating timer	+/- 2% or 30 ms, whichever is greater

Operating time	
Operating time (Freq. Av Cycles setting = 0)	<125 ms

Reference conditions: To maintain accuracy, the minimum time delay setting should be:

Dt> 0.375 x Df + 0.23 (f0r Df setting <1Hz)

Dt> 0.156 x Df + 0.47 (for Df setting >= 1Hz)

4.11 LOAD RESTORATION

Accuracy	
Pick-up	Setting +/- 2.5%
Drop-off	0.95% x Setting +/- 2.5%
Restoration timer	+/- 2% or 50 ms, whichever is greater
Holding timer	+/- 2% or 50 ms, whichever is greater

5 POWER PROTECTION FUNCTIONS

5.1 OVERPOWER / UNDERPOWER

Accuracy	
Pick-up	Setting +/- 10%
Reverse/Overpower Drop-off	0.95 x Setting +/- 10%
Low forward power Drop-off	1.05 x Setting +/- 10%
Angle variation pick-up	+/- 2°
Angle variation drop-off	+/- 2.5°
Operating time	+/- 2% or 50 ms, whichever is greater
Repeatability	< 5%
Disengagement time	<50 ms
tRESET	+/- 5%
Instantaneous operating time	< 50 ms

5.2 SENSITIVE POWER

Accuracy	
Pick-up	Setting +/- 10%
Reverse/Overpower Drop-off	0.9 x Setting +/- 10%
Low forward power Drop-off	1.1 x Setting +/- 10%
Angle variation pick-up	+/- 2°
Angle variation drop-off	+/- 2.5°
Operating time	+/- 2% or 50 ms, whichever is greater
Repeatability	< 5%
Disengagement time	<50 ms
tRESET	+/- 5%
Instantaneous operating time	< 50 ms

6 MONITORING AND CONTROL

6.1 VOLTAGE TRANSFORMER SUPERVISION

Accuracy	
Fast block operation	< 25 ms
Fast block reset	< 30 ms
Time delay	+/- 2% or 20 ms, whichever is greater

6.2 CURRENT TRANSFORMER SUPERVISION

Standard CTS Accuracy	
IN> Pick-up	Setting +/- 5%
VN< Pick-up	Setting +/- 5%
IN> Drop-off	0.9 x setting +/- 5%
VN< Drop-off	1.05 x setting +/-5% or 1 V, whichever is greater
Time delay operation	Setting +/-2% or 20 ms, whichever is greater
CTS block operation	< 1 cycle
CTS reset	< 35 ms

6.3 CB STATE AND CONDITION MONITORING

Accuracy	
Timers	+/- 40 ms or 2%, whichever is greater
Broken current accuracy	< +/- 5%

6.4 PSL TIMERS

Accuracy	
Output conditioner timer	Setting +/- 2% or 50 ms, whichever is greater
Dwell conditioner timer	Setting +/- 2% or 50 ms, whichever is greater
Pulse conditioner timer	Setting +/- 2% or 50 ms, whichever is greater

6.5 CHECK SYNCHRONISATION

Accuracy	
Timers	+/- 20 ms or 2%, whichever is greater

6.6 DC SUPPLY MONITOR

Accuracy	
Measuring Range	19 V-310 V ±5%

Accuracy	
Tolerance	±1.5 V for 19-100 V ±2% for 100-200 V ±2.5% for 200-300 V
Pickup	100% of Setting ± Tolerance *
Dropoff	Hysteresis 2% 102% of Setting ± Tolerance for the upper limit * 98% of Setting ± Tolerance for the lower limit *
Operating Time	Setting ± (2% or 500 ms whichever is greater)
Disengage Time	< 250 ms

* Tested at 21°C

7 MEASUREMENTS AND RECORDING

7.1 GENERAL

General Measurement Accuracy	
General measurement accuracy	Typically +/- 1%, but +/- 0.5% between 0.2 - 2 In/Vn
Phase	0° to 360° +/- 0.5%
Current	0.05 to 3 In +/- 1.0% of reading
Voltage	0.05 to 2 Vn +/- 1.0% of reading
Frequency	40 to 70 Hz +/- 0.025 Hz
Power (W)	0.2 to 2 Vn and 0.05 to 3 In +/- 5.0% of reading at unity power factor
Reactive power (Vars)	0.2 to 2 Vn and 0.05 to 3 In +/- 5.0% of reading at zero power factor
Apparent power (VA)	0.2 to 2 Vn and 0.05 to 3 In +/- 5.0% of reading
Energy (Wh)	0.2 to 2 Vn and 0.2 to 3 In +/- 5.0% of reading at zero power factor
Energy (Varh)	0.2 to 2 Vn and 0.2 to 3 In +/- 5.0% of reading at zero power factor

7.2 DISTURBANCE RECORDS

Disturbance Records Measurement Accuracy	
Maximum record duration	50 s
No of records	Minimum 5 at 10 seconds each Maximum 50 at 1 second each (8 records of 3 seconds, each via IEC 60870-5-103 protocol)
Magnitude and relative phases accuracy	±5% of applied quantities
Duration accuracy	±2%
Trigger position accuracy	±2% (minimum Trigger 100 ms)

7.3 EVENT, FAULT AND MAINTENANCE RECORDS

Event, Fault & Maintenance Records	
Record location	Flash memory
Viewing method	Front panel display or MiCOM S1 Agile
Extraction method	Extracted via the USB port
Number of Event records	Up to 2048 time tagged event records
Number of Fault Records	Up to 5
Number of Maintenance Records	Up to 10

7.4 FAULT LOCATOR

Accuracy	
Fault Location	+/- 3.5% of line length Reference conditions: solid fault applied on line

8 STANDARDS COMPLIANCE

8.1 EMC COMPLIANCE: 2004/108/EC

Compliance with the European Commission Directive on EMC is demonstrated using a Technical File.

Compliance with EN60255-26:2009 was used to establish conformity.

8.2 PRODUCT SAFETY: 2006/95/EC

Compliance with the European Commission Low Voltage Directive (LVD) is demonstrated using a Technical File.

Compliance with EN 60255-27: 2005 was used to establish conformity:

8.3 R&TTE COMPLIANCE

Radio and Telecommunications Terminal Equipment (R&TTE) directive 99/5/EC.

Conformity is demonstrated by compliance to both the EMC directive and the Low Voltage directive, to zero volts.

8.4 UL/CUL COMPLIANCE

Canadian and USA Underwriters Laboratory

File Number E202519 (where marked)

9 MECHANICAL SPECIFICATIONS

9.1 PHYSICAL PARAMTERS

Physical Measurements	
Case Types	20TE 30TE
Weight (20TE case)	2 kg – 3 kg (depending on chosen options)
Weight (30TE case)	3 kg – 4 kg (depending on chosen options)
Dimensions in mm (w x h x l) (20TE case)	W: 102.4mm H: 177.0mm D: 243.1mm
Dimensions in mm (w x h x l) (30TE case)	W: 154.2mm H: 177.0mm D: 243.1mm
Mounting	Panel, rack, or retrofit

9.2 ENCLOSURE PROTECTION

Enclosure Protection	
Against dust and dripping water (front face)	IP52 as per IEC 60529:2002
Protection against dust (whole case)	IP50 as per IEC 60529:2002
Protection for sides of the case (safety)	IP30 as per IEC 60529:2002
Protection for rear of the case (safety)	IP10 as per IEC 60529:2002

9.3 MECHANICAL SPECIFICATIONS

Mechanical Robustness	
Vibration test per EN 60255-21-1:1996	Response: class 2, Endurance: class 2
Shock and bump immunity per EN 60255-21-2:1995	Shock response: class 4, Shock withstand: class 1, Bump withstand: class 4
Seismic test per EN 60255-21-3: 1995	Class 2

9.4 TRANSIT PACKAGING PERFORMANCE

Packaging	
Primary packaging carton protection	ISTA 1C
Vibration tests	3 orientations, 7 Hz, amplitude 5.3mm, acceleration 1.05g
Drop tests	10 drops from 610mm height on multiple carton faces, edges and corners

10 RATINGS

10.1 AC MEASURING INPUTS

AC Measuring Inputs	
Nominal frequency	50 and 60 Hz (settable)
Operating range	40 to 70 Hz
Phase rotation	ABC or CBA

10.2 CURRENT TRANSFORMER INPUTS

AC Current	
Nominal current (In)	1A and 5A dual rated*
Nominal burden per phase	< 0.05 VA at In
AC current thermal withstand	Continuous: 4 x In 10 s: 30 x In 1 s: 100 x In Linear to 40 x In (non-offset ac current)

Note:
A single input is used for both 1A and 5A applications. 1 A or 5 A operation is determined by means of software in the product's database.

10.3 VOLTAGE TRANSFORMER INPUTS

AC Voltage	
Nominal voltage	100 V to 120 V, or 380V to 480 V phase-phase
Nominal burden per phase	< 0.1 VA at Vn
Thermal withstand	Continuous: 2 x Vn, 10 s: 2.6 x Vn

10.4 AUXILIARY SUPPLY VOLTAGE

Power Supply Voltage	
Nominal operating range	24-250 V DC +/-20% 110-240 V AC -20% + 10%
Maximum operating range	19 to 300 V DC
Frequency range for AC supply	45 – 65 Hz
Ripple	<15% for a DC supply (compliant with IEC 60255-11:2008)

10.5 NOMINAL BURDEN

Nominal Burden		
Quiescent burden	20TE	5 W max.

Nominal Burden		
	30TE	6 W max.
	30TE with 2nd rear communications	6.2 W max.
	30TE with Ethernet or TCS	7 W max.
Additions for energised relay outputs		0.26 W per output relay
Opto-input burden	24 V	0.065 W max.
	48 V	0.125 W max.
	110 V	0.36 W max.
	220 V	0.9 W max.

10.6 POWER SUPPLY INTERRUPTION

Power Supply Interruption				
Standard	IEC 60255-11:2008 (dc) IEC 61000-4-11:2004 (ac)			
	Quiescent / half load		Full load	
	19.2 V – 110 V dc	>110 Vdc	19.2 V – 110 V dc	>110 Vdc
20TE	50 ms	100 ms	50 ms	100 ms
30TE	50 ms	100 ms	30 ms	50 ms
30TE with 2nd rear communications	30 ms	100 ms	20 ms	50 ms
30TE with Ethernet or TCS	50 ms	100 ms	20 ms	100 ms

Note:
Maximum loading = all inputs/outputs energised.

Note:
Quiescent or 1/2 loading = 1/2 of all inputs/outputs energised.

10.7 OUTPUT CONTACTS

Standard Contacts	
Compliance	In accordance with IEC 60255-1:2009
Use	General purpose relay outputs for signalling, tripping and alarming
Rated voltage	300 V
Maximum continuous current	10 A
Short duration withstand carry	30 A for 3 s 250 A for 30 ms
Make and break, dc resistive	50 W
Make and break, dc inductive	62.5 W (L/R = 50 ms)
Make and break, ac resistive	2500 VA resistive (cos f = unity)
Make and break, ac inductive	2500 VA inductive (cos f = 0.7)
Make and carry, dc resistive	30 A for 3 s, 10000 operations (subject to the above limits)
Make, carry and break, dc resistive	4 A for 1.5 s, 10000 operations (subject to the above limits)

Standard Contacts	
Make, carry and break, dc inductive	0.5 A for 1 s, 10000 operations (subject to the above limits)
Make, carry and break ac resistive	30 A for 200 ms, 2000 operations (subject to the above limits)
Make, carry and break ac inductive	10 A for 1.5 s, 10000 operations (subject to the above limits)
Loaded contact	1000 operations min.
Unloaded contact	10000 operations min.
Operate time	< 5 ms
Reset time	< 10 ms

10.8 WATCHDOG CONTACTS

Watchdog Contacts	
Use	Non-programmable contacts for relay healthy/relay fail indication
Breaking capacity, dc resistive	30 W
Breaking capacity, dc inductive	15 W (L/R = 40 ms)
Breaking capacity, ac inductive	375 VA inductive (cos f = 0.7)

10.9 ISOLATED DIGITAL INPUTS

Opto-isolated digital inputs (opto-inputs)	
Options	The opto-inputs with programmable voltage thresholds may be energized from the 48 V field voltage, or the external battery supply
Rated nominal voltage	24 to 250 V dc
Operating range	19 to 265 V dc
Withstand	300 V dc
Recognition time with half-cycle ac immunity filter removed	< 2 ms
Recognition time with filter on	< 12 ms

10.9.1 NOMINAL PICKUP AND RESET THRESHOLDS

Nominal Battery voltage	Logic levels: 60-80% DO/PU	Logic Levels: 50-70% DO/PU
24/27 V	Logic 0 < 16.2 V : Logic 1 > 19.2 V	Logic 0 <12.0 V : Logic 1 > 16.8
30/34	Logic 0 < 20.4 V : Logic 1 > 24.0 V	Logic 0 < 15.0 V : Logic 1 > 21.0 V
48/54	Logic 0 < 32.4 V : Logic 1 > 38.4 V	Logic 0 < 24.0 V : Logic 1 > 33.6 V
110/125	Logic 0 < 75.0 V : Logic 1 > 88.0 V	Logic 0 < 55.0 V : Logic 1 > 77.0 V
220/250	Logic 0 < 150 V : Logic 1 > 176.0 V	Logic 0 < 110.V : Logic 1 > 154.0 V

Note:
Filter is required to make the opto-inputs immune to induced AC voltages.

11 ENVIRONMENTAL CONDITIONS

11.1 AMBIENT TEMPERATURE RANGE

Ambient Temperature Range	
Compliance	IEC 60255-27: 2005
Test Method	IEC 60068-2-1: 1993 and 60068-2-2: 2007
Operating temperature range	-25°C to +55°C (-13°F to +131°F)
Storage and transit temperature range	-25°C to +70°C (-13°F to +158°F)

11.2 TEMPERATURE ENDURANCE TEST

Temperature Endurance Test	
Test Method	IEC 60068-2-1: 1993 and 60068-2-2: 2007
Operating temperature range	-40°C operation (96 hours) +85°C operation (96 hours)
Storage and transit temperature range	-40°C operation (96 hours) +85°C operation (96 hours)

11.3 AMBIENT HUMIDITY RANGE

Ambient Humidity Range	
Compliance	IEC 60068-2-78: 2001 and IEC 60068-2-30: 2005
Durability	56 days at 93% relative humidity and +40°C
Damp heat cyclic	six (12 + 12) hour cycles, 93% RH, +25 to +55°C

11.4 CORROSIVE ENVIRONMENTS

Corrosive Environments	
Compliance	IEC 60068-2-42: 2003, IEC 60068-2-43: 2003
Industrial corrosive environment/poor environmental control, Sulphur Dioxide	21 days exposure to elevated concentrations (25ppm) of SO2 at 75% relative humidity and +25°C
Industrial corrosive environment/poor environmental control, Hydrogen Sulphide	21 days exposure to elevated concentrations (10ppm) of SO2 at 75% relative humidity and +25°C
Salt mist	IEC 60068-2-52: 1996 KB severity 3

12 TYPE TESTS

12.1 INSULATION

Insulation	
Compliance	IEC 60255-27: 2005
Insulation resistance	> 100 M ohm at 500 V DC (Using only electronic/brushless insulation tester)

12.2 CREEPAGE DISTANCES AND CLEARANCES

Creepage Distances and Clearances	
Compliance	IEC 60255-27: 2005
Pollution degree	3
Overvoltage category	III
Impulse test voltage (not RJ45)	5 kV
Impulse test voltage (RJ45)	1 kV

12.3 HIGH VOLTAGE (DIELECTRIC) WITHSTAND

High Voltage (Dielectric) Withstand	
IEC Compliance	IEC 60255-27: 2005
Between all independent circuits	2 kV ac rms for 1 minute
Between independent circuits and protective earth conductor terminal	2 kV ac rms for 1 minute
Between all case terminals and the case earth	2 kV ac rms for 1 minute
Across open watchdog contacts	1 kV ac rms for 1 minute
Across open contacts of changeover output relays	1 kV ac rms for 1 minute
Between all RJ45 contacts and protective earth	1 kV ac rms for 1 minute
Between all screw-type EIA(RS)485 contacts and protective earth	1 kV ac rms for 1 minute
ANSI/IEEE Compliance	ANSI/IEEE C37.90-1989
Across open contacts of normally open output relays	1.5 kV ac rms for 1 minute
Across open contacts of normally open changeover output relays	1 kV ac rms for 1 minute
Across open watchdog contacts	1 kV ac rms for 1 minute

12.4 IMPULSE VOLTAGE WITHSTAND TEST

Impulse Voltage Withstand Test	
Compliance	IEC 60255-27: 2005
Between all independent circuits	Front time: 1.2 µs, Time to half-value: 50 µs, Peak value: 5 kV, 0.5 J
Between terminals of all independent circuits	Front time: 1.2 µs, Time to half-value: 50 µs, Peak value: 5 kV, 0.5 J
Between all independent circuits and protective earth conductor terminal	Front time: 1.2 µs, Time to half-value: 50 µs, Peak value: 5 kV, 0.5 J

Note:
Exceptions are communications ports and normally-open output contacts

13 ELECTROMAGNETIC COMPATIBILITY

13.1 1 MHZ BURST HIGH FREQUENCY DISTURBANCE TEST

1 MHz Burst High Frequency Disturbance Test	
Compliance	IEC 60255-22-1: 2007 2008, Class III
Common-mode test voltage (level 3)	2.5 kV
Differential test voltage (level 3)	1.0 kV

13.2 DAMPED OSCILLATORY TEST

Damped Oscillatory Test	
Compliance	EN61000-4-18: 2011: Level 3, 100 kHz and 1 MHz. Level 4: 3 MHz, 10 MHz and 30 MHz
Common-mode test voltage (level 3)	2.5 kV
Common-mode test voltage (level 4)	4.0 kV
Differential mode test voltage	1.0 kV

13.3 IMMUNITY TO ELECTROSTATIC DISCHARGE

Immunity to Electrostatic Discharge	
Compliance	IEC 60255-22-2: 2008 Class 3 and Class 4,
Class 4 Condition	15 kV discharge in air to user interface, display, and exposed metalwork
Class 3 Condition	8 kV discharge in air to all communication ports

13.4 ELECTRICAL FAST TRANSIENT OR BURST REQUIREMENTS

Electrical Fast Transient or Burst Requirements	
Compliance	IEC 60255-22-4: 2008 and EN61000-4-4:2004. Test severity level III and IV
Applied to communication inputs	Amplitude: 2 kV, burst frequency 5 kHz and 100 KHz (level 4)
Applied to power supply and all other inputs except for communication inputs	Amplitude: 4 kV, burst frequency 5 kHz and 100 KHz (level 4)

13.5 SURGE WITHSTAND CAPABILITY

Surge Withstand Capability	
Compliance	IEEE/ANSI C37.90.1: 2002
Condition 1	4 kV fast transient and 2.5 kV oscillatory applied common mode and differential mode to opto inputs, output relays, CTs, VTs, power supply, field voltage
Condition 2	4 kV fast transient and 2.5 kV oscillatory applied common mode to communications, IRIG-B

13.6 SURGE IMMUNITY TEST

Surge Immunity Test	
Compliance	IEC 61000-4-5: 2005 Level 4
Pulse duration	Time to half-value: 1.2/50 µs
Between all groups and protective earth conductor terminal	Amplitude 4 kV
Between terminals of each group (excluding communications ports)	Amplitude 2 kV

13.7 IMMUNITY TO RADIATED ELECTROMAGNETIC ENERGY

Immunity to Radiated Electromagnetic Energy	
Compliance	IEC 60255-22-3: 2007, Class III
Frequency band	80 MHz to 3.0 GHz
Spot tests at	80, 160, 380, 450, 900, 1850, 2150 MHz
Test field strength	10 V/m
Test using AM	1 kHz @ 80%
Compliance	IEEE/ANSI C37.90.2: 2004
Frequency band	80 MHz to 1 GHz
Spot tests at	80, 160, 380, 450 MHz
Waveform	1 kHz @ 80% am and pulse modulated
Field strength	35 V/m

13.8 RADIATED IMMUNITY FROM DIGITAL COMMUNICATIONS

Radiated Immunity from Digital Communications	
Compliance	IEC 61000-4-3: 2006, Level 4
Frequency bands	800 to 960 MHz, 1.4 to 2.0 GHz
Test field strength	30 V/m
Test using AM	1 kHz / 80%

13.9 RADIATED IMMUNITY FROM DIGITAL RADIO TELEPHONES

Radiated Immunity from Digital Radio Telephones	
Compliance	IEC 61000-4-3: 2002
Frequency bands	1.89 GHz
Test field strength	10 V/m

13.10 IMMUNITY TO CONDUCTED DISTURBANCES INDUCED BY RADIO FREQUENCY FIELDS

Immunity to Conducted Disturbances Induced by Radio Frequency Fields	
Compliance	IEC 61000-4-6: 2008, Level 3
Frequency bands	150 kHz to 80 MHz

Immunity to Conducted Disturbances Induced by Radio Frequency Fields	
Test disturbance voltage	10 V rms
Test using AM	1 kHz @ 80%
Spot tests	27 MHz and 68 MHz

13.11 MAGNETIC FIELD IMMUNITY

Magnetic Field Immunity	
Compliance	IEC 61000-4-8: 2009 Level 5 IEC 61000-4-9/10: 2001 Level 5
IEC 61000-4-8 test	100 A/m applied continuously, 1000 A/m applied for 3 s
IEC 61000-4-9 test	1000 A/m applied in all planes
IEC 61000-4-10 test	100 A/m applied in all planes at 100 kHz/1 MHz with a burst duration of 2 seconds

13.12 CONDUCTED EMISSIONS

Conducted Emissions	
Compliance	EN 55022: 2010
Power supply test 1	0.15 - 0.5 MHz, 79 dBμV (quasi peak) 66 dBμV (average)
Power supply test 2	0.5 – 30 MHz, 73 dBμV (quasi peak) 60 dBμV (average)¤
RJ45 test 1	0.15 - 0.5 MHz, 97 dBμV (quasi peak) 84 dBμV (average)
RJ45 test 2	0.5 – 30 MHz, 87 dBμV (quasi peak) 74 dBμV (average)

13.13 RADIATED EMISSIONS

Radiated Emissions	
Compliance	EN 55022: 2010
Test 1	30 – 230 MHz, 40 dBμV/m at 10 m measurement distance
Test 2	230 – 1 GHz, 47 dBμV/m at 10 m measurement distance
Test 3	1 – 2 GHz, 76 dBμV/m at 10 m measurement distance

13.14 POWER FREQUENCY

Radiated Emissions	
Compliance	IEC 60255-22-7:2003
Opto-inputs (Compliance is achieved using the opto-input filter)	300 V common-mode (Class A) 150 V differential mode (Class A)

Note:
Compliance is achieved using the opto-input filter

SYMBOLS AND GLOSSARY

APPENDIX A

1 CHAPTER OVERVIEW

This appendix contains terms and symbols you will find throughout the manual.

This chapter contains the following sections:

2 ACRONYMS AND ABBREVIATIONS

Term	Description
A	Ampere
AA	Application Association
AC / ac	Alternating Current
ACSI	Abstract Communication Service Interface
ACSR	Aluminum Conductor Steel Reinforced
ALF	Accuracy Limit Factor
AM	Amplitude Modulation
ANSI	American National Standards Institute
AR	Auto-Reclose.
ARIP	Auto-Reclose In Progress
ASDU	Application Service Data Unit
ASCII	American Standard Code for Information Interchange
AUX / Aux	Auxiliary
AWG	American Wire Gauge
BAR	Block Auto-Reclose signal.
BCD	Binary Coded Decimal
BCR	Binary Counter Reading
BDEW	Bundesverband der Energie- und Wasserwirtschaft | Startseite (i.e. German Association of Energy and Water Industries)
BMP	BitMaP – a file format for a computer graphic
BOP	Blocking Overreach Protection - a blocking aided-channel scheme.
BRCB	Buffered Report Control Block
BRP	Beacon Redundancy Protocol
BU	Backup: Typically a back-up protection element
C/O	A ChangeOver contact having normally-closed and normally-open connections: Often called a "form C" contact.
CB	Circuit Breaker
CB Aux.	Circuit Breaker auxiliary contacts: Indication of the breaker open/closed status.
CBF	Circuit Breaker Failure protection
CDC	Common Data Class
CF	Control Function
Ch	Channel: usually a communications or signaling channel
CIP	Critical Infrastructure Protection standards
CLK / Clk	Clock
Cls	Close - generally used in the context of close functions in circuit breaker control.
CMV	Complex Measured Value
CNV	Current No Volts
COT	Cause of Transmission
CPNI	Centre for the Protection of National Infrastructure
CRC	Cyclic Redundancy Check
CRP	Cross-network Redundancy Protocol

Term	Description
CRV	Curve (file format for curve information)
CRx	Channel Receive: Typically used to indicate a teleprotection signal received.
CS	Check Synchronism.
CSV	Comma Separated Values (a file format for database information)
CT	Current Transformer
CTRL.	Control
CTS	Current Transformer Supervision: To detect CT input failure.
CTx	Channel Transmit: Typically used to indicate a teleprotection signal send.
CU	Communication Unit
CVT	Capacitor-coupled Voltage Transformer - equivalent to terminology CCVT.
DAU	Data Acquisition Unit
DC	Data Concentrator
DC / dc	Direct Current
DCC	An Omicron compatible format
DDB	Digital Data Bus within the programmable scheme logic: A logic point that has a zero or 1 status. DDB signals are mapped in logic to customize the relay's operation.
DDR	Dynamic Disturbance Recorder
DEF	Directional earth fault protection: A directionalized ground fault aided scheme.
DG	Distributed Generation
DHCP	Dynamic Host Configuration Protocol
DHP	Dual Homing Protocol
Diff	Differential protection.
DIN	Deutsches Institut für Normung (German standards body)
Dist	Distance protection.
DITA	Darwinian Information Typing Architecture
DLDB	Dead-Line Dead-Bus: In system synchronism check, indication that both the line and bus are de-energized.
DLLB	Dead-Line Live-Bus: In system synchronism check, indication that the line is de-energized whilst the bus is energized.
DLR	Dynamic Line Rating
DLY / Dly	Time Delay
DMT	Definite Minimum Time
DNP	Distributed Network Protocol
DPWS	Device Profile for Web Services
DST	Daylight Saving Time
DT	Definite Time: in the context of protection elements: An element which always responds with the same constant time delay on operation. Abbreviation of "Dead Time" in the context of auto-reclose:
DTD	Document Type Definition
DTOC	Definite Time Overcurrent
DTS	Date and Time Stamp
EF or E/F	Earth Fault (Directly equivalent to Ground Fault)
EIA	Electronic Industries Alliance
ELR	Environmental Lapse Rate
ER	Engineering Recommendation

Term	Description
FCB	Frame Count Bit
FFT	Fast Fourier Transform
FIR	Finite Impulse Response
FLC	Full load current: The nominal rated current for the circuit.
FLT / Flt	Fault - typically used to indicate faulted phase selection.
Fn or FN	Function
FPGA	Field Programmable Gate Array
FPS	Frames Per Second
FTP	File Transfer Protocol
FWD, Fwd or Fwd.	Indicates an element responding to a flow in the "Forward" direction
GIF	Graphic Interchange Format – a file format for a computer graphic
GND / Gnd	Ground: used in distance settings to identify settings that relate to ground (earth) faults.
GOOSE	Generic Object Oriented Substation Event
GPS	Global Positioning System
GRP / Grp	Group. Typically an alternative setting group.
GSE	General Substation Event
GSSE	Generic Substation Status Event
GUI	Graphical User Interface
HMI	Human Machine Interface
HIF	High Impedance Fault
HiZ	High Impedance (for Restricted Earth Fault)
HSR	High-availability Seamless Ring
HTML	Hypertext Markup Language
I	Current
I/O	Input/Output
I/P	Input
ICAO	International Civil Aviation Organization
ID	Identifier or Identification. Often a label used to track a software version installed.
IDMT	Inverse Definite Minimum Time. A characteristic whose trip time depends on the measured input (e.g. current) according to an inverse-time curve.
IEC	International Electro-technical Commission
IED	Intelligent Electronic Device
IEEE	Institute of Electrical and Electronics Engineers
IIR	Infinite Impulse Response
Inh	An Inhibit signal
Inst	An element with Instantaneous operation: i.e. having no deliberate time delay.
IP	Internet Protocol
IRIG	InterRange Instrumentation Group
ISA	International Standard Atmosphere
ISA	Instrumentation Systems and Automation Society
ISO	International Standards Organization
JPEF	Joint Photographic Experts Group – a file format for a computer graphic
L	Live
LAN	Local Area Network

Term	Description
LCD	Liquid Crystal Display: The front-panel text display on the relay.
LD	Level Detector: An element responding to a current or voltage below its set threshold.
LDOV	Level Detector for Overvoltage
LDUV	Level Detector for Undervoltage
LED	Light Emitting Diode: Red or green indicator on the front-panel.
LLDB	Live-Line Dead-Bus : In system synchronism check, indication that the line is energized whilst the bus is de-energized.
Ln	Natural logarithm
LN	Logical Node
LoL	A Loss of Load scheme, providing a fast distance trip without needing a signaling channel.
LPDU	Link Protocol Data Unit
LPHD	Logical Physical Device
MC	MultiCast
MCB	Miniature Circuit Breaker
MCL	MiCOM Configuration Language
MICS	Model Implementation Conformance Statement
MMF	Magneto-Motive Force
MMS	Manufacturing Message Specification
MRP	Media Redundancy Protocol
MU	Merging Unit
MV	Measured Value
N	Neutral
N/A	Not Applicable
N/C	A Normally Closed or "break" contact: Often called a "form B" contact.
N/O	A Normally Open or "make" contact: Often called a "form A" contact.
NERC	North American Reliability Corporation
NIST	National Institute of Standards and Technology
NPS	Negative Phase Sequence
NVD	Neutral voltage displacement: Equivalent to residual overvoltage protection.
NXT	Abbreviation of "Next": In connection with hotkey menu navigation.
O/C	Overcurrent
O/P	Output
Opto	A generic term for a digital input.
OSI	Open Systems Interconnection
PCB	Printed Circuit Board
PCT	Protective Conductor Terminal (Ground)
PDC	Phasor Data Concentrator
Ph	Phase - used in distance settings to identify settings that relate to phase-phase faults.
PICS	Protocol Implementation Conformance Statement
PMU	Phasor Measurement Unit
PNG	Portable Network Graphics – a file format for a computer graphic
Pol	Polarize - typically the polarizing voltage used in making directional decisions.
POR	Permissive Over Reach
POST	Power On Self Test

Term	Description
POTT	Permissive Over Reach Transfer Tripping
PRP	Parallel Redundancy Protocol
PSB	Power Swing Blocking, to detect power swing/out of step functions (ANSI 78).
PSL	Programmable Scheme Logic: The part of the relay's logic configuration that can be modified by the user, using the graphical editor within S1 Studio software.
PT	Power Transformer
PTP	Precision Time Protocol
PUR	A Permissive UnderReaching transfer trip scheme (alternative terminology: PUTT).
Q	Quantity defined as per unit value
R	Resistance
RBAC	Role Based Access Control
RCA	Relay Characteristic Angle - The center of the directional characteristic.
REB	Redundant Ethernet Board
REF	Restricted Earth Fault
Rev.	Indicates an element responding to a flow in the "reverse" direction
RMS / rms	Root mean square. The equivalent a.c. current: Taking into account the fundamental, plus the equivalent heating effect of any harmonics.
RP	Rear Port: The communication ports on the rear of the IED
RS232	A common serial communications standard defined by the EIA
RS485	A common serial communications standard defined by the EIA (multi-drop)
RST or Rst	Reset generally used in the context of reset functions in circuit breaker control.
RSTP	Rapid Spanning Tree Protocol
RTU	Remote Terminal Unit
Rx	Receive: Typically used to indicate a communication transmit line/pin.
SBS	Straight Binary Second
SC	Synch-Check or system Synchronism Check.
SCADA	Supervisory Control and Data Acquisition
SCL	Substation Configuration Language
SCU	Substation Control Unit
SEF	Sensitive Earth Fault
SHP	Self Healing Protocol
SIR	Source Impedance Ratio
SMV	Sampled Measured Values
SNTP	Simple Network Time Protocol
SOA	Service Oriented Architecture
SOAP	Simple Object Access Protocol
SOC	Second of Century
SOTF	Switch on to Fault protection. Modified protection on manual closure of the circuit breaker.
SP	Single pole.
SPAR	Single pole auto-reclose.
SPC	Single Point Controllable
SPDT	Single Pole Dead Time. The dead time used in single pole auto-reclose cycles.
SPS	Single Point Status
SQRT	Square Root

Term	Description
STP	Spanning Tree Protocol
SV	Sampled Values
SVM	Sampled Value Model
TAF	Turbine Abnormal Frequency
TCP	Transmission Control Protocol
TCS	Trip Circuit Supervision
TD	Time Dial. The time dial multiplier setting: Applied to inverse-time curves (ANSI/IEEE).
TE	Unit for case measurements: One inch = 5TE units
THD	Total Harmonic Distortion
TICS	Technical Issues Conformance Statement
TIFF	Tagged Image File Format – a file format for a computer graphic
TLS	Transport Layer Security protocol
TMS	Time Multiplier Setting: Applied to inverse-time curves (IEC)
TOC	Trip On Close ("line check") protection. Offers SOTF and TOR functionality.
TOR	Trip On Reclose protection. Modified protection on autoreclosure of the circuit breaker.
TP	Two-Part
TUC	Timed UnderCurrent
TVE	Total Vector Error
Tx	Transmit
UDP	User Datagram Protocol
UPCT	User Programmable Curve Tool
USB	Universal Serial bus
UTC	Universal Time Coordinated
V	Voltage
VA	Phase A voltage: Sometimes L1, or red phase
VB	Phase B voltage: Sometimes L2, or yellow phase
VC	Phase C voltage: Sometimes L3, or blue phase
VDR	Voltage Dependant Resistor
VT	Voltage Transformer
VTS	Voltage Transformer Supervision: To detect VT input failure.
WAN	Wide Area Network
XML	Extensible Markup Language
XSD	XML Schema Definition
ZS / ZL	Source to Line Impedance Ratio

3 UNITS FOR DIGITAL COMMUNICATIONS

Unit	Description
b	bit
B	Byte
kb	Kilobit(s)
kbps	Kilobits per second
kB	Kilobyte(s)
Mb	Megabit(s)
Mbps	Megabits per second
MB	Megabyte(s)
Gb	Gigabit(s)
Gbps	Gigabits per second
GB	Gigabyte(s)
Tb	Terabit(s)
Tbps	Terabits per second
TB	Terabyte(s)

4 AMERICAN VS BRITISH ENGLISH TERMINOLOGY

British English	American English
…ae…	…e…
…ence	…ense
…ise	…ize
…oe…	…e…
…ogue	…og
…our	…or
…ourite	…orite
…que	…ck
…re	…er
…yse	…yze
Aluminium	Aluminum
Centre	Center
Earth	Ground
Fibre	Fiber
Ground	Earth
Speciality	Specialty

5 LOGIC SYMBOLS AND TERMS

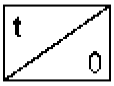
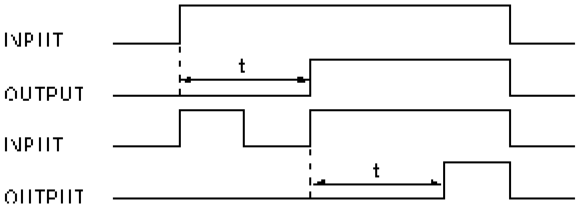
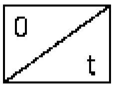
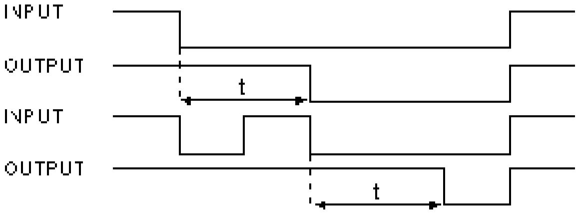
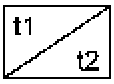
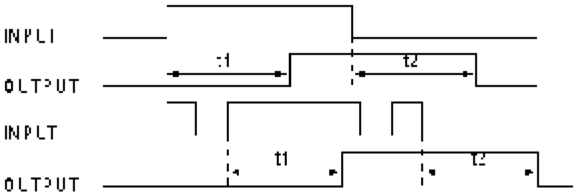
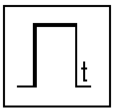
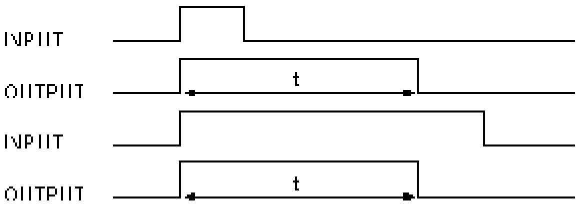
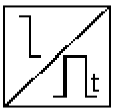
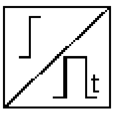
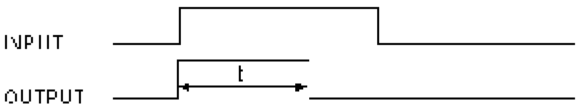
Symbol	Description	Units
&	Logical "AND": Used in logic diagrams to show an AND-gate function.	
Σ	"Sigma": Used to indicate a summation, such as cumulative current interrupted.	
τ	"Tau": Used to indicate a time constant, often associated with thermal characteristics.	
δ	Angular displacement	rad
θ	Angular displacement	rad
Φ	Flux	rad
ϕ	Phase shift	rad
ω	System angular frequency	rad
<	Less than: Used to indicate an "under" threshold, such as undercurrent (current dropout).	
>	Greater than: Used to indicate an "over" threshold, such as overcurrent (current overload)	
1	Logical "OR": Used in logic diagrams to show an OR-gate function.	
ABC	Anti-clockwise phase rotation.	
ACB	Clock-wise phase rotation.	
C	Capacitance	A
df/dt	Rate of Change of Frequency protection	Hz/s
df/dt>1	First stage of df/dt protection	Hz/s
F<1	First stage of underfrequency protection: Could be labeled 81-U in ANSI terminology.	Hz
F>1	First stage of overfrequency protection: Could be labeled 81-O in ANSI terminology.	Hz
fmax	Minimum required operating frequency	Hz
fmin	Minimum required operating frequency	Hz
fn	Nominal operating frequency	Hz
I	Current	A
IÙ	Current raised to a power: Such as when breaker statistics monitor the square of ruptured current squared (Ù power = 2).	An
I'f	Maximum internal secondary fault current (may also be expressed as a multiple of In)	A
I<	An undercurrent element: Responds to current dropout.	A
I>>	Current setting of short circuit element	In
I>1	First stage of phase overcurrent protection: Could be labeled 51-1 in ANSI terminology.	A
I>2	Second stage of phase overcurrent protection: Could be labeled 51-2 in ANSI terminology.	A
I>3	Third stage of phase overcurrent protection: Could be labeled 51-3 in ANSI terminology.	A
I>4	Fourth stage of phase overcurrent protection: Could be labeled 51-4 in ANSI terminology.	A
I0	Earth fault current setting Zero sequence current: Equals one third of the measured neutral/residual current.	A
I1	Positive sequence current.	A
I2	Negative sequence current.	A
I2>	Negative sequence overcurrent protection (NPS element).	A
I2pol	Negative sequence polarizing current.	A
IA	Phase A current: Might be phase L1, red phase.. or other, in customer terminology.	A
IB	Phase B current: Might be phase L2, yellow phase.. or other, in customer terminology.	A
IC	Phase C current: Might be phase L3, blue phase.. or other, in customer terminology.	A
Idiff	Current setting of biased differential element	A

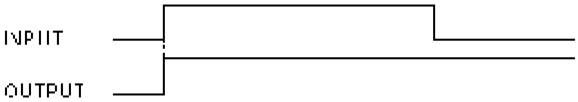
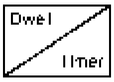
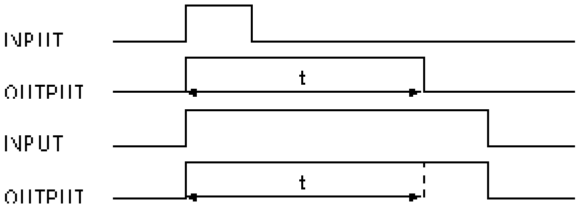
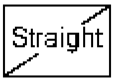
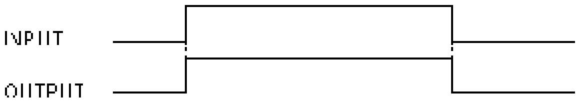
Symbol	Description	Units
If	Maximum secondary through-fault current	A
If max	Maximum secondary fault current (same for all feeders)	A
If max int	Maximum secondary contribution from a feeder to an internal fault	A
If Z1	Maximum secondary phase fault current at Zone 1 reach point	A
Ife	Maximum secondary through fault earth current	A
IfeZ1	Maximum secondary earth fault current at Zone 1 reach point	A
Ifn	Maximum prospective secondary earth fault current or 31 x I> setting (whichever is lowest)	A
Ifp	Maximum prospective secondary phase fault current or 31 x I> setting (whichever is lowest)	A
Im	Mutual current	A
IM64	InterMiCOM^{64}.	
IMx	InterMiCOM^{64} bit (x=1 to 16)	
In	Current transformer nominal secondary current. The rated nominal current of the relay: Software selectable as 1 amp or 5 amp to match the line CT input.	A
IN	Neutral current, or residual current: This results from an internal summation of the three measured phase currents.	A
IN>	A neutral (residual) overcurrent element: Detects earth/ground faults.	A
IN>1	First stage of ground overcurrent protection: Could be labeled 51N-1 in ANSI terminology.	A
IN>2	Second stage of ground overcurrent protection: Could be labeled 51N-2 in ANSI terminology.	A
Is	Value of stabilizing current	A
IS1	Differential current pick-up setting of biased differential element	A
IS2	Bias current threshold setting of biased differential element	A
ISEF>	Sensitive earth fault overcurrent element.	A
Isn	Rated secondary current (I secondary nominal)	A
Isp	Stage 2 and 3 setting	A
Ist	Motor start up current referred to CT secondary side	A
K	Dimensioning factor	
K1	Lower bias slope setting of biased differential element	%
K2	Higher bias slope setting of biased differential element	%
Ke	Dimensioning factor for earth fault	
km	Distance in kilometers	
Kmax	Maximum dimensioning factor	
Krpa	Dimensioning factor for reach point accuracy	
Ks	Dimensioning factor dependent upon through fault current	
Kssc	Short circuit current coefficient or ALF	
Kt	Dimensioning factor dependent upon operating time	
kZm	The mutual compensation factor (mutual compensation of distance elements and fault locator for parallel line coupling effects).	
kZN	The residual compensation factor: Ensuring correct reach for ground distance elements.	
L	Inductance	A
mi	Distance in miles.	
N	Indication of "Neutral" involvement in a fault: i.e. a ground (earth) fault.	
P1	Used in IEC terminology to identify the primary CT terminal polarity: Replace by a dot when using ANSI standards.	
P2	Used in IEC terminology to identify the primary CT terminal polarity: The non-dot terminal.	
Pn	Rotating plant rated single phase power	W
PN>	Wattmetric earth fault protection: Calculated using residual voltage and current quantities.	

Symbol	Description	Units
R	Resistance	W
R Gnd.	A distance zone resistive reach setting: Used for ground (earth) faults.	
R Ph	A distance zone resistive reach setting used for Phase-Phase faults.	
Rct	Secondary winding resistance	W
Rl	Resistance of single lead from relay to current transformer	W
Rr	Resistance of any other protective relays sharing the current transformer	W
Rrn	Resistance of relay neutral current input	W
Rrp	Resistance of relay phase current input	W
Rs	Value of stabilizing resistor	W
Rx	Receive: typically used to indicate a communication receive line/pin.	
S1	Used in IEC terminology to identify the secondary CT terminal polarity: Replace by a dot when using ANSI standards.	
S2	Used in IEC terminology to identify the secondary CT terminal polarity: The non-dot terminal.	
t	A time delay.	
t'	Duration of first current flow during auto-reclose cycle	s
T1	Primary system time constant	s
tfr	Auto-reclose dead time	s
tIdiff	Current differential operating time	s
Ts	Secondary system time constant	s
Tx	Transmit: typically used to indicate a communication transmit line/pin.	
V	Voltage.	V
V<	An undervoltage element.	V
V<1	First stage of undervoltage protection: Could be labeled 27-1 in ANSI terminology.	V
V<2	Second stage of undervoltage protection: Could be labeled 27-2 in ANSI terminology.	V
V>	An overvoltage element.	V
V>1	First stage of overvoltage protection: Could be labeled 59-1 in ANSI terminology.	V
V>2	Second stage of overvoltage protection: Could be labeled 59-2 in ANSI terminology.	V
V0	Zero sequence voltage: Equals one third of the measured neutral/residual voltage.	V
V1	Positive sequence voltage.	V
V2	Negative sequence voltage.	V
V2pol	Negative sequence polarizing voltage.	V
VA	Phase A voltage: Might be phase L1, red phase.. or other, in customer terminology.	V
VB	Phase B voltage: Might be phase L2, yellow phase.. or other, in customer terminology.	V
VC	Phase C voltage: Might be phase L3, blue phase.. or other, in customer terminology.	V
Vf	Theoretical maximum voltage produced if CT saturation did not occur	V
Vin	Input voltage e.g. to an opto-input	V
Vk	Required CT knee-point voltage. IEC knee point voltage of a current transformer.	V
VN	Neutral voltage displacement, or residual voltage.	V
Vn	Nominal voltage	V
Vn	The rated nominal voltage of the relay: To match the line VT input.	V
VN>1	First stage of residual (neutral) overvoltage protection.	V
VN>2	Second stage of residual (neutral) overvoltage protection.	V
Vres.	Neutral voltage displacement, or residual voltage.	V
Vs	Value of stabilizing voltage	V

Symbol	Description	Units
Vx	An auxiliary supply voltage: Typically the substation battery voltage used to power the relay.	V
WI	Weak Infeed logic used in teleprotection schemes.	
X	Reactance	None
X/R	Primary system reactance/resistance ratio	None
Xe/Re	Primary system reactance/resistance ratio for earth loop	None
Xt	Transformer reactance (per unit)	p.u.
Y	Admittance	p.u.
Z	Impedance	p.u.
Z0	Zero sequence impedance.	
Z1	Positive sequence impedance.	
Z1	Zone 1 distance protection.	
Z1X	Reach-stepped Zone 1X, for zone extension schemes used with auto-reclosure.	
Z2	Negative sequence impedance.	
Z2	Zone 2 distance protection.	
ZP	Programmable distance zone that can be set forward or reverse looking.	
Zs	Used to signify the source impedance behind the relay location.	
Φal	Accuracy limit flux	Wb
Ψr	Remanent flux	Wb
Ψs	Saturation flux	Wb

6 LOGIC TIMERS

Logic symbols	Explanation	Time chart
	Delay on pick-up timer, t	
	Delay on drop-off timer, t	
	Delay on pick-up/drop-off timer	
	Pulse timer	
	Pulse pick-up falling edge	
	Pulse pick-up raising edge	

Logic symbols	Explanation	Time chart
	Latch	
	Dwell timer	
	Straight (non latching): Hold value until input reset signal	

7 LOGIC GATES

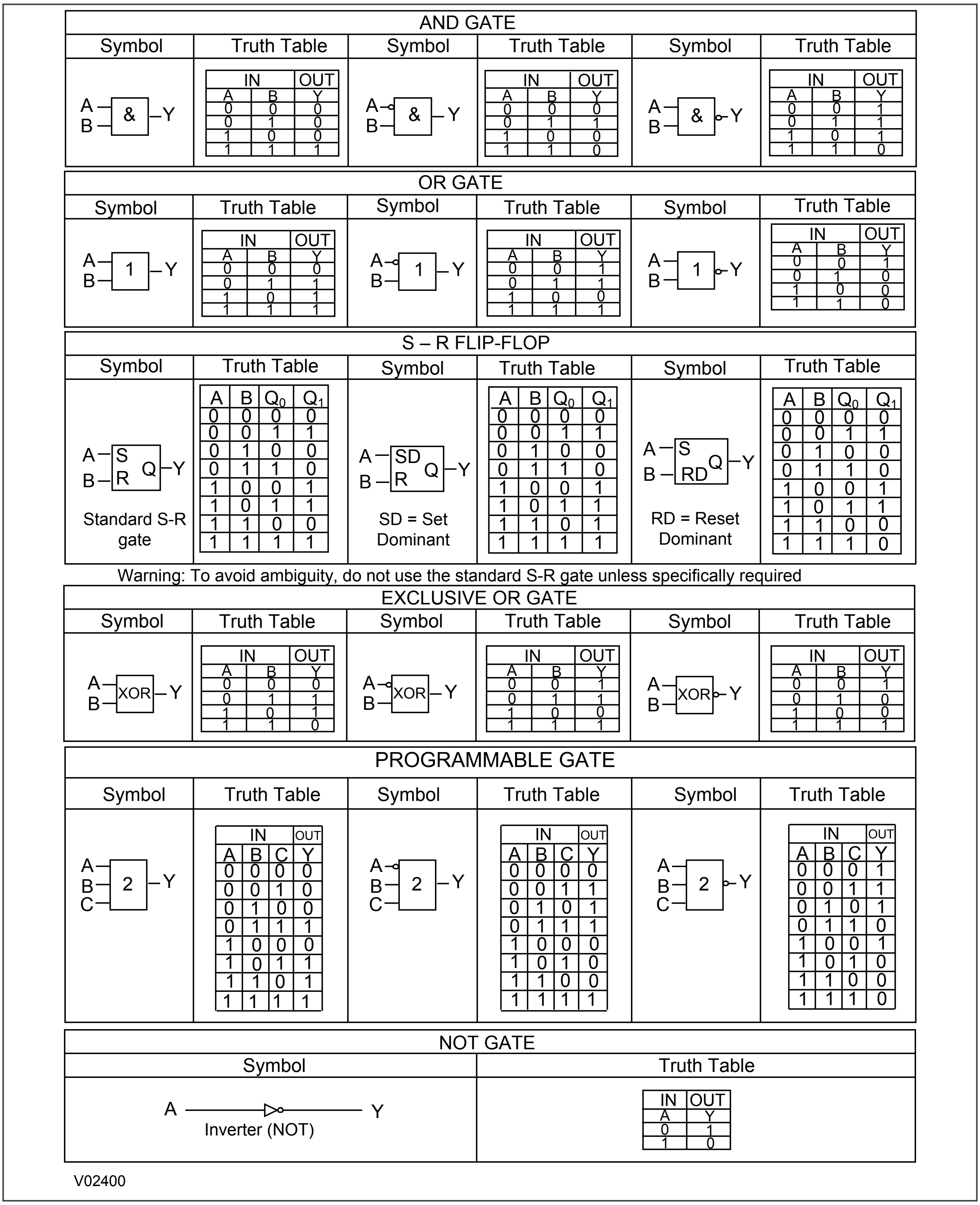


Figure 170: Logic Gates

COMMISSIONING RECORD

APPENDIX B

1 TEST RECORD

1.1 ENGINEER DETAILS

Item	Value
Engineer's name	
Commissioning date	
Station	
Circuit	
System Frequency	
VT Ratio	
CT Ratio	

1.2 FRONT PLATE INFORMATION

Item	Value
Device	
Model number	
Serial number	
Rated current In	
Rated voltage Vn	
Auxiliary voltage Vx	

1.3 TEST EQUIPMENT

Test Equipment	Model	Serial Number
Injection test set		
Phase angle meter		
Phase rotation meter		
Insulation tester		
Setting application software		
IEC61850 configurator software		
DNP3 configurator software		

1.4 TESTS WITH PRODUCT DE-ENERGISED

Test	Result (mark where appropriate)
Was the IED damaged on visual inspection?	Yes / No
Is the rating information correct for installation?	Yes / No
Is the case earth installed?	Yes / No
Are the current transformer shorting contacts closed?	Yes / No / Not checked
Is the insulation resistance >100 MOhms at 500 V DC?	Yes / No / Not tested
Wiring checked against diagram?	Yes / No
Test block connections checked?	Yes / No / N/A

Test	Result (mark where appropriate)
N/C Watchdog contacts closed?	Yes / No
N/O Watchdog contacts open?	Yes / No
Measured auxiliary supply	……………………..V DC / AC

1.5 TESTS WITH PRODUCT ENERGISED

General Tests	Result (mark where appropriate)
N/C Watchdog contacts open?	Yes / No
N/O Watchdog contacts closed?	Yes / No
LCD contrast setting used	....
Clock set to local time?	Yes / No
Time maintained when auxiliary supply removed?	Yes / No
Alarm (yellow) LED working?	Yes / No
Out of service (yellow) LED working?	Yes / No
Programmable LEDs working?	Yes / No
All opto-inputs working?	Yes / No
All output relays working?	Yes / No

1.6 COMMUNICATION TESTS

Communications	Result (mark where appropriate)
SCADA Communication standard (Courier, DNP3.0, IEC61850, IEC60870, Modbus)	
Communications established?	Yes / No
Protocol converter tested?	Yes / No / N/A

1.7 CURRENT INPUT TESTS

Current Inputs (if applicable)		Result (mark where appropriate)
Displayed current		Primary / Secondary
Phase CT ratio (if applicable)		
Input CT	Applied Value	Displayed Value
IA		
IB		
IC		
IN		
ISEF (if applicable)		

1.8 VOLTAGE INPUT TESTS

Voltage Inputs (if applicable)		Result (mark where appropriate)
Displayed voltage		Primary / Secondary
Main VT ratio (if applicable)		
Input VT	Applied Value	Displayed value

Voltage Inputs (if applicable)		Result (mark where appropriate)
VAN		
VBN		
VCN		

1.9 OVERCURRENT CHECKS

Overcurrent Checks	Result
Overcurrent type	Directional / Non-directional
Applied voltage	V
Applied current	A
Expected operating time	s
Measured operating time	s

1.10 ON-LOAD CHECKS

On-load checks	Result
Test wiring removed?	Yes / No
Voltage inputs and phase rotation OK?	Yes / No
Current inputs and polarities OK?	Yes / No
On-load test performed?	Yes / No
(If No, give reason why) …	
IED is correctly directionalised?	Yes / No / N/A

1.11 ON-LOAD CHECKS

Final Checks	Result
All test equipment, leads, shorts and test blocks removed safely?	Yes / No
Ethernet connected ?	Yes / No / N/A
Disturbed customer wiring re-checked?	Yes / No / N/A
All commissioning tests disabled?	Yes / No
Circuit breaker operations counter reset?	Yes / No / N/A
Current counters reset?	Yes / No / N/A
Event records reset?	Yes / No
Fault records reset?	Yes / No
Disturbance records reset?	Yes / No
Alarms reset?	Yes / No
LEDs reset?	Yes / No

WIRING DIAGRAMS

APPENDIX C

1 APPENDIX OVERVIEW

This chapter contains the wiring diagrams for all possible situations.

This chapter contains the following sections:

2 I/O OPTION A

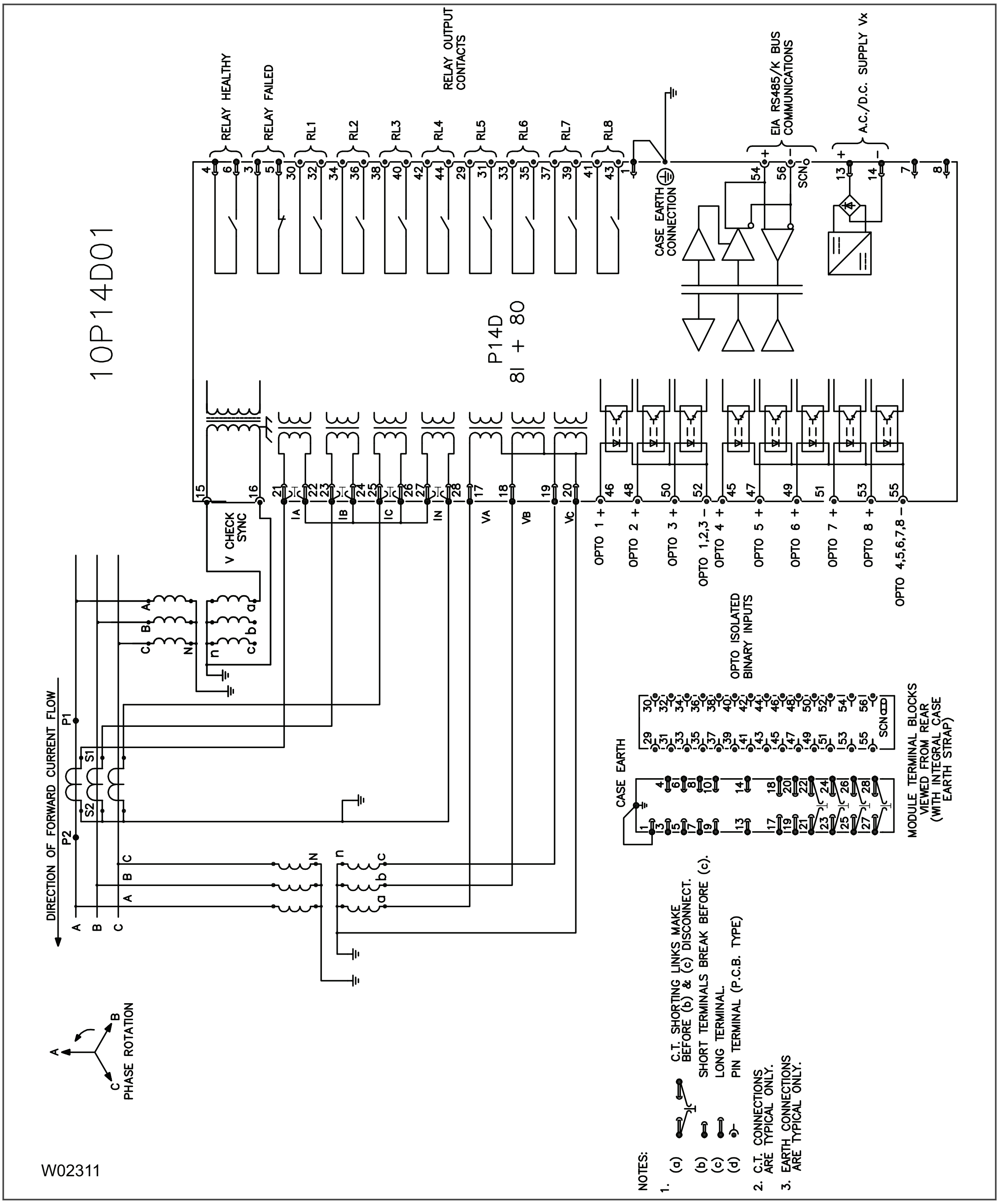


Figure 171: P14D Directional IED with 8 inputs and 8 outputs

3 I/O OPTION A WITH SEF

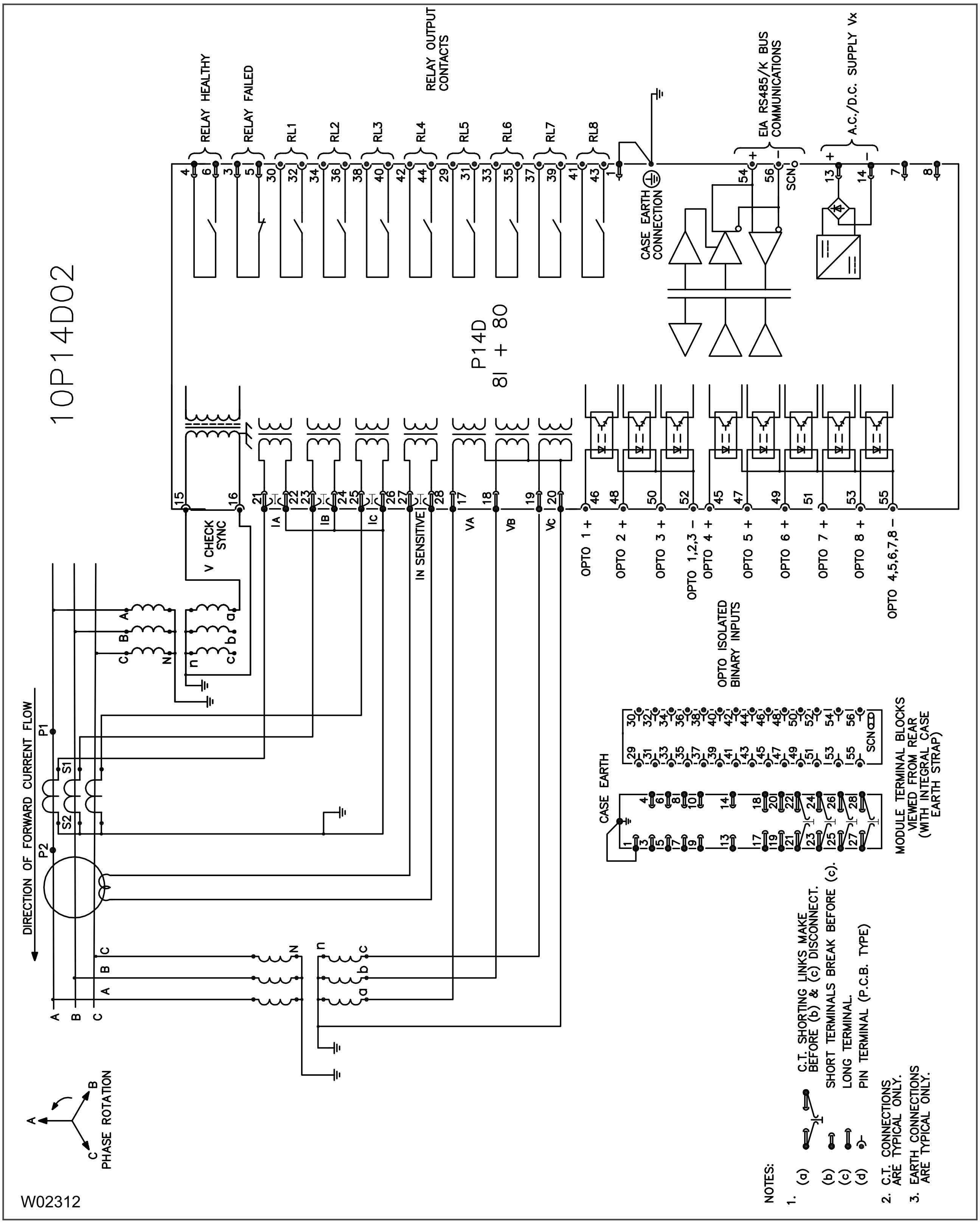


Figure 172: P14D Directional IED with 8 inputs, 8 outputs and SEF option

4 I/O OPTION A WITH ETHERNET

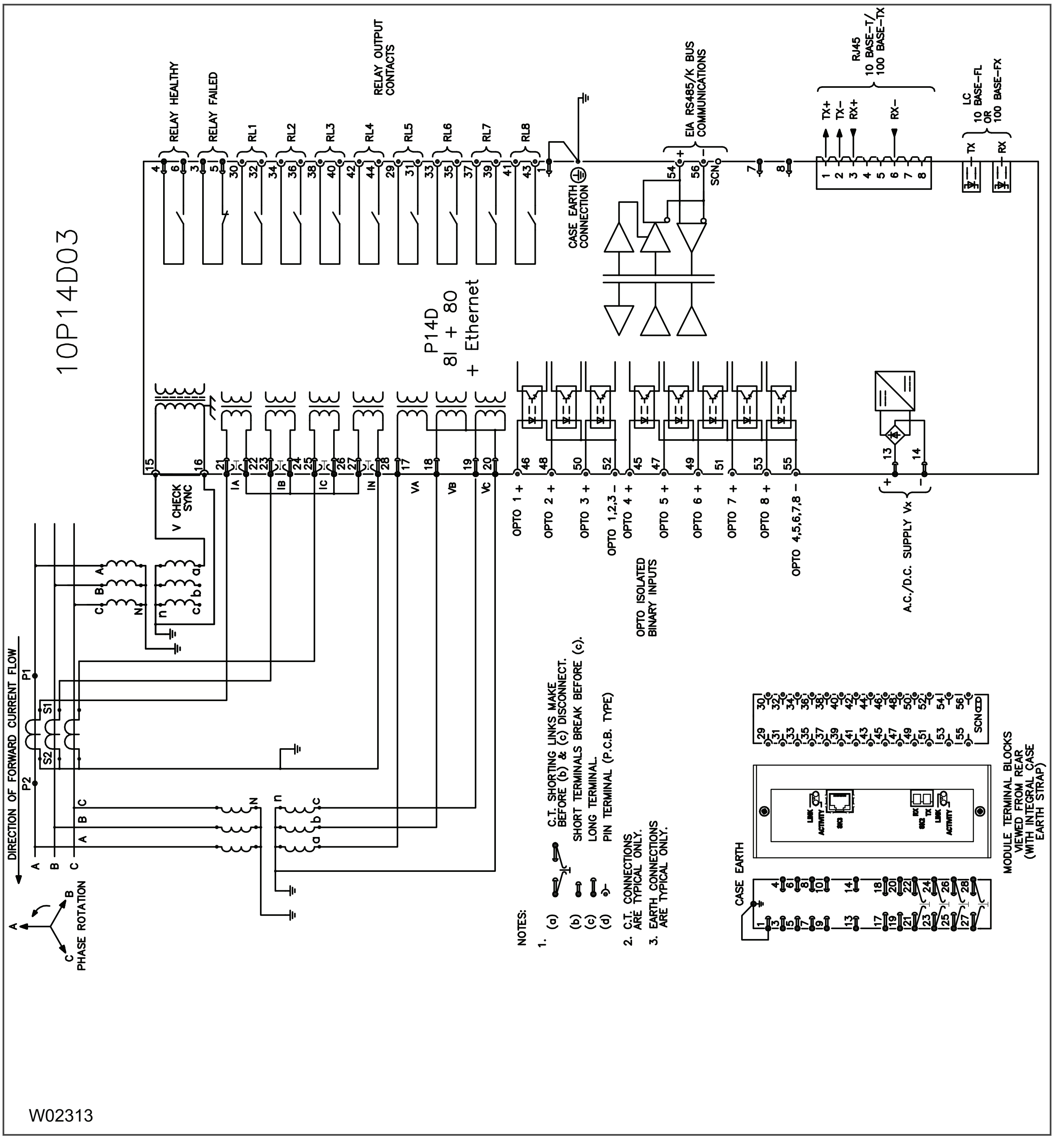


Figure 173: P14D Directional IED with 8 inputs, 8 outputs and Ethernet

5 I/O OPTION A WITH ETHERNET AND SEF

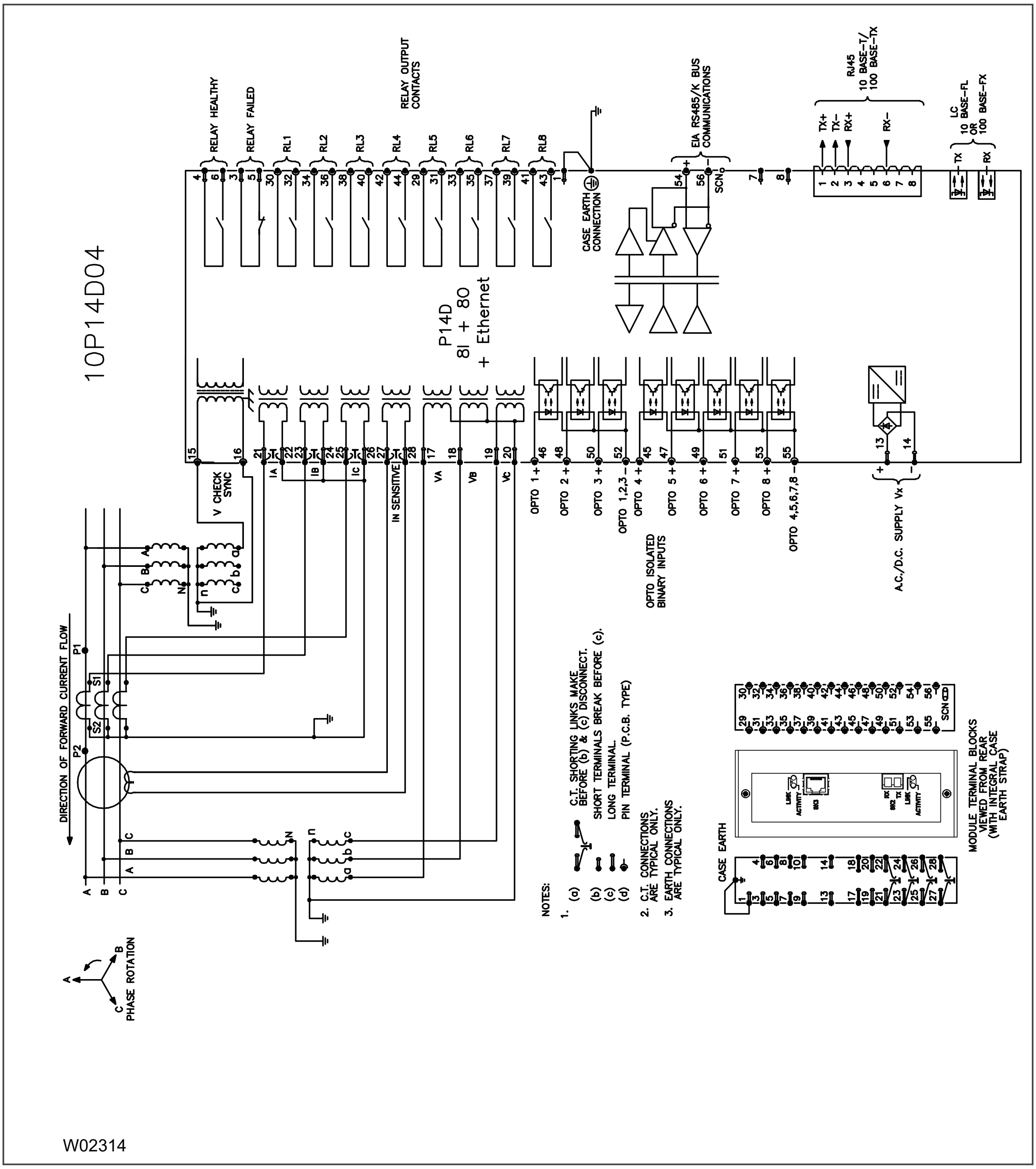


Figure 174: P14D Directional IED with 8 inputs, 8 outputs, Ethernet and SEF option

6 I/O OPTION B WITH 2 REAR PORTS

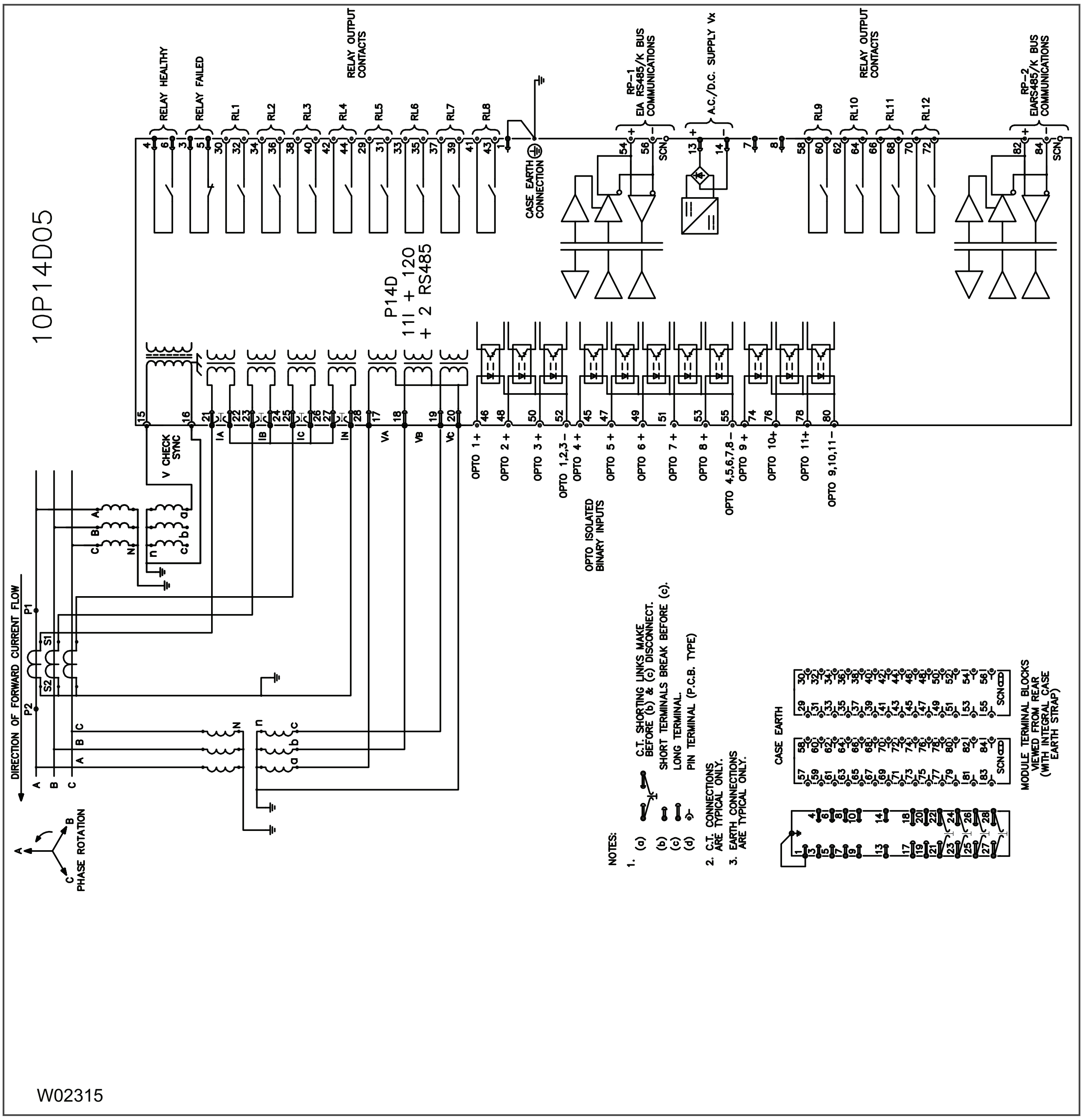


Figure 175: P14D Directional IED with 11 inputs, 12 outputs and two rear ports

7 I/O OPTION B WITH 2 REAR PORTS AND SEF

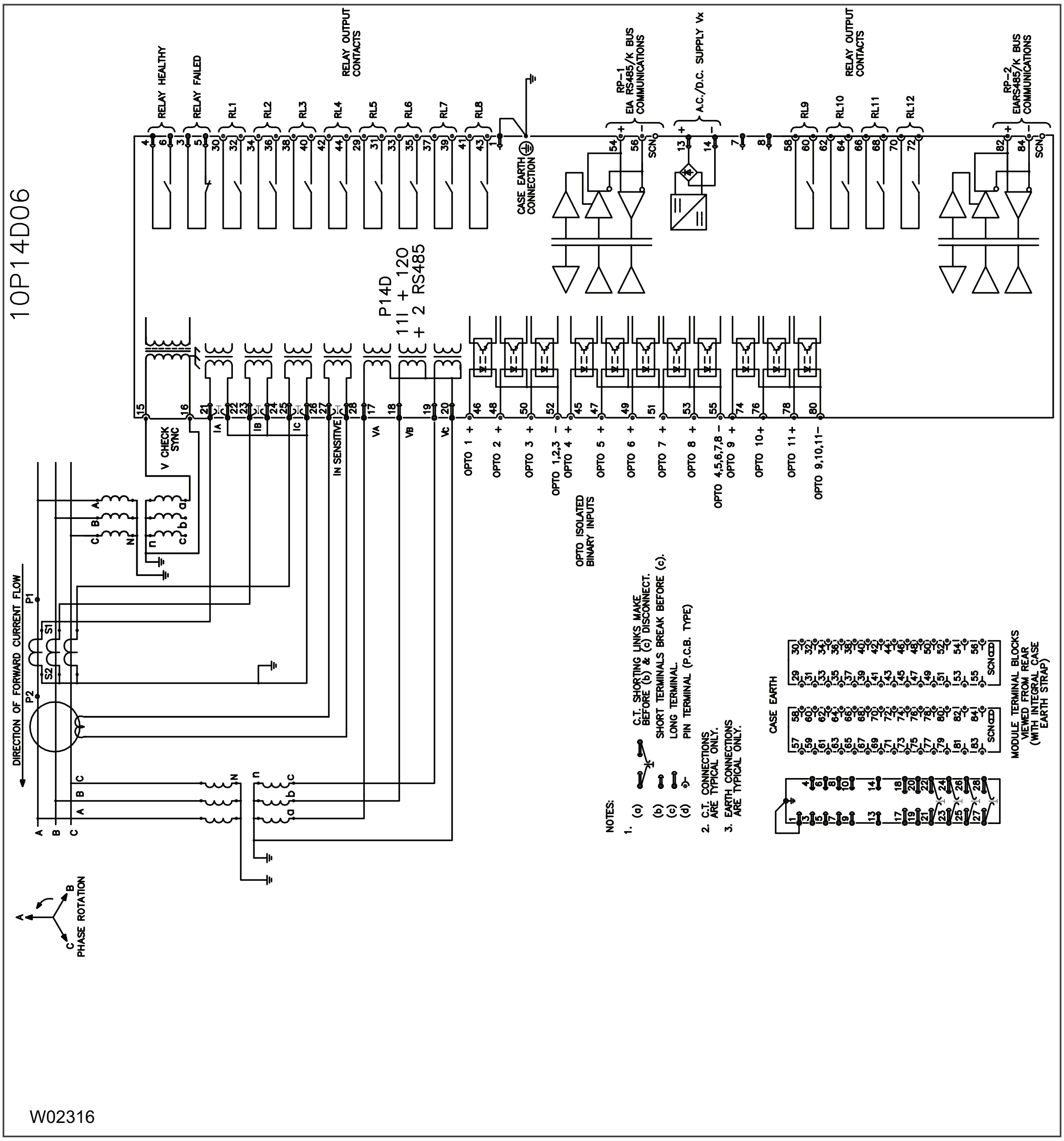


Figure 176: P14D Directional IED with 11 inputs, 12 outputs, 2 rear ports and SEF option

8 I/O OPTION C WITH TCS

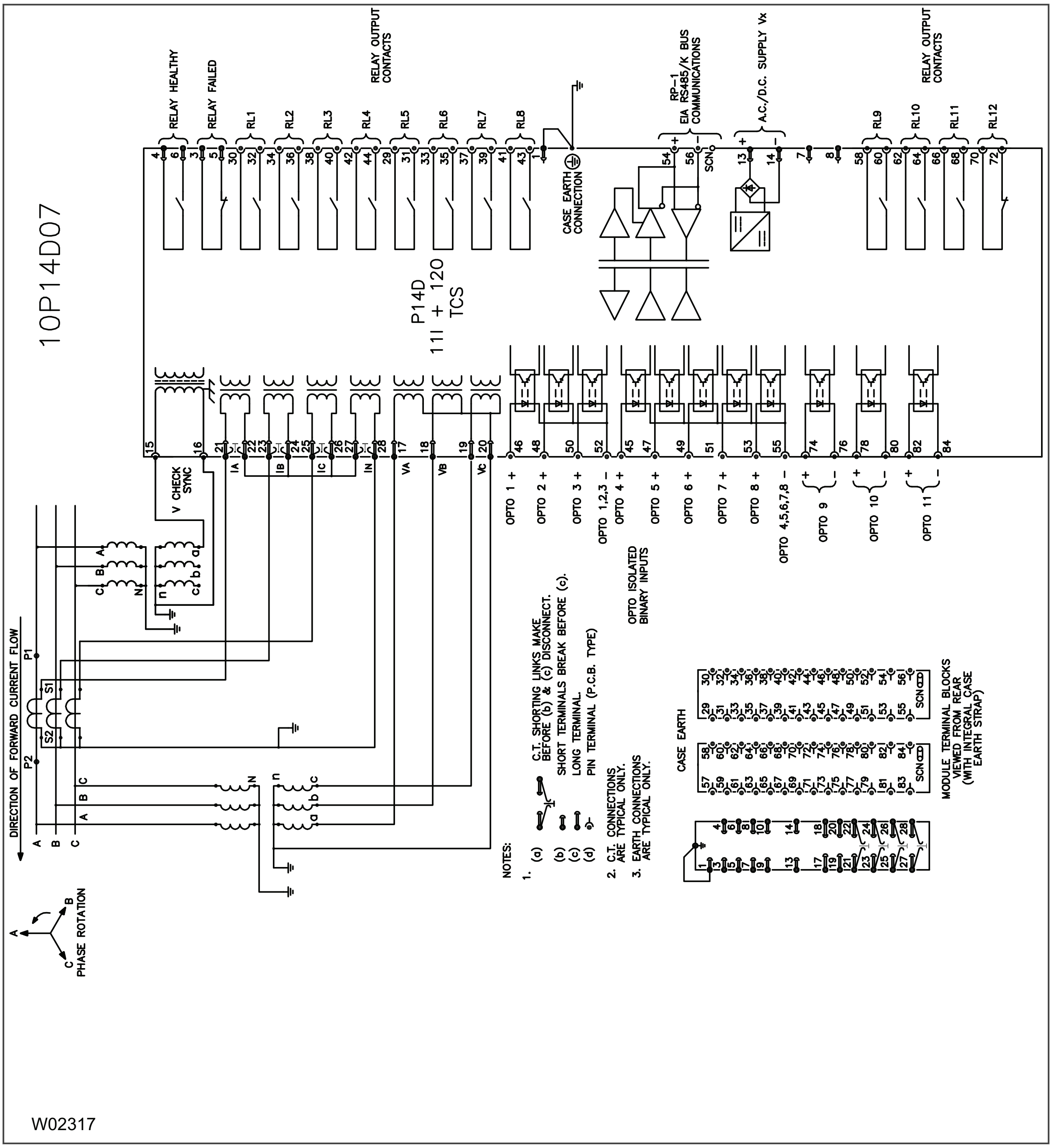


Figure 177: P14D Directional IED with 11 inputs and 12 outputs, for Trip Circuit Supervision

9 I/O OPTION C WITH TCS AND SEF

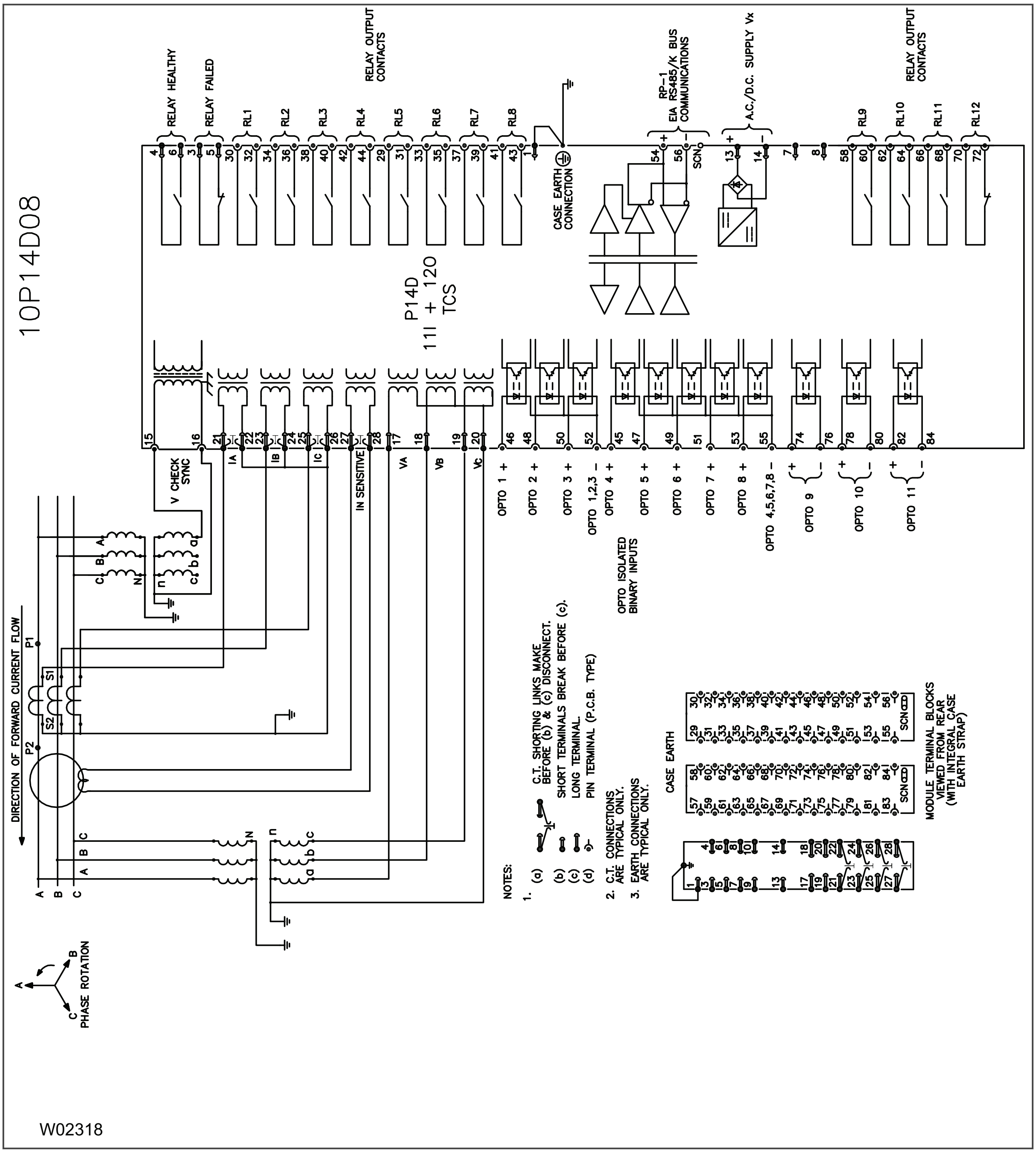


Figure 178: P14D Directional IED with 11 inputs, 12 outputs and SEF option, for trip Circuit Supervision

10 I/O OPTION D

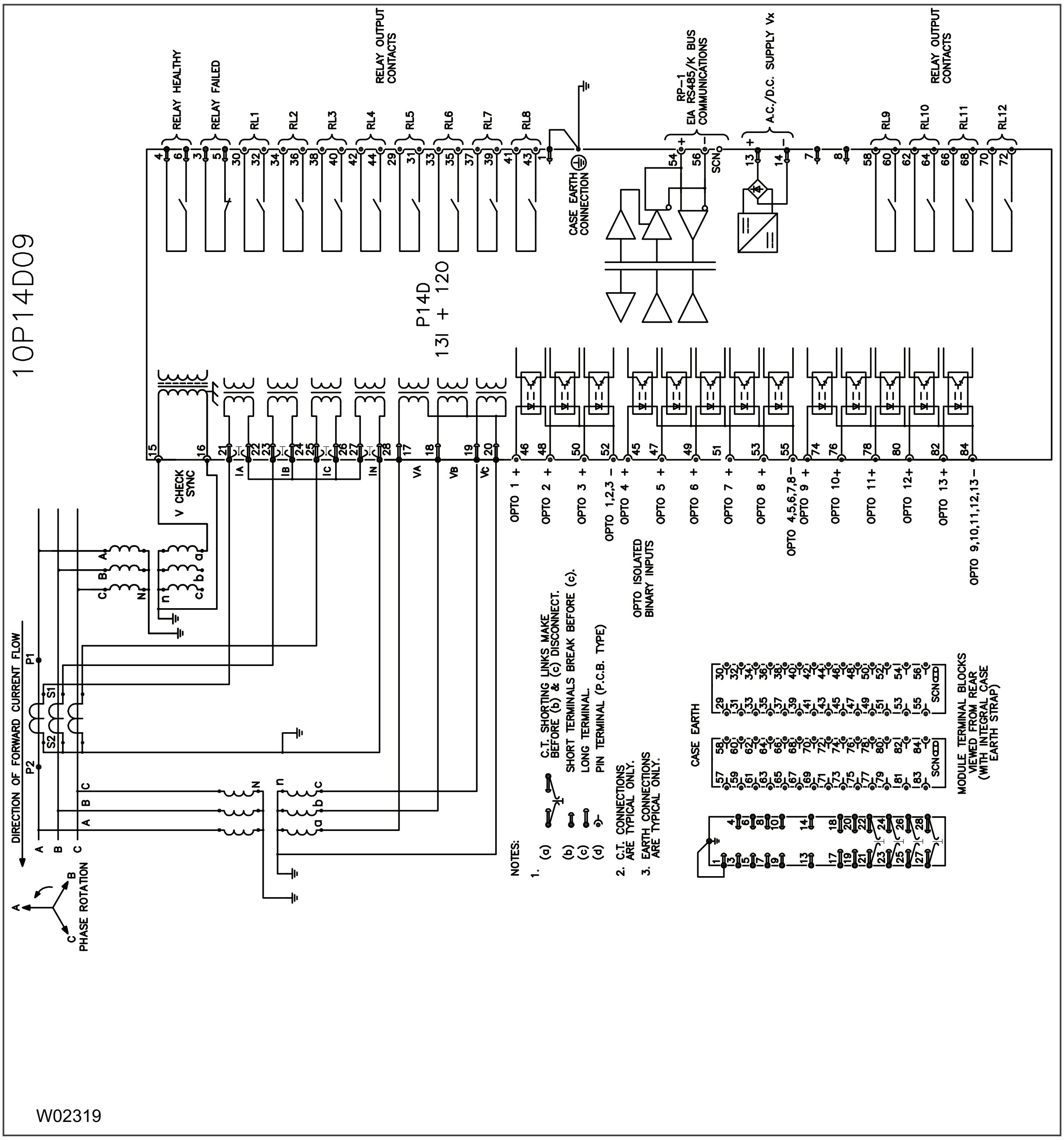


Figure 179: P14D Directional IED with 13 inputs and 12 outputs

11 I/O OPTION D WITH SEF

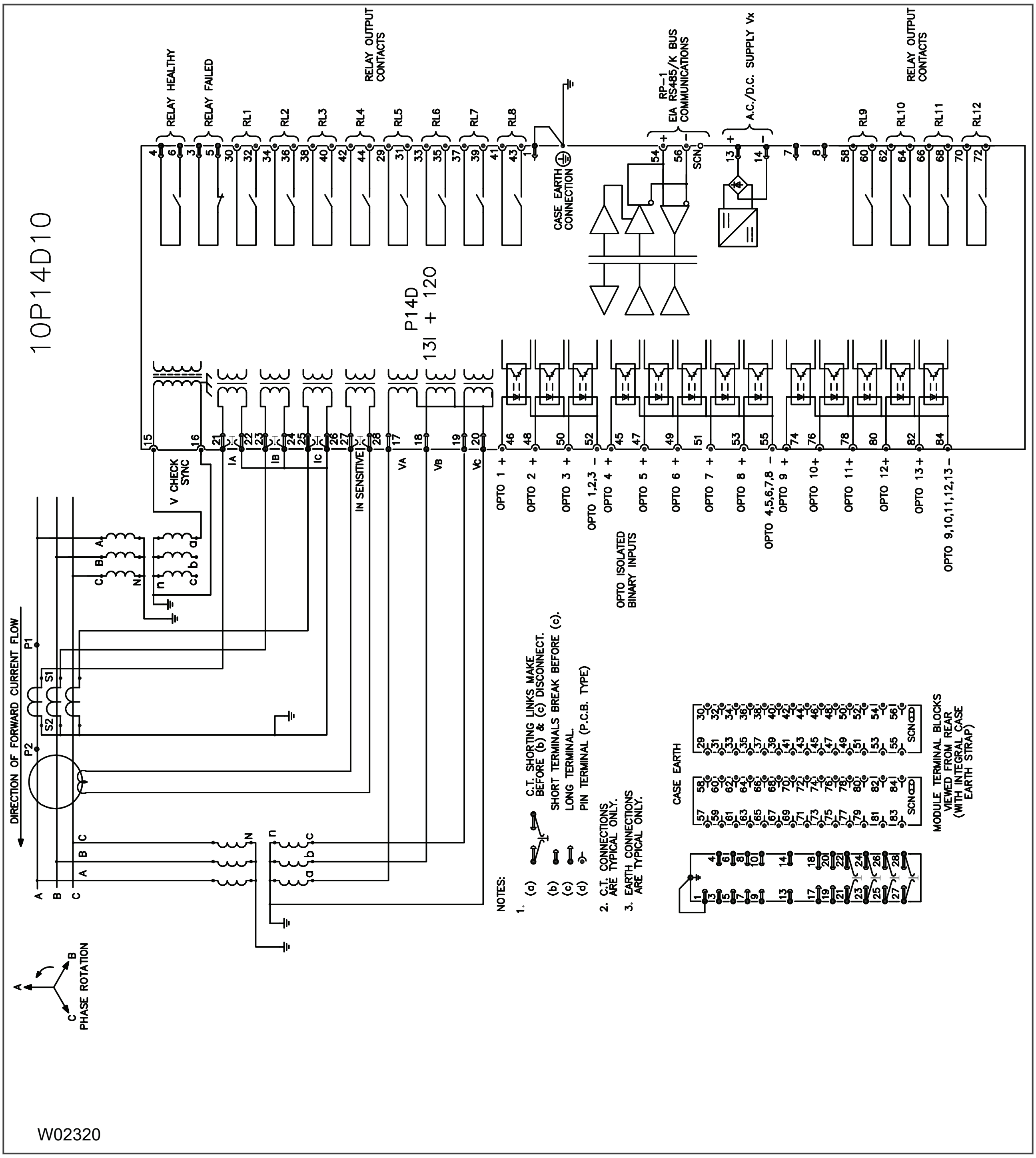


Figure 180: P14D Directional IED with 13 inputs , 12 outputs and SEF option

12 KCEG142 RETROFIT

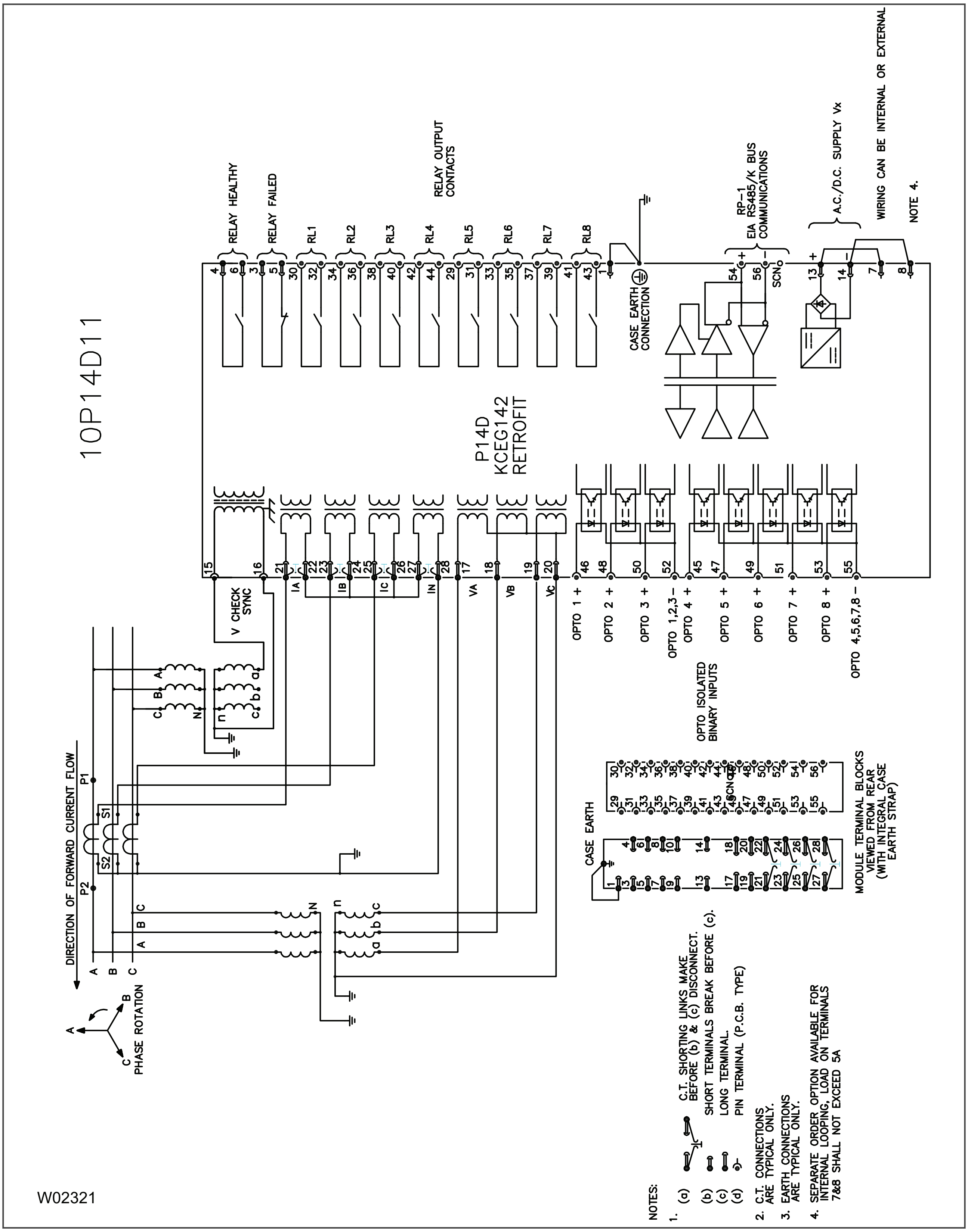


Figure 181: P14D Directional IED with 8 inputs and 8 outputs for KCEG142 retrofit applications

13 I/O OPTION A WITH NVD INPUT

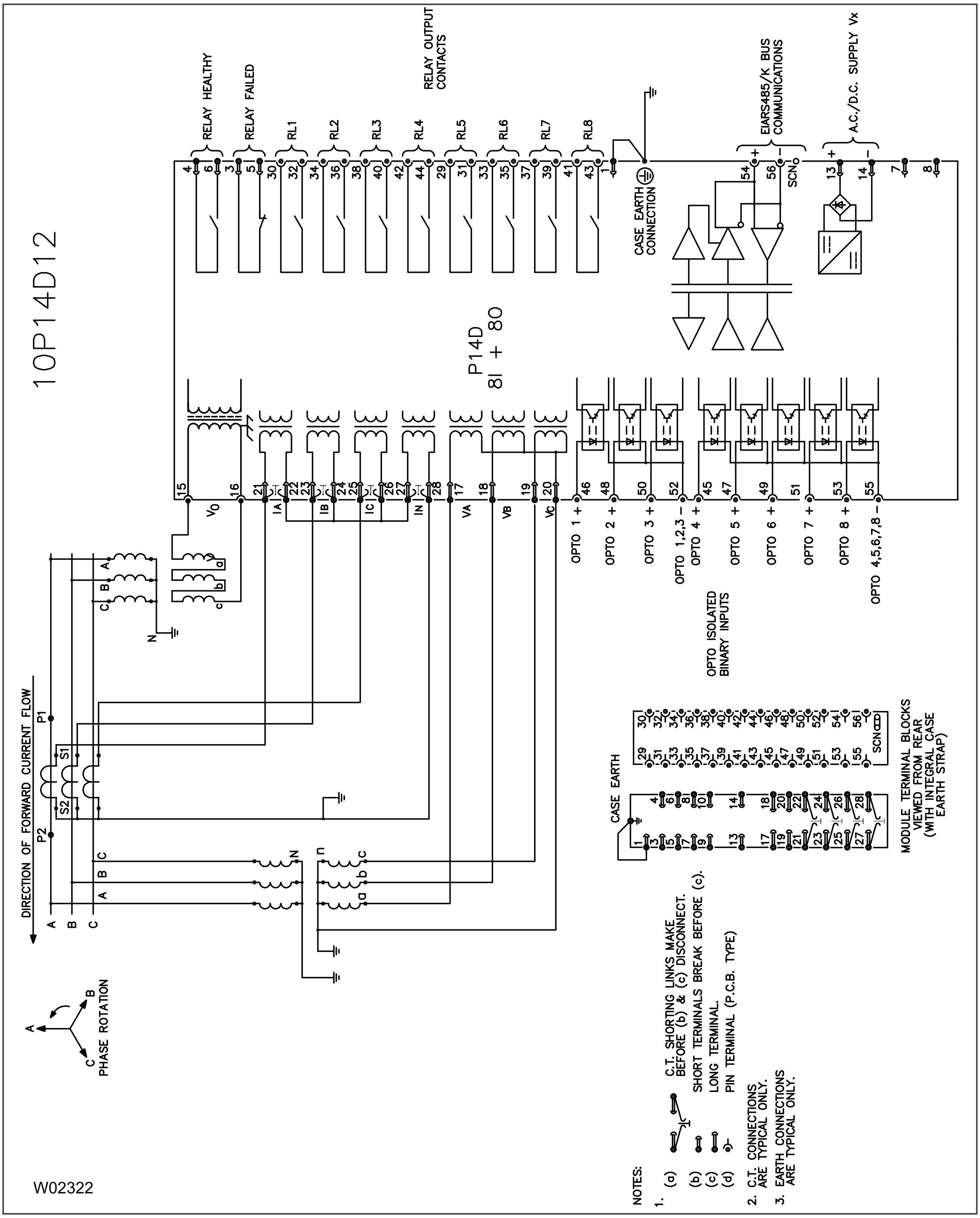


Figure 182: P14D Directional IED with 8 inputs, 8 outputs and NVD input

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