P40 Agile P14N

Technical Manual

Feeder Management IED

Platform Hardware Version: A
Platform Software Version: 51
Publication Reference: P14N-TM-EN-2

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 P14N, 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. Also, 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.
- Filenames and paths use the courier font
  For example: `Example\File.text`
- Special terminology is written with leading capitals
  For example: Sensitive Earth Fault
- If reference is made to the IED's internal settings and signals database, the menu group heading (column) text is written in upper case italics
  For example: The *SYSTEM DATA* column
- If reference is made to the IED's internal settings and signals database, the setting cells and DDB signals are written in bold italics
  For example: The ***Language*** cell in the *SYSTEM DATA* column
- If reference is made to the IED's internal settings and signals database, the value of a cell's content is written in the Courier font
  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: Restricted Earth Fault Protection
- Chapter 7: Circuit Breaker Fail Protection
- Chapter 8: Autoreclose
- Chapter 9: Monitoring and Control Functions
- Chapter 10: SCADA 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 P14N feeder management IED has been designed for the protection of a wide range of overhead lines and underground cables. The P14N provides integral non-directional overcurrent 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 many other features to aid with power system diagnosis and fault analysis.

The P14N can be used in various applications, depending on the chosen firmware. There are two different models according to which firmware is installed: P14NB, P14NZ

- The P14NB is the base device for general application
- The P14NZ is for high impedance earth fault applications

3 FEATURES AND FUNCTIONS

3.1 PROTECTION FUNCTIONS

The P14N models offer the following protection functions:

ANSI	IEC 61850	Protection Function	P14NB	P14NZ
37		Undercurrent detection (low load)	Yes	Yes
46	NgcPTOC	Negative sequence overcurrent	Yes	Yes
46BC		Broken Conductor	Yes	Yes
49	ThmPTTR	Thermal Overload	Yes	Yes
50 SOTF		Switch onto Fault	Yes	Yes
50BF	RBRF	CB Failure	Yes	Yes
50	OcpPTOC	Definite time overcurrent protection	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
51	OcpPTOC	IDMT overcurrent protection (stages)	Yes	Yes
51N	EfdPTOC	Neutral/Ground IDMT overcurrent protection	Yes	Yes
64N	RefPDIF	Restricted Earth Fault	Yes	Yes
		Sensitive Earth Fault (with SEF CT only)	Yes	Yes
68		2nd Harmonic Blocking	Yes	Yes
79	RREC	Autoreclose (3 phases)	No	4 shots
		Cold load pick up	Yes	Yes
		High Impedance Earth Fault	No	Yes
		Blocking scheme	Yes	Yes
		Programmable curves	Yes	Yes
		CB Monitoring	Yes	Yes
86		Latching output contacts (Lockout)	Yes	Yes

3.2 CONTROL FUNCTIONS

Feature	IEC 61850	ANSI
Power-up diagnostics and continuous self-monitoring		
Fully customizable menu texts		
Function keys	FnkGGIO	
Alternative setting groups (4)		
Programmable LEDs	LedGGIO	
Programmable hotkeys		
Watchdog contacts		
Read-only mode		
NERC compliant cyber-security		
Programmable allocation of digital inputs and outputs		
Control inputs	PloGGIO1	
Graphical programmable scheme logic (PSL)		
Circuit breaker control, status & condition monitoring	XCBR	52
Trip circuit and coil supervision		

Feature	IEC 61850	ANSI
CT supervision (only for products with VT inputs)		
VT supervision (only for products with VT inputs)		
Fault locator (only for products with VT inputs)	RFLO	

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 or Ethernet
Seriall Protocols available	IEC 60870-5-103, MODBUS, Courier, DNP3
Ethernet Protocols available	IEC 61850, DNP3 over Ethernet
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 chapter.

Compliance Standards

Condition	Compliance
EMC compliance (compulsory)	2004/108/EC (demonstrated by EN60255-26:2009)
Product safety (compulsory)	2006/95/EC (demonstrated by EN60255-27:2005)
R&TTE Compliance (compulsory)	99/5/EC
EMC	EN50263, IEC 60255-22-1/2/3/4/5/6/7, IEC 61000-4-5/6/8/9/10/16 EN61000-4-3/18, IEEE/ANSI C37.90.1/2/3, ENV50204, EN55022
Product Safety for North America	UL/CL File No. UL/CUL E202519
Environmental conditions	IEC 60255-27:2005, IEC 60068-2-78:2001, -30:2005, -42:2003, -42:2003
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 60529:2002 – IP10, IP30, IP52
Mechanical robustness	IEC 60255-21-1/2/3
Documentation	IEC 60255-151

5 FUNCTIONAL OVERVIEW

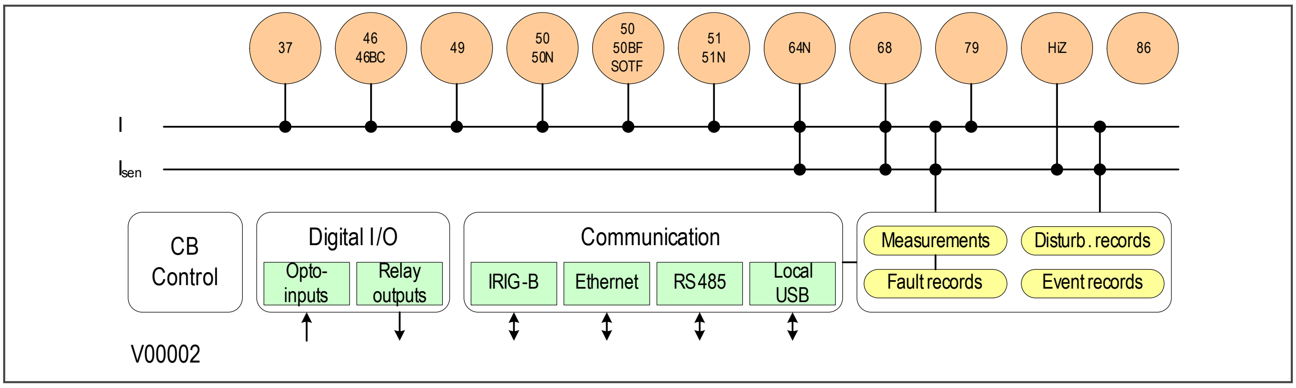


Figure 1: Functional Overview

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 - Non Directional	P14N										
Application											
Base		B									
Autoreclose (plus HIF when used with SEF CT)		Z									
Current transformer											
Standard Earth CT			1								
SEF CT			2								
Hardware Options											
EIA RS485 only				1							
Two ports - EIA RS 485 and Ethernet - Single channel Fibre/Copper				6							
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/EAI 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/EAI RS485						8					
Case											
20TE Flush (no function keys, 4 programmable LEDs)							B				
30TE Flush (3 function keys with LEDs, 8 programmable LEDs)							C				
Software only							0				
20TE Flush (Adapted field voltage for KCGG retrofit)							2				
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

V00005

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.

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.

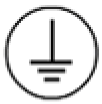
3 SYMBOLS

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 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 so 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:
Use a suitable protective barrier 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 reducing 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

The information in this section is applicable only to equipment carrying UL/CSA/CUL markings.

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, install the equipment using UL/CSA-recognised parts for: cables, protective fuses, fuse holders and circuit breakers, insulation crimp terminals, and replacement internal batteries.

4.4 FUSING REQUIREMENTS

Caution:
Where UL/CSA listing of the equipment is required 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).
For P60 models, use a 4A maximum T-type fuse.

Caution:
Auxiliary supply wiring and digital input circuits should be protected by a high rupture capacity NIT or TIA fuse with maximum rating of 16 A. for safety reasons, current transformer circuits must never be fused. Other circuits should be appropriately fused to protect the wire used.

4.5 EQUIPMENT CONNECTIONS

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

Caution:
Tighten M4 clamping screws of heavy duty terminal block connectors to a nominal torque of 1.3 Nm.
Tighten captive screws of terminal blocks to 0.5 Nm minimum and 0.6 Nm maximum.

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 on some products. We strongly recommend that you hard wire these contacts into the substation's automation system, for alarm purposes.

4.6 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 stud-connected PCTs.

Caution:
The recommended minimum PCT wire size is 2.5 mm^2 for countries whose mains supply is 230 V (e.g. Europe) and 3.3 mm^2 for countries whose mains supply is 110 V (e.g. North America). This may be superseded by local or country wiring regulations.
For P60 products, the recommended minimum PCT wire size is 6 mm^2. See manual for details.

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.

4.7 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.

4.8 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. Short the secondary of the line CT before opening any connections to it.

Note:
For most Alstom equipment with ring-terminal connections, the threaded terminal block for current transformer termination is automatically shorted when the module is removed. 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. Ensure that CT shorting links are in place before removing MMLB test plugs, to avoid potentially lethal voltages.

4.9 UPGRADING/SERVICING

Warning:
Do not insert or withdraw modules, PCBs or expansion boards from the equipment while energised, as this may result in damage to the equipment. Hazardous live voltages would also be exposed, 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, completely isolate 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 using the external terminals before to decommissioning.

Caution:
Avoid incineration or disposal to water courses. Dispose of the equipment in a safe, responsible 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 following figure, which shows typical modules and the flow of data between them.

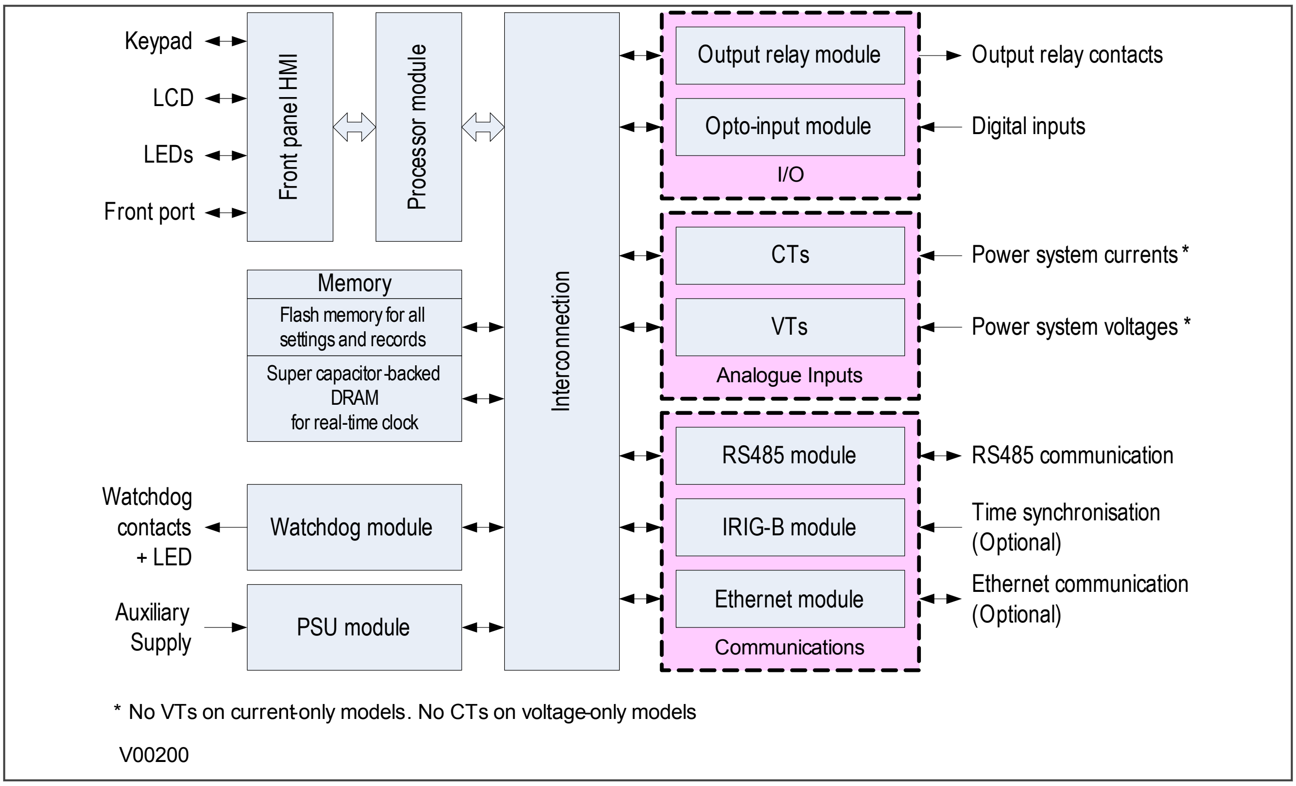


Figure 2: Hardware design overview

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.

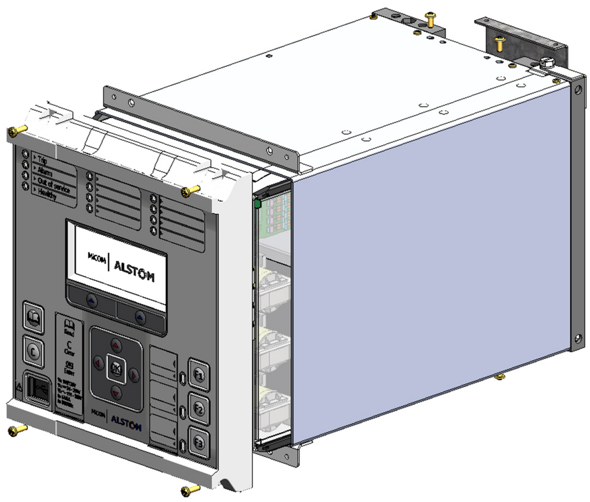


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Figure 3: Exploded view of IED

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 inches = 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 resistance 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 P40Agile 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 20TE REAR PANEL

The 20TE rear panel consists of two MIDOS heavy duty terminal blocks.

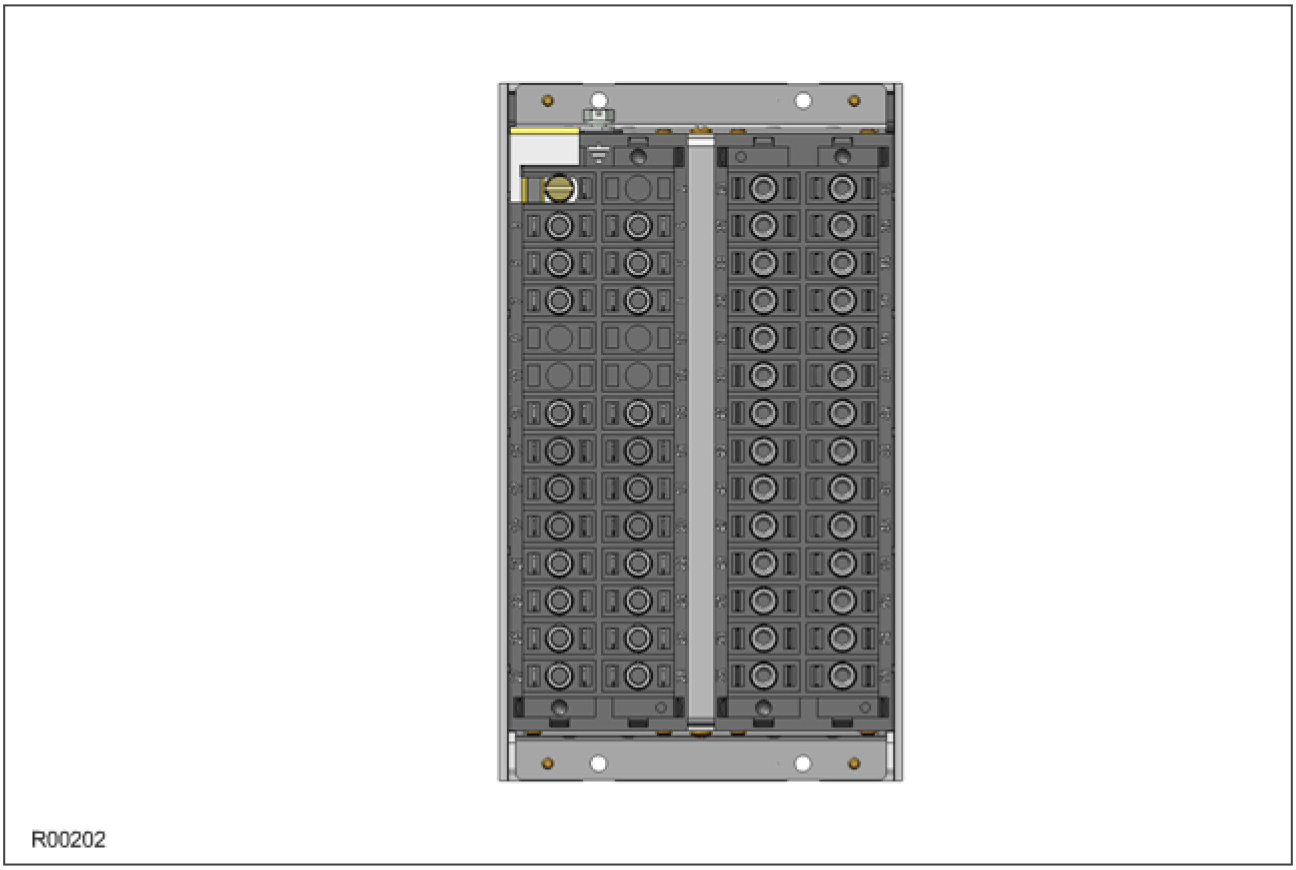

Figure 4: 20TE rear panel

3.3 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

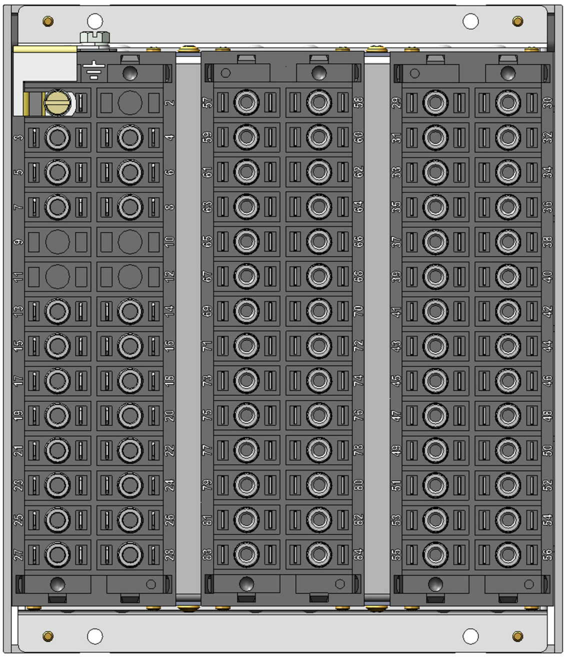

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Figure 5: 30TE Three-MIDOS block rear panel

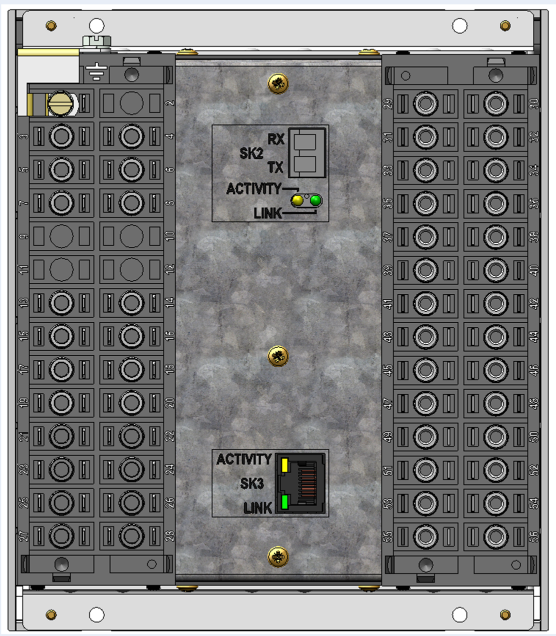

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Figure 6: 30TE Two-MIDOS block + communications rear panel

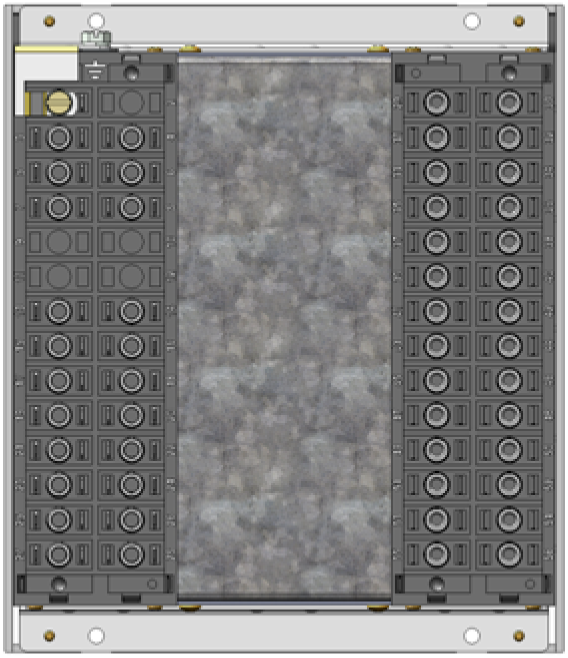


Figure 7: 30TE Two-MIDOS block + blanking plate

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 P14N HARDWARE CONFIGURATION 1

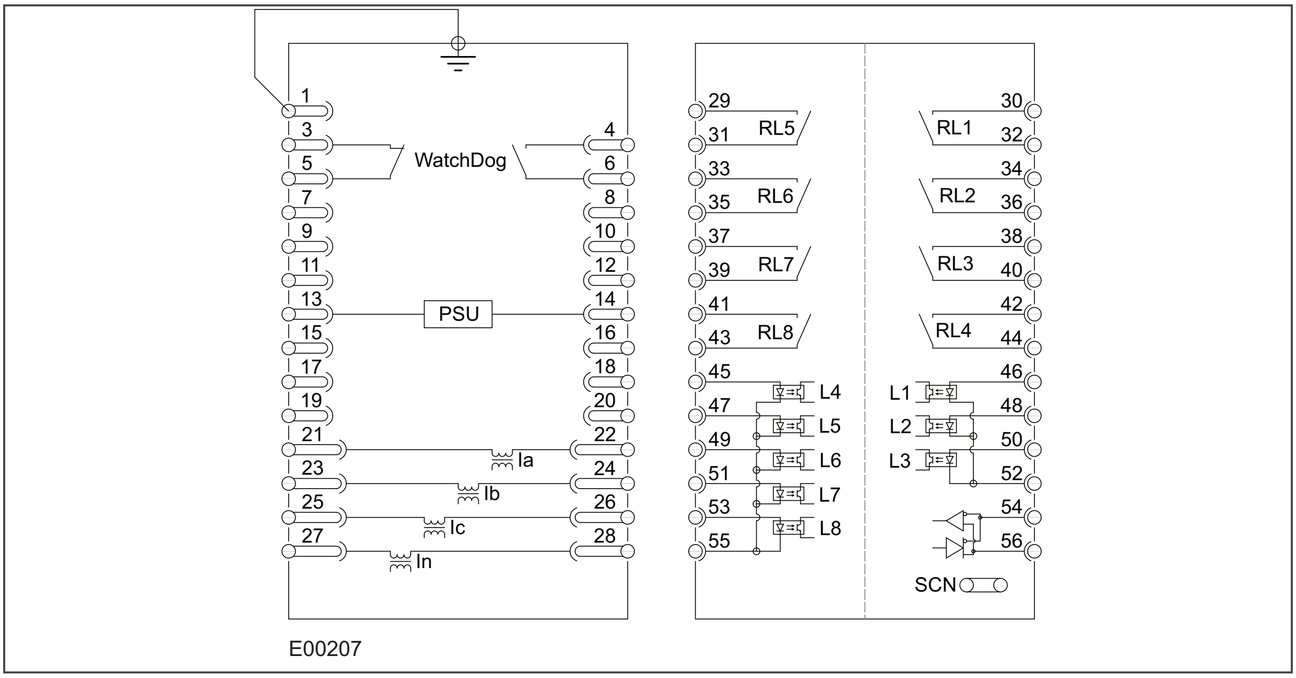


Figure 8: P14N in 20TE case with I/O option A

4.2.1 TERMINAL BLOCK LEFT

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 to 20	Not used

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

4.2.2 TERMINAL BLOCK RIGHT

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 P14N HARDWARE CONFIGURATION 2

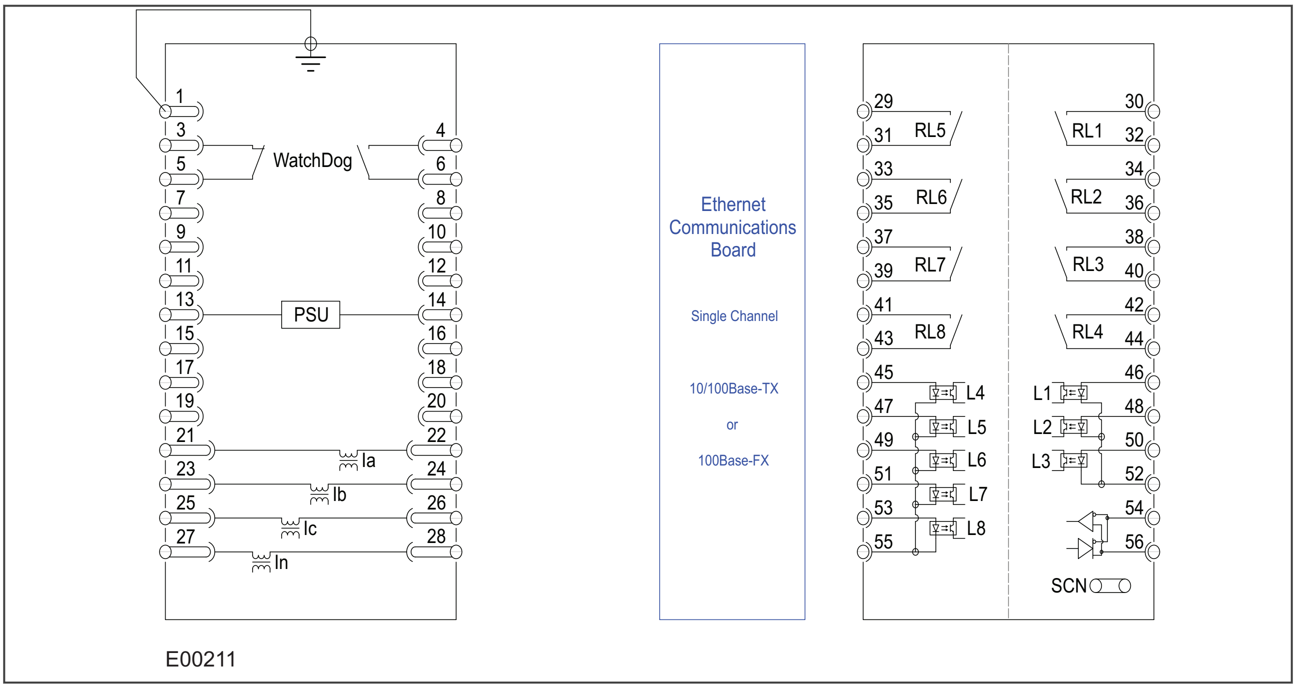


Figure 9: P14N in 30TE case with I/O option A1 + Ethernet communications

4.3.1 TERMINAL BLOCK LEFT

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 to 20	Not used
21 + 22	Current Transformer Ia
23 + 24	Current Transformer Ib
25 + 26	Current Transformer Ic
27 + 28	Current Transformer In

4.3.2 TERMINAL BLOCK RIGHT

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 P14N HARDWARE CONFIGURATION 3

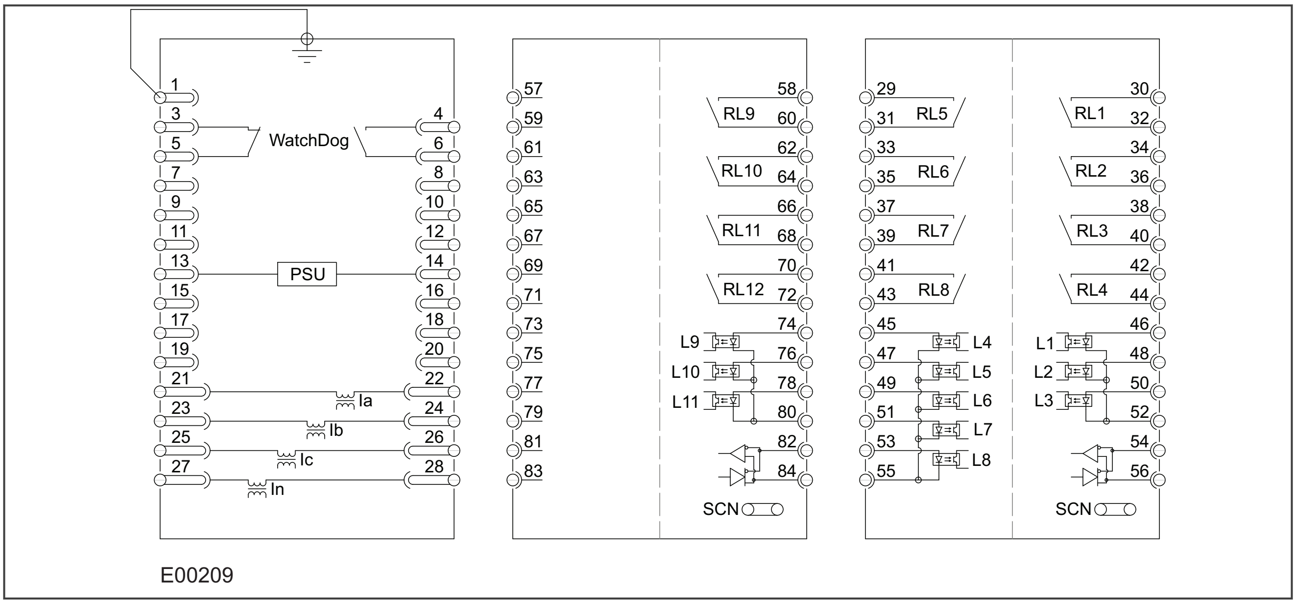


Figure 10: P14N in 30TE case with I/O option B

4.4.1 TERMINAL BLOCK LEFT

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 to 20	Not used
21 + 22	Current Transformer Ia
23 + 24	Current Transformer Ib

Terminal	Description
25 + 26	Current Transformer Ic
27 + 28	Current Transformer In

4.4.2 TERMINAL BLOCK RIGHT

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

4.4.3 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 P14N HARDWARE CONFIGURATION 4

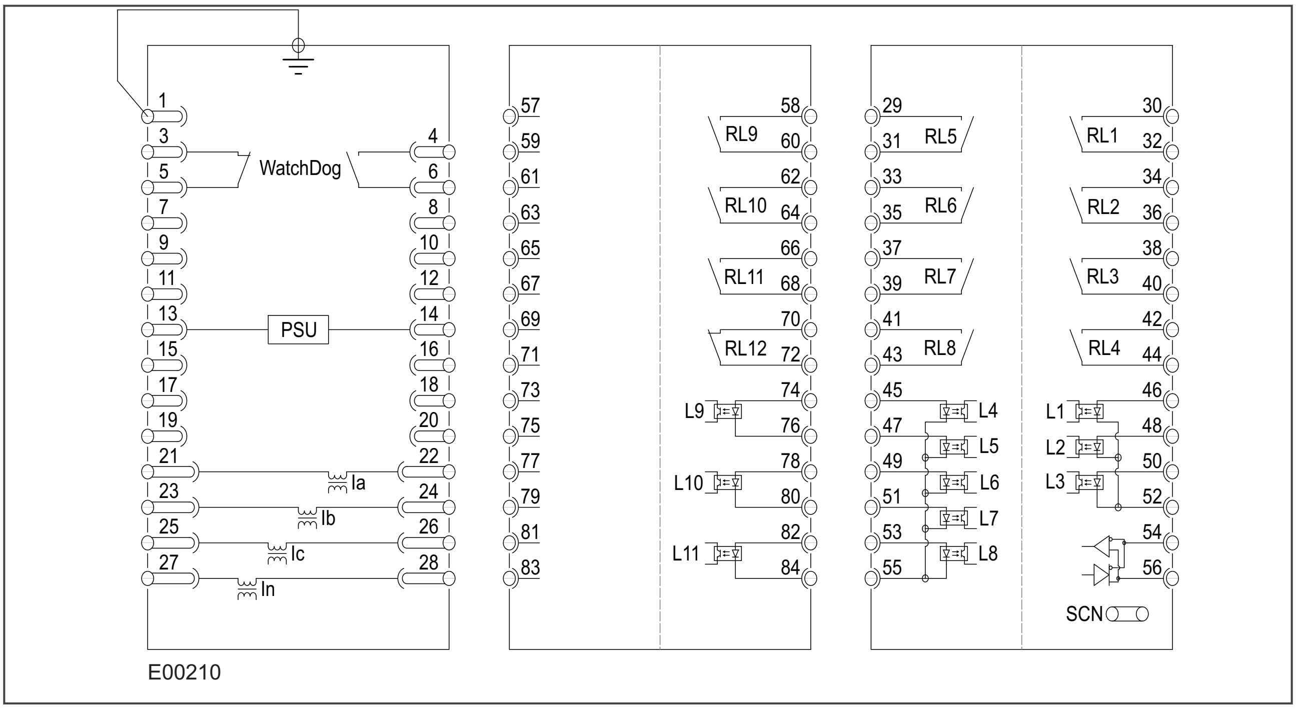


Figure 11: P14N in 30TE case with I/O option C

4.5.1 TERMINAL BLOCK LEFT

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 to 20	Not used
21 + 22	Current Transformer Ia
23 + 24	Current Transformer Ib
25 + 26	Current Transformer Ic
27 + 28	Current Transformer In

4.5.2 TERMINAL BLOCK RIGHT

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

Terminal	Description
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

4.5.3 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 + 76	Opto-input L9
78 + 80	Opto-input L10
82 + 84	Opto-input L11
The rest	Not used

4.6 P14N HARDWARE CONFIGURATION 5

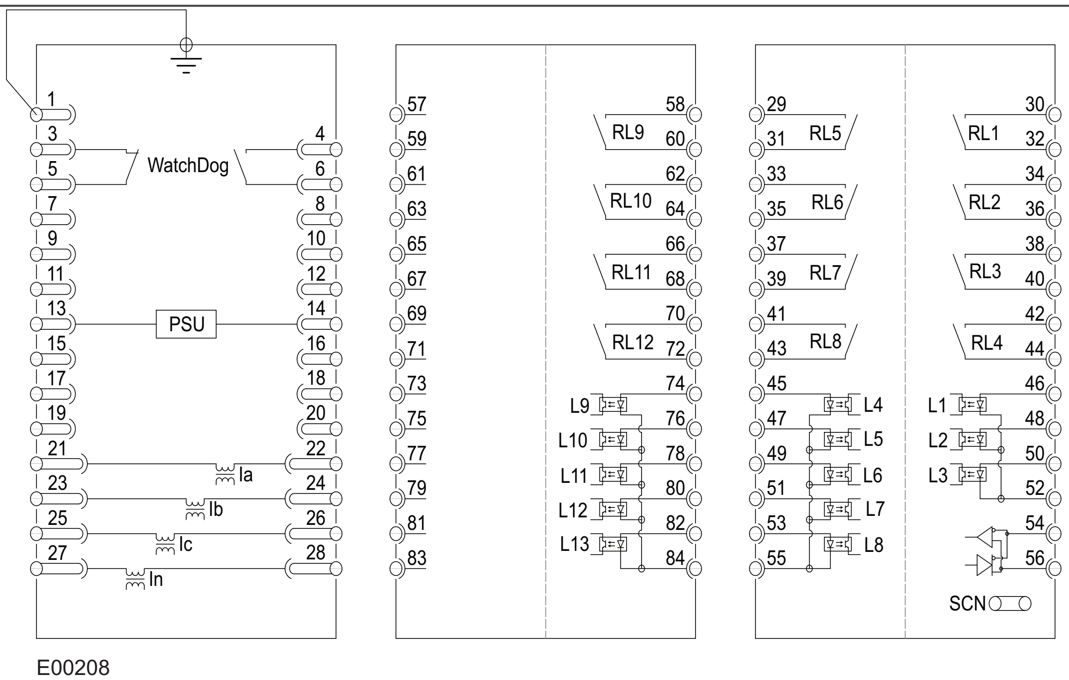


Figure 12: P14N in 30TE case with I/O option D

4.6.1 TERMINAL BLOCK LEFT

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 to 20	Not used
21 + 22	Current Transformer Ia
23 + 24	Current Transformer Ib
25 + 26	Current Transformer Ic
27 + 28	Current Transformer In

4.6.2 TERMINAL BLOCK RIGHT

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

4.6.3 TERMINAL BLOCK CENTRE

PTerminal	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 5)
76 + 84	Opto-input L10 (group 5)
78 + 84	Opto-input L11 (group 5)
80 + 84	Opto-input L12 (group 5)
82 + 84	Opto-input L13 (group 5)
The rest	Not used

5 FRONT PANEL

5.1 20TE FRONT PANEL

R00205

Figure 13: Front panel (20TE)

The figures show the front panels for the 20TE variant.

It consists of:

- LCD display
- Keypad
- USB port
- 4 x fixed function tri-colour LEDs
- 4 x programmable tri-colour LEDs

5.2 30TE FRONT PANEL

R00206

Figure 14: Front panel (30TE)

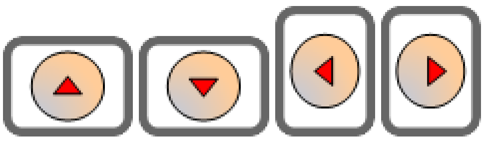
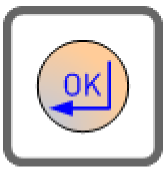
The figures show the front panels for the 30TE variant.

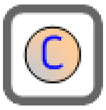
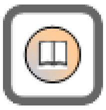
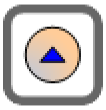
It consists of:

- 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

5.3 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	

5.4 LIQUID CRYSTAL DISPLAY

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

5.5 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 5 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.

5.6 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.

5.7 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.

5.8 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.

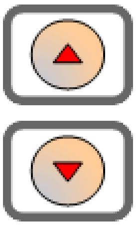
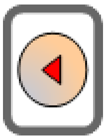
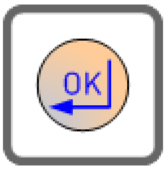
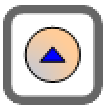
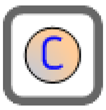
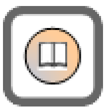
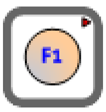
This chapter contains the following sections:

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 using 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.

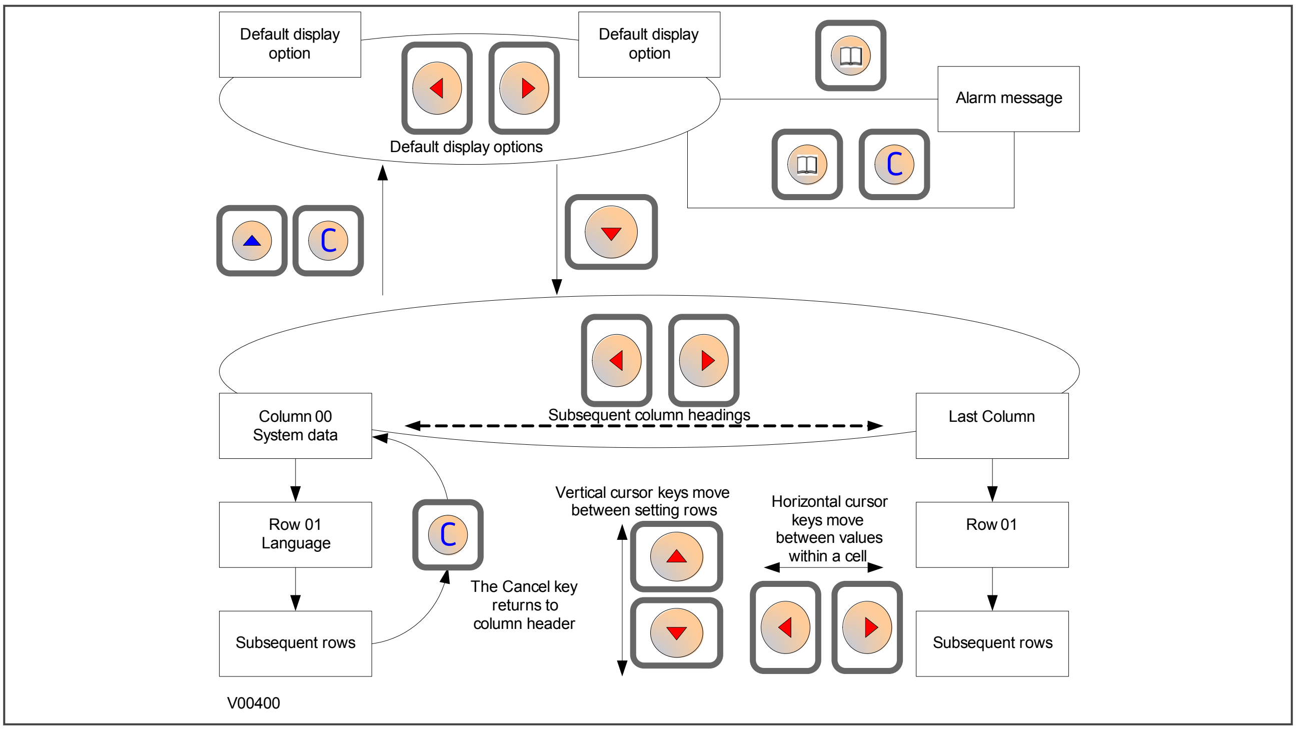


Figure 15: Menu navigation

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.

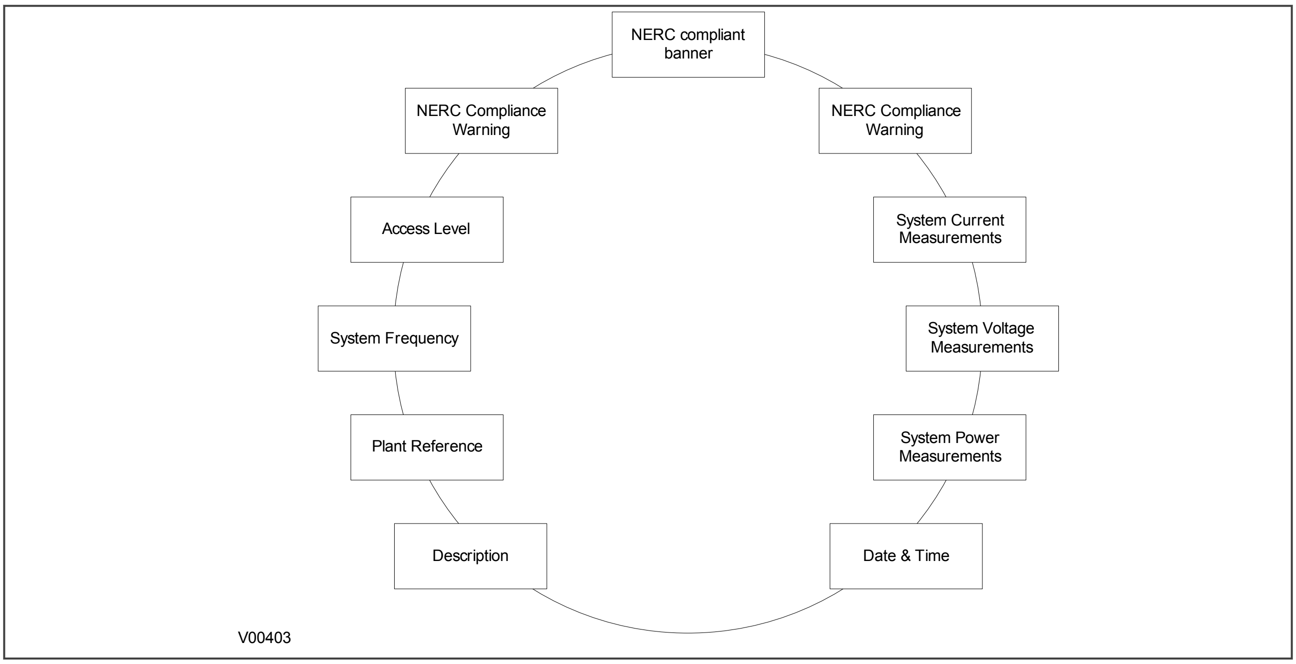


Figure 16: Default display navigation

If the device is not yet configured for NERC compliance (see Cyber-security chapter), 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** keyto confirm the password. If you enter an incorrect password, an invalid password message is displayed then the display reverts to ***Enter password***. On 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 the ***Password*** setting in the *SYSTEM DATA* column. 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 ***Password***, then press the CLEAR key instead of entering a password.

> *Note:*
> *In the SECURITY CONFIG column, you can set the maximum number of attemps, the time window in which the failed attempts are counted and the time duration for which the user is blocked.*

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 an 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 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
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

Setting	Column	Row	Description
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 much of the product ranges. 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 **Clear** 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 **Clear** 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 a long 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`.

2.10 FUNCTION KEYS

With the exception of products housed in 20TE cases, the products have 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.

Depending on the exact model, the following choices may be available:

- Courier
- Tunneled Courier over Ethernet
- MODBUS
- DNP3
- DNP3 Over Ethernet
- IEC 60870-5-103
- IEC61850

> *Note:*
> *Not all protocols are available on all products*

You can configure the settings using the settings application software or the HMI. This section describes how to configure the device using the HMI.

3.1 COURIER CONFIGURATION

To configure the device:

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 configure the device:

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 configure the device:

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.

Setting:	Description:
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 configure the device:

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 IEC 61850 Configurator, which is part of the settings application software.

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 test (using simulation tools), a substation's entire protection scheme before the products are installed into the substation.

To help with this process, the settings application software provides an IEC 61850 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 all products, 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:*
> *Some configuration data is available in the IEC61850 CONFIG. 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 device has 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 IEC 61850 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 *IEC61850 CONFIG.* column of the HMI.

The SCL Name and Revision attributes of both configuration banks are also available in the *IEC61850 CONFIG.* column of the HMI.

3.5.2 IEC 61850 NETWORK CONNECTIVITY

Configuration of the IP parameters and SNTP (Simple Network Time Protocol) time synchronisation parameters is performed by the IEC 61850 Configurator tool. If these parameters are not available using an SCL (Substation Configuration Language) file, they must be configured manually.

Every IP address on the Local Area Network must be unique. Duplicate IP addresses result in conflict and must be avoided. Most IEDs check for a conflict on every IP configuration change and at power up and they raise an alarm 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 Co-ordination) 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	Not settable
This cell displays the IED model number. This cannot be edited.				
Serial Number	00	08	Serial Number	Not settable
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	Not settable
This cell displays the Courier communications conformance level				
IED Address	00	0B	255	0 to 255 (Courier)
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 247 (Modbus)
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 254 (CS103)
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 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				
Plant Status	00	0C		Not settable 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	Not settable 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		Not settable
This cell displays the IED software version including the protocol and IED model.				
Software Ref. 2	00	12		Not settable
This cell displays the software version of the Ethernet card for models equipped with IEC 61850.				
Opto I/P Status	00	20		Not settable 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		Not settable 32 bit binary flag (data type G9): 0 = operated state 1 = non-operated state
This cell displays the status of the available output relays.				
Alarm Status 1	00	22		Not settable Binary flag (data type G96-1): Bit 0 = Unused 1= HIF Alarm 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
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		Not settable 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		Not settable Binary flag (data type G9): 0 = operated state, 1 = non-operated state

Menu Text	Col	Row	Default Setting	Available Options
Description				
This cell displays the status of the available output relays. This information is repeated for system purposes.				
Alarm Status 1	00	50		Not settable 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 =
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		Not settable 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		Not settable 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 Mismatch Bit
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		Not settable 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)
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		Not settable

Menu Text	Col	Row	Default Setting	Available Options
Description				
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 = None 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 = Disabled 1 = Signal Healthy 2 = No Signal
This cell displays the IRIG-B status				
SNTP Status	08	13		Not settable
This cell displays the SNTP time synchronisation status for IEC61850 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 offfset for the local time zone from -12 hours to +12 hrs 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
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

Menu Text	Col	Row	Default Setting	Available Options
Description				
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 hrs 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 hrs 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				
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 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.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
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.				
Thermal Overload	09	17	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the Thermal Overload 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 Selective Logic element.				
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.				
Auto-Reclose	09	24	Disabled	0 = Disabled or 1 = Enabled
This setting enables or disables the Autoreclose function.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
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.				
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
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.				
HIF Detection	09	37	Disabled	0 = Disabled
This setting enables or disables the High Impedance (HIF) function.				
Direct Access	09	39	Enabled	0 = Disabled 1 = Enabled 2 = Hotkey Only 3 = CB Ctrl Only
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.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
LCD Contrast	09	FF	13	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				
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.				

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

Menu Text	Col	Row	Default Setting	Available Options
Description				
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 P14N 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 IEC 60255 IDMT CURVES

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:

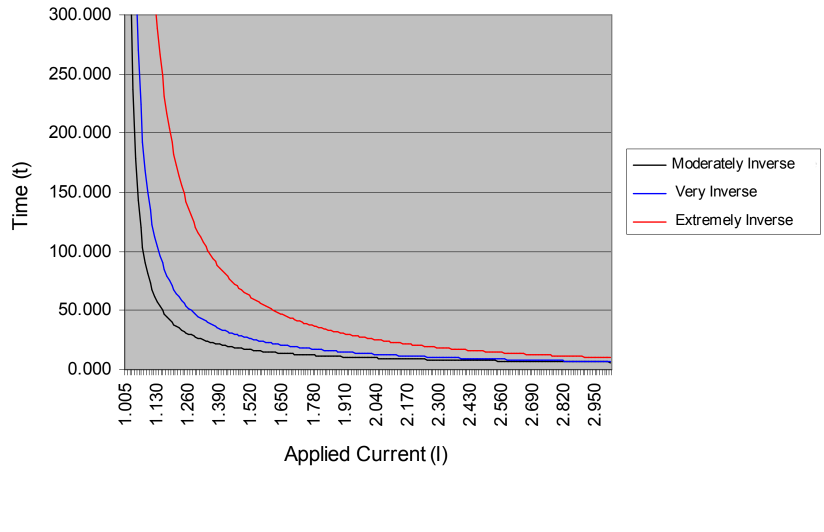


Figure 17: IEC 60255 IDMT curves

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
IEC Extremely Inverse Reset	44.1	3.03	0

Curve Description	β constant	α constant	L constant
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
IEEE Moderately Inverse Reset	4.85	2	0

Curve Description	β constant	α constant	L constant
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 the User Programmable Curve Tool, described in the Settings Application Software 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:

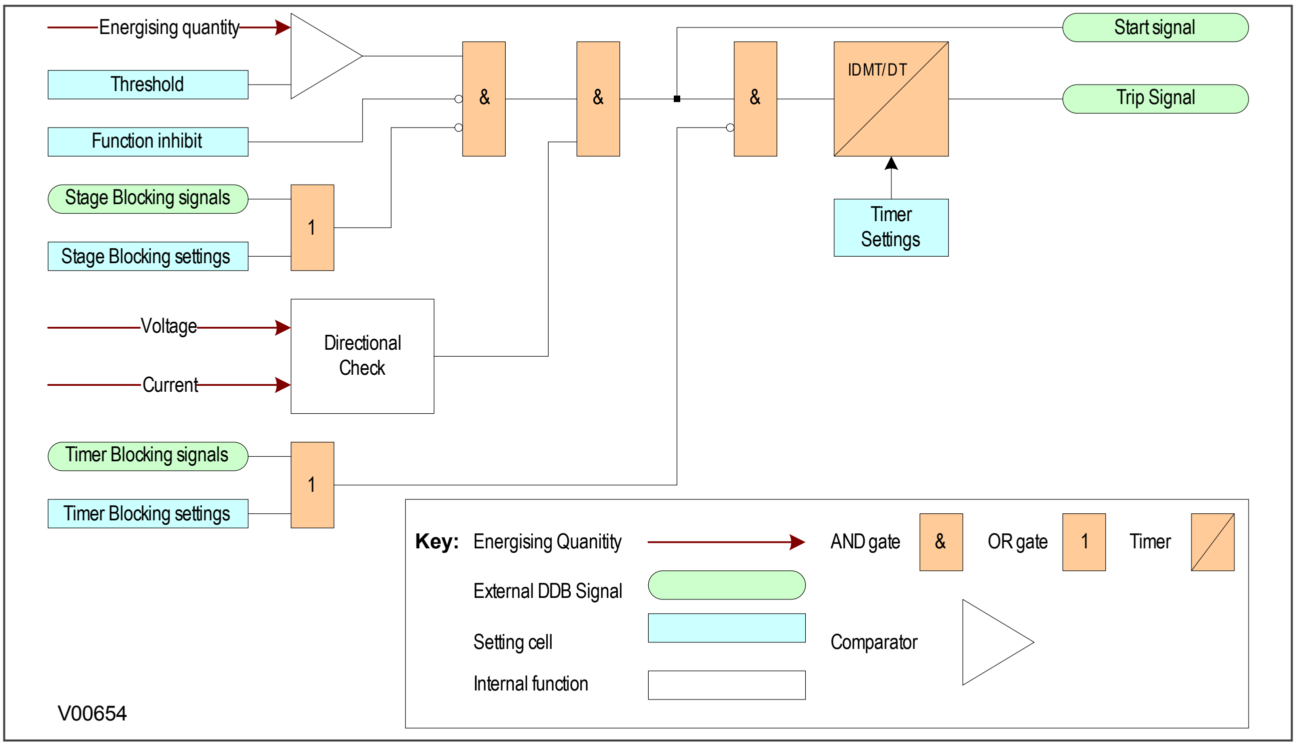


Figure 18: Principle of protection function implementation

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 (FSL) and Programmable Scheme Logic (PSL) 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:

- Phase to phase (accounting for approximately 8% of all faults)
- Phase to phase to Earth (accounting for approximately 5% of all faults)
- Phase to phase to phase (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. 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

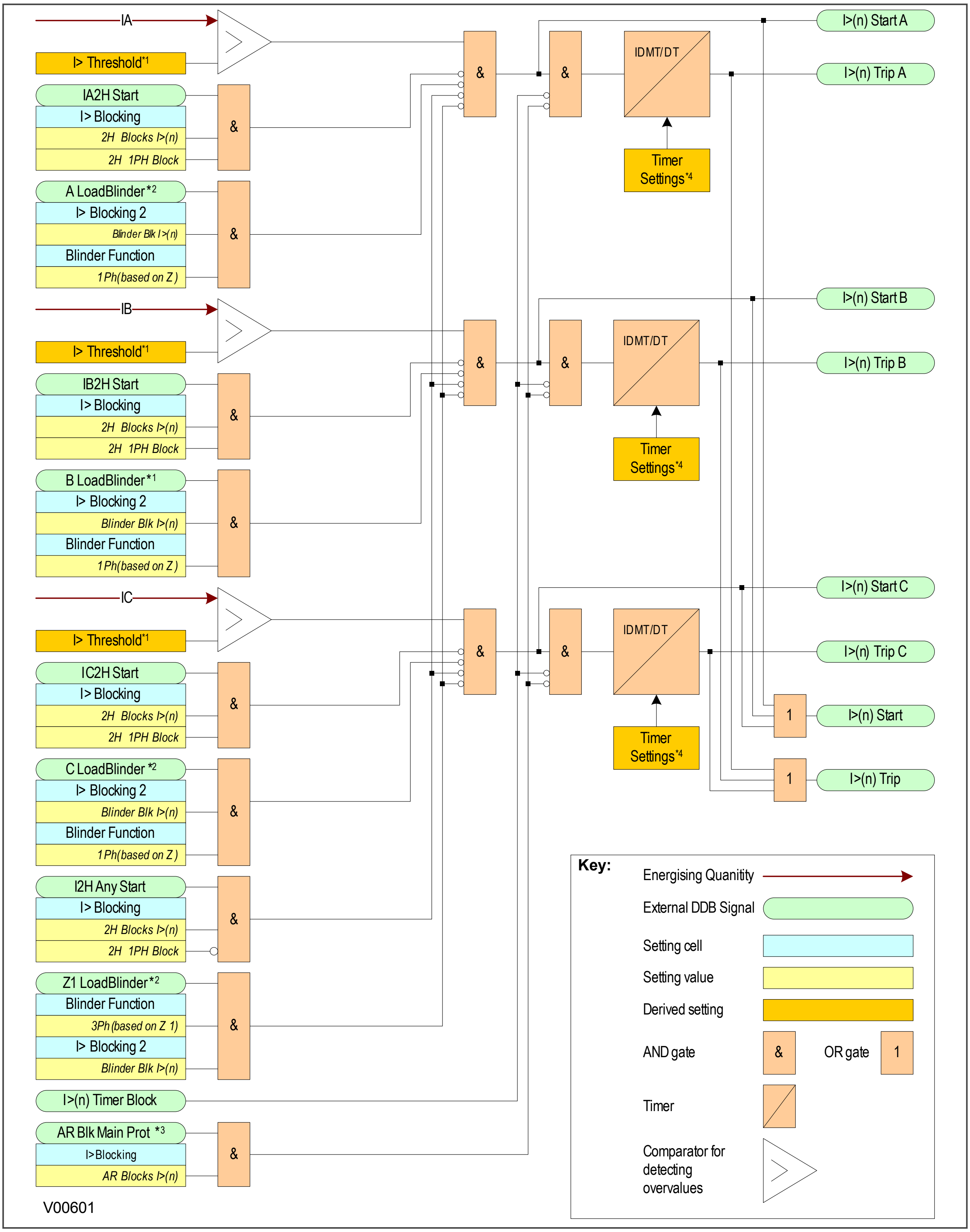


Figure 19: Non-directional Overcurrent Logic diagram

> *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 100) and Voltage Dependent Overcurrent (VDep OC) functions, if this functionality is available and used. Likewise, the timer settings can be influenced by the Selective Logic (on page 106) 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:

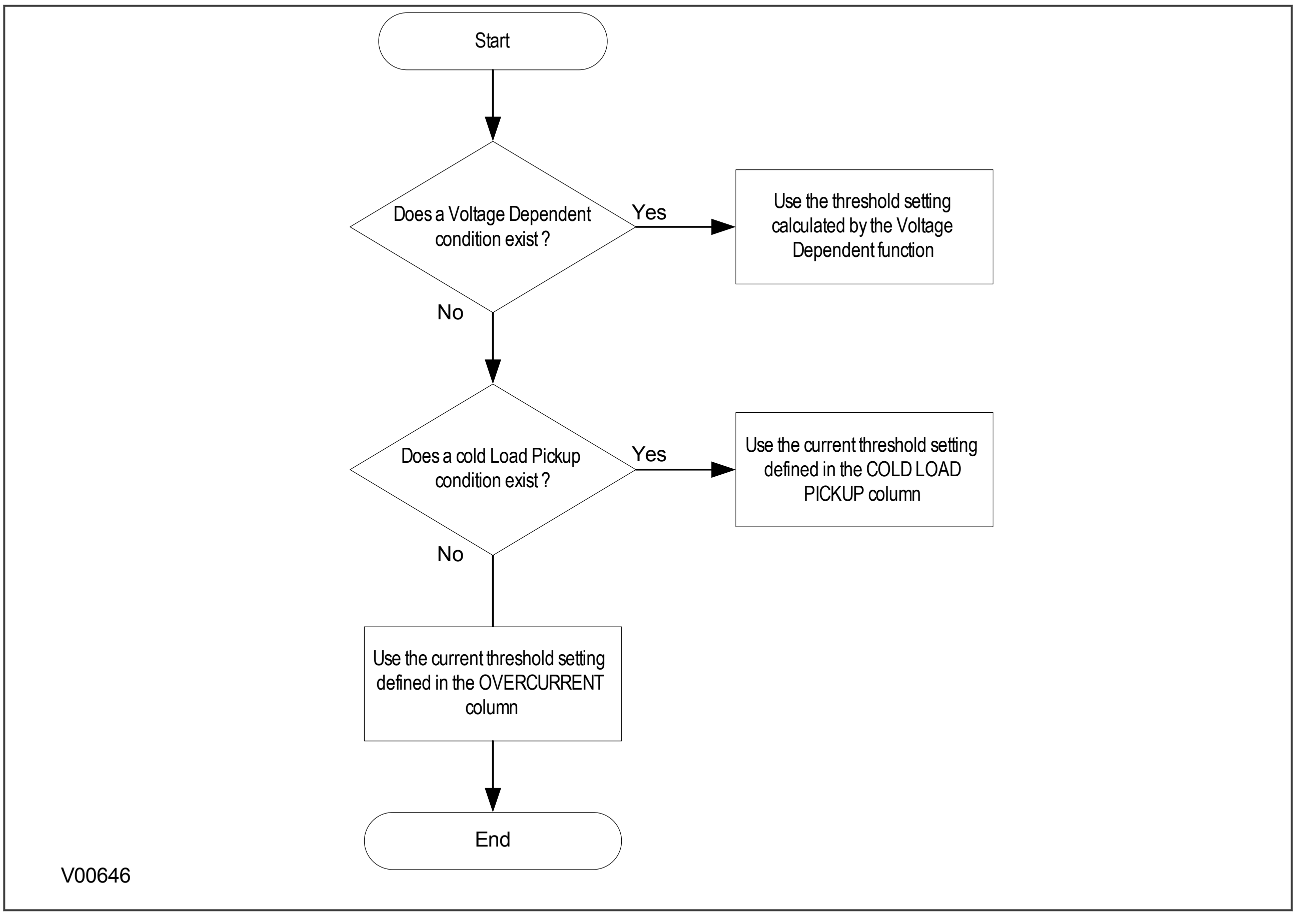


Figure 20: Selecting the current threshold setting

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:

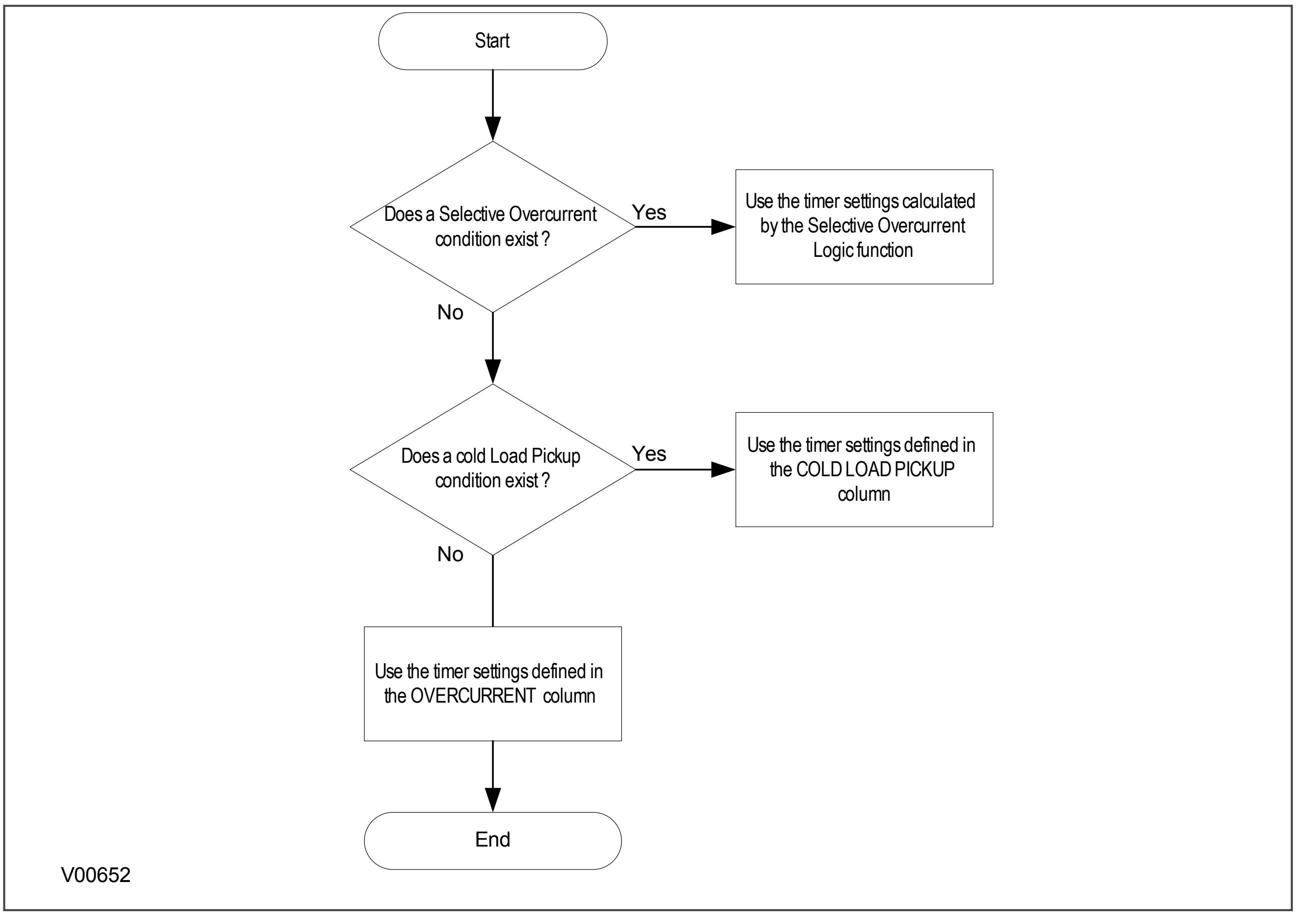


Figure 21: Selecting the timer settings

3.5 OVERCURRENT DDB SIGNALS

Ordinal	Signal Name	Use	Unique ID
Description			
203	I>1 Timer Block	PSL output	DDB_POC_1_TIMER_BLOCK
This DDB signal blocks the first stage overcurrent time delay			
204	I>2 Timer Block	PSL output	DDB_POC_2_TIMER_BLOCK
This DDB signal blocks the second stage overcurrent time delay			
205	I>3 Timer Block	PSL output	DDB_POC_3_TIMER_BLOCK
This DDB signal blocks the third stage overcurrent time delay			
206	I>4 Timer Block	PSL output	DDB_POC_4_TIMER_BLOCK
This DDB signal blocks the fourth stage overcurrent time delay			
243	I>1 Trip	PSL input	DDB_POC_1_3PH_TRIP
This DDB signal is the first stage any-phase Phase Overcurrent trip signal			
244	I>1 Trip A	PSL input	DDB_POC_1_PH_A_TRIP
This DDB signal is the first stage A-phase Phase Overcurrent trip signal			
245	I>1 Trip B	PSL input	DDB_POC_1_PH_B_TRIP
This DDB signal is the first stage B-phase Phase Overcurrent trip signal			
246	I>1 Trip C	PSL input	DDB_POC_1_PH_C_TRIP

Ordinal	Signal Name	Use	Unique ID
Description			
This DDB signal is the first stage C-phase Phase Overcurrent trip signal			
247	I>2 Trip	PSL input	DDB_POC_2_3PH_TRIP
This DDB signal is the second stage any-phase Phase Overcurrent trip signal			
248	I>2 Trip A	PSL input	DDB_POC_2_PH_A_TRIP
This DDB signal is the second stage A-phase Phase Overcurrent trip signal			
249	I>2 Trip B	PSL input	DDB_POC_2_PH_B_TRIP
This DDB signal is the second stage B-phase Phase Overcurrent trip signal			
250	I>2 Trip C	PSL input	DDB_POC_2_PH_C_TRIP
This DDB signal is the second stage C-phase Phase Overcurrent trip signal			
251	I>3 Trip	PSL input	DDB_POC_3_3PH_TRIP
This DDB signal is the third stage any-phase Phase Overcurrent trip signal			
252	I>3 Trip A	PSL input	DDB_POC_3_PH_A_TRIP
This DDB signal is the third stage A-phase Phase Overcurrent trip signal			
253	I>3 Trip B	PSL input	DDB_POC_3_PH_B_TRIP
This DDB signal is the third stage B-phase Phase Overcurrent trip signal			
254	I>3 Trip C	PSL input	DDB_POC_3_PH_C_TRIP
This DDB signal is the third stage C-phase Phase Overcurrent trip signal			
255	I>4 Trip	PSL input	DDB_POC_4_3PH_TRIP
This DDB signal is the fourth stage any-phase Phase Overcurrent trip signal			
256	I>4 Trip A	PSL input	DDB_POC_4_PH_A_TRIP
This DDB signal is the fourth stage A-phase Phase Overcurrent trip signal			
257	I>4 Trip B	PSL input	DDB_POC_4_PH_B_TRIP
This DDB signal is the fourth stage B-phase Phase Overcurrent trip signal			
258	I>4 Trip C	PSL input	DDB_POC_4_PH_C_TRIP
This DDB signal is the fourth stage C-phase Phase Overcurrent trip signal			
295	I>1 Start	PSL input	DDB_POC_1_3PH_START
This DDB signal is the first stage any-phase Overcurrent start signal			
296	I>1 Start A	PSL input	DDB_POC_1_PH_A_START
This DDB signal is the first stage A-phase Overcurrent start signal			
297	I>1 Start B	PSL input	DDB_POC_1_PH_B_START
This DDB signal is the first stage B-phase Overcurrent start signal			
298	I>1 Start C	PSL input	DDB_POC_1_PH_C_START
This DDB signal is the first stage C-phase Overcurrent start signal			
299	I>2 Start	PSL input	DDB_POC_2_3PH_START
This DDB signal is the second stage any-phase Overcurrent start signal			
300	I>2 Start A	PSL input	DDB_POC_2_PH_A_START
This DDB signal is the second stage A-phase Overcurrent start signal			
301	I>2 Start B	PSL input	DDB_POC_2_PH_B_START
This DDB signal is the second stage B-phase Overcurrent start signal			
302	I>2 Start C	PSL input	DDB_POC_2_PH_C_START
This DDB signal is the second stage C-phase Overcurrent start signal			
303	I>3 Start	PSL input	DDB_POC_3_3PH_START

Ordinal	Signal Name	Use	Unique ID
Description			
This DDB signal is the third stage any-phase Overcurrent start signal			
304	I>3 Start A	PSL input	DDB_POC_3_PH_A_START
This DDB signal is the third stage A-phase Overcurrent start signal			
305	I>3 Start B	PSL input	DDB_POC_3_PH_B_START
This DDB signal is the third stage B-phase Overcurrent start signal			
306	I>3 Start C	PSL input	DDB_POC_3_PH_C_START
This DDB signal is the third stage C-phase Overcurrent start signal			
307	I>4 Start	PSL input	DDB_POC_4_3PH_START
This DDB signal is the fourth stage any-phase Overcurrent start signal			
308	I>4 Start A	PSL input	DDB_POC_4_PH_A_START
This DDB signal is the fourth stage A-phase Overcurrent start signal			
309	I>4 Start B	PSL input	DDB_POC_4_PH_B_START
This DDB signal is the fourth stage B-phase Overcurrent start signal			
310	I>4 Start C	PSL input	DDB_POC_4_PH_C_START
This DDB signal is the fourth stage C-phase Overcurrent start signal			
350	VTS Fast Block	PSL input	DDB_VTS_SLOW_BLOCK
This DDB signal is a purposely delayed output from the VTS which can block other functions			
538	IA2H Start	PSL input	DDB_2ND_HARMONIC_IA
This DDB signal is the A-phase 2nd Harmonic start signal			
539	IB2H Start	PSL input	DDB_2ND_HARMONIC_IB
This DDB signal is the B-phase 2nd Harmonic start signal			
540	IC2H Start	PSL input	DDB_2ND_HARMONIC_IC
This DDB signal is the C-phase 2nd Harmonic start signal			
541	I2H Any Start	PSL input	DDB_2ND_HARMONIC
This DDB signal is the 2nd Harmonic start signal for any phase			
567	I>5 Timer Block	PSL output	DDB_POC_5_TIMER_BLOCK
This DDB signal blocks the fifth stage overcurrent time delay			
568	I>6 Timer Block	PSL output	DDB_POC_6_TIMER_BLOCK
This DDB signal blocks the sixth stage overcurrent time delay			
570	I>5 Trip	PSL input	DDB_POC_5_3PH_TRIP
This DDB signal is the fifth stage three-phase Phase Overcurrent trip signal			
571	I>5 Trip A	PSL input	DDB_POC_5_PH_A_TRIP
This DDB signal is the fifth stage A-phase Phase Overcurrent trip signal			
572	I>5 Trip B	PSL input	DDB_POC_5_PH_B_TRIP
This DDB signal is the fifth stage B-phase Phase Overcurrent trip signal			
573	I>5 Trip C	PSL input	DDB_POC_5_PH_C_TRIP
This DDB signal is the fifth stage C-phase Phase Overcurrent trip signal			
574	I>6 Trip	PSL input	DDB_POC_6_3PH_TRIP
This DDB signal is the sixth stage three-phase Phase Overcurrent trip signal			
575	I>6 Trip A	PSL input	DDB_POC_6_PH_A_TRIP
This DDB signal is the sixth stage A-phase Phase Overcurrent trip signal			
576	I>6 Trip B	PSL input	DDB_POC_6_PH_B_TRIP

Ordinal	Signal Name	Use	Unique ID
Description			
This DDB signal is the sixth stage B-phase Phase Overcurrent trip signal			
577	I>6 Trip C	PSL input	DDB_POC_6_PH_C_TRIP
This DDB signal is the sixth stage C-phase Phase Overcurrent trip signal			
579	I>5 Start	PSL input	DDB_POC_5_3PH_START
This DDB signal is the fifth stage three-phase Phase Overcurrent start signal			
580	I>5 Start A	PSL input	DDB_POC_5_PH_A_START
This DDB signal is the fifth stage A-phase Phase Overcurrent start signal			
581	I>5 Start B	PSL input	DDB_POC_5_PH_B_START
This DDB signal is the fifth stage B-phase Phase Overcurrent start signal			
582	I>5 Start C	PSL input	DDB_POC_5_PH_C_START
This DDB signal is the fifth stage C-phase Phase Overcurrent start signal			
583	I>6 Start	PSL input	DDB_POC_6_3PH_START
This DDB signal is the sixth stage three-phase Phase Overcurrent start signal			
584	I>6 Start A	PSL input	DDB_POC_6_PH_A_START
This DDB signal is the sixth stage A-phase Phase Overcurrent start signal			
585	I>6 Start B	PSL input	DDB_POC_6_PH_B_START
This DDB signal is the sixth stage B-phase Phase Overcurrent start signal			
586	I>6 Start C	PSL input	DDB_POC_6_PH_C_START
This DDB signal is the sixth stage C-phase Phase Overcurrent start signal			
630	A LoadBlinder	PSL input	DDB_POC_LOAD_BLINDER_Z_PH_A
This DDB signal is the Phase A Load Blinder signal, either direction			
633	B LoadBlinder	PSL input	DDB_POC_LOAD_BLINDER_Z_PH_B
This DDB signal is the Phase B Load Blinder signal, either direction			
636	C LoadBlinder	PSL input	DDB_POC_LOAD_BLINDER_Z_PH_C
This DDB signal is the Phase C Load Blinder signal, either direction			
639	Z1 LoadBlinder	PSL input	DDB_POC_LOAD_BLINDER_Z1
This DDB signal is the 3-phase Load Blinder signal, either direction			

3.6 OVERCURRENT SETTINGS

Menu Text	Col	Row	Default Setting	Available Options
Description				
GROUP 1 OVERCURRENT	35	00		
This column contains settings for Overcurrent				

Menu Text	Col	Row	Default Setting	Available Options
Description				
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
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
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 Rst Char	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.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
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
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
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 Rst Char	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
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

Menu Text	Col	Row	Default Setting	Available Options
Description				
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
This setting determines the direction of measurement for the fourth 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	0x00	Bit 0=Unused Bit 1=Unused Bit 2=Unused Bit 3=Unused Bit 4=Unused Bit 5=Unused 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 1
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 and second harmonic blocking.				
I> Blocking	35	4E	0x00	Bit 0=Unused Bit 1=Unused Bit 2=Unused Bit 3=Unused Bit 4=Unused Bit 5=Unused 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=
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 second harmonic blocking.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
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
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
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 Rst Char	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
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

Menu Text	Col	Row	Default Setting	Available Options
Description				
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.				

3.7 APPLICATION NOTES

3.7.1 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.

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.***

4 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 energisation (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.

4.1 IMPLEMENTATION

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.*

4.2 CLP LOGIC

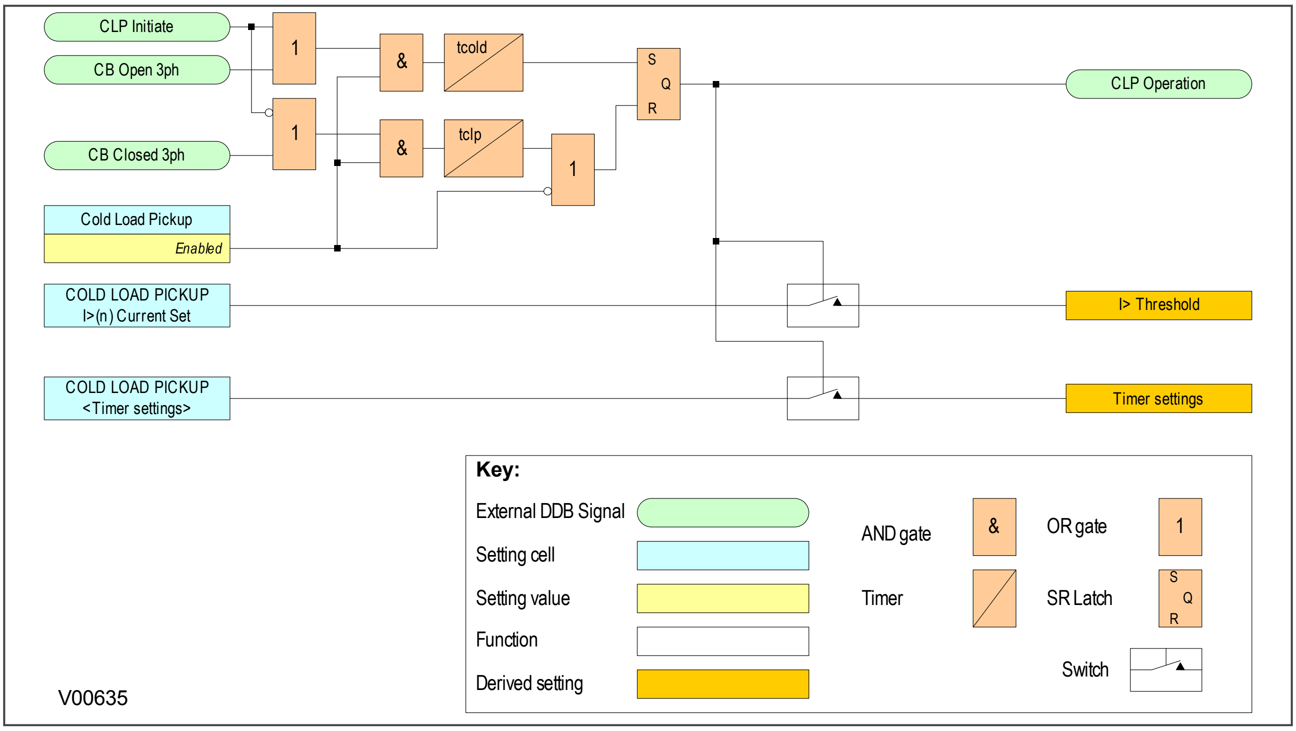


Figure 22: Cold Load Pickup logic

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`.

4.3 CLP DDB SIGNALS

Ordinal	Signal Name	Use	Unique ID
Description			
226	CLP Initiate	PSL output	DDB_CLP_INITIATE
This DDB signal initiates the CLP operation			
347	CLP Operation	PSL input	DDB_CLP_OPERATION
This DDB signal indicates that the CLP is operating and informs the Overcurrent protection to use the CLP settings			
378	CB Open 3 ph	PSL input	DDB_CB_OPEN
This DDB signal indicates that the CB is open on all 3 phases			
379	CB Closed 3 ph	PSL input	DDB_CB_CLOSED
This DDB signal indicates that the CB is closed on all 3 phases			

4.4 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 IEEE/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 IEEE/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.				

4.5 APPLICATION NOTES

4.5.1 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.

4.5.2 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 therefore 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.

4.5.3 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.

5 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.

5.1 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 on 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)

5.2 SELECTIVE OVERCURRENT LOGIC DIAGRAM

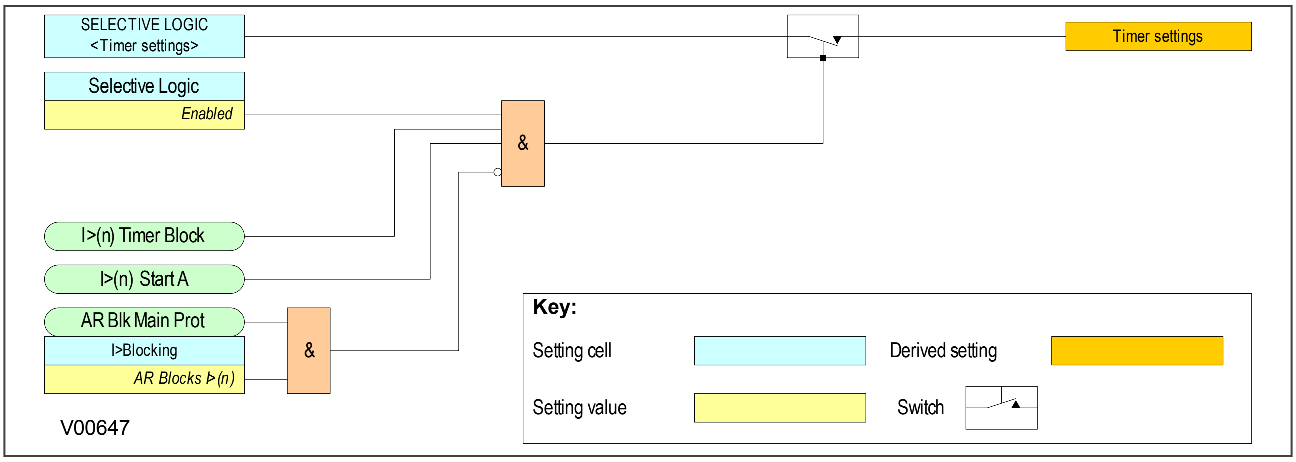


Figure 23: Selective Overcurrent logic

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.

5.3 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.				

6 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.

6.1 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. 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.

6.2 NON-DIRECTIONAL NEGATIVE SEQUENCE OVERCURRENT LOGIC

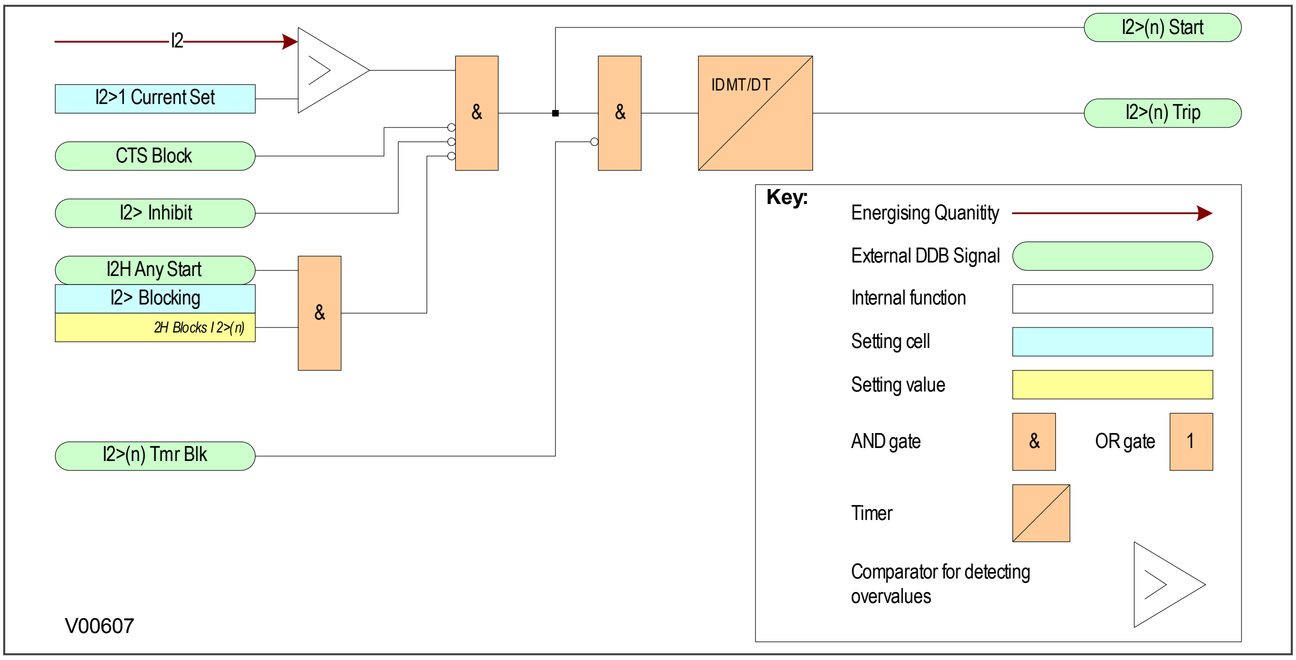


Figure 24: Negative Sequence Overcurrent logic - non-directional operation

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.

6.3 NPS OVERCURRENT DDB SIGNALS

Ordinal	Signal Name	Use	Unique ID
Description			
351	VTS Slow Block	PSL input	DDB_VTS_SLOW_BLOCK
This DDB signal is a purposely delayed output from the VTS which can block other functions			
352	CTS Block	PSL input	DDB_CTS_BLOCK
This DDB signal is an instantaneously blocking output from the CTS which can block other functions			
378	CB Open 3 ph	PSL input	DDB_CB_OPEN
This DDB signal indicates that the CB is open on all 3 phases			
379	CB Closed 3 ph	PSL input	DDB_CB_CLOSED
This DDB signal indicates that the CB is closed on all 3 phases			
504	I2> Inhibit	PSL output	DDB_NPSOC_INHIBIT
This DDB signal inhibits the Negative Phase Overcurrent protection			
505	I2>1 Tmr Blk	PSL output	DDB_NPSOC_1_TIMER_BLOCK
This DDB signal blocks the first stage Negative Phase Overcurrent timer			

Ordinal	Signal Name	Use	Unique ID
Description			
506	I2>2 Tmr Blk	PSL output	DDB_NPSOC_2_TIMER_BLOCK
This DDB signal blocks the second stage Negative Phase Overcurrent timer			
507	I2>3 Tmr Blk	PSL output	DDB_NPSOC_3_TIMER_BLOCK
This DDB signal blocks the third stage Negative Phase Overcurrent timer			
508	I2>4 Tmr Blk	PSL output	DDB_NPSOC_4_TIMER_BLOCK
This DDB signal blocks the fourth stage Negative Phase Overcurrent timer			
509	I2>1 Start	PSL input	DDB_NPSOC_1_START
This DDB signal is the first stage NPSOC start signal			
510	I2>2 Start	PSL input	DDB_NPSOC_2_START
This DDB signal is the second stage NPSOC start signal			
511	I2>3 Start	PSL input	DDB_NPSOC_3_START
This DDB signal is the third stage NPSOC start signal			
512	I2>4 Start	PSL input	DDB_NPSOC_4_START
This DDB signal is the fourth stage NPSOC start signal			
513	I2>1 Trip	PSL input	DDB_NPSOC_1_TRIP
This DDB signal is the first stage NPSOC trip signal			
514	I2>2 Trip	PSL input	DDB_NPSOC_2_TRIP
This DDB signal is the second stage NPSOC trip signal			
515	I2>3 Trip	PSL input	DDB_NPSOC_3_TRIP
This DDB signal is the third stage NPSOC trip signal			
516	I2>4 Trip	PSL input	DDB_NPSOC_4_TRIP
This DDB signal is the fourth stage NPSOC trip signal			
541	I2H Any Start	PSL input	DDB_2ND_HARMONIC
This DDB signal is the 2nd Harmonic start signal for any phase			

6.4 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
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
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
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
This setting enables or disables the fourth stage NPSOC element. There is no choice of curves because this stage is DT only.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
I2>4 Direction	36	42	Non-Directional	0 = Non-Directional
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	0x0	Bit 0=Unused Bit 1=Unused Bit 2=Unused Bit 3=Unused 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 G158N), where you can define which blocking signals block which stage. The available settings depend on the model chosen. This description is for models with 2nd harmonic blocking.				

6.5 APPLICATION NOTES

6.5.1 SETTING GUIDELINES (CURRENT THRESHOLD)

A negative sequence element can be connected in the primary supply to the transformer and set as sensitively as required to protect for secondary phase-to-ground or phase-to-phase faults. This function will also provide better protection than the phase overcurrent function for internal transformer faults. The NPS overcurrent protection should be set to coordinate with the low-side phase and earth elements for phase-to-earth and phase-to-phase faults.

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.

6.5.2 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 and earth fault elements.

7 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.

7.1 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

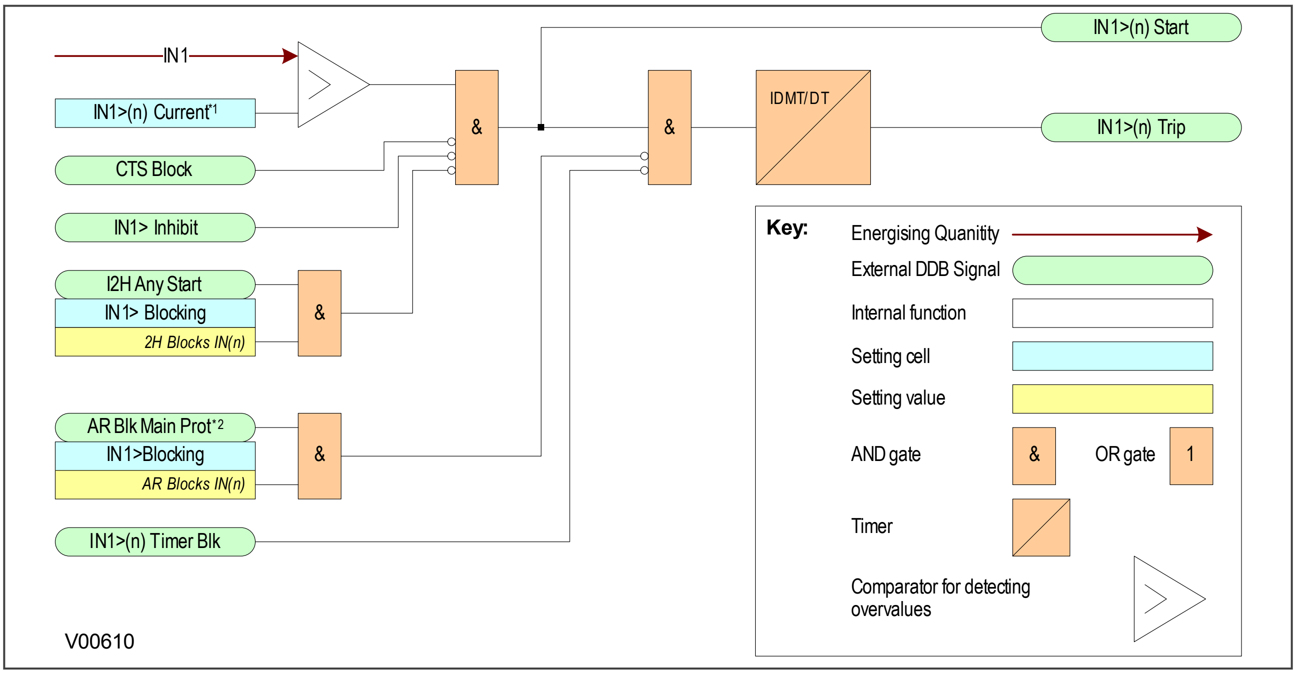
where (n) is the number of the stage.

Stages 1 and 2 provide a Timer Hold facility (on page 85). 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.

7.2 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 25: 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).

7.3 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.

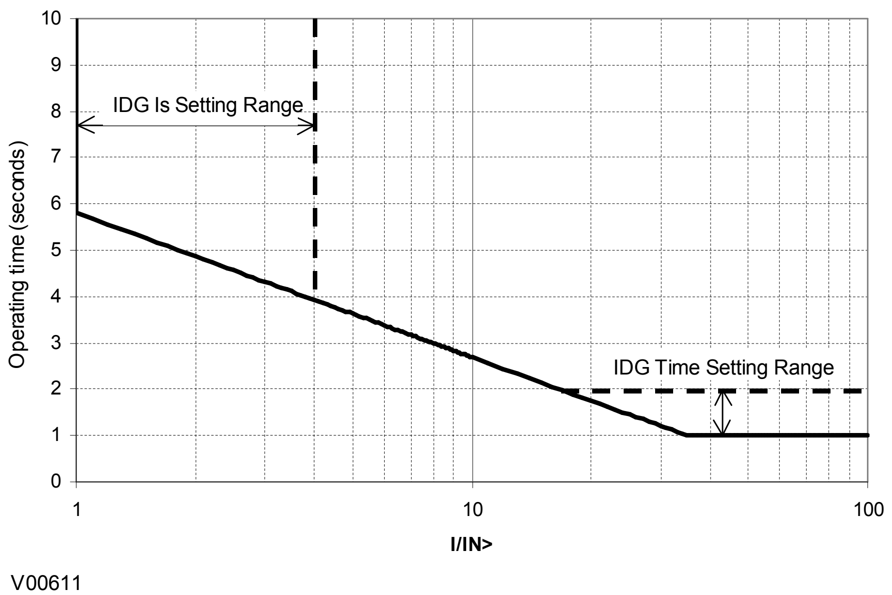


Figure 26: IDG Characteristic

7.4 MEASURED AND DERIVED EARTH FAULT DDB SIGNALS

Ordinal	Signal Name	Use	Unique ID
Description			
208	IN1>1 Timer Blk	PSL output	DDB_EF1_1_TIMER_BLOCK
This DDB signal blocks the first stage measured Earth Fault time delay			
209	IN1>2 Timer Blk	PSL output	DDB_EF1_2_TIMER_BLOCK
This DDB signal blocks the second stage measured Earth Fault time delay			
210	IN1>3 Timer Blk	PSL output	DDB_EF1_3_TIMER_BLOCK
This DDB signal blocks the third stage measured Earth Fault time delay			
211	IN1>4 Timer Blk	PSL output	DDB_EF1_4_TIMER_BLOCK
This DDB signal blocks the fourth stage measured Earth Fault time delay			
212	IN2>1 Timer Blk	PSL output	DDB_EF2_1_TIMER_BLOCK

Ordinal	Signal Name	Use	Unique ID
Description			
This DDB signal blocks the first stage derived Earth Fault time delay			
213	IN2>2 Timer Blk	PSL output	DDB_EF2_2_TIMER_BLOCK
This DDB signal blocks the second stage derived Earth Fault time delay			
214	IN2>3 Timer Blk	PSL output	DDB_EF2_3_TIMER_BLOCK
This DDB signal blocks the third stage derived Earth Fault time delay			
215	IN2>4 Timer Blk	PSL output	DDB_EF2_4_TIMER_BLOCK
This DDB signal blocks the fourth stage derived Earth Fault time delay			
351	VTS Slow Block	PSL input	DDB_VTS_SLOW_BLOCK
This DDB signal is a purposely delayed output from the VTS which can block other functions			
352	CTS Block	PSL input	DDB_CTS_BLOCK
This DDB signal is an instantaneously blocking output from the CTS which can block other functions			
358	AR Blk Main Prot	PSL input	DDB_AR_BLOCK_MAIN_PROTECTION
This DDB signal, generated by the Autoreclose function, blocks the Main Protection elements (POC, EF1, EF2, NPSOC)			
528	IN1> Inhibit	PSL output	DDB_EF1_INHIBIT
This DDB signal inhibits the measured Earth Fault protection			
529	IN2> Inhibit	PSL output	DDB_EF2_INHIBIT
This DDB signal inhibits the derived Earth Fault protection			
541	I2H Any Start	PSL input	DDB_2ND_HARMONIC
This DDB signal is the 2nd Harmonic start signal for any phase			

7.5 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'				
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.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
IN1>1 Direction	38	26	Non-Directional	0 = Non-Directional
This setting determines the direction of measurement for the first stage EF1 element.				
IN1>1 Current	38	29	0.2	0.05*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 overcurrent 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.				
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

Menu Text	Col	Row	Default Setting	Available Options
Description				
This setting determines the direction of measurement for the second stage EF1 element.				
IN1>2 Current	38	3A	0.2	0.05*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 overcurrent 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				
IN1>2 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
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	0.05*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	0.05*In to 32*In step 0.01In
This setting sets the pick-up threshold for the fourth stage EF1 element.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
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=Not Used Bit 1=Not Used Bit 2=Not Used Bit 3=Not Used 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 Bit 10=Not Used
This setting cell contains a binary string (data type G63B), where you can define which blocking signals block which stage. The available settings depend on the model chosen. This description is for models without VTS blocking				
IN1> Blocking	38	54	0x00F	Bit 0=Not Used Bit 1=Not Used Bit 2=Not Used Bit 3=Not Used 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 G63C), where you can define which blocking signals block which stage. The available settings depend on the model chosen. This description is for models without VTS blocking and without Autoreclose.				

7.6 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'				

Menu Text	Col	Row	Default Setting	Available Options
Description				
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
This setting determines the direction of measurement for the first stage EF2 element.				
IN2>1 Current	39	29	0.2	0.05*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.				
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.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
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
This setting determines the direction of measurement for the second stage EF2 element.				
IN2>2 Current	39	3A	0.2	0.05*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 overcurrent 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
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

Menu Text	Col	Row	Default Setting	Available Options
Description				
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	0.05*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	0.05*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=Not Used Bit 1=Not Used Bit 2=Not Used Bit 3=Not Used 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 G63B), where you can define which blocking signals block which stage. The available settings depend on the model chosen. This description is for models without VTS blocking				
IN2> Blocking	39	54	0x00F	Bit 0=Not Used Bit 1=Not Used Bit 2=Not Used Bit 3=Not Used 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 G63C), where you can define which blocking signals block which stage. The available settings depend on the model chosen. This description is for models without VTS blocking and without Autoreclose.				

8 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

8.1 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 85). This is configured using the cells ***ISEF>(n) tReset***.

Stages 3 and 4 can have definite time characteristics only.

8.2 NON-DIRECTIONAL SEF LOGIC

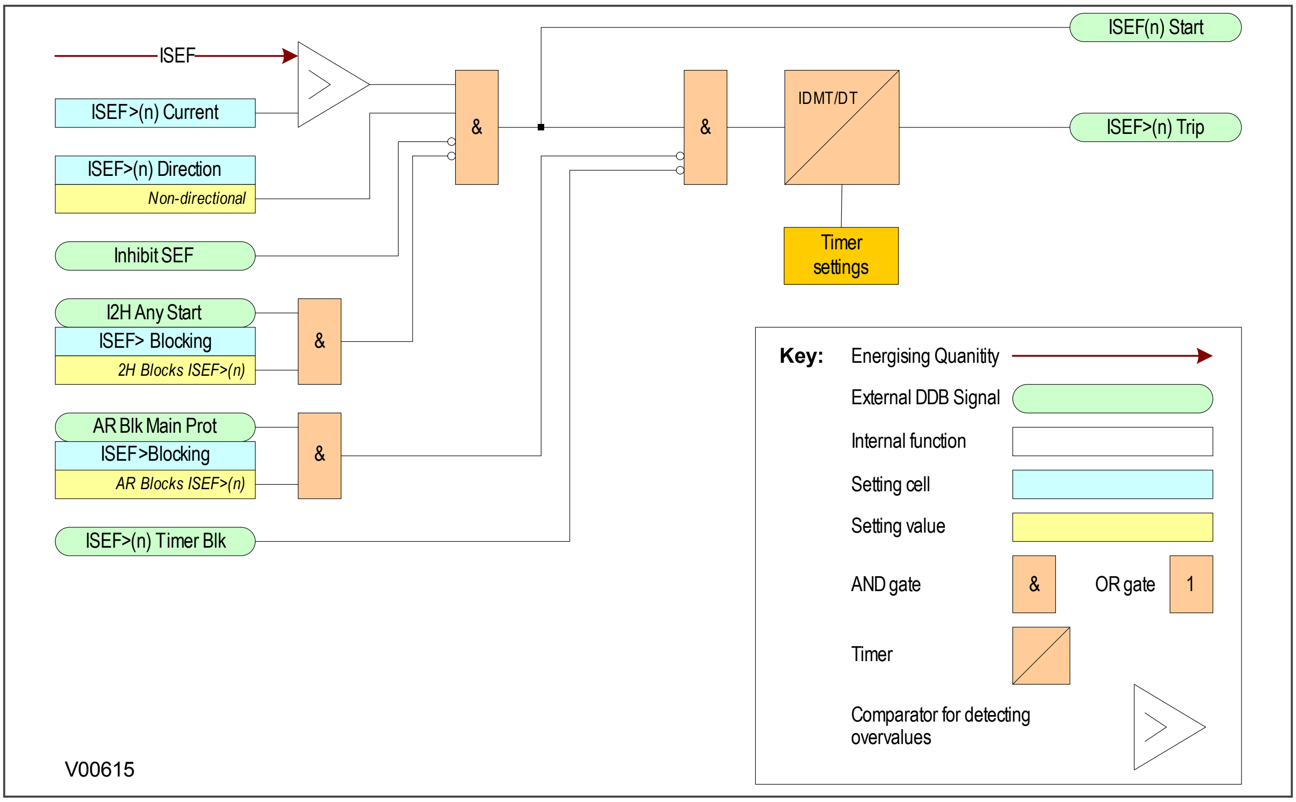


Figure 27: Non-directional SEF logic

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.

8.3 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.

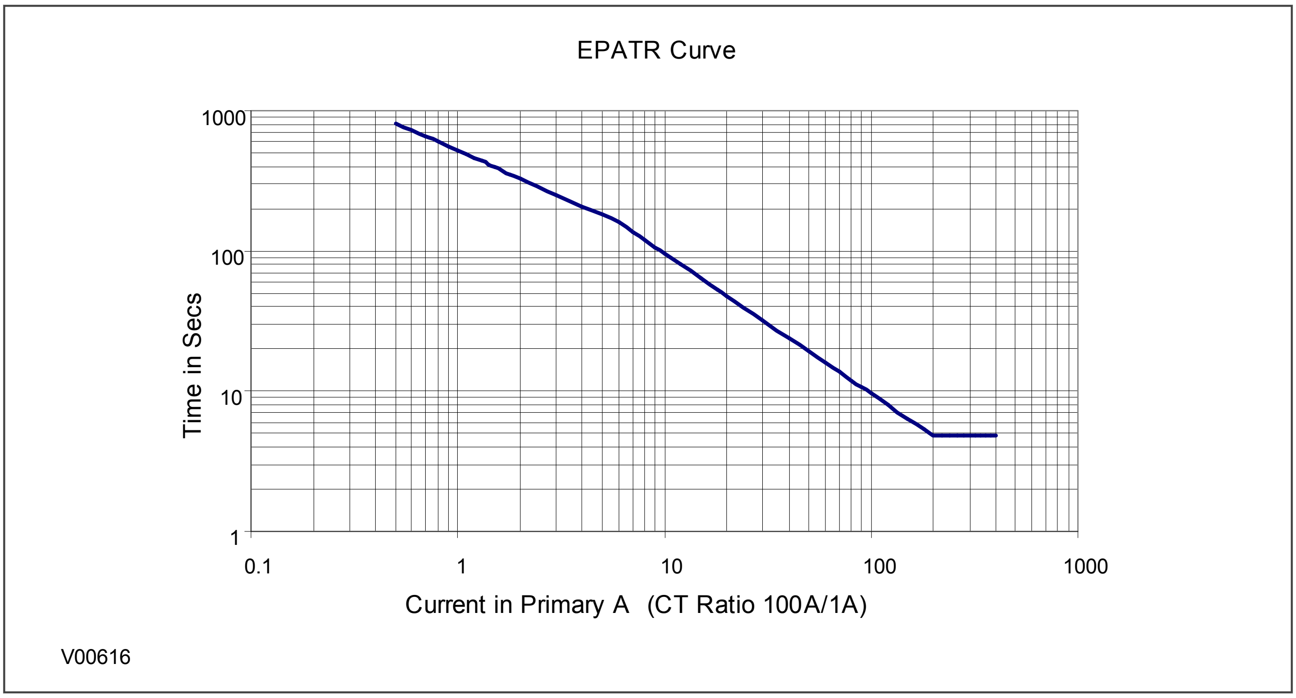


Figure 28: EPATR B characteristic shown for TMS = 1.0

8.4 SEF DDB SIGNALS

Ordinal	Signal Name	Use	Unique ID
Description			
216	ISEF>1 Timer Blk	PSL output	DDB_SEF_1_TIMER_BLOCK
This DDB signal blocks the first stage Sensitive Earth Fault time delay			
217	ISEF>2 Timer Blk	PSL output	DDB_SEF_2_TIMER_BLOCK
This DDB signal blocks the second stage Sensitive Earth Fault time delay			
218	ISEF>3 Timer Blk	PSL output	DDB_SEF_3_TIMER_BLOCK
This DDB signal blocks the third stage Sensitive Earth Fault time delay			
219	ISEF>4 Timer Blk	PSL output	DDB_SEF_4_TIMER_BLOCK
This DDB signal blocks the fourth stage Sensitive Earth Fault time delay			
269	ISEF>1 Trip	PSL input	DDB_SEF_1_TRIP
This DDB signal is the first stage Sensitive Earth Fault trip signal			
270	ISEF>2 Trip	PSL input	DDB_SEF_2_TRIP
This DDB signal is the second stage Sensitive Earth Fault trip signal			
271	ISEF>3 Trip	PSL input	DDB_SEF_3_TRIP
This DDB signal is the third stage Sensitive Earth Fault trip signal			
272	ISEF>4 Trip	PSL input	DDB_SEF_4_TRIP
This DDB signal is the fourth stage Sensitive Earth Fault trip signal			
323	ISEF>1 Start	PSL input	DDB_SEF_1_START
This DDB signal is the first stage Sensitive Earth Fault start signal			
324	ISEF>2 Start	PSL input	DDB_SEF_2_START
This DDB signal is the second stage Sensitive Earth Fault start signal			
325	ISEF>3 Start	PSL input	DDB_SEF_3_START

Ordinal	Signal Name	Use	Unique ID
Description			
This DDB signal is the third stage Sensitive Earth Fault start signal			
326	ISEF>4 Start	PSL input	DDB_SEF_4_START
This DDB signal is the fourth stage Sensitive Earth Fault start signal			
351	VTS Slow Block	PSL input	DDB_VTS_SLOW_BLOCK
This DDB signal is a purposely delayed output from the VTS which can block other functions			
352	CTS Block	PSL input	DDB_CTS_BLOCK
This DDB signal is an instantaneously blocking output from the CTS which can block other functions			
358	AR Blk Main Prot	PSL input	DDB_AR_BLOCK_MAIN_PROTECTION
This DDB signal, generated by the Autoreclose function, blocks the Main Protection elements (POC, EF1, EF2, NPSOC)			
442	Inhibit SEF	PSL output	DDB_SEF_INHIBIT
This DDB signal inhibits Sensitive Earth Fault protection			
541	I2H Any Start	PSL input	DDB_2ND_HARMONIC
This DDB signal is the 2nd Harmonic start signal for any phase			
626	ISEF> Any Start	PSL input	DDB_SEF_ANY_START
This DDB signal is the any-phase start signal for SEF			

8.5 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
This setting selects the type of sensitive earth fault protection function. For non-directional models, only standard SEF is available.				
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.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
ISEF>1 IDG Is	3A	2F	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>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 UsrRstChr	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	0.001*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

Menu Text	Col	Row	Default Setting	Available Options
Description				
This setting sets the DT time delay for the first stage SEF element.				
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 UsrRstChr	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	0.001*In to 2*In step 0.001In
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	0.001*In to 2*In step 0.001In
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	0x000	Bit 0=Not Used, Bit 1=Not Used, Bit 2=Not Used, Bit 3=Not Used, 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 G64B), where you can define which blocking signals block which stage. The available settings depend on the model chosen. This description is for models without VTS blocking				
ISEF> Blocking	3A	57	0x000	Bit 0=Not Used, Bit 1=Not Used, Bit 2=Not Used, Bit 3=Not Used, 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 G64C), where you can define which blocking signals block which stage. The available settings depend on the model chosen. This description is for models without VTS blocking and without Autoreclose.				

8.6 APPLICATION NOTES

8.6.1 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.

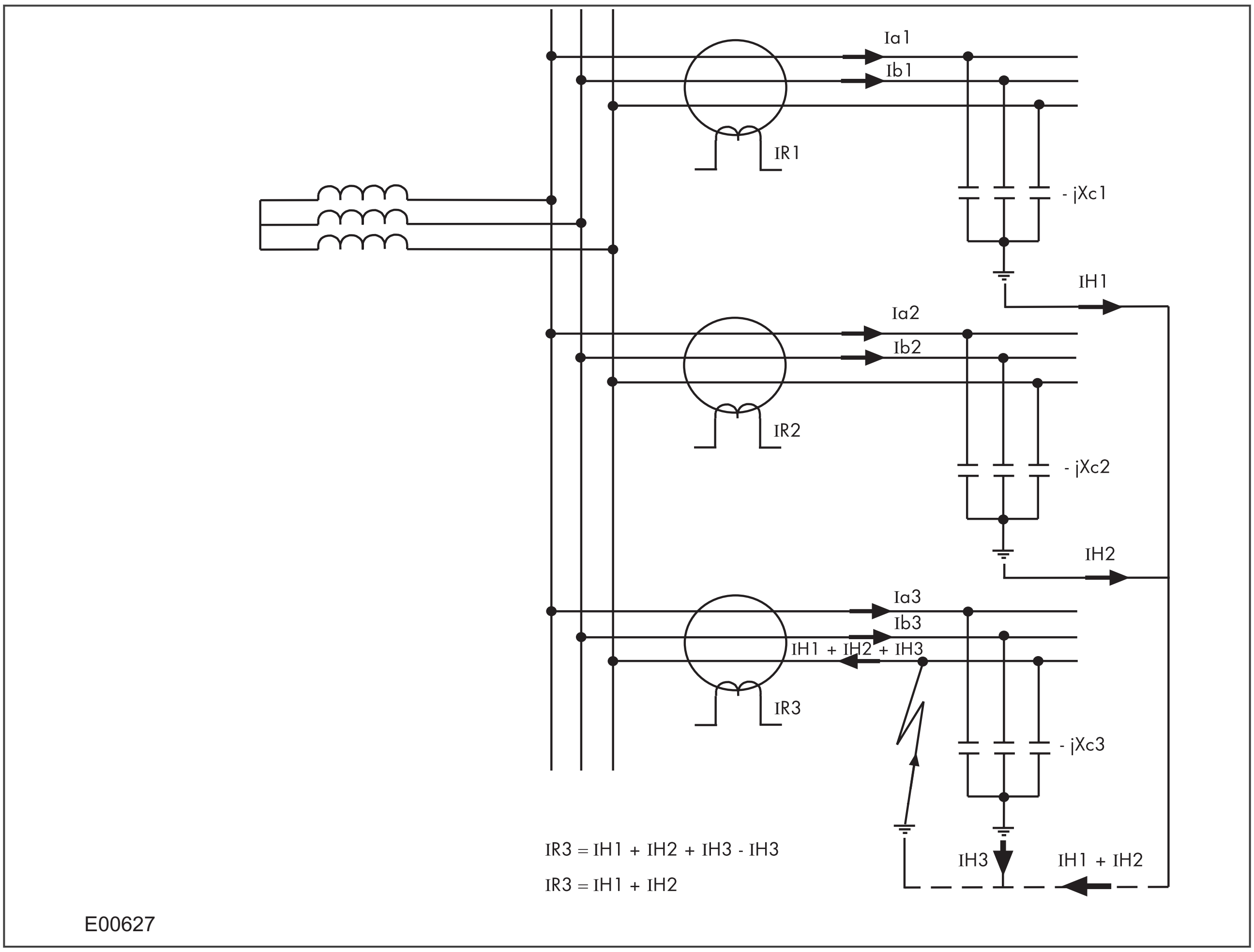


Figure 29: E00627 Current distribution in an insulated system with C phase fault

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°.

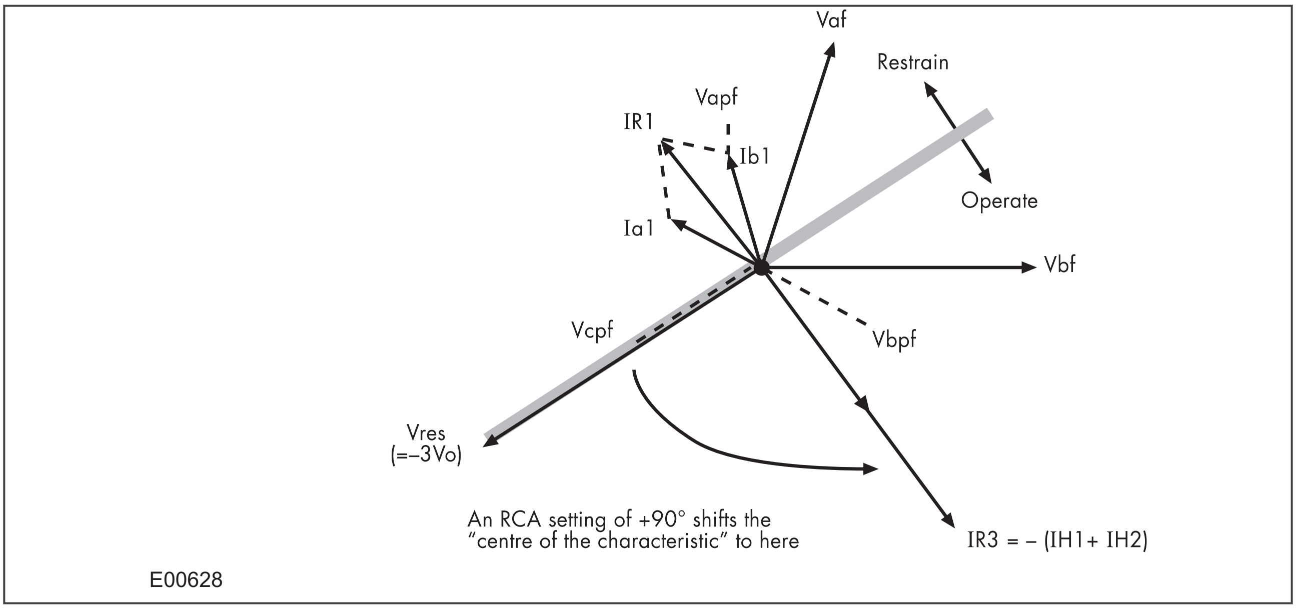


Figure 30: E00628 Phasor diagrams for insulated system with C phase fault

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 √3, the charging currents on these phases are also √3 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 (if available) 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.

8.6.2 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:

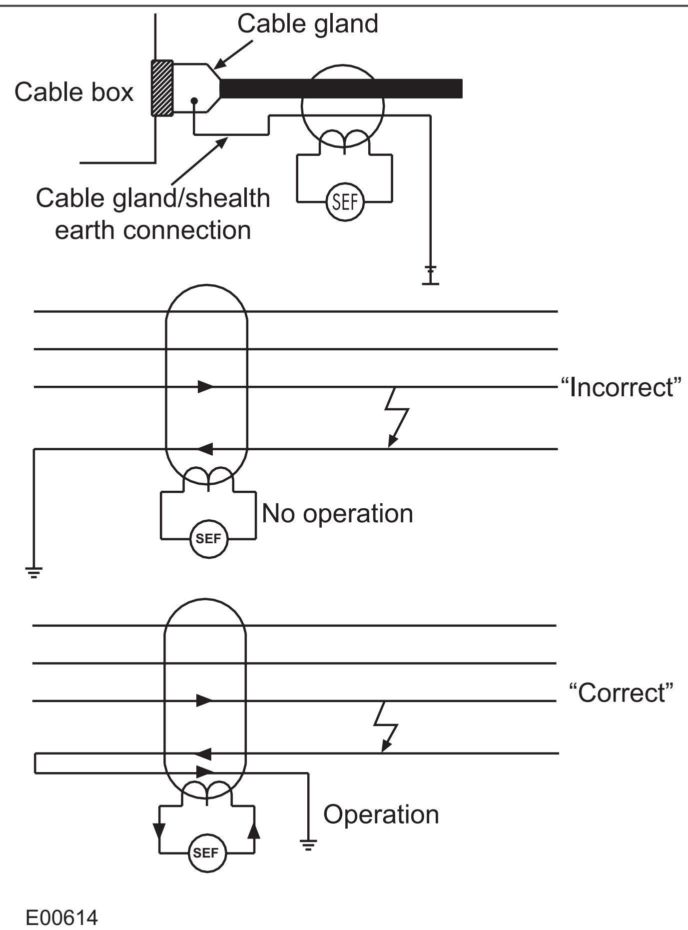


Figure 31: Positioning of core balance current transformers

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.

9 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.

9.1 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

9.2 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

9.3 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.

9.4 THERMAL OVERLOAD PROTECTION LOGIC

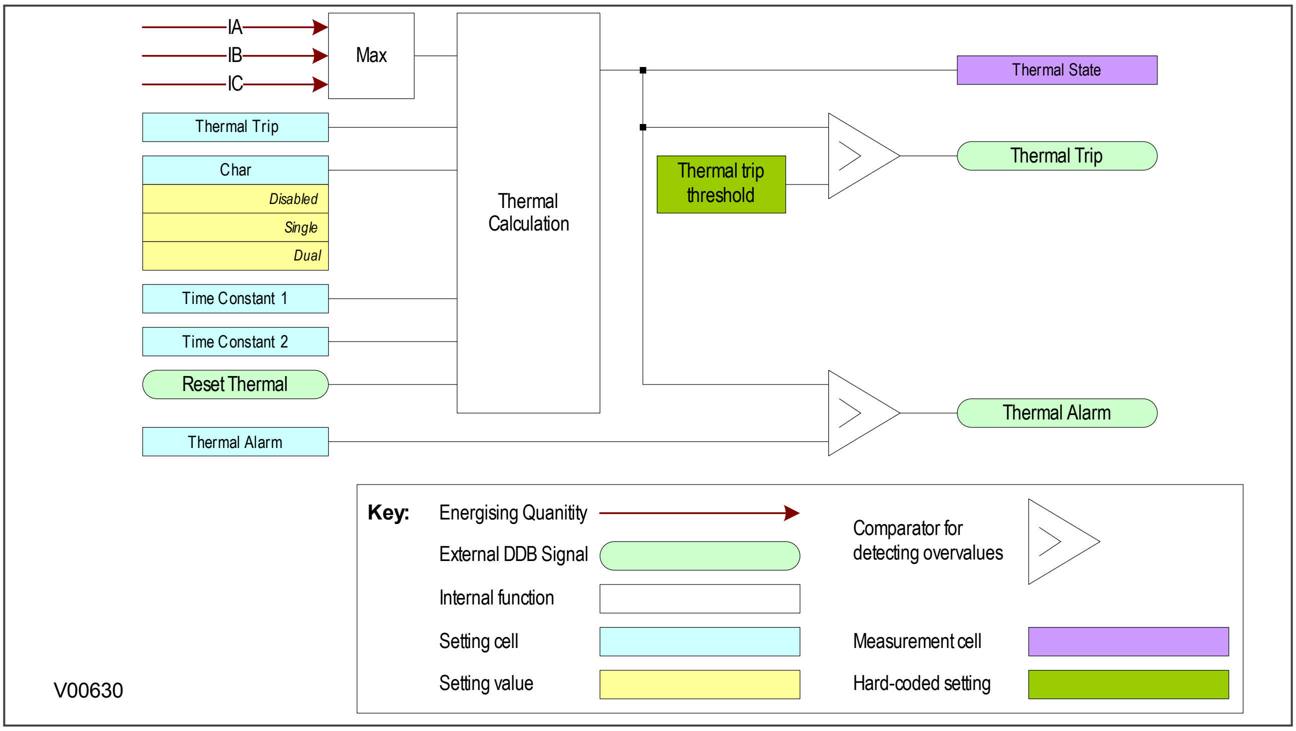


Figure 32: Thermal overload protection logic diagram

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.

9.5 THERMAL OVERLOAD DDB SIGNALS

Ordinal	Signal Name	Use	Unique ID
Description			
236	Reset Thermal	PSL output	DDB_RESET_THERMAL
This DDB signal resets the Thermal State			
276	Thermal Trip	PSL input	DDB_THERMAL_TRIP
This DDB signal is the Thermal Overload trip signal			
329	Thermal Alarm	PSL input	DDB_THERMAL_ALARM
This DDB signal is the Thermal Overload start signal			

9.6 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.				

9.7 APPLICATION NOTES

9.7.1 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.

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

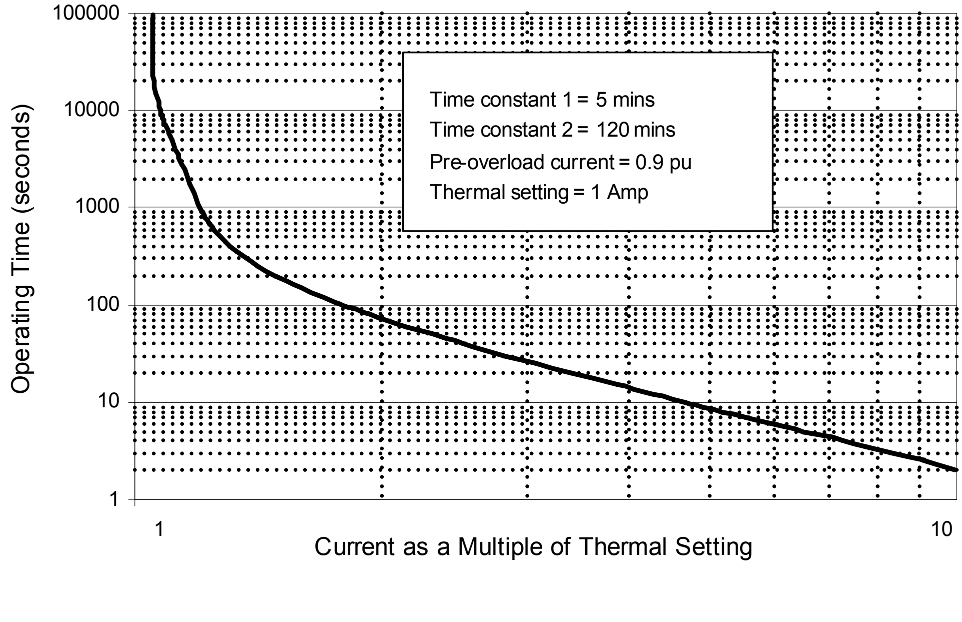


Figure 33: Dual time constant thermal characteristic

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.*

9.7.2 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 mm^2	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

10 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.

10.1 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.

10.2 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.

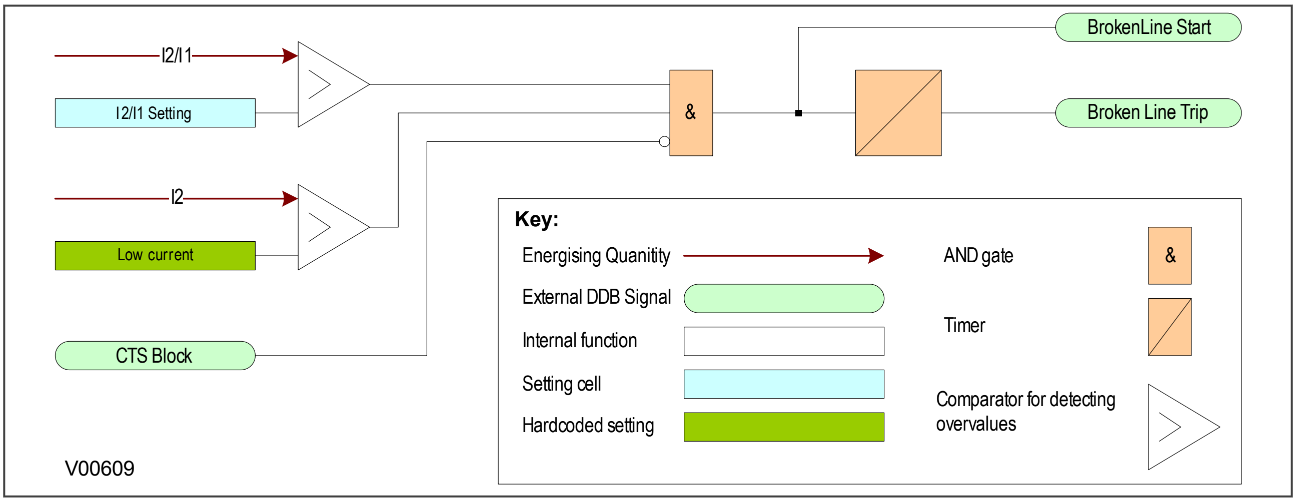


Figure 34: Broken conductor logic

10.3 BROKEN CONDUCTOR DDB SIGNALS

Ordinal	Signal Name	Use	Unique ID
Description			
260	Broken Line Trip	PSL input	DDB_BROKEN_CONDUCTOR_TRIP
This DDB signal is the Broken Conductor trip signal			

Ordinal	Signal Name	Use	Unique ID
Description			
352	CTS Block	PSL input	DDB_CTS_BLOCK
This DDB signal is an instantaneously blocking output from the CTS which can block other functions			
535	BrokenLine Start	PSL input	DDB_BROKEN_CONDUCTOR_START
This DDB signal is the Broken Conductor start signal			

10.4 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				

10.5 APPLICATION NOTES

10.5.1 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.

11 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.

11.1 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.

11.2 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***:

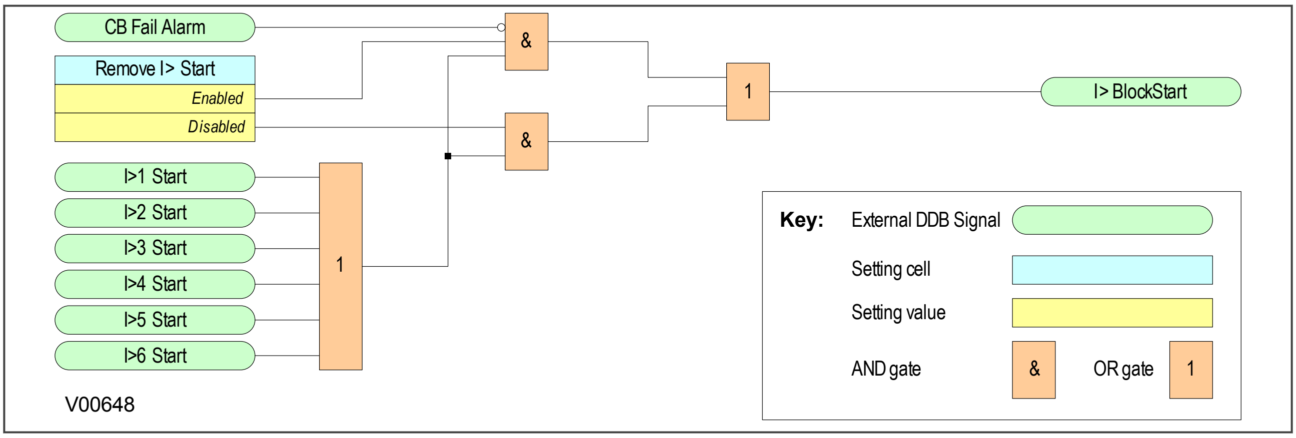


Figure 35: Blocked Overcurrent logic

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.

11.3 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***:

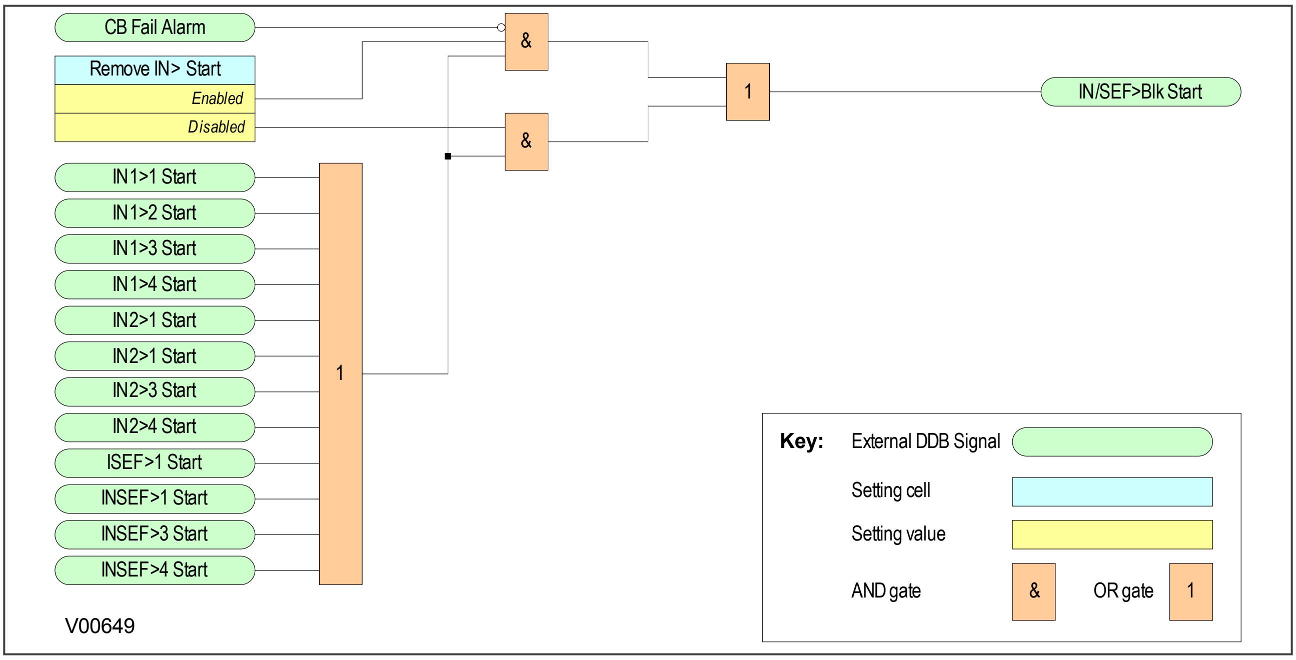


Figure 36: Blocked Earth Fault logic

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.

11.4 BLOCKED OVERCURRENT DDB SIGNALS

Ordinal	Signal Name	Use	Unique ID
Description			
150	CB Fail Alarm	PSL input	DDB_BREAKER_FAIL_ALARM
This DDB signal is an alarm indicating CB Failure			
295	I>1 Start	PSL input	DDB_POC_1_3PH_START
This DDB signal is the first stage any-phase Overcurrent start signal			
299	I>2 Start	PSL input	DDB_POC_2_3PH_START
This DDB signal is the second stage any-phase Overcurrent start signal			
303	I>3 Start	PSL input	DDB_POC_3_3PH_START
This DDB signal is the third stage any-phase Overcurrent start signal			
307	I>4 Start	PSL input	DDB_POC_4_3PH_START
This DDB signal is the fourth stage any-phase Overcurrent start signal			
315	IN1>1 Start	PSL input	DDB_EF1_1_START
This DDB signal is the first stage measured Earth Fault start signal			
316	IN1>2 Start	PSL input	DDB_EF1_2_START
This DDB signal is the second stage measured Earth Fault start signal			
317	IN1>3 Start	PSL input	DDB_EF1_3_START
This DDB signal is the third stage measured Earth Fault start signal			
318	IN1>4 Start	PSL input	DDB_EF1_4_START
This DDB signal is the fourth stage measured Earth Fault start signal			
319	IN2>1 Start	PSL input	DDB_EF2_1_START
This DDB signal is the first stage derived Earth Fault start signal			

Ordinal	Signal Name	Use	Unique ID
Description			
320	IN2>2 Start	PSL input	DDB_EF2_2_START
This DDB signal is the second stage derived Earth Fault start signal			
321	IN2>3 Start	PSL input	DDB_EF2_3_START
This DDB signal is the third stage derived Earth Fault start signal			
322	IN2>4 Start	PSL input	DDB_EF2_4_START
This DDB signal is the fourth stage derived Earth Fault start signal			
323	ISEF>1 Start	PSL input	DDB_SEF_1_START
This DDB signal is the first stage Sensitive Earth Fault start signal			
324	ISEF>2 Start	PSL input	DDB_SEF_2_START
This DDB signal is the second stage Sensitive Earth Fault start signal			
325	ISEF>3 Start	PSL input	DDB_SEF_3_START
This DDB signal is the third stage Sensitive Earth Fault start signal			
326	ISEF>4 Start	PSL input	DDB_SEF_4_START
This DDB signal is the fourth stage Sensitive Earth Fault start signal			
348	I> BlockStart	PSL input	DDB_PH_BLOCKED_OC_START
This DDB signal is the start signal for Blocked Overcurrent functionality			
349	IN/SEF>Blk Start	PSL input	DDB_N_BLOCKED_OC_START
This DDB signal is the start signal for Blocked Earth Fault functionality			
579	I>5 Start	PSL input	DDB_POC_5_3PH_START
This DDB signal is the fifth stage three-phase Phase Overcurrent start signal			
583	I>6 Start	PSL input	DDB_POC_6_3PH_START
This DDB signal is the sixth stage three-phase Phase Overcurrent start signal			

11.5 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				

11.6 APPLICATION NOTES

11.6.1 BUSBAR BLOCKING SCHEME

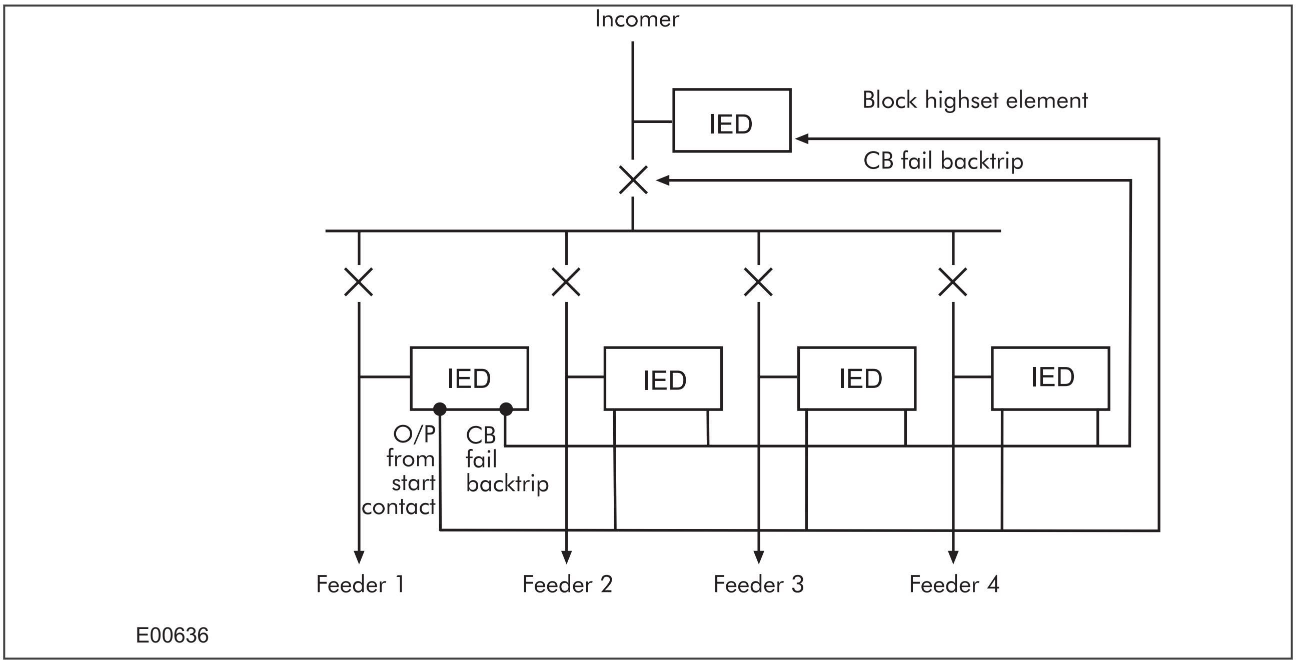


Figure 37: Simple busbar blocking scheme

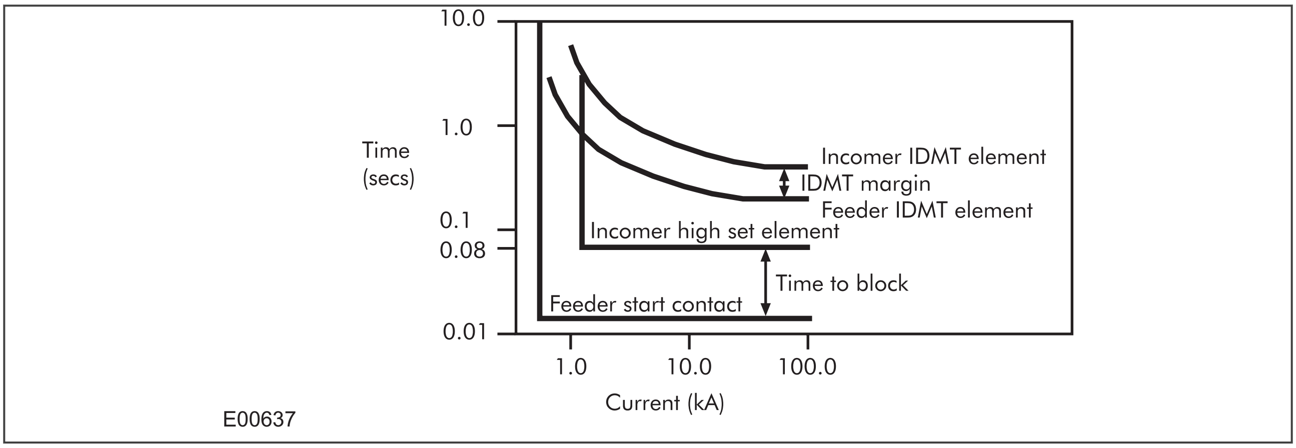


Figure 38: Simple busbar blocking scheme characteristics

12 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.

12.1 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 *SYSTEM CONFIG* column of the relevant setting groupwhere group.

Second harmonic blocking 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

12.2 SECOND HARMONIC BLOCKING LOGIC

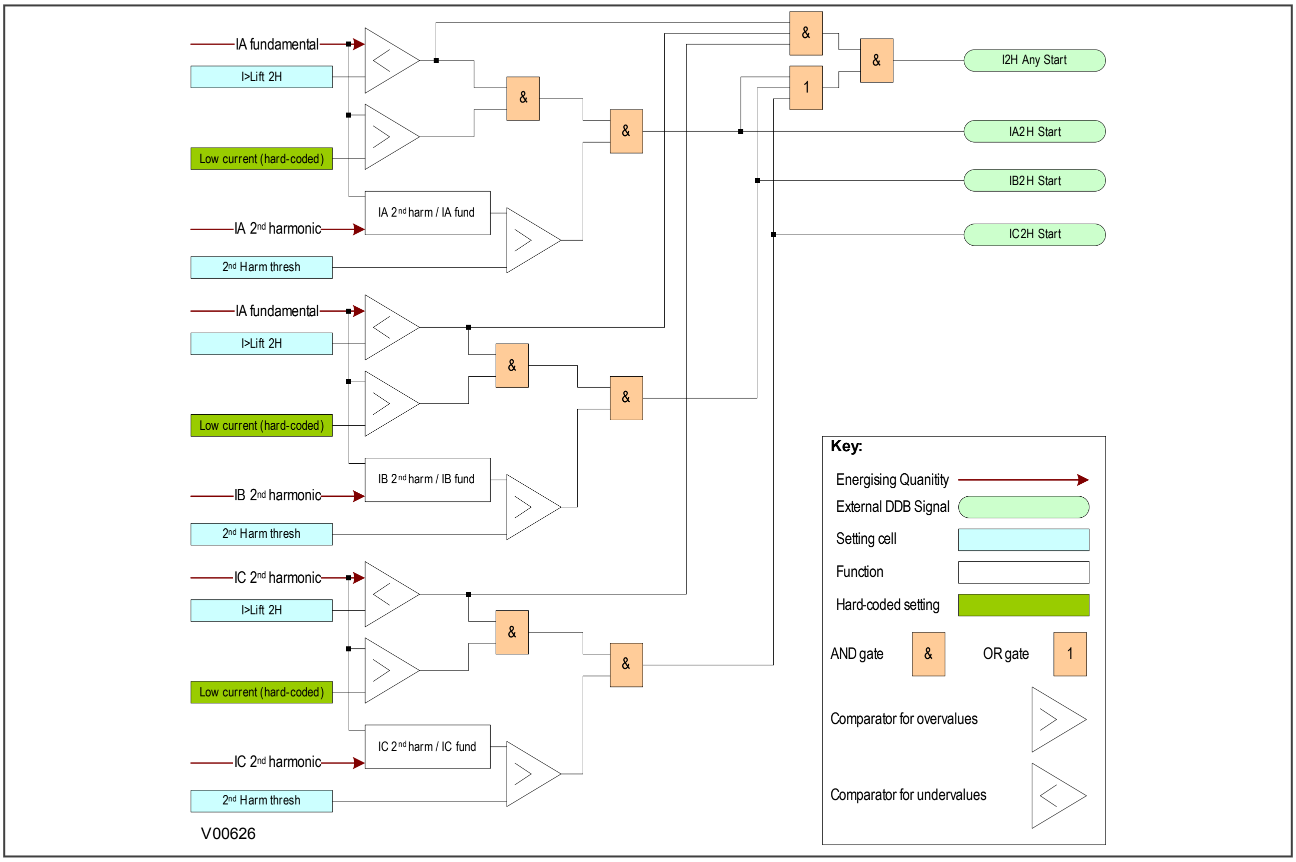


Figure 39: 2nd Harmonic Blocking Logic

12.3 SECOND HARMONIC DDB SIGNALS

Ordinal	Signal Name	Use	Unique ID
Description			
538	IA2H Start	PSL input	DDB_2ND_HARMONIC_IA
This DDB signal is the A-phase 2nd Harmonic start signal			
539	IB2H Start	PSL input	DDB_2ND_HARMONIC_IB
This DDB signal is the B-phase 2nd Harmonic start signal			
540	IC2H Start	PSL input	DDB_2ND_HARMONIC_IC
This DDB signal is the C-phase 2nd Harmonic start signal			
541	I2H Any Start	PSL input	DDB_2ND_HARMONIC
This DDB signal is the 2nd Harmonic start signal for any phase			

12.4 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				
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.				

12.5 APPLICATION NOTES

12.5.1 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.

13 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)

13.1 HIGH IMPEDANCE FAULT PROTECTION IMPLEMENTATION

13.2 HIGH IMPEDANCE FAULT PROTECTION LOGIC

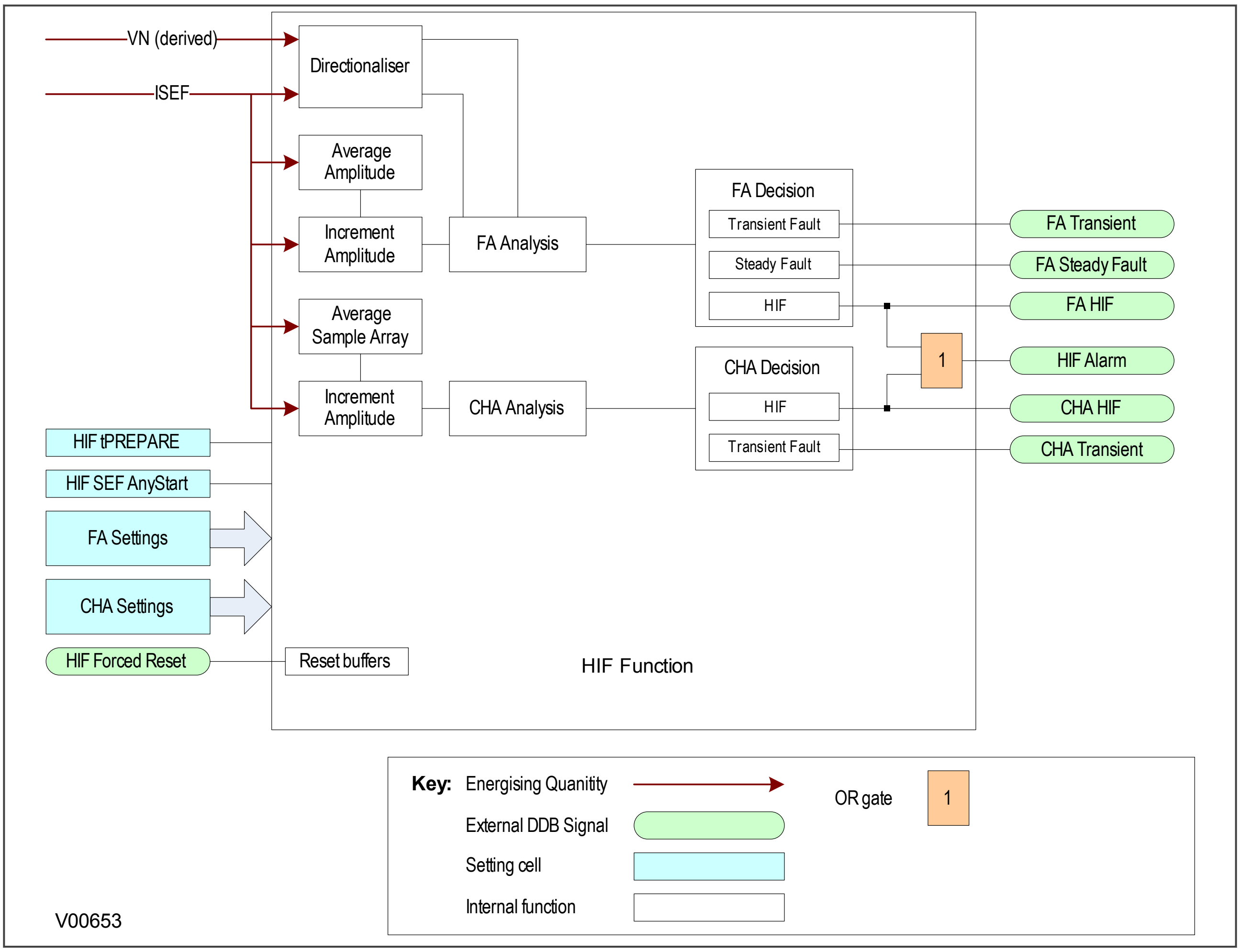


Figure 40: HIF Protection Logic

13.3 HIGH IMPEDANCE PROTECTION DDB SIGNALS

Ordinal	Signal Name	Use	Unique ID
Description			
1208	HIF Any Start	Hidden	DDB_HIZ_START
HIF Any Start			
1209	HIF Alarm	PSL input	DDB_HIZ_ALARM
HIF Alarm = FA HIF || CHA HIF			
1210	FA HIF	PSL input	DDB_HIZ_FA_HIF
HIF FA detected HIF			
1211	FA Transient	PSL input	DDB_HIZ_FA_TRANSIENT
HIF FA detected Transient Event			
1212	FA Steady Fault	PSL input	DDB_HIZ_FA_STEADY
HIF FA detected Steady Event			

Ordinal	Signal Name	Use	Unique ID
Description			
1213	CHA HIF	PSL input	DDB_HIZ_CHA_HIF
HIF CHA detected HIF			
1214	CHA Transient	PSL input	DDB_HIZ_CHA_TRANSIENT
HIF CHA detected Transient Event			
1216	HIF Forced Reset	PSL output	DDB_HIZ_RESET
HIF Forced Resetting of all calculation			

13.4 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
This setting enables or disables FA Direction Detection.				
COMP.HARM.ANALYS	4C	20		
This sub-heading contains settings for the Component Harmonic Analysis (CHA) algorithm.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
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.				

14 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)

14.1 OVERCURRENT AND EARTH FAULT PROTECTION

14.1.1 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

$$V_K = I_{sn}(R_{CT} + 2R_L + R_p + R_n)$$

14.2 SEF PROTECTION (RESIDUALLY CONNECTED)

14.2.1 NON-DIRECTIONAL ELEMENTS

Time delayed SEF protection

$$V_K \geq \frac{I_{cn}}{2}(R_{CT} + 2R_L + R_p + Rn)$$

Instantaneous SEF protection

$$V_K \geq \frac{I_{sn}}{2}(R_{CT} + 2R_L + R_p + Rn)$$

14.3 SEF PROTECTION (CORE-BALANCED CT)

14.3.1 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.

14.4 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:

$$V_K = 1.05(C\,rating\,in\,volts) + 100R_{CT}$$

RESTRICTED EARTH FAULT PROTECTION

CHAPTER 6

1 CHAPTER OVERVIEW

The device provides extensive Restricted Earth Fault functionality. This chapter describes the operation of this function including the principles of operation, logic diagrams and applications.

This chapter contains the following sections:

2 REF PROTECTION PRINCIPLES

Winding-to-core faults in a transformer are quite common due to insulation breakdown. Such faults can have very low fault currents, but they still need to be picked up. If such faults are not identified, this could result in extreme damage to very expensive equipment.

Often the associated fault currents are 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 each transformer winding. Restricted Earth Fault protection is the protection mechanism used to protect individual transformer winding sets.

The following figure shows a REF protection arrangement for protecting the delta side of a delta-star transformer.

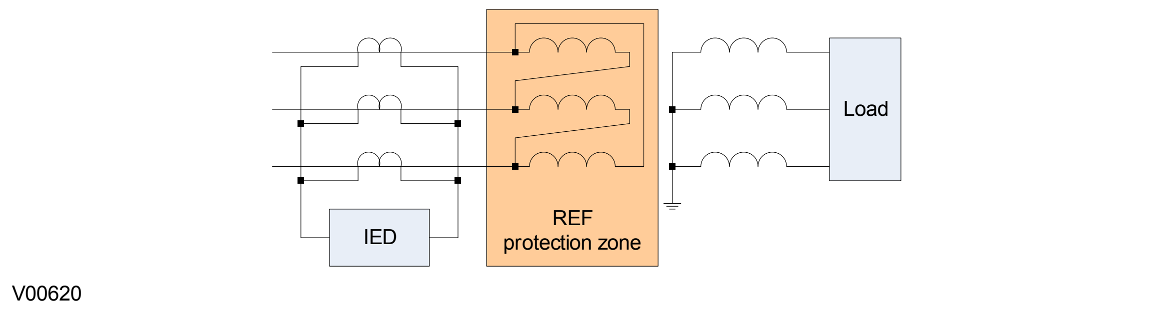


Figure 41: REF protection for delta side

The current transformers measuring the currents in each phase are connected in parallel. The currents from all three phases are summed to form a differential current, sometimes known as a spill current. Under normal operating conditions the currents of the three phases add up to zero resulting in zero spill current. A fault on the star side will also 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.

The following figure shows a REF protection arrangement for the star side of a delta-star transformer.

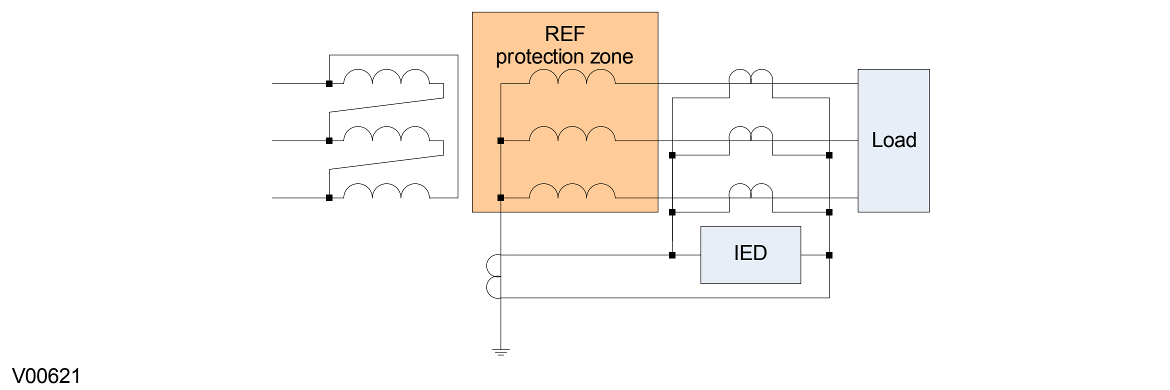


Figure 42: REF protection for star side

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.

2.1 RESISTANCE-EARTHED STAR WINDINGS

Most distribution systems use resistance-earthed systems to limit the fault current. Consider the diagram below, which depicts an earth fault on the star winding of a resistance-earthed Dyn transformer.

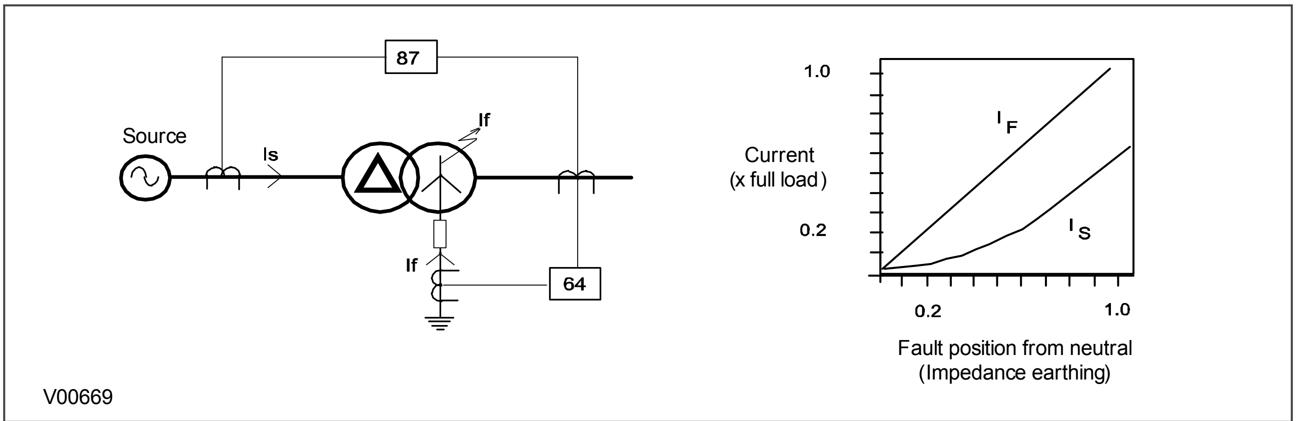


Figure 43: REF Protection for resistance-earthed systems

The value of fault current (I_F) depends on two factors:

- The value of earthing resistance (which makes the fault path impedance negligible)
- The fault point voltage (which is governed by the fault location).

Because the fault current (I_F) is governed by the resistance, its value is directly proportional to the location of the fault.

A restricted earth fault element (64) is connected to measure If directly. This provides very sensitive earth fault protection. The overall differential protection (87) is less sensitive, since it only measures the HV current Is. The value of Is is limited by the number of faulty secondary turns in relation to the HV turns.

2.2 SOLIDLY-EARTHED STAR WINDINGS

Most transmission systems use solidly-earthed systems. Consider the diagram below, which depicts an earth fault on the star winding of a resistance-earthed Dyn transformer.

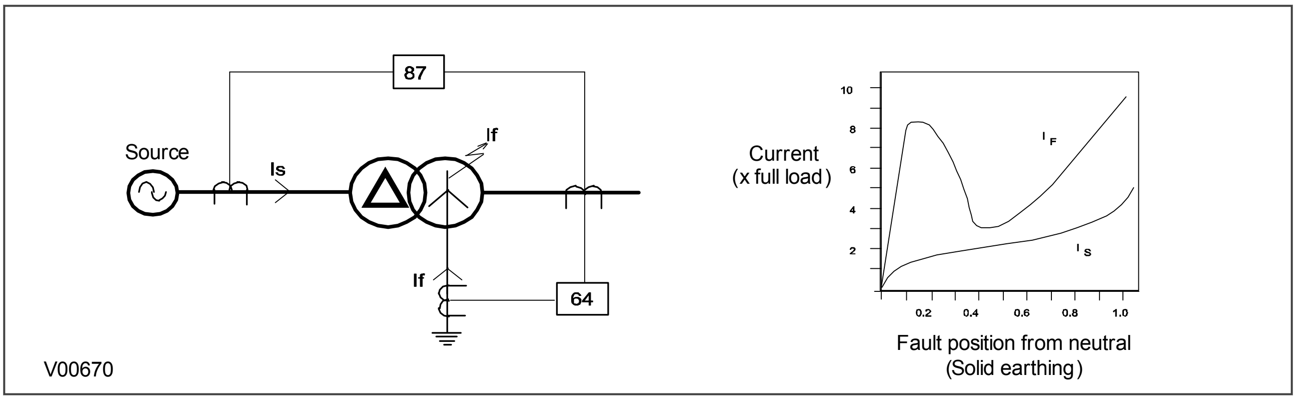


Figure 44: REF Protection for solidly earthed system

In this case, the fault current If is dependent on:

- The leakage reactance of the winding
- The impedance in the fault path
- The fault point voltage (which is governed by the fault location)

In this case, the value of fault current (I_F) varies with the fault location in a complex manner.

A restricted earth fault element (64) is connected to measure If directly. This provides very sensitive earth fault protection.

For solidly earthed systems, the operating current for the transformer differential protection (87) is still significant for faults over most of the winding. For this reason, independent REF protection may not have been previously considered, especially where an additional device would have been needed.

2.3 THROUGH FAULT STABILITY

With any form of differential protection, it is important that the CTs have the same characteristics. This is to avoid unnecessarily creating a differential current. However, in reality CTs can never be identical, therefore a certain amount of differential current is inevitable. As the through-fault current in the primary increases, the discrepancies introduced by the imperfectly matched CTs is magnified, causing the differential current to build up. Eventually, the value of the differential current reaches the pickup current threshold, causing the IED to trip. In such cases, the differential scheme is said to have lost stability. To specify a differential scheme's ability to restrain from tripping on external faults, we define a parameter called 'through-fault stability limit', which is the maximum through-fault current a system can handle without losing stability.

2.4 RESTRICTED EARTH FAULT TYPES

There are two different types of Restricted Earth Fault; Low Impedance REF (also known as Biased REF) and High Impedance REF. Each method compensates for the effect of through-fault errors in a different manner.

With Low Impedance REF, the through-fault current is measured and this is used to alter the sensitivity of the REF element accordingly by applying a bias characteristic. So the higher the through fault current, the higher the differential current must be for the device to issue a trip signal, Often a transient bias component is added to improve stability during external faults.

With High Impedance REF, there is no bias characteristic, and the trip threshold is set to a constant level. However, the High Impedance differential technique ensures that the impedance of the circuit is sufficiently high such that the differential voltage under external fault conditions is lower than the voltage needed to drive differential current through the device. This ensures stability against external fault conditions so the device will operate only for faults occurring inside the protected zone.

The choice of REF used in a particular application depends on various factors such as the quality of the CTs and the required sensitivity.

2.4.1 LOW IMPEDANCE REF PRINCIPLE

Low Impedance REF can be used for either delta windings or star windings in both solidly grounded and resistance grounded systems. The connection to a modern IED is as follows:

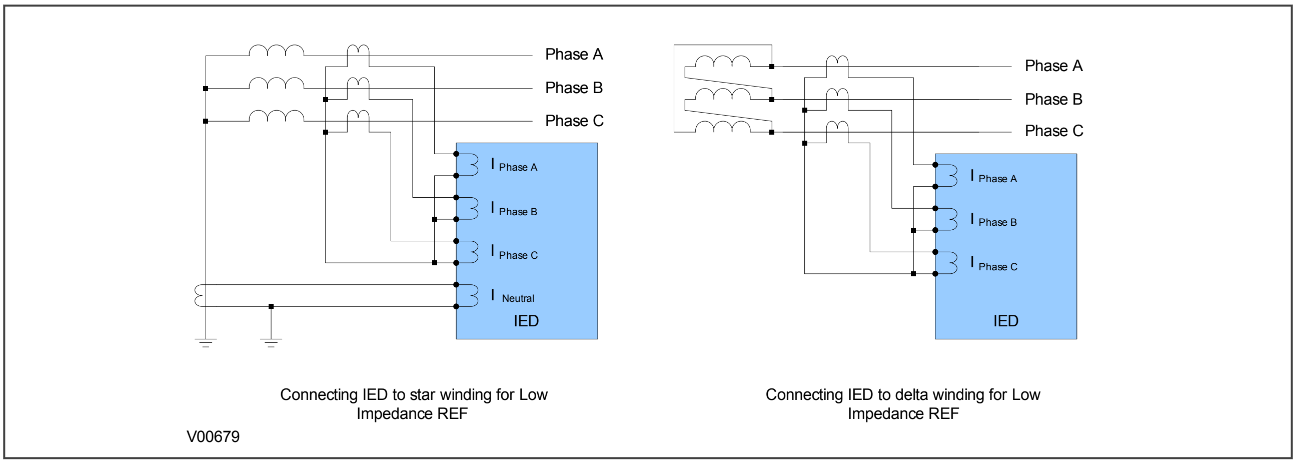


Figure 45: Low Impedance REF Connection

2.4.1.1 LOW IMPEDANCE BIAS CHARACTERISTIC

Usually, a triple slope biased characteristic is used as follows:

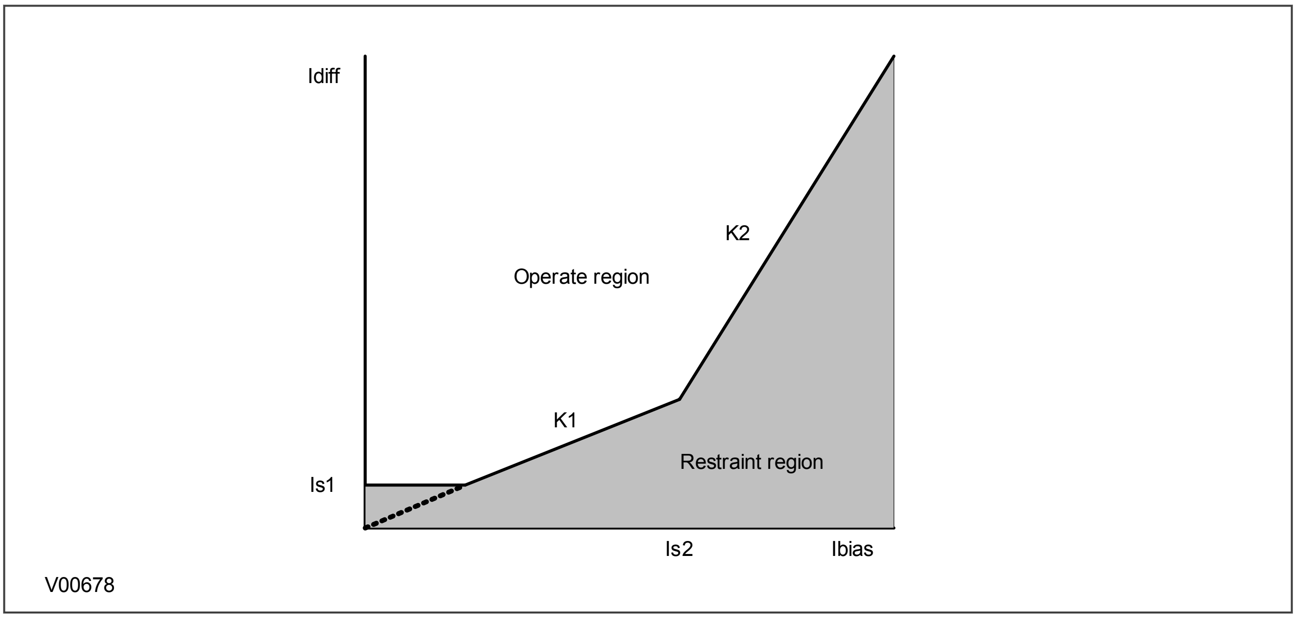


Figure 46: Three-slope REF bias characteristic

The characteristic can be defined by setting the following parameters:

- Is1: this sets the minimum operating current
- Is2: this marks the start of the steeper slope
- K1: this constant defines the gradient of the first slope
- K2: this constant defines the gradient of the second slope

The first knee is dependent on the settings of Is1 and K1. The second knee is defined by the setting Is2. The lower slope provides sensitivity for internal faults. The higher slope provides stability under through fault conditions. the regions of the characteristic can be defined as follows:

$$Flat\ slope: I_{bias} \leq \frac{I_{s1}}{K1}$$

$$K1\ slope: \quad \frac{I_{s1}}{K1} \leq I_{bias} \leq I_{s2}$$

$$K2\ slope: \quad I_{s2} \leq I_{bias}$$

The bias current is defined as:

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

And the operation conditions are defined as follows (where K1 > 0):

For $I_{BIAS} \leq Is1/K1$: Operate when $I_{DIFF} > Is1$

For $Is1/K1 \leq I_{BIAS} \leq Is2$: Operate when $I_{DIFF} > K1(I_{BIAS})$

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

Very often, a simplified version of this characteristic is used whereby K1 is set to 0%. In this case:

For $I_{BIAS} \leq Is2$: Operate when $I_{DIFF} > Is1$

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

> *Note:*
> *In Restricted Earth Fault applications, Bias Current Compensation is also known as Low Impedance REF.*

2.4.2 HIGH IMPEDANCE REF PRINCIPLE

This scheme is very sensitive and can protect against low levels of fault current, typical of winding faults.

High Impedance REF protection is based on the differential principle. It works on the circulating current principle as shown in the following diagram.

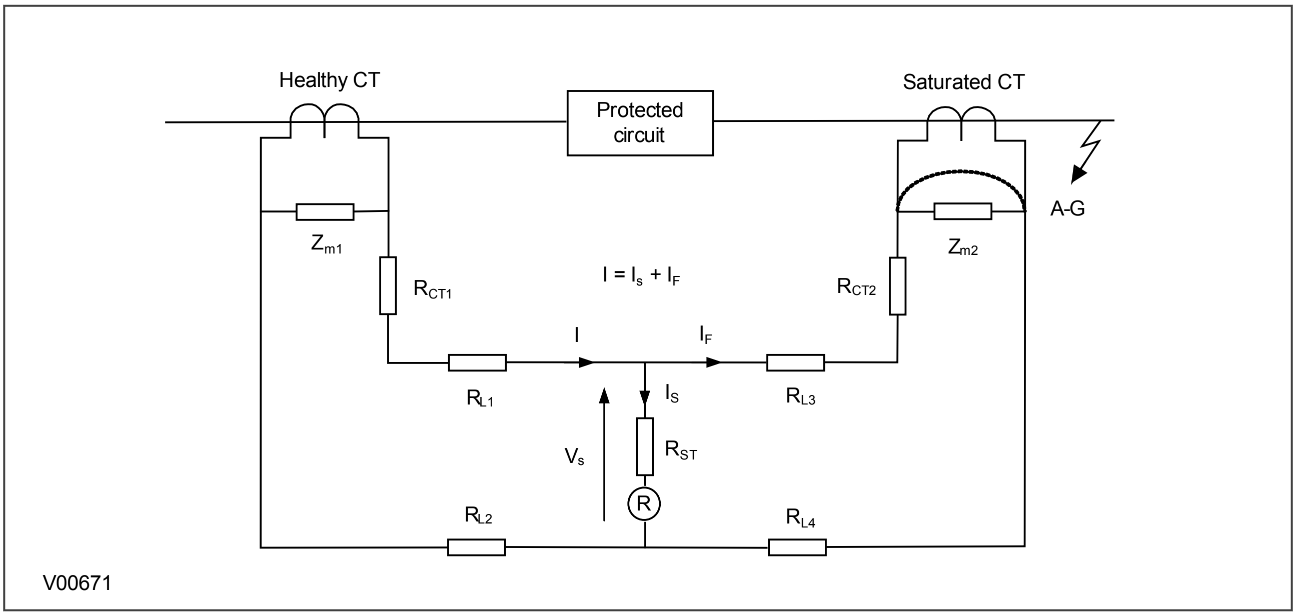


Figure 47: High Impedance REF principle

When subjected to heavy through faults the line current transformer may enter saturation unevenly, resulting in imbalance. To ensure stability under these conditions a series connected external resistor is required, so that most of the unbalanced current will flow through the saturated CT. As a result, the current flowing through the device will be less than the setting, therefore maintaining stability during external faults.

Voltage across REF element $V_S = I_F (R_{CT2} + R_{L3} + R_{L4})$

Stabilising resistor $R_{ST} = V_S/I_S - R_R$

where:

- I_F = maximum secondary through fault current
- R_R = device burden
- R_{CT} = CT secondary winding resistance
- R_{L2} and R_{L3} = Resistances of leads from the device to the current transformer
- R_{ST} = Stabilising resistor

High Impedance REF can be used for either delta windings or star windings in both solidly grounded and resistance grounded systems. The connection to a modern IED are as follows:

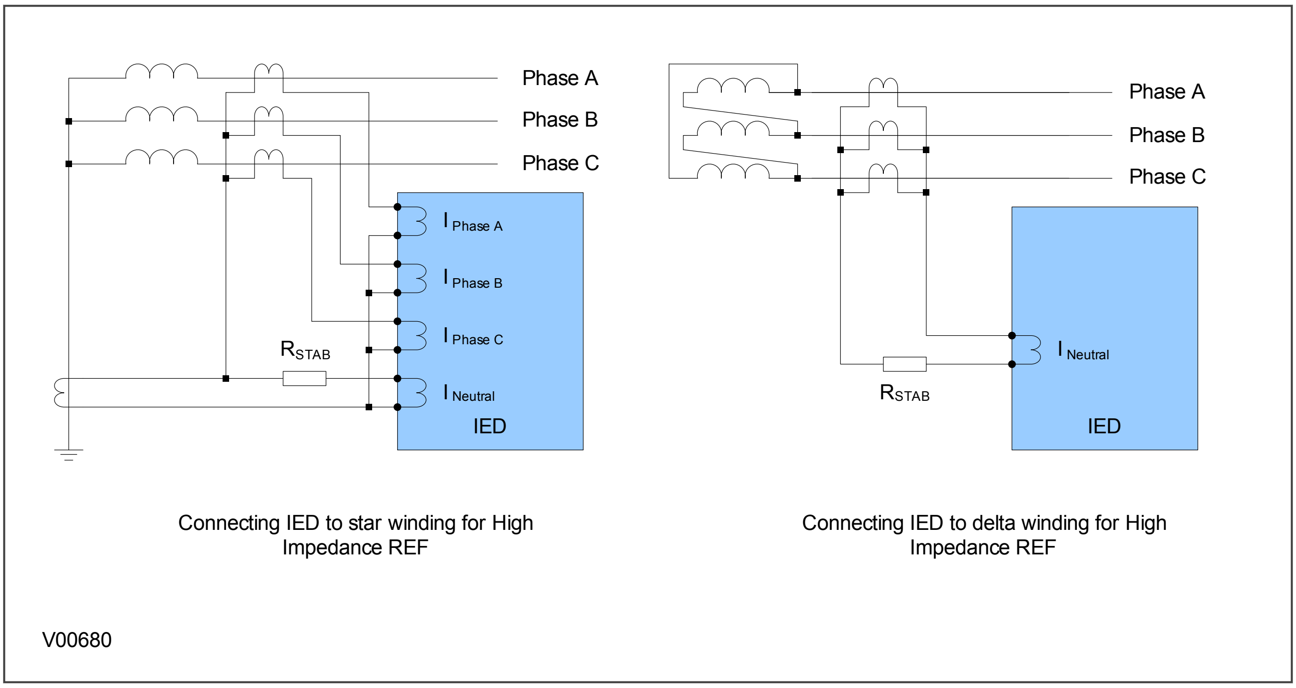


Figure 48: High Impedance REF Connection

3 RESTRICTED EARTH FAULT PROTECTION IMPLEMENTATION

3.1 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.

3.2 LOW IMPEDANCE REF

The current required to trip the differential IED is called the Operate current. This Operate current is a function of the differential current and the bias current.

The differential current is as follows:

$$I_{diff} = \left(\bar{I}_A + \bar{I}_B + \bar{I}_C\right) + K\bar{I}_N$$

The bias current is as follows:

$$I_{bias} = \frac{1}{2}\left\{\max\left[\left|I_A\right|,\left|I_B\right|,\left|I_C\right|\right] + K\left|I_N\right|\right\}$$

where:

- K = Line CT ratio / Neutral CT ratio (0.05 < K < 20)
- IN = current measured by the neutral CT

3.2.1 DELAYED BIAS

The bias quantity used is actually delayed by one cycle. It is the maximum value of the mean bias quantities calculated within the previous cycle, where the mean bias is the fundamental bias current. This means the bias level, and thus through-fault stability is maintained after an external fault has been cleared.

The algorithm, shown below, is executed eight times per cycle.

$$I_{bias} = Maximum\ [I_{bias}\ (n),\ I_{bias}\ (n\text{-}1),\ \ldots I_{bias},\ (n - (K\text{-}1))]$$

It is this delayed bias that is used to calculate the operating current.

3.2.2 SETTING THE BIAS CHARACTERISTIC

The following settings are provided to define the bias characteristic:

- ***IREF>Is1***: sets the minimum trip threshold
- ***IREF>Is2***: sets the bias current kneepoint whereby the required trip current starts increasing
- ***IREF> k1***: defines the first slope (often set to 0%)
- ***IREF> k2***: defines the second slope

> *Note:*
> *Is1 and Is2 are relative to the line CT, which is always the reference CT.*

3.3 HIGH IMPEDANCE REF

The device provides a high impedance restricted earth fault protection function. An external resistor is required to provide stability in the presence of saturated line current transformers. Current transformer supervision signals do not block the high impedance REF protection. The appropriate logic must be configured in PSL to block the high impedance REF when any of the above signals is asserted.

3.3.1 HIGH IMPEDANCE REF CALCULATION PRINCIPLES

The faulot current, or primary operating current (Iop) is a function of the current transformer ratio, the device operate current (***IREF>Is***), the number of current transformers in parallel with a REF element (n) and the magnetizing current of each current transformer (Ie) at the stability voltage (Vs). This relationship can be expressed in three ways:

1. The maximum current transformer magnetizing current to achieve a specific primary operating current with a particular operating current:

$$I_e < \frac{1}{n}\left(\frac{I_{op}}{CT\,ratio} - [IREF > Is]\right)$$

2. The maximum current setting to achieve a specific primary operating current with a given current transformer magnetizing current:

$$[IREF > Is] < \left(\frac{I_{op}}{CT\,ratio} - nI_e\right)$$

3. The protection primary operating current for a particular operating current with a particular level of magnetizing current:

$$I_{op} = (CT\,ratio)\left([IREF > Is] + nI_e\right)$$

In order to achieve the required primary operating current with the current transformers that are used, you must select a current setting for the high impedance element, as detailed in expression 2 above. You can calculate the value of the stabilising resistor (R_{ST}) in the following manner.

$$R_{st} = \frac{Vs}{[IREF > Is]} = \frac{I_F\left(R_{CT} + 2R_L\right)}{[IREF > Is]}$$

where:

- R_{CT} = the resistance of the CT winding
- R_L = the resistance of the lead from the CT to the IED.

> *Note:*
> *The above formula assumes negligible relay burden.*

We recommend a stabilizing resistor, which is continuously adjustable up to its maximum declared resistance.

4 DDB SIGNALS

Ordinal	Signal Name	Use	Unique ID
Description			
273	IREF> Trip	PSL input	DDB_REF_TRIP
This DDB signal is the Restricted Earth Fault trip signal			

5 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.				

6 APPLICATION NOTES

6.1 STAR WINDING RESISTANCE EARTHED

Consider the following resistance earthed star winding below.

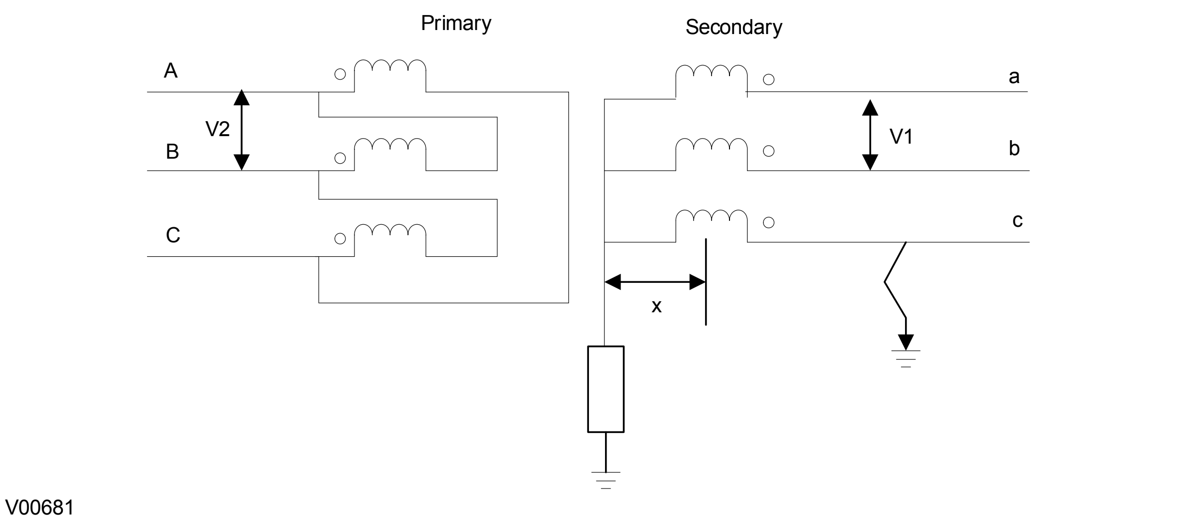


Figure 49: Star winding, resistance earthed

An earth fault on such a winding causes a current which is dependent on the value of earthing impedance. This earth fault current is proportional to the distance of the fault from the neutral point since the fault voltage is directly proportional to this distance.

The ratio of transformation between the primary winding and the short circuited turns also varies with the position of the fault. Therefore the current that flows through the transformer terminals is proportional to the square of the fraction of the winding which is short circuited.

The earthing resistor is rated to pass the full load current $I_{FLC} = V1/\sqrt{3}R$

Assuming that V1 = V2 then T2 = $\sqrt{3}$T1

For a fault at x PU distance from the neutral, the fault current If = $xV1/\sqrt{3}R$

Therefore the secondary fault current referred to the primary is $I_{primary} = x^2.I_{FLC}/\sqrt{3}$

If the fault is a single end fed fault, the primary current should be greater than 0.2 pu (Is1 default setting) for the differential protection to operate. Therefore $x^2/\sqrt{3} > 20\%$

The following diagram shows that 41% of the winding is protected by the differential element.

X in %	Idiff in %
10	0.58
20	2.31
30	5.20
40	9.24
50	14.43
60	20.00
70	28.29
80	36.95
90	46.77
100	57.74

59% of unprotected winding (X = 10 to 60)

41% of unprotected winding (X = 60 to 100)

V00682

Figure 50: Percentage of winding protected

6.2 LOW IMPEDANCE REF PROTECTION APPLICATION

6.2.1 SETTING GUIDELINES FOR BIASED OPERATION

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 is 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. We recommend a setting of 20% in this case.

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

According to ESI 48-3 1977, typical settings for the Is1 thresholds are are 10-60% of the winding rated current when solidly earthed and 10-25% of the minimum earth fault current for a fault at the transformer terminals when resistance earthed.

6.2.2 LOW IMPEDANCE REF SCALING FACTOR

The three line CTs are connected to the three-phase CTs, and the neutral CT is connected to the neutral 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. 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 provide the measurement for the Standby Earth Fault Protection. Also, no external components such as stabilizing resistors or Metrosils are required.

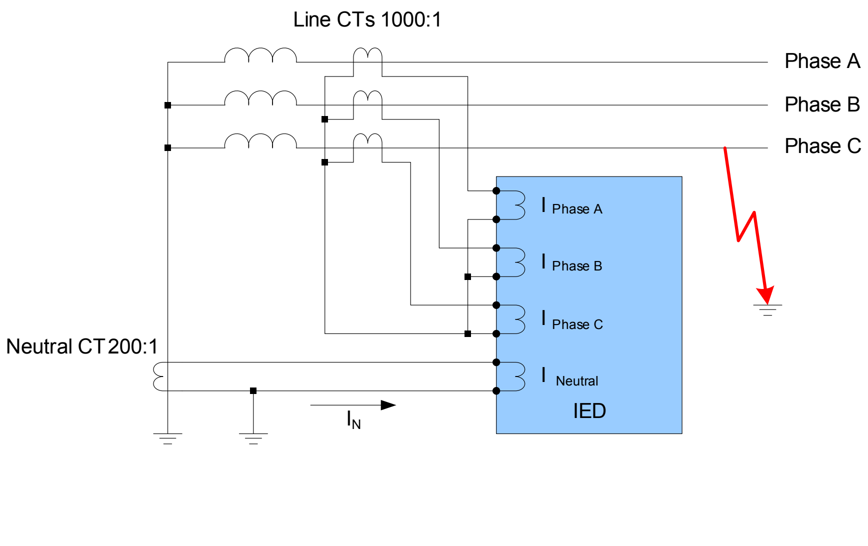


Figure 51: Low Impedance REF Scaling Factor

Another advantage of Low Impedance REF protection is that you can use a neutral CT with a lower ratio than the line CTs in order to provide better earth fault sensitivity. In the bias calculation, the device applies a scaling factor to the neutral current. This scaling factor is as follows:

Scaling factor = K = Line CT ratio / Neutral CT ratio

This results in the following differential and bias current equations:

$$I_{diff} = \left(\bar{I}_A + \bar{I}_B + \bar{I}_C\right) + K\bar{I}_N$$

$$I_{bias} = \frac{1}{2}\left\{\max\left[|I_A|,|I_B|,|I_C|\right] + K|I_N|\right\}$$

6.2.3 PARAMETER CALCULATIONS

Consider a solidly earthed 90 MVA transformer with a REF-protected star winding. Assume line CTS with a ratio of 400:1.

Is1 is set to 10% of the winding nominal current:

$= (0.1 \times 90 \times 10^6) / (\sqrt{3} \times 132 \times 10^3)$

= 39 Amps primary

= 39/400 = 0.0975 Amps secondary (approx 0.1 A)

Is2 is set to the rated current of the transformer:

$= 90 \times 10^6 / (\sqrt{3} \times 132 \times 10^3)$

= 390 Amps primary

= 390/400 = 0.975 Amps secondary (approx 1 A)

Set ***K1*** to 0% and ***K2*** to 150%

6.3 HIGH IMPEDANCE REF PROTECTION APPLICATION

6.3.1 HIGH IMPEDANCE REF OPERATING MODES

In the examples below, the respective Line CTS and measurement CTs must have the same CT ratios and similar magnetising characteristics.

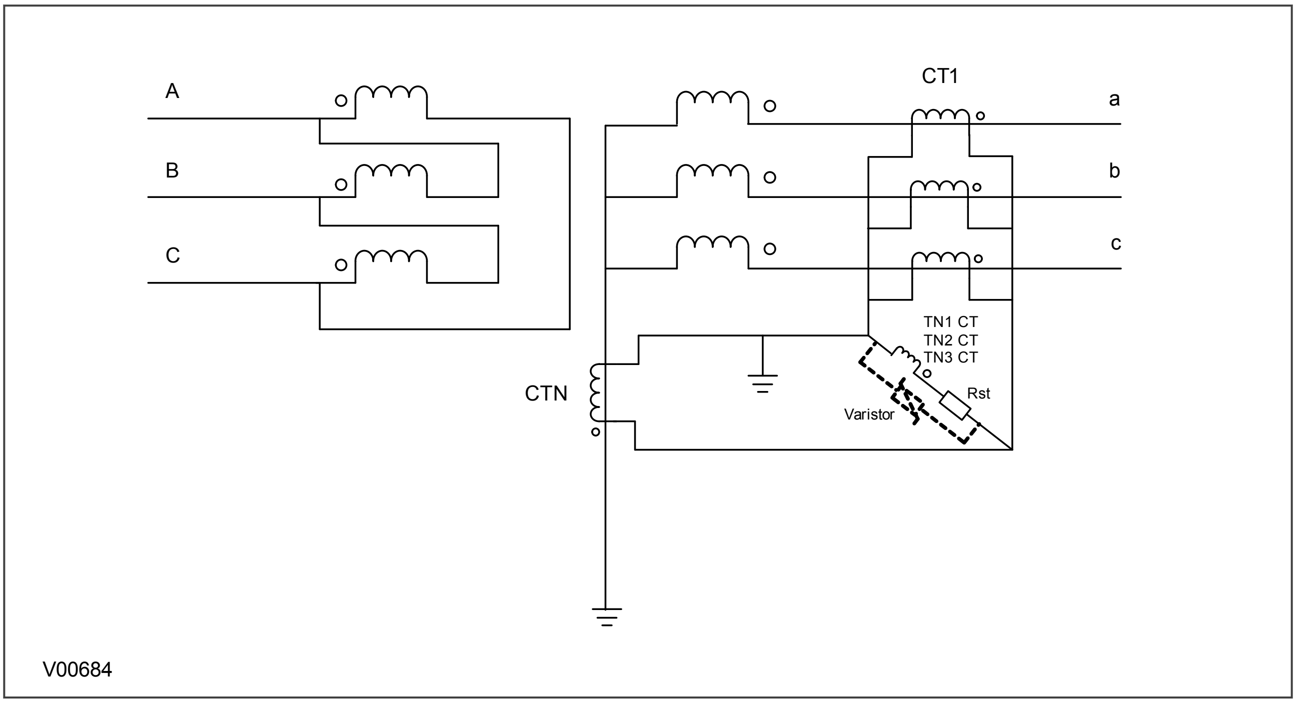


Figure 52: Hi-Z REF protection for a grounded star winding

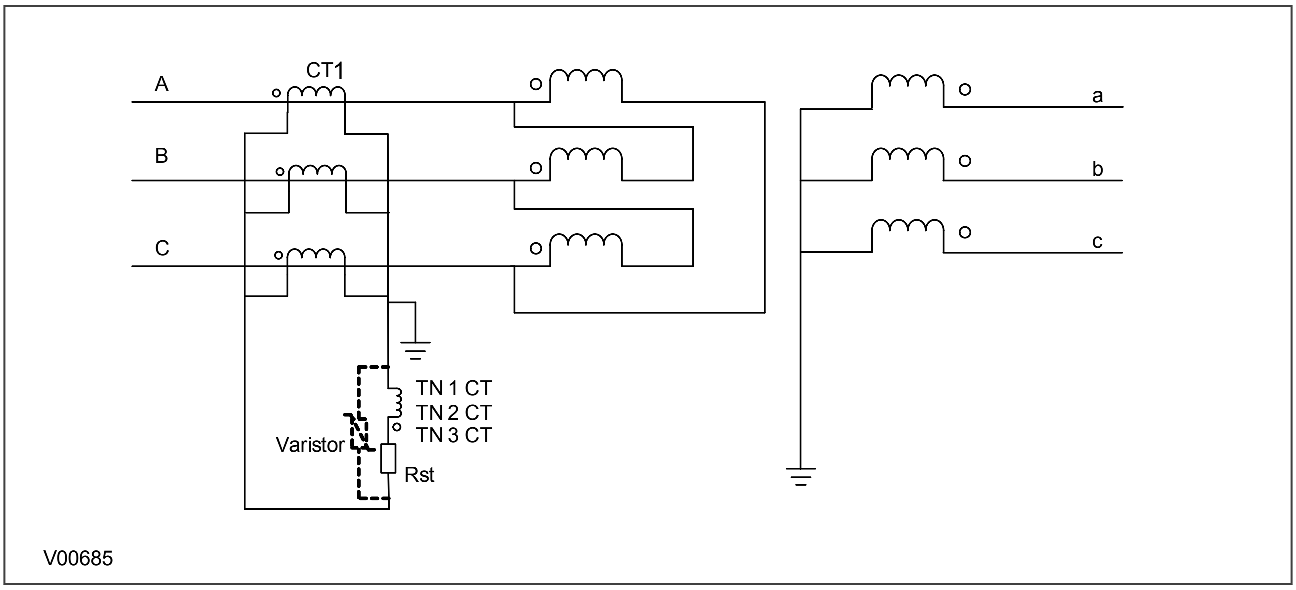


Figure 53: Hi-Z REF protection for a delta winding

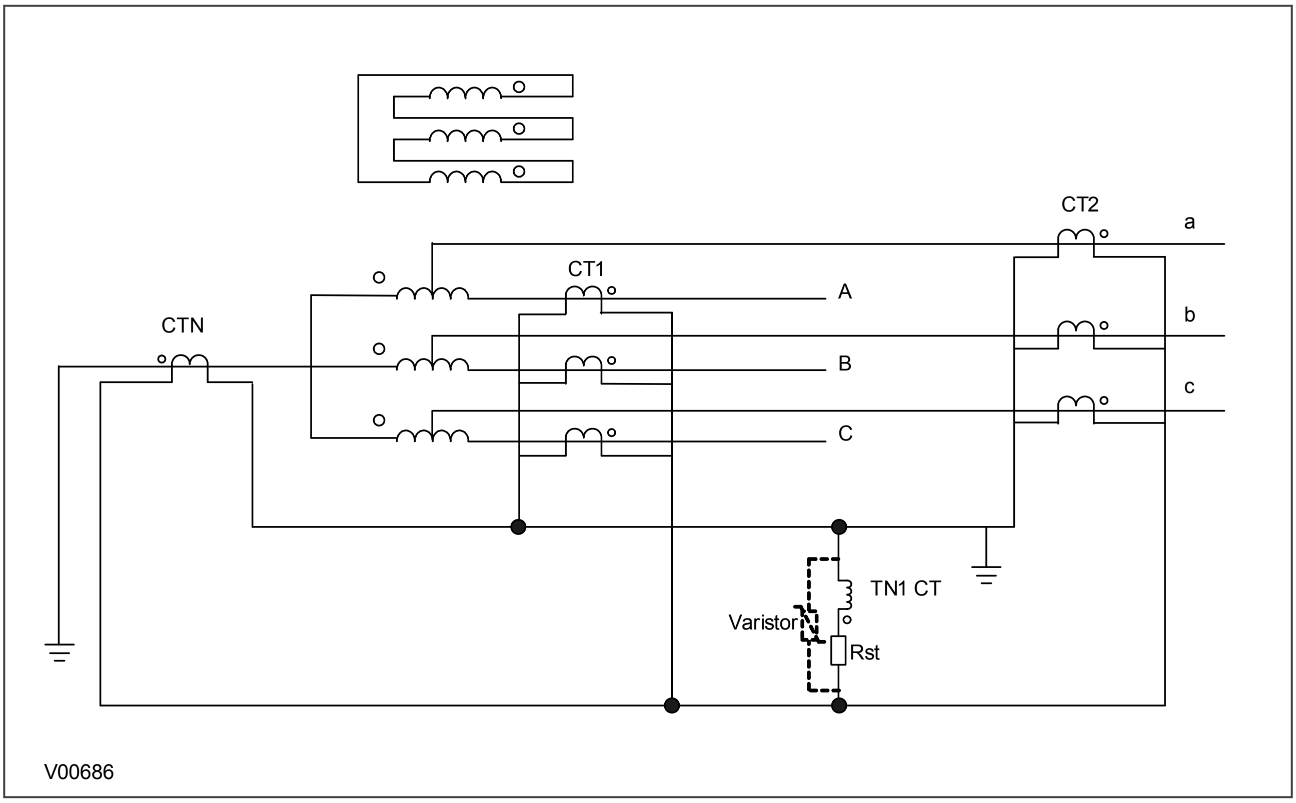


Figure 54: Hi-Z REF Protection for autotransformer configuration

6.3.2 SETTING GUIDELINES FOR HIGH IMPEDANCE OPERATION

This scheme is very sensitive and can protect against low levels of fault current in resistance grounded systems. In this application, the ***IREF>Is*** settings should be chosen to provide a primary operating current less than 10-25% of the minimum earth fault level.

This scheme can also be used in a solidly grounded system. In this application, the ***IREF>Is*** settings should be chosen to provide a primary operating current between 10% and 60 % of the winding rated current.

The following diagram shows the application of a high impedance REF element to protect the LV winding of a power transformer.

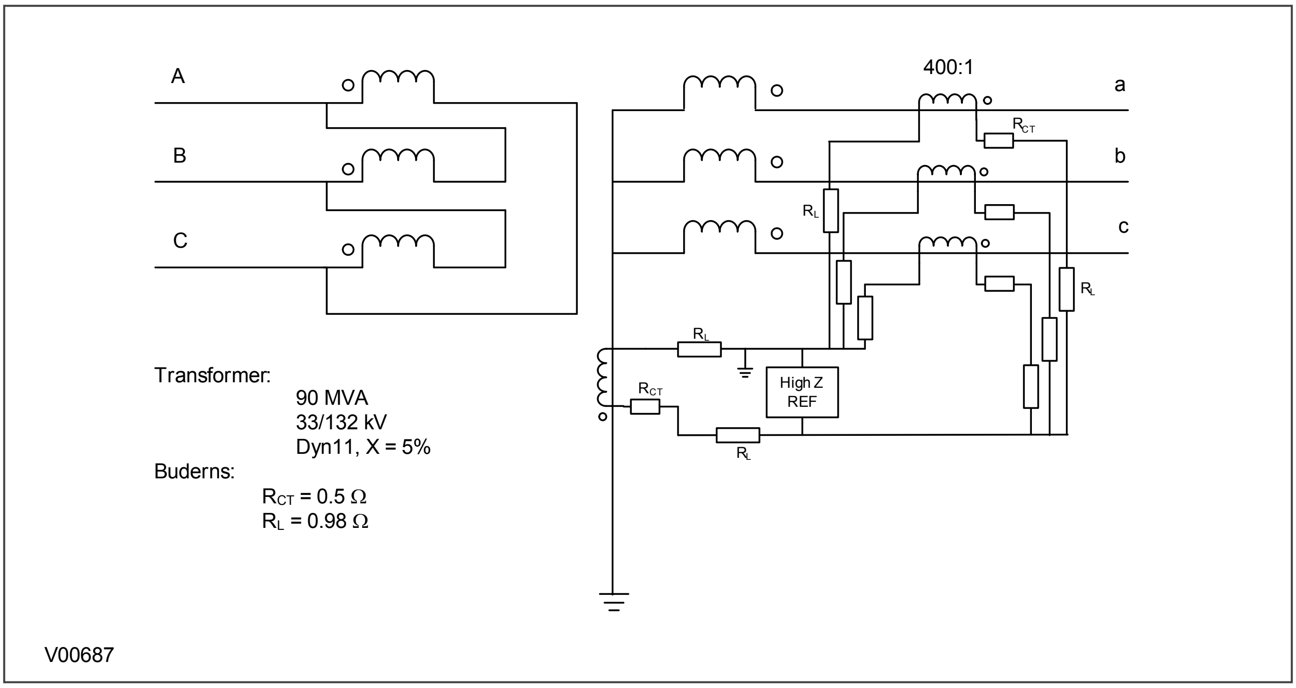


Figure 55: High Impedance REF for the LV winding

6.3.2.1 STABILITY VOLTAGE CALCULATION

The transformer full load current, IFLC, is:

$$I_{FLC} = (90 \times 10^6) / (132 \times 103 \times \sqrt{3}) = 394\ A$$

To calculate the stability voltage the maximum through fault level should be considered. The maximum through fault level, ignoring the source impedance, I_F, is:

$$I_F = I_{FLC} / X_{TX} = 394 / 0.05 = 7873\ A$$

The required stability voltage, VS, and assuming one CT saturated is:

$$V_s = KI_F(R_{CT} + 2R_L)$$

The figure shown below can be used to determine the K factor and the operating time.

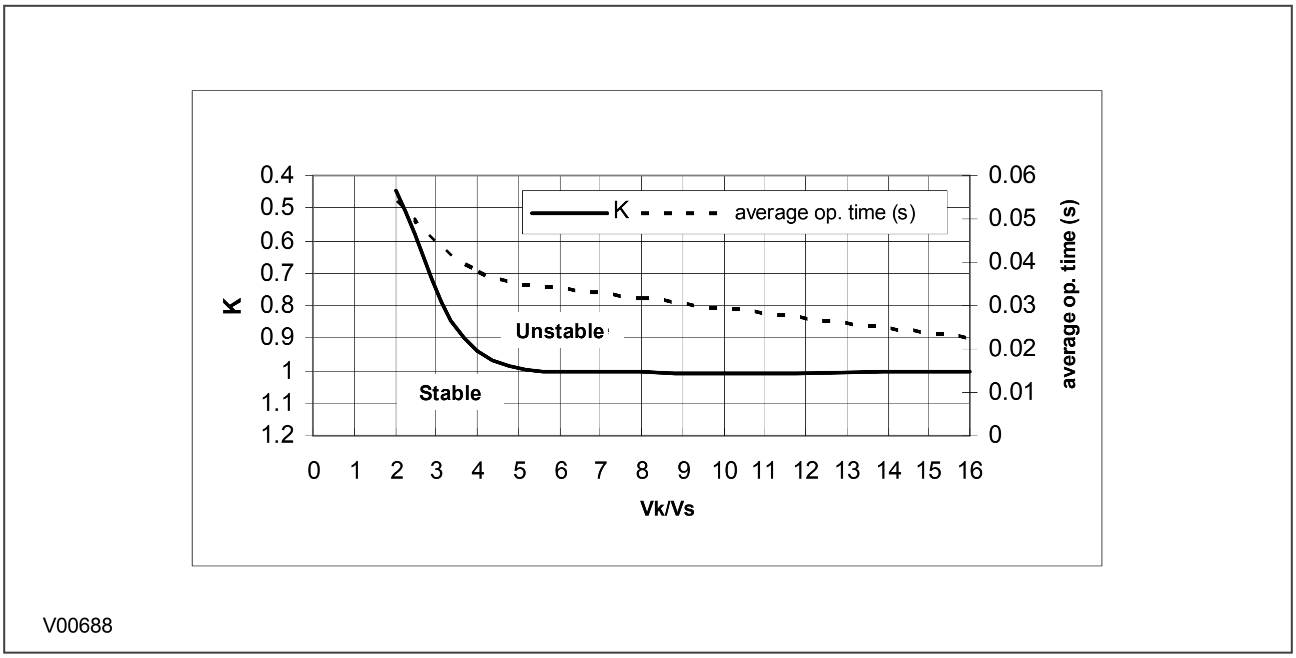


Figure 56: Variation of K and the average operating time as a function of Vk/Vs

Assume the operating time is 40 ms. The corresponding Vk/Vs of approximately 3.5 can then be obtained from the graph and subsequently an approximate K value of 0.9, for stable operation, can be obtained from the same graph.

$$V_s = 0.9 \times 7873 \times (0.5 + 2 \times 0.98) / 400 = 45.5 V$$

The CTs knee point voltage should be at least 4 times Vs so that an average operating time of 40 ms is achieved.

6.3.2.2 PRIMARY CURRENT CALCULATION

The primary operating current should be between 10 and 60 % of the winding rated current. Assuming that the relay effective setting or primary operating current is approximately 30% of the full load current, the calculation below shows that a setting of less than 0.3 A is required.

$$Effective\ setting = 0.3I_{FLC} / CT\ Ratio = 30.3 \times 394 / 400 = approximately\ 0.3 A$$

6.3.2.3 STABILISING RESISTOR CALCULATION

Assuming that a setting of 0.1A is selected the value of the stabilizing resistor, R_{ST}, required is

$$R_{ST} = V_s / (IREF> Is1\ (HV)) = 45.5 / 0.1 = 455\ ohms$$

To achieve an average operating time of 40 ms, Vk/Vs should be 3.5.

The Kneepoint voltage is:

$$V_K = 4V_s = 4 \times 45.5 = 182 V.$$

If the actual V_K is greater than 4 times V_s, then the K factor increases. In this case, V_s should be recalculated.

> *Note:*
> *K can reach a maximum value of approximately 1.*

6.3.2.4 CURRENT TRANSFORMER CALCULATION

The effective primary operating current setting is:

$$I_P = N(I_s + nI_e)$$

By re-arranging this equation, you can calculate the excitation current for each of the current transformers at the stability voltage. This turns out to b:e

$$I_e = (0.3 - 0.1) / 4 = 0.05\ A$$

In summary, the current transformers used for this application must have a kneepoint voltage of 182 V or higher (note that maximum Vk/Vs that may be considered is 16 and the maximum K factor is 1), with a secondary winding resistance of 0.5 ohms or lower and a magnetizing current at 45.5 V of less than 0.05 A.

Assuming a CT kneepoint voltage of 200 V, the peak voltage can be estimated as:

$$V_P = 2\sqrt{2V_K(V_F-V_K)} = 2\sqrt{2(200)(9004-200)} = 3753\ V$$

This value is above the peak voltage of 3000 V and therefore a non-linear resistor is required.

Note:
The kneepoint voltage value used in the above formula should be the actual voltage obtained from the CT magnetizing characteristic and not a calculated value.

Note:
One stabilizing resistor, Alstom part No. ZB9016 756, and one varistor, Alstom part No. 600A/S1/S256 might be used.

6.3.3 USE OF METROSIL NON-LINEAR RESISTORS

Current transformers can develop high peak voltages under internal fault conditions. Metrosils are used to limit these peak voltages to a value below the maximum withstand voltage (usually 3 kV)

You can use the following formulae to estimate the peak transient voltage that could be produced for an internal fault. The peak voltage produced during an internal fault is a function of the current transformer kneepoint voltage and the prospective voltage that would be produced for an internal fault if current transformer saturation did not occur.

$$Vp = 2\sqrt{(2VK(V_F-V_K))}$$

$$Vf = I'f(R_{CT}+2_{RL}+R_{ST})$$

where:

- Vp = Peak voltage developed by the CT under internal fault conditions
- Vk = Current transformer kneepoint voltage
- Vf = Maximum voltage that would be produced if CT saturation did not occur
- I'f = Maximum internal secondary fault current
- R_{CT} = Current transformer secondary winding resistance
- R_L = Maximum lead burden from current transformer to relay
- R_{ST} = Relay stabilizing resistor

You should always use Metrosils when the calculated values are greater than 3000 V. Metrosils are connected across the circuit to shunt the secondary current output of the current transformer from the device to prevent very high secondary voltages.

Metrosils are externally mounted and take the form of annular discs. Their operating characteristics follow the expression:

$$V = CI^{0.25}$$

where:

- V = Instantaneous voltage applied to the Metrosil
- C = Constant of the Metrosil
- I = Instantaneous current through the Metrosil

With a sinusoidal voltage applied across the Metrosil, the RMS current would be approximately 0.52 x the peak current. This current value can be calculated as follows:

$$I_{RMS} = 0.52\left(\frac{\sqrt{2}V_{S(RMS)}}{C}\right)^4$$

where:

- $V_{S(RMS)}$ = RMS value of the sinusoidal voltage applied across the metrosil.

This is due to the fact that the current waveform through the Metrosil is not sinusoidal but appreciably distorted.

The Metrosil characteristic should be such that it complies with the following requirements:

- The Metrosil current should be as low as possible, and no greater than 30 mA RMS for 1 A current transformers or 100 mA RMS for 5 A current transformers.
- At the maximum secondary current, the Metrosil should limit the voltage to 1500 V RMS or 2120 V peak for 0.25 second. At higher device voltages it is not always possible to limit the fault voltage to 1500 V rms, so higher fault voltages may have to be tolerated.

The following tables show the typical Metrosil types that will be required, depending on relay current rating, REF voltage setting etc.

Metrosils for devices with a 1 Amp CT

The Metrosil units with 1 Amp CTs have been designed to comply with the following restrictions:

- The Metrosil current should be less than 30 mA rms.
- At the maximum secondary internal fault current the Metrosil should limit the voltage to 1500 V rms if possible.

The Metrosil units normally recommended for use with 1Amp CTs are as shown in the following table:

	Nominal Characteristic		Recommended Metrosil Type	
Device Voltage Setting	**C**	**β**	**Single Pole Relay**	**Triple Pole Relay**
Up to 125 V RMS	450	0.25	600A/S1/S256	600A/S3/1/S802
125 to 300 V RMS	900	0.25	600A/S1/S1088	600A/S3/1/S1195

Note:
Single pole Metrosil units are normally supplied without mounting brackets unless otherwise specified by the customer.

Metrosils for devices with a 5 Amp CT

These Metrosil units have been designed to comply with the following requirements:

- The Metrosil current should be less than 100 mA rms (the actual maximum currents passed by the devices shown below their type description.
- At the maximum secondary internal fault current the Metrosil should limit the voltage to 1500 V rms for 0.25secs. At the higher relay settings, it is not possible to limit the fault voltage to 1500 V rms so higher fault voltages have to be tolerated.

The Metrosil units normally recommended for use with 5 Amp CTs and single pole relays are as shown in the following table:

Secondary Internal Fault Current	Recommended Metrosil types for various voltage settings			
Amps RMS	Up to 200 V RMS	250 V RMS	275 V RMS	300 V RMS
50A	600A/S1/S1213 C = 540/640 35 mA RMS	600A/S1/S1214 C = 670/800 40 mA RMS	600A/S1/S1214 C =670/800 50 mA RMS	600A/S1/S1223 C = 740/870 50 mA RMS
100A	600A/S2/P/ S1217 C = 470/540 70 mA RMS	600A/S2/P/S1215 C = 570/670 75 mA RMS	600A/S2/P/S1215 C =570/670 100 mA RMS	600A/S2/P/S1196 C =620/740 100 mA RMS
150A	600A/S3/P/ S1219 C = 430/500 100 mA RMS	600A/S3/P/S1220 C = 520/620 100 mA RMS	600A/S3/P/S1221 C = 570/670 100 mA RMS	600A/S3/P/S1222 C =620/740 100 mA RMS

In some situations single disc assemblies may be acceptable, contact Alstom Grid for detailed applications.

> *Note:*
> *The Metrosils recommended for use with 5 Amp CTs can also be used with triple pole relays and consist of three single pole units mounted on the same central stud but electrically insulated from each other. To order these units please specify "Triple pole Metrosil type", followed by the single pole type reference. Metrosil for higher voltage settings and fault currents are available if required.*

6.4 REF CT REQUIREMENTS

6.4.1 LOW IMPEDANCE REF PROTECTION

For X/R < 40 and I_f < 15I_n

$$V_K \geq 24 I_n (R_{CT} + 2R_L)$$

For 40 < X/R < 120 and 15I_n < If < 40I_n

$$V_K \geq 48 I_n (R_{CT} + 2R_L)$$

> *Note:*
> *Class x or Class 5P CTs should be used for low impedance REF applications.*

6.4.2 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.*

CB FAIL PROTECTION

CHAPTER 7

1 CHAPTER OVERVIEW

The device provides a Circuit Breaker Fail Protection function. This chapter describes the operation of this functions including the principles, logic diagrams and applications.

This chapter contains the following sections:

2 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.

3 CIRCUIT BREAKER FAIL IMPLEMENTATION

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

3.1 SUBSIDENCE CURRENT

When there is a fault and the circuit breaker interrupts the CT primary current, the flux in the CT core decays to a residual level. This decaying flux introduces a decaying DC current in the CT secondary circuit known as subsidence current. The closer the CT is to its saturation point, the higher the subsidence current.

The time constant of this subsidence current depends on the CT secondary circuit time constant and it is generally long for correct operation. If the protection clears the fault, the CB Fail function should reset fast to avoid maloperation due to the subsidence current. To compensate for this the device includes a zero-crossing detection algorithm, which ensures that the CB Fail re-trip and back-trip signals are not asserted while subsidence current is flowing. If all the samples within half a cycle are greater than or smaller than 0 A (10 mS for a 50 Hz system), then zero crossing detection is asserted, thereby blocking the operation of the CB Fail function. The zero-crossing detection algorithm is used after the circuit breaker in the primary system has opened ensuring that the only current flowing in the AC secondary circuit is the subsidence current.

3.2 CIRCUIT BREAKER FAIL TIMERS

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.

You can configure the CBF elements ***CB Fail 1 Timer*** and ***CBF Fail 2 Timer*** to operate for trips triggered by protection elements within the device or by using an external protection trip. You can do the latter by allocating one of the opto-inputs to the ***External Trip*** DDB signal in the PSL.

Resetting of the CBF is possible from a breaker open indication (from the relay's pole dead logic) or from a protection reset. In these cases resetting is only allowed provided the undercurrent elements have also reset. The resetting mechanism is determined by the settings ***Volt Prot Reset*** and ***Ext Prot Reset***.

4 CIRCUIT BREAKER FAIL LOGIC

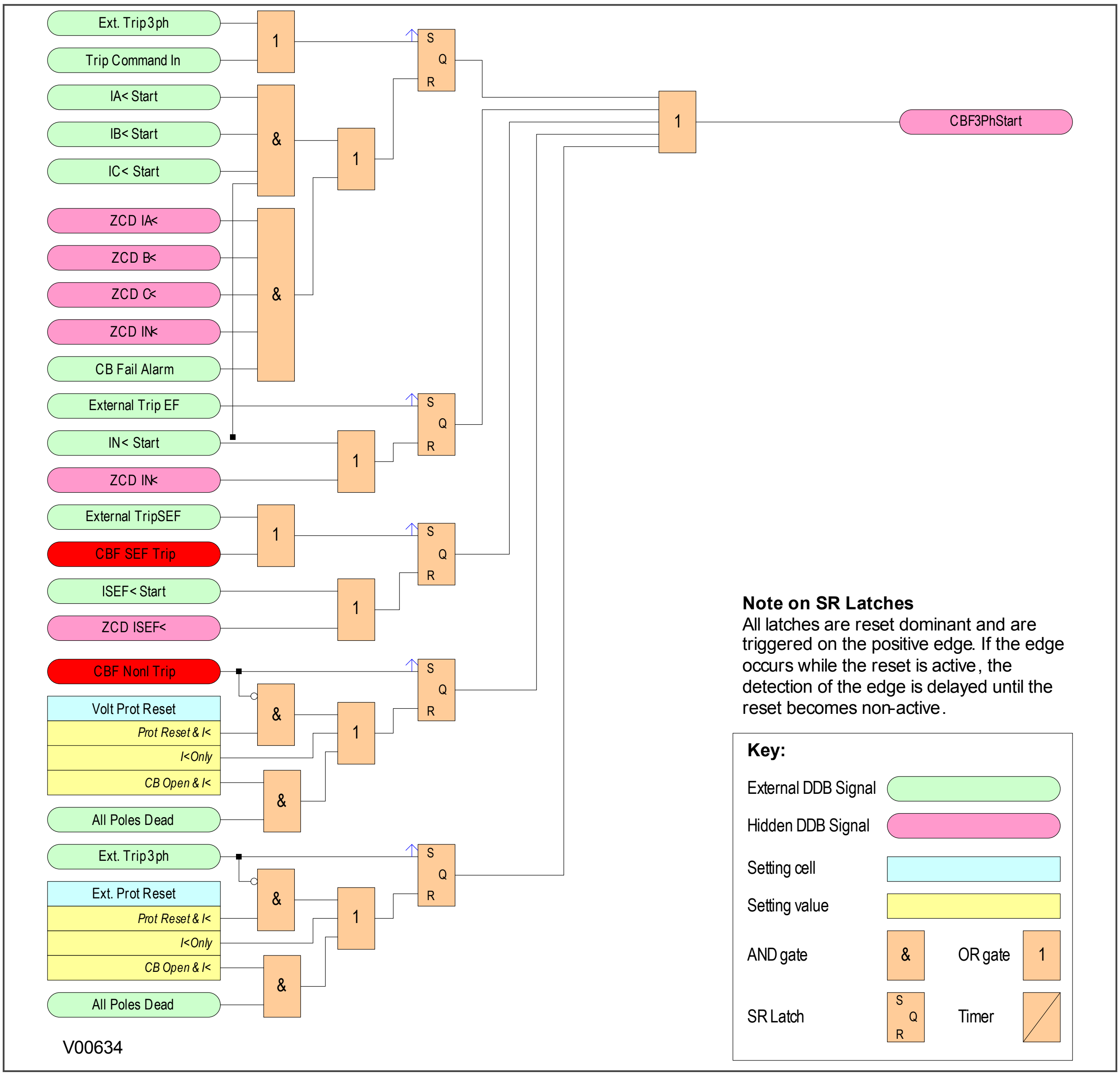


Figure 57: Circuit Breaker Fail logic - three phase start

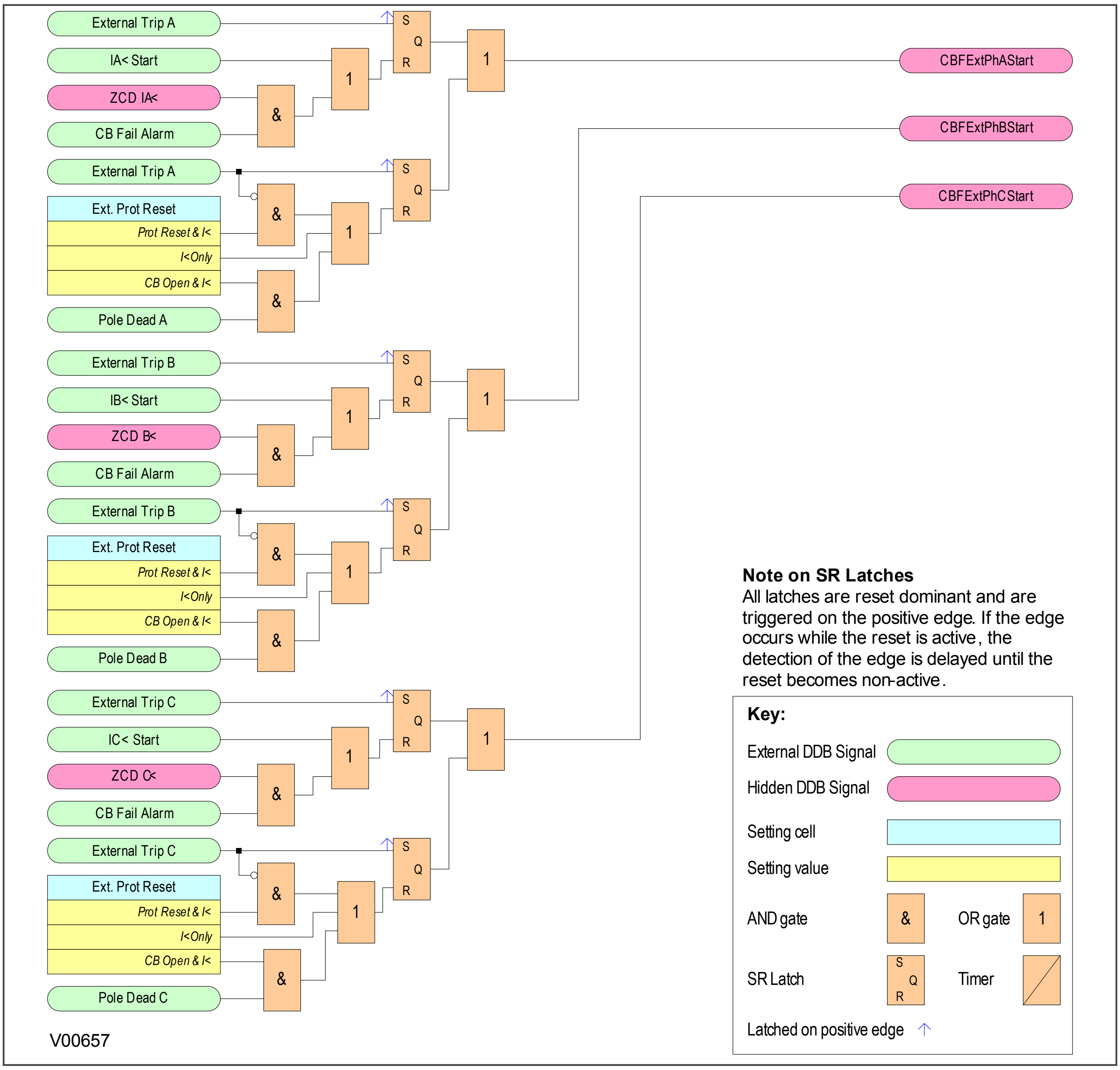


Figure 58: Circuit Breaker Fail logic - single phase start

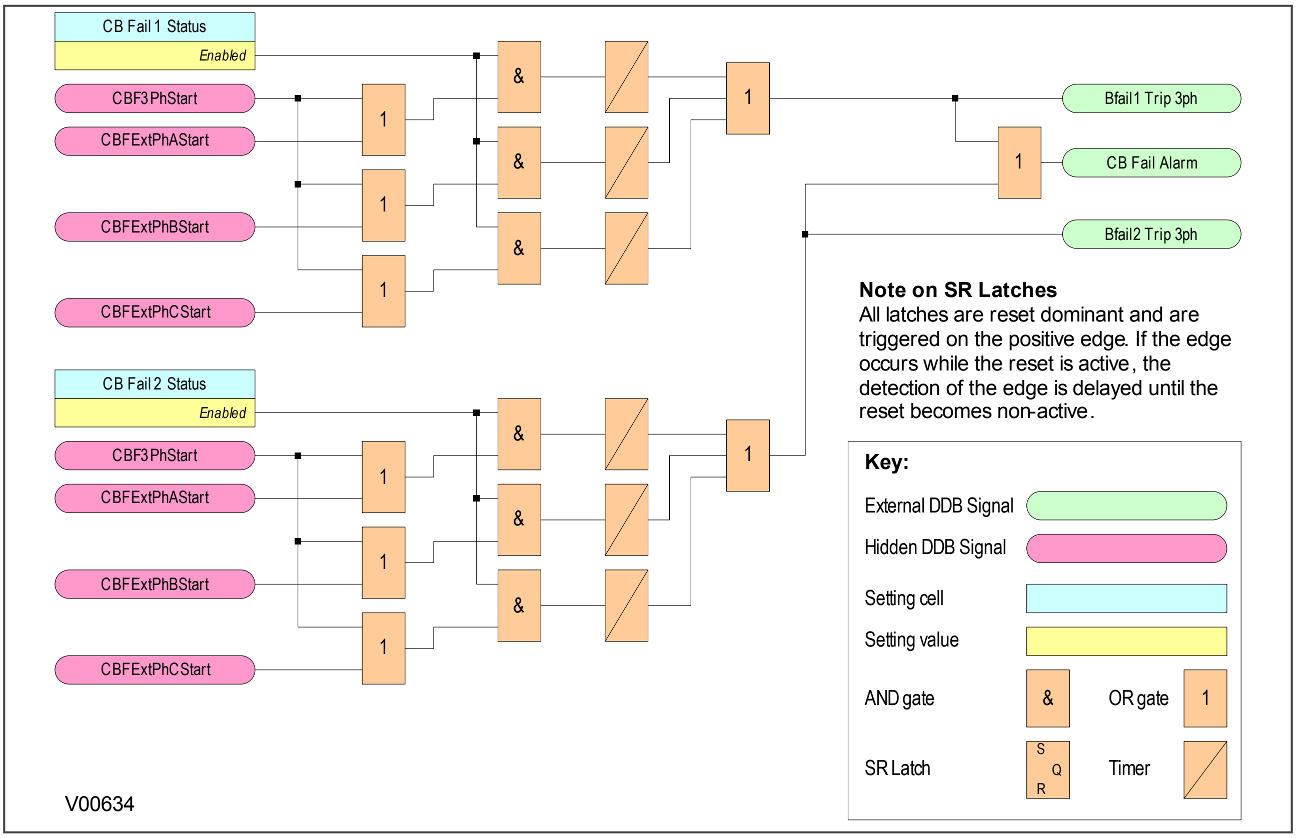


Figure 59: CB Fail part 2

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
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`.

5 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.				
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.				

6 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 breaker fail and undercurrent protection.				
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.				
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				
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.				

7 APPLICATION NOTES

7.1 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 on the feeder normally being loaded. Also, tripping the circuit breaker may not remove the initiating condition from the busbar, and so 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.

7.2 SETTING GUIDELINES (CB FAIL TIMER)

The following timing chart shows the CB Fail timing during normal and CB Fail operation. The maximum clearing time should be less than the critical clearing time which is determined by a stability study. The CB Fail back-up trip time delay considers the maximum CB clearing time, the CB Fail reset time plus a safety margin. Typical CB clearing times are 1.5 or 3 cycles. The CB Fail reset time should be short enough to avoid CB Fail back-trip during normal operation. Phase and ground undercurrent elements must be asserted for the CB Fail to reset. The assertion of the undercurrent elements might be delayed due to the subsidence current that might be flowing through the secondary AC circuit.

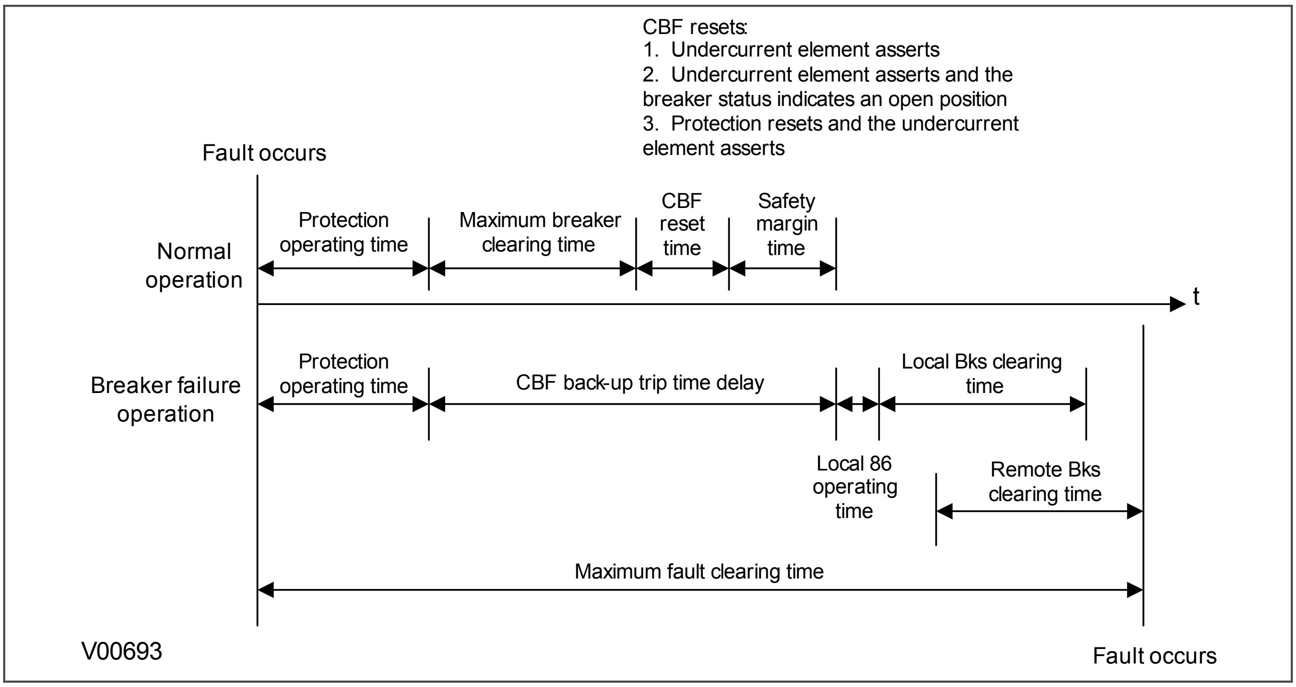


Figure 60: CB Fail timing

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 10-15 ms must be added to allow for trip relay operation.

7.3 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% of In are common for generator CB Fail.

The earth fault undercurrent elements must be set less than the respective trip. For example:

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

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 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 LIVELINE 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 (if applicable), 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 Trip*** 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 Start*** 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 DEADTIME 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 TRIPTEST (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 **A*R 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 CONTRO*L 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.

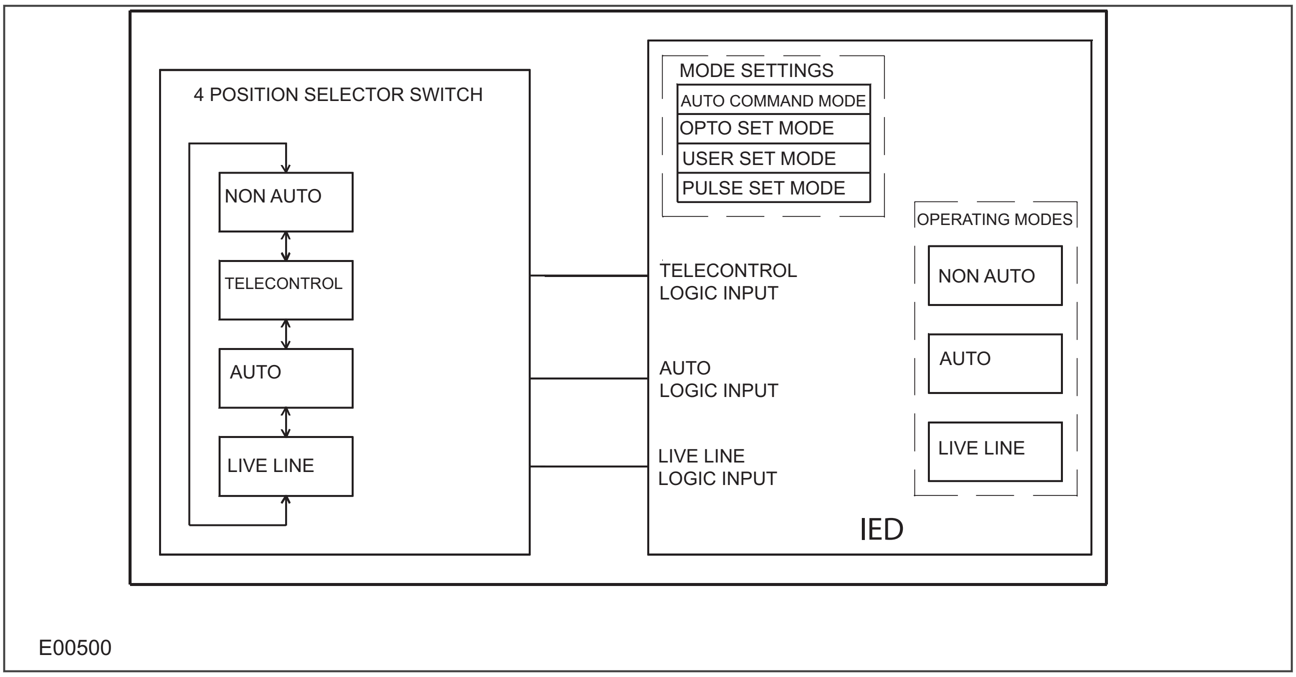


Figure 61: Four-position selector switch implementation

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

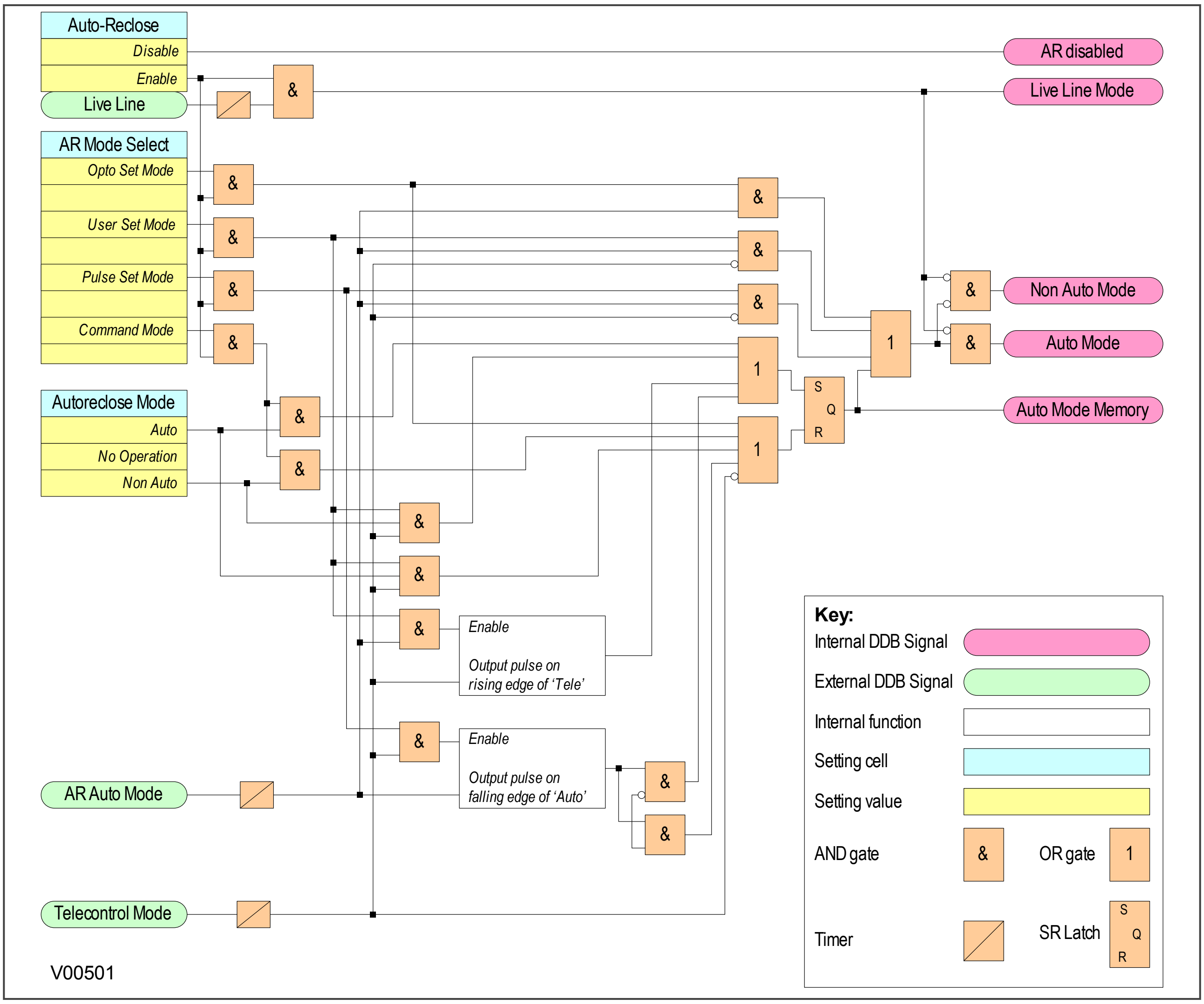


Figure 62: Autoreclose mode select logic

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

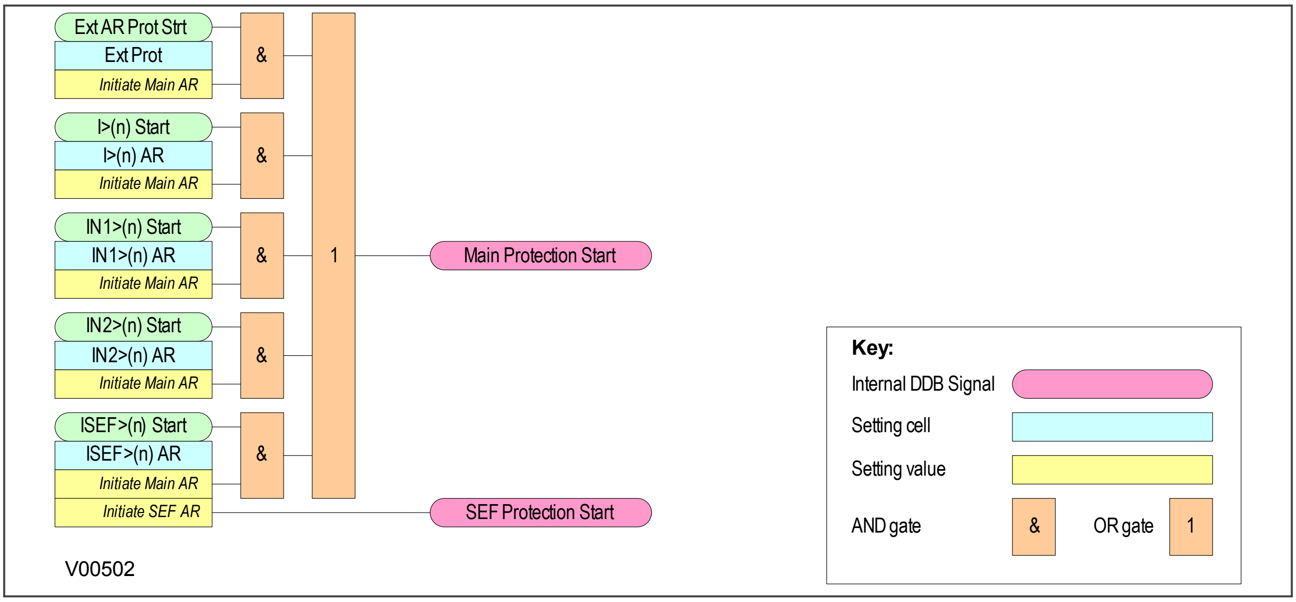


Figure 63: Start signal logic

7.2.2 TRIP SIGNAL LOGIC

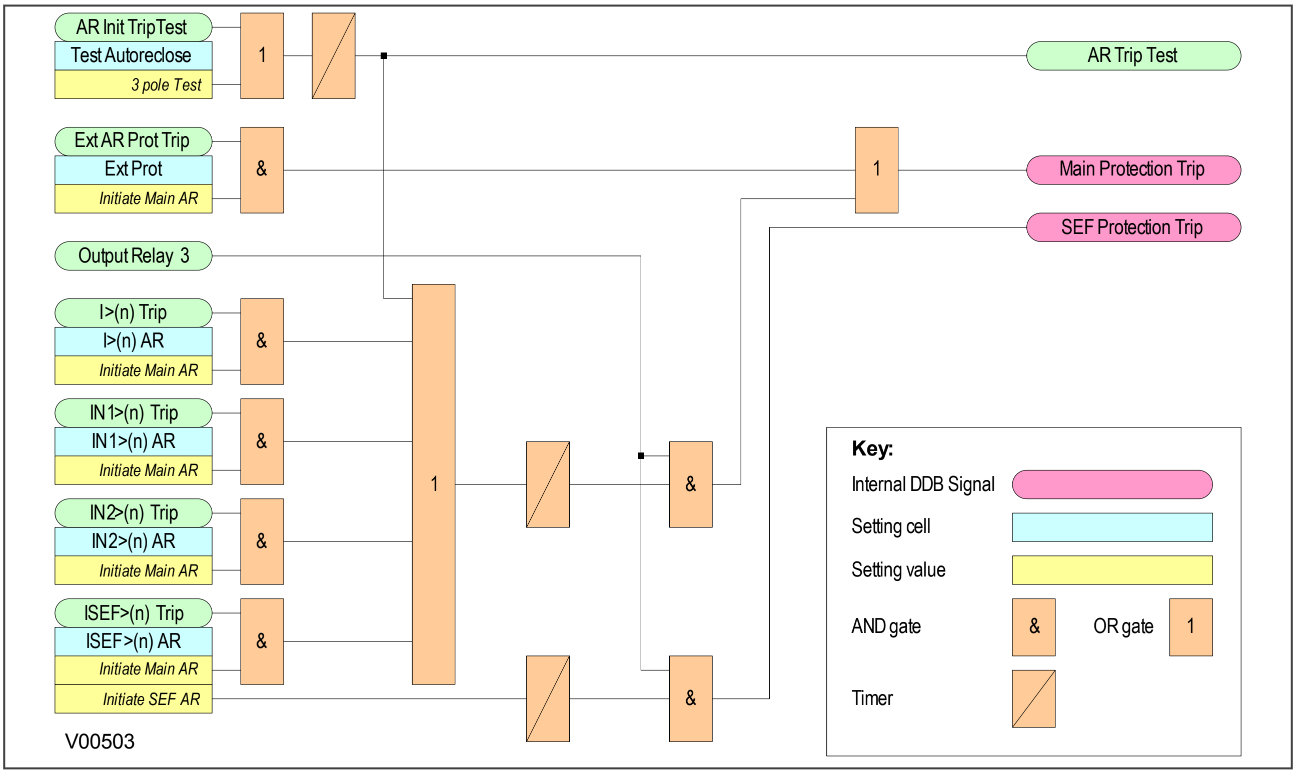


Figure 64: Trip signal logic

7.2.3 BLOCKING SIGNAL LOGIC

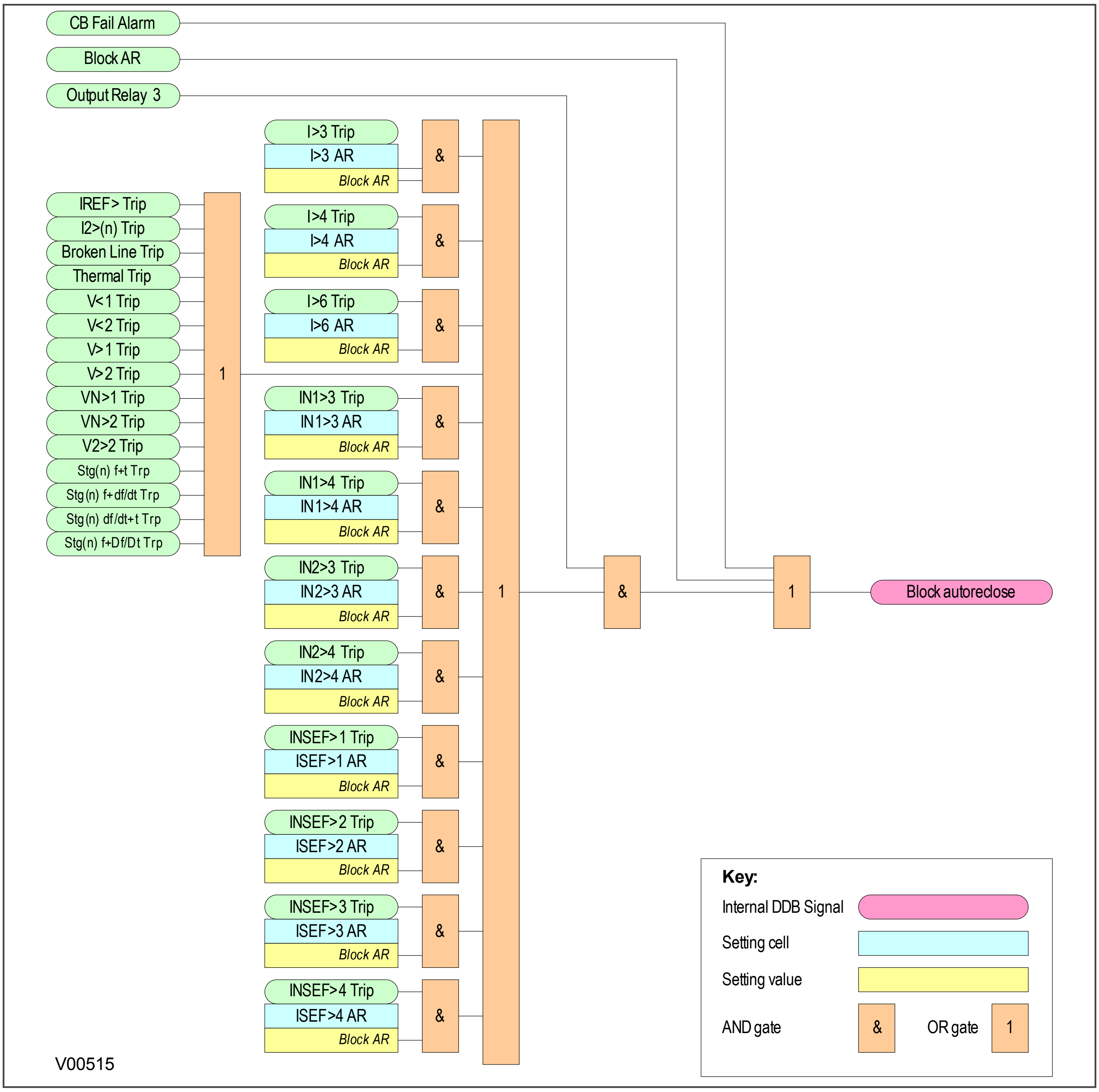


Figure 65: Blocking signal logic

7.2.4 SHOTS EXCEEDED LOGIC

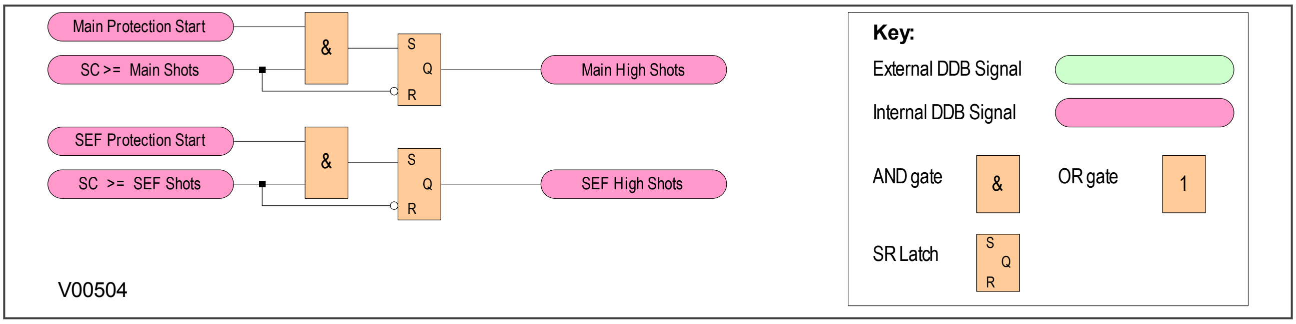


Figure 66: Shots Exceeded logic

7.2.5 AR INITIATION LOGIC

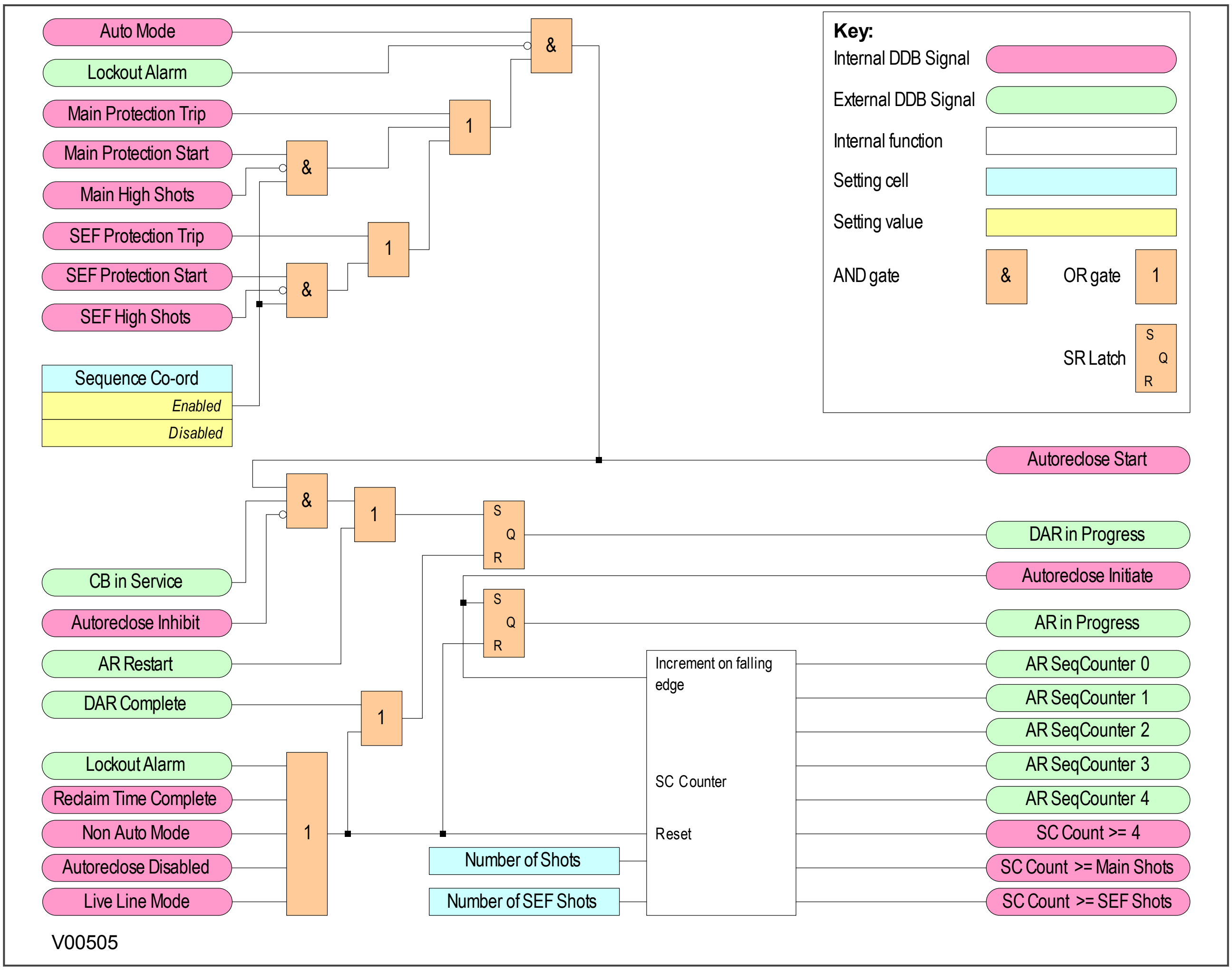


Figure 67: AR initiation logic

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.

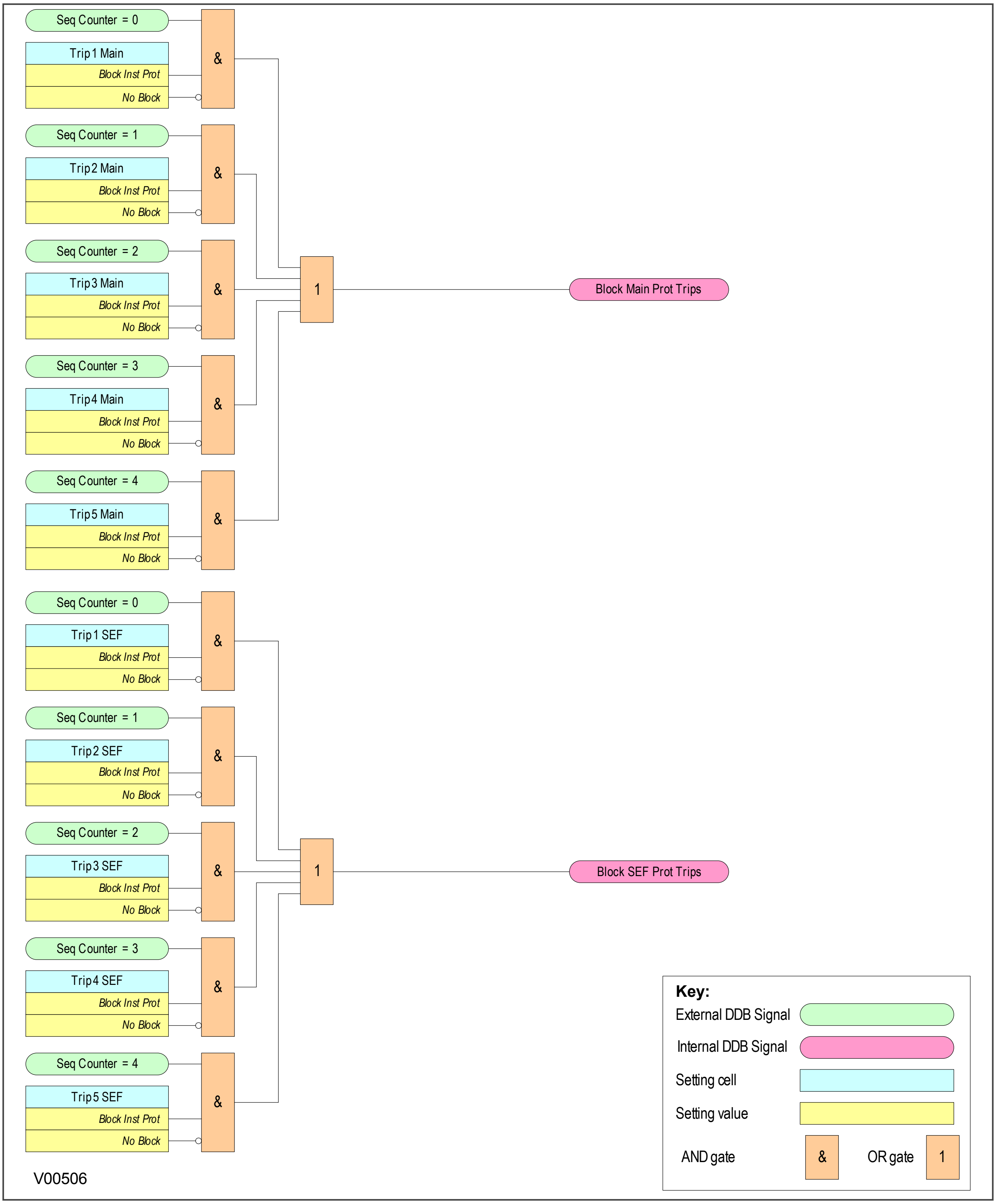


Figure 68: Blocking instantaneous protection for selected trips

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.

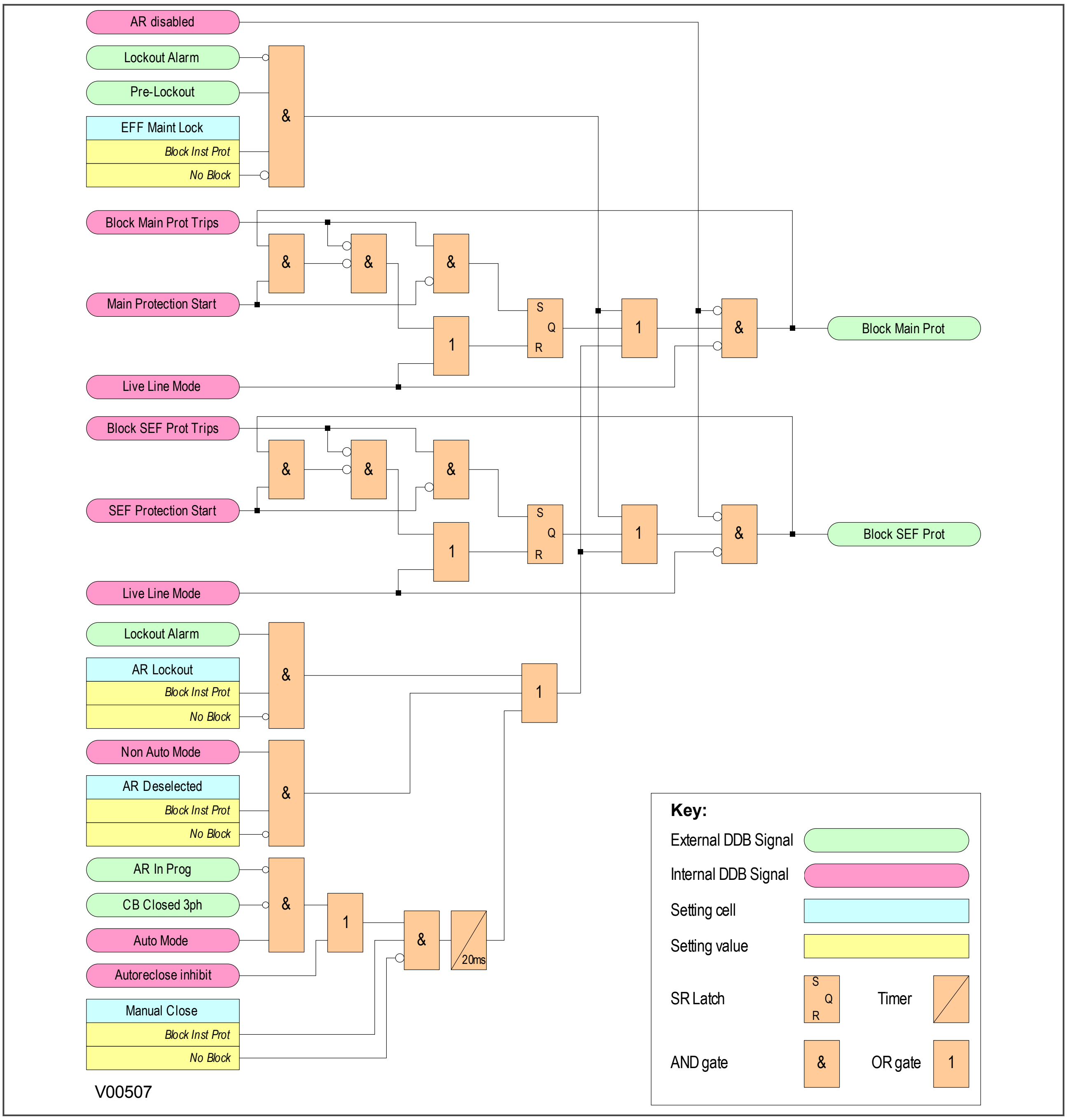


Figure 69: Blocking instantaneous protection for lockouts

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.

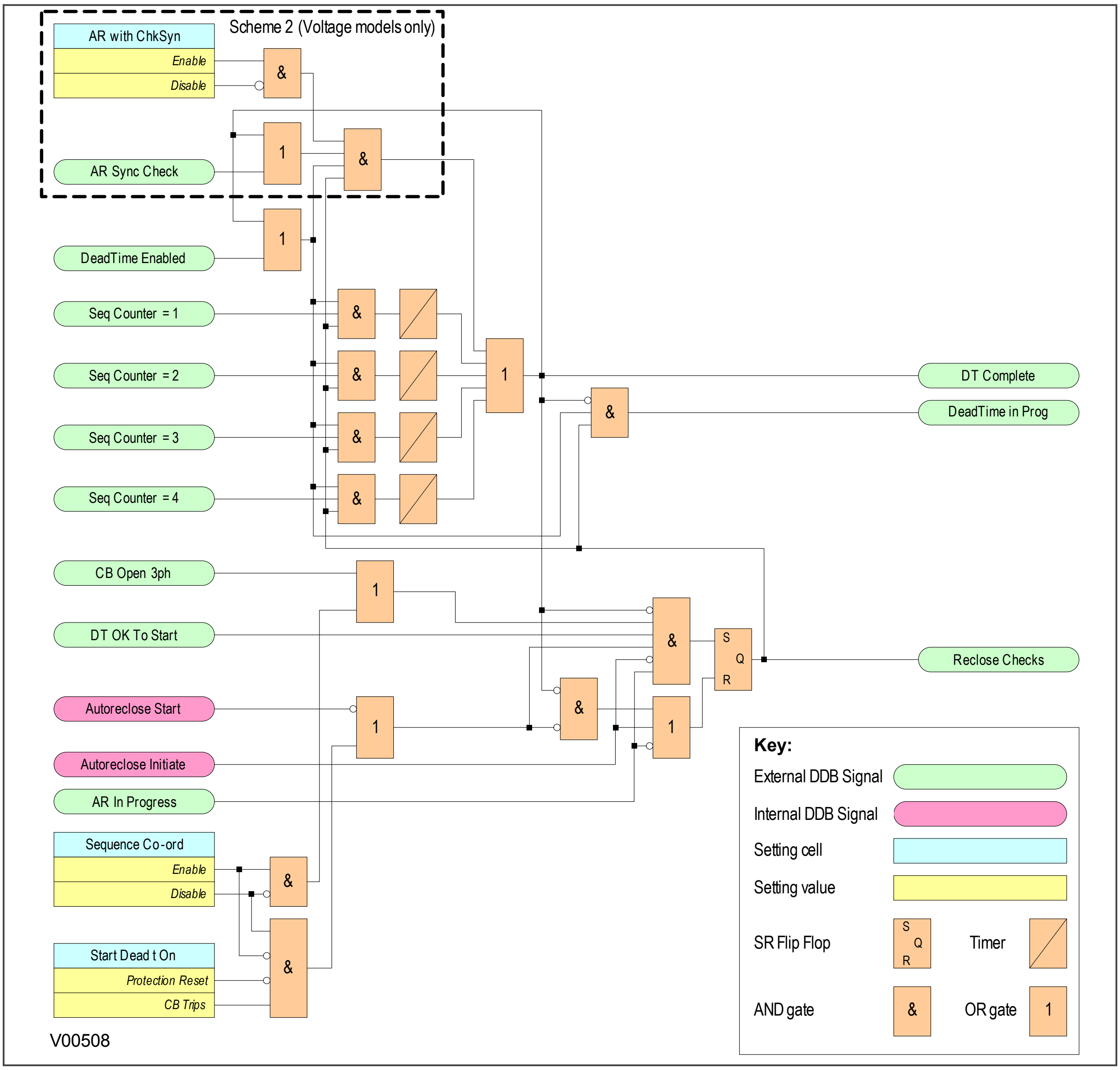


Figure 70: Dead Time Control logic

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.

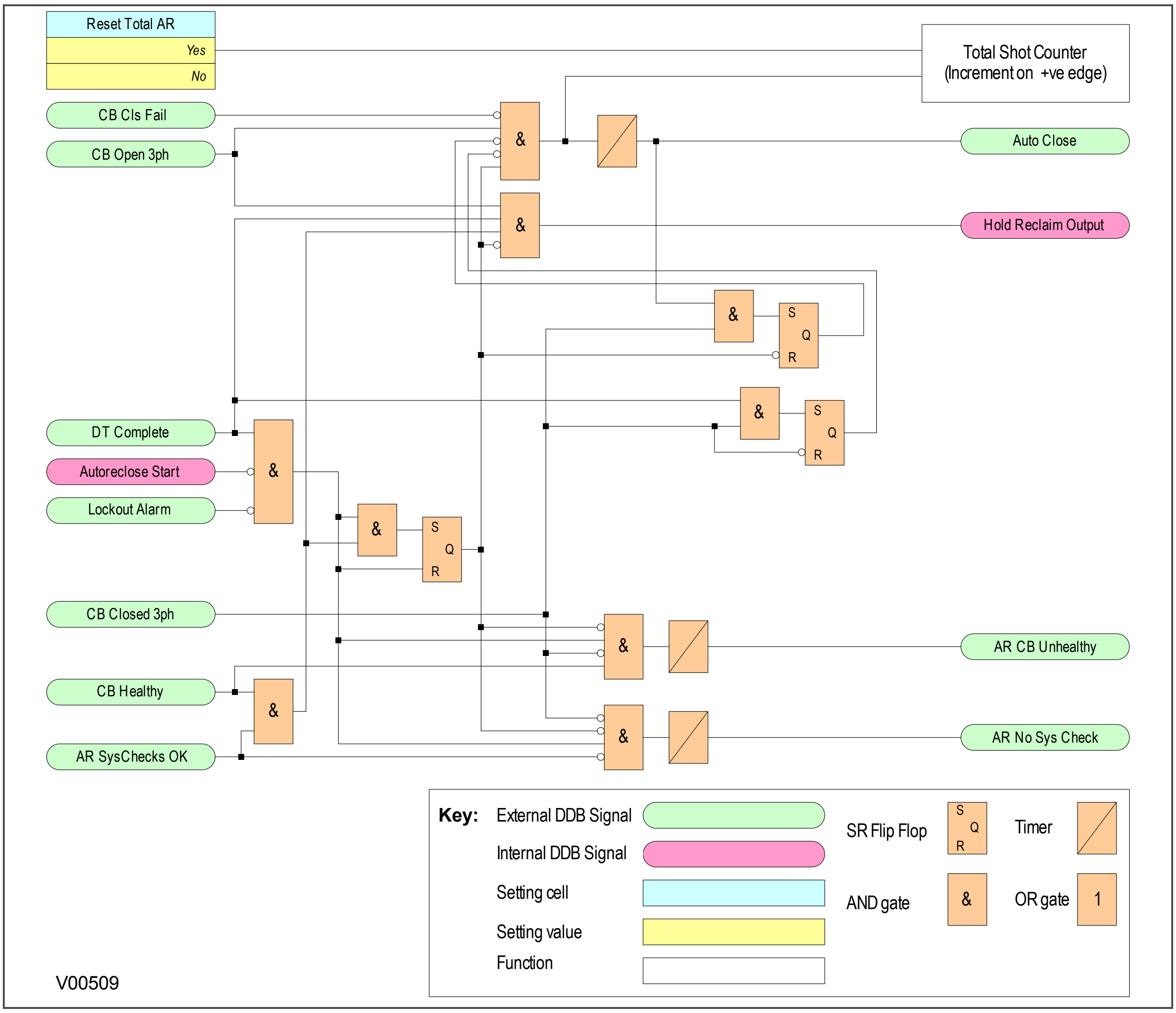


Figure 71: AR CB Close Control logic

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:

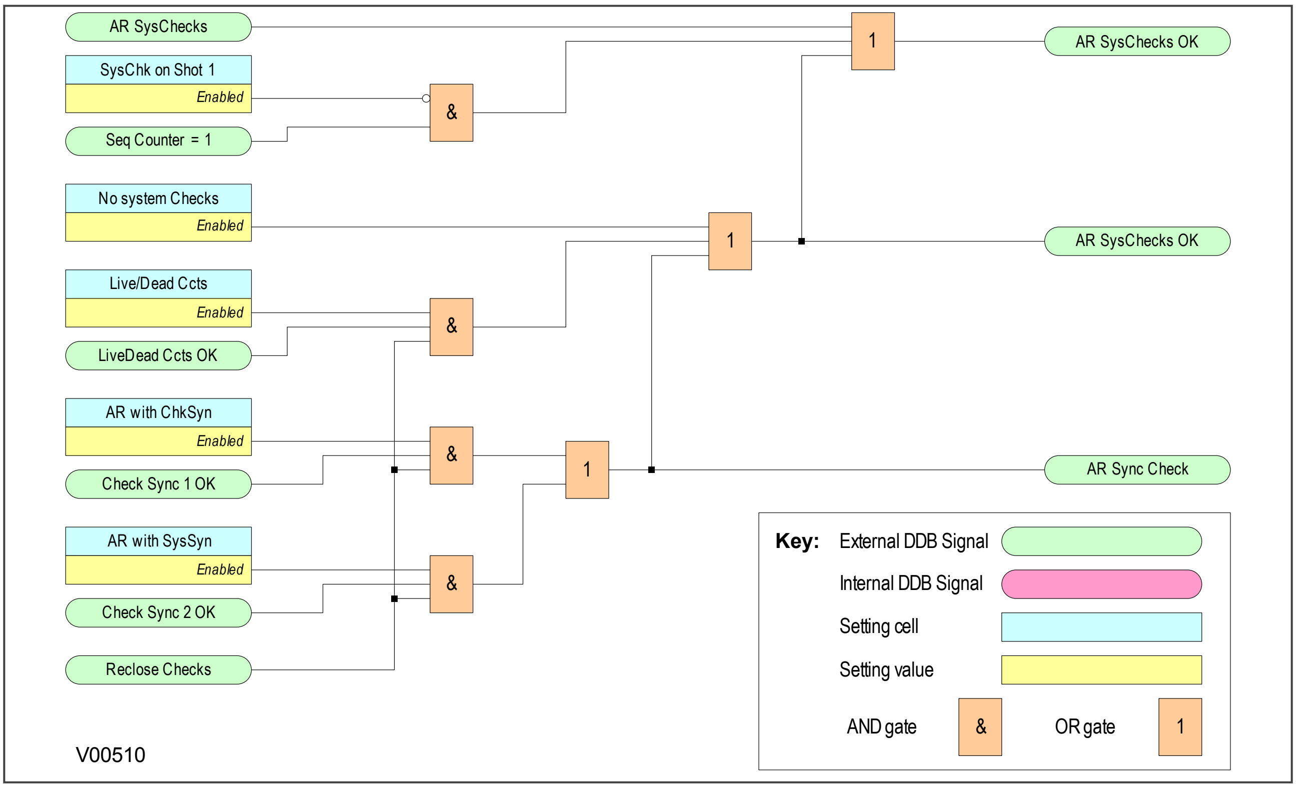


Figure 72: AR System Check logic

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.

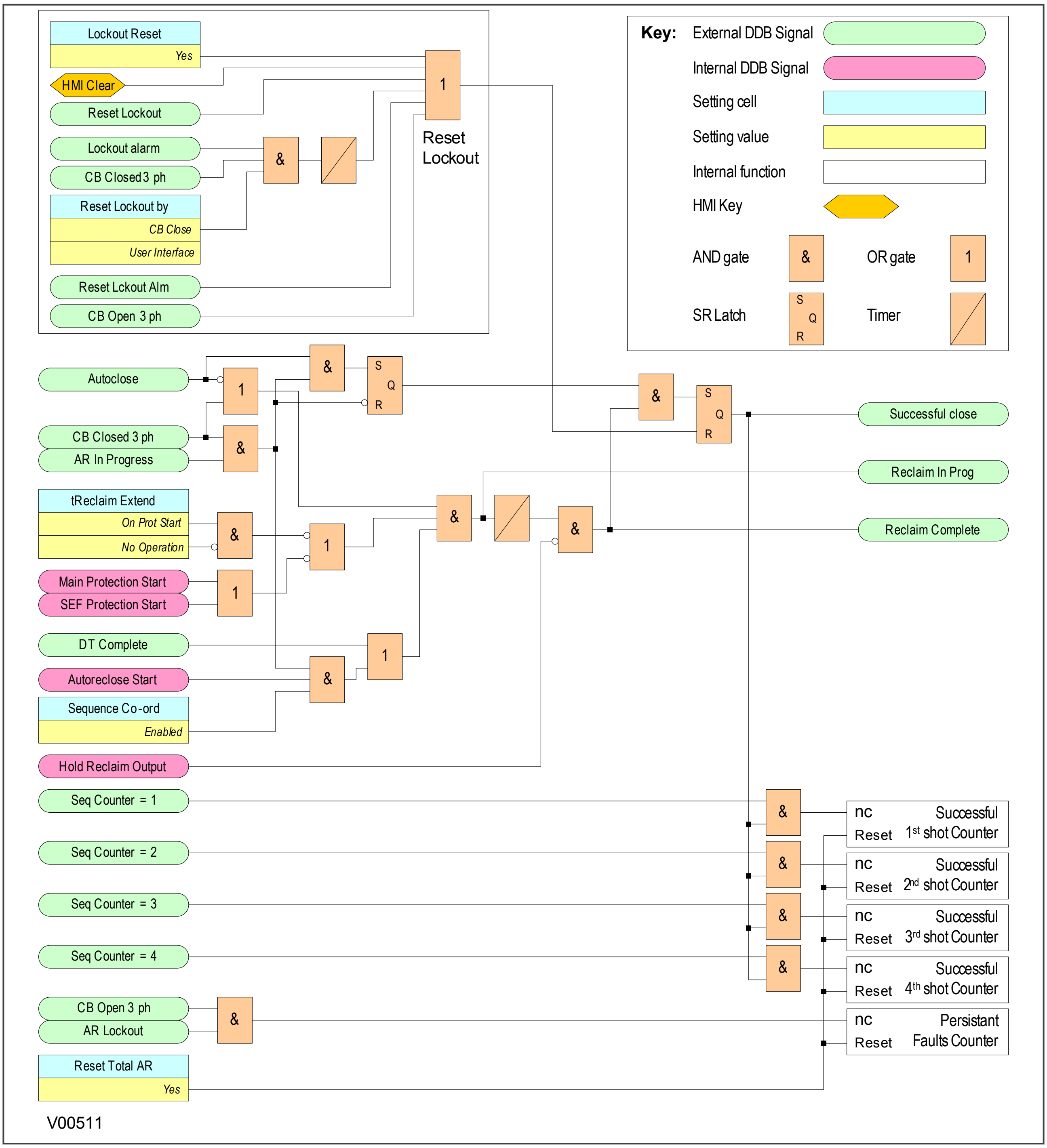


Figure 73: Reclaim Time logic

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:

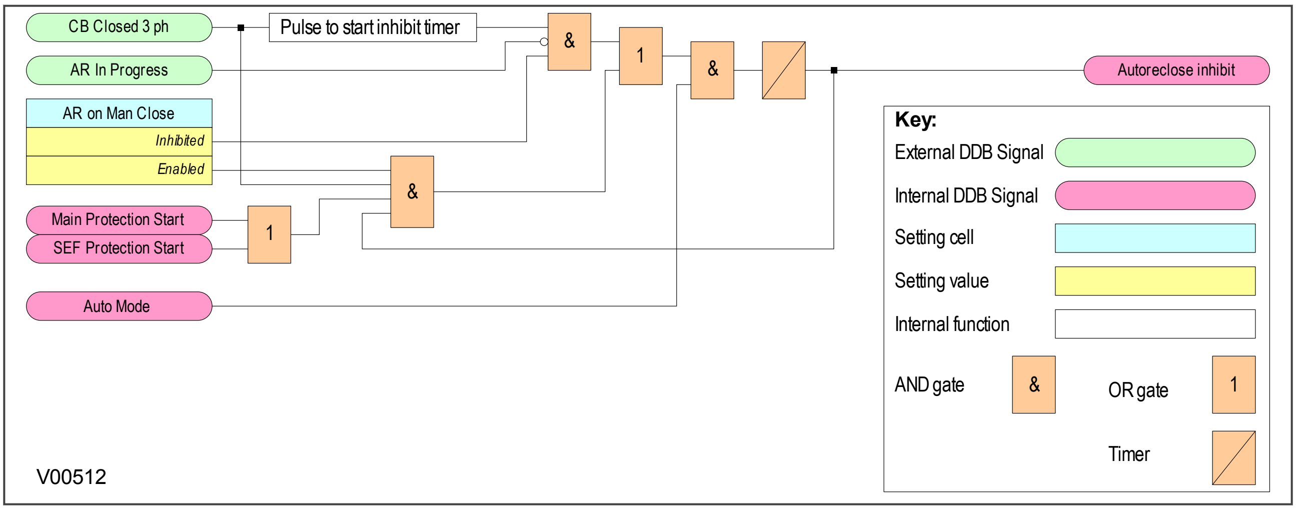


Figure 74: AR Initiation inhibit

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:

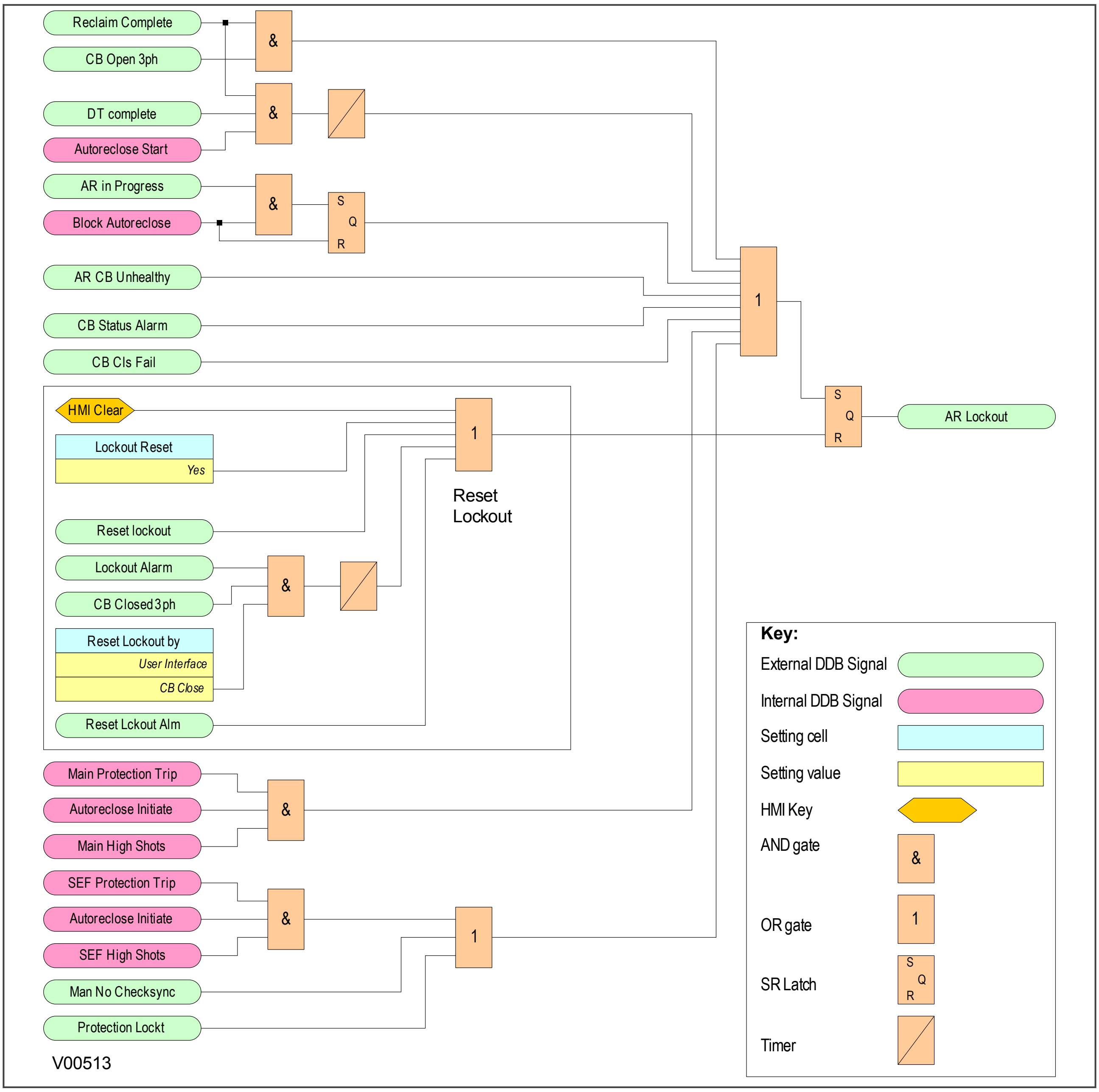


Figure 75: Overall Lockout logic

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:

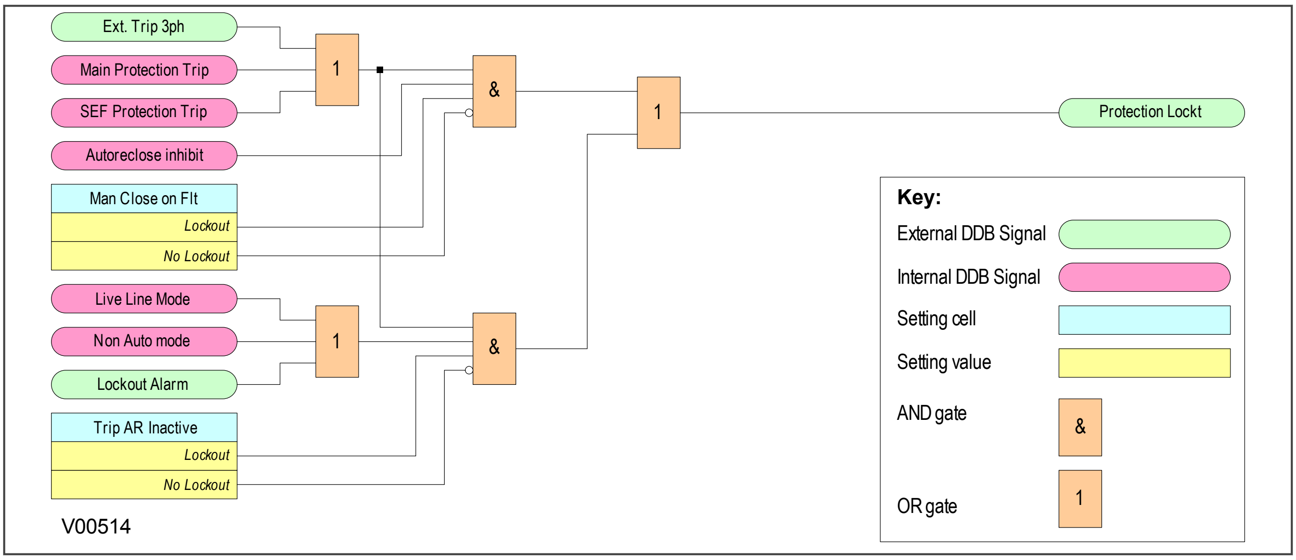


Figure 76: Lockout for protection trip when AR is not available

> *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	Use	Unique ID
Description			
163	AR Lockout	PSL input	DDB_AR_LOCKOUT
This DDB signal indicates that the AR did not result in successful reclosure and locks out further reclose attempts			
164	AR CB Unhealthy	PSL input	DDB_AR_CB_UNHEALTHY
The scheme has waited for the "CB HEALTHY" signal for the HEALTHY WINDOW time.			
165	AR No Sys Check	PSL input	DDB_AR_NO_SYS_CHECK
The scheme has waited for the "SYSTEM OK TO CLOSE" input for the SYSTEM CHECK WINDOW time			
230	CB Healthy	PSL output	DDB_CB_HEALTHY
This DDB signal indicates that the CB is healthy.			
237	Reset Lockout	PSL output	DDB_RESET_LOCKOUT
This DDB Resets a lockout condition			
239	Block AR	PSL output	DDB_BLOCK_AR
This DDB signal blocks the Autoreclose function			
240	AR LiveLine Mode	PSL output	DDB_LIVE_LINE_MODE
This DB indicates that the autoreclose function is in Live Line mode			
241	AR Auto Mode	PSL output	DDB_AUTO_MODE
This DB indicates that the autoreclose function is in Auto mode			
242	Telecontrol Mode	PSL output	DDB_TELECONTROL_MODE
This DB indicates that the autoreclose function is in Telecontrol mode			
358	AR Blk Main Prot	PSL input	DDB_AR_BLOCK_MAIN_PROTECTION
This DDB signal, generated by the Autoreclose function, blocks the Main Protection elements (POC, EF1, EF2, NPSOC)			
359	AR Blk SEF Prot	PSL input	DDB_AR_BLOCK_SEF_PROTECTION
This DDB signal, generated by the Autoreclose function, blocks the SEF Protection element (POC, EF1, EF2, NPSOC)			
360	AR In Progress	PSL input	DDB_AR_3_POLE_IN_PROGRESS
This DDB signal indicates that three-pole Autoreclose is in progress			
361	AR In Service	PSL input	DDB_AR_IN_SERVICE
This DDB signal indicates that Autoreclose is in or out of service (auto, or non-auto mode)			
362	AR SeqCounter 0	PSL input	DDB_SEQ_COUNT_0
This DDB signal indicates that the AR has not been initiated			
363	AR SeqCounter 1	PSL input	DDB_SEQ_COUNT_1
This DDB signal indicates that the AR function is in its first shot			
364	AR SeqCounter 2	PSL input	DDB_SEQ_COUNT_2
This DDB signal indicates that the AR function is in its second shot			
365	AR SeqCounter 3	PSL input	DDB_SEQ_COUNT_3
This DDB signal indicates that the AR function is in its third shot			
366	AR SeqCounter 4	PSL input	DDB_SEQ_COUNT_4
This DDB signal indicates that the AR function is in its fourth shot			
367	Successful Close	PSL input	DDB_AR_SUCCESSFUL_RECLOSE
This DDB signal indicates a successful reclosure			
368	DeadTime in Prog	PSL input	DDB_DEAD_TIME_IN_PROGRESS
This DDB signal indicates that the Autoreclose dead time is in progress			

Ordinal	Signal Name	Use	Unique ID
Description			
369	Protection Lockt	PSL input	DDB_AR_PROTECTION_LOCKOUT
This DB signal locks out the Autoreclose function			
370	Reset Lckout Alm	PSL input	DDB_AR_RESET_LOCKOUT_ALARM
This DDB signal indicates that a lockout has been reset.			
371	Auto Close	PSL input	DDB_AUTO_CLOSE
This DDB signal tells the CB to close, originating from Autoreclose only. This DDB signal has a fixed reset time.			
372	AR Trip Test	PSL input	DDB_AR_TRIP_TEST
This DDB signal is used to test the Autoreclose function Autoreclose trip test			
403	AR Sys Checks	PSL output	DDB_SYNC_AR_SYS_CHECK_OK
This DDB signal tells the Autoreclose that the system checks are satisfied.			
439	Ext AR Prot Trip	PSL output	DDB_EXT_AR_PROT_TRIP
This DDB can initiate an Autoreclose sequence from an external trip			
440	Ext AR Prot Strt	PSL output	DDB_EXT_AR_PROT_START
This DDB informs the Autoreclose function of an external start			
453	DAR Complete	PSL output	DDB_DAR_COMPLETE
This DDB signal resets the AR in Progress 1 signal			
454	CB in Service	PSL output	DDB_CB_IN_SERVICE
This DDB signal indicates that the Circuit Breaker is in service			
455	AR Restart	PSL output	DDB_AR_RESTART
This DDB signal triggers a Restart of the Autoreclose initiation process			
456	DAR In Progress	PSL input	DDB_AR_IP_1
This DDB signal indicates that delayed Auto-Reclose is in progress			
457	DeadTime Enabled	PSL output	DDB_DEADTIME_ENABLE
This DDB signal enables the Dead Time timers			
458	DT OK To Start	PSL output	DDB_DEADTIME_OK_TO_START
This DDB signal tells the AR that it is OK to start the Autoreclose Dead Timer.			
459	DT Complete	PSL input	DDB_DEADTIME_COMPLETE
This DDB signal indicates that the Autoreclose Dead Time is complete			
460	Reclose Checks	PSL input	DDB_ARCHECKS_IN_PROGRESS
This DDB signal indicates that Autoreclose system checks are in progress			
461	LiveDead Ccts OK	PSL output	DDB_AR_LIVEDEAD_CCTS_OK
This DDB informs the AR function that there is a Live/Dead circuit condition			
462	AR Sync Check	PSL input	DDB_AR_SYNC_CHECK
This DDB signal indicates that the Autoreclose Synchronisation Check is OK			
463	AR SysChecks OK	PSL input	DDB_AR_SYSTEMCHECKS_OK
This DDB signal indicates that the Autoreclose System Checks are is OK			
464	AR Init TripTest	PSL output	DDB_INIT_AR_TRIP_TEST
This DDB signal initiates an Autoreclose trip test.			
530	AR Skip Shot 1	PSL output	DDB_AR_SKIP_SHOT_1
This DDB signal forces the Autoreclose function to skip shot 1 of a reclose sequence.			
532	Inh Reclaim Time	PSL output	DDB_AR_INHIBIT_RECLAIM_TIME
This DDB signal inhibits the Autoreclose Reclaim Timer			

Ordinal	Signal Name	Use	Unique ID
Description			
533	Reclaim In Prog	PSL input	DDB_AR_RECLAIM_IN_PROGRESS
This DDB signal indicates that the Autoreclose Reclaim Time is in progress			
534	Reclaim Complete	PSL input	DDB_AR_RECLAIM_TIME_COMPLETE
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 DE-IONISATION 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 EVENT RECORDS

IEDs record all events in an event log. This allows you to establish the sequence of events that led up to a particular situation. For example, a change in a digital input signal or protection element output signal would cause an event record to be created and stored in the event log. This could be used to analyse how a particular power system condition was caused. These events are stored in the IED's non-volatile memory. When available space is exhausted, the oldest event is overwritten by the new one. The IED's internal clock provides a time tag for each event.

The event records can be displayed on an IED's front panel but it is easier to view them through the settings application software. This can extract the events log from the device and store it as a single .evt file for analysis on a PC.

If viewing the event on the IED's front panel they can be found in the *VIEW RECORDS* column. The first event (0) is always the latest event. After selecting the required event, you can scroll through the menus to obtain further details.

If viewing the event with the settings application software, simply open the extracted event file. All the events are displayed chronologically. Each event is summarised with a time stamp (obtained from the ***Time & Date*** cell) and a short description relating to the event (obtained from the ***Event Text*** cell. You can expand the details of the event by clicking on the **+** icon to the left of the time stamp.

The following table shows the correlation between the fields in the setting application software's event viewer and the cells in the courier database.

Field in Event Viewer	Equivalent cell in Courier DB	Cell reference	User settable?
Left hand column header	VIEW RECORDS → Time & Date	01 03	No
Right hand column header	VIEW RECORDS → Event Text	01 04	No
Description	SYSTEM DATA → Description	00 04	Yes
Plant reference	SYSTEM DATA → Plant Reference	00 05	Yes
Model number	SYSTEM DATA → Model Number	00 06	No
Address	Displays the Courier address relating to the event	N/A	No
Event type	VIEW RECORDS → Menu Cell Ref	01 02	No
Event Value	VIEW RECORDS → Event Value	01 05	No
Evt Unique Id	VIEW RECORDS → Evt Unique ID	01 FE	No

2.1 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
- Fault record events
- Standard events
- Security Events

Standard events are further sub-categorised internally to include different pieces of information. These are:

- Protection events (starts and trips)
- Maintenance record events
- Platform Events

2.1.1 OPTO-INPUT EVENTS

If one or more of the opto-inputs has changed state since the last time the protection algorithm ran, a new event is created, which logs the logic states of all opto-inputs. You can tell which opto-input has changed state by comparing the new event with the previous one.

The description of this event type, as shown in the ***Event Text*** cell 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 ***Event Value*** cell for this type of event is a binary string. This shows the logical states of the opto-inputs, where the LSB (on the right) corresponds to the first opto-input `Input L1`.

The same information is also shown in the ***Opto I/P Status*** cell in the *SYSTEM DATA* column. This information is updated continuously, whereas the information in the event log is a snapshot at the time when the event was created.

2.1.2 CONTACT EVENTS

If one or more of the output relays (also known as output contacts) has changed state since the last time the protection algorithm ran, a new event is created, which logs the logic states of all output relays. You can tell which output relay has changed state by comparing the new event with the previous one.

The description of this event type, as shown in the ***Event Text*** cell is always `Output Contacts #` where # is the batch number of the output relay 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 ***Event Value*** cell for this type of event is a binary string. This shows the logical states of the output relays, where the LSB (on the right) corresponds to the first output contact `Output R1`.

The same information is also shown in the ***Relay O/P Status*** cell in the *SYSTEM DATA* column. This information is updated continuously, whereas the information in the event log is a snapshot at the time when the event was created.

2.1.3 ALARM EVENTS

The IED monitors itself on power up and continually thereafter. If it notices any problems, it will register an alarm event.

The description of this event type, as shown in the ***Event Text*** cell is cell dependent on the type of alarm and will be one of those shown in the following tables, followed by `OFF` or `ON`.

The event value shown in the ***Event Value*** cell for this type of event is a 32 bit binary string. There are one or more banks 32 bit registers, depending on the device model. These contain all the alarm types and their logic states (`ON` or `OFF`).

The same information is also shown in the ***Alarm Status (n)*** cells in the *SYSTEM DATA* column. This information is updated continuously, whereas the information in the event log is a snapshot at the time when the event was created.

2.1.3.1 PRODUCT ALARM STATUS 1

Bit Number	Event Text	Description
Bit 1	Unused	Unused
Bit 2	HIF Alarm	High Impedance Fault Alarm
Bit 3	SG-opto Invalid ON/OFF	Setting group via opto invalid
Bit 4	Prot'n Disabled ON/OFF	Protection disabled
Bit 5	F out of Range ON/OFF	Frequency out of range

Bit Number	Event Text	Description
Bit 6	VT Fail Alarm ON/OFF	VTS Alarm
Bit 7	CT Fail Alarm ON/OFF	CTS Alarm
Bit 8	CB Fail Alarm ON/OFF	CB Trip Fail Protection
Bit 9	I^ Maint Alarm ON/OFF	Broken current Maintenance Alarm
Bit 10	I^ Lockout Alarm ON/OFF	Broken current Lockout Alarm
Bit 11	CB Ops Maint ON/OFF	No of CB Ops Maintenance Alarm
Bit 12	CB Ops Lockout ON/OFF	No of CB Ops Lockout Alarm
Bit 13	CB Op Time Maint ON/OFF	CB Op Time Maintenance Alarm
Bit 14	CB Op Time Lock ON/OFF	CB Op Time Lockout Alarm
Bit 15	Fault Freq Lock ON/OFF	Excessive Fault Frequency Lockout Alarm
Bit 16	CB Status Alarm ON/OFF	CB Status Alarm
Bit 17	Man CB Trip Fail ON/OFF	CB Fail Trip Control
Bit 18	Man CB Cls Fail ON/OFF	CB Fail Close Control
Bit 19	Man CB Unhealthy ON/OFF	No Healthy Control Close
Bit 20	Man No Checksync ON/OFF	No C/S control close
Bit 21	A/R Lockout ON/OFF	A/R Lockout
Bit 22	A/R CB Unhealthy ON/OFF	A/R CB Not healthy
Bit 23	A/R No Checksync ON/OFF	A/R No Checksync
Bit 24	System Split ON/OFF	System Split
Bit 25	UV Block ON/OFF	UV Block
Bit 26	SR User Alarm 1 ON/OFF	User Definable Alarm 1 (Self Reset)
Bit 27	SR User Alarm 2 ON/OFF	User Definable Alarm 2 (Self Reset)
Bit 28	SR User Alarm 3 ON/OFF	User Definable Alarm 3 (Self Reset)
Bit 29	SR User Alarm 4 ON/OFF	User Definable Alarm 4 (Self Reset)
Bit 30	SR User Alarm 5 ON/OFF	User Definable Alarm 5 (Self Reset)
Bit 31	SR User Alarm 6 ON/OFF	User Definable Alarm 6 (Self Reset)
Bit 32	SR User Alarm 7 ON/OFF	User Definable Alarm 7 (Self Reset)

Note:
Alarm Status 1 is duplicated in cells 22 and 50 to maintain backward compatibility for older models

2.1.3.2 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 Number	Event Text	Description
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 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)

2.1.3.3 PLATFORM ALARMS

Bit Number	Event Text	Description
Bit 1	DC Supply Fail	DC Supply Fail
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 Number	Event Text	Description
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 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

2.1.4 FAULT RECORD EVENTS

An event record is created for every fault the IED detects. This is also known as a fault record.

The event type description shown in the ***Event Text*** cell for this type of event is always `Fault Recorded`.

The IED contains a separate register containing the latest fault records. This provides a convenient way of viewing the latest fault records and saves searching through the event log. You access these fault records using the ***Select Fault*** setting, where fault number 0 is the latest fault.

A fault record is triggered by the ***Fault REC TRIG*** signal DDB, which is assigned in the PSL. The fault recorder records the values of all parameters associated with the fault for the duration of the fault. These parameters are stored in separate Courier cells, which become visible depending on the type of fault.

The fault recorder stops recording only when:

The Start signal is reset AND the undercurrent is ON OR the Trip signal is reset, as shown below:

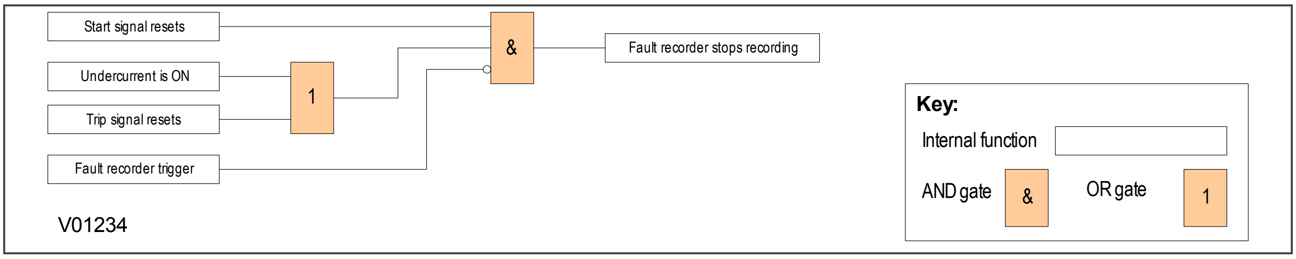


Figure 77: Fault recorder stop conditions

The event is logged the moment the fault recorder stops. The time stamp assigned to the fault corresponds to the start of the fault, whereas the timestamp assigned to the fault record event corresponds to the time when the fault recorder stops, i.e. the end of the fault.

> *Note:*
> *We recommend that you do not set the triggering contact to latching. This is because if you use a latching contact, the fault record would not be generated until the contact has been fully reset.*

2.1.5 MAINTENANCE EVENTS

Internal failures detected by the self-test procedures are logged as maintenance records. Maintenance records are special types of standard events.

The event type description shown in the ***Event 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.

The IED contains a separate register containing the latest maintenance records. This provides a convenient way of viewing the latest maintenance records and saves searching through the event log. You access these fault records using the ***Select Maint*** setting.

The maintenance record has a number of extra Courier cells relating to the maintenance event. These parameters are ***Maint Text***, ***Maint Type*** and ***Maint Data***. They contain details about the maintenance event selected with the ***Select Maint*** cell.

The possible maintenance records are as follows:

Event Value	Event Text	Description
6	FPGA Health Err	There is a Field Programmable Gate Array error
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 been 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

2.1.6 PROTECTION EVENTS

The IED logs protection starts and trips as individual events. Protection events are special types of standard events.

The event type description shown in the ***Event 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 ***Event Text*** cell.

The ***Event Value*** cell for this type of event is a 32 bit binary string representing the state of the relevant DDB signals. These binary strings can also be viewed in the *COMMISSION TESTS* column in the relevant DDB batch cells.

Not all DDB signals can generate an event. Those that can are listed in the *RECORD CONTROL* column. In this column, you can set which DDBs generate events.

2.1.7 SECURITY EVENTS

An event record is generated each time a setting is executed, which requires an access level.

The event type description shown in the ***Event 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

Event Value	Event Text	Description
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"
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"

2.1.8 PLATFORM EVENTS

Platform events are special types of standard events.

The event type description shown in the ***Event 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

2.2 RECORD CONTROL COLUMN

You can control which events cause an event record to be logged in the *RECORD CONTROL* column.

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.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
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.				
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

Menu Text	Col	Row	Default Setting	Available Options
Description				
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)				
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)				

Menu Text	Col	Row	Default Setting	Available Options
Description				
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)				
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)				

Menu Text	Col	Row	Default Setting	Available Options
Description				
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)				
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)				

Menu Text	Col	Row	Default Setting	Available Options
Description				
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)				
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)				

Menu Text	Col	Row	Default Setting	Available Options
Description				
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)				
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)				

2.3 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)	Not settable
This cell indicates the type of event				
Time & Date	01	03	(From Record)	Not settable
This cell shows the Time & Date of the event, given by the internal Real Time Clock.				
Event Text	01	04		Not settable
This cell shows the description of the event - up to 32 Characters over 2 lines.				
Event Value	01	05		Not settable
This cell displays a 32 bit binary flag representing the event.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
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		Not settable
This cell displays the faulted phase.				
Start Elements 1	01	08		Not settable
This cell displays the status of the first set of 32 start signals.				
Start Elements 2	01	09		Not settable
This cell displays the status of the second set of 32 start signals.				
Start Elements 3	01	0A		Not settable
This cell displays the status of the third set of 32 start signals.				
Start Elements 4	01	0B		Not settable
This cell displays the status of the fourth set of 32 start signals.				
Trip Elements 1	01	0C		Not settable
This cell displays the status of the first set of 32 trip signals.				
Trip Elements 2	01	0D		Not settable
This cell displays the status of the second set of 32 trip signals.				
Trip Elements 3	01	0E		Not settable
This cell displays the status of the third set of 32 trip signals.				
Trip Elements 4	01	0F		Not settable
This cell displays the status of the fourth set of 32 trip signals.				
Fault Alarms	01	10		Not settable
This cell displays the status of the fault alarm signals.				
Fault Time	01	11		Not settable
This cell displays the time and date of the fault				
Active Group	01	12		Not settable
This cell displays the active settings group				
System Frequency	01	13		Not settable
This cell displays the system frequency				
Fault Duration	01	14		Not settable
This cell displays the duration of the fault time				
CB Operate Time	01	15		Not settable
This cell displays the CB operate time				
IED Trip Time	01	16		Not settable
This cell displays the time from protection start to protection trip				
IA	01	1B		Not settable
This cell displays the phase A current				
IB	01	1C		Not settable
This cell displays the phase B current				
IC	01	1D		Not settable
This cell displays the phase C current				
IN Measured	01	21		Not settable
This cell displays the value of measured neutral current				

Menu Text	Col	Row	Default Setting	Available Options
Description				
IN Derived	01	22		Not settable
This cell displays the value of derived neutral current				
IN Sensitive	01	23		Not settable
This cell displays the value of sensitive neutral current				
IREF Diff	01	24		Not settable
This cell displays the value of Restricted Earth Fault differential current				
IREF Bias	01	25		Not settable
This cell displays the value of Restricted Earth Fault bias current				
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		Not settable
This cell displays the description of the maintenance record				
Maint Type	01	F2		Not settable
This is the type of maintenance record				
Maint Data	01	F3		Not settable
This is the maintenance record data (error code)				
Evt Iface Source	01	FA		Not settable
This cell displays the interface on which the event was logged				
Evt Access Level	01	FB		Not settable
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		Not settable
This cell provides supporting information for the event and can vary between the different event types.				
Evt Unique Id	01	FE		Not settable
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 and collates the received data into a disturbance record. The disturbance records can be extracted using the disturbance record viewer in the settings application software. The disturbance record file can also be stored in the COMTRADE format. This allows 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 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 a number of analogue data channels and digital data channels. The relevant CT and VT ratios for the analogue channels are also extracted to enable scaling to primary quantities.

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, 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 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 setting application software such as MiCOM S1 Agile.

3.1 DISTURBANCE RECORDER SETTINGS

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.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
Analog Channel 1	0C	04	Analog 1 Unused	0=Analog 1 Unused 1=Analog 2 Unused 2=Analog 3 Unused 3=Analog 4 Unused 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.				
Analog Channel 2	0C	05	Analog 2 Unused	0=Analog 1 Unused 1=Analog 2 Unused 2=Analog 3 Unused 3=Analog 4 Unused 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.				
Analog Channel 3	0C	06	Analog 3 Unused	0=Analog 1 Unused 1=Analog 2 Unused 2=Analog 3 Unused 3=Analog 4 Unused 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.				
Analog Channel 4	0C	07	Analog 4 Unused	0=Analog 1 Unused 1=Analog 2 Unused 2=Analog 3 Unused 3=Analog 4 Unused 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.				
Analog Channel 5	0C	08	IA	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.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
Analog Channel 6	0C	09	IB	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.				
Analog Channel 7	0C	0A	IC	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.				
Analog Channel 8	0C	0B	IN-ISEF	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.				
Analog Channel 9	0C	0C	Frequency	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	0C	0D	Output R1	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 Trigger	0C	0E	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).				
Digital Input 2	0C	0F	Output R2	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 2 Trigger	0C	10	No Trigger	0 = No Trigger, 1 = Trigger L/H, 2 = Trigger H/L

Menu Text	Col	Row	Default Setting	Available Options
Description				
This setting defines whether the digital input is triggered and if so, the trigger polarity (low to high or high to low).				
Digital Input 3	0C	11	Output R3	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 3 Trigger	0C	12	Trigger L/H	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).				
Digital Input 4	0C	13	Output R4	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 4 Trigger	0C	14	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).				
Digital Input 5	0C	15	Output R5	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 5 Trigger	0C	16	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).				
Digital Input 6	0C	17	Output R6	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 6 Trigger	0C	18	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).				
Digital Input 7	0C	19	Output R7	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 7 Trigger	0C	1A	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).				
Digital Input 8	0C	1B	Output R8	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 8 Trigger	0C	1C	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).				
Digital Input 9	0C	1D	Unused	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 9 Trigger	0C	1E	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).				
Digital Input 10	0C	1F	Unused	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 10 Trigger	0C	20	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).				
Digital Input 11	0C	21	Unused	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 11 Trigger	0C	22	No Trigger	0 = No Trigger, 1 = Trigger L/H, 2 = Trigger H/L

Menu Text	Col	Row	Default Setting	Available Options
Description				
This setting defines whether the digital input is triggered and if so, the trigger polarity (low to high or high to low).				
Digital Input 12	0C	23	Unused	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 12 Trigger	0C	24	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).				
Digital Input 13	0C	25	Input L1	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 13 Trigger	0C	26	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).				
Digital Input 14	0C	27	Input L2	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 14 Trigger	0C	28	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).				
Digital Input 15	0C	29	Input L3	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 15 Trigger	0C	2A	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).				
Digital Input 16	0C	2B	Input L4	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 16 Trigger	0C	2C	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).				
Digital Input 17	0C	2D	Input L5	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 17 Trigger	0C	2E	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).				
Digital Input 18	0C	2F	Input L6	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 18 Trigger	0C	30	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).				
Digital Input 19	0C	31	Input L7	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 19 Trigger	0C	32	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).				
Digital Input 20	0C	33	Input L8	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 20 Trigger	0C	34	No Trigger	0 = No Trigger, 1 = Trigger L/H, 2 = Trigger H/L

Menu Text	Col	Row	Default Setting	Available Options
Description				
This setting defines whether the digital input is triggered and if so, the trigger polarity (low to high or high to low).				
Digital Input 21	0C	35	Unused	See Data Types - G32
The digital channels may monitor any of the opto isolated inputs or output contacts, in addition to a number of internal IED digital signals, such as protection starts, LEDs etc.				
Input 21 Trigger	0C	36	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).				
Digital Input 22	0C	37	Unused	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 22 Trigger	0C	38	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).				
Digital Input 23	0C	39	Unused	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 23 Trigger	0C	3A	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).				
Digital Input 24	0C	3B	Unused	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 24 Trigger	0C	3C	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).				
Digital Input 25	0C	3D	Unused	See Data Types - G32
The digital channels may monitor any of the opto isolated inputs or output contacts, in addition to a number of internal IED digital signals, such as protection starts, LEDs etc.				
Input 25 Trigger	0C	3E	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).				
Digital Input 26	0C	3F	Unused	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 26 Trigger	0C	40	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).				
Digital Input 27	0C	41	Unused	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 27 Trigger	0C	42	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).				
Digital Input 28	0C	43	Unused	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 28 Trigger	0C	44	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).				
Digital Input 29	0C	45	Unused	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 29 Trigger	0C	46	No Trigger	0 = No Trigger, 1 = Trigger L/H, 2 = Trigger H/L

Menu Text	Col	Row	Default Setting	Available Options
Description				
This setting defines whether the digital input is triggered and if so, the trigger polarity (low to high or high to low).				
Digital Input 30	0C	47	Unused	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 30 Trigger	0C	48	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).				
Digital Input 31	0C	49	Unused	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 31 Trigger	0C	4A	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).				
Digital Input 32	0C	4B	Unused	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 32 Trigger	0C	4C	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).				

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 Measurement Viewer in the settings application software. 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 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 = Date and Time, 3 = Description, 4 = Plant Reference, 5 = Frequency, 6 = Access Level 7 = 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

Menu Text	Col	Row	Default Setting	Available Options
Description				
This setting controls whether remote measured values (via rear comms ports) are displayed as primary or secondary quantities.				
Measurement Ref	0D	04	IA	0 = IA, 1 = IB, 2 = IC
This setting sets the phase reference for all angular measurements (for Measurements 1 only).				
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.				
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 MEASUREMENTS TABLE 1

Menu Text	Col	Row	Default Setting	Available Options
Description				
MEASUREMENTS 1	02	00		
This column contains measurement parameters				
IA Magnitude	02	01		Not settable
This cell displays the A-phase current magnitude.				
IA Phase Angle	02	02		Not settable
This cell displays the A-phase phase angle.				
IB Magnitude	02	03		Not settable
This cell displays the B-phase current magnitude.				
IB Phase Angle	02	04		Not settable
This cell displays the B-phase phase angle.				
IC Magnitude	02	05		Not settable
This cell displays the C-phase current magnitude.				
IC Phase Angle	02	06		Not settable
This cell displays the C-phase phase angle.				
IN Measured Mag	02	07		Not settable
This cell displays the measured neutral current magnitude.				
IN Measured Ang	02	08		Not settable
This cell displays the measured neutral phase angle.				
IN Derived Mag	02	09		Not settable
This cell displays the derived neutral current magnitude.				
IN Derived Angle	02	0A		Not settable
This cell displays the derived neutral phase angle.				
ISEF Magnitude	02	0B		Not settable
This cell displays the sensitive earth fault current magnitude.				
ISEF Angle	02	0C		Not settable

Menu Text	Col	Row	Default Setting	Available Options
Description				
This cell displays the sensitive earth fault phase angle.				
I1 Magnitude	02	0D		Not settable
This cell displays the positive sequence current magnitude.				
I2 Magnitude	02	0E		Not settable
This cell displays the negative sequence current magnitude.				
I0 Magnitude	02	0F		Not settable
This cell displays the zero sequence current magnitude.				
IA RMS	02	10		Not settable
This cell displays the A-phase RMS current.				
IB RMS	02	11		Not settable
This cell displays the B-phase RMS current.				
IC RMS	02	12		Not settable
This cell displays the C-phase RMS current.				
Frequency	02	2D		Not settable
This cell displays the system frequency				
I1 Magnitude	02	40		Not settable
This cell displays the positive sequence current magnitude.				
I1 Phase Angle	02	41		Not settable
This cell displays the positive sequence phase angle.				
I2 Magnitude	02	42		Not settable
This cell displays the negative sequence current magnitude.				
I2 Phase Angle	02	43		Not settable
This cell displays the negative sequence phase angle.				
I0 Magnitude	02	44		Not settable
This cell displays the zero sequence current magnitude.				
I0 Phase Angle	02	45		Not settable
This cell displays the zero sequence phase angle.				

4.4 MEASUREMENTS TABLE 2

Menu Text	Col	Row	Default Setting	Available Options
Description				
MEASUREMENTS 2	03	00		
This column contains measurement parameters				
IA Fixed Demand	03	18		Not settable
This cell displays the A-phase current fixed demand measurement				
IB Fixed Demand	03	19		Not settable
This cell displays the B-phase current fixed demand measurement				
IC Fixed Demand	03	1A		Not settable
This cell displays the C-phase current fixed demand measurement				
IA Roll Demand	03	1D		Not settable
This cell displays the A-phase current rolling demand measurement				

Menu Text	Col	Row	Default Setting	Available Options
Description				
IB Roll Demand	03	1E		Not settable
This cell displays the B-phase current rolling demand measurement				
IC Roll Demand	03	1F		Not settable
This cell displays the C-phase current rolling demand measurement				
IA Peak Demand	03	22		Not settable
This cell displays the A-phase current peak demand measurement				
IB Peak Demand	03	23		Not settable
This cell displays the B-phase current peak demand measurement				
IC Peak Demand	03	24		Not settable
This cell displays the C-phase current peak demand measurement				
Reset Demand	03	25	No	0 = No or 1 = Yes
This command resets all acquired demand values.				

4.5 MEASUREMENTS 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
This cell displays the highest phase current				
Thermal State	04	02		Not settable
This cell displays the thermal state				
Reset Thermal	04	03	No	0 = No or 1 = Yes
This command resets the thermal state				
IREF Diff	04	04		Not settable
This cell displays the Restricted Earth Fault differential current				
IREF Bias	04	05		Not settable
This cell displays the Restricted Earth Fault bias current				
I2/I1 Ratio	04	0C		Not settable
This cell displays the negative sequence current to positive sequence current ratio				
IA 2ndHarm	04	0F		Not settable
This cell displays the A-phase 2nd harmonic current component				
IB 2ndHarm	04	10		Not settable
This cell displays the B-phase 2nd harmonic current component				
IC 2ndHarm	04	11		Not settable
This cell displays the C-phase 2nd harmonic current component				
DC Supply Mag	04	20		Not settable
This cell displays the 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 therefore 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	Use	Unique ID
Description			
712	Function Key 1	Function key	DDB_FN_KEY_1
DDB signal indicates that Function key 1 is active			

Ordinal	Signal Name	Use	Unique ID
Description			
713	Function Key 2	Function key	DDB_FN_KEY_2
DDB signal indicates that Function key 2 is active			
714	Function Key 3	Function key	DDB_FN_KEY_3
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:

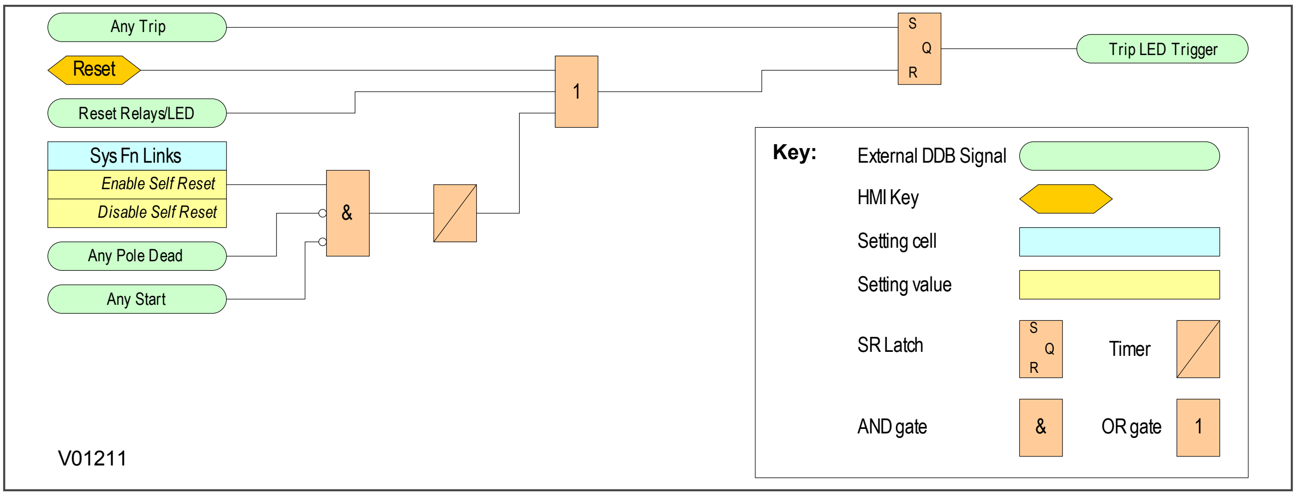


Figure 78: Trip LED logic

5.2.5 LED DDB SIGNALS

Ordinal	Signal Name	Use	Unique ID
Description			
640	LED1 Red	Tri-colour LED	DDB_OUTPUT_TRI_LED_1_RED
DDB signal indicates that the red LED is active			
641	LED1 Grn	Tri-colour LED	DDB_OUTPUT_TRI_LED_1_GRN
DDB signal indicates that the green LED is active			
642	LED2 Red	Tri-colour LED	DDB_OUTPUT_TRI_LED_2_RED
DDB signal indicates that the red LED is active			
643	LED2 Grn	Tri-colour LED	DDB_OUTPUT_TRI_LED_2_GRN
DDB signal indicates that the green LED is active			
644	LED3 Red	Tri-colour LED	DDB_OUTPUT_TRI_LED_3_RED
DDB signal indicates that the red LED is active			
645	LED3 Grn	Tri-colour LED	DDB_OUTPUT_TRI_LED_3_GRN
DDB signal indicates that the green LED is active			
646	LED4 Red	Tri-colour LED	DDB_OUTPUT_TRI_LED_4_RED
DDB signal indicates that the red LED is active			
647	LED4 Grn	Tri-colour LED	DDB_OUTPUT_TRI_LED_4_GRN
DDB signal indicates that the green LED is active			
648	LED5 Red(30TE)	Tri-colour LED	DDB_OUTPUT_TRI_LED_5_RED
DDB signal indicates that the red LED is active			
649	LED5 Grn(30TE)	Tri-colour LED	DDB_OUTPUT_TRI_LED_5_GRN
DDB signal indicates that the green LED is active			
650	LED6 Red(30TE)	Tri-colour LED	DDB_OUTPUT_TRI_LED_6_RED
DDB signal indicates that the red LED is active			
651	LED6 Grn(30TE)	Tri-colour LED	DDB_OUTPUT_TRI_LED_6_GRN
DDB signal indicates that the green LED is active			
652	LED7 Red(30TE)	Tri-colour LED	DDB_OUTPUT_TRI_LED_7_RED
DDB signal indicates that the red LED is active			

Ordinal	Signal Name	Use	Unique ID
Description			
653	LED7 Grn(30TE)	Tri-colour LED	DDB_OUTPUT_TRI_LED_7_GRN
DDB signal indicates that the green LED is active			
654	LED8 Red(30TE)	Tri-colour LED	DDB_OUTPUT_TRI_LED_8_RED
DDB signal indicates that the red LED is active			
655	LED8 Grn(30TE)	Tri-colour LED	DDB_OUTPUT_TRI_LED_8_GRN
DDB signal indicates that the green LED is active			
656	FnKey LED1 Red	Tri-colour LED	DDB_OUTPUT_TRI_LED_9_RED
DDB signal indicates that the red Function Key LED is active			
657	FnKey LED1 Grn	Tri-colour LED	DDB_OUTPUT_TRI_LED_9_GRN
DDB signal indicates that the green Function Key LED is active			
658	FnKey LED2 Red	Tri-colour LED	DDB_OUTPUT_TRI_LED_10_RED
DDB signal indicates that the red Function Key LED is active			
659	FnKey LED2 Grn	Tri-colour LED	DDB_OUTPUT_TRI_LED_10_GRN
DDB signal indicates that the green Function Key LED is active			
660	FnKey LED3 Red	Tri-colour LED	DDB_OUTPUT_TRI_LED_11_RED
DDB signal indicates that the red Function Key LED is active			
661	FnKey LED3 Grn	Tri-colour LED	DDB_OUTPUT_TRI_LED_11_GRN
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 376), 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	Use	Unique ID
Description			
676	LED1 Con R	Tri-colour LED conditioner	DDB_TRI_LED_RED_CON_1
This DDB signal drives the red LED Conditioner 1			
677	LED1 Con G	Tri-colour LED conditioner	DDB_TRI_LED_GRN_CON_1
This DDB signal drives the green LED Conditioner 1			
678	LED2 Con R	Tri-colour LED conditioner	DDB_TRI_LED_RED_CON_2
This DDB signal drives the red LED Conditioner 2			
679	LED2 Con G	Tri-colour LED conditioner	DDB_TRI_LED_GRN_CON_2
This DDB signal drives the green LED Conditioner 2			
680	LED3 Con R	Tri-colour LED conditioner	DDB_TRI_LED_RED_CON_3
This DDB signal drives the red LED Conditioner 3			
681	LED3 Con G	Tri-colour LED conditioner	DDB_TRI_LED_GRN_CON_3
This DDB signal drives the green LED Conditioner 3			
682	LED4 Con R	Tri-colour LED conditioner	DDB_TRI_LED_RED_CON_4
This DDB signal drives the red LED Conditioner 4			
683	LED4 Con G	Tri-colour LED conditioner	DDB_TRI_LED_GRN_CON_4

Ordinal	Signal Name	Use	Unique ID
Description			
This DDB signal drives the green LED Conditioner 4			
684	LED5 Con R(30TE)	Tri-colour LED conditioner	DDB_TRI_LED_RED_CON_5
This DDB signal drives the red LED Conditioner 5			
685	LED5 Con G(30TE)	Tri-colour LED conditioner	DDB_TRI_LED_GRN_CON_5
This DDB signal drives the green LED Conditioner 5			
686	LED6 Con R(30TE)	Tri-colour LED conditioner	DDB_TRI_LED_RED_CON_6
This DDB signal drives the red LED Conditioner 6			
687	LED6 Con G(30TE)	Tri-colour LED conditioner	DDB_TRI_LED_GRN_CON_6
This DDB signal drives the green LED Conditioner 6			
688	LED7 Con R(30TE)	Tri-colour LED conditioner	DDB_TRI_LED_RED_CON_7
This DDB signal drives the red LED Conditioner 7			
689	LED7 Con G(30TE)	Tri-colour LED conditioner	DDB_TRI_LED_GRN_CON_7
This DDB signal drives the green LED Conditioner 7			
690	LED8 Con R(30TE)	Tri-colour LED conditioner	DDB_TRI_LED_RED_CON_8
This DDB signal drives the red LED Conditioner 8			
691	LED8 Con G(30TE)	Tri-colour LED conditioner	DDB_TRI_LED_GRN_CON_8
This DDB signal drives the green LED Conditioner 8			
692	FnKey LED1 ConR	Tri-colour LED conditioner	DDB_TRI_LED_RED_CON_9
This DDB signal drives the red Function Key LED Conditioner 1			
693	FnKey LED1 ConG	Tri-colour LED conditioner	DDB_TRI_LED_GRN_CON_9
This DDB signal drives the green Function Key LED Conditioner 1			
694	FnKey LED2 ConR	Tri-colour LED conditioner	DDB_TRI_LED_RED_CON_10
This DDB signal drives the red Function Key LED Conditioner 2			
695	FnKey LED2 ConG	Tri-colour LED conditioner	DDB_TRI_LED_GRN_CON_10
This DDB signal drives the green Function Key LED Conditioner 2			
696	FnKey LED3 ConR	Tri-colour LED conditioner	DDB_TRI_LED_RED_CON_11
This DDB signal drives the red Function Key LED Conditioner 3			
697	FnKey LED3 ConG	Tri-colour LED conditioner	DDB_TRI_LED_GRN_CON_11
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 (n)	4A	01 – 0D	Input L(n)	ASCII text
This setting defines the label for opto-input				

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	Use	Unique ID
Description			
32	Input L1	Opto-input	DDB_OPTO_ISOLATOR_1
DDB signal connected to opto-input 1			
33	Input L2	Opto-input	DDB_OPTO_ISOLATOR_2
DDB signal connected to opto-input 2			
34	Input L3	Opto-input	DDB_OPTO_ISOLATOR_3
DDB signal connected to opto-input 3			
35	Input L4	Opto-input	DDB_OPTO_ISOLATOR_4
DDB signal connected to opto-input 4			
36	Input L5	Opto-input	DDB_OPTO_ISOLATOR_5
DDB signal connected to opto-input 5			
37	Input L6	Opto-input	DDB_OPTO_ISOLATOR_6
DDB signal connected to opto-input 6			
38	Input L7	Opto-input	DDB_OPTO_ISOLATOR_7
DDB signal connected to opto-input 7			
39	Input L8	Opto-input	DDB_OPTO_ISOLATOR_8
DDB signal connected to opto-input 8			
40	Input L9	Opto-input	DDB_OPTO_ISOLATOR_9
DDB signal connected to opto-input 9			
41	Input L10	Opto-input	DDB_OPTO_ISOLATOR_10
DDB signal connected to opto-input 10			
42	Input L11	Opto-input	DDB_OPTO_ISOLATOR_11
DDB signal connected to opto-input 11			

Ordinal	Signal Name	Use	Unique ID
Description			
43	Input L12	Opto-input	DDB_OPTO_ISOLATOR_12
DDB signal connected to opto-input 12			
44	Input L13	Opto-input	DDB_OPTO_ISOLATOR_13
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 (n)	4B	01 – 0C	Output R(n)	ASCII text
This setting defines the label for output relay				

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	Use	Unique ID
Description			
0	Output R1	Output relay	DDB_OUTPUT_RELAY_1
DDB signal connected to output relay contact 1			
1	Output R2	Output relay	DDB_OUTPUT_RELAY_2
DDB signal connected to output relay contact 2			
2	Output R3	Output relay	DDB_OUTPUT_RELAY_3
DDB signal connected to output relay contact 3			
3	Output R4	Output relay	DDB_OUTPUT_RELAY_4

Ordinal	Signal Name	Use	Unique ID
Description			
DDB signal connected to output relay contact 4			
4	Output R5	Output relay	DDB_OUTPUT_RELAY_5
DDB signal connected to output relay contact 5			
5	Output R6	Output relay	DDB_OUTPUT_RELAY_6
DDB signal connected to output relay contact 6			
6	Output R7	Output relay	DDB_OUTPUT_RELAY_7
DDB signal connected to output relay contact 7			
7	Output R8	Output relay	DDB_OUTPUT_RELAY_8
DDB signal connected to output relay contact 8			
8	Output R9	Output relay	DDB_OUTPUT_RELAY_9
DDB signal connected to output relay contact 9			
9	Output R10	Output relay	DDB_OUTPUT_RELAY_10
DDB signal connected to output relay contact 10			
10	Output R11	Output relay	DDB_OUTPUT_RELAY_11
DDB signal connected to output relay contact 11			
11	Output R12	Output relay	DDB_OUTPUT_RELAY_12
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 Settings Application Software 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	Use	Unique ID
Description			
72	Relay Cond 1	Output relay conditioner	DDB_OUTPUT_CON_1
DDB signal connected to output relay conditioner 1			
73	Relay Cond 2	Output relay conditioner	DDB_OUTPUT_CON_2
DDB signal connected to output relay conditioner 2			
74	Relay Cond 3	Output relay conditioner	DDB_OUTPUT_CON_3
DDB signal connected to output relay conditioner 3			
75	Relay Cond 4	Output relay conditioner	DDB_OUTPUT_CON_4
DDB signal connected to output relay conditioner 4			
76	Relay Cond 5	Output relay conditioner	DDB_OUTPUT_CON_5
DDB signal connected to output relay conditioner 5			
77	Relay Cond 6	Output relay conditioner	DDB_OUTPUT_CON_6
DDB signal connected to output relay conditioner 6			
78	Relay Cond 7	Output relay conditioner	DDB_OUTPUT_CON_7
DDB signal connected to output relay conditioner 7			
79	Relay Cond 8	Output relay conditioner	DDB_OUTPUT_CON_8
DDB signal connected to output relay conditioner 8			

Ordinal	Signal Name	Use	Unique ID
Description			
80	Relay Cond 9	Output relay conditioner	DDB_OUTPUT_CON_9
DDB signal connected to output relay conditioner 9			
81	Relay Cond 10	Output relay conditioner	DDB_OUTPUT_CON_10
DDB signal connected to output relay conditioner 10			
82	Relay Cond 11	Output relay conditioner	DDB_OUTPUT_CON_11
DDB signal connected to output relay conditioner 11			
83	Relay Cond 12	Output relay conditioner	DDB_OUTPUT_CON_12
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 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 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 32	12	10 to 4F	No Operation	0 = No Operation, 1 = Set , 2 = Reset
These commands set or reset Control Inputs 1 to 32				

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.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
Control Inputs 1 to 64	13	10 to ED (evens)	Latched	0 = Latched or 1 = Pulsed
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	Use	Unique ID
Description			
800	Control Input 1	Control input	DDB_CONTROL_1
This DDB signal is a control input signal			
801	Control Input 2	Control input	DDB_CONTROL_2
This DDB signal is a control input signal			
802	Control Input 3	Control input	DDB_CONTROL_3
This DDB signal is a control input signal			
803	Control Input 4	Control input	DDB_CONTROL_4
This DDB signal is a control input signal			
804	Control Input 5	Control input	DDB_CONTROL_5
This DDB signal is a control input signal			
805	Control Input 6	Control input	DDB_CONTROL_6
This DDB signal is a control input signal			
806	Control Input 7	Control input	DDB_CONTROL_7
This DDB signal is a control input signal			
807	Control Input 8	Control input	DDB_CONTROL_8
This DDB signal is a control input signal			
808	Control Input 9	Control input	DDB_CONTROL_9
This DDB signal is a control input signal			
809	Control Input 10	Control input	DDB_CONTROL_10
This DDB signal is a control input signal			

Ordinal	Signal Name	Use	Unique ID
Description			
810	Control Input 11	Control input	DDB_CONTROL_11
This DDB signal is a control input signal			
811	Control Input 12	Control input	DDB_CONTROL_12
This DDB signal is a control input signal			
812	Control Input 13	Control input	DDB_CONTROL_13
This DDB signal is a control input signal			
813	Control Input 14	Control input	DDB_CONTROL_14
This DDB signal is a control input signal			
814	Control Input 15	Control input	DDB_CONTROL_15
This DDB signal is a control input signal			
815	Control Input 16	Control input	DDB_CONTROL_16
This DDB signal is a control input signal			
816	Control Input 17	Control input	DDB_CONTROL_17
This DDB signal is a control input signal			
817	Control Input 18	Control input	DDB_CONTROL_18
This DDB signal is a control input signal			
818	Control Input 19	Control input	DDB_CONTROL_19
This DDB signal is a control input signal			
819	Control Input 20	Control input	DDB_CONTROL_20
This DDB signal is a control input signal			
820	Control Input 21	Control input	DDB_CONTROL_21
This DDB signal is a control input signal			
821	Control Input 22	Control input	DDB_CONTROL_22
This DDB signal is a control input signal			
822	Control Input 23	Control input	DDB_CONTROL_23
This DDB signal is a control input signal			
823	Control Input 24	Control input	DDB_CONTROL_24
This DDB signal is a control input signal			
824	Control Input 25	Control input	DDB_CONTROL_25
This DDB signal is a control input signal			
825	Control Input 26	Control input	DDB_CONTROL_26
This DDB signal is a control input signal			
826	Control Input 27	Control input	DDB_CONTROL_27
This DDB signal is a control input signal			
827	Control Input 28	Control input	DDB_CONTROL_28
This DDB signal is a control input signal			
828	Control Input 29	Control input	DDB_CONTROL_29
This DDB signal is a control input signal			
829	Control Input 30	Control input	DDB_CONTROL_30
This DDB signal is a control input signal			
830	Control Input 31	Control input	DDB_CONTROL_31
This DDB signal is a control input signal			

Ordinal	Signal Name	Use	Unique ID
Description			
831	Control Input 32	Control input	DDB_CONTROL_32
This DDB signal is a control input signal			
1248	Control Input 33	Control input	DDB_CONTROL_33
This DDB signal is a control input signal			
1249	Control Input 34	Control input	DDB_CONTROL_34
This DDB signal is a control input signal			
1250	Control Input 35	Control input	DDB_CONTROL_35
This DDB signal is a control input signal			
1251	Control Input 36	Control input	DDB_CONTROL_36
This DDB signal is a control input signal			
1252	Control Input 37	Control input	DDB_CONTROL_37
This DDB signal is a control input signal			
1253	Control Input 38	Control input	DDB_CONTROL_38
This DDB signal is a control input signal			
1254	Control Input 39	Control input	DDB_CONTROL_39
This DDB signal is a control input signal			
1255	Control Input 40	Control input	DDB_CONTROL_40
This DDB signal is a control input signal			
1256	Control Input 41	Control input	DDB_CONTROL_41
This DDB signal is a control input signal			
1257	Control Input 42	Control input	DDB_CONTROL_42
This DDB signal is a control input signal			
1258	Control Input 43	Control input	DDB_CONTROL_43
This DDB signal is a control input signal			
1259	Control Input 44	Control input	DDB_CONTROL_44
This DDB signal is a control input signal			
1260	Control Input 45	Control input	DDB_CONTROL_45
This DDB signal is a control input signal			
1261	Control Input 46	Control input	DDB_CONTROL_46
This DDB signal is a control input signal			
1262	Control Input 47	Control input	DDB_CONTROL_47
This DDB signal is a control input signal			
1263	Control Input 48	Control input	DDB_CONTROL_48
This DDB signal is a control input signal			
1264	Control Input 49	Control input	DDB_CONTROL_49
This DDB signal is a control input signal			
1265	Control Input 50	Control input	DDB_CONTROL_50
This DDB signal is a control input signal			
1266	Control Input 51	Control input	DDB_CONTROL_51
This DDB signal is a control input signal			
1267	Control Input 52	Control input	DDB_CONTROL_52
This DDB signal is a control input signal			

Ordinal	Signal Name	Use	Unique ID
Description			
1268	Control Input 53	Control input	DDB_CONTROL_53
This DDB signal is a control input signal			
1269	Control Input 54	Control input	DDB_CONTROL_54
This DDB signal is a control input signal			
1270	Control Input 55	Control input	DDB_CONTROL_55
This DDB signal is a control input signal			
1271	Control Input 56	Control input	DDB_CONTROL_56
This DDB signal is a control input signal			
1272	Control Input 57	Control input	DDB_CONTROL_57
This DDB signal is a control input signal			
1273	Control Input 58	Control input	DDB_CONTROL_58
This DDB signal is a control input signal			
1274	Control Input 59	Control input	DDB_CONTROL_59
This DDB signal is a control input signal			
1275	Control Input 60	Control input	DDB_CONTROL_60
This DDB signal is a control input signal			
1276	Control Input 61	Control input	DDB_CONTROL_61
This DDB signal is a control input signal			
1277	Control Input 62	Control input	DDB_CONTROL_62
This DDB signal is a control input signal			
1278	Control Input 63	Control input	DDB_CONTROL_63
This DDB signal is a control input signal			
1279	Control Input 64	Control input	DDB_CONTROL_64
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:

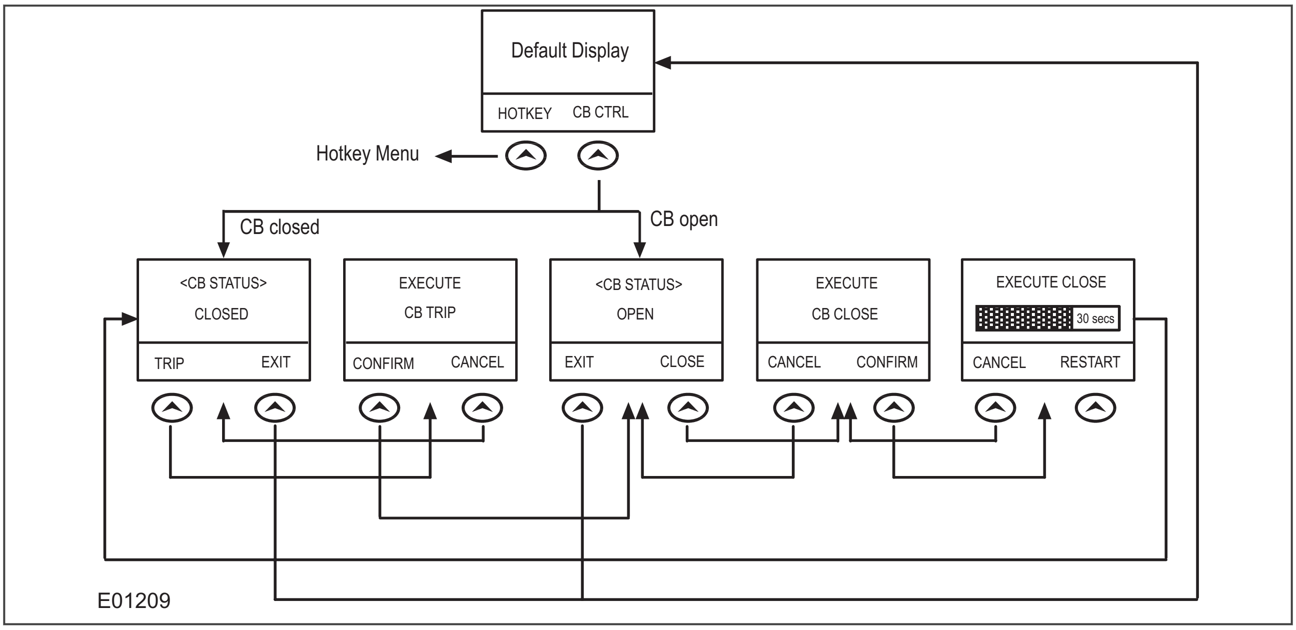


Figure 79: Direct Access menu navigation

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.

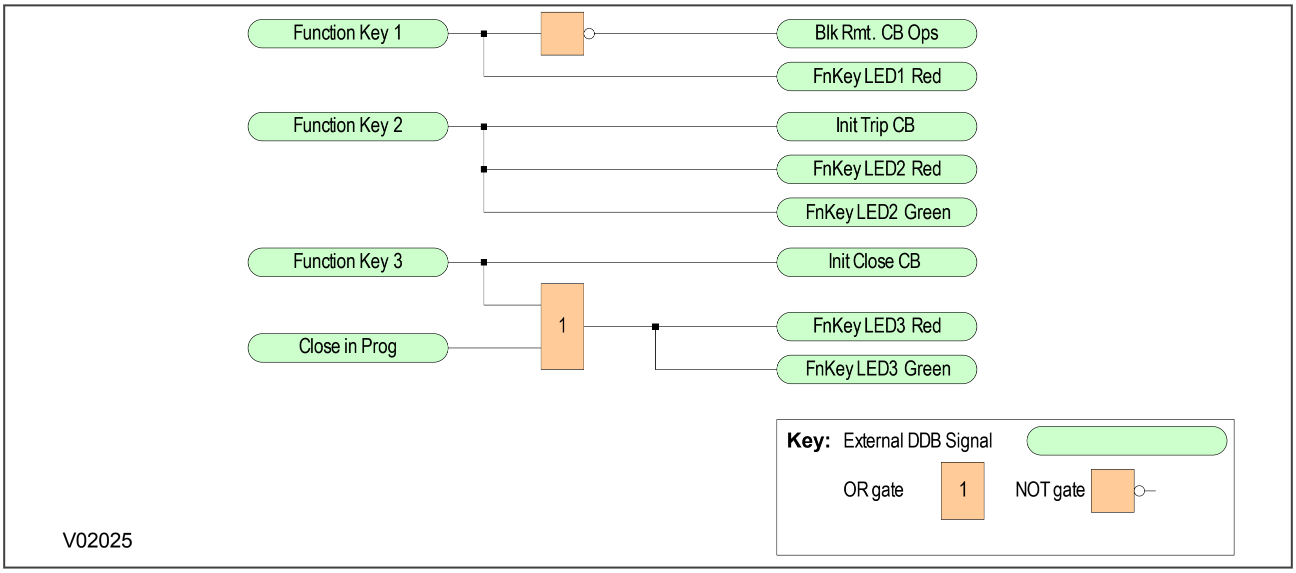


Figure 80: Default function key PSL

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	Signal Name	Use	Unique ID
Description			
232	Init Trip CB	PSL output	DDB_LOGIC_INPUT_TRIP
This DDB signals the circuit breaker to open			
233	Init Close CB	PSL output	DDB_LOGIC_INPUT_CLOSE
This DDB signals the circuit breaker to open			
234	Reset Close Dly	PSL output	DDB_RESET_CB_CLOSE_DELAY
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.

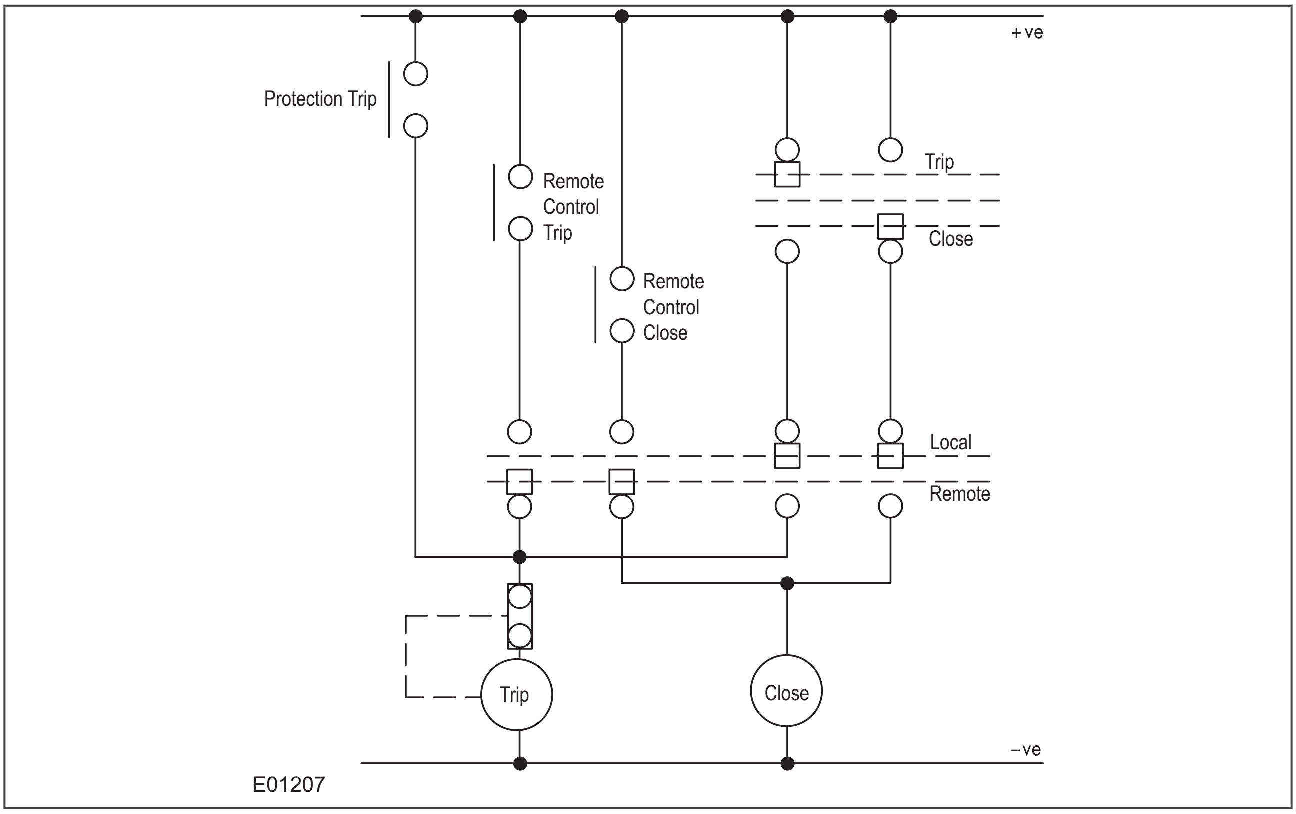


Figure 81: Remote Control of Circuit Breaker

7.6 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.

7.7 CB CONTROL LOGIC

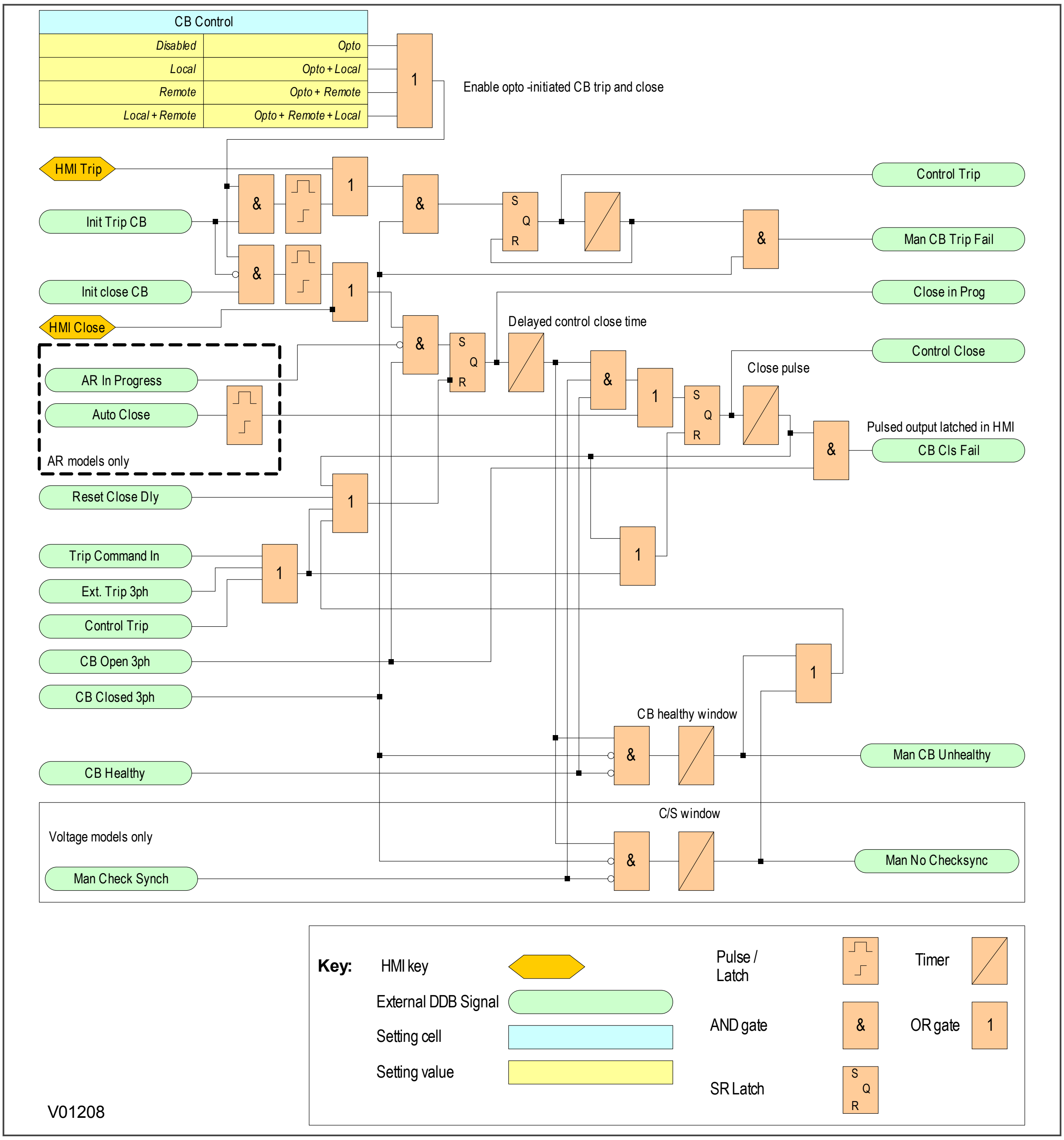


Figure 82: CB Control logic

7.8 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.				
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 dcfines 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
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				

Menu Text	Col	Row	Default Setting	Available Options
Description				
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 5 s
Open	Open	State unknown	Alarm raised if the condition persists for greater than 5 s

8.1 CB STATE MONITORING LOGIC

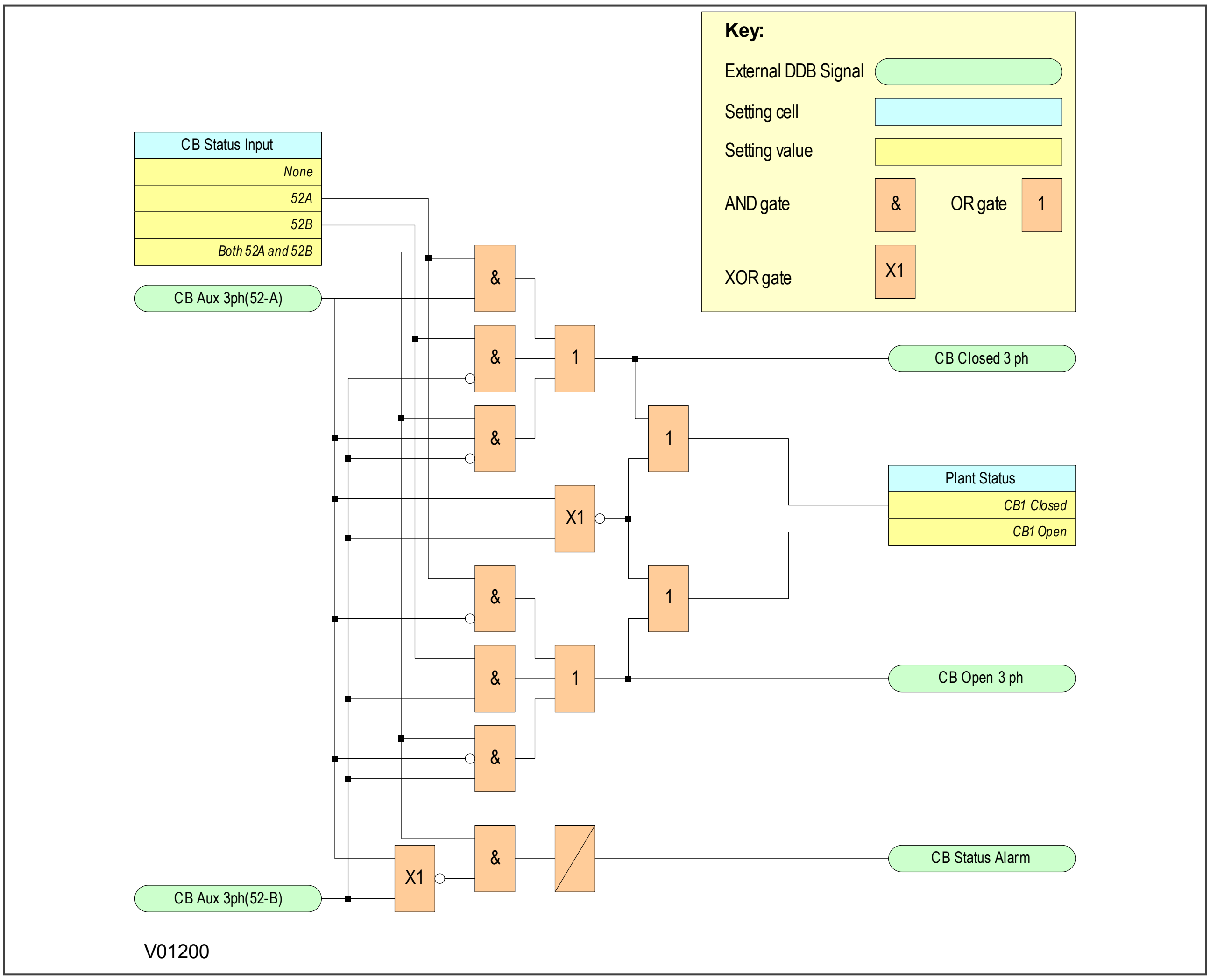


Figure 83: CB State Monitoring logic

9 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.

9.1 POLE DEAD LOGIC

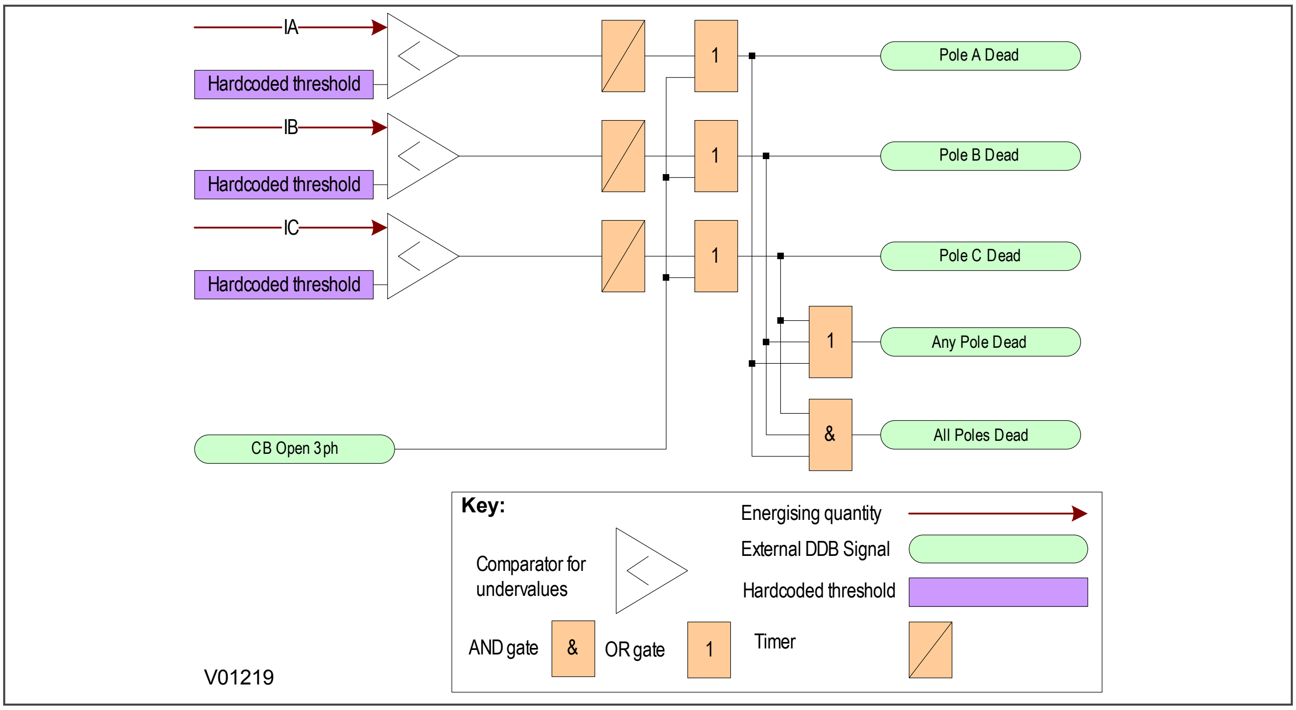


Figure 84: Pole Dead logic

If the line current falls below a certain threshold the device initiates a Pole Dead condition. The undercurrent (I<) threshold is 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.

A ***CB Open 3ph*** signal automatically initiates a Pole Dead condition regardless of the current measurement.

9.2 POLE DEAD DDB SIGNALS

Ordinal	Signal Name	Use	Unique ID
Description			
378	CB Open 3 ph	PSL input	DDB_CB_OPEN
This DDB signal indicates that the CB is open on all 3 phases			
380	All Poles Dead	PSL input	DDB_ALL_POLEDEAD
This DDB signal indicates that all poles are dead			
381	Any Pole Dead	PSL input	DDB_ANY_POLEDEAD
This DDB signal indicates that one or more of the poles is dead.			

Ordinal	Signal Name	Use	Unique ID
Description			
382	Pole Dead A	PSL input	DDB_PHASE_A_POLEDEAD
This DDB signal indicates that the A-phase pole is dead.			
383	Pole Dead B	PSL input	DDB_PHASE_B_POLEDEAD
This DDB signal indicates that the B-phase pole is dead.			
384	Pole Dead C	PSL input	DDB_PHASE_C_POLEDEAD
This DDB signal indicates that the C-phase pole is dead.			

10 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.

10.1 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:

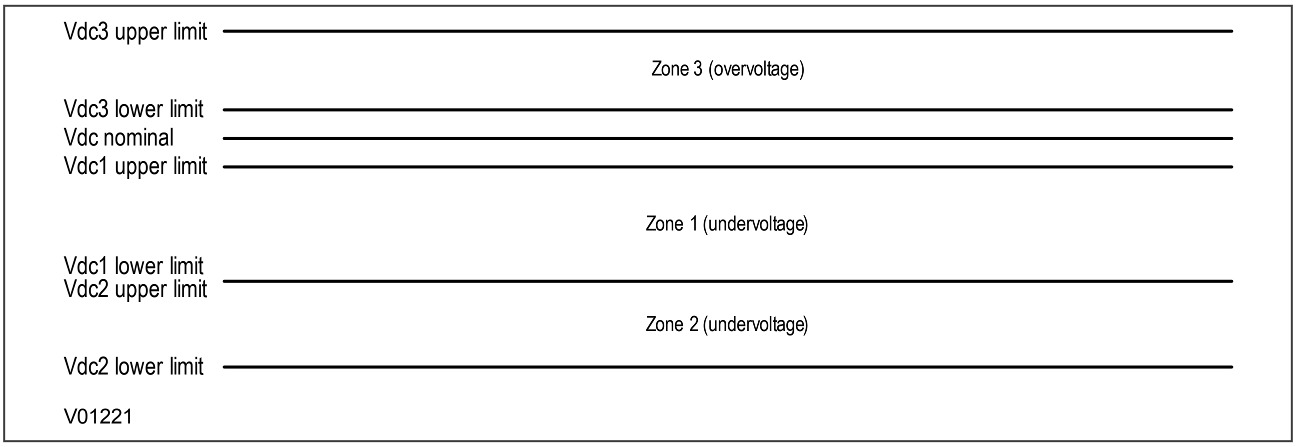


Figure 85: DC Supply Monitor zones

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

10.2 DC SUPPLY MONITOR LOGIC

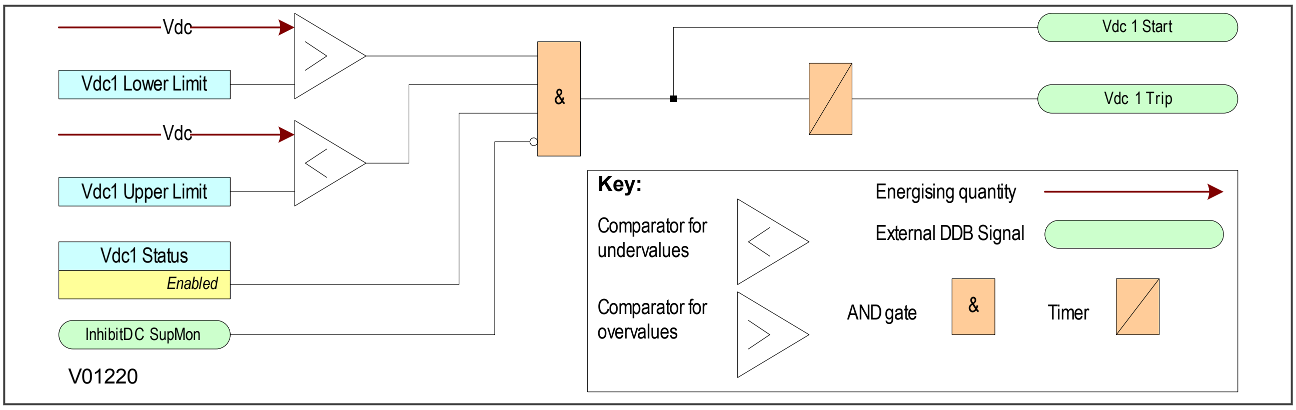


Figure 86: DC Supply Monitor logic

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.

The Vdc(n) Trip signals from all stages are OR'd together to produce an alarm signal ***DC Supply Fail***.

10.3 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.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
Vdc2 Timer	2A	15	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 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.				

10.4 DC SUPPLY MONITOR DDB SIGNALS

Ordinal	Signal Name	Use	Unique ID
Description			
762	Vdc1 Start	PSL input	DDB_ZONE_1_VDC_START
This DDB signal is the DC Supply Monitoring Zone 1 Start signal			
763	Vdc2 Start	PSL input	DDB_ZONE_2_VDC_START
This DDB signal is the DC Supply Monitoring Zone 2 Start signal			
764	Vdc3 Start	PSL input	DDB_ZONE_3_VDC_START
This DDB signal is the DC Supply Monitoring Zone 3 Start signal			
765	Vdc1 Trip	PSL input	DDB_ZONE_1_VDC_TRIP
This DDB signal is the DC Supply Monitoring Zone 1 Trip signal			
766	Vdc2 Trip	PSL input	DDB_ZONE_2_VDC_TRIP
This DDB signal is the DC Supply Monitoring Zone 2 Trip signal			
767	Vdc3 Trip	PSL input	DDB_ZONE_3_VDC_TRIP
This DDB signal is the DC Supply Monitoring Zone 3 Trip signal			
768	InhibitDC SupMon	PSL output	DDB_DC_SUPPLY_MON_INHIBIT
This DDB signal is the DC Supply Monitoring Inhibit Signal			
769	DC Supply Fail	PSL input	DDB_DC_SUPPLY_MON_ALARM
This DDB signal is the DC Supply Monitoring Alarm Signal			

11 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.

11.1 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.

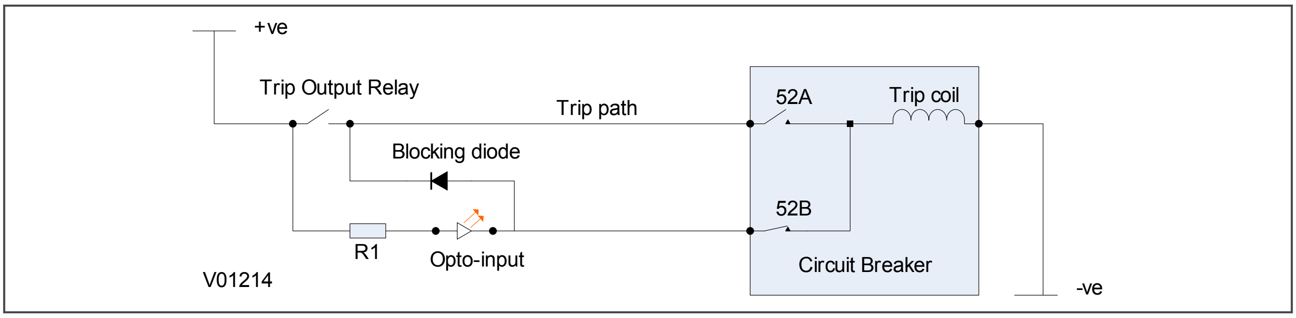


Figure 87: TCS Scheme 1

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.

11.1.1 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
24/27	620 Ohms at 2 Watts

Trip Circuit Voltage	Resistor R1
30/34	820 Ohms at 2 Watts
48/54	1.2 kOhms at 5 Watts
110/125	2.7 kOhms at 10 Watts
220/250	5.2 kOhms at 15 Watts

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*.

11.1.2 PSL FOR TCS SCHEME 1

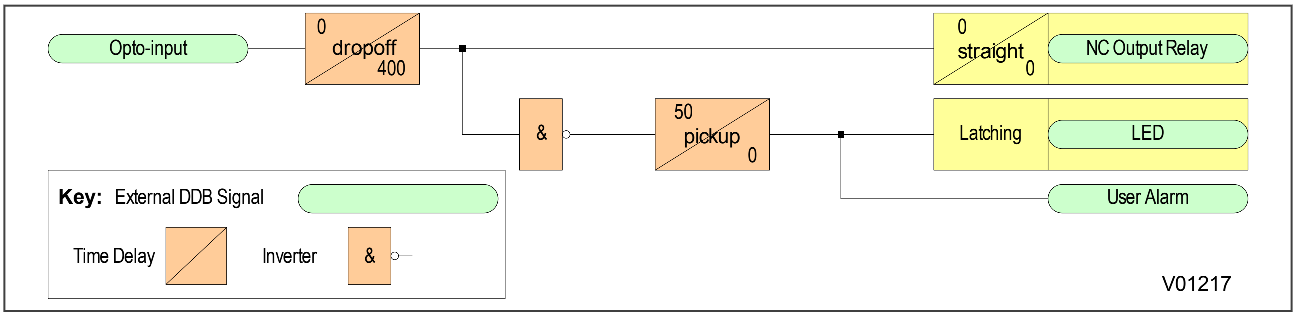


Figure 88: PSL for TCS Scheme 1

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.

11.2 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.

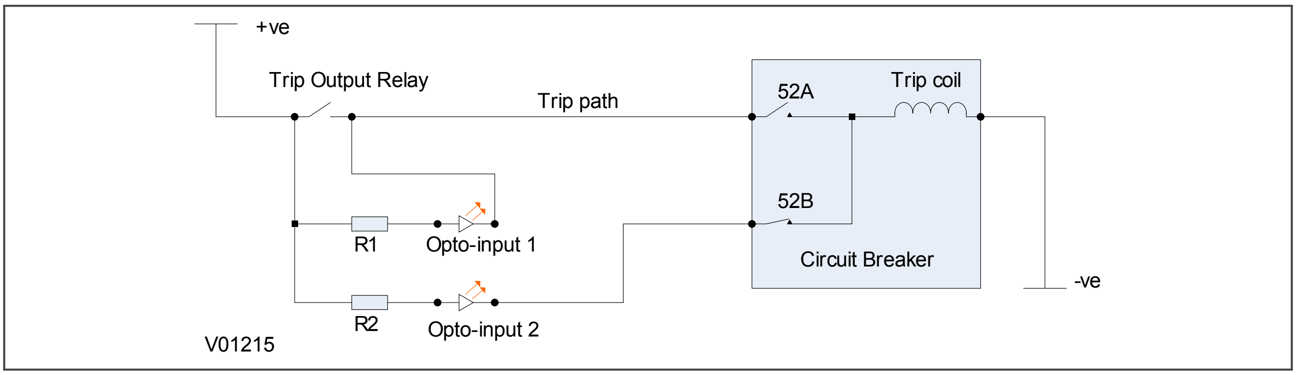


Figure 89: TCS Scheme 2

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.

11.2.1 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
24/27	620 Ohms at 2 Watts
30/34	820 Ohms at 2 Watts
48/54	1.2 kOhms at 5 Watts
110/125	2.7 kOhms at 10 Watts
220/250	5.2 kOhms at 15 Watts

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`.

11.2.2 PSL FOR TCS SCHEME 2

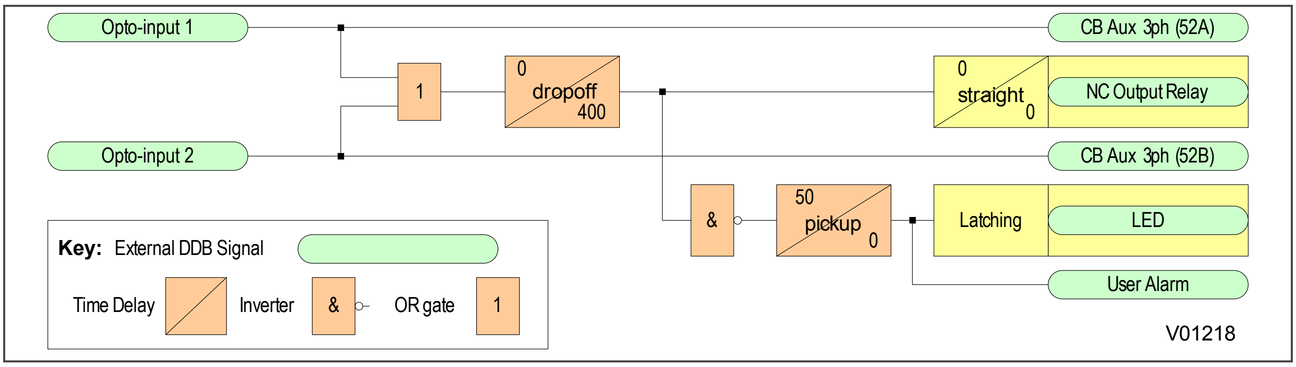


Figure 90: PSL for TCS Scheme 2

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.

11.3 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.

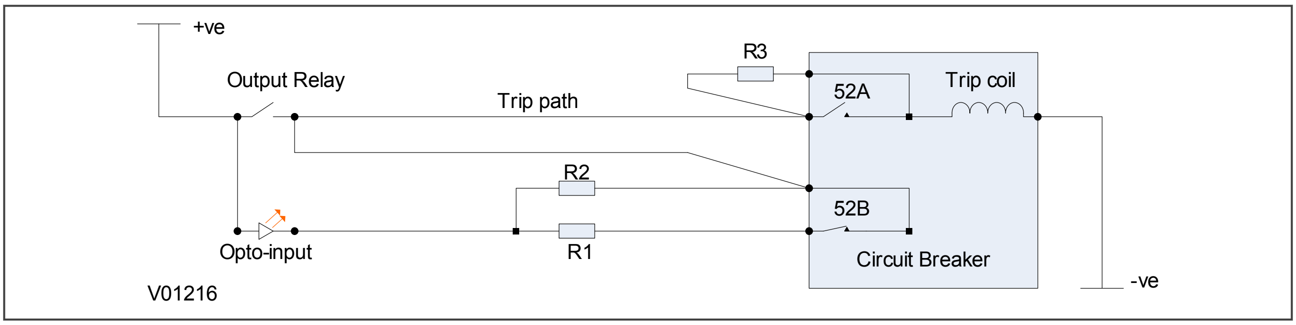


Figure 91: TCS Scheme 3

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.

11.3.1 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	Resistor R3
24/27	620 Ohms at 2 Watts	330 Ohms at 5 Watts
30/34	820 Ohms at 2 Watts	430 Ohms at 5 Watts
48/54	1.2 kOhms at 5 Watts	620 Ohms at 10 Watts
110/125	2.7 kOhms at 10 Watts	1.5 k Ohms at 15 Watts
220/250	5.2 kOhms at 15 Watts	2.7 k Ohms at 25 Watts

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*.

11.3.2 PSL FOR TCS SCHEME 3

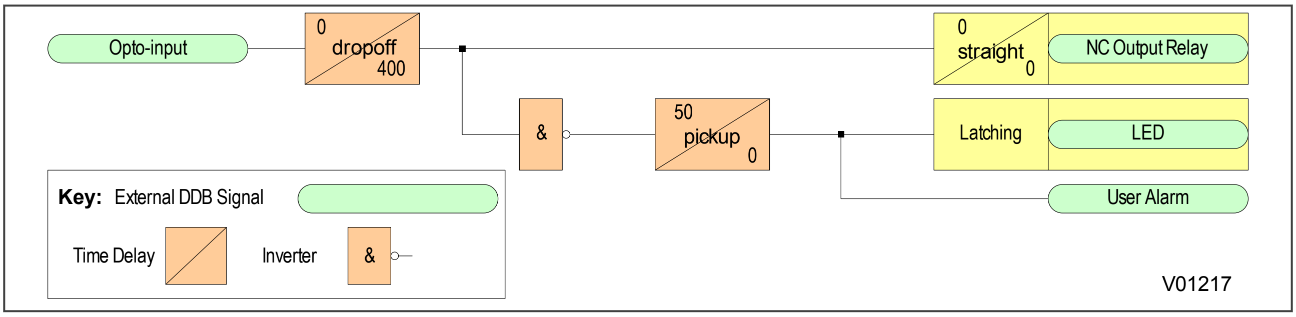


Figure 92: PSL for TCS Scheme 3

11.3.3 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.

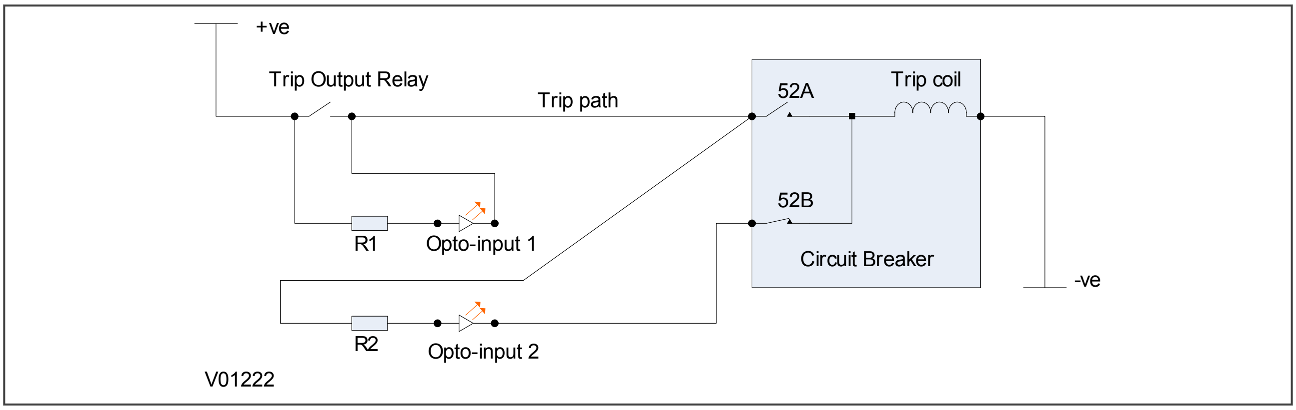


Figure 93: TCS Scheme 4

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.

11.3.3.1 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 Ohms at 2 Watts
30/34	820 Ohms at 2 Watts
48/54	1.2 kOhms at 5 Watts
110/125	2.7 kOhms at 10 Watts
220/250	5.2 kOhms at 15 Watts

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`.

11.3.3.2 PSL FOR TCS SCHEME 4

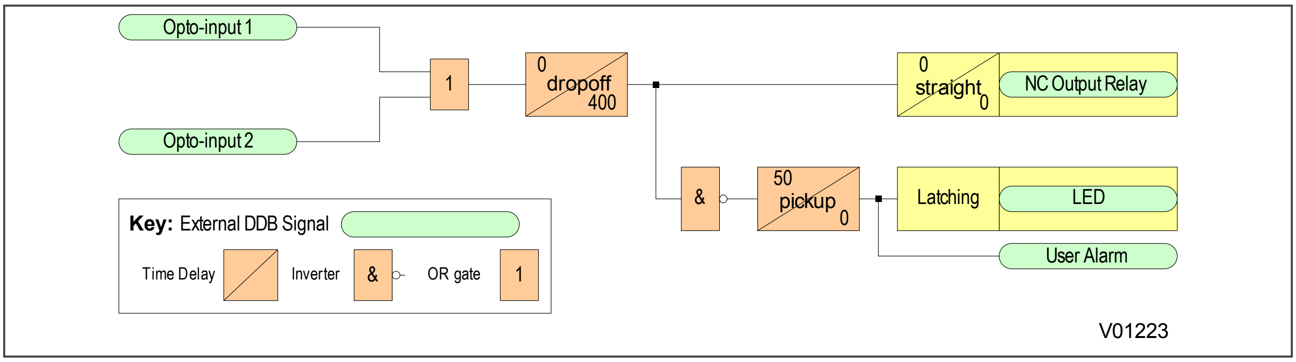


Figure 94: PSL for TCS Scheme 4

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 306) 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.*

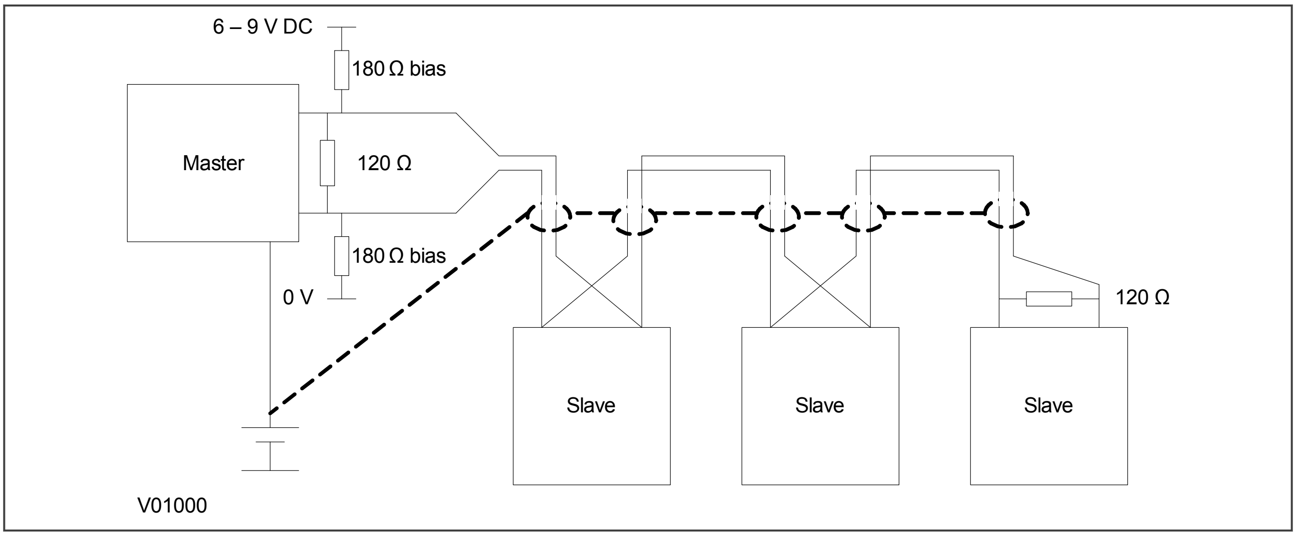


Figure 95: RS485 biasing circuit

> **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.**

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.

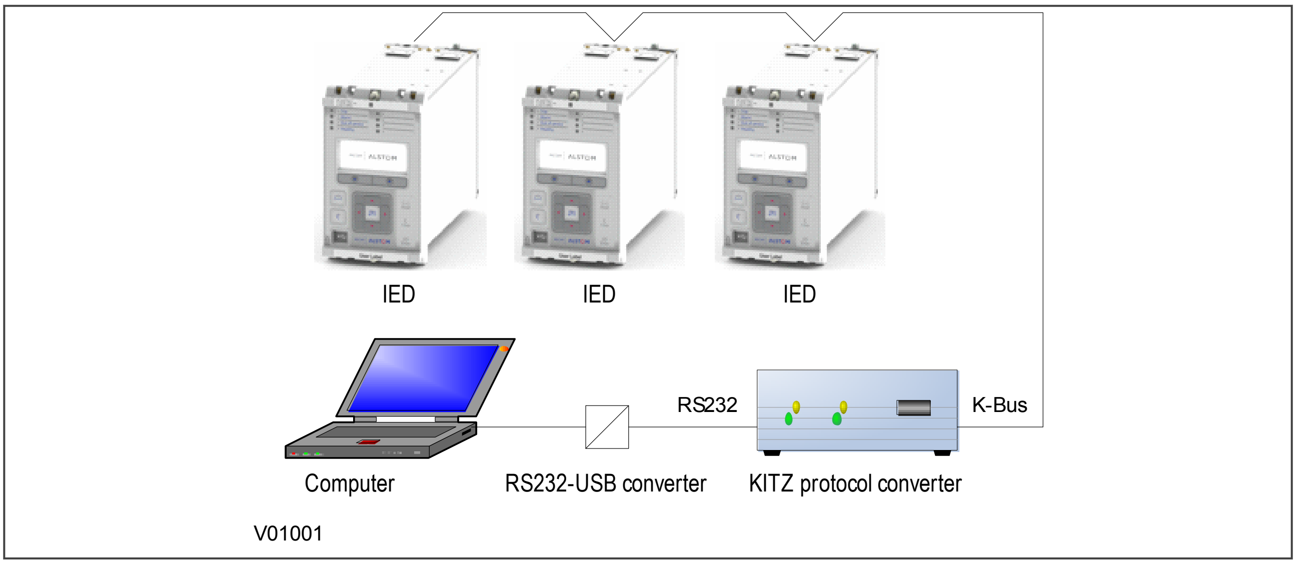


Figure 96: Remote communication using K-Bus

> *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><th>Data Protocols</th><td>IEC 60870-5-103
MODBUS
DNP3.0
Courier</td><td>IEC 61850
DNP3.0
Courier</td><td>Courier</td><td>Courier</td></tr>
<tr><th>Data Link Layer</th><td>EIA(RS)485</td><td>Ethernet</td><td>USB</td><td>K-Bus</td></tr>
<tr><th>Physical Layer</th><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.

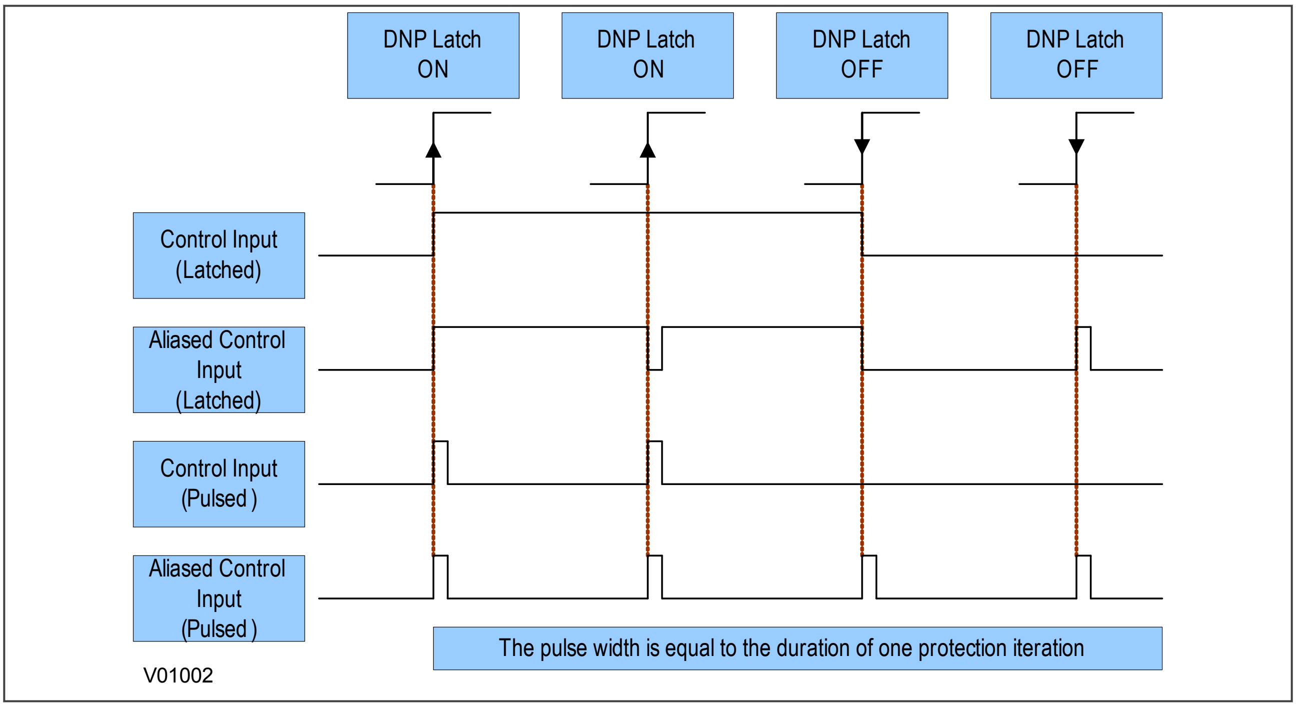


Figure 97: Control input behaviour

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.

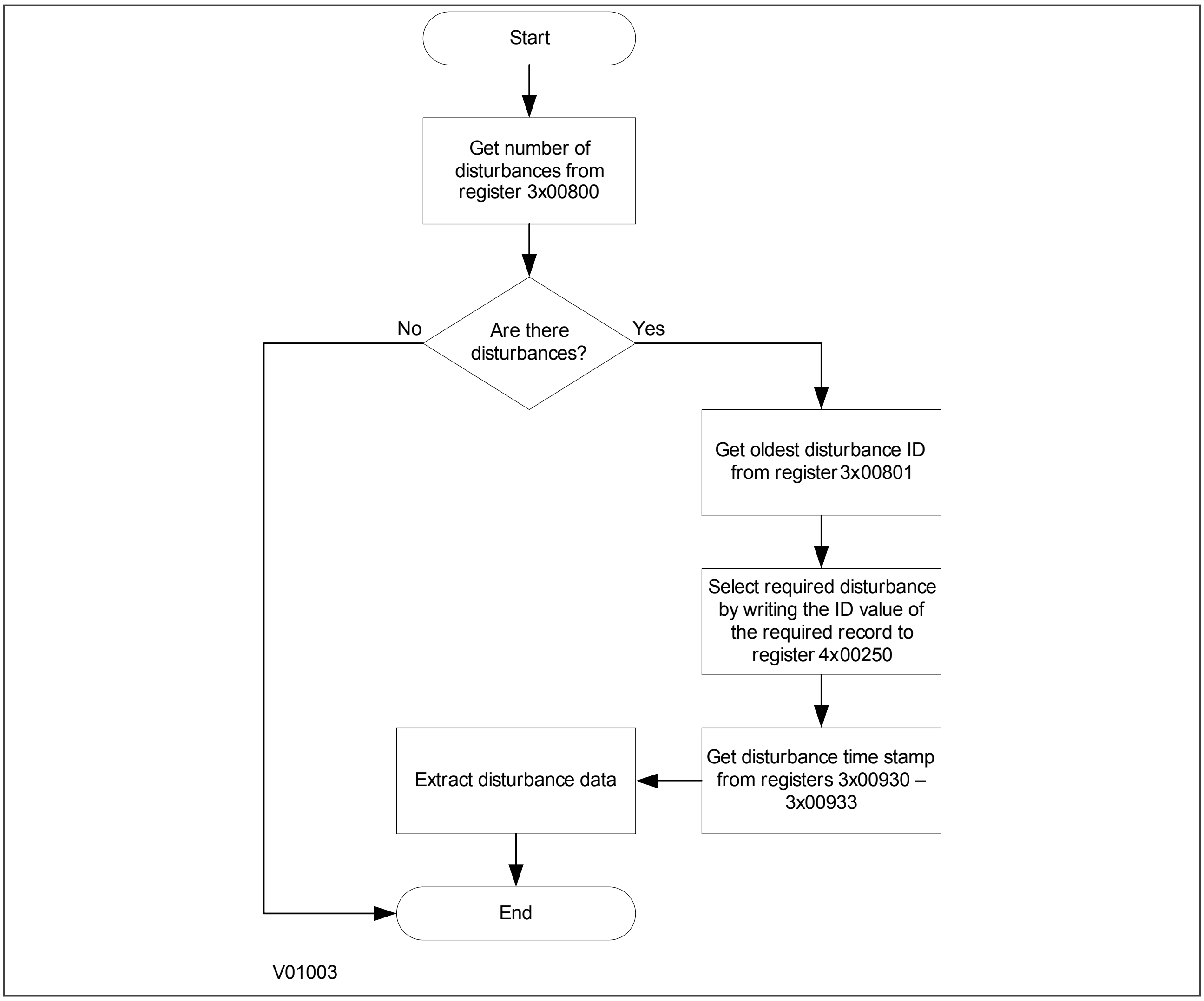


Figure 98: Manual selection of a disturbance record

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).

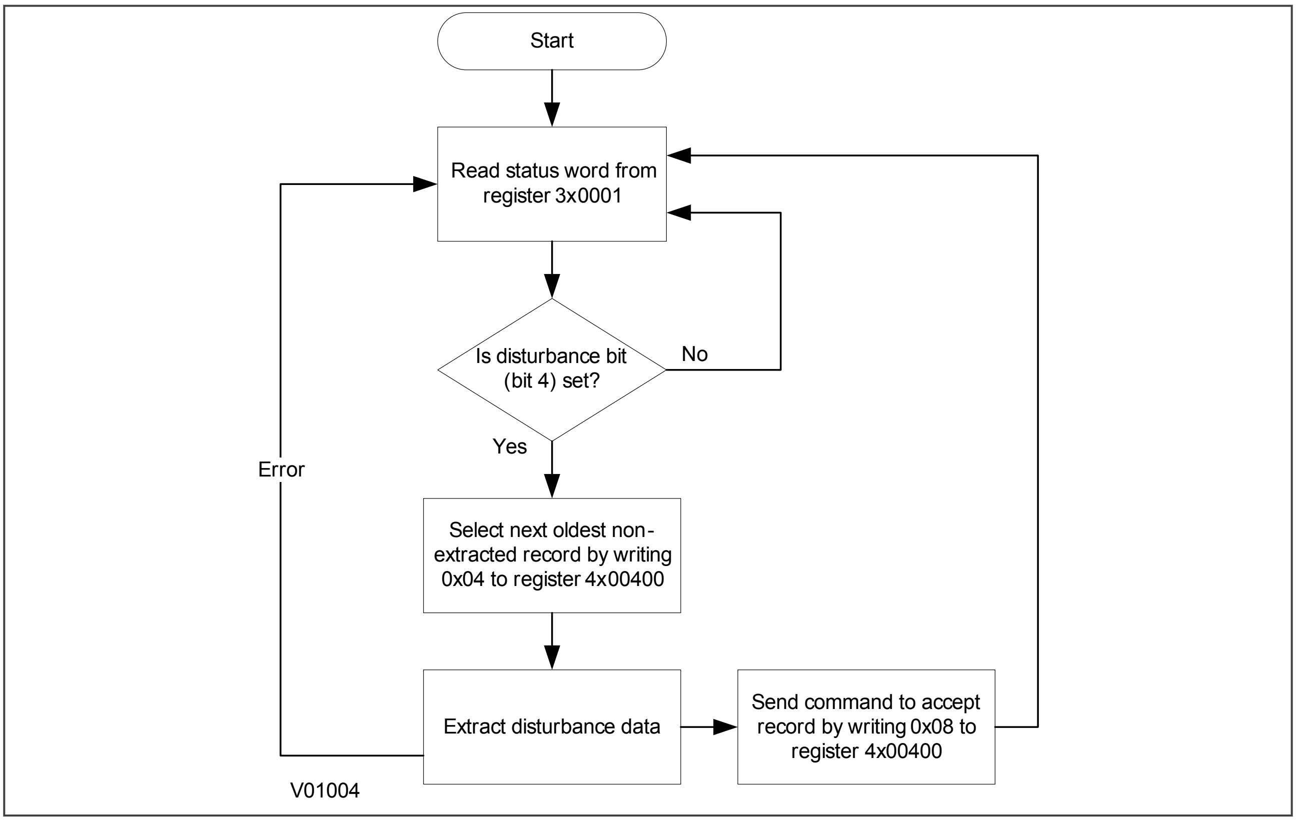


Figure 99: Automatic selection of disturbance record - method 1

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.

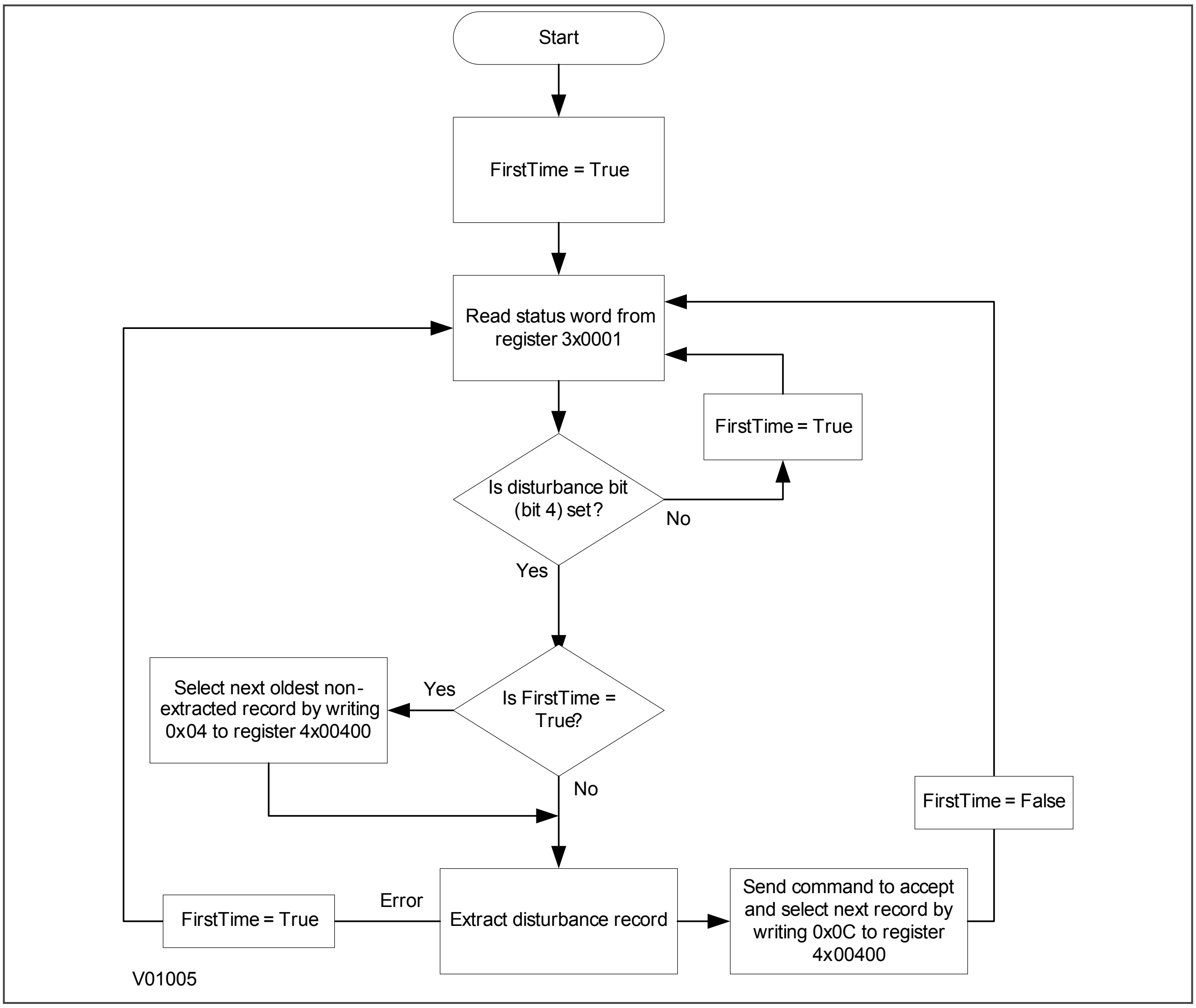


Figure 100: Automatic selection of disturbance record - method 2

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

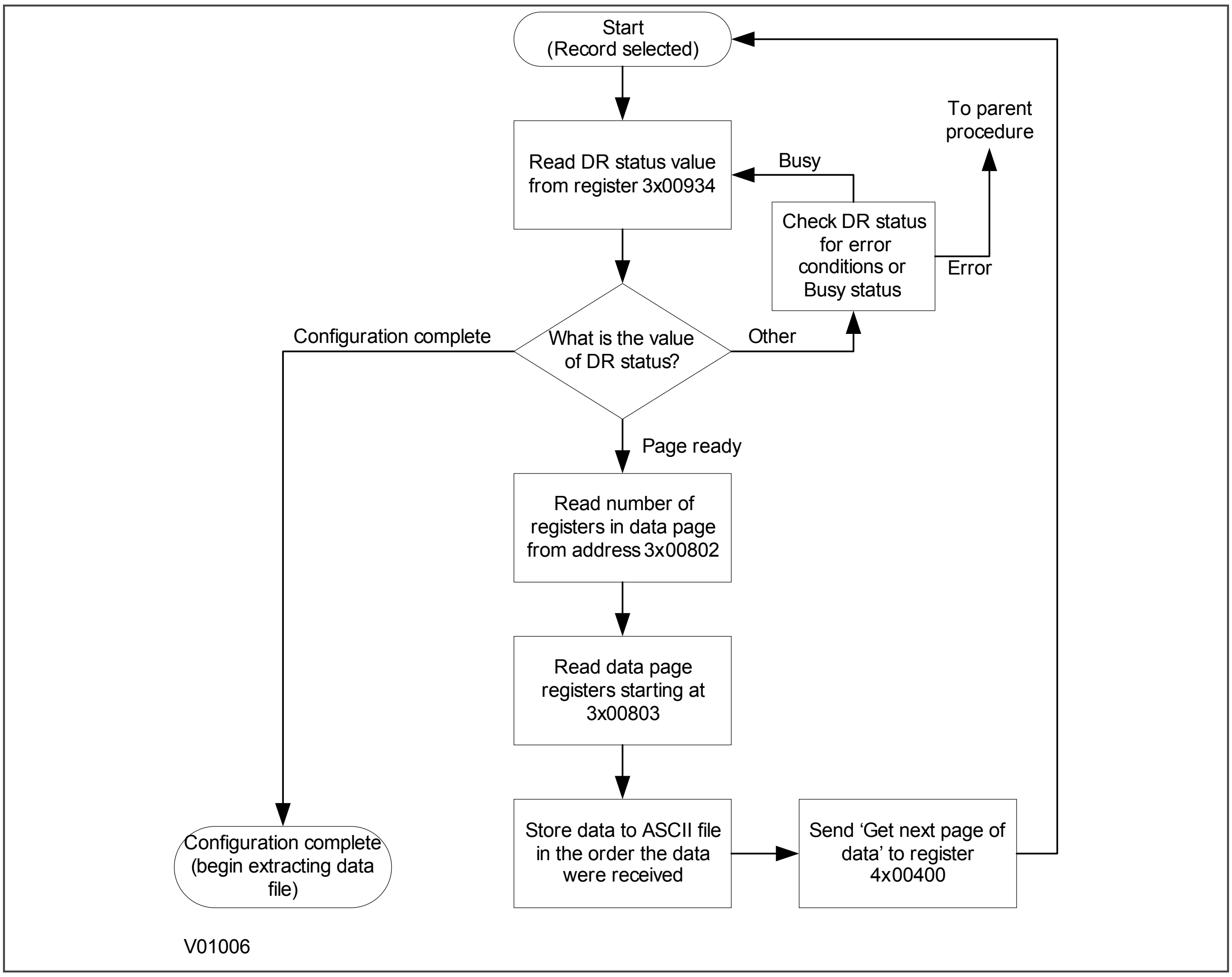


Figure 101: Configuration file extraction

Extracting the comtrade data file

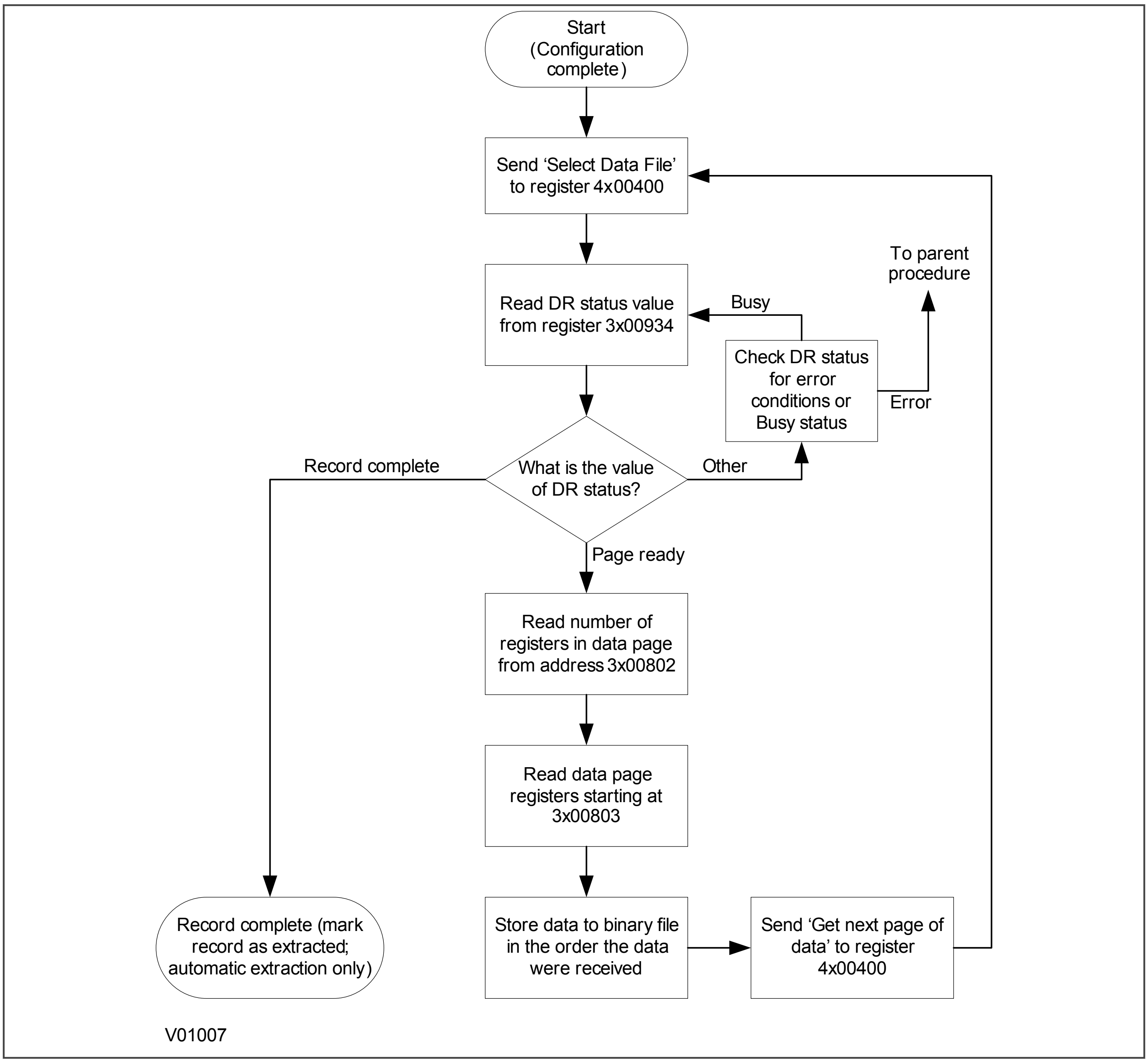


Figure 102: Data file extraction

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 Alstom Grid products. 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 tens 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.

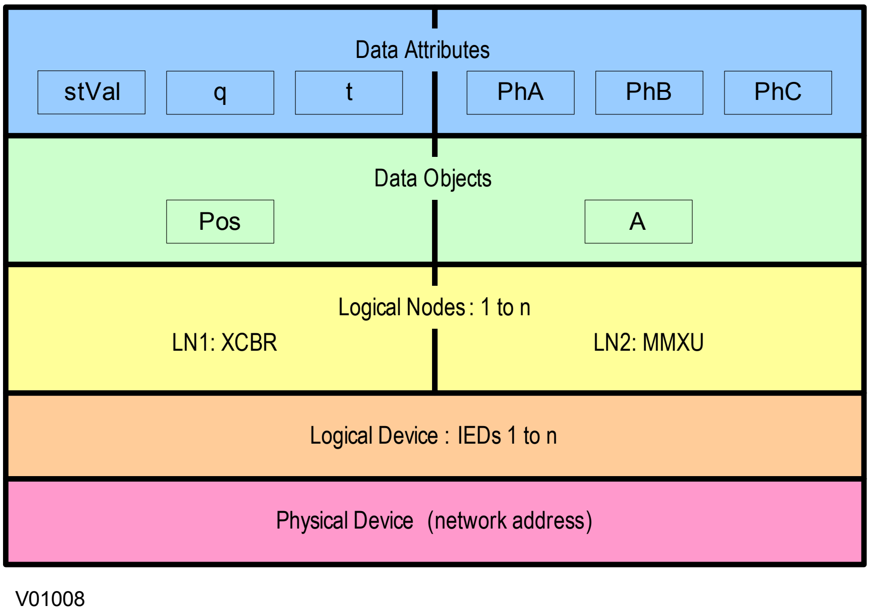


Figure 103: Data model layers in IEC 61850

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 bay 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 IEC 61850 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 IEC 61850 Configurator.

Menu Text	Col	Row	Default Setting	Available Options
Description				
IEC61850 CONFIG.	19	00		
This column contains settings for the IEC61850 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 351) 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 (where Ethernet is available)

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 (where Ethernet is available)

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 IEC 61850 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.

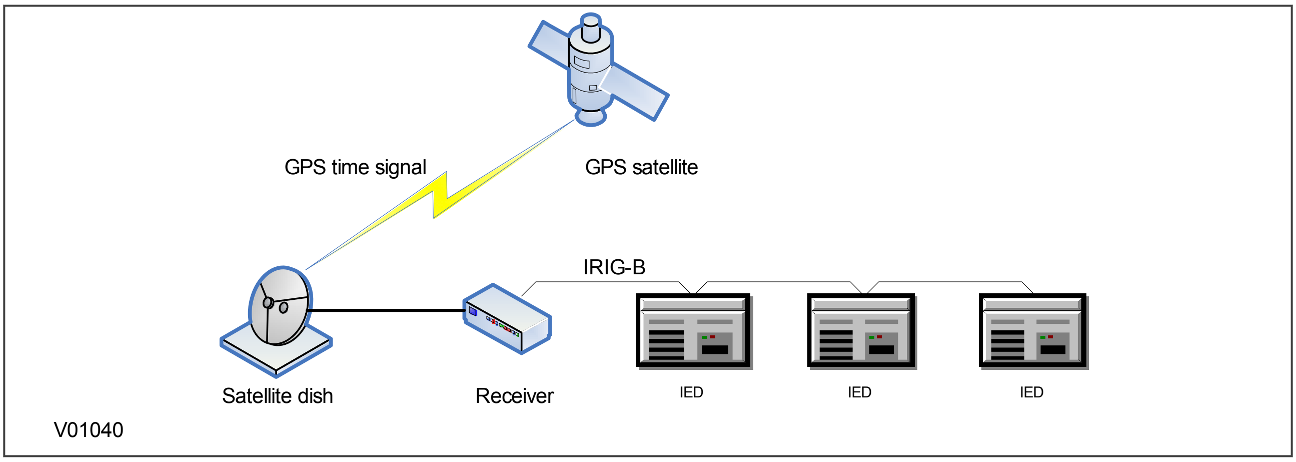


Figure 104: GPS Satellite timing signal

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 IEC 61850 Configurator software 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 IEC 61850 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 313)
- IEC 60870-5-103 Time synchronisation (on page 314)
- DNP 3 Time Synchronisation (on page 319)
- Modbus time Synchronisation (on page 331)

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 (i.e. CB Trip/Close, change setting group etc.). 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 1m to 30m step 1m
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 1m to 30m step 1m
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 bits/s	0 = 9600 bits/s, 1 = 19200 bits/s, 2 = 38400 bits/s
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 1m to 30m step 1m
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 0.1m to 60m step 0.1m
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 receiving confirmation from the master. DNP 3.0 versions only.				
DNP SBO Timeout	0E	B4	10	From 1s to 10s step 1s

<table>
<tr><th>Menu Text</th><th>Col</th><th>Row</th><th>Default Setting</th><th>Available Options</th></tr>
<tr><th colspan="5">Description</th></tr>
<tr><td colspan="5">This setting sets the maximum waiting time between receiving a select command and awaiting an operate confirmation from the master. DNP 3.0 versions only.</td></tr>
</table>

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 often 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 our range of Intelligent Electronic Devices (IEDs).

> *Note:*
> *Cyber-security compatible devices do not enforce NERC compliance, they merely facilitate it. It is the responsibility of the user to ensure that compliance is adhered to as and when necessary.*

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 unauthorised access to information)
- Integrity (preventing unauthorised modification)
- Availability / Authentication (preventing the denial of service and assuring authorised 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 analyse 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 (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 (users turn off security measures)
- Inadequate technology (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 organisations have produced various standards. Compliance with these standards 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 perimeters where Critical Cyber Assets reside. Define and document 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 with 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:

- 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.
- The audit trail is recorded, 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. This is 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

For the device to be NERC-compliant, it must provide the option for a NERC-compliant default display. The default display that is implemented in our cyber-security concept contains a warning that the IED can be accessed by authorised users. You can change this if required with the ***User Banner*** setting in the *SECURITY CONFIG* column.

```
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.

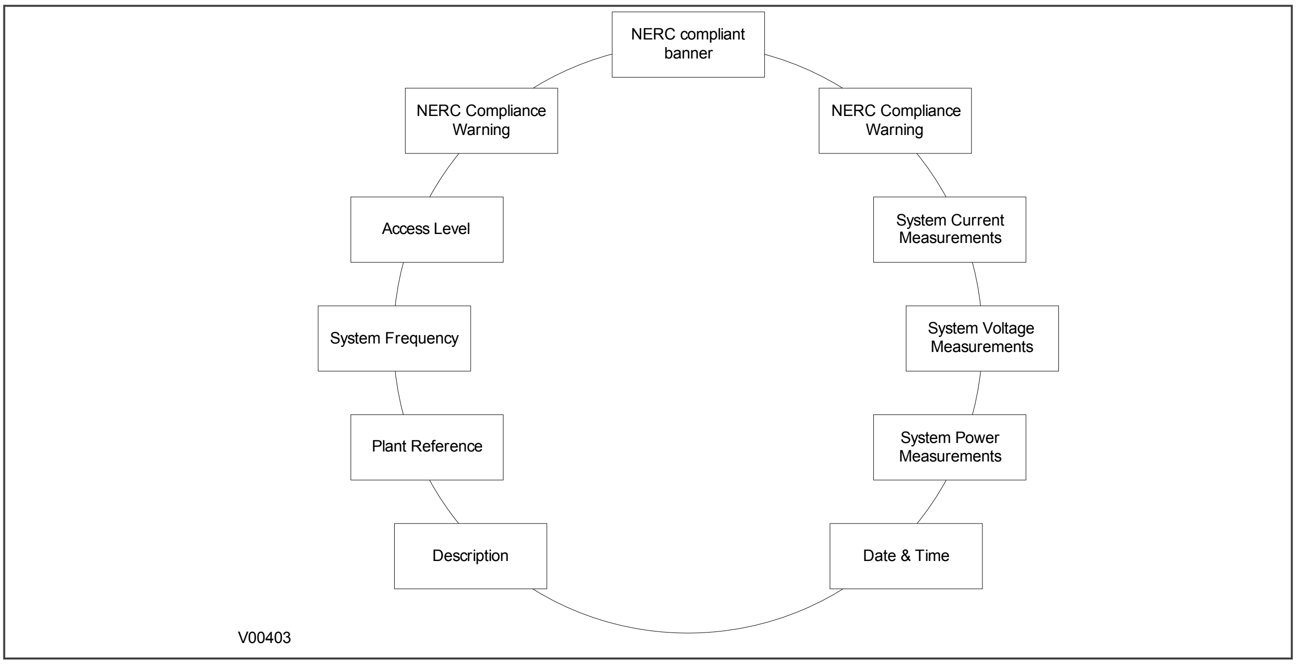


Figure 105: Default display navigation

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 (IEC61850 CONFIG) 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 (IEC61850 CONFIG) 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 is 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 the lower level password is not blank.

Blank passwords affect the 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 are 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***
- ***HMI Access Lvl 3***
- ***FPort AccessLvl1***
- ***FPort AccessLvl2***
- ***FPort AccessLvl3***
- ***RPrt1 AccessLvl1***
- ***RPrt1 AccessLvl2***
- ***RPrt1 AccessLvl3***
- ***RPrt2 AccessLvl1***
- ***RPrt2 AccessLvl2***
- ***RPrt2 AccessLvl3***

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 have the following 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, this is briefly displayed on the LCD.

If the entered password is NERC compliant, the following text is displayed.

```
NERC COMPLIANT
P/WORD WAS SAVED
```

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 is 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 device will store the password, irrespective of whether it is NERC-compliant or not. It then uses appropriate response codes to inform the client of the NERC-compliancy status. You can then choose to enter a new NERC-compliant password or accept the non-NERC compliant password just entered.

4.3.3 PASSWORD BLOCKING

You are locked out temporarily, after a defined number of failed password entry attempts. 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 started. Attempts to access the interface while the 'blocking timer' is running results in an error message, irrespective of whether the correct password is entered or not. Once the 'blocking timer' has expired, access to the interface is unblocked and the attempts counter is reset to zero.

If you try to enter the password while the interface is blocked, the following message is displayed for 2 seconds.

```
NOT ACCEPTED
ENTRY IS BLOCKED
```

A similar response occurs if you try to enter the password through a communications port.

The parameters can then be configured using the ***Attempts Count***, ***Attempts Timer*** and ***Blocking Timer*** settings in the *SYSTEM CONFIG* column.

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

If you mislay a device's password, they can be recovered. To obtain the recovery password you must contact the Contact Centre and supply the Serial Number and its Security Code. The Contact Centre will use these items to generate a Recovery Password.

The security code is a 16-character string of upper case characters. It is a read-only parameter. The device 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, 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 is displayed on confirmation. The validity timer is then 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. Each password should be appropriate for its intended function, 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
```

The following ports can be disabled, depending on the model.

- Front port (***Front Port*** setting)
- Rear port 1 (***Rear Port 1*** setting)
- Rear port 2 (***Rear Port 2*** setting)
- Ethernet port (***Ethernet*** setting)

> *Note:*
> *It is not possible to disable a port from which the disabling port command originates.*

> *Note:*
> *We do not generally advise disabling the physical Ethernet port.*

4.6 DISABLING LOGICAL PORTS

It is possible to disable unused logical ports. A level 3 password is needed to perform this action.

> *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.*

The following protocols can be disabled:

- IEC 61850 (***IEC61850*** setting)
- DNP3 Over Ethernet (***DNP3 OE*** setting)
- Courier Tunnelling (***Courier Tunnel*** setting)

> *Note:*
> *If any of these protocols are enabled or disabled, the Ethernet card will reboot.*

4.7 SECURITY EVENTS MANAGEMENT

To implement NERC-compliant cyber-security, a range of Event records need to be generated. These 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 new event has an incremented unique number, therefore missing events appear as ‘gap’ in the sequence. 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 #
```

Where x is the current fallback level.

If you decide not to log out, the following message is displayed for 2 seconds.

```
LOGOUT CANCELLED
Access Level #
```

where # is the current access level.

5 CYBER-SECURITY SETTINGS

General security settings, which are necessary for cyber-security implementation can be found in the SYSTEM DATA column as follows:

Menu Text	Col	Row	Default Setting	Available Options
Description				
SYSTEM DATA	00	00		
This column contains general system settings and records.				
Password	00	02		ASCII text (characters 33 to 122 inclusive)
This setting sets the device default password				
Access Level	00	D0	2 = Read + Execute + Edit	0 = Read only or 1 = Read + Execute, or 2 = Read + Execute + Edit
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 2	00	D3	BBBB	ASCII text (characters 33 to 122 inclusive)
This setting allows you to change password level 2.				
Password Level 3	00	D4	AAAA	ASCII text (characters 33 to 122 inclusive)
This setting allows you to change password level 3.				
Security Features	00	DF	1	{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		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		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		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.				

Cyber-security specific settings can be found in the SECURITY CONFIGURATION column as follows:

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	2	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.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
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	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				
IEC61850	25	0A	Enabled	0 = Disabled or 1 = Enabled
This setting enables or disables the logical IEC61850 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	2	Not Settable
This cell displays the number of password attempts remaining				
Blk Time Remain	25	12	0	Not Settable
This cell displays the remaining blocking time.				
Fallbck PW Level	25	20	1	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. UI only cell.				

SETTINGS APPLICATION SOFTWARE

CHAPTER 12

1 INTRODUCTION TO THE SETTINGS APPLICATION SOFTWARE

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 summary of each software tool. Further information is available in the Help system and in the Settings Application Software Guide P40-M&CR-UG-EN-n, where n is the latest version of the settings application software.

The 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.

1.1 GETTING STARTED

S1 Agile allows you to create a model of a protection system which simulates a real-world protection system. You can add substations, bays, voltage levels and devices to the system. First you need to download the data models for the devices in the system. Then you can either create a new system or open an existing system. You can connect to an IED either directly through the front port or to an IED in the system model. You can then send or extract settings. You can also extract PSL, DNP3, Events or Disturbance Record files.

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** then **Preferences** then check the checkbox **Reopen last System at start-up**.

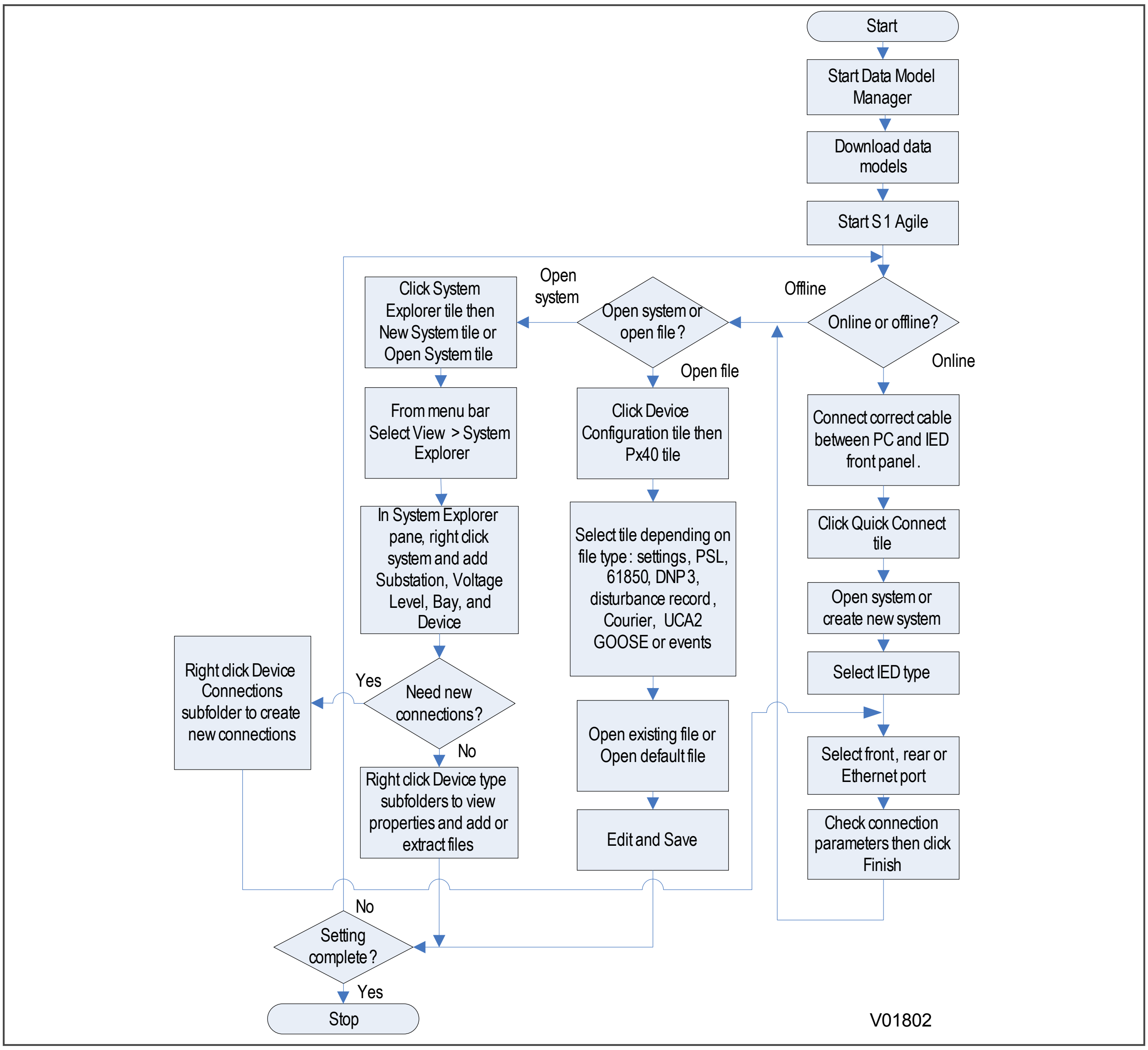


Figure 106: Flowchart showing how S1 Agile can be used to set up and save a protection system offline or online.

1.1.1 QUICK SYSTEM GUIDE

S1 Agile allows you to create a model of a protection system which simulates a real-world protection system. You can add substations, bays, voltage levels and devices to the system. First you need to download the data models for the devices in the system. Then you can either create a new system or open an existing system.

You can connect to an IED either directly through the front port or to an IED in the system model. You can then send or extract settings. You can also extract a PSL, DNP3, Events or Disturbance Record file.

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** then **Preferences** then check the checkbox **Reopen last System at start-up**.

1.1.2 DOWNLOAD DATA MODELS

1. Close S1 Agile and run the Data Model Manager.
2. Follow the on-screen instructions.

1.1.3 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** then **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.

1.1.4 CONNECT 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**.

1.1.5 CONNECT 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**.

1.1.6 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.

1.1.7 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**.

1.1.8 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.*

1.1.9 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**.

1.1.10 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**.

1.1.11 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**.

1.2 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 combining the IED's digital inputs with internally generated digital signals using logic gates and timers, then 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.

1.3 IEC 61850 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 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.

1.4 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.

1.5 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 IED. You can use this tool to create programmable operate and reset curves. You can also create and visualize curves either by entering formulae or data points.

1.6 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 the date and time on a device
- set the active group on a device
- change the address of a device
- save settings, DNP 3.0 configuration, events and disturbance files to disk

1.7 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.

1.8 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.

1.9 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.

- File management
- Query management
- Log management
- Report generation
- Sequence of Events(SOE)
- Conversion of COMTRADE files
- Waveform summary

1.10 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 from the PC to the IED, 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.

1.11 EVENT VIEWER

IEDs record all events in an event log. This allows you to establish the sequence of events that led up to a particular situation. For example, a change in a digital input signal or protection element output signal would cause an event record to be created and stored in the event log. This could be used to analyse how a particular power system condition was caused.

When available space is exhausted, the oldest event is overwritten by the new one. The IED's internal clock provides a time tag for each event.

The event records can be displayed on an IED's front panel but it is easier to view them through the settings application software. This can extract the events log from the device and store it as a single .evt file for analysis on a PC.

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.

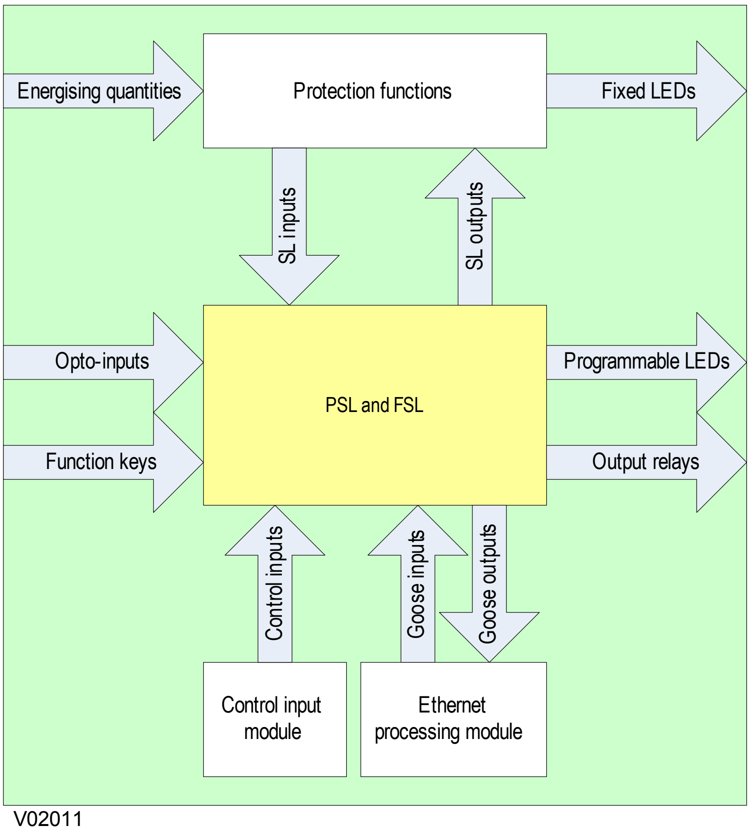


Figure 107: Scheme Logic Interfaces

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 IEC 61850 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 IEC 61850 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

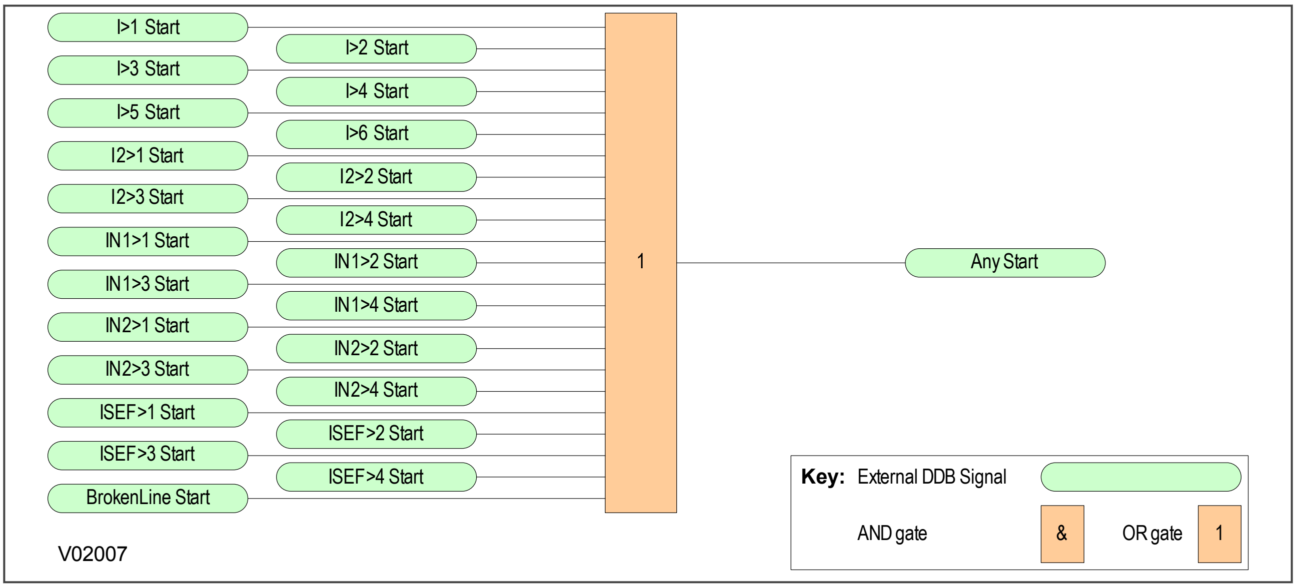


Figure 108: Any Start Logic

3.2 CB FAIL SEF PROTECTION LOGIC

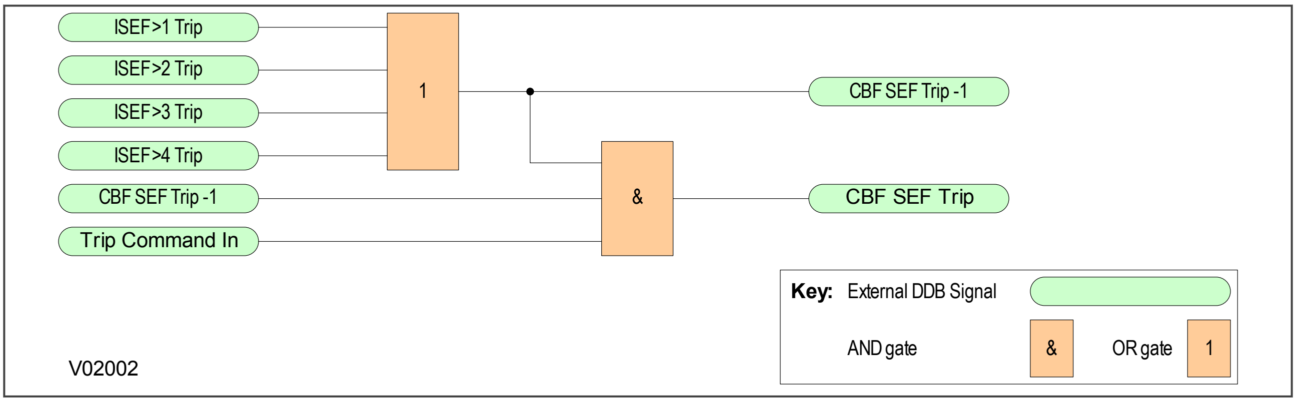


Figure 109: CB Fail SEF Protection Logic

3.3 COMPOSITE EARTH FAULT START LOGIC

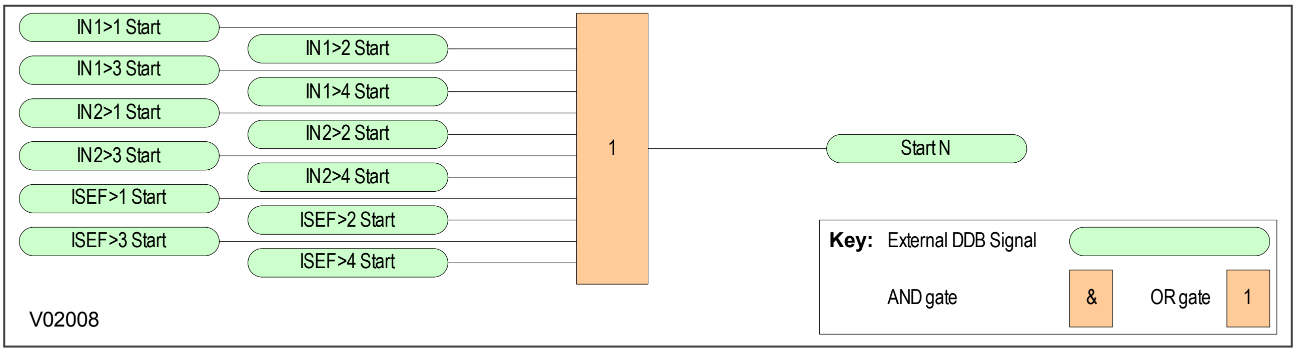


Figure 110: Composite Earth Fault Start Logic

3.4 ANY TRIP LOGIC

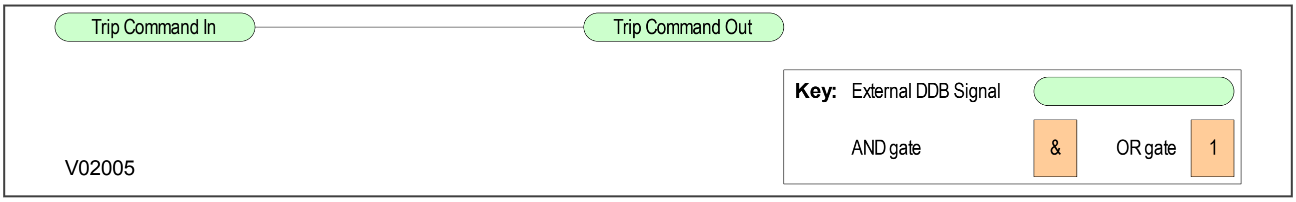


Figure 111: Any Trip Logic

3.5 SEF ANY START LOGIC

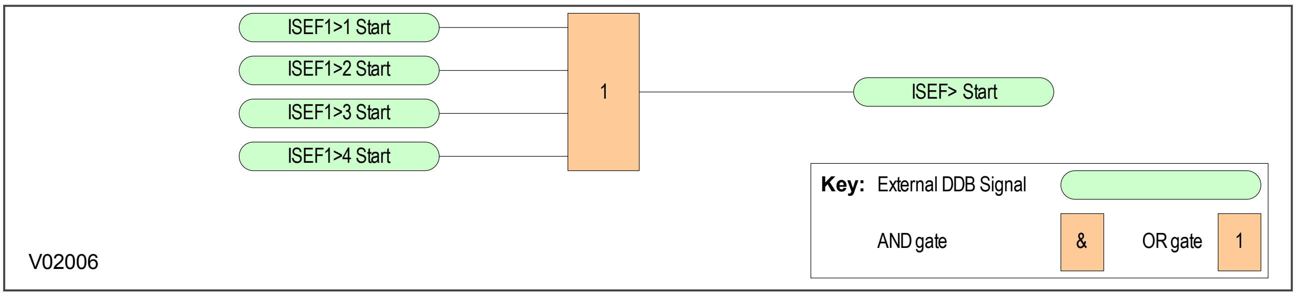


Figure 112: SEF Any Start Logic

4 PROGRAMMABLE SCHEME LOGIC

This section contains tables and 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

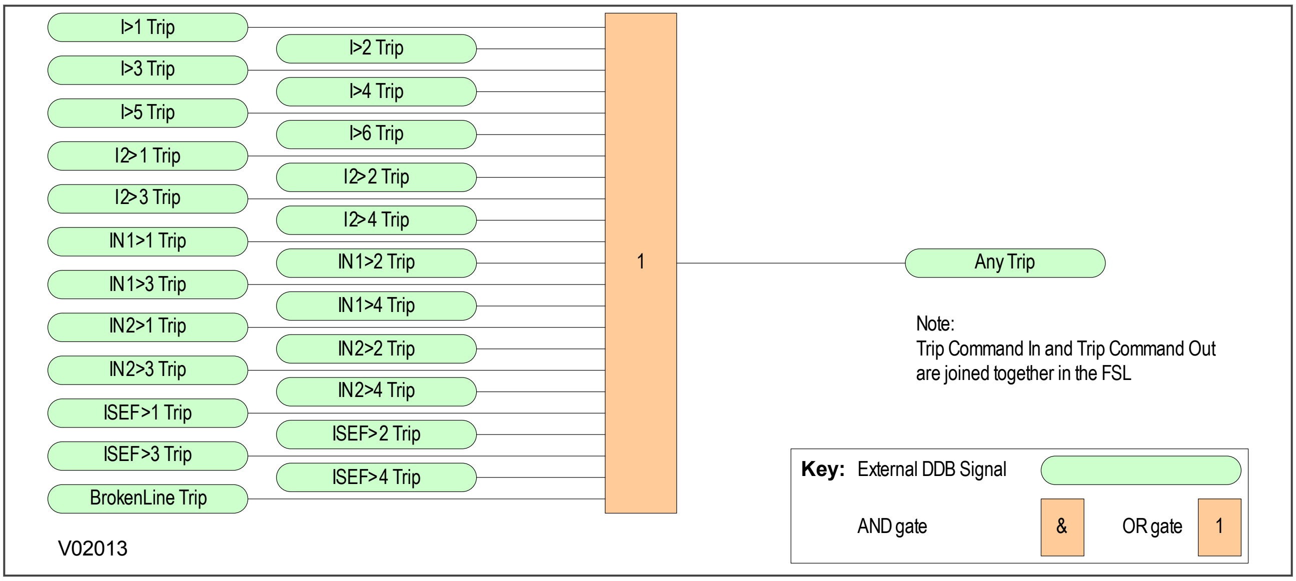


Figure 113: Trip Output Mappings

4.2 OPTO-INPUT MAPPINGS

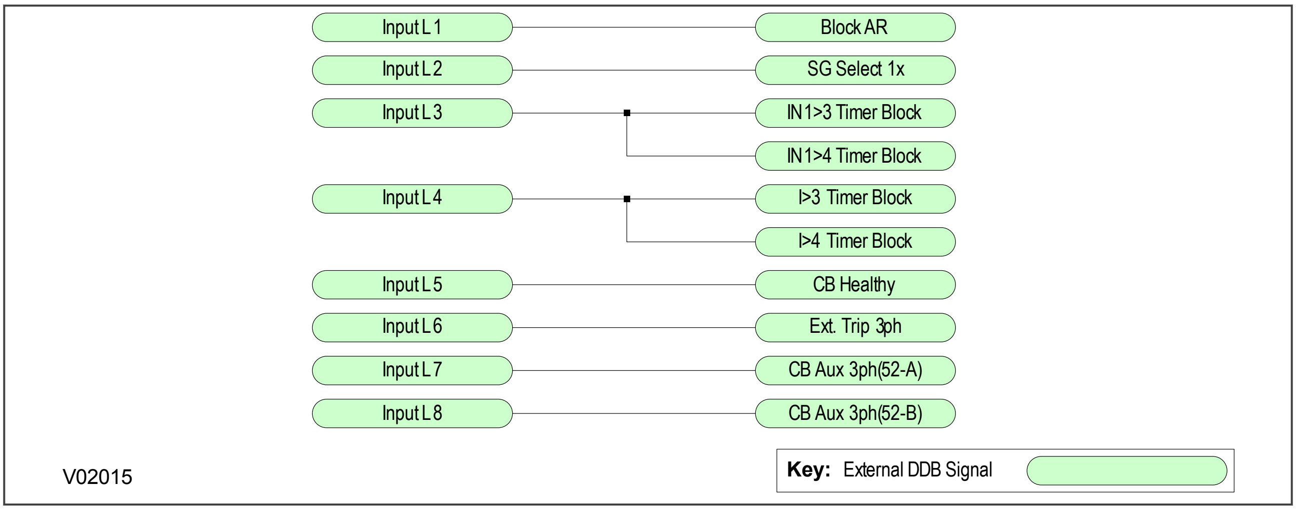


Figure 114: Opto-Input Mappings

4.3 OUTPUT RELAY MAPPINGS

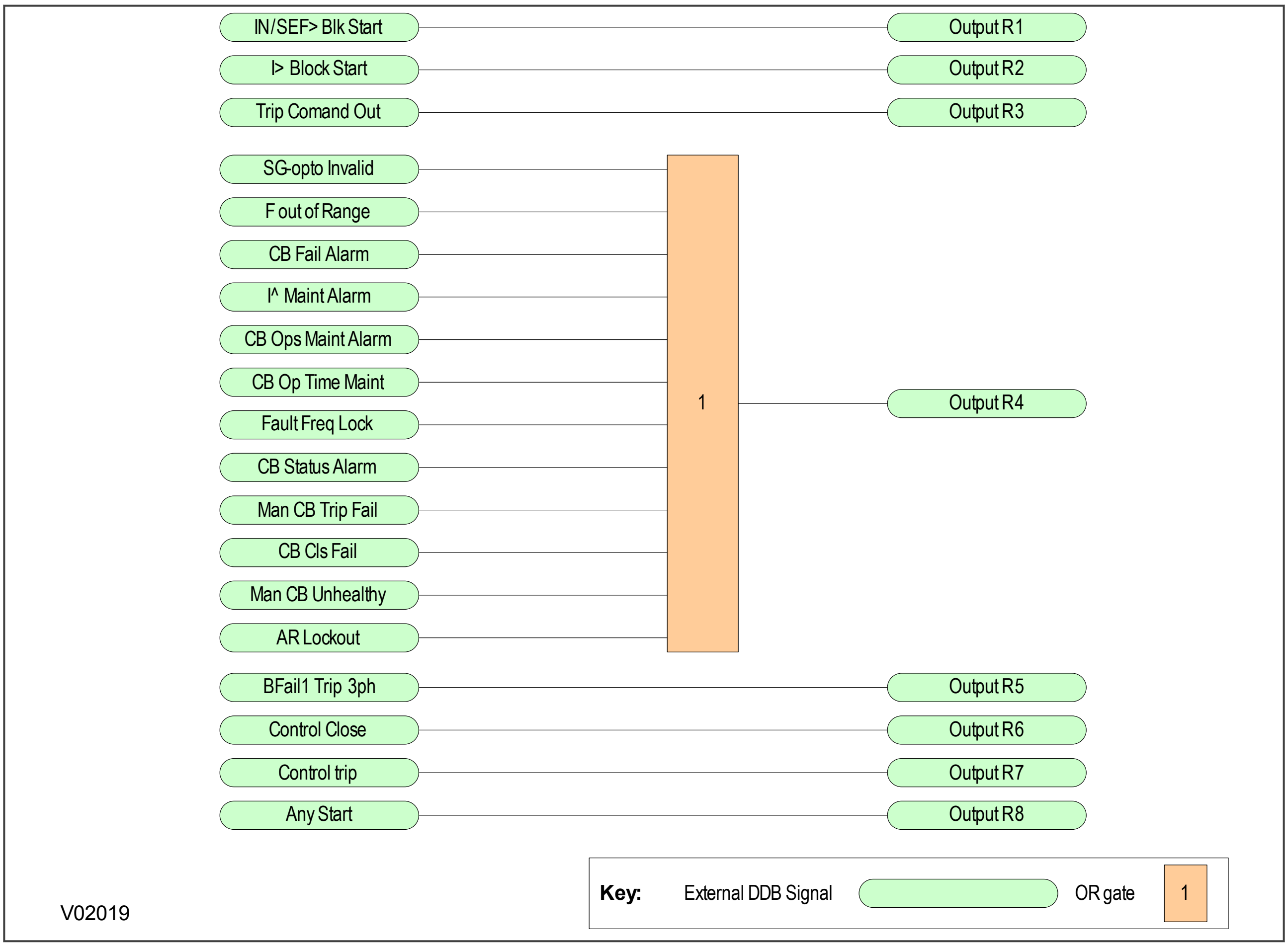


Figure 115: Output Relay Mappings

4.4 LED MAPPINGS

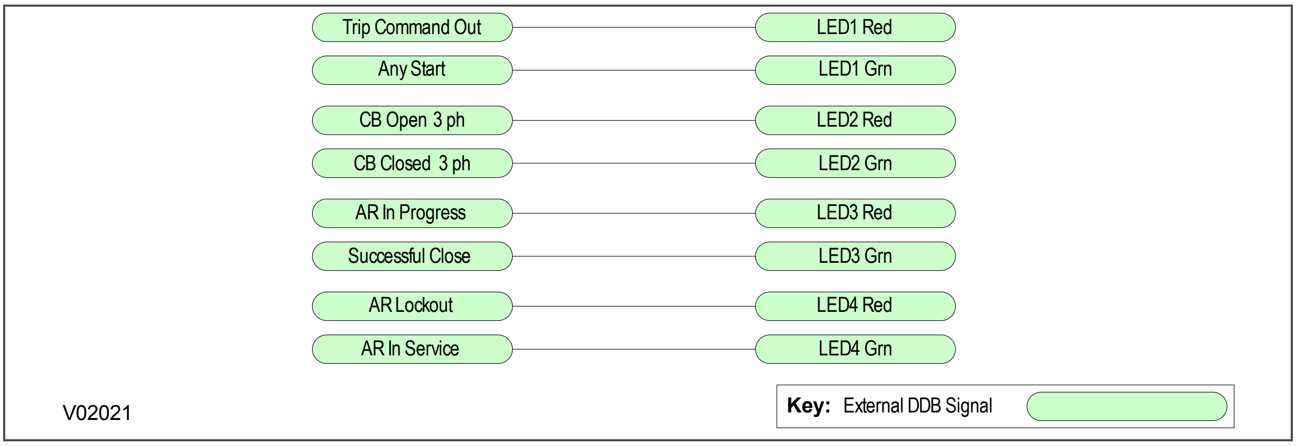


Figure 116: LED Mappings

4.5 CONTROL INPUT MAPPINGS

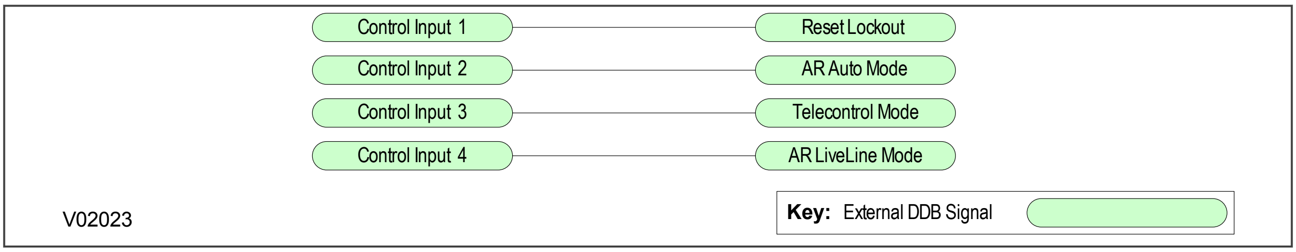


Figure 117: Control Input Mappings

4.6 CIRCUIT BREAKER MAPPING

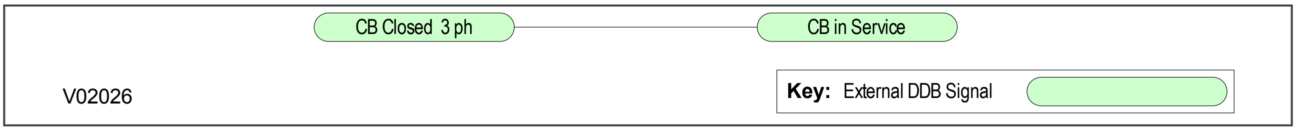


Figure 118: Circuit Breaker mapping

4.7 FAULT RECORD TRIGGER MAPPING

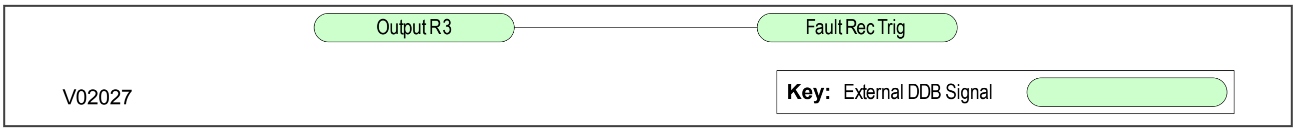


Figure 119: Fault Record Trigger mapping

4.8 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 for unlimited periods or between -40°C to + 85°C for up to 96 hours (see technical specifications).

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

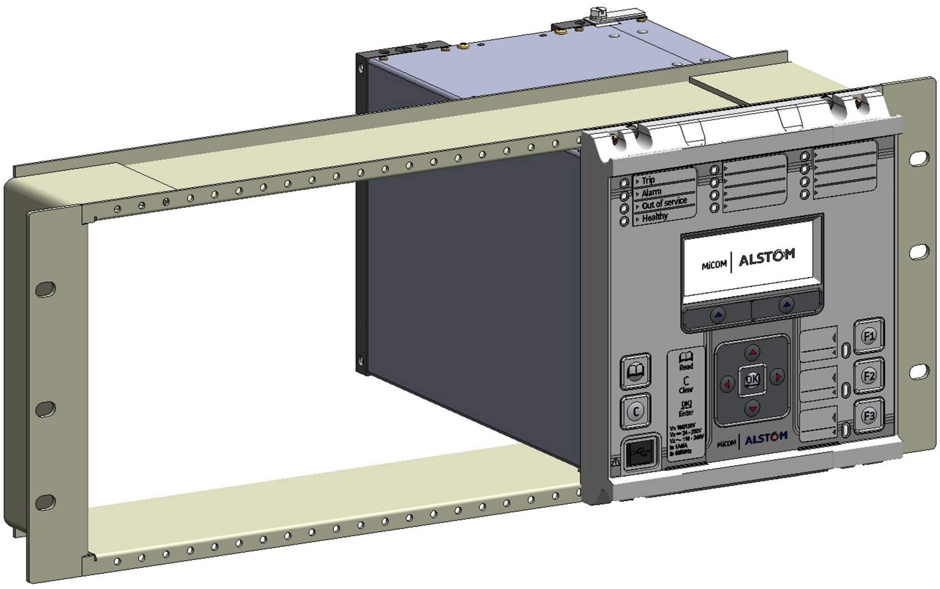
3.1.1 RACK MOUNTING

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 120: 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

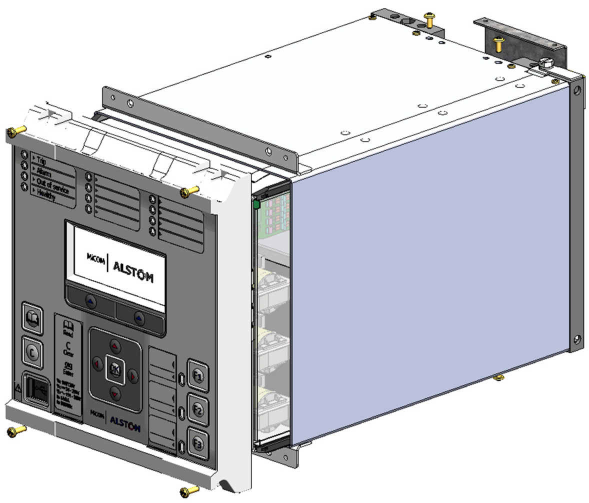
3.2 K-SERIES RETROFIT

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 121: 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.

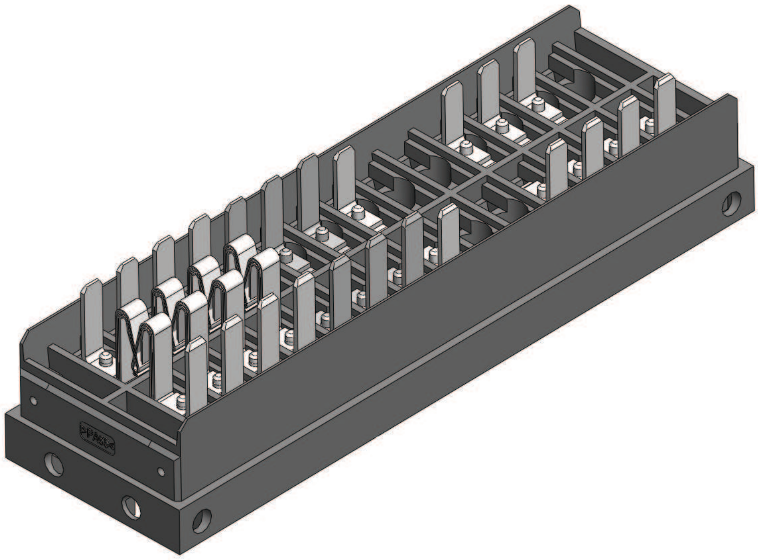


Figure 122: Spring-loaded CT shorting contacts

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 48 V 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 mirrors that of the auxiliary supply voltage. If the auxiliary supply voltage on terminals 13 and 14 is not 48 V DC, then the voltage on terminals 7 and 8 is also not 48 V 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.

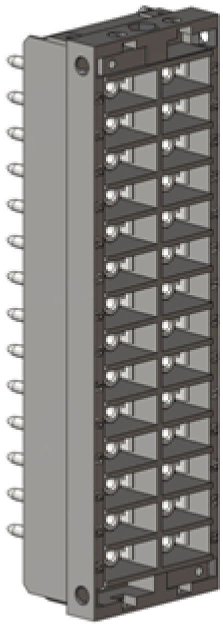
4 CABLES AND CONNECTORS

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 device uses MiDOS terminal blocks as shown below.



R01401

Figure 123: 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 mm^2 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:

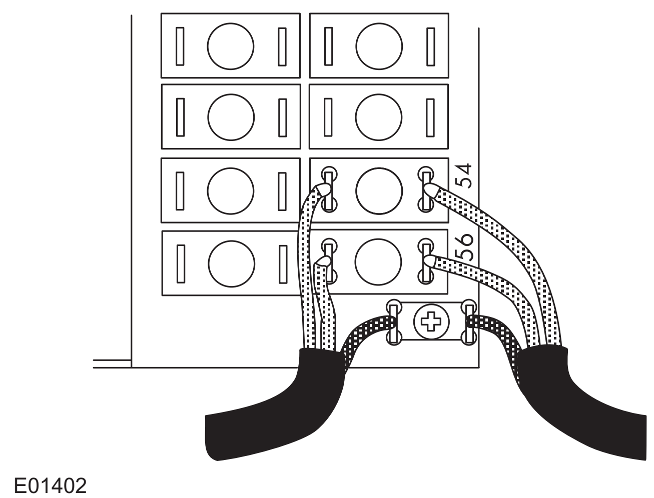


Figure 124: Earth link for cable screen

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

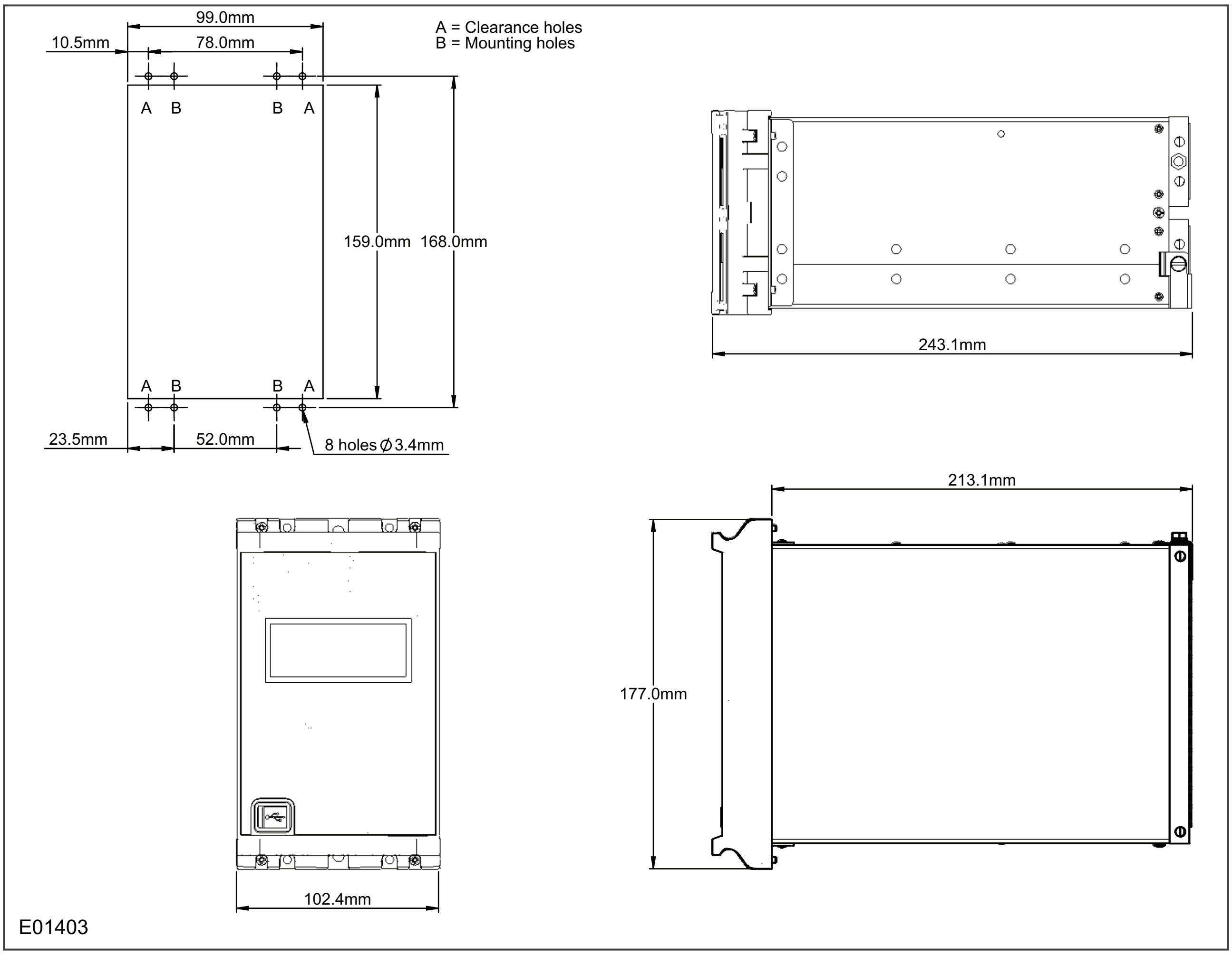


Figure 125: 20TE case dimensions

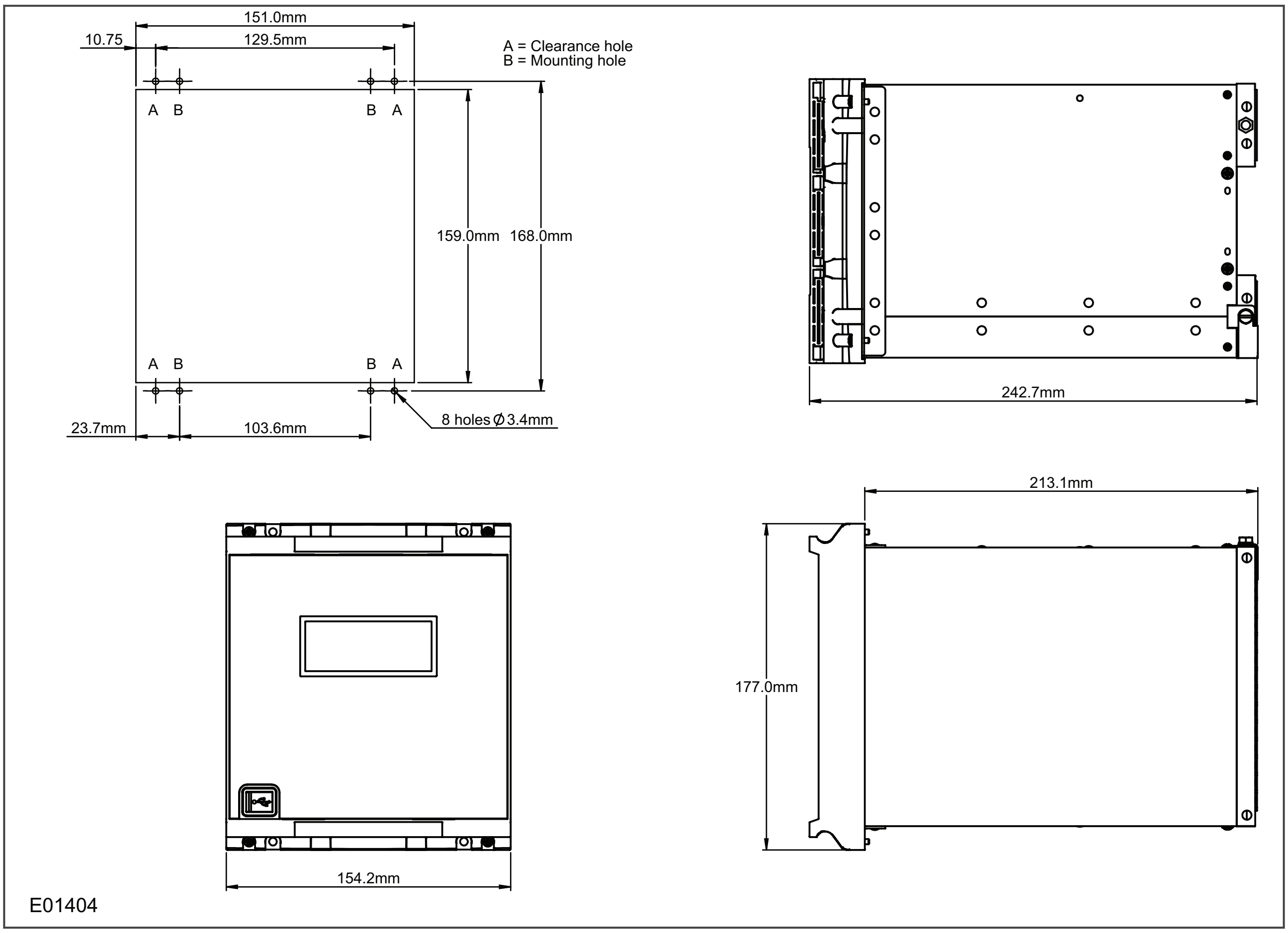


Figure 126: 30TE case dimensions

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

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 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 or more.

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 Tes`t. 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:

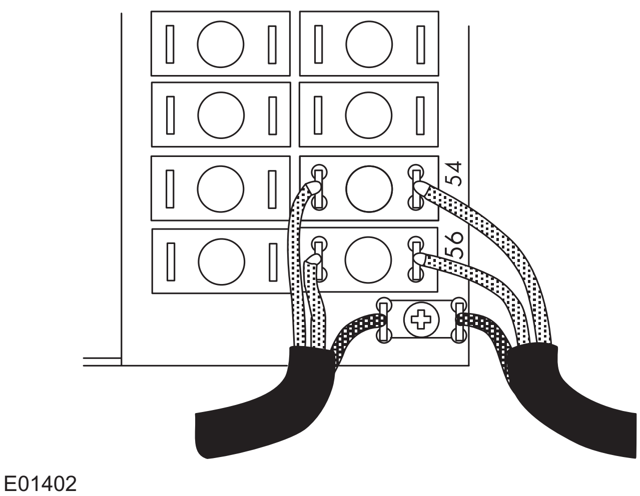


Figure 127: RP1 physical connection

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.

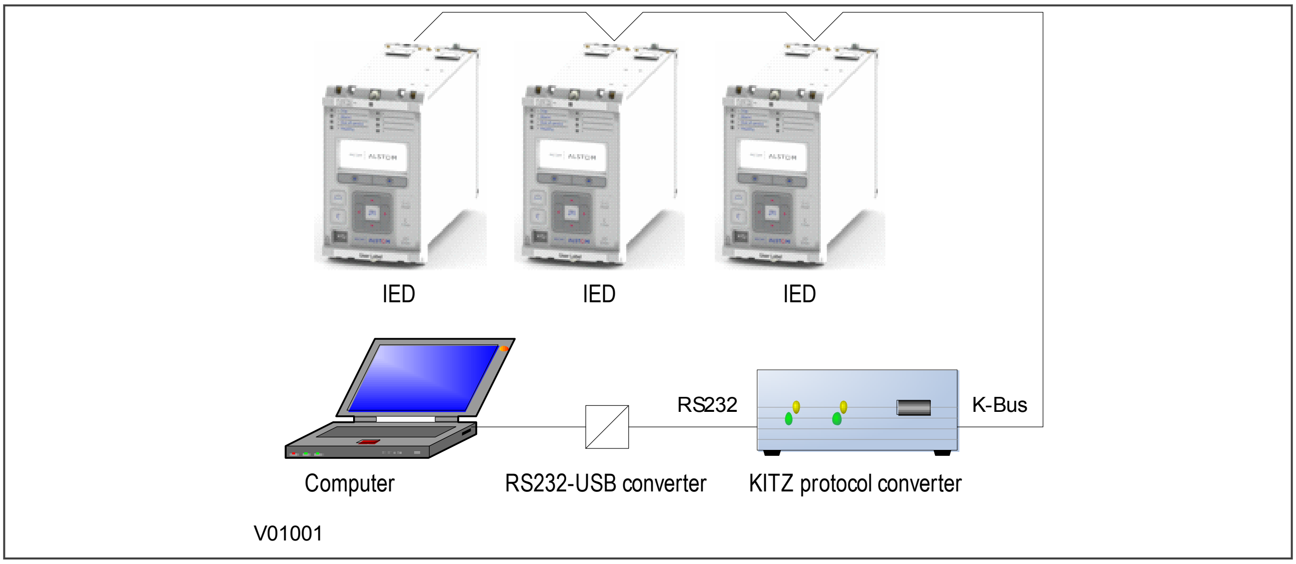


Figure 128: Remote communication using K-bus

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 IEC 61850 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
ISEF magnitude	SEF CT Primary / SEF CT 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 the default PSL is used, output relay 3 can be used as this is already mapped to the DDB signal* ***Trip Command Out****.*

1. Connect the output relay so that its operation will trip the test set and stop the timer.
2. Connect the current output of the test set to the A-phase current transformer input.
3. Ensure that the timer starts when the current is applied.

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

Characteristic	Operating time at twice current setting and time multiplier/ time dial setting of 1.0	
	Nominal (seconds)	Range (seconds)
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

The objectives of the on-load checks are to:

- Confirm the external wiring to the current and voltage inputs is correct
- Check the polarity of the line current transformers
- Check the magnitudes and phase angles of the phase currents

These checks can only be carried out if there are no restrictions preventing the energization 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. Ensure the current flowing in the neutral circuit of the current transformers is negligible.
3. 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.

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.

10 COMMISSIONG TEST SETTINGS

Menu Text	Col	Row	Default Setting	Available Options
Description				
COMMISSION TESTS	0F	00		
This column contains commissioning test settings				
Opto I/P Status	0F	01		32 bit Binary flag (data type G8): 0 = energised 1 = de-energised
This cell displays the status of the available opto-inputs.				
Relay O/P Status	0F	02		32 bit Binary flag (data type G9): 0 = operated state 1 = non-operated state
This cell displays the status of the available output relays. Warning; When in Test Mode, this cell cannot be used to confirm operation of the output relays, therefore it will be necessary to monitor the state of each contact in turn.				
Test Port Status	0F	03		8 bit Binary flag
This cell displays the logic state of the DDB signals that have been allocated in the 'Monitor Bit' cells.				
Monitor Bit 1	0F	05	640	From 0 to 1279 step 1
The 'Monitor Bit' cells allow the user to select which DDB signals can be observed in the 'Test Port Status' cell.				
Monitor Bit 2	0F	06	642	From 0 to 1279 step 1
The 'Monitor Bit' cells allow the user to select which DDB signals can be observed in the 'Test Port Status' cell.				
Monitor Bit 3	0F	07	644	From 0 to 1279 step 1
The 'Monitor Bit' cells allow the user to select which DDB signals can be observed in the 'Test Port Status' cell.				
Monitor Bit 4	0F	08	646	From 0 to 1279 step 1
The 'Monitor Bit' cells allow the user to select which DDB signals can be observed in the 'Test Port Status' cell.				
Monitor Bit 5	0F	09	648	From 0 to 1279 step 1
The 'Monitor Bit' cells allow the user to select which DDB signals can be observed in the 'Test Port Status' cell.				
Monitor Bit 6	0F	0A	650	From 0 to 1279 step 1
The 'Monitor Bit' cells allow the user to select which DDB signals can be observed in the 'Test Port Status' cell.				
Monitor Bit 7	0F	0B	652	From 0 to 1279 step 1
The 'Monitor Bit' cells allow the user to select which DDB signals can be observed in the 'Test Port Status' cell.				
Monitor Bit 8	0F	0C	654	From 0 to 1279 step 1
The 'Monitor Bit' cells allow the user to select which DDB signals can be observed in the 'Test Port Status' cell.				
Test Mode	0F	0D	Disabled	0 = Disabled, 1 = Test Mode, 2 = Contacts Blocked
This cell is used to allow secondary injection testing to be performed on the IED without operation of the trip contacts. It also enables a facility to directly test the output contacts by applying menu controlled test signals.				
Test Pattern	0F	0E	0x0	Binary flag (data type G9) 0=Not Operated 1=Operated
This cell is used to select the output relay contacts that will be tested when the 'Contact Test' cell is set to 'Apply Test'.				
Contact Test	0F	0F	No Operation	0 = No Operation, 1 = Apply Test, 2 = Remove Test
This command changes the state of the output relay contacts in the Test Pattern cell. After the test has been applied the command text on the LCD changes to 'No Operation' and the contacts will remain in the Test State until reset.				
Test LEDs	0F	10	No Operation	0 = No Operation or 1 = Apply Test
This command illuminates the user-programmable LEDs for approximately 2 seconds, before they extinguish and the command text on the LCD reverts to 'No Operation'.				

Menu Text	Col	Row	Default Setting	Available Options
Description				
Test Autoreclose	0F	11	No Operation	0=No Operation, 1=3 Pole Test
This command simulates tripping in order to test Autoreclose cycle.				
Red LED Status	0F	15		Binary string: 0 = not illuminated, 1 = illuminated
This cell indicates which of the user-programmable red LEDs are illuminated.				
Green LED Status	0F	16		Binary string: 0 = not illuminated, 1 = illuminated
This cell indicates which of the user-programmable green LEDs are illuminated.				
DDBs (banks of 32)	0F	20 – 5F		32 bit binary flag
This cell displays the logic state of the DDB signals				

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 device 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 device'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 all 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 device, 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 device 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, in 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 (Cyclic Redundancy 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
   An electronic version of the RMA form is available from the following web page:
   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,visit the following web page:
   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
Connector	USB type B
Isolation	Isolation to ELV level
Constraints	Maximum cable length 5 m

2.2 REAR SERIAL PORT 1

Rear serial port 1 (RP1)	
Use	For SCADA communications (multi-drop)
Standard	EIA(RS)485, K-bus
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

* Not all models support all protocols - see ordering options

2.3 REAR SERIAL PORT 2

Optional rear serial port (RP2)	
Use	For SCADA communications (multi-drop)
Standard	EIA(RS)485, K-bus, EIA(RS)232
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)
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 using fibre-optic cabling	
Main Use	IEC 61850 or DNP3 OE 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 OE
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 using CAT 5/6/7 wiring	
Main Use	Substation Ethernet communications
Standard	IEEE 802.3 10BaseT/100BaseTX
Connector	RJ45
Cable type	Screened twisted pair (STP)
Isolation	1 kV
Supported Protocols	IEC 61850, DNP3.0 OE
Constraints	Maximum cable length 10 m

3 PERFORMANCE OF CURRENT PROTECTION FUNCTIONS

3.1 THREE-PHASE OVERCURRENT PROTECTION

IDMT pick-up	1.05 x Setting +/-5%
DT Pick-up	Setting +/- 5%
Drop-off (IDMT and DT)	0.95 x setting +/- 5%
IDMT operate	+/- 5% or 60 ms, whichever is greater (1.05 – <2) Is +/- 5% or 40 ms, whichever is greater (2 – 20) Is
Disengagement	< 40 ms
DT operate	+/- 2% or 70 ms, whichever is greater (1.05 – <2) Is +/- 2% or 50 ms, whichever is greater (2 – 20) Is
DT reset	Setting +/- 5%
Repeatability	+/- 2.5%
Overshoot of overcurrent elements	<30 ms

3.2 EARTH FAULT PROTECTION

Measured and Derived	
IDMT pick-up	1.05 x Setting +/-5%
DT Pick-up	Setting +/- 5%
Drop-off (IDMT and DT)	0.95 x Setting +/-5%
IDMT operate	+/- 5% or 60 ms, whichever is greater (1.05 – 2) Is +/- 5% or 40 ms, whichever is greater (2 – 20) Is
Disengagement	< 40 ms
DT operate	+/- 2% or 70 ms, whichever is greater (1.05 – 2) Is +/- 2% or 50 ms, whichever is greater (2 – 20) Is
DT reset	Setting +/- 5%
Repeatability	+/- 2.5% (measured), +/-5% (derived)

3.3 SENSITIVE EARTH FAULT PROTECTION

IDMT pick-up	1.05 x Setting +/-5%
DT Pick-up	Setting +/- 5%
Drop-off (IDMT + DT)	0.95 x Setting +/-5%
IDMT operate	+/- 2% or 70 ms, whichever is greater (1.05 - <2) Is +/- 2% or 50 ms, whichever is greater (2 - 20) Is
Disengagement	< 40 ms
DT operate	+/- 2% or 70 ms, whichever is greater (1.05 - <2) Is +/- 2% or 50 ms, whichever is greater (2 - 20) Is
DT reset	Setting +/- 5%
Repeatability	+/- 5%

> *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.*

3.4 RESTRICTED EARTH FAULT PROTECTION

High Impedance Retricted Earth Fault (REF) accuracy	
Pick-up	Setting formula +/- 5%
Drop-off	0.95 x Setting formula +/-5%
Operating time	< 60 ms
High pick-up	Setting +/- 10%
High operating time	< 30 ms
Repeatability	< 15%

Low Impedance Retricted Earth Fault (REF) accuracy	
Pick-up	Setting formula +/- 5%
Drop-off	0.9 x Setting formula +/-5%
Operating time	< 60 ms
High pick-up	Setting +/- 5%
High operating time	< 30 ms
Repeatability	< 15%

3.5 NEGATIVE SEQUENCE OVERCURRENT PROTECTION

IDMT pick-up	1.05 x Setting +/-5%
DT pick-up	Setting +/- 5%
Drop-off (IDMT + DT)	0.95 x Setting +/-5%
IDMT operate	+/- 5% or 60 ms, whichever is greater (1.05 – <2) Is +/- 5% or 40 ms, whichever is greater (2 – 20) Is
Disengagement	< 40 ms
DT operate	+/- 2% or 70 ms, whichever is greater (1.05 – <2) Is +/- 2% or 50 ms, whichever is greater (2 – 20) Is
DT Reset	Setting +/- 5%

3.6 CIRCUIT BREAKER FAIL AND UNDERCURRENT PROTECTION

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	< 35 ms

3.7 BROKEN CONDUCTOR PROTECTION

Pick-up	Setting +/- 2.5%
Drop-off	0.95 x Setting +/- 2.5%
DT operate	+/- 2% or 55 ms, whichever is greater

3.8 THERMAL OVERLOAD PROTECTION

Thermal alarm pick-up	Calculated trip time +/- 10%
Thermal overload pick-up	Calculated trip time +/- 10%
Cooling time accuracy	+/- 15% of theoretical
Repeatability	<5%

Note:
Operating time measured with applied current of 20% above thermal setting.

3.9 COLD LOAD PICKUP PROTECTION

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 operate	+/- 0.5% or 50 ms, whichever is greater
Repeatability	+/- 1%

3.10 SELECTIVE OVERCURRENT PROTECTION

Fast Block operation	< 25 ms
Fast Block reset	< 30 ms
Time delay	Setting +/- 2% or 20 ms, whichever is greater

4 PERFORMANCE OF MONITORING AND CONTROL FUNCTIONS

4.1 CB STATE AND CONDITION MONITORING

Timers	+/- 40 ms or 2%, whichever is greater
Broken current accuracy	< +/- 5%

4.2 PSL TIMERS

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

4.3 DC SUPPLY MONITOR

Measuring Range	19 V-310 V ±5%
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 *
Operate Time	Setting ± (2% or 500 ms whichever is greater)
Disengagement Time	< 250 ms

Note:
** Tested at 21°C*

5 MEASUREMENTS AND RECORDING

5.1 GENERAL

General Measurement Accuracy	
General measurement accuracy	Typically +/- 1%, but +/- 0.5% between 0.2 - 2 In/Vn
Current magnitude	0.05 to 4 In +/- 1.0% of reading (5A input) 0.05 to 4 In +/- 0.5% of reading (1A input)
Current phase	0° to 360° +/- 0.5° (0.05 to 4 In for 5A input) 0° to 360° +/- 1° (0.05 to 4 In for 1A input)

5.2 DISTURBANCE RECORDS

Disturbance Records Measurement Accuracy	
Minimum record duration	0.1 s
Maximum record duration	10.5 s
Minimum number of records at 10.5 seconds	15
Magnitude and relative phases accuracy	±5% of applied quantities
Duration accuracy	±2%
Trigger position accuracy	±2% (minimum Trigger 100 ms)

5.3 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 10
Number of Maintenance Records	Up to 10

6 STANDARDS COMPLIANCE

6.1 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.

6.2 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:

6.3 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.

6.4 UL/CUL COMPLIANCE

Canadian and USA Underwriters Laboratory

File Number E202519 (where marked)

7 MECHANICAL SPECIFICATIONS

7.1 PHYSICAL PARAMETERS

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

7.2 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

7.3 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 2, Shock withstand: class 2, Bump withstand: class 2
Seismic test per EN 60255-21-3: 1995	Class 2

7.4 TRANSIT PACKAGING PERFORMANCE

Primary packaging carton protection	ISTA 1C
Vibration tests	3 orientations, 7 Hz, amplitude 5.3 mm, acceleration 1.05g
Drop tests	10 drops from 610 mm height on multiple carton faces, edges and corners

8 RATINGS

8.1 AC MEASURING INPUTS

AC Measuring Inputs	
Nominal frequency	50 Hz or 60 Hz (settable)
Operating range	40 Hz to 70 Hz
Phase rotation	ABC or CBA

8.2 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.*

> *Note:*
> *These specifications are applicable to all CTs.*

8.3 VOLTAGE TRANSFORMER INPUTS

AC Voltage	
Nominal voltage	100 V to 120 V
Nominal burden per phase	< 0.1 VA at Vn
Thermal withstand	Continuous: 2 x Vn, 10 s: 2.6 x Vn

9 POWER SUPPLY

9.1 AUXILIARY 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)

9.2 NOMINAL BURDEN

Quiescent burden	20TE	5 W max.
	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.

9.3 AUXILIARY 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 INPUT / OUTPUT CONNECTIONS

10.1 ISOLATED DIGITAL INPUTS

Opto-isolated digital inputs (opto-inputs)	
Compliance	ESI 48-4
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

10.1.1 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.

10.2 STANDARD OUTPUT 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)
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

10.3 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)

11 ENVIRONMENTAL CONDITIONS

11.1 AMBIENT TEMPERATURE RANGE

Compliance	IEC 60255-27: 2005
Test Method	IEC 60068-2-1:2007 and IEC 60068-2-2 2007
Operating temperature range	-25°C to +55°C (continuous)
Storage and transit temperature range	-25°C to +70°C (continuous)

11.2 TEMPERATURE ENDURANCE TEST

Temperature Endurance Test	
Test Method	IEC 60068-2-1: 2007 and 60068-2-2: 2007
Operating temperature range	-40°C (96 hours) +70°C (96 hours)
Storage and transit temperature range	-40°C (96 hours) +85°C (96 hours)

11.3 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

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

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

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

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

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, where applicable.

13 ELECTROMAGNETIC COMPATIBILITY

13.1 1 MHZ BURST HIGH FREQUENCY DISTURBANCE TEST

Compliance	IEC 60255-22-1: 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

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

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

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

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
Condition 2	4 kV fast transient and 2.5 kV oscillatory applied common mode to communications, IRIG-B

13.6 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, where applicable)	Amplitude 2 kV

13.7 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

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

Compliance	IEC 61000-4-3: 2002
Frequency bands	900 MHz and 1.89 GHz
Test field strength	10 V/m

13.10 IMMUNITY TO CONDUCTED DISTURBANCES INDUCED BY RADIO FREQUENCY FIELDS

Compliance	IEC 61000-4-6: 2008, Level 3
Frequency bands	150 kHz to 80 MHz

Test disturbance voltage	10 V rms
Test using AM	1 kHz @ 80%
Spot tests	27 MHz and 68 MHz

13.11 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

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 (where applicable)	0.15 - 0.5 MHz, 97 dBμV (quasi peak) 84 dBμV (average)
RJ45 test 2 (where applicable)	0.5 – 30 MHz, 87 dBμV (quasi peak) 74 dBμV (average)

13.13 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

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
CLIO	Current Limited Input Output
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

Term	Description
CRP	Cross-network Redundancy Protocol
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

Term	Description
ER	Engineering Recommendation
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

Term	Description
LAN	Local Area Network
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

Term	Description
POST	Power On Self Test
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
RTD	Resistive Temperature Device
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.

Term	Description
SPS	Single Point Status
SQRT	Square Root
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

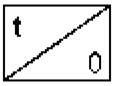
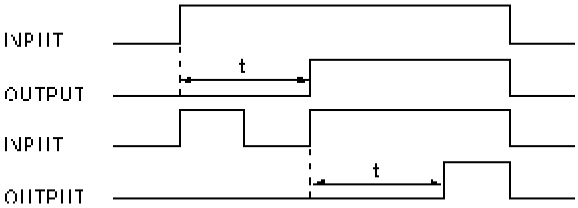
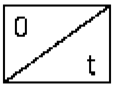
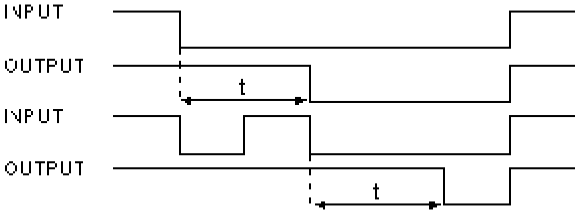
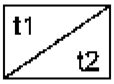
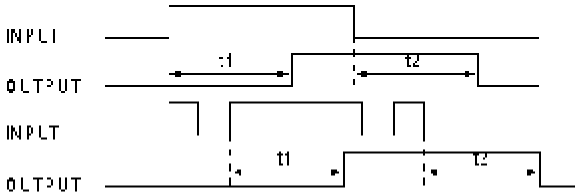
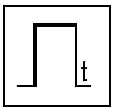
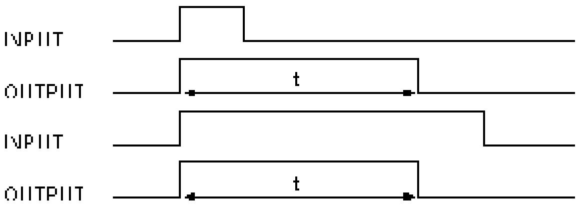
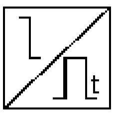
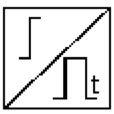
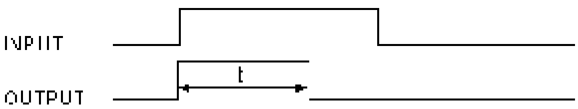
Symbol	Description	Units
&	Logical "AND": Used in logic diagrams to show an AND-gate function.	
Σ	"Sigma": Used to indicate a summation, such as cumulative current interrupted.	
τ	"Tau": Used to indicate a time constant, often associated with thermal characteristics.	
δ	Angular displacement	rad
θ	Angular 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

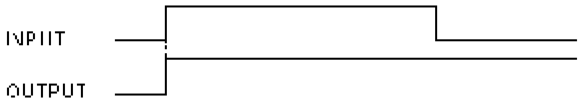
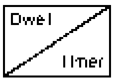
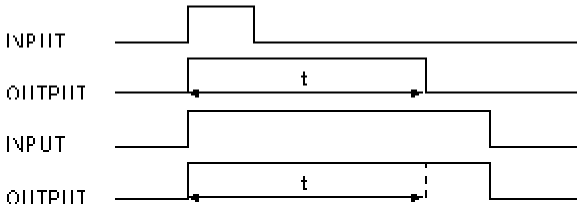
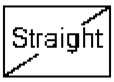
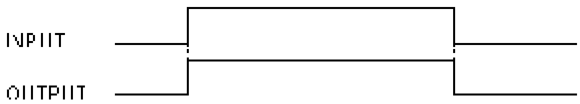
Symbol	Description	Units
If	Maximum secondary through-fault current	A
If max	Maximum secondary fault current (same for all feeders)	A
If max int	Maximum secondary contribution from a feeder to an internal fault	A
If Z1	Maximum secondary phase fault current at Zone 1 reach point	A
Ife	Maximum secondary 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

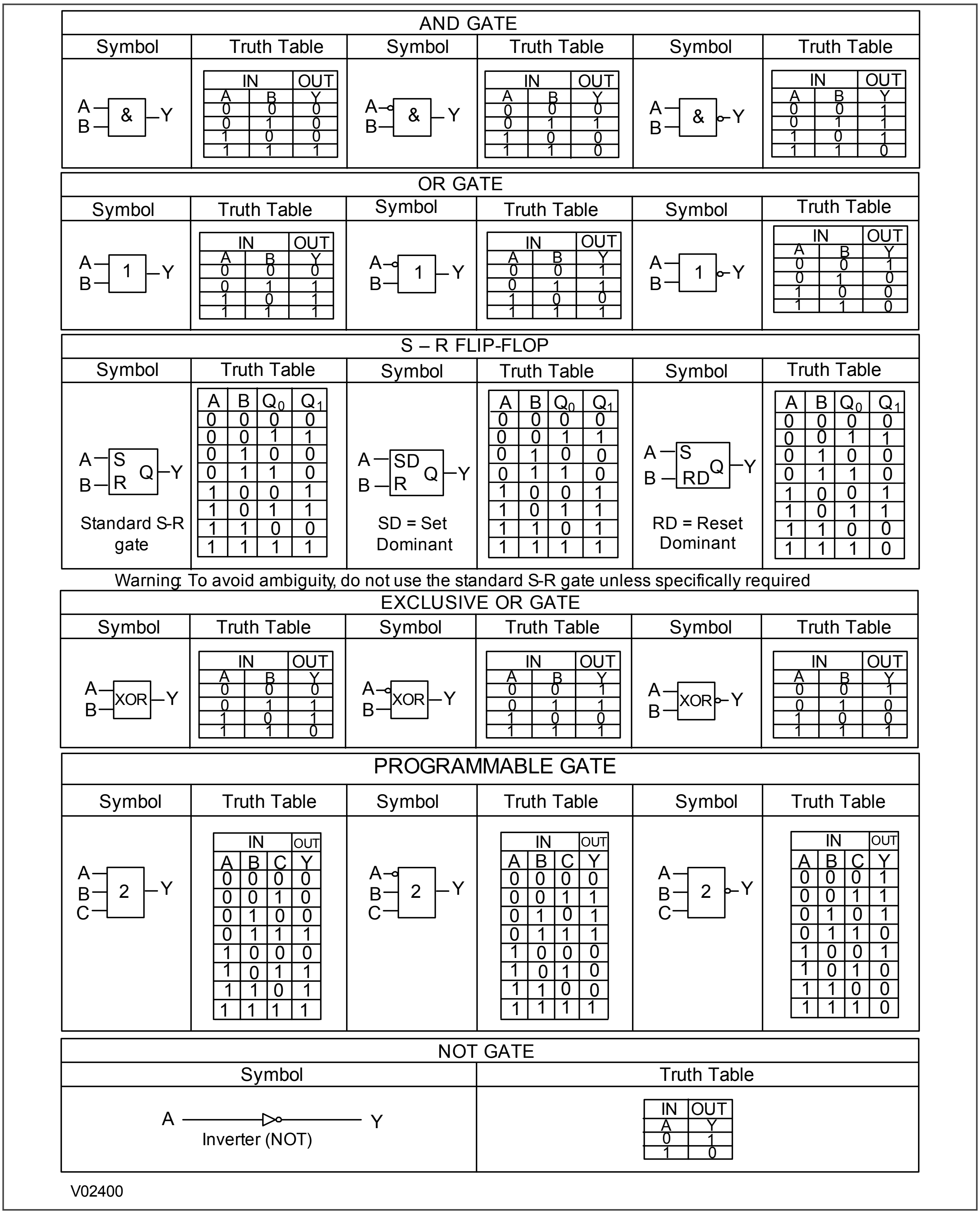


Figure 129: Logic Gates

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		
IEC 61850 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, IEC 61850, IEC 60870, 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 FINAL 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 rechecked?	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

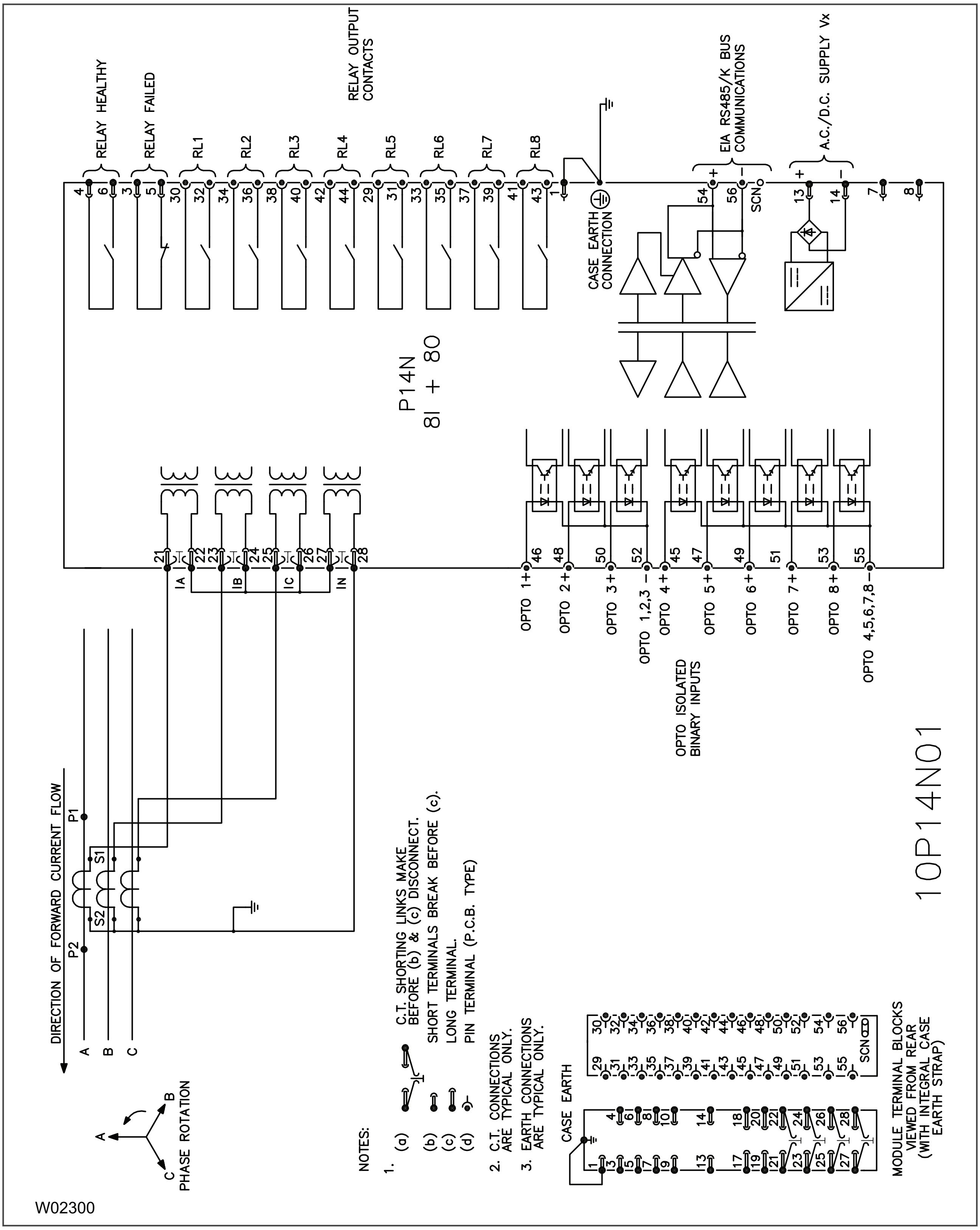


Figure 130: P14N Non-directional IED with 8 inputs and 8 outputs

3 I/O OPTION A WITH SEF

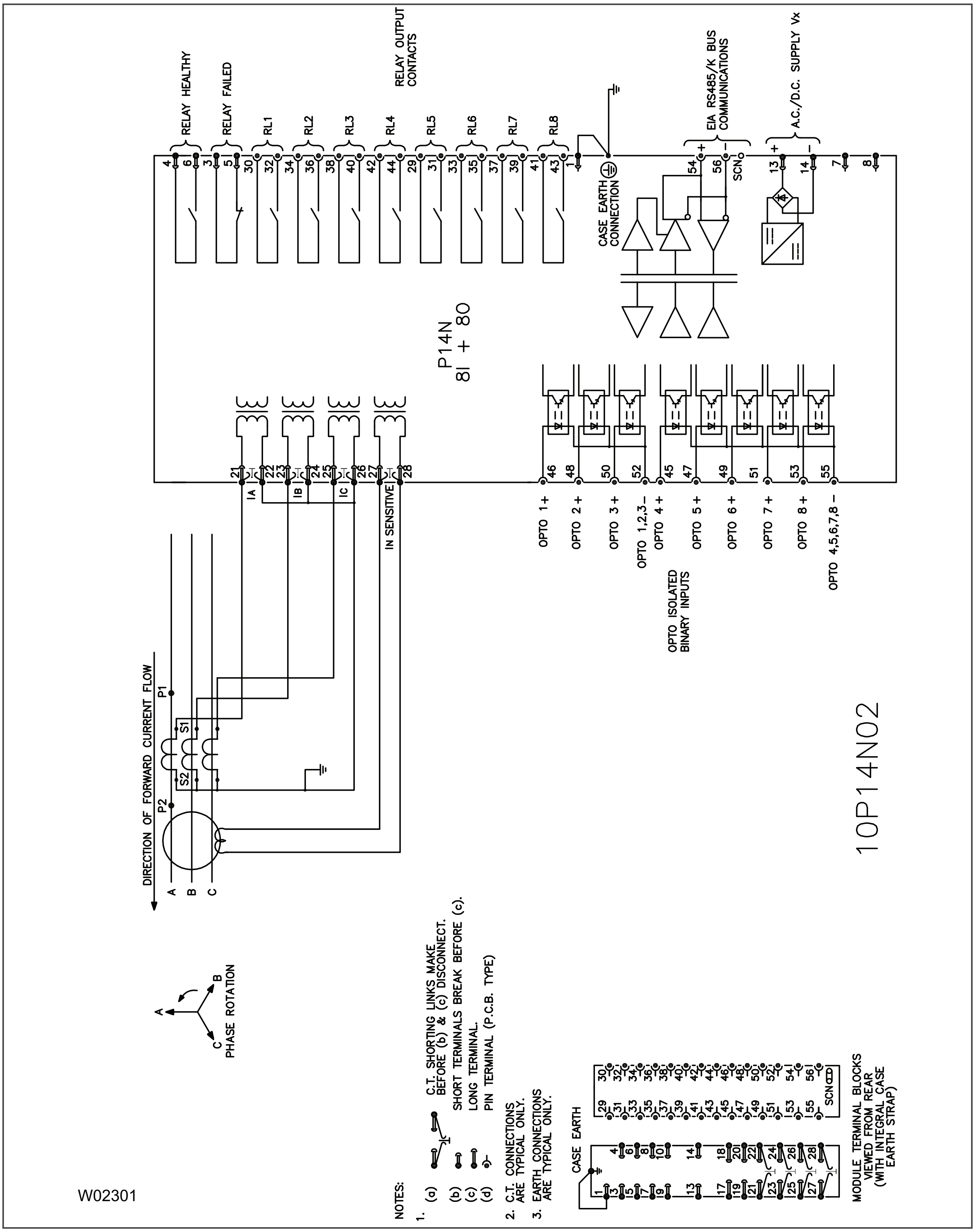


Figure 131: P14N Non-directional IED with 8 inputs, 8 outputs and SEF option

4 I/O OPTION A WITH ETHERNET

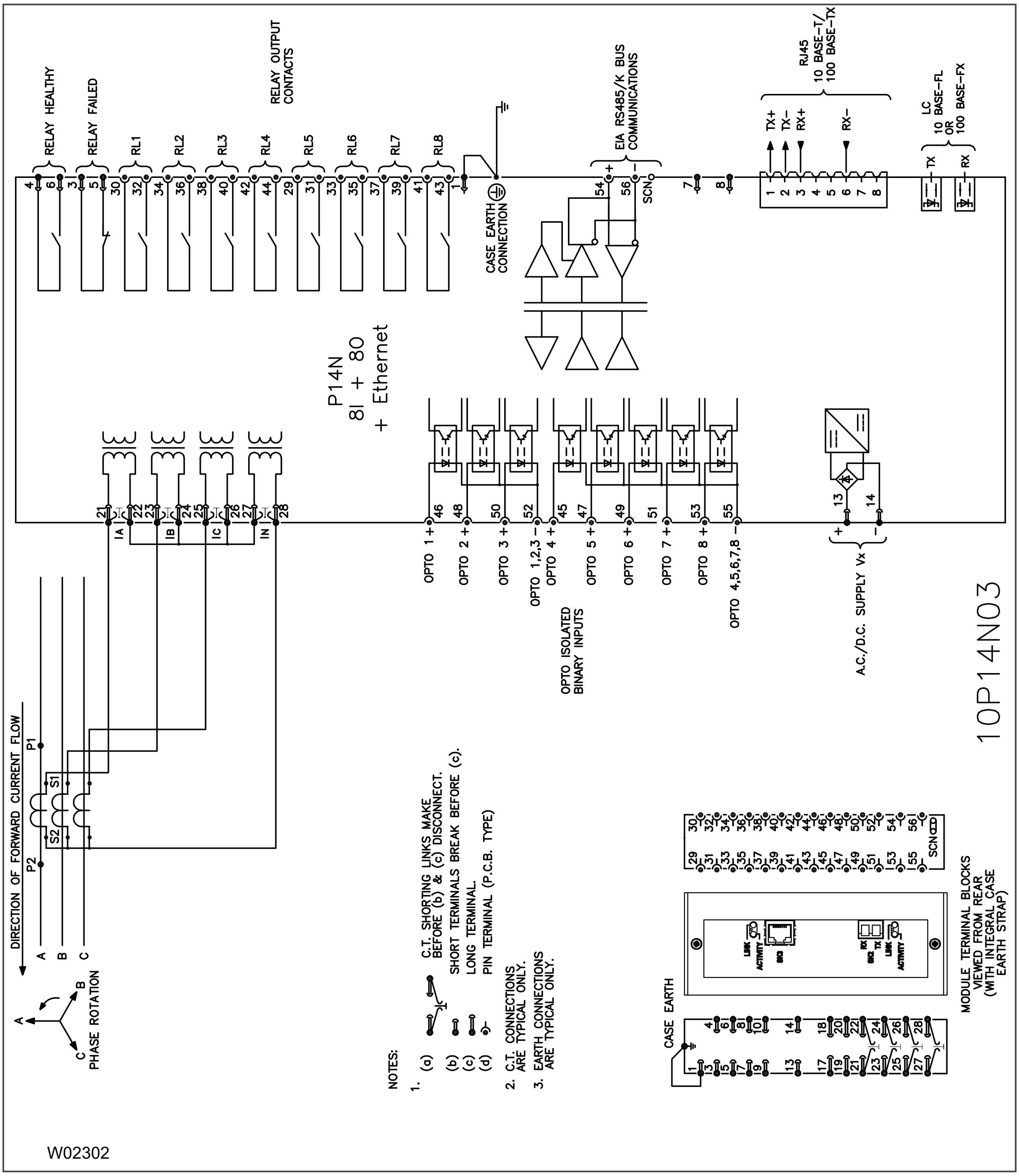


Figure 132: P14N Non-directional IED with 8 inputs, 8 outputs and Ethernet

5 I/O OPTION A WITH ETHERNET AND SEF

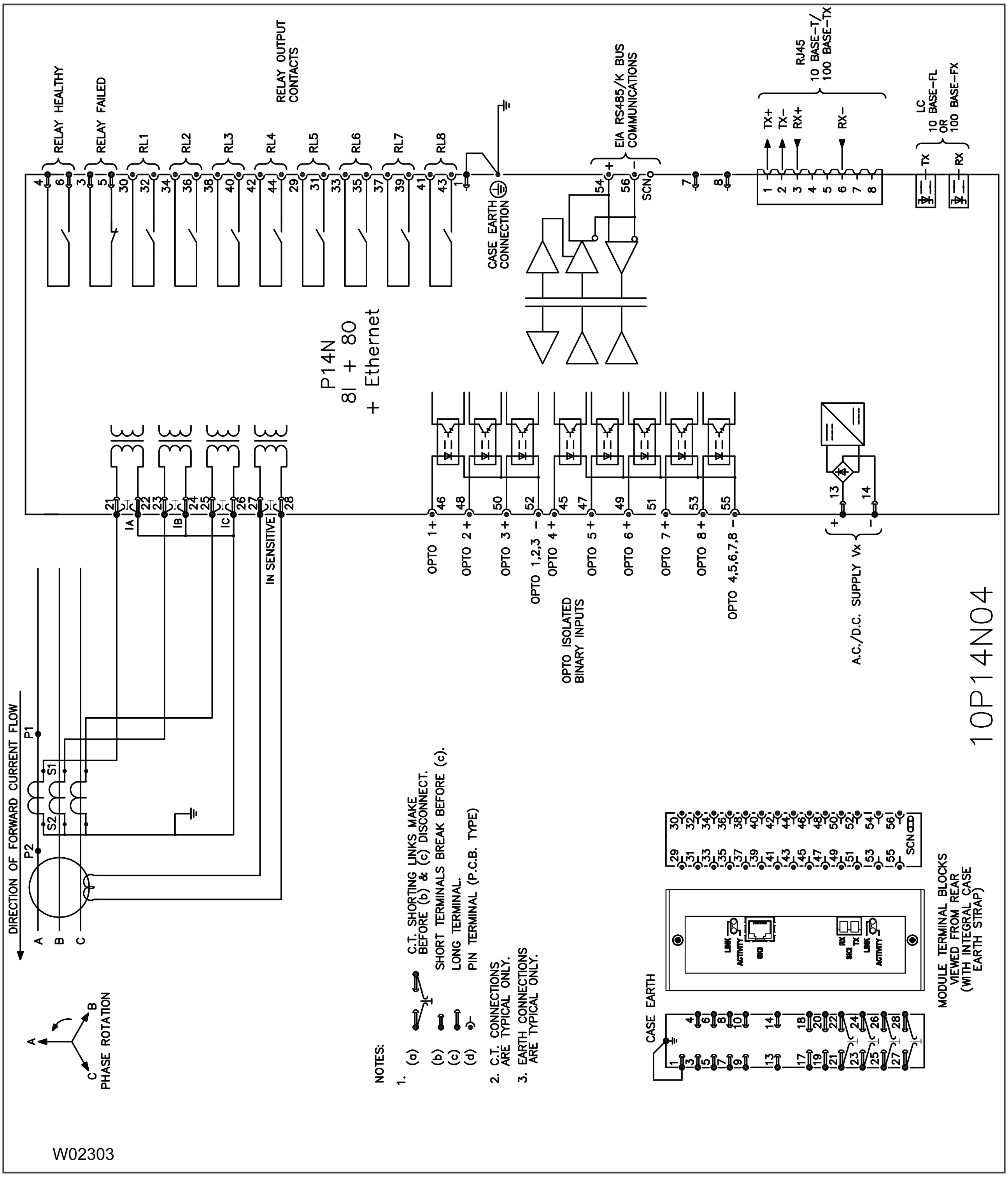


Figure 133: P14N Non-directional IED with 8 inputs, 8 outputs, Ethernet and SEF option

6 I/O OPTION B WITH 2 REAR PORTS

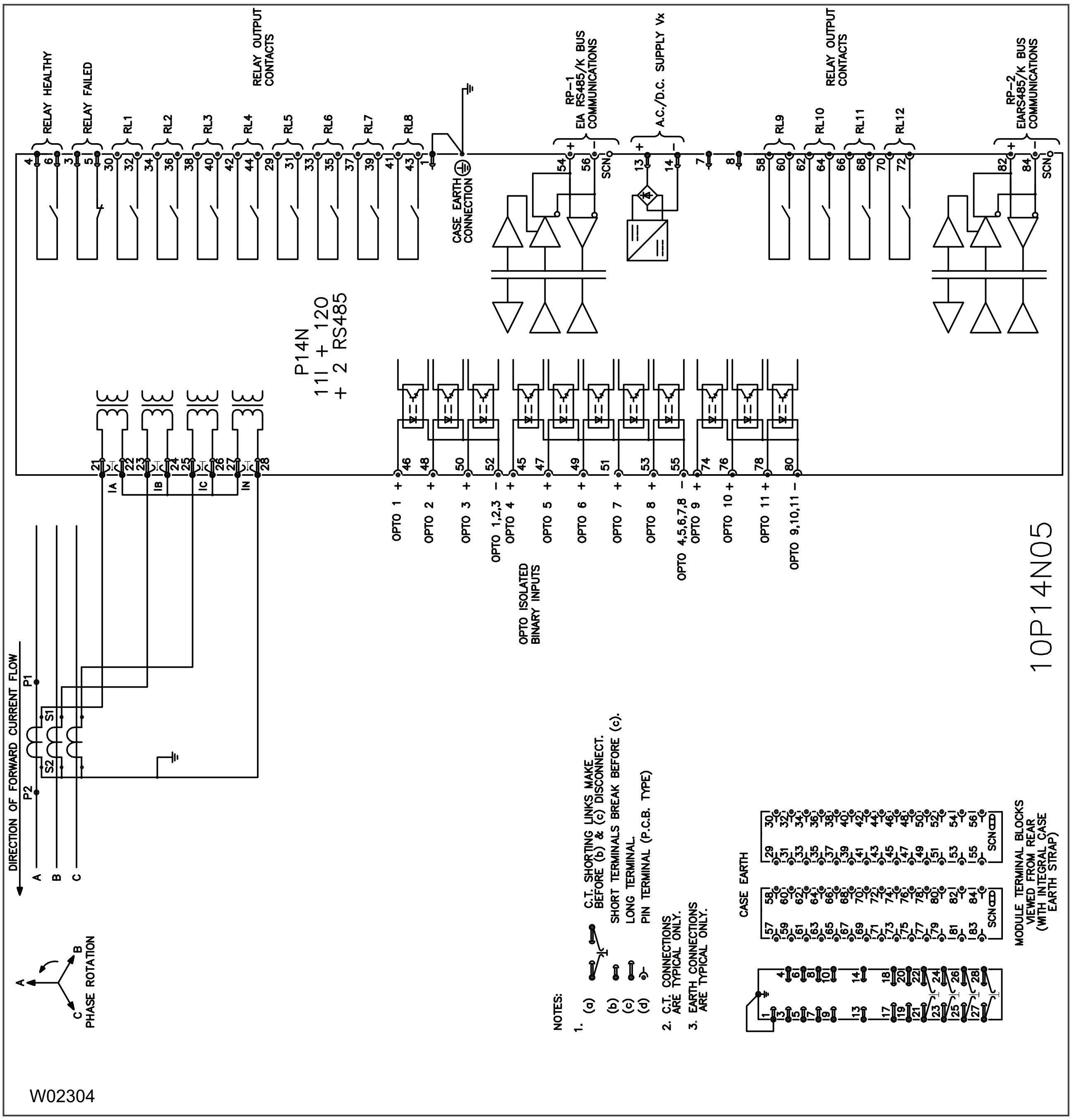


Figure 134: P14N Non-directional IED with 11 inputs, 12 outputs and two rear ports

7 I/O OPTION B WITH 2 REAR PORTS AND SEF

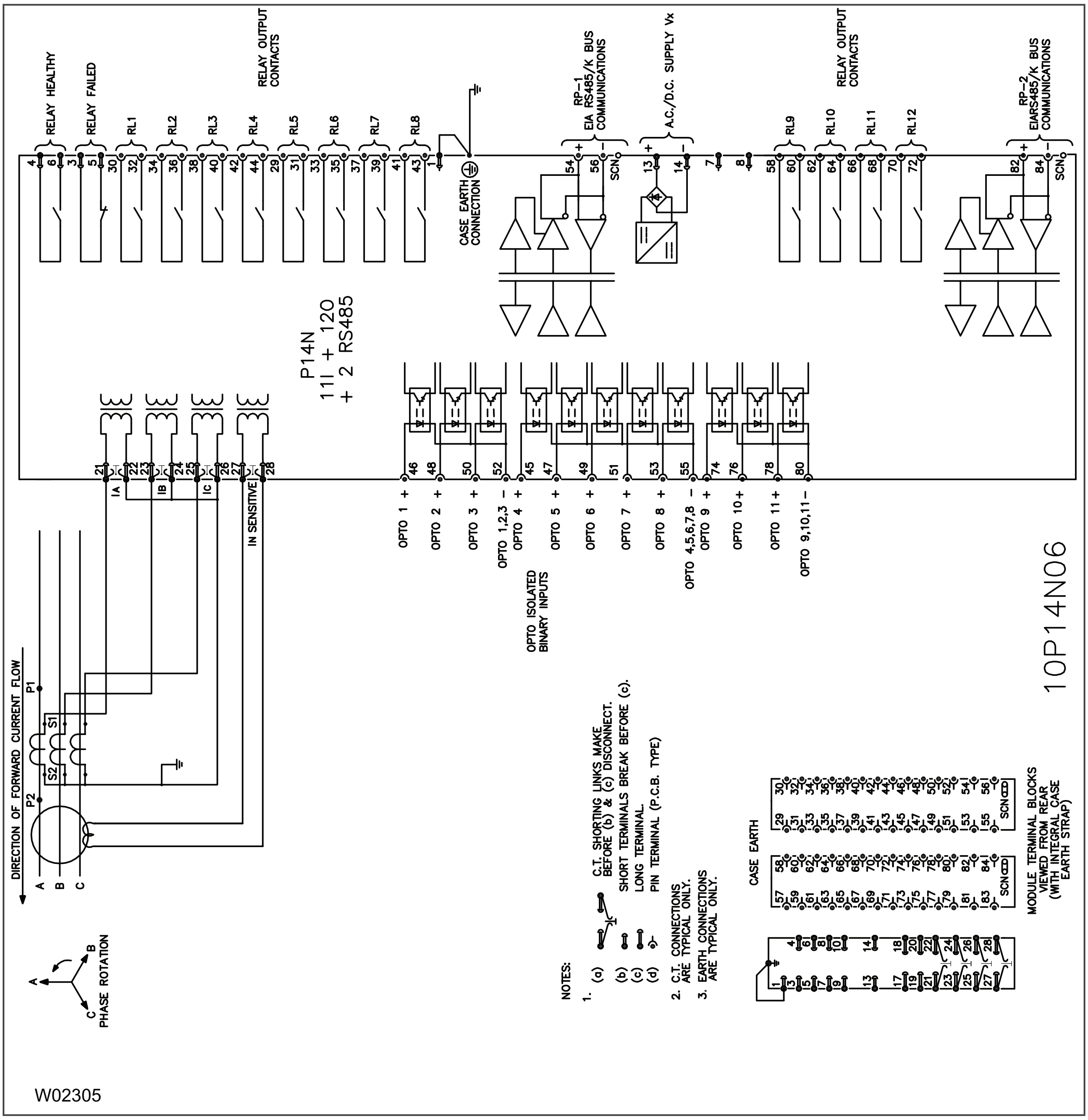


Figure 135: P14N Non-directional IED with 11 inputs, 12 outputs, two rear ports and SEF option

8 I/O OPTION C WITH TCS

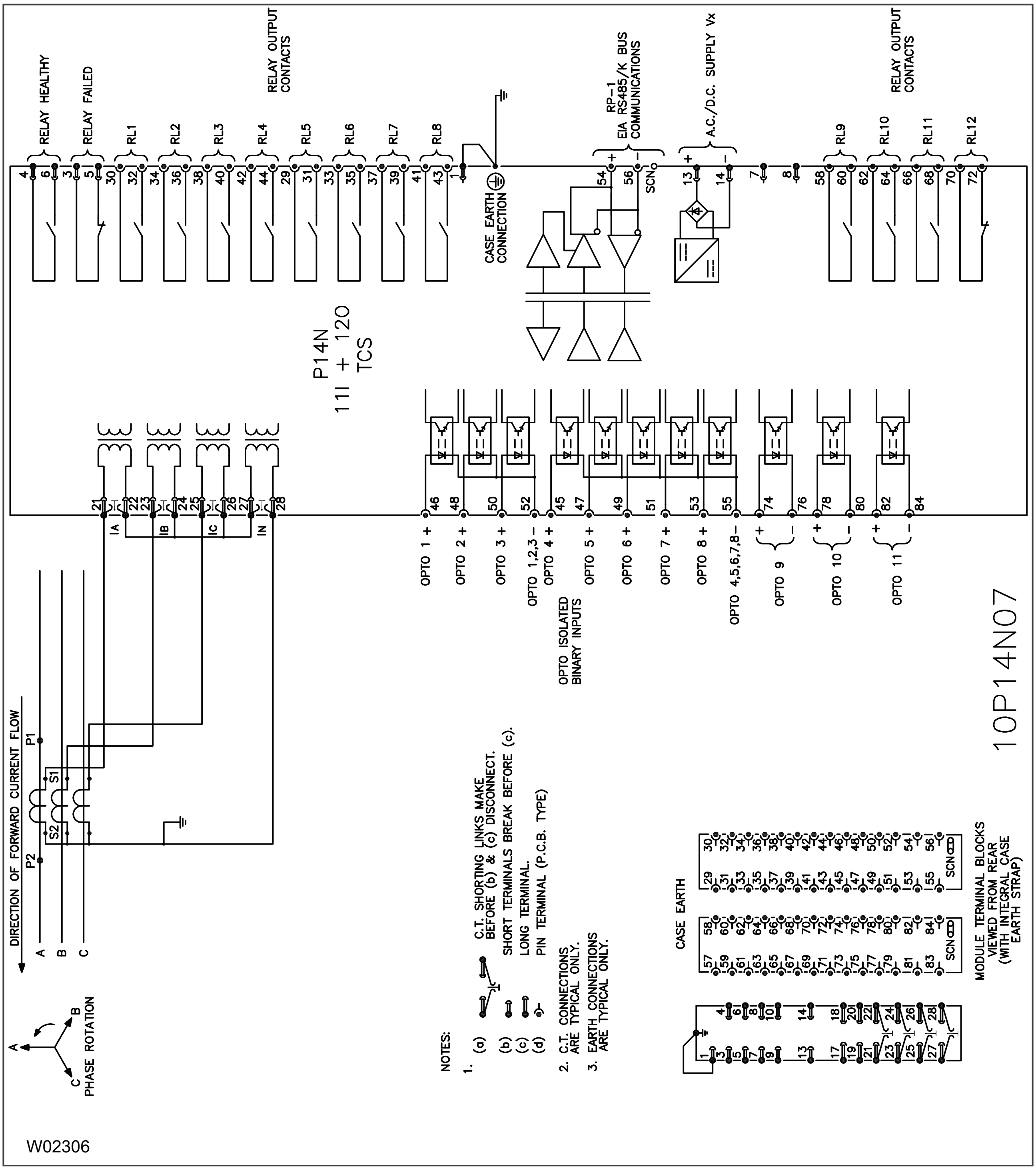


Figure 136: P14N Non-directional IED with 11 inputs and 12 outputs, for Trip Circuit Supervision

9 I/O OPTION C WITH TCS AND SEF

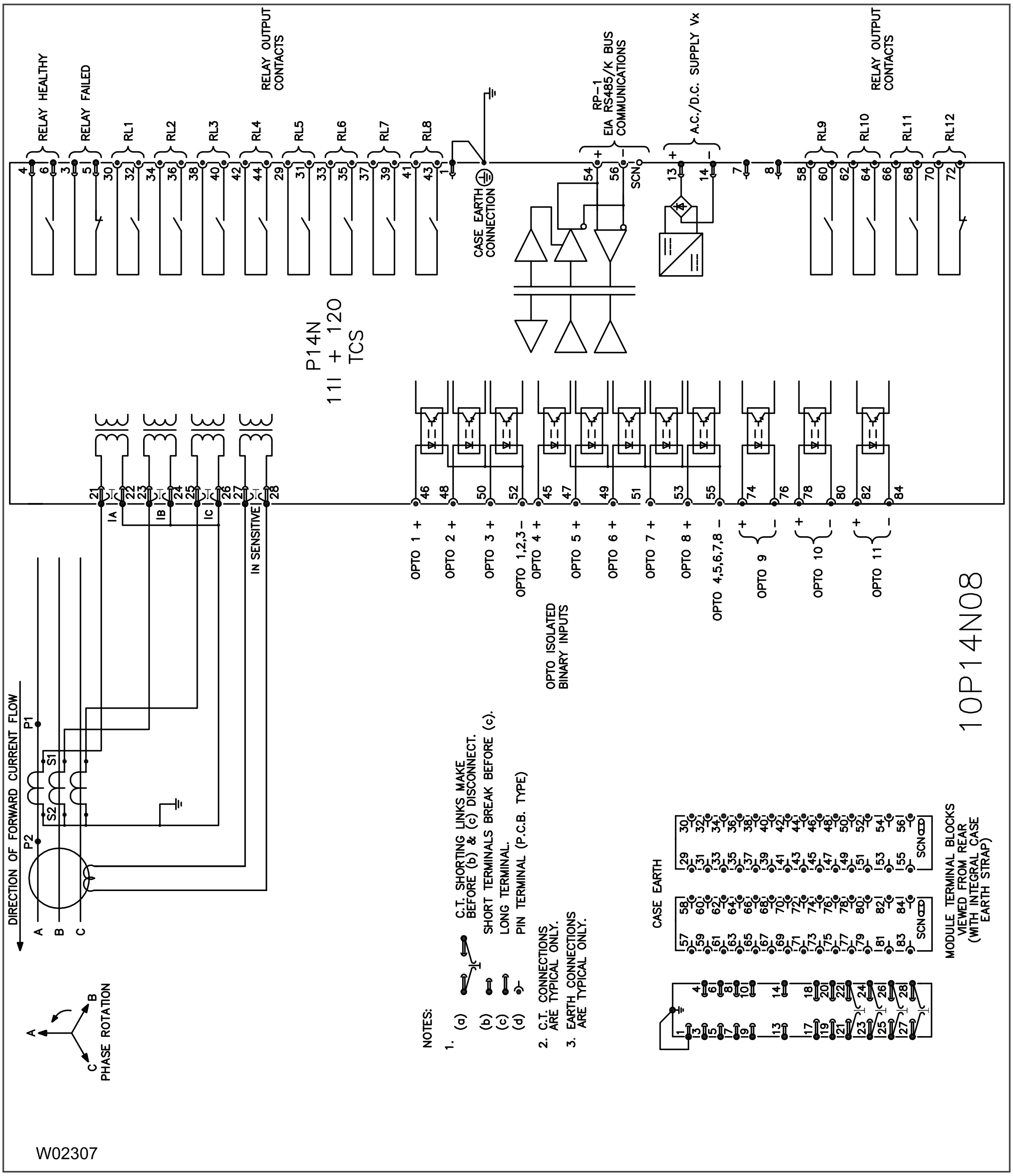


Figure 137: P14N Non-directional IED with 11 inputs, 12 outputs and SEF option, for Trip Circuit Supervision

10 I/O OPTION D

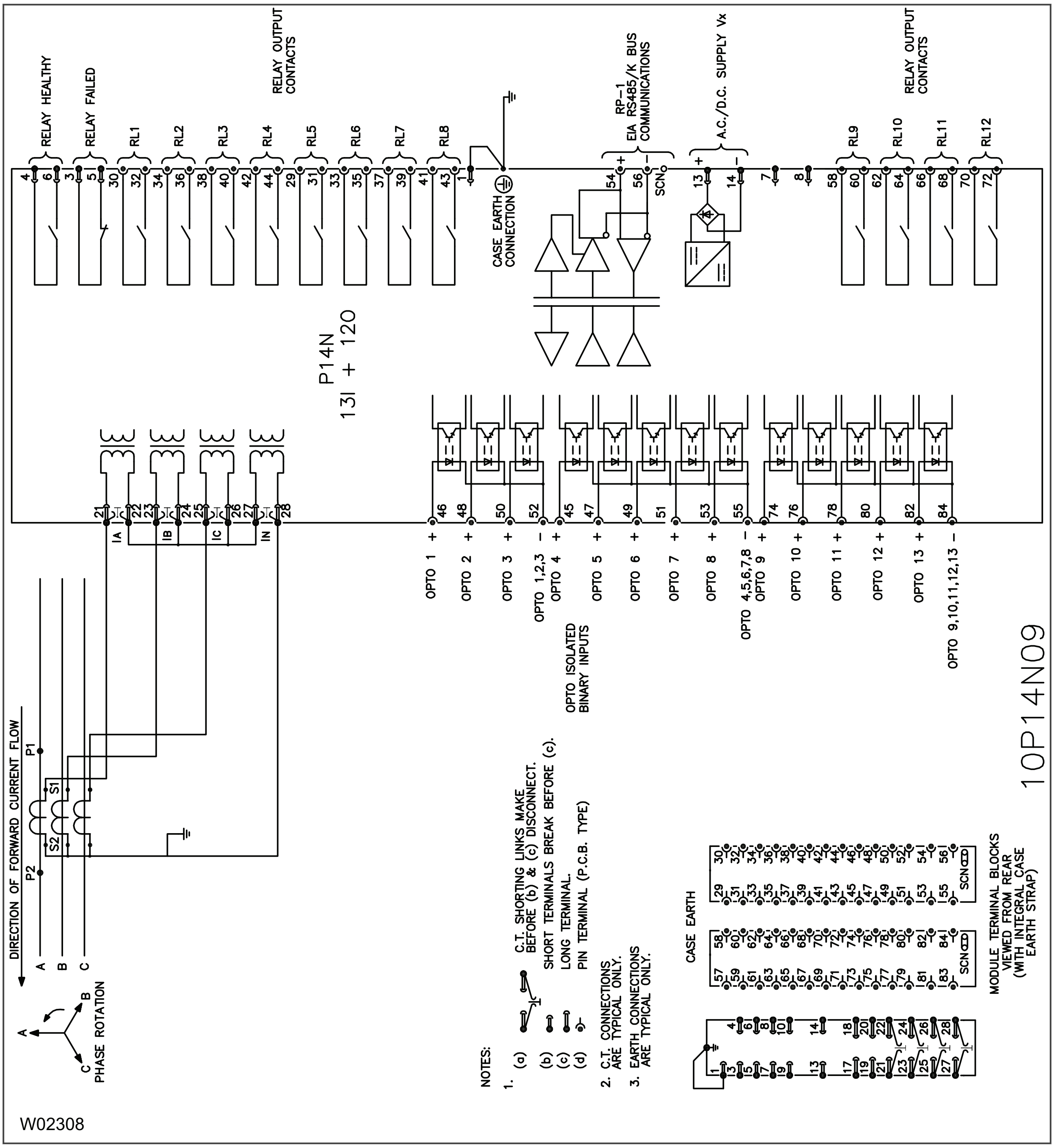


Figure 138: P14N Non-directional IED with 13 inputs and 12

11 I/O OPTION D WITH SEF

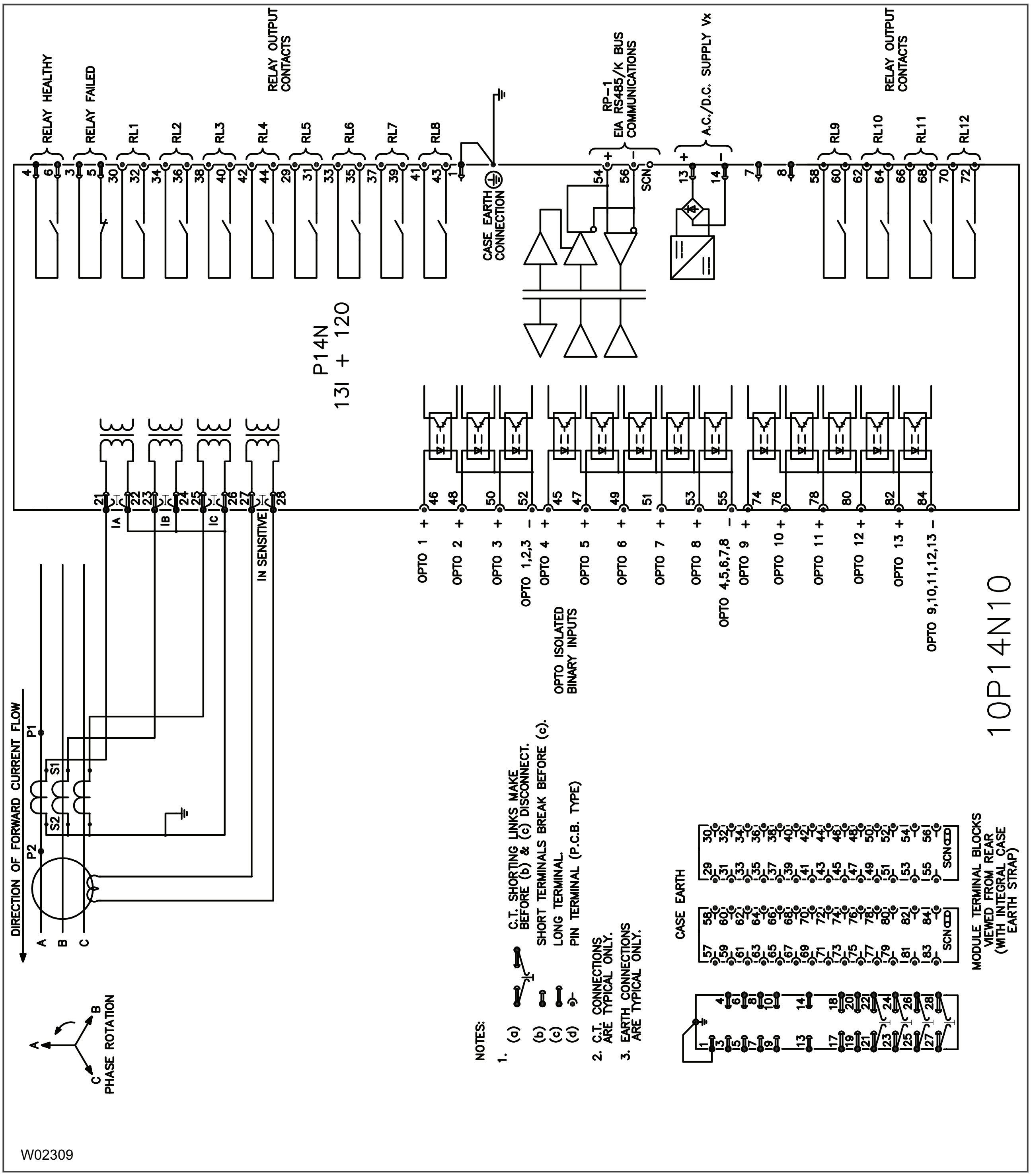


Figure 139: P14N Non-directional IED with 13 inputs, 12 outputs and SEF option

12 KCGG142 RETROFIT

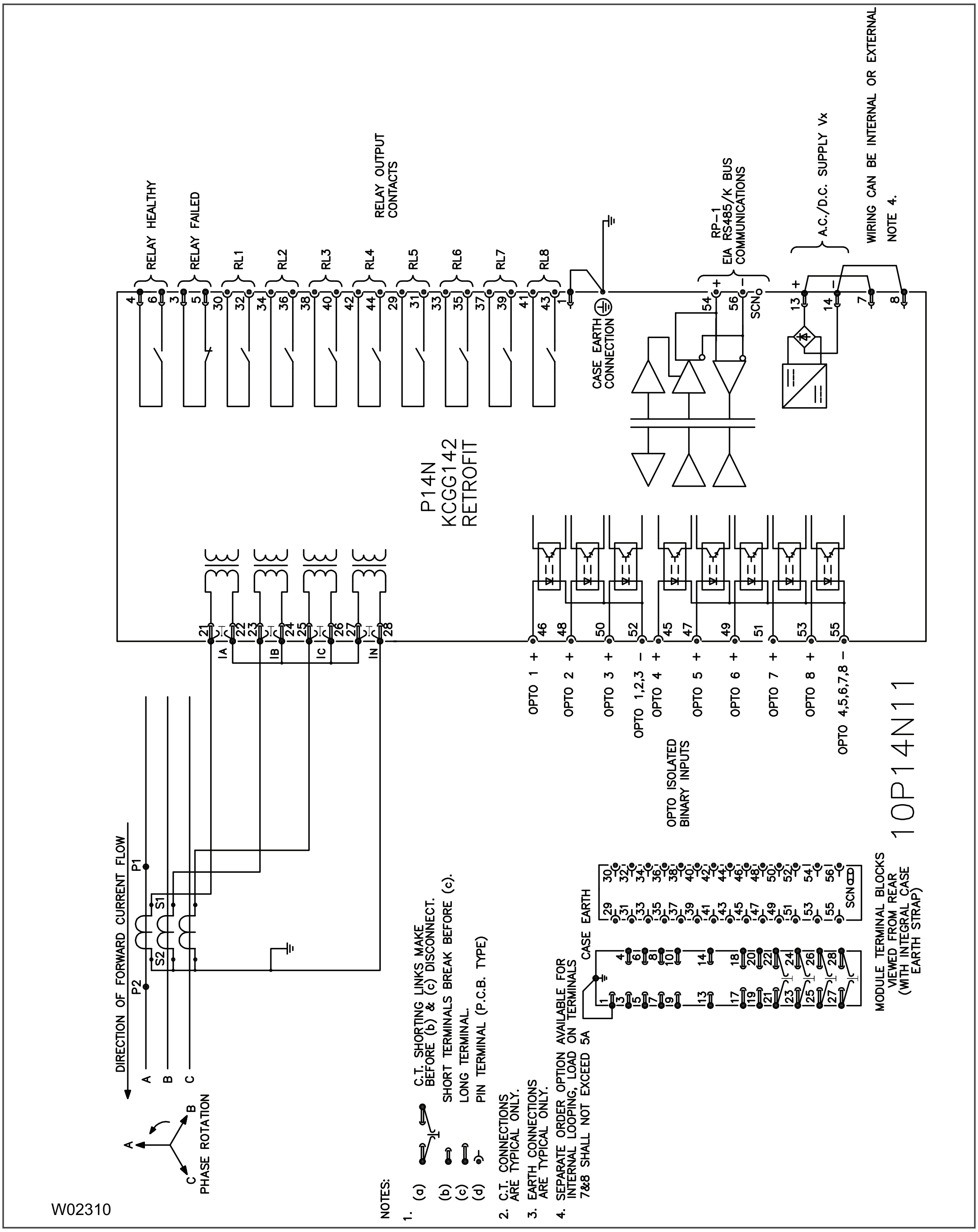


Figure 140: P14N Non-directional IED with 8 inputs and 8 outputs for KCEG142 retrofit applications

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