GE
Grid Solutions

MiCOM P40 Agile

P24DM, P24NM

Technical Manual
Motor Protection IED

Hardware Version: A
Software Version: 62
Publication Reference: P24xM-TM-EN-2.1

Contents

Chapter 4   Software Design   43

Chapter 5   Configuration   53

Chapter 11   Frequency Protection Functions   221

Chapter 14   Supervision   271

Chapter 15   Digital I/O and PSL Configuration   289

Chapter 17   Cyber-Security   363

Table of Figures

CHAPTER 1

INTRODUCTION

1   CHAPTER OVERVIEW

This chapter provides some general information about the technical manual and an introduction to the device(s) described in this technical manual.

This chapter contains the following sections:

2 FOREWORD

This technical manual provides a functional and technical description of General Electric's P24DM, P24NM, as well as a comprehensive set of instructions for using the device. The level at which this manual is written assumes that you are already familiar with protection engineering and have experience in this discipline. The description of principles and theory is limited to that which is necessary to understand the product. For further details on general protection engineering theory, we refer you to General Electric's publication NPAG, which is available online or from our contact centre.

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. Our policy is to provide the information necessary to help you safely specify, engineer, install, commission, maintain, and eventually dispose of this product. We consider that this manual provides the necessary information, but if you consider that more details are needed, please contact us.

All feedback should be sent to our contact centre via:

contact.centre@ge.com

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 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 General Electric. The first instance of any acronym or term used in a particular chapter is explained. In addition, a separate glossary is available on the General Electric website, or from the General Electric contact centre.

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

● The word 'relay' is no longer used to describe the device itself. Instead, the device is referred to as the 'IED' (Intelligent Electronic Device), the 'device', or the 'product'. 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   COMPLIANCE

The device has undergone a range of extensive testing and certification processes to ensure and prove compatibility with all target markets. A detailed description of these criteria can be found in the Technical Specifications chapter.

3   PRODUCT SCOPE

P24xM motor protection IEDs are part of the P40 Agile Series protective relay platform and has been designed for the protection, control and management of medium voltage motors in industrial applications.

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

There are two different P24xM models: P24NM and P24DM.

- The P24NM is a basic motor protection device with current input only
- The P24ND is an advanced motor protection device with current and voltage inputs

All models are available in 20TE, 30TE and 40TE case sizes with a range of Input/Output options, which are described in the hardware design chapter and summarised in the ordering options.

3.1   ORDERING OPTIONS

All current models and variants for this product are defined in an interactive spreadsheet called the CORTEC. This is available on the company website.

Alternatively, you can obtain it via the Contact Centre at:

contact.centre@ge.com

A copy of the CORTEC is also supplied as a static table in the Appendices of this document. However, it should only be used for guidance as it provides a snapshot of the interactive data taken at the time of publication.

4   FEATURES AND FUNCTIONS

4.1   PROTECTION FUNCTIONS

The P24xM models offer the following protection functions:

ANSI	IEC 61850	Protection Function	P24NM	P24DM
50	OcpPTOC	Definite time overcurrent protection	6 stages	6 stages
50N	EfdPTOC	Neutral/earth definite time overcurrent protection Measured and derived (standard EF CT), derived (SEF CT)	4 stages	4 stages
51	OcpPTOC	IDMT overcurrent protection (stages)	3 stages	3 stages
51N	EfdPTOC	Neutral/earth IDMT overcurrent protection	2 stages	2 stages
50/51SEF	SenEftPTOC	Sensitive earth fault	4 stages	4 stages
68		Inrush blocking	Yes	Yes
		Cold load pick up	Yes	Yes
46	NgcPTOC	Negative sequence overcurrent	4 stages	4 stages
		Programmable curves	4 stages	4 stages
67	OcpPTOC	Directional phase overcurrent	No	6 stages
67N	EfdPTOC	Directional neutral overcurrent	No	4 stages
		Sensitive directional earth fault	No	4 stages
		Blocking scheme	Yes	Yes
37		Undercurrent detection (low load)	Yes	Yes
32	RevPowPDOP	Phase directional power (reverse)	No	Yes
49	ThmPTTR	Motor thermal overload	Yes	Yes
50BF	RBRF	CB failure	2 stages	2 stages
66	MotPMSS	Number of starts	Yes	Yes
27	VtpPhsPTUV	Undervoltage	No	3 stages
27V	PsvPTUV	Positive sequence undervoltage	No	2 stages
59	VtpPhsPTOV	Overvoltage	No	3 stages
59V	PsvPTOV	Positive sequence overvoltage	No	2 stages
59N	VtpResPTOV	Residual overvoltage	No	3 stages
47	NgvPTOV	Negative sequence overvoltage	No	2 stages
27Abs	AbsPTUV	Anti-backspin	No	Yes
81O	FrqPTOF	Overfrequency	No	9 stages
81U	FrqPTUF	Underfrequency	No	9 stages
81V	DfpPFRC	Undervoltage blocking of frequency protection	No	Yes
81df/dt		Rate of change of frequency (dv/dt)	No	9 stages
81RF	DfpPFRC	Frequency supervised rate of change of frequency	No	Yes
81RAV	DfpPFRC	Frequency supervised average rate of change of frequency	No	Yes
81R		Frequency Restoration	No	Yes
48/51LR	MotPMRI	Start/Stalled Protection	Yes	Yes
		Emergency restart	Yes	Yes
		Motor reacceleration	No	Yes
PSL		Programmable scheme logic	Yes	Yes
86		Latching output contacts (Lockout)	Yes	Yes

ANSI	IEC 61850	Protection Function	P24NM	P24DM
		Switch status control	Yes	Yes
14		Speed switch input	Yes	Yes
VTS	TVTR	VT supervision	No	Yes
CTS		CT supervision	No	Yes
		DC supply monitoring	Yes	Yes
		CB condition monitoring	Yes	Yes
		Setting groups	4	4

4.2   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		
CT supervision (only for products with VT inputs)		
VT supervision (only for products with VT inputs)	TVTR	

4.3   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

Measurement Function	Details
Time Stamping of Opto-inputs	Yes

4.4   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 single channel Ethernet or dual redundant Ethernet
Serial Protocols available	IEC 60870-5-103, MODBUS, Courier, DNP3
Ethernet Protocols available	IEC 61850, DNP3 over Ethernet, PRP, HSR
Virtual inputs	64
Cyber-security	Yes
Enhanced Studio (S1 Agile)	Yes

5 LOGIC DIAGRAMS

This technical manual contains many logic diagrams, which should help to explain the functionality of the device. Although this manual has been designed to be as specific as possible to the chosen product, it may contain diagrams, which have elements applicable to other products. If this is the case, a qualifying note will accompany the relevant part.

The logic diagrams follow a convention for the elements used, using defined colours and shapes. A key to this convention is provided below. We recommend viewing the logic diagrams in colour rather than in black and white. The electronic version of the technical manual is in colour, but the printed version may not be. If you need coloured diagrams, they can be provided on request by calling the contact centre and quoting the diagram number.

Key:

Energising Quantity	⟶	AND gate	&
Internal Signal		OR gate	1
DDB Signal		XOR gate	XOR
Internal function		NOT gate	
Setting cell		Logic 0	0
Setting value		Timer	
Hardcoded setting		Pulse / Latch	
Measurement Cell		SR Latch	S Q / R
Internal Calculation		SR Latch Reset Dominant	S Q / R_D
Derived setting		Latched on positive edge	↑
HMI key		Inverted logic input	
Connection / Node		Soft switch	1 / 2
Switch		Multiplier	X
Switch		Comparator for detecting undervalues	
Bandpass filter		Comparator for detecting overvalues	

V00063

Figure 1: Key to logic diagrams

6   FUNCTIONAL OVERVIEW
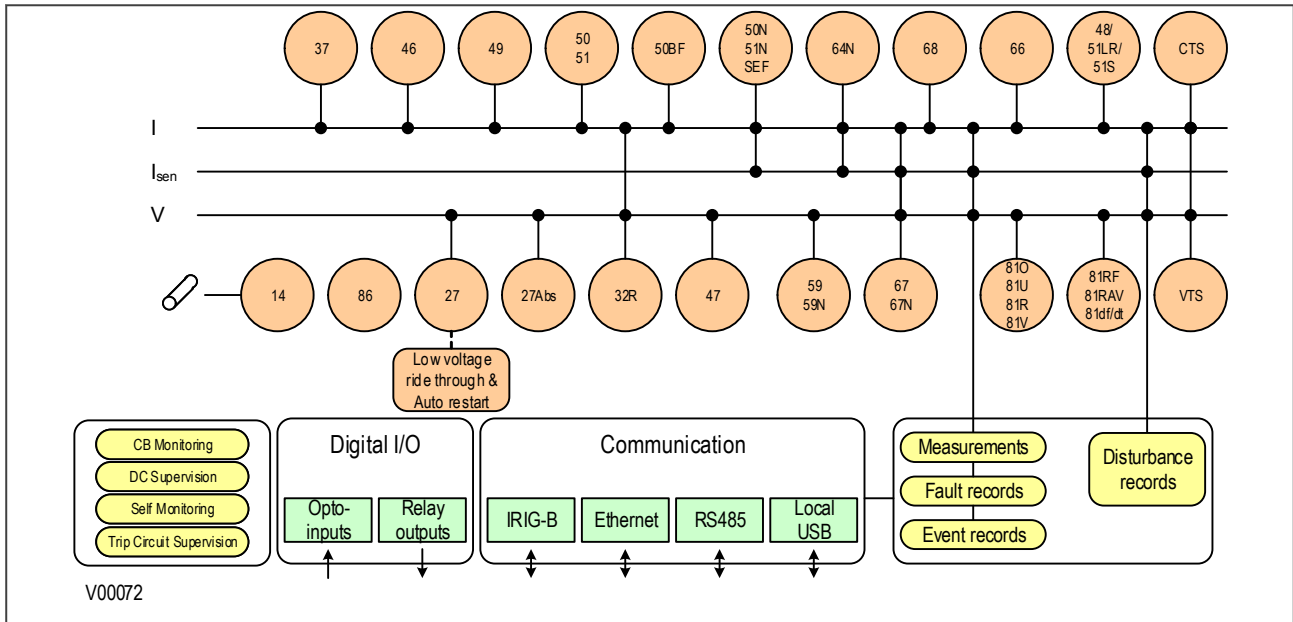
Figure 2: Functional Overview (P24DM)

CHAPTER 2

SAFETY INFORMATION

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.
- familiar with accepted safety engineering practises and are authorised to energise and de-energise equipment in the correct manner.
- trained in the care and use of safety apparatus in accordance with safety engineering practises
- trained in emergency procedures (first aid).

The documentation provides instructions for installing, commissioning and operating the equipment. It cannot, however cover all conceivable circumstances. In the event of questions or problems, do not take any action without proper authorisation. Please contact your local 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**
☀	**Warning:** **Risk of damage to eyesight**
⏚	Earth terminal. *Note: This symbol may also be used for a protective conductor (earth) terminal if that terminal is part of a terminal block or sub-assembly.*
⏚	Protective conductor (earth) terminal
🗑	Instructions on disposal requirements

Note:
The term 'Earth' used in this manual is the direct equivalent of the North American term 'Ground'.

4   INSTALLATION, COMMISSIONING AND SERVICING

4.1   LIFTING HAZARDS

Many injuries are caused by:

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

Plan carefully, identify any possible hazards and determine how best to move the product. Look at other ways of moving the load to avoid manual handling. Use the correct lifting techniques and Personal Protective Equipment (PPE) to reduce the risk of injury.

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 as specified. 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 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.**

	Warning: NEVER look into optical fibres or optical output connections. Always use optical power meters to determine operation or signal level.
	Warning: Testing may leave capacitors charged to dangerous voltage levels. Discharge capacitors by reducing test voltages to zero before disconnecting 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 for the auxiliary supply. 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 the auxiliary supply (for example Red Spot type NIT or TIA). For P50 models, use a 1A maximum T-type fuse. For P60 models, use a 4A maximum T-type fuse.

Caution:
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.

Caution:
CTs must NOT be fused since open circuiting them may produce lethal hazardous voltages

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 mm² for countries whose mains supply is 230 V (e.g. Europe) and 3.3 mm² for countries whose mains supply is 110 V (e.g. North America). This may be superseded by local or country wiring regulations.
> For P60 products, the recommended minimum PCT wire size is 6 mm². See product documentation 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, or connected to a common grouped potential.

4.7   PRE-ENERGISATION 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 General Electric equipment with ring-terminal connections, the threaded terminal block for current transformer termination is automatically shorted if the module is removed. Therefore external shorting of the CTs may not be required. Check the equipment documentation and wiring diagrams 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 P990, as hazardous voltages may be exposed. Ensure that CT shorting links are in place before removing test plugs, to avoid potentially lethal voltages.

Warning:
Data communication cables with accessible screens and/or screen conductors, (including optical fibre cables with metallic elements), may create an electric shock hazard in a sub-station environment if both ends of the cable screen are not connected to the same equipotential bonded earthing system.

To reduce the risk of electric shock due to transferred potential hazards:

i. The installation shall include all necessary protection measures to ensure that no fault currents can flow in the connected cable screen conductor.

ii. The connected cable shall have its screen conductor connected to the protective conductor terminal (PCT) of the connected equipment at both ends. This connection may be inherent in the connectors provided on the equipment but, if there is any doubt, this must be confirmed by a continuity test.

iii. The protective conductor terminal (PCT) of each piece of connected equipment shall be connected directly to the same equipotential bonded earthing system.

iv. If, for any reason, both ends of the cable screen are not connected to the same equipotential bonded earth system, precautions must be taken to ensure that such screen connections are made safe before work is done to, or in proximity to, any such cables.

v. No equipment shall be connected to any download or maintenance circuits or connectors of this product except temporarily and for maintenance purposes only.

vi. Equipment temporarily connected to this product for maintenance purposes shall be protectively earthed (if the temporary equipment is required to be protectively earthed), directly to the same equipotential bonded earthing system as the product.

Warning:
Small Form-factor Pluggable (SFP) modules which provide copper Ethernet connections typically do not provide any additional safety isolation. Copper Ethernet SFP modules must only be used in connector positions intended for this type of connection.

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 and may have sharp edges. 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 decommissioning.

Caution:
Avoid incineration or disposal to water courses. Dispose of the equipment in a safe, responsible and environmentally friendly manner, and if applicable, in accordance with country-specific regulations.

6   REGULATORY COMPLIANCE

Compliance with the European Commission Directive on EMC and LVD is demonstrated using a technical file.

$$C\!\in$$

6.1   EMC COMPLIANCE: 2014/30/EU

The product specific Declaration of Conformity (DoC) lists the relevant harmonised standard(s) or conformity assessment used to demonstrate compliance with the EMC directive.

6.2   LVD COMPLIANCE: 2014/35/EU

The product specific Declaration of Conformity (DoC) lists the relevant harmonized standard(s) or conformity assessment used to demonstrate compliance with the LVD directive.

Safety related information, such as the installation I overvoltage category, pollution degree and operating temperature ranges are specified in the Technical Data section of the relevant product documentation and/or on the product labelling.

Unless otherwise stated in the Technical Data section of the relevant product documentation, the equipment is intended for indoor use only. Where the equipment is required for use in an outdoor location, it must be mounted in a specific cabinet or housing to provide the equipment with the appropriate level of protection from the expected outdoor environment.

6.3   R&TTE COMPLIANCE: 2014/53/EU

Radio and Telecommunications Terminal Equipment (R&TTE) directive 2014/53/EU.

Conformity is demonstrated by compliance to both the EMC directive and the Low Voltage directive, to zero volts.

6.4   UL/CUL COMPLIANCE

If marked with this logo, the product is compliant with the requirements of the Canadian and USA Underwriters Laboratories.

The relevant UL file number and ID is shown on the equipment.

$$_{c}\!\langle\!U\!L\!\rangle_{US}$$

6.5   ATEX COMPLIANCE: 2014/34/EU

Products marked with the 'explosion protection' Ex symbol (shown in the example, below) are compliant with the ATEX directive. The product specific Declaration of Conformity (DoC) lists the Notified Body, Type Examination Certificate, and relevant harmonized standard or conformity assessment used to demonstrate compliance with the ATEX directive.

The ATEX Equipment Protection level, Equipment group, and Zone definition will be marked on the

product.

For example:

$$\langle\!\mathcal{E}\!x\!\rangle \ \text{II (2) G}$$

Where:

'II'   Equipment Group: Industrial.

'(2)G'   High protection equipment category, for control of equipment in gas atmospheres in Zone 1 and 2. This equipment (with parentheses marking around the zone number) is not itself suitable for operation within a potentially explosive atmosphere.

CHAPTER 3

HARDWARE DESIGN

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.
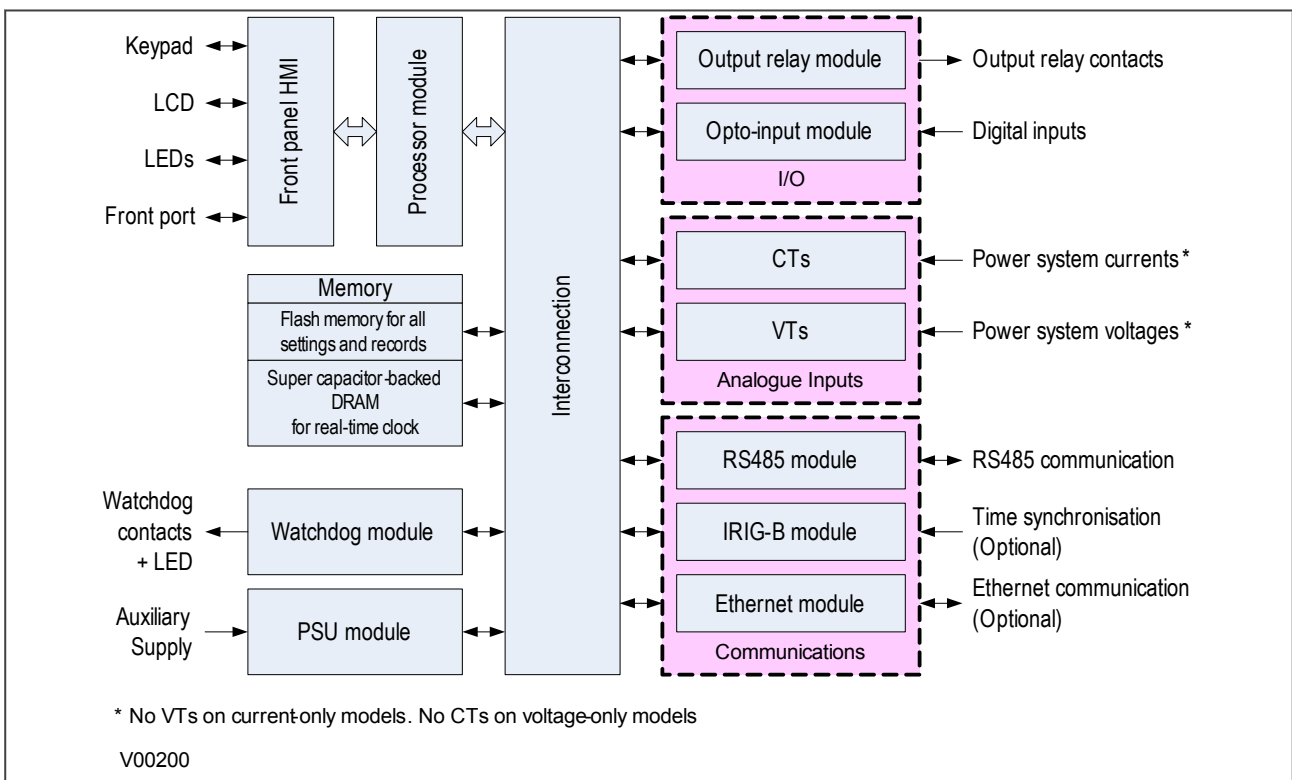
Figure 3: Hardware design overview

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.

R00201
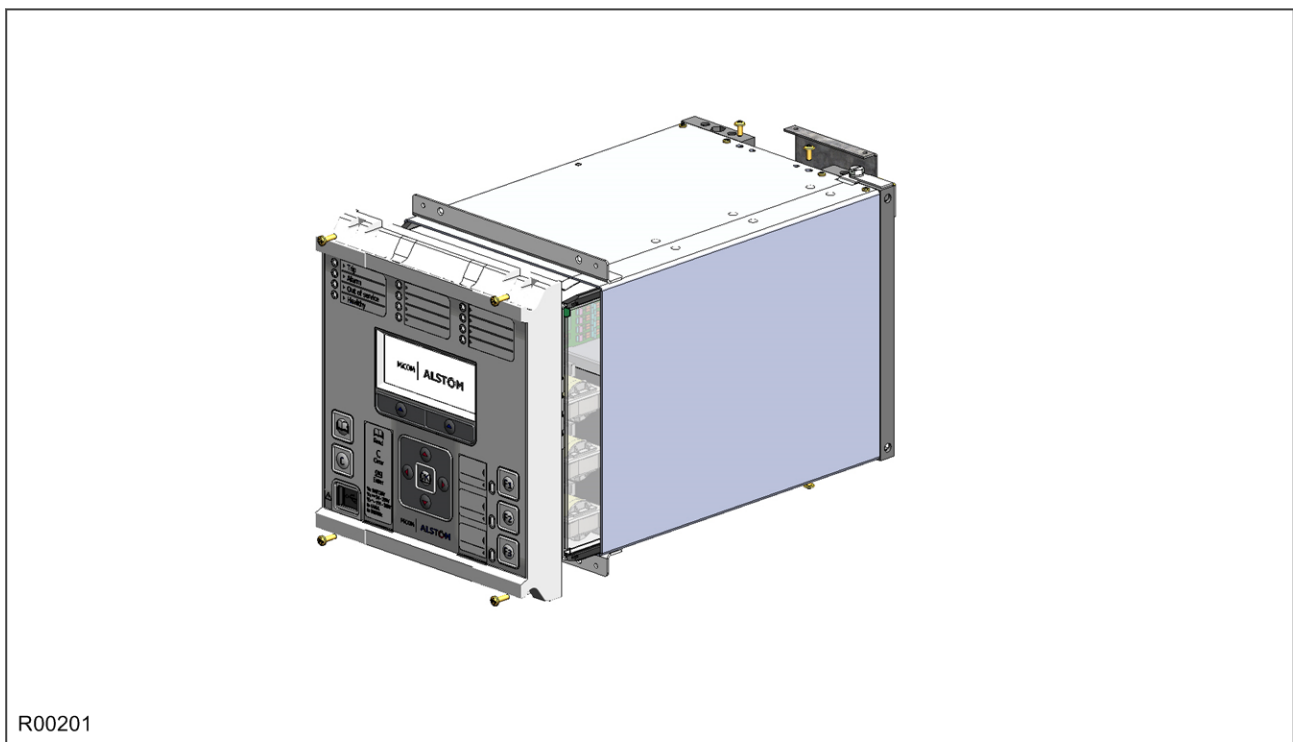
Figure 4: Exploded view of IED

3.1   HOUSING VARIANTS

The P40 Agile range of products are implemented in one of three 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 three different case widths for the described range of products: 20TE, 30TE and 40TE. 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
20TE	102.4 mm (4 inches)	KCGG140/142
30TE	154.2 mm (6 inches)	KCEG140/142
40TE	203.2 mm (8 inches)	KCEG140/142

3.2   20TE REAR PANEL

The 20TE rear panel consists of two MIDOS heavy duty terminal blocks.
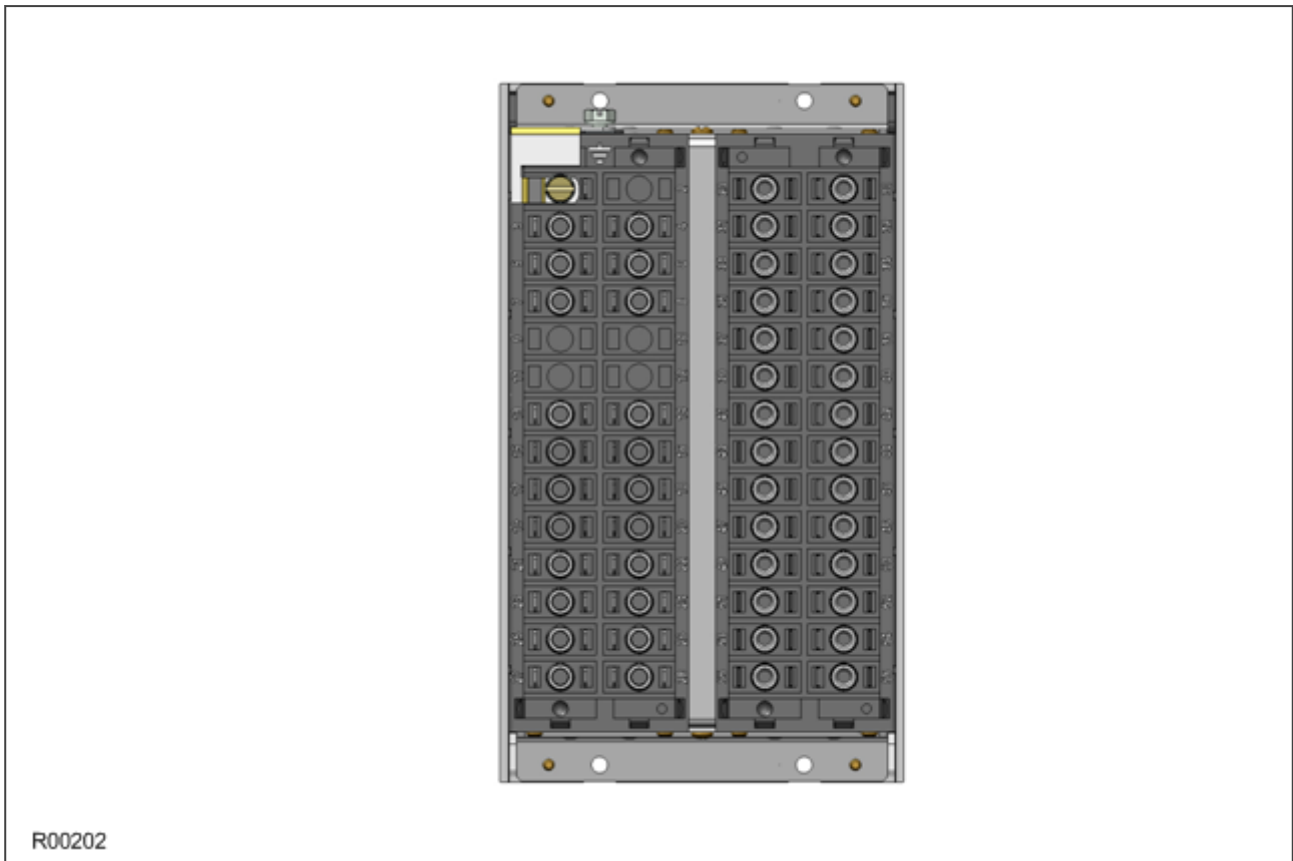
Figure 5: 20TE rear panel

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

R00203
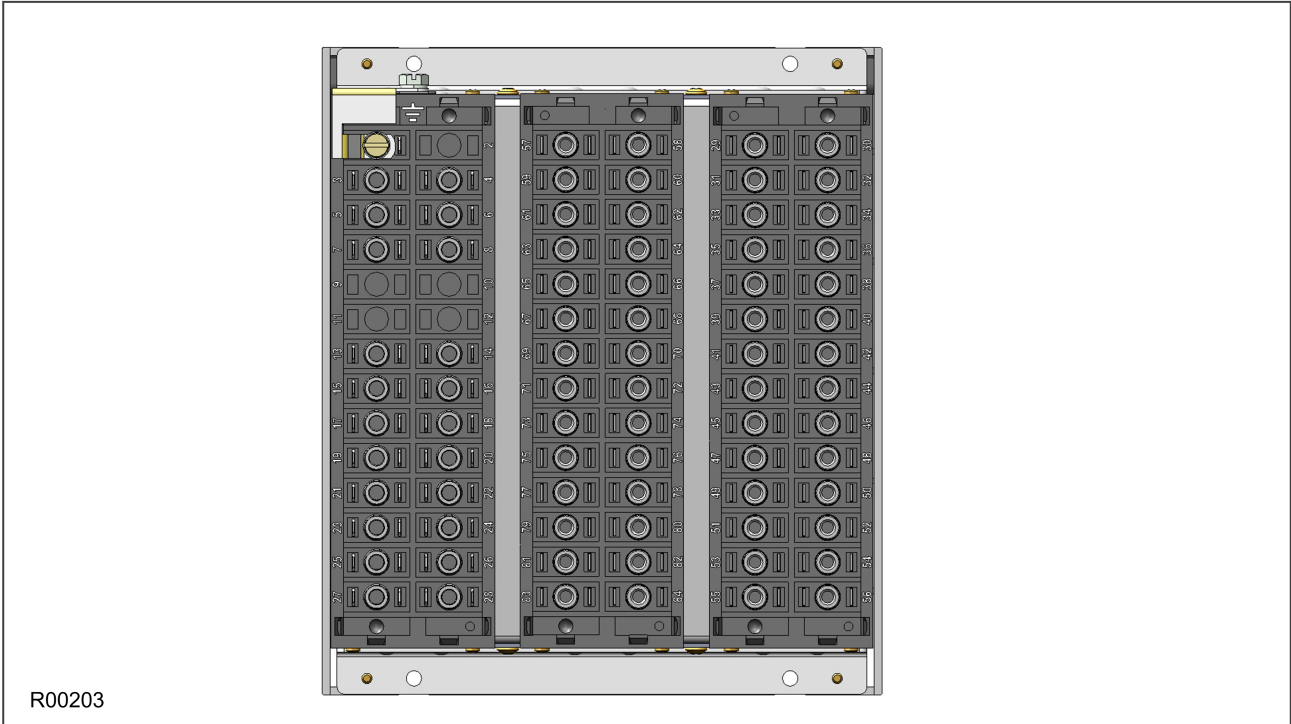
Figure 6: 30TE Three-MIDOS block rear panel

R00204
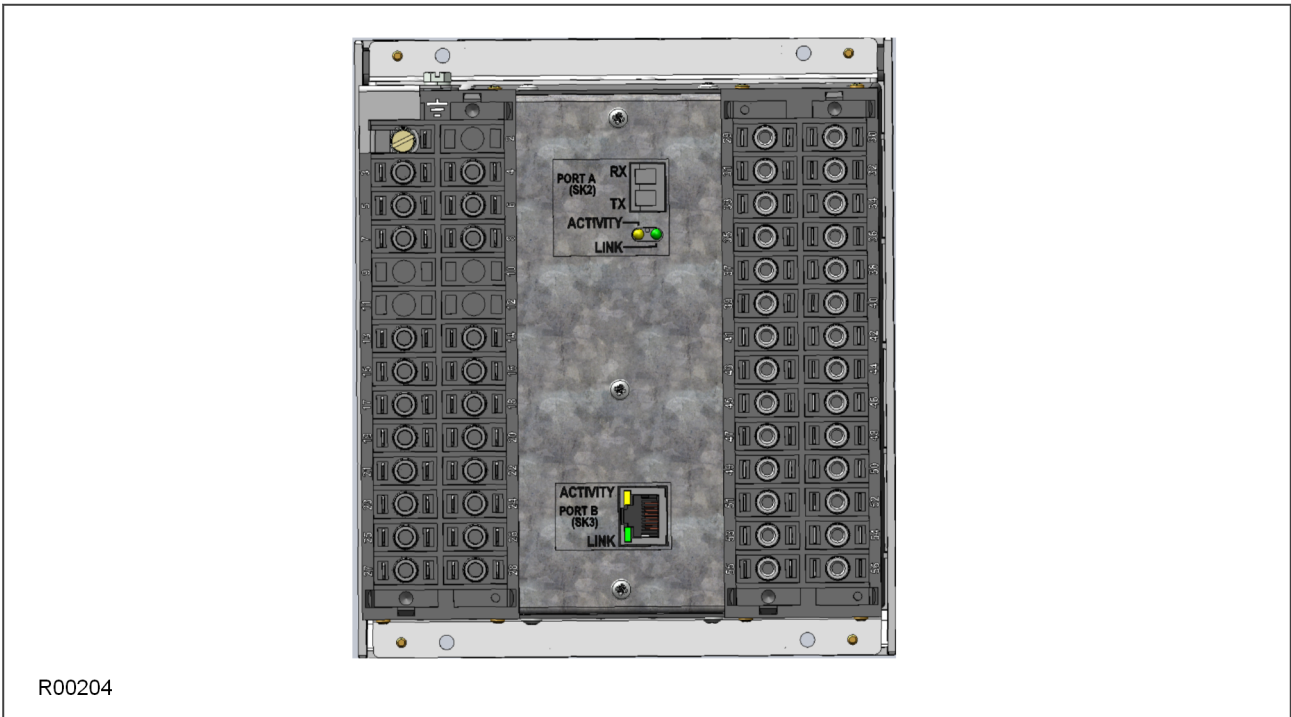
Figure 7: 30TE Two-MIDOS block + communications rear panel
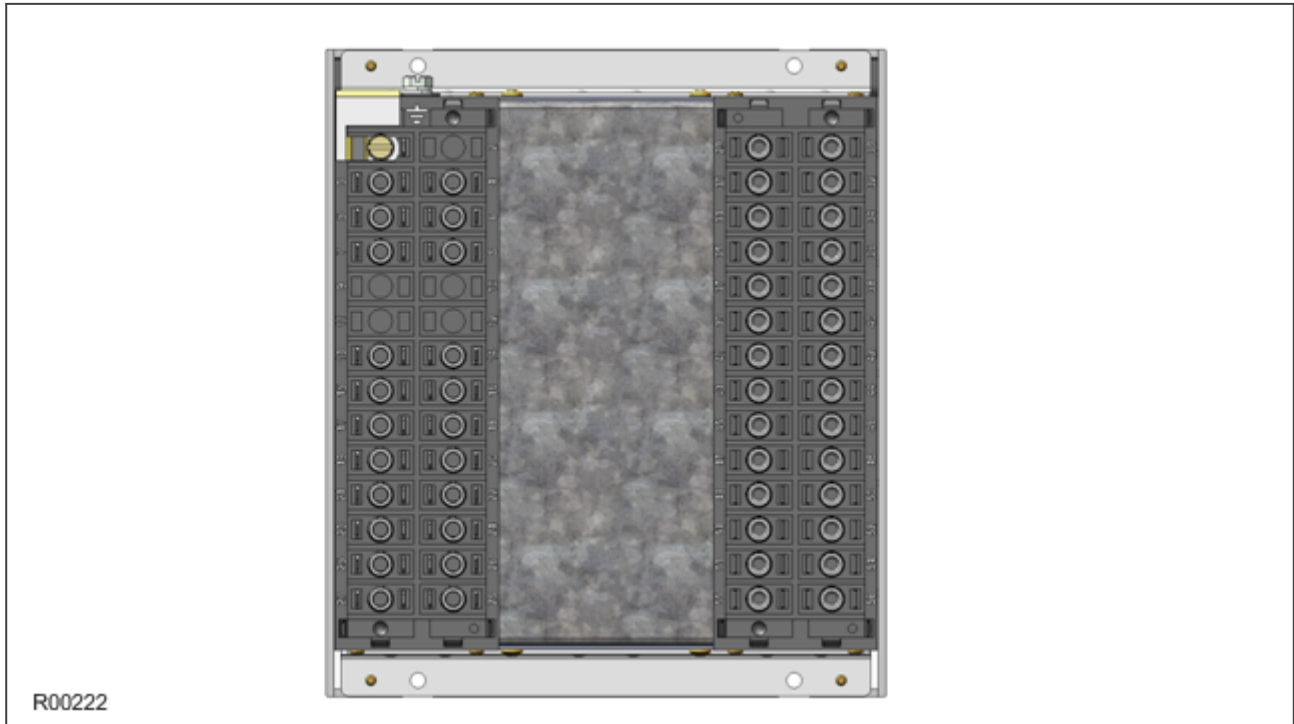
Figure 8: 30TE Two-MIDOS block + blanking plate

3.4   40TE REAR PANEL

The 40TE rear panel consists of:

- Three MIDOS heavy duty terminal blocks and a communication board
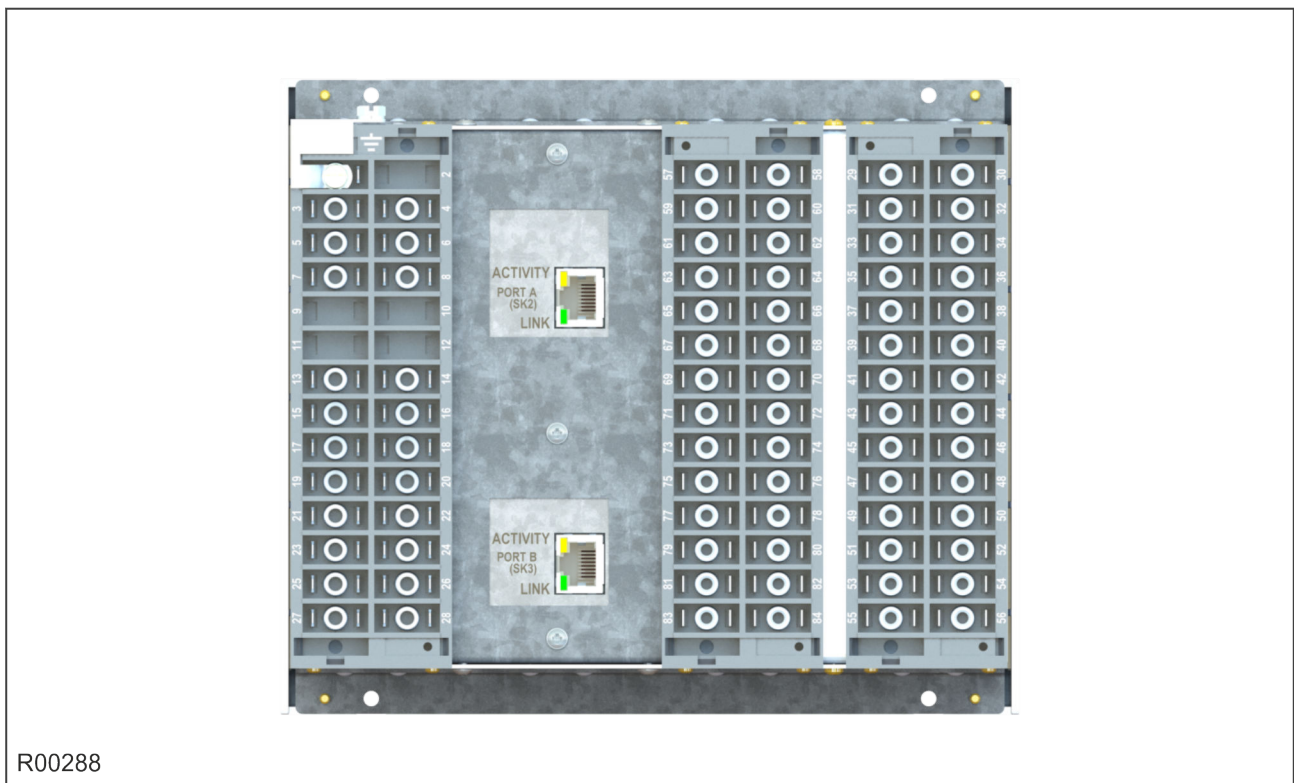
Figure 9: 40TE Three-MIDOS block + communications rear panel

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	I/O option E	I/O option F	I/O option G	I/O option H	I/O option J
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)	3 (1 group of 3)	6 (1 group of 3 and 3 individual)	7 1 group of 5 and 2 individual)	10 1 group of 3, 1 group of 5 and 2 individual)	12 (2 groups of 5 and 2 individual)
Output relays	8 (NO)	12 (NO)	12 (11 NO, 1 NC)	12 (NO)	4 (NO)	8 (7 NO, 1 NC)	8 (NO)	12 (NO)	12 (NO)

> *Note:*
> *I/O options C, F, G, H and J are suitable for Trip Circuit Supervision (TCS) applications.*

> *Note:*
> *For details of terminal connections, refer to the Wiring Diagrams Appendix.*

5   FRONT PANEL

5.1   20TE FRONT PANEL

Figure 10: 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

Figure 11: 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 40TE FRONT PANEL

R00289

Figure 12: Front panel (40TE)

The figure shows the front panel for the 40TE 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

5.4 KEYPAD

The keypad consists of the following keys:

4 arrow keys to navigate the menus (organised around the Enter key)	
An enter key for executing the chosen option	

A clear key for clearing the last command	C
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. These are situated directly below the LCD display.	▲

5.5   LIQUID CRYSTAL DISPLAY

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

5.6   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.

5.7   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 functions are 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.

5.8   FUNCTION KEYS

The programmable function keys are available for custom use for some models.

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 LEDs, which are usually set to be associated with their respective function keys.

5.9   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 and 40TE, eight are available.

CHAPTER 4

SOFTWARE DESIGN

1   CHAPTER OVERVIEW

This chapter describes the software design of the IED.

This chapter contains the following sections:

2   SOFTWARE DESIGN OVERVIEW

The range of products based on the <platform> platform can be conceptually categorised into several elements as follows:

- The system level software
- The platform software
- The protection and control software

These elements are not distinguishable to the user, and the distinction is made purely for the purposes of explanation.
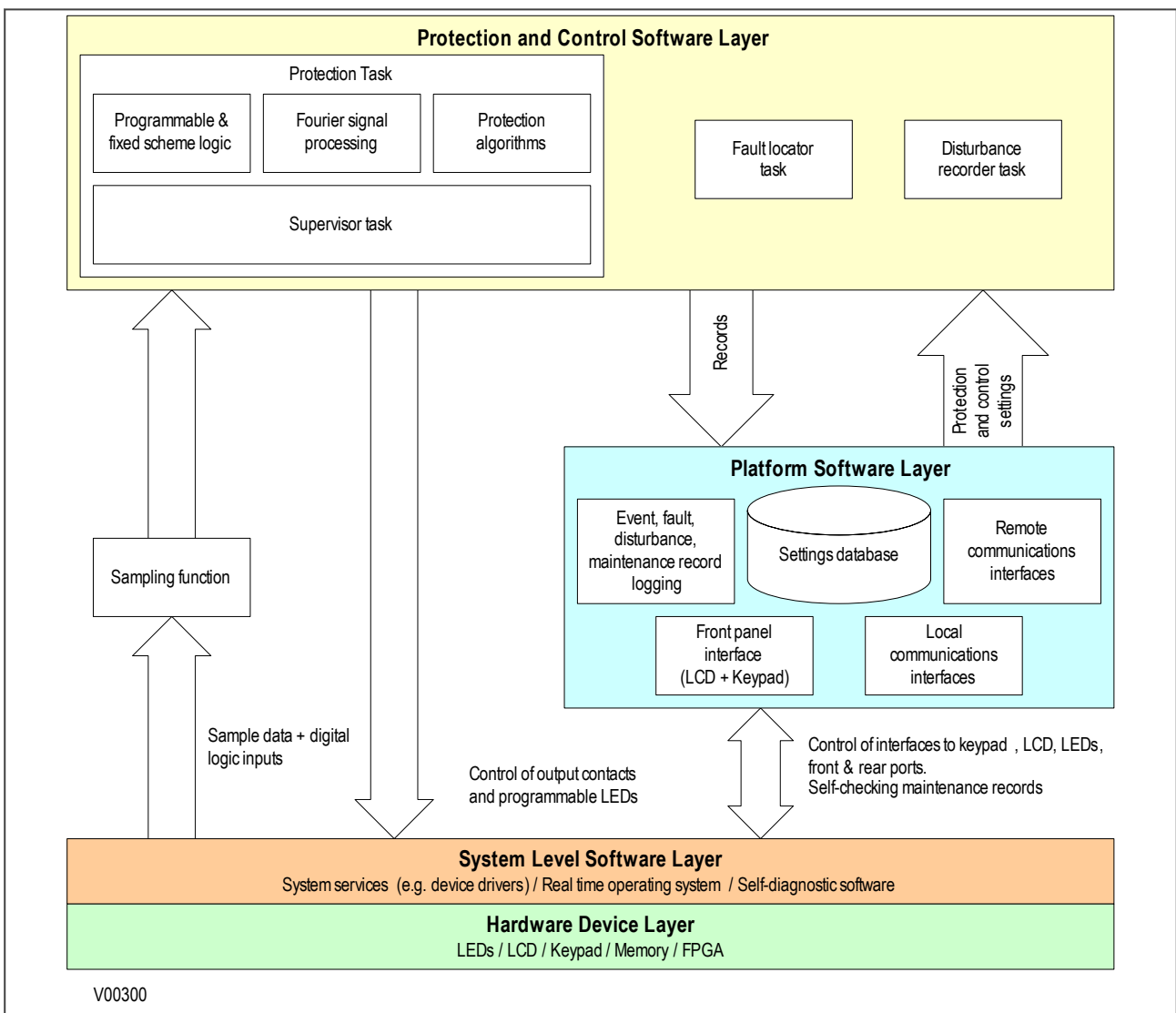
Figure 13: Software structure

The software can be divided into a number of functions as illustrated above. Each function is further broken down into a number of separate tasks. These tasks are then run according to a scheduler. They are run at either a fixed rate or they are event driven. The tasks communicate with each other as required.

3   SYSTEM LEVEL SOFTWARE

3.1   REAL TIME OPERATING SYSTEM

The real-time operating system is used to schedule the processing of the various tasks. This ensures that they are processed in the time available and in the desired order of priority. The operating system also plays a part in controlling the communication between the software tasks.

3.2   SYSTEM SERVICES SOFTWARE

The system services software provides the layer between the hardware and the higher-level functionality of the platform software and the protection and control software. For example, the system services software provides drivers for items such as the LCD display, the keypad and the remote communication ports. It also controls things like the booting of the processor and the downloading of the processor code into RAM at startup.

3.3   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.

3.4   STARTUP SELF-TESTING

The self-testing takes a few seconds to complete, during which time the IED's measurement, recording, control, and protection functions are unavailable. On a successful start-up and self-test, the 'health-state' LED on the front of the unit is switched on. If a problem is detected during the start-up testing, the device remains out of service until it is manually restored to working order.

The operations that are performed at start-up are:

1.   System boot
2.   System software initialisation
3.   Platform software initialisation and monitoring

3.4.1   SYSTEM BOOT

The integrity of the Flash memory is verified using a checksum before the program code and stored data is loaded into RAM for execution by the processor. When the loading has been completed, the data held in RAM is compared to that held in the Flash memory to ensure that no errors have occurred in the data transfer and that the two are the same. The entry point of the software code in RAM is then called. This is the IED's initialisation code.

3.4.2 SYSTEM LEVEL SOFTWARE INITIALISATION

The initialization process initializes the processor registers and interrupts, starts the watchdog timers (used by the hardware to determine whether the software is still running), starts the real-time operating system and creates and starts the supervisor task. In the initialization process the device checks the following:

- The status of the supercapacitor (which is used to back up the SRAM)
- The integrity of the non-volatile memory, which is used to store event, fault and disturbance records
- The operation of the LCD controller
- The watchdog operation

At the conclusion of the initialization software the supervisor task begins the process of starting the platform software.

3.4.3 PLATFORM SOFTWARE INITIALISATION AND MONITORING

When starting the platform software, the IED checks the following:

- The integrity of the data held in non-volatile memory (using a checksum)
- The operation of the real-time clock
- The optional IRIG-B function (if applicable)
- The presence and condition of the input board
- The analog data acquisition system (it does this by sampling the reference voltage)

At the successful conclusion of all of these tests the unit is entered into service and the application software is started up.

3.5 CONTINUOUS SELF-TESTING

When the IED is in service, it continually checks the operation of the critical parts of its hardware and software. The checking is carried out by the system services software and the results are reported to the platform software. The functions that are checked are as follows:

- The Flash memory containing all program code and language text is verified by a checksum
- The code and constant data held in system memory is checked against the corresponding data in Flash memory to check for data corruption
- The system memory containing all data other than the code and constant data is verified with a checksum
- The integrity of the digital signal I/O data from the opto-isolated inputs and the output relay coils is checked by the data acquisition function every time it is executed.
- The operation of the analog data acquisition system is continuously checked by the acquisition function every time it is executed. This is done by sampling the reference voltages
- The operation of the optional Ethernet board is checked by the software on the main processor card. If the Ethernet board fails to respond an alarm is raised and the card is reset in an attempt to resolve the problem.
- The operation of the optional IRIG-B function is checked by the software that reads the time and date from the board

In the event that one of the checks detects an error in any of the subsystems, the platform software is notified and it attempts to log a maintenance record.

If the problem is with the supercapacitor or IRIG-B board, the device continues in operation. For problems detected in any other area, the device initiates a shutdown and re-boot, resulting in a period of up to 10 seconds when the functionality is unavailable.

A restart should clear most problems that may occur. If, however, the diagnostic self-check detects the same problem that caused the IED to restart, it is clear that the restart has not cleared the problem, and the device takes itself permanently out of service. This is indicated by the "health-state' LED on the front of the device, which switches OFF, and the watchdog contact which switches ON.

4   PLATFORM SOFTWARE

The platform software has three main functions:

- To control the logging of records generated by the protection software, including alarms, events, faults, and maintenance records
- To store and maintain a database of all of the settings in non-volatile memory
- To provide the internal interface between the settings database and the user interfaces, using the front panel interface and the front and rear communication ports

4.1   RECORD LOGGING

The logging function is used to store all alarms, events, faults and maintenance records. The records are stored in non-volatile memory to provide a log of what has happened. The IED maintains four types of log on a first in first out basis (FIFO). These are:

- Alarms
- Event records
- Fault records
- Maintenance records

The logs are maintained such that the oldest record is overwritten with the newest record. The logging function can be initiated from the protection software. The platform software is responsible for logging a maintenance record in the event of an IED failure. This includes errors that have been detected by the platform software itself or errors that are detected by either the system services or the protection software function. See the Monitoring and Control chapter for further details on record logging.

4.2   SETTINGS DATABASE

The settings database contains all the settings and data, which are stored in non-volatile memory. The platform software manages the settings database and ensures that only one user interface can modify the settings at any one time. This is a necessary restriction to avoid conflict between different parts of the software during a setting change.

Changes to protection settings and disturbance recorder settings, are first written to a temporary location SRAM memory. This is sometimes called 'Scratchpad' memory. These settings are not written into non-volatile memory immediately. This is because a batch of such changes should not be activated one by one, but as part of a complete scheme. Once the complete scheme has been stored in SRAM, the batch of settings can be committed to the non-volatile memory where they will become active.

4.3   INTERFACES

The settings and measurements database must be accessible from all of the interfaces to allow read and modify operations. The platform software presents the data in the appropriate format for each of the interfaces (LCD display, keypad and all the communications interfaces).

5   PROTECTION AND CONTROL FUNCTIONS

The protection and control software processes all of the protection elements and measurement functions. To achieve this it has to communicate with the system services software, the platform software as well as organise its own operations.

The protection task software has the highest priority of any of the software tasks in the main processor board. This ensures the fastest possible protection response.

The protection and control software provides a supervisory task, which controls the start-up of the task and deals with the exchange of messages between the task and the platform software.

5.1   ACQUISITION OF SAMPLES

After initialization, the protection and control task waits until there are enough samples to process. The acquisition of samples on the main processor board is controlled by a 'sampling function' which is called by the system services software.

This sampling function takes samples from the input module and stores them in a two-cycle FIFO buffer. The sample rate is 24 samples per cycle. This results in a nominal sample rate of 1,200 samples per second for a 50 Hz system and 1,440 samples per second for a 60 Hz system. However the sample rate is not fixed. It tracks the power system frequency as described in the next section.

5.2   FREQUENCY TRACKING

The device provides a frequency tracking algorithm so that there are always 24 samples per cycle irrespective of frequency drift within a certain frequency range (see technical specifications). If the frequency falls outside this range, the sample rate reverts to its default rate of 1200 Hz for 50 Hz or 1440 Hz for 60 Hz.

The frequency tracking of the analog input signals is achieved by a recursive Fourier algorithm which is applied to one of the input signals. It works by detecting a change in the signal's measured phase angle. The calculated value of the frequency is used to modify the sample rate being used by the input module, in order to achieve a constant sample rate per cycle of the power waveform. The value of the tracked frequency is also stored for use by the protection and control task.

The frequency tracks off any voltage or current in the order VA, VB, VC, IA, IB, IC, down to 10%Vn for voltage and 5%In for current.

5.3   FOURIER SIGNAL PROCESSING

When the protection and control task is re-started by the sampling function, it calculates the Fourier components for the analog signals. Although some protection algorithms use some Fourier-derived harmonics (e.g. second harmonic for magnetizing inrush), most protection functions are based on the Fourier-derived fundamental components of the measured analog signals. The Fourier components of the input current and voltage signals are stored in memory so that they can be accessed by all of the protection elements' algorithms.

The Fourier components are calculated using single-cycle Fourier algorithm. This Fourier algorithm always uses the most recent 24 samples from the 2-cycle buffer.

Most protection algorithms use the fundamental component. In this case, the Fourier algorithm extracts the power frequency fundamental component from the signal to produce its magnitude and phase angle. This can be represented in either polar format or rectangular format, depending on the functions and algorithms using it.

The Fourier function acts as a filter, with zero gain at DC and unity gain at the fundamental, but with good harmonic rejection for all harmonic frequencies up to the nyquist frequency. Frequencies beyond this nyquist frequency are known as alias frequencies, which are introduced when the sampling frequency becomes less than twice the frequency component being sampled. However, the Alias frequencies are significantly attenuated by an anti-aliasing filter (low pass filter), which acts on the analog signals before they are sampled. The ideal cut-off point of an anti-aliasing low pass filter would be set at:

(samples per cycle) × (fundamental frequency)/2

At 24 samples per cycle, this would be nominally 600 Hz for a 50 Hz system, or 720 Hz for a 60 Hz system.

The following figure shows the nominal frequency response of the anti-alias filter and the Fourier filter for a 24-sample single cycle fourier algorithm acting on the fundamental component:
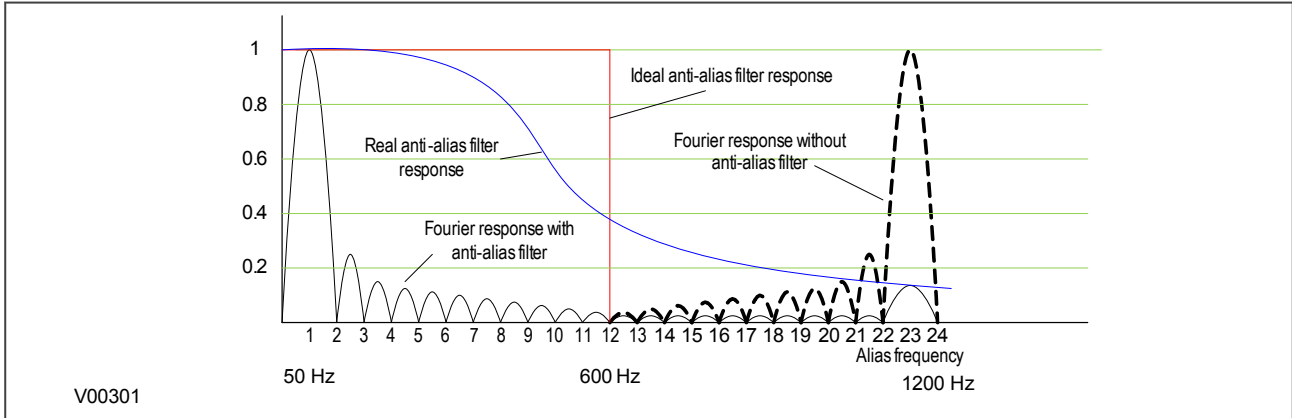
Figure 14: Frequency Response (indicative only)

5.4 PROGRAMMABLE SCHEME LOGIC

The purpose of the programmable scheme logic (PSL) is to allow you to configure your own protection schemes to suit your particular application. This is done with programmable logic gates and delay timers. To allow greater flexibility, different PSL is allowed for each of the four setting groups.

The input to the PSL is any combination of the status of the digital input signals from the opto-isolators on the input board, the outputs of the protection elements such as protection starts and trips, and the outputs of the fixed protection scheme logic (FSL). The fixed scheme logic provides the standard protection schemes. The PSL consists of software logic gates and timers. 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, and/or to condition the logic outputs, such as to create a pulse of fixed duration on the output regardless of the length of the pulse on the input. The outputs of the PSL are the LEDs on the front panel of the relay and the output contacts at the rear.

The execution of the PSL logic is event driven. The logic is processed whenever any of its inputs change, for example as a result of a change in one of the digital input signals or a trip output from a protection element. Also, 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 that is used by the PSL. The protection & control software updates the logic delay timers and checks for a change in the PSL input signals every time it runs.

The PSL can be configured to create very complex schemes. Because of this PSL desing is achieved by means of a PC support package called the PSL Editor. This is available as part of the settings application software MiCOm S1 Agile, or as a standalone software module.

5.5 EVENT RECORDING

A change in any digital input signal or protection element output signal is used to indicate that an event has taken place. When this happens, the protection and control task sends a message to the supervisor task to indicate that an event is available to be processed and writes the event data to a fast buffer controlled by the supervisor task. When the supervisor task receives an event record, it instructs the platform software to create the appropriate log in non-volatile memory (flash memory). The operation of the record logging to SRAM is slower than the supervisor buffer. This means that the protection software is not delayed waiting for the records to be logged by the platform software. However, in the rare case when a large number of records to be logged are created in a short period of time, it is possible that some will be lost, if the supervisor buffer is full before the platform software is able to create a new log in SRAM. If this occurs then an event is logged to indicate this loss of information.

Maintenance records are created in a similar manner, with the supervisor task instructing the platform software to log a record when it receives a maintenance record message. However, it is possible that a maintenance record may be triggered by a fatal error in the relay in which case it may not be possible to successfully store a maintenance record, depending on the nature of the problem.

For more information, see the Monitoring and Control chapter.

5.6   DISTURBANCE RECORDER

The disturbance recorder operates as a separate task from the protection and control task. It can record the waveforms of the calibrated analog channels, plus the values of the digital signals. The recording time is user selectable up to a maximum of 10.5 seconds. The disturbance recorder is supplied with data by the protection and control task once per cycle, and collates the received data into the required length disturbance record. The disturbance records can be extracted using application software or the SCADA system, which can also store the data in COMTRADE format, allowing the use of other packages to view the recorded data.

For more information, see the Monitoring and Control chapter.

5.7   FUNCTION KEY INTERFACE

The function keys interface directly into the PSL as digital input signals. A change of state is only recognized when a key press is executed on average for longer than 200 ms. The time to register a change of state depends on whether the function key press is executed at the start or the end of a protection task cycle, with the additional hardware and software scan time included. A function key press can provide a latched (toggled mode) or output on key press only (normal mode) depending on how it is programmed. It can be configured to individual protection scheme requirements. The latched state signal for each function key is written to non-volatile memory and read from non-volatile memory during relay power up thus allowing the function key state to be reinstated after power-up, should power be inadvertently lost.

CHAPTER 5

CONFIGURATION

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.

Some of the communications setup can only be carried out using the HMI, and cannot be carried out using settings applications software. This chapter includes concise instructions of how to configure the device, particularly with respect to the communications setup, as well as a description of the common methodology used to configure the device in general.

This chapter contains the following sections:

2   SETTINGS APPLICATION SOFTWARE

To configure this device you will need to use 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 setting up and managing the IEDs.

Although you can change many settings using the front panel HMI, some of the features cannot be configured without the Settings Application Software; for example the programmable scheme logic, or IEC61850 communications.

If you do not already have a copy of the Settings Application Software, you can obtain it from General Electric contact centre.

To configure your product, you will need a data model that matches your product. When you launch the Settings Application Software, you will be presented with a panel that allows you to invoke the "Data Model Manager". This will close the other aspects of the software in order to allow an efficient import of the chosen data model. If you don't have, or can't find, the data model relating to your product, please call the General Electric contact centre.

When you have loaded all the data models you need, you should restart the Settings Application Software and start to create a model of your system using the "System Explorer" panel.
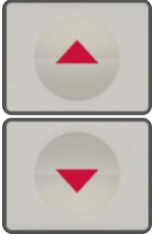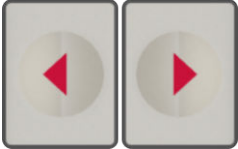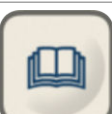
The software is designed to be intuitive, but help is available in an online help system and also the Settings Application Software user guide P40-M&CR-SAS-UG-EN-n, where 'Language' is a 2 letter code designating the language version of the user guide and 'n' is the latest version of the settings application software.

3   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 all models)	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.*

3.1 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.
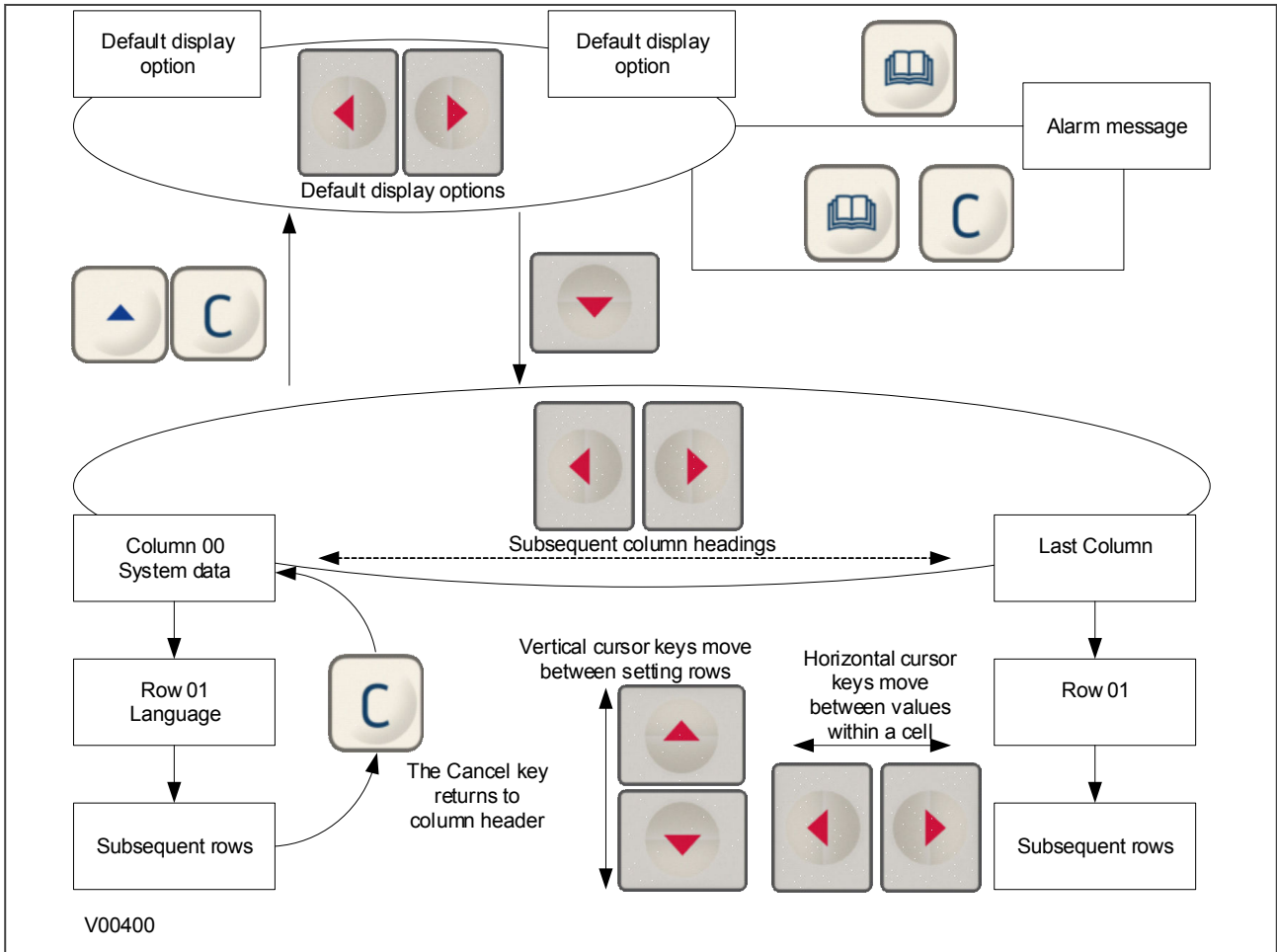
Figure 15: Navigating the HMI

3.2 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, you will first need to connect the device to an active Ethernet network to clear the alarm and get the default display.

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

3.3 DEFAULT DISPLAY

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

NERC Compliant banner

If the device is a cyber-security model, it will provide a NERC-compliant default display. If the device does not contain the cyber-security option, this display option is not available.

```
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.

3.4 DEFAULT DISPLAY NAVIGATION

The following diagram is an example of the default display navigation. In this example, we have used a cyber-secure model. This is an example only and may not apply in its entirety to all models. The actual display options available depend on the exact model.

Use the horizontal cursor keys to step through from one display to the next.
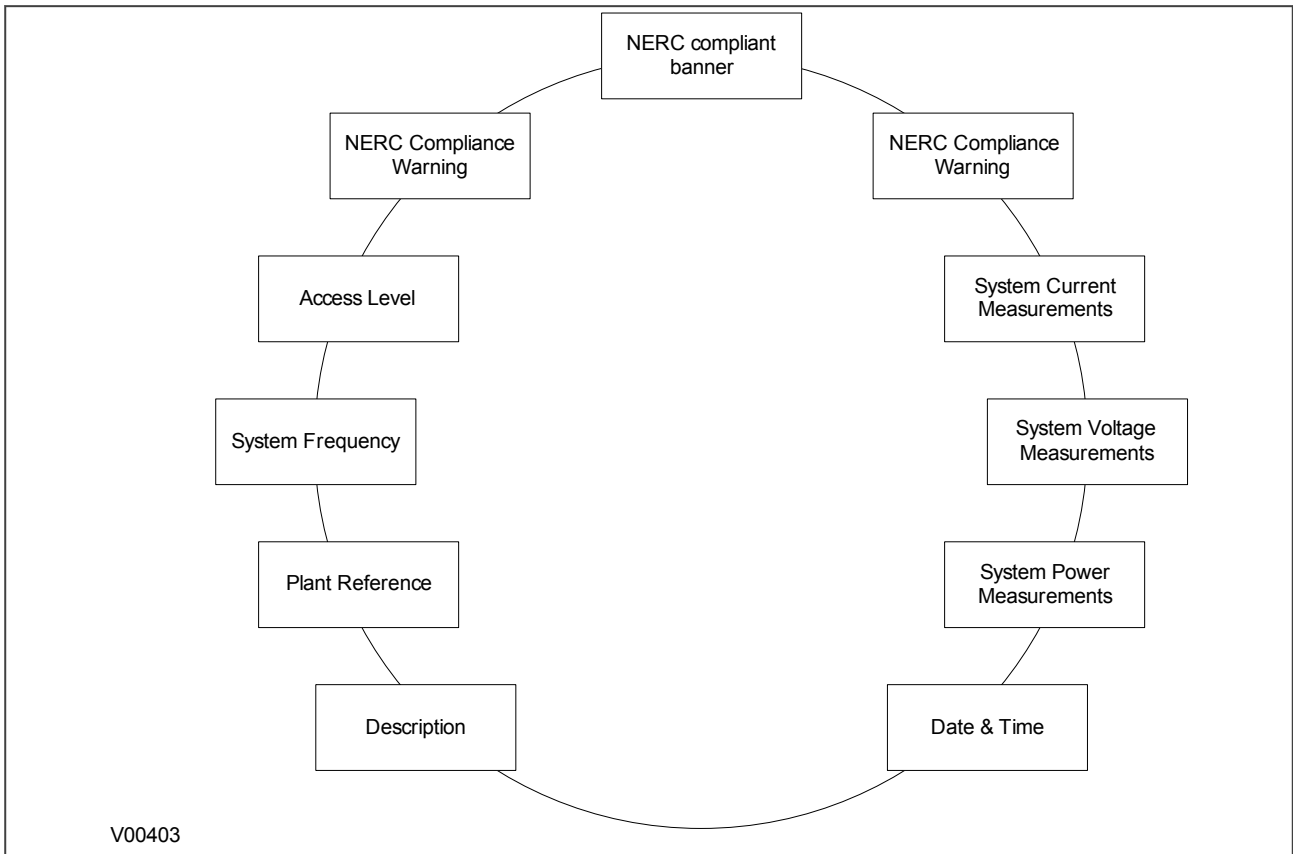
Figure 16: Default display navigation

If the device is cyber-secure but 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.

3.5   PASSWORD ENTRY

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

```
Enter Password
```

1.   A flashing cursor shows which character field of the password can be changed. Press the up or down cursor keys to change each character (tip: pressing the up arrow once will return an upper case "A" as required by the default level 3 password).

2.   Use the left and right cursor keys to move between the character fields of the password.

3.   Press the **Enter** key to confirm the password. If you enter an incorrect password, an invalid password message is displayed then the display reverts to *Enter password*. 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.

3.6   PROCESSING ALARMS AND 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.*

3.7   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
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.

3.8   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 horizontal 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:*
> *For the protection group and disturbance recorder settings, if the menu time-out occurs before the changes have been confirmed, the setting values are discarded. Control and support settings, howeverr, are updated immediately after they are entered, without the* ***Update settings?*** *prompt.*

3.9 DIRECT ACCESS (THE HOTKEY MENU)

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. These so called **Hotkeys** 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
- Circuit Breaker (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*.

3.9.1 SETTING GROUP SELECTION USING HOTKEYS

In some models you can use the hotkey menu to select the settings group. By default, only Setting group 1 is enabled. Other setting groups will only be available if they are first enabled. To be able to select a different setting group, you must first enable them in the *CONFIGURATION* column.

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

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

Use the right cursor keys to enter the *SETTING GROUP* menu.

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

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

3.9.2   CONTROL INPUTS

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

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

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

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

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

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

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

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

3.9.3   CIRCUIT BREAKER CONTROL

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

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

For example:

```
Plant Reference
MiCOM
HOTKEY   CLOSE
```

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

```
Execute
CB CLOSE
Cancel Confirm
```

More detailed information on this can be found in the Monitoring and Control chapter.

3.10   FUNCTION KEYS

Most 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 binary string, which represents the function key commands. Their status can be read from this binary string.

```
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 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 assigned to 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. This feature avoids accidental double presses.

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. You can also set the date and time manually using 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, the date and time would be displayed on the device irrespective of its location.

You may wish to display the local time corresponding to its geographical location. You can do this 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 the Simple Network Time Protocol (SNTP), are compensated to display the local time.

With `Flexible`, a local time zone adjustment is defined using the **LocalTime Offset** setting. 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, each of which can be set to UTC or Local.:

- 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   SETTINGS GROUP SELECTION

You can select the setting group using opto inputs, a menu selection, and for some models the hotkey menu or function keys. You choose which method using the Setting Group setting in the *CONFIGURATION* column. There are two possibilities; Select via Menu, or Select via PSL. If you choose **Select via Menu**, you set the settings group using the **Active Settings** setting or with the hotkeys. If you choose **Select via PSL** , you set the settings group with DDB signals according to the following table:

SG Select 1X	SG Select X1	Selected Setting Group
0	0	1
0	1	2
1	0	3
1	1	4

Each setting group has its own PSL. Once a PSL configuration has been designed it can be allocated to any one of the 4 setting groups. When downloading or extracting a PSL configuration, you will be prompted to enter the required setting group to which it will allocated.

CHAPTER 6

CURRENT PROTECTION FUNCTIONS

1   CHAPTER OVERVIEW

The P24DM, P24NM 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   THERMAL OVERLOAD PROTECTION

For the thermal overload protection function to operate correctly, the circuit breaker must be closed and its associated closing signal 52a recognized by the relay.

2.1   THERMAL OVERLOAD PROTECTION

Introduction

Overloads can result in stator temperature rises which exceed the thermal limit of the winding insulation. Studies suggest that the life of insulation is approximately halved for each 10°C rise in temperature above the rated value. The life of insulation is not wholly dependent on the rise in temperature, but on the time the insulation is maintained at this elevated temperature. Due to the relatively large heat storage capacity of an induction motor, infrequent overloads of short duration should not damage the machine. However, sustained overloads of a few per cent can result in premature ageing and failure of insulation.

The physical and electrical complexity of motor construction, their diverse applications, variety of possible abnormal operating conditions and the different modes of failure that may occur, result in a complex thermal relationship. Therefore, it is not possible to create an accurate mathematical model of the true thermal characteristics of the machine.

However, if a motor is considered to be a homogeneous body, developing heat internally at a constant rate and dissipating heat at a rate directly proportional to its temperature rise, you can see that the temperature at any instant is given by:

$$T = T_{max} (1 - e^{-t/\tau})$$

Where:

T_{max} = Final steady state temperature,

τ = Heating time constant.

This assumes a thermal equilibrium in the form:

Heat developed = Heat stored + Heat dissipated

Temperature rise is proportional to the current squared:

$$T = KI_R^2 (1 - e^{-t/\tau})$$

Where:

I_R = That current, which when left to flow continuously, would produce a temperature T_{max}, in the motor.

For an overload current 'I', the temperature is given by:

$$T = KI^2 (1 - e^{-t/\tau})$$

For a motor not to exceed the rated temperature, the time 't' for which the motor can withstand the current 'I' can be shown to be given by:

$$t = \tau \, Ln \, [1/\{1-(I_R/I)^2\}]$$

An overload protection element should therefore satisfy the above relationship. The value of I_R may be the full load motor current or a percentage of it, depending on the motor design.

It is an oversimplification to regard a motor as a homogeneous body. The temperature rise of different parts, or even of various points in the same part, can be very uneven. However, it is reasonable to consider the current-time relationship follows an inverse fashion.

2.2 THERMAL REPLICA

The P24xM relay models the time-current thermal characteristic of a motor by internally generating a thermal replica of the machine. The thermal overload protection can be selectively enabled or disabled. The rms and negative sequence components of the load current are measured independently and are combined together to form an equivalent current, I_{eq}, which is supplied to this replica circuit. The heating effect in the thermal replica is produced by I_{eq}^2 and so takes into account the heating effect due to both positive or rms and negative sequence components of current.

The equivalent current for operation of the overload protection is in accordance with the following expression:

$I_{eq} = \sqrt{(I_{RMS}^2 + K\,I_2^2)}$

Where:

I_{RMS} = Root mean square current

I_2 = Negative sequence current

K = A user settable constant proportional to the thermal capacity of the motor.

The temperature of a motor rises exponentially with increasing current. When current decreases, the temperature also decreases in a similar manner. Therefore, to achieve close sustained overload protection, the P24xM relay incorporates a wide range of thermal time constants. These allow the relay replica to closely match the protected motor during heating and cooling.

Furthermore, the thermal withstand capability of the motor is affected by heating in the winding prior to the fault. The thermal replica is designed to take into account the extremes of zero pre-fault current, known as the 'cold' condition, and full rated pre-fault current, known as the 'hot' condition. With no pre-fault current, the relay operates on the 'cold curve'. When a motor is, or has been, running at full load prior to a fault, the windings dissipate heat and the 'hot curve' is applicable. Therefore, during normal operation, the relay operates in these two limits, unless programmed to do otherwise.

To protect the motor during all operating conditions, three independently adjustable time constants are employed in the overload curve:

T1 = Overload time constant applied when the current is between I_{th} & $2I_{th}$.

T2 = Overload time constant applied for currents above $2I_{th}$.

Tr = Cooling time constant applied when the motor is stopped.

The following equation is used to calculate the trip time for a given current.

> *Note:*
> *The relay trips at a value corresponding to 100% of its thermal state. The percentage of thermal capacity follows the relationship* $\%\theta = (I_{eq}/I_{th})^2 \times 100$.

$t = T\,Ln\,[(k^2 - A^2)/(k^2 - 1)]$

The following equation is used to calculate the time it takes for the thermal alarm to be set.

$t_{alarm} = T\,Ln\,[(k^2 - A^2)/(k^2 - (\text{Thermal Alarm}/100))]$

Where:

T = T1 if $I_{th} < I_{eq} <= 2I_{th}$

T = T2 if $I_{eq} > 2I_{th}$

T = Tr if $I_{eq} = 0$ (CB open)

$k = I_{eq}/I_{th}$

A = initial thermal state of the machine.

I_{th} = Thermal current setting

Thermal Alarm = Thermal alarm setting (20%-100%)

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

2.3   THERMAL TRIP

A multiple time constant thermal replica is used to account for different operating conditions of the motor overload, starting or cooling conditions.

The equation used to calculate the trip time at 100% of thermal state is:

$t = \tau \ln((k^2 - A^2)/(k^2-1))$

Where the value of τ (thermal time constant) depends on the current value absorbed by the motor:

Over load time constant $\tau = T_1$ if $I_{th} < I_{eq} <= 2I_{th}$

Start-up time constant $\tau = T_2$ if $I_{eq} > 2I_{th}$

Cooling time constant $\tau = T_r$ if interrupting device opened

Measured thermal load (or thermal capacity) $k = I_{eq} / I_{th}$

I_{th} is thermal setting

A is initial state of the machine in percentage of the thermal state

The initial state of the machine is included in the time to trip calculation algorithm. This is so that the operating time for a thermal trip is decreased if there is a hot motor start.

Some motors have extreme starting conditions such as a very long start time or a very high start current value. During start-up of these motors, the thermal curve is inhibited to avoid false trips.

> *Note:*
> *When the thermal state of the motor reaches 90%, this value is retained at 90% during the remaining period of the **Prol. Start Time***

Comprehensive measurements and diagnostics can be accessed through the HMI. For example, the estimated time to the next thermal trip is calculated (see '*MEASUREMENTS 3*' menu).

Motor thermal state

The thermal state is stored in non-volatile memory and updated every second. When the power supply is resumed, the value of the thermal state is restored if it is less than 90%. However, if it is greater than 90% it is reset to 90%. This allows adequate protection and reduces the possibility of premature thermal overload tripping.

The thermal state of the motor is displayed in the measurements column

MEASUREMENTS 3 of the relay menu. This can be reset by an opto input (**M Reset Thermal**), using the user interface or through the remote communications. The latter two methods are password protected.

> *Note:*
> *Resetting the thermal state, any associated inhibits also reset (for example start inhibit threshold).*

The DDB signal **Thermal Trip** indicates tripping of the element . A further DDB signal **Thermal Alarm** is generated from the thermal alarm stage. The state of the DDB signal can be programmed to be viewed in the Monitor Bit × cells of the *COMMISSION TESTS* column in the relay.
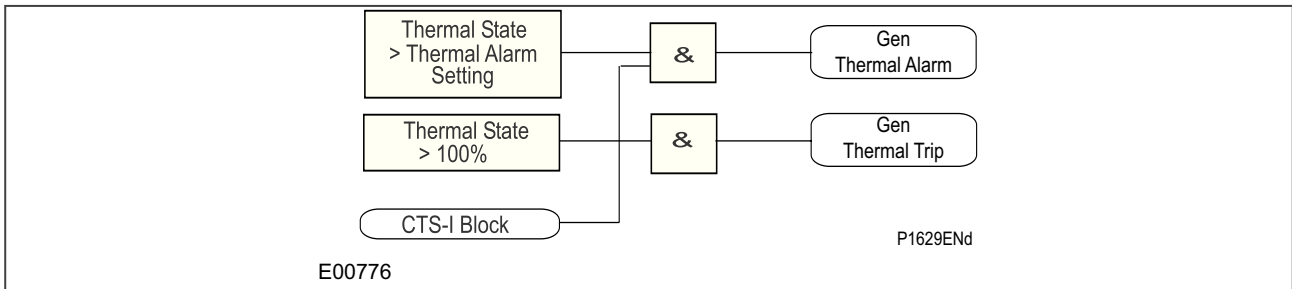
Figure 17: Thermal overload protection logic diagram

Thermal lockout

This function compares the thermal capacity available with the lockout setting immediately after a trip, for example when the interrupting device is open. If the thermal capacity available is insufficient to allow restart, an output contact programmed for the lockout function (**Thermal Lockout**) is energized, which inhibits a restart. When the motor has cooled down, this function resets the lockout output contact.

The thermal lockout drops off at 97% of the thermal lockout threshold.

The estimated time to next start is the time to reach the thermal lockout threshold. This is in the *MEASUREMENTS 3* menu and is given by the following formula:

$T = T_r * Ln (\theta_1/\theta_2)$

Where:

T_r = cooling time constant,

θ_1 = initial thermal state,

θ_2 = final thermal state = 97% of thermal lockout threshold.
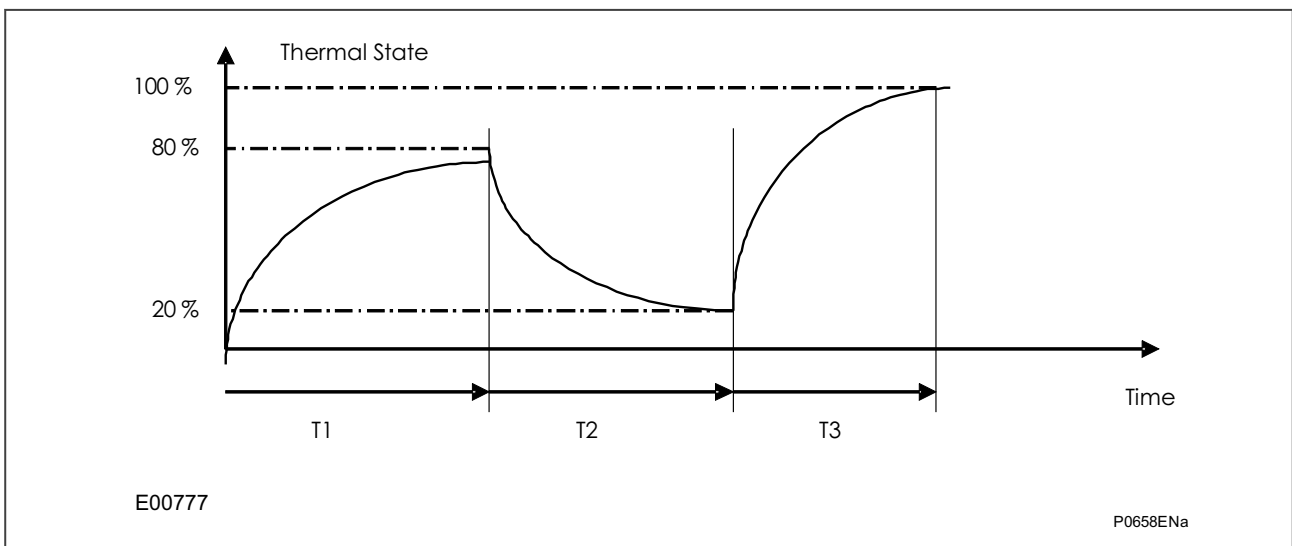
Figure 18: Cooling time constant

Emergency restart

Circumstances may dictate the necessity to restart a hot motor. An emergency restart can be enabled via an opto input (***Emergency Rest.***), via the user interface, or via the remote communications. This feature effectively removes all start inhibits (***Thermal Lockout***, ***Hot start Nb***, ***Cold start Nb***, and ***Time betwe start***).

This feature will reset the thermal memory to 90% if it is greater than 90% or stays as it is if less than 90%.

When an emergency restart is required, the inhibition of thermal curve during start-up will be active, even if this function is not used during a start-up in normal operation.

2.4   USER PROGRAMMABLE CURVE FOR THERMAL OVERLOAD PROTECTION

For information on how to program a customised thermal overload curve and send and extract curves to and from the relay, refer to the MiCOM S1 Agile Settings Application Software user guide.

> *Note:*
> *If a user programmable curve is enabled in the Thermal Overload protection, the thermal state remains at 0% for as long as I_{eq} is less than I_{th}. Therefore the number of hot starts and cold starts should not be used.*

> *Note:*
> *If Data Points rather than a Formula are used to configure a customised curve, data entered in the Time column can be in scientific format and the maximum time allowed by the tool is 1E+308.*

2.5   APPLICATION NOTES

2.5.1   THERMAL OVERLOAD SETTING GUIDELINES

2.5.1.1   THERMAL SETTING ITH

The ***Ith Current Set*** setting chosen depends on the type of motor being protected. Most machines are termed CMR (continuous maximum rating) motors. These motors are designed to carry the nameplate value or full load current continuously. A CMR motor can be run at a value less than its CMR and set to trip at its CMR.

Alternatively, if the machine is not a CMR motor, then the I_{th} setting needs to take into account the amount of overload, which can be tolerated without resulting in thermal damage. A typical allowable overload can be in the region of 10% of rated temperature. It is important to realize that the temperature build up in the machine is approximately equal to the current squared. Therefore a 10% temperature overload is equivalent to a 5% current overload.

Setting example:

The following motor parameters are used to show how to determine the P24xM settings.

Voltage	11 kV
Full load current	293 A
Starting current	470 %
Starting time	10 s
Heating time constant	20 min
Cooling time constant	100 min
Hot locked rotor withstand time	20 s
Cold locked rotor withstand time	30 s
CT Ratio	300 / 1
VT Ratio	11.5 kV / 110 V

Voltage	11 kV
Starting	D.O.L

For this application we have assumed the machine is a CMR motor so the Ith setting is calculated as follows:

$I_{th} = I_{CMR} \times (1/CT\ Ratio)$

Where:

I_{CMR} = Continuous Motor Rating

Therefore: $I_{th} = 293 \times 1/300 = 0.976$ In

Therefore set: $I_{th} = 0.98$ In

2.5.1.2 K COEFFICIENT

The constant *K Coefficient* is used to increase the influence of negative sequence current on the thermal replica. This factor should be set equal to the ratio of negative phase sequence, rotor resistance to positive sequence resistance at rated speed. When an exact setting cannot be calculated, a default setting of 3 should be used. This is a typical setting and is sufficient for the majority of applications.

Therefore set: K Coefficient = 3

2.5.1.3 THERMAL TIME CONSTANTS

The relay heating and cooling time constants are set in accordance with the stator thermal heating and cooling time constants. The relay heating time constant (*Thermal Const T1*) should be set equal to, or as close to, the stator heating thermal time constant, which is obtainable from the motor manufacturer. It is good practice to set T1 slightly less than the stator heating thermal time constant to allow for relay tolerances. However, this is not always necessary as the stator thermal time constants provided by the motor manufacturer are usually conservative.

Thermal Const T2 is automatically applied above 2 I_{th} and is used to modify the relay thermal curve during starting for certain applications. For example, where star/delta starters are being utilized. During normal running, with the motor connected in delta, the current in the motor winding is only 57% of that monitored by the relay. However, during starting, with the motor connected in star, the current monitored by the relay is equal to the current in the motor winding. For this reason, T2 can be used to reduce the operating time of the relay during starting. For applications where direct on line (DOL) starting is utilized, T2 should be set equal to T1, resulting in one continuous thermal curve.

It is important to plot the chosen thermal characteristics on a time-current graph to ensure that the cold curve does not intersect the starting characteristic.

In certain applications the thermal time constants are not available. However, a graphical representation of these values may be given. In such applications, a stator heating time constant must be chosen, so that when plotted on a time-current graph, it closely matches the cold withstand curve of the motor.

Cooling Const Tr is the cooling time constant. This setting is important for cyclic operation of the motor, since precise information of the thermal state of the motor is required during heating and cooling. It is set as a multiple of T1 and should be set to the nearest value above the motor cooling time constant.

Setting Example:

For this application the stator thermal time constants of the motor are known so the required time constant settings are as follows:

Therefore set: T1 = 20 minutes

T2 = T1 since machine is DOL starting

Tr to 5 x T1 = 100 mins.

These settings are shown in the figure below.
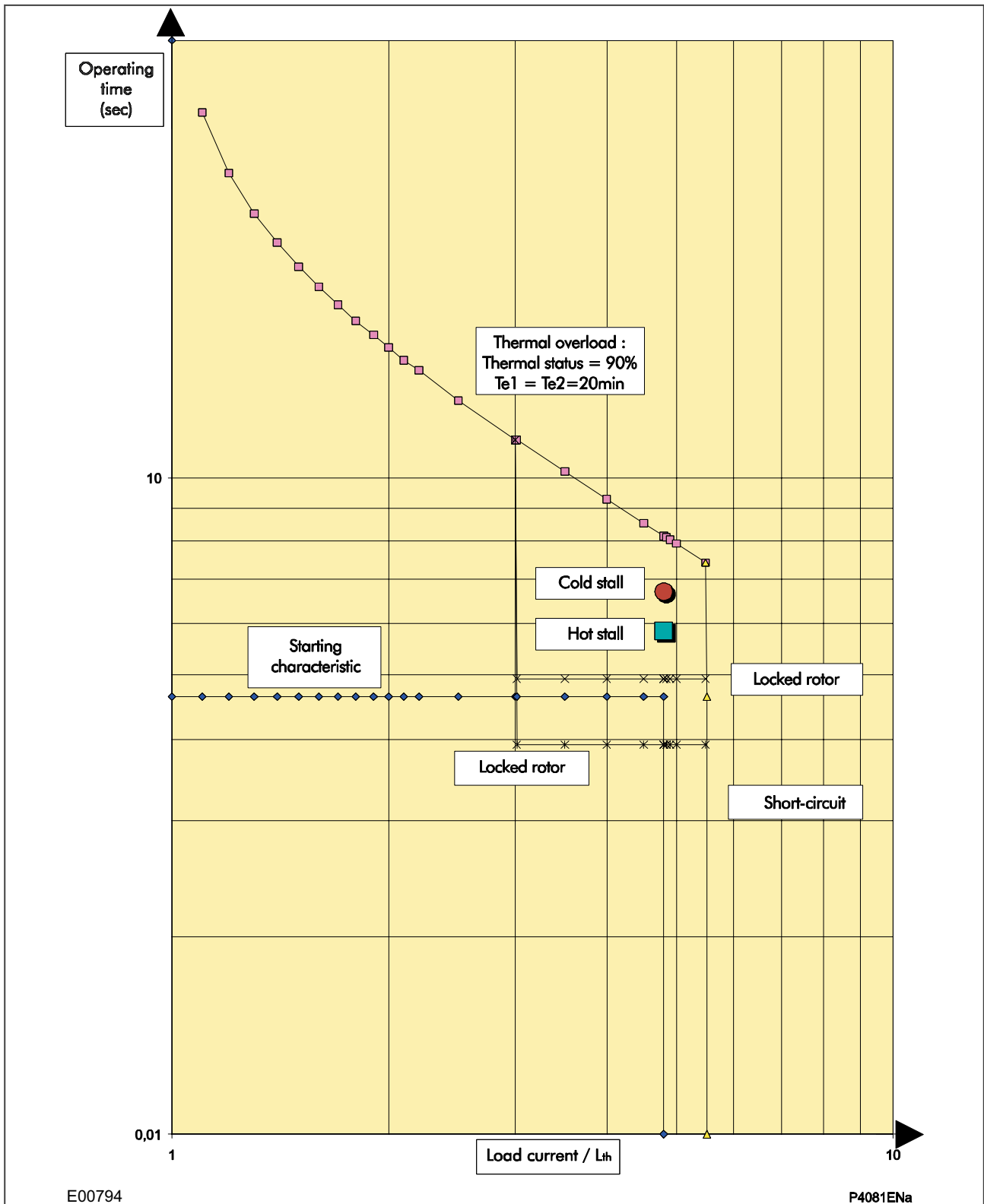
Figure 19: Example of settings

2.5.1.4 THERMAL STATE MODIFICATION

If a CMR induction motor is fully loaded it is equivalent to a temperature of 100%, as far as the thermal replica is concerned. The motor protection relay is normally set to trip when the temperature reaches 100%. However, a stator temperature of 100% does not necessarily correspond to a rotor temperature of 100%, the rotor

temperature could be as low as 50% of the permitted level. The main reason for this is that the rotor winding is able to dissipate the heat more efficiently than the stator winding, particularly with fan-driven, air-flow machines.

During starting, the slip is low and both the stator and rotor currents are high, thereby creating heat in both windings. However, a motor is usually designed to allow one start when it has previously been run at a stator temperature not exceeding its rating.

From cold, the motor thermal replica characteristic is on its 'cold' curve, with the highest tripping times. As the machine is run over a period of time, the projected thermal trip times are reduced, eventually reaching their minimum when operating on the 'hot' curve. Unfortunately, any rapid increase in current, for example a starting condition, may result in an unnecessary trip. This is shown in the figure below.
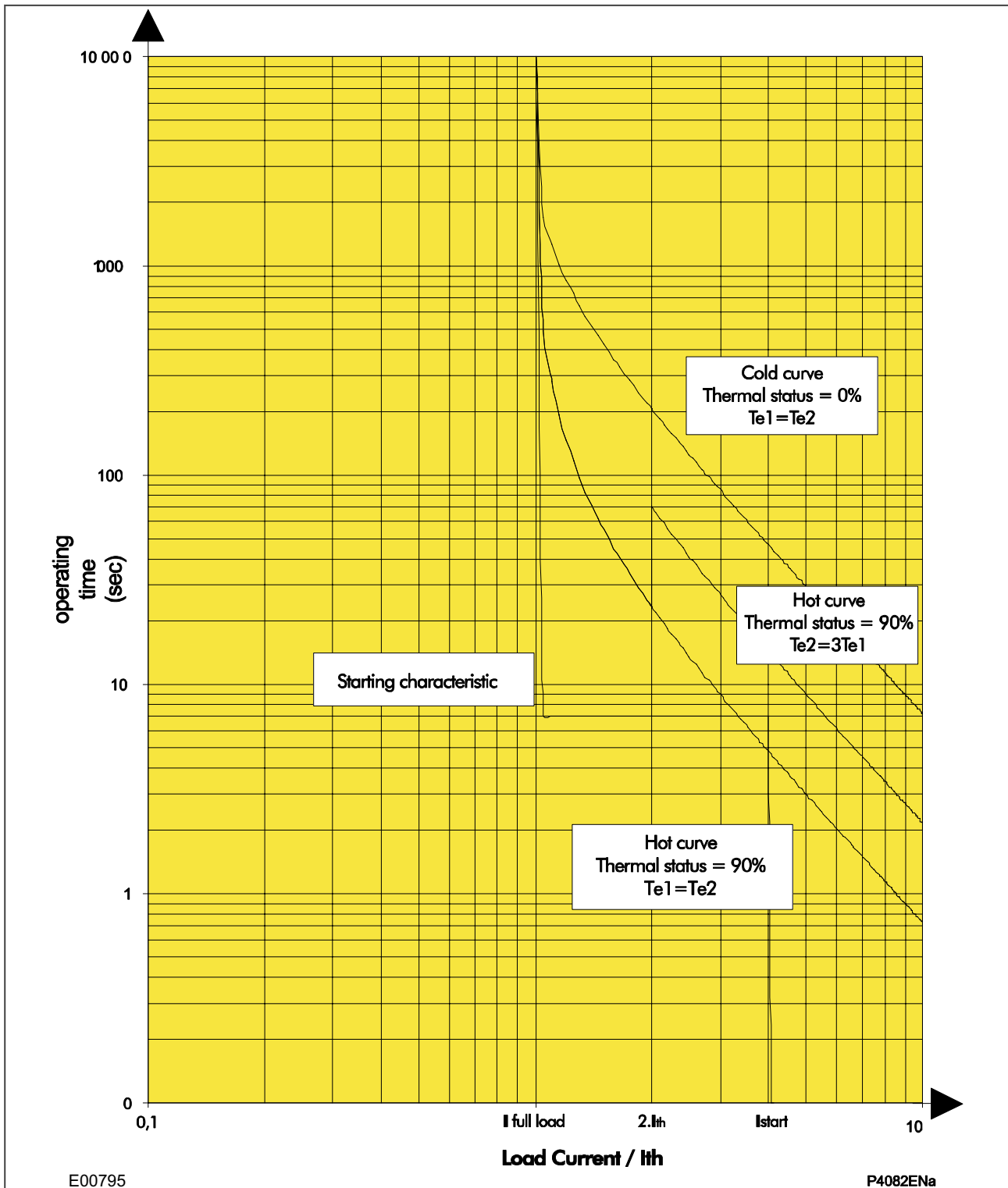
Figure 20: Thermal curve modification

Motor manufacturers and end users are aware of the limitation of the stator thermal model, but the possible solution to oversize the machine is expensive.

The P24xM relay incorporates a feature where the thermal curve can be modified to overcome this problem. Previously, the relay had a dual time constant (T1 and T2) characteristic for applications such as star/delta starting. In this example T2 was set to a lower value than T1. To enable a hot re-start, for a DOL machine, you can set T2 to a higher value than T1 to avoid the starting characteristic. This is shown in the figure above.

2.5.1.5   INHIBITION OF THE THERMAL TRIP DURING STARTING

It may be necessary to disable the thermal overload curve when starting motors which have extreme starting conditions, such as very long start times or very high start current values. With this feature enabled, if the calculated thermal state reaches 90% before the end of the starting period, this value is retained at 90% for the remaining starting period. At the end of the starting period the inhibit is removed.

> *Note:*
> *This function does not affect the operation of the Thermal Alarm feature.*

2.5.1.6   EMERGENCY RESTART

Where a motor forms part of an essential process, it is sometimes desirable for it to continue operation, even under severe overload conditions. This means the motor being subjected to temperatures in excess of its design limits. Even though this may decrease the life of the motor, or even under extreme circumstances, burn the motor out, this may be justified for the application.

2.5.1.7   THERMAL ALARM

The Thermal Alarm threshold is expressed as a percentage of the thermal state of the machine and is used to give an alarm when the thermal state reaches a predetermined value. There is no definitive setting for the thermal alarm threshold since it is application dependent. However, a typical setting would be 90%.

2.5.1.8   LOCKOUT THRESHOLD

This facility can be used to inhibit a hot restart until the motor has cooled to the **Lockout Thresh**. This setting is expressed as a percentage of the thermal state of the motor. A contact is designed to open when the thermal state of the machine reaches this setting and close again when the thermal state drops below this setting. This contact would therefore be wired into the starting circuitry to provide the inhibit.

There is no definitive setting for the lockout threshold since it is based on the motors capability to withstand a hot restart. However, it is typically set to the minimum value of 20%Ith.

3 OVERCURRENT PROTECTION PRINCIPLES

Most electrical 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 faults. The general principle is to isolate the faults as quickly as possible to limit the danger and prevent 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 power grid that are absolutely necessary, to prevent unnecessary blackouts. The protection devices that control the tripping of the power 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

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 alone 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.

3.1 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. With IDMT protection applied to radial feeders, this probem 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.

IDMT characteristics are described by operating curves. Traditionally, these were defined by the performance of electromechanical relays. In numerical protection, equations are used to replicate these characteristics so that they can be used to grade with older equipment.

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.

3.1.1 IEC 60255 IDMT CURVES

There are four well-known variants of this characteristic:

- Standard Inverse
- Very inverse
- Extremely inverse
- UK Long Time inverse

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

Standard Inverse

This characteristic is commonly known as the 3/10 characteristic, i.e. at ten times setting current and TMS of 1 the relay will operate in 3 seconds.

The characteristic curve can be defined by the mathematical expression:

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

The standard inverse time characteristic is widely applied at all system voltages – as back up protection on EHV systems and as the main protection on HV and MV distribution systems.

In general, the standard inverse characteristics are used when:

- There are no co-ordination requirements with other types of protective equipment further out on the system, e.g. Fuses, thermal characteristics of transformers, motors etc.
- The fault levels at the near and far ends of the system do not vary significantly.
- There is minimal inrush on cold load pick up. Cold load inrush is that current which occurs when a feeder is energised after a prolonged outage. In general the relay cannot be set above this value but the current should decrease below the relay setting before the relay operates.

Very Inverse

This type of characteristic is normally used to obtain greater time selectivity when the limiting overall time factor is very low, and the fault current at any point does not vary too widely with system conditions. It is particularly suitable, if there is a substantial reduction of fault current as the distance from the power source increases. The steeper inverse curve gives longer time grading intervals. Its operating time is approximately doubled for a reduction in setting from 7 to 4 times the relay current setting. This permits the same time multiplier setting for several relays in series.

The characteristic curve can be defined by the mathematical expression:

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

Extremely Inverse

With this characteristic the operating time is approximately inversely proportional to the square of the current. The long operating time of the relay at peak values of load current make the relay particularly suitable for grading with fuses and also for protection of feeders which are subject to peak currents on switching in, such as feeders supplying refrigerators, pumps, water heaters etc., which remain connected even after a prolonged interruption of supply.

For cases where the generation is practically constant and discrimination with low tripping times is difficult to obtain, because of the low impedance per line section, an extremely inverse relay can be very useful since only a small difference of current is necessary to obtain an adequate time difference.

Another application for this relay is with auto reclosers in low voltage distribution circuits. As the majority of faults are of a transient nature, the relay is set to operate before the normal operating time of the fuse, thus preventing perhaps unnecessary blowing of the fuse.

Upon reclosure, if the fault persists, the recloser locks itself in the closed position and allows the fuse to blow to clear the fault.

This characteristic is also widely used for protecting plant against overheating since overheating is usually an I2t function.

This characteristic curve can be defined by the mathematical expression:

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

UK Long Time Inverse

This type of characteristic has a long time characteristic and may be used for protection of neutral earthing resistors (which normally have a 30 second rating). The relay operating time at 5 times current setting is 30 seconds at a TMS of 1.

This can be defined by:

$$t_{op} = T \frac{120}{\left(\dfrac{I}{I_s}\right) - 1}$$

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 curves are plotted as follows:
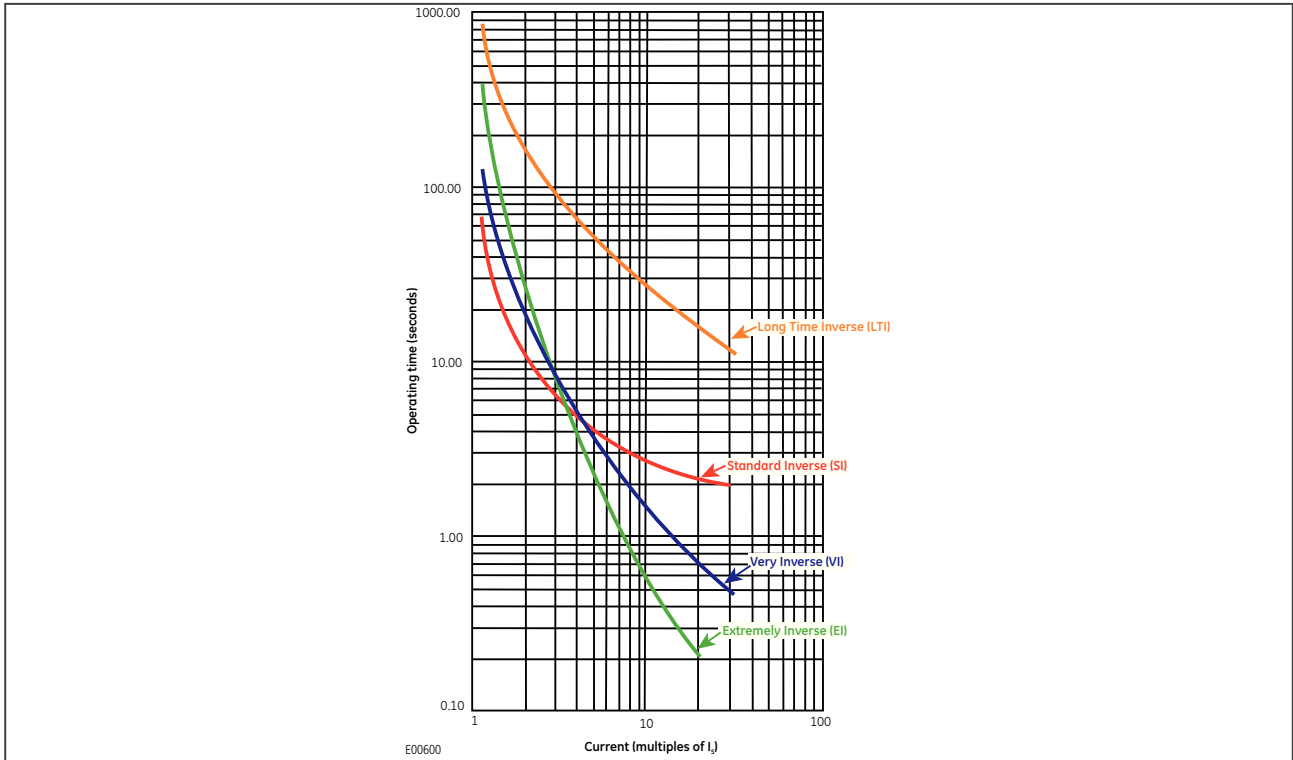
Figure 21: IEC 60255 IDMT curves

3.1.2   EUROPEAN STANDARDS

The IEC 60255 IDMT Operate equation is:

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

and the IEC 60255 IDMT Reset equation is:

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

where:

- t_{op} is the operating time
- t_r is the reset 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

Curve Description	β constant	α constant	L constant
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
UK Long Time Inverse Operate*	120	1	0
UK Rectifier Operate*	45900	5.6	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, UK Rectifier or RI for the Operate characteristic, DT (Definite Time) is always used for the Reset characteristic.

3.1.3   NORTH AMERICAN STANDARDS

The IEEE IDMT Operate equation is:

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

and the IEEE IDMT Reset equation is:

$$t_r = TD \left(\frac{\beta}{1 - M^\alpha} \right)$$

where:

- t_{op} is the operating time
- t_r is the reset 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
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

The constant values for the ANSI curves are as follows:

Curve Description	β constant	α constant	L constant
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 or UK Rectifier for the Operate characteristic, DT is always used for the Reset characteristic.*

3.1.4   IEC AND IEEE INVERSE CURVES
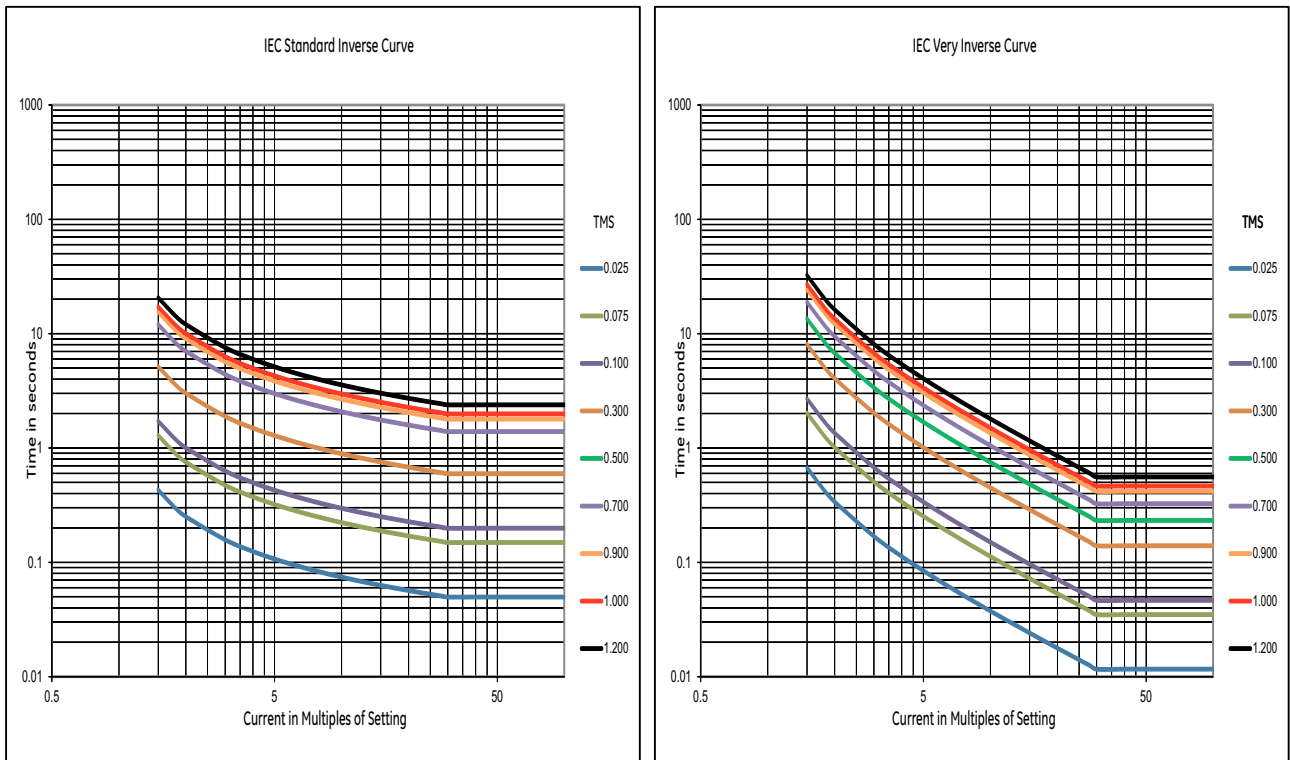
E00757

Figure 22: IEC standard and very inverse curves
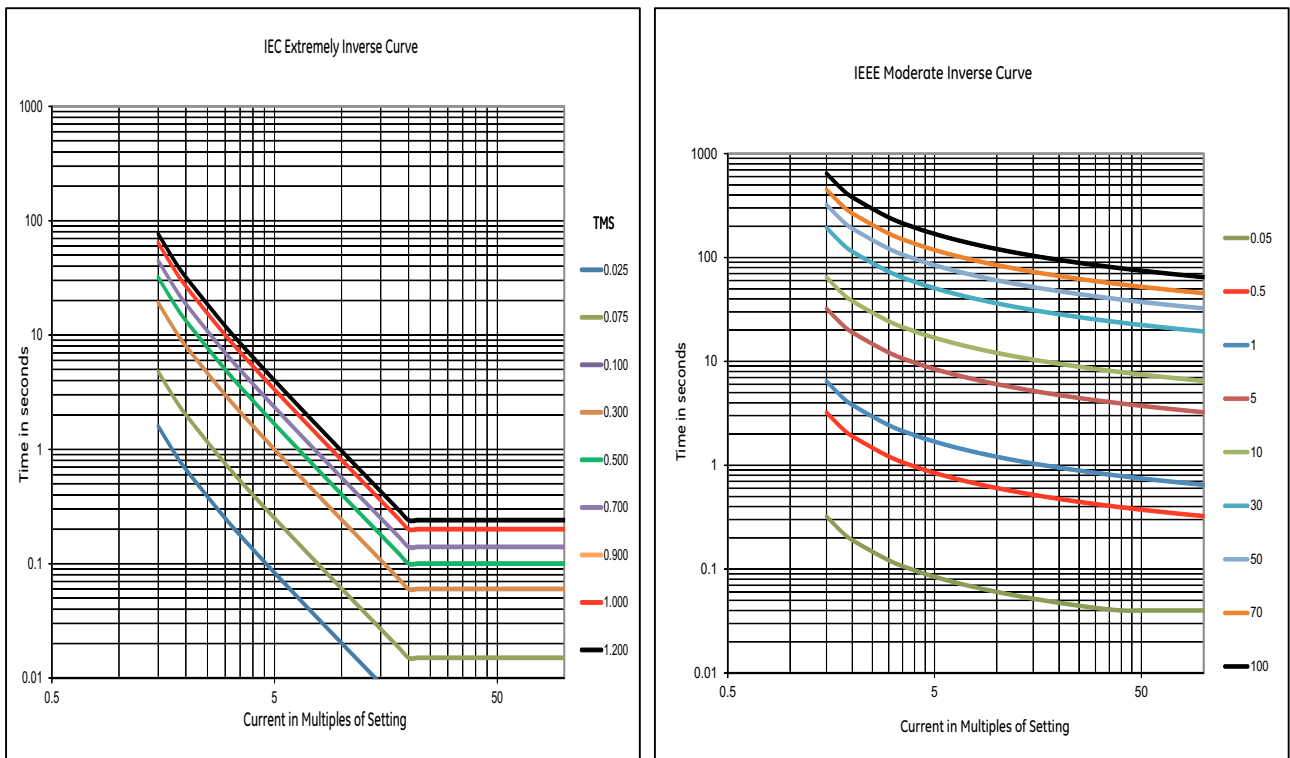
E00758

Figure 23: IEC Extremely inverse and IEEE moderate inverse curves
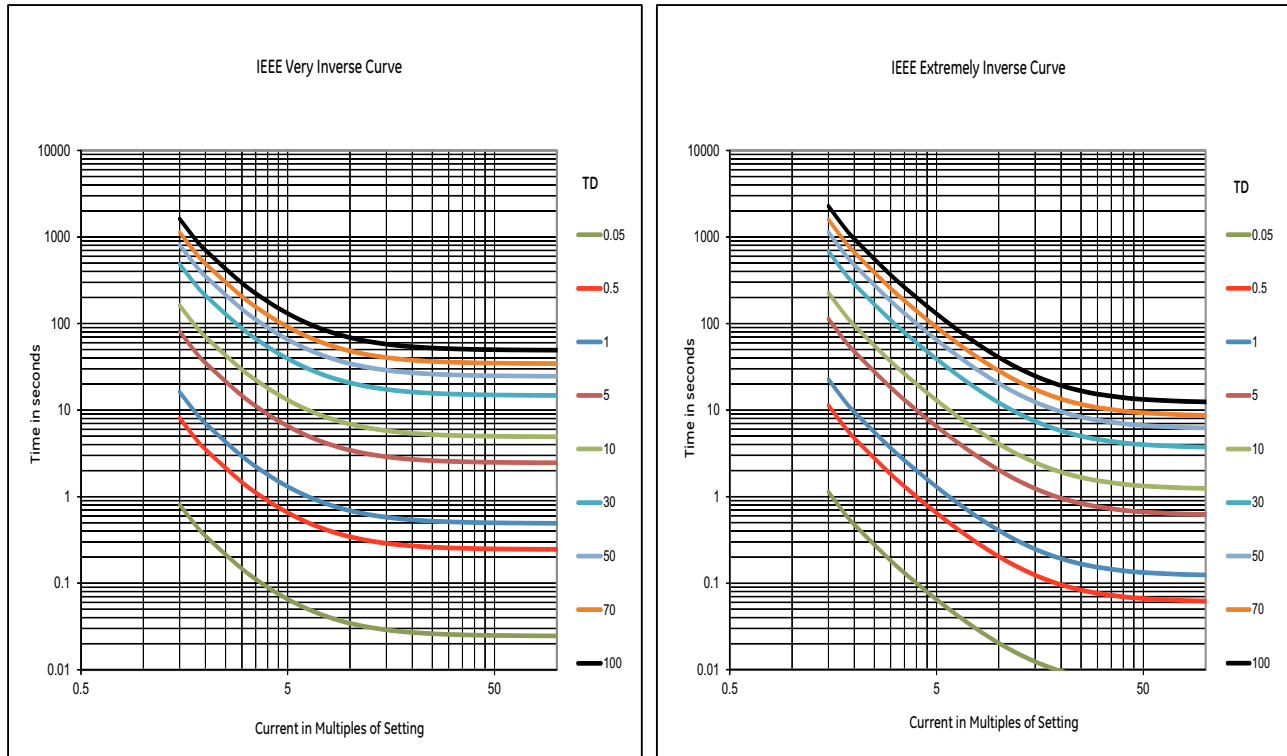
E00759

Figure 24: IEEE very and extremely inverse curves

3.1.5   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.

3.1.6   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.

3.2   PRINCIPLES OF IMPLEMENTATION

The 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 simple representation of protection functionality is shown in the following diagram:
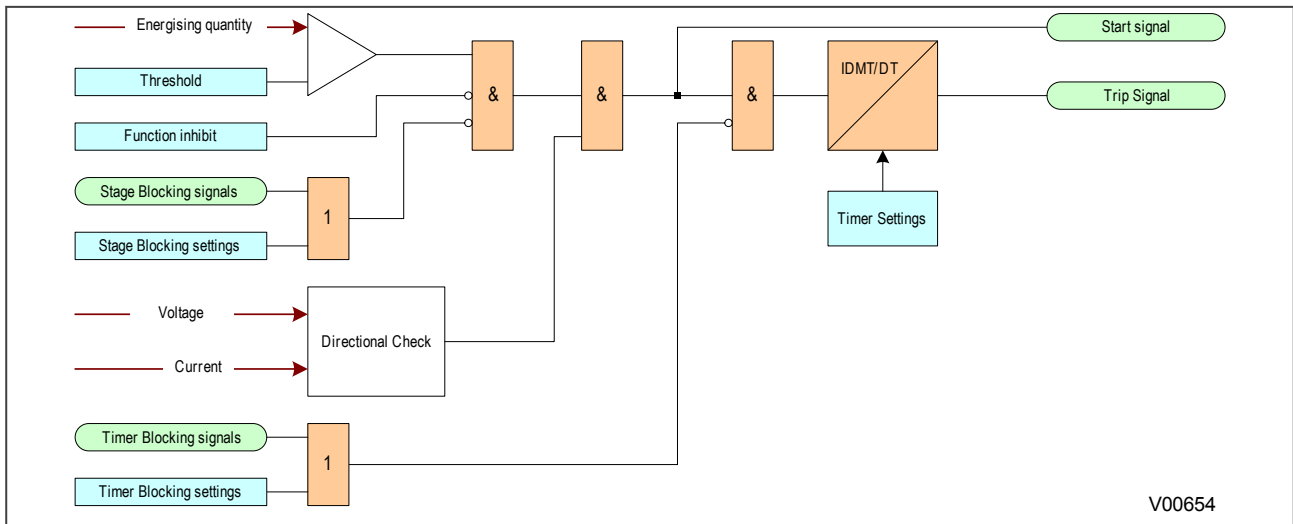
Figure 25: Principle of protection function implementation

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. The signals are converted to digital quantities where they can be processed by the IEDs internal processor.

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.

In General Electric 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 some stages use an Inverse Definite Minumum time (IDMT) timer function, and others use a Definite Time timer (DT) 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.

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.

Note:
In the logic diagrams and descriptive text, it is usually sufficient to show only the first stage, as the design principles for subsequent stages are usually the same (or at least very similar). Where there are differences between the functionality of different stages, this is clearly indicated.

3.2.1   TIMER HOLD FACILITY

The Timer Hold facility is 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).

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 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.

4   PHASE OVERCURRENT PROTECTION

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

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

4.1   PHASE OVERCURRENT PROTECTION IMPLEMENTATION

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

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

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

- A range of IDMT (Inverse Definite Minimum Time) curves based on IEC and IEEE standards
- A range of programmable user-defined curves
- DT (Definite Time) characteristic

For stage 1, this is achieved using the following settings:

- *I>1 Function* for the overcurrent operate characteristic
- *I>1 Reset Char* for the overcurrent reset characteristic
- *I>1 Usr Rst Char* for the reset characteristic for user-defined curves

The setting names for other stages follow the same principles.

The IDMT-equipped stages, (1,2 and 5) also provide a Timer Hold facility. Stage 1 for example, is configured using the cells *I>1 tReset*. This setting does not apply to IEEE curves.

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

4.2   NON-DIRECTIONAL OVERCURRENT LOGIC
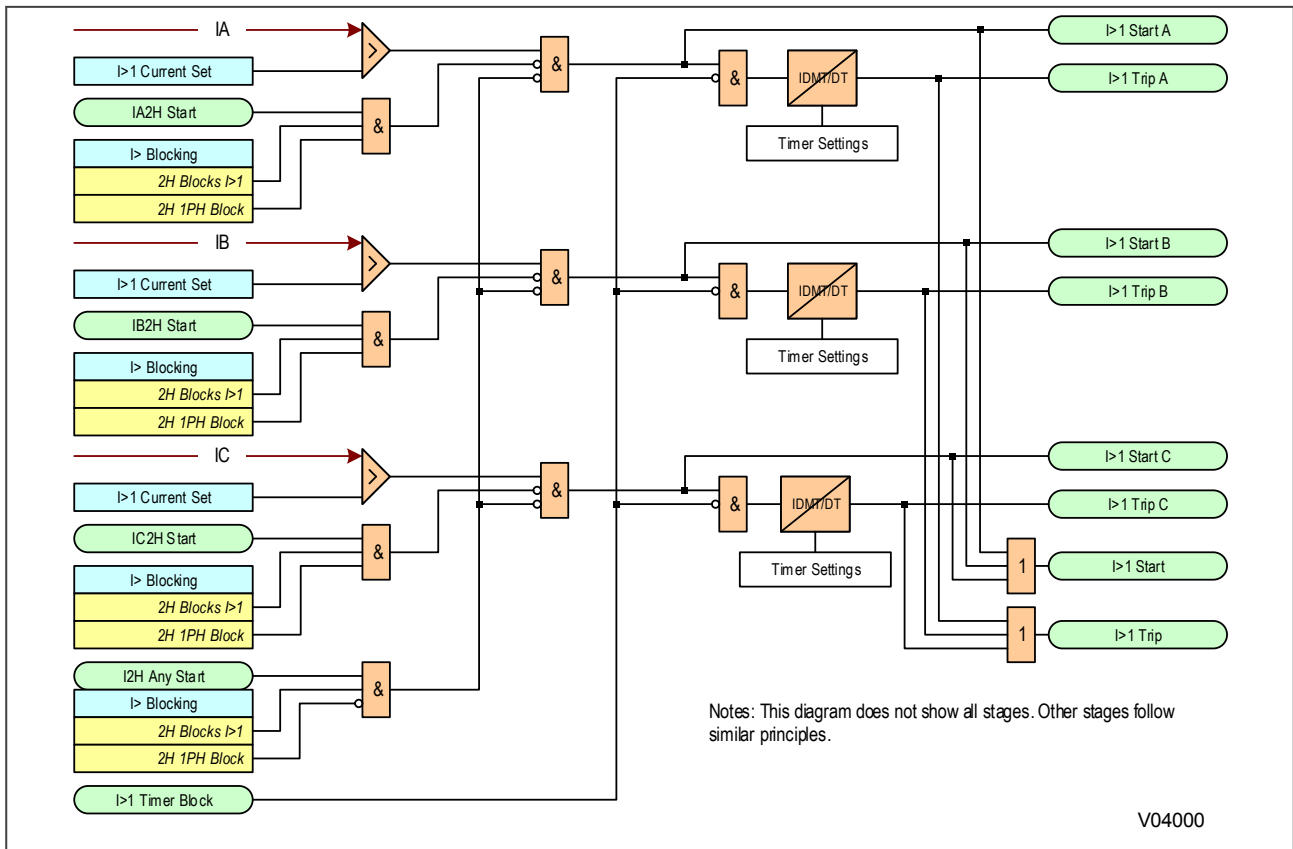
Figure 26: Non-directional Overcurrent Logic diagram

Phase Overcurrent Modules are level detectors that detect when the current magnitude exceeds a set threshold. When this happens, a Start signal is generated unless it is inhibited by a blocking signal. This Start signal initiates the timer module, which can be configured as an IDMT timer or DT timer, depending on the stage number. The Start signal is also available 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 combined to form a 3-phase Start signal.

The Start signals can be blocked by the Second Harmonic blocking function; on a per phase basis (single-phase blocking) or for all three phases at once (three-phase blocking). The relevant bits are set in the *I> Blocking* cell and this is combined with the relevant second harmonic blocking DDBs.

The timer can be configured with several settings depening on which type of timer is selected. Taking stage 1 as an example:

The setting *I>1 Time Delay* sets the DT time delay

The setting *I>1 TMS* sets the Time Multiplier setting for IEC IDMT curves

The setting *I>1 Time Dial* sets the Time Multiplier setting for IEEE/US IDMT curves

The setting *I>1 DT Adder* adds a fixed time delay to the IDMT operate characteristic

The setting *I>1 tRESET* determines the reset time for the DT characteristic

The outputs of the timer modules are the single-phase trip signals. These trip signals are combined to form a 3-phase Trip signal.

The timer modules can be blocked by a Phase Overcurrent Timer Block (for example *I>1 Timer Block*).

For DT-only stages, the DT timer can be blocked by the Autoreclose function. An Autoreclose blocking signal is produced by the DDB signal *AR Blk Main Prot* and the relevant settings in the *I> Blocking* cell.

4.3   DIRECTIONAL ELEMENT

If fault current can flow in both directions through a protected location, you will need to use a directional overcurrent element to determine the direction of the fault. Once the direction has been determined the device can decide whether to allow tripping or to block tripping. To determine the direction of a phase overcurrent fault, the device must compare the phase angle of the fault current with that of a known reference quantity. The phase angle of this known reference quantity must be independent of the faulted phase. Typically this will be the line voltage between the other two phases.

The phase fault elements of the IEDs are internally polarized by the quadrature phase-phase voltages, as shown in the table below:

Phase of protection	Operate current	Polarizing voltage
A Phase	IA	VBC
B Phase	IB	VCA
C Phase	IC	VAB

Under system fault conditions, the fault current vector lags its nominal phase voltage by an angle depending on the system X/R ratio. The IED must therefore operate with maximum sensitivity for currents lying in this region. This is achieved using the IED characteristic angle (RCA) setting. The RCA is the angle by which the current applied to the IED must be displaced from the voltage applied to the IED to obtain maximum sensitivity.

There are two ways you can change set the characteristic and trip angles. This is controlled by the **Dir Char Setting** cell in the SECURITY CONFIG column. This setting provides two options: `Simple` and `Advanced`.

In `Advanced` mode, the characteristic angle can be set independently for each stage. For stage 1, for example, this would be the setting **I>1 Char Angle**. It is possible to set characteristic angles anywhere in the range – 180° to + 180°.

The opening angle of the forward or reverse trip zone can also be set independently for each stage. This allows you to set a tripping angle of less than 180° for each stage. For stage 1, for example, you do this using the **I>1 Trip Angle** setting.

In `Simple` mode, the angle can only be changed globally for all overcurrent stages.

A directional check is performed based on the following criteria:

Directional forward

$$\angle V + RCA - 90° + (180° - tripping\ angle)/2 < \angle I < \angle V + RCA +90° - (180° - tripping\ angle)/2$$

Directional reverse

$$\angle V + RCA - 90° - (180° - tripping\ angle)/2 > \angle I > \angle V + RCA +90° + (180° - tripping\ angle)/2$$

This can be best visualised with reference to the following diagram:
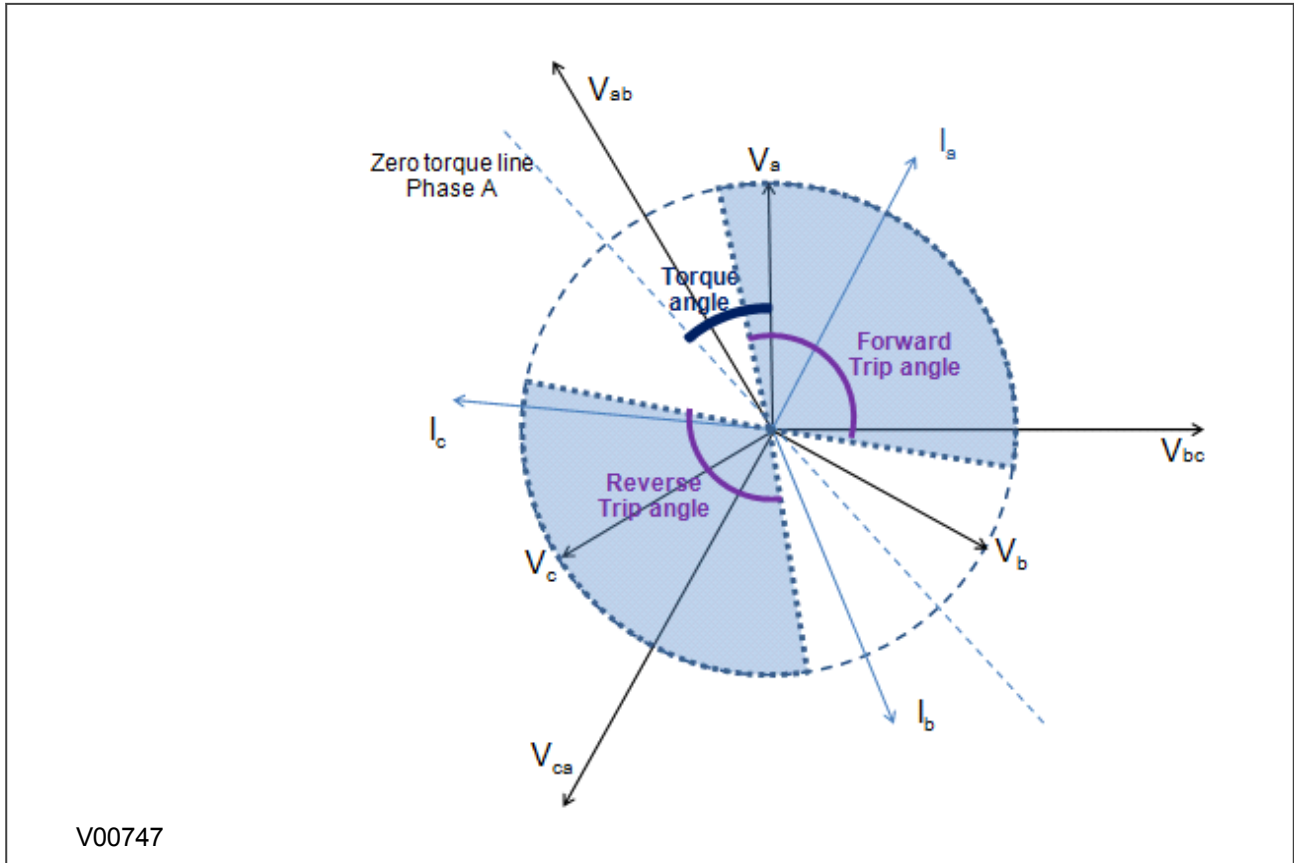
Figure 27: Directional trip angles

For close up three-phase faults, all three voltages will collapse to zero and no healthy phase voltages will be present. For this reason, the device includes a synchronous polarisation feature that stores the pre-fault voltage information and continues to apply this to the directional overcurrent elements for a time period of 3.2 seconds. This ensures that either instantaneous or time-delayed directional overcurrent elements will be allowed to operate, even with a three-phase voltage collapse.

4.3.1   DIRECTIONAL OVERCURRENT LOGIC
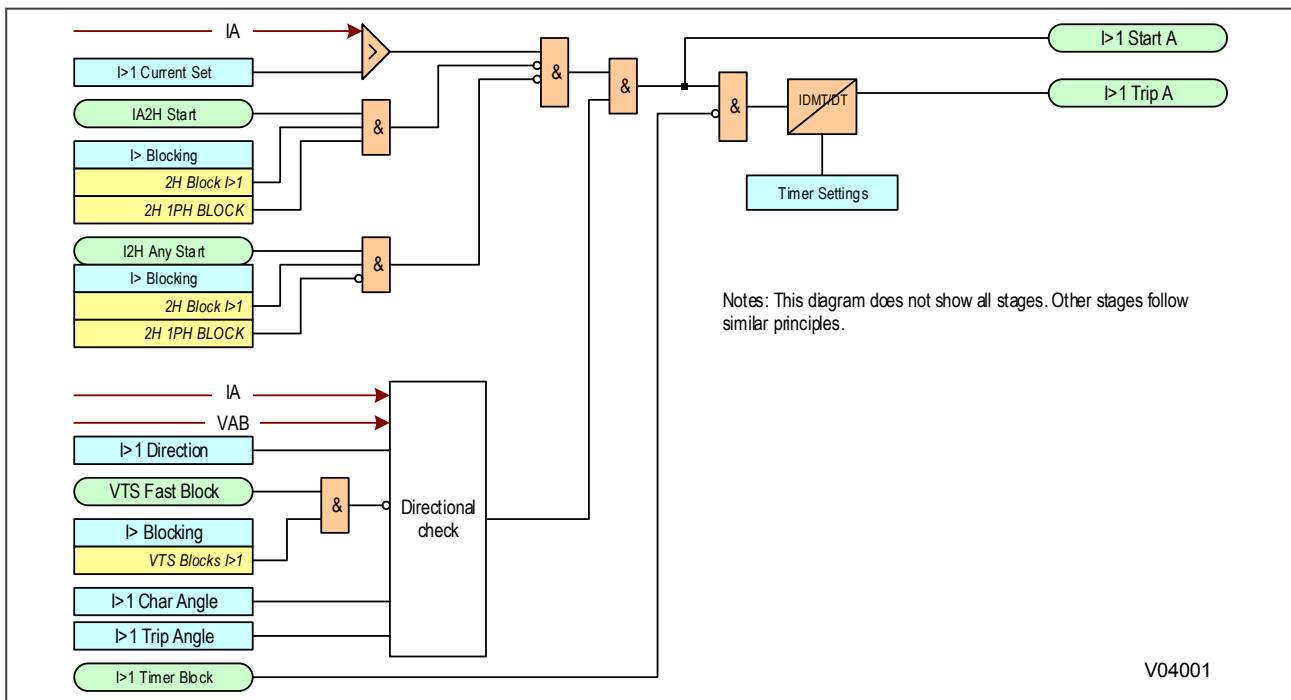
Figure 28: Directional Overcurrent Logic diagram (Phase A shown only)

Voltage Transformer Supervision (VTS) can be used to block operation of directional overcurrent elements.

This is achieved using the *I> Blocking* cell. When the relevant bit is set to 1, operation of the VTS will block the stage if directionalised. When set to 0, the stage will revert to non-directional upon operation of the VTS.

4.4   APPLICATION NOTES

4.4.1   SHORT CIRCUIT PROTECTION

Faults between phases seldom occur because of the amount of insulation between phase windings. As the stator windings are completely enclosed in earthed metal, most faults involve earth, which would then operate the earth fault protection. However, a fast operating overcurrent element is often employed to protect against phase faults occurring at the motor terminals. For example, terminal flashovers.

The short circuit protection included within the P24xM relays consists of a four stage non-directional overcurrent element. The first two stages have a time delayed characteristic that can be set as either Inverse Definite Minimum Time (IDMT) or Definite Time (DT). The third and fourth stages have a definite time delay. Each stage can be selectively enabled or disabled.

This element uses Ia, Ib, and Ic relay inputs and can be fed from CTs at the terminal of the motor.

If a definite time setting of less than 100 ms is set (to avoid tripping during start-up as a result of asymmetric CT saturation) the definite time element has a minimum operating time of 100 ms for currents in the range 1xI> to 1.13xI>. This is shown in the definite time overcurrent element figure below.

If required to set I> below the starting current to increase the sensitivity, it is possible to use undervoltage protection function in conjunction with negative sequence overvoltage protection. This blocks the short circuit protection function under normal conditions and unblocks the function when there is a genuine short circuit condition. Under a genuine short circuit condition and depending on the type of the fault, either or both undervoltage and negative sequence overvoltage start elements are picked up. The associated DDBs can then be utilized in the PSL to unblock the short circuit protection function. Typical settings to implement this algorithm are 60% for undervoltage protection function and 5% for negative sequence overvoltage protection function.

Typical PSL schemes to implement this algorithm are shown below:

V00778

Figure 29: OR logic

V00779
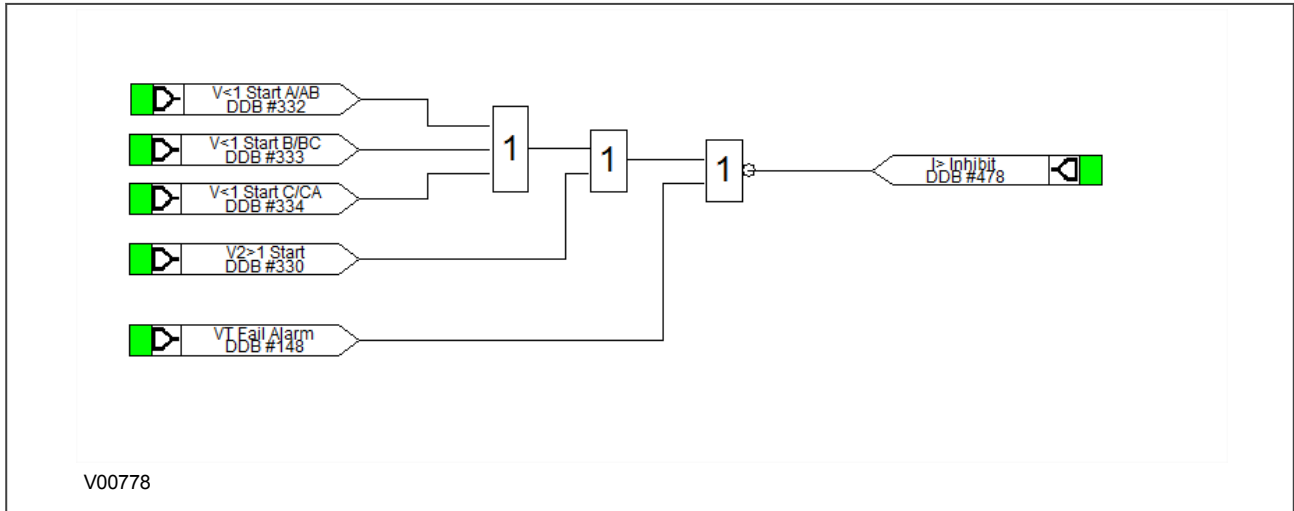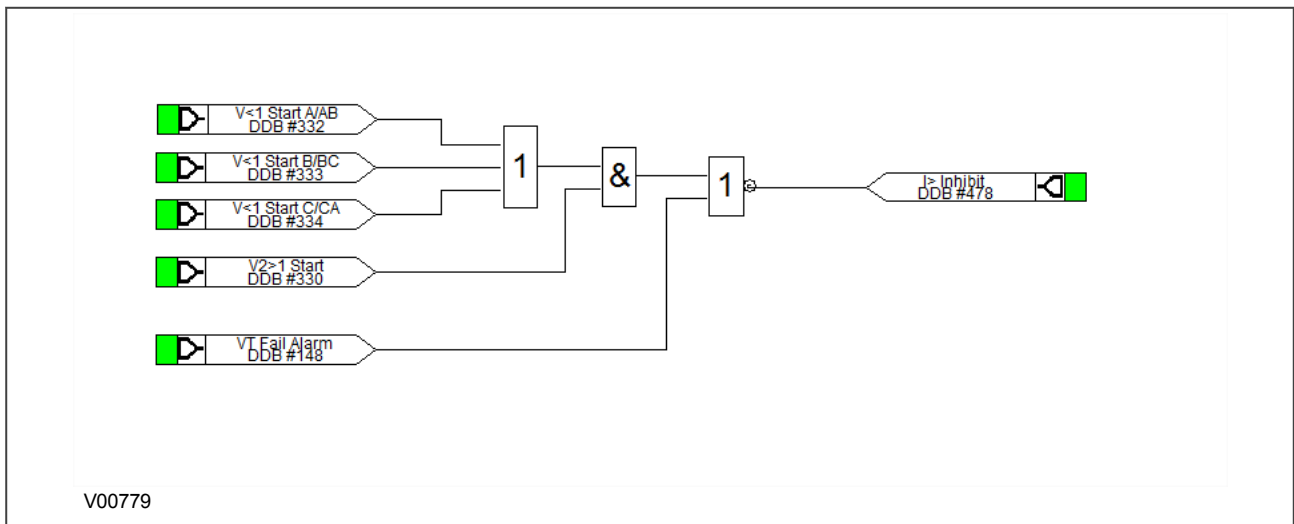
Figure 30: AND logic
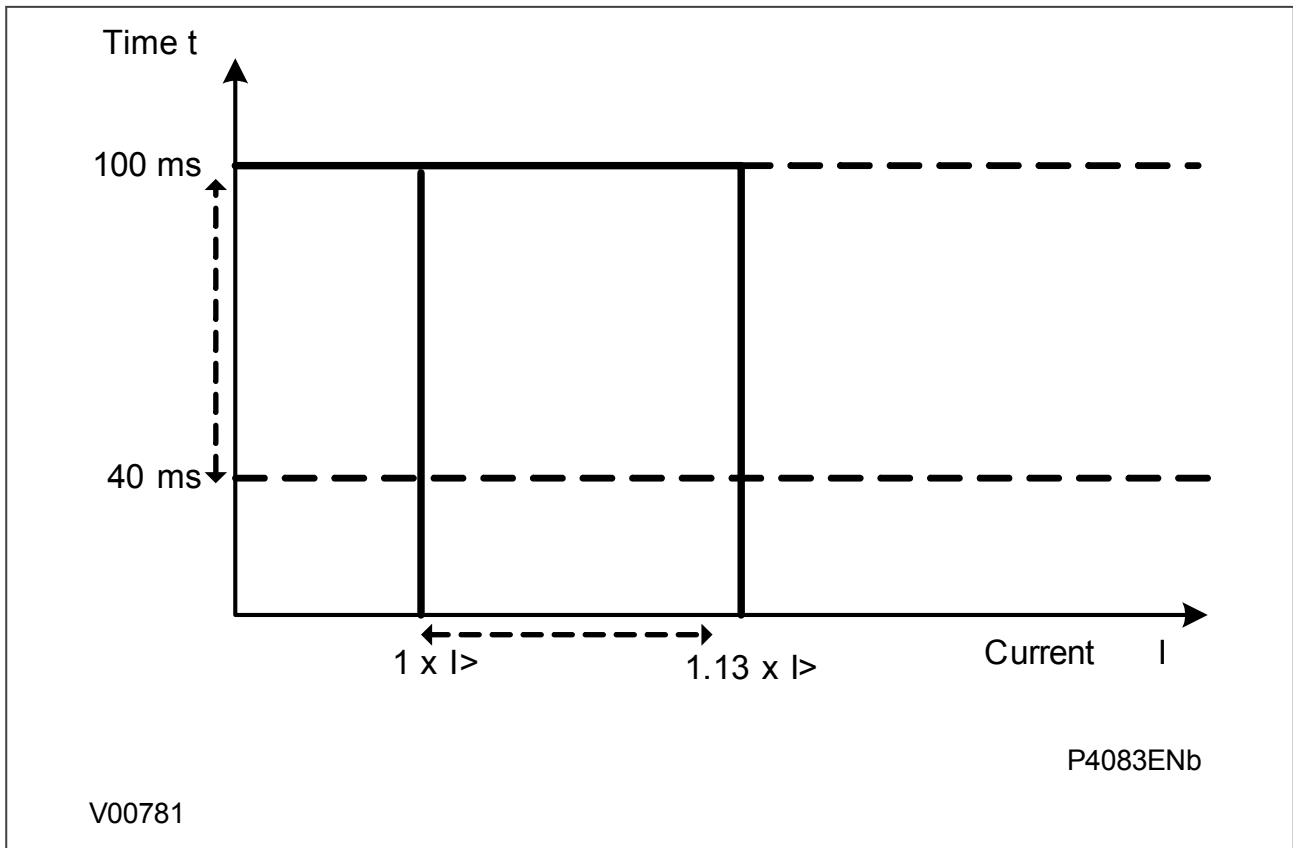
Figure 31: Definite time overcurrent element

Setting guidelines

To prevent operation during starting the instantaneous element is usually set to 1.25 times the maximum starting current.

The timer setting is system dependent and can be set to a value in the region of 100 ms. A time delay setting of less than 2 cycles duration is not realistic due to the fact that a minimum confirmation time, equivalent to two cycle duration, is required before tripping.

> *Note:*
> *If the motor is controlled by a fused contactor it needs to be coordinated with the fuse. This prevents the contactor attempting to interrupt current in excess of its breaking capacity.*

Setting example

Utilizing the previously specified motor parameters, set:

I>Current Set = (1.25 x 4.7 x 293)/300 = 5.7 In

I> Time Delay = 100 ms

5   CURRENT SETTING THRESHOLD SELECTION

The Phase Overcurrent protection threshold setting can be influenced by the Cold Load Pickup (CLP), should this functionality be used.

The Overcurrent function selects the threshold setting according to the following diagram:
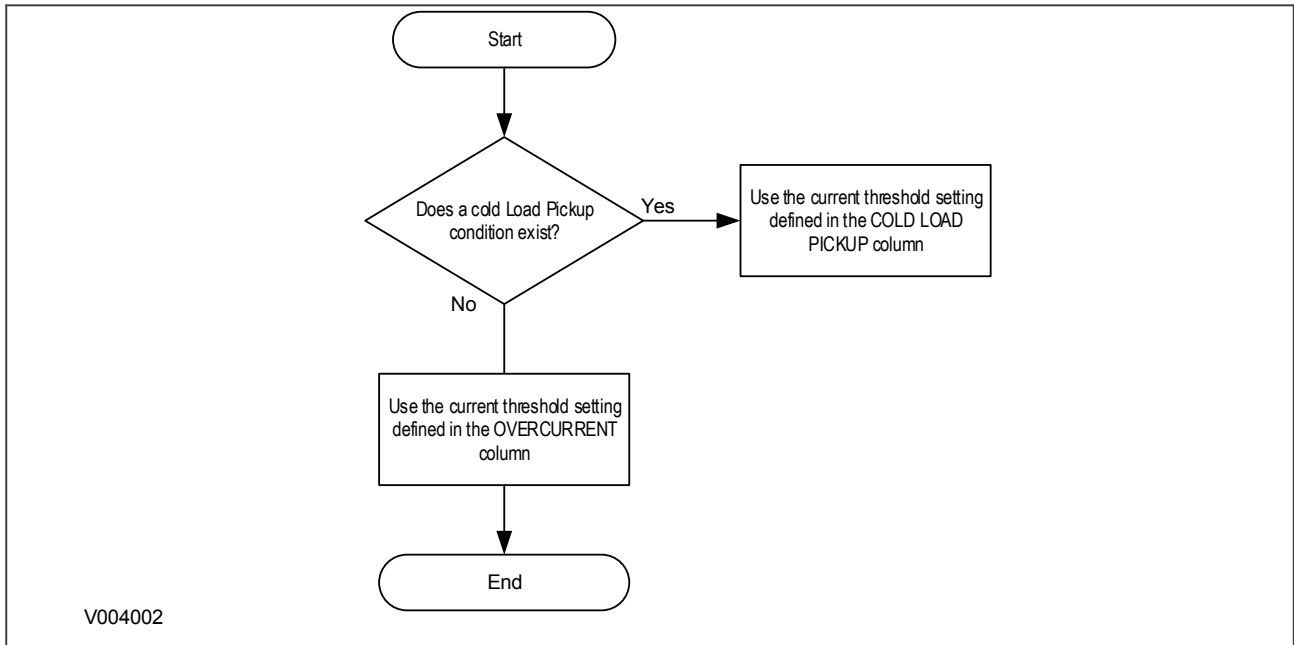
Figure 32: Selecting the current threshold setting

6   NEGATIVE SEQUENCE OVERCURRENT PROTECTION

When applying standard phase overcurrent protection, the overcurrent elements must be set significantly higher than the maximum load current. This limits 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 Phase Sequence Overcurrent elements can help 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 Phase 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.

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)

For stage 1, this is achieved using the following settings:

- *I2>1 Function* for the overcurrent operate characteristic
- *I2>1 Reset Char* for the overcurrent reset characteristic
- *I2>1 Usr RstChar* for the reset characteristic for user-defined curves

The setting names for other stages follow the same principles.

The IDMT-equipped stages, (1 and 2) also provide a Timer Hold facility. Stage 1, for example, is configured using the cells *I2>1 tRESET*. This setting is not applicable for curves based on the IEEE standard.

Stages 3 and 4 have definite time characteristics only.

> *Note:*
> `46 IDMT Curve` *is a motor specific IDMT curve using the following equation:*
> *T = (1.2*TMS)/(I2/I2thres).*
> *Where:*
> *T is time*
> *TMS is factor settable*
> *I2 is the Negative sequence current*
> *I2thres is the corresponding threshold set*

6.2   NON-DIRECTIONAL NEGATIVE SEQUENCE OVERCURRENT LOGIC
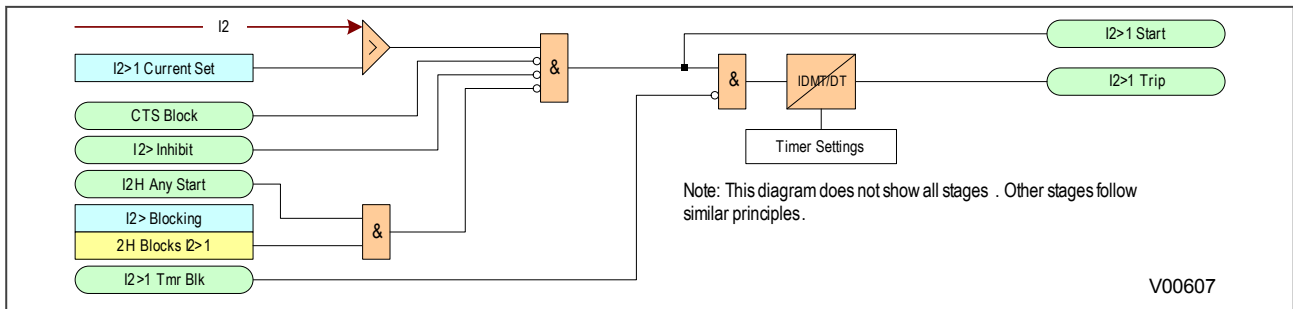
Figure 33: Negative Sequence Overcurrent logic - non-directional operation

For Negative Phase Sequence Overcurrent Protection, the energising quanitiy *I2>* is compared with the threshold voltage *I2>1 Current Set*. If the value exceeds this setting a Start signal (*I2>1 Start*) is generated, provided there are no blocks.

The function can be blocked if a CTS or second harmonic condition is detected.

The *I2>1 Start* signal is fed into a timer to produce the *I2>1 trip* signal. The timer can be blocked by the timer block signal *I2>1 Tmr Blk*.

This diagram and description applies to each stage.

6.3   DIRECTIONAL ELEMENT

Where negative phase sequence current may flow in either direction, directional control should be used.

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

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

6.3.1   DIRECTIONAL NEGATIVE SEQUENCE OVERCURRENT LOGIC
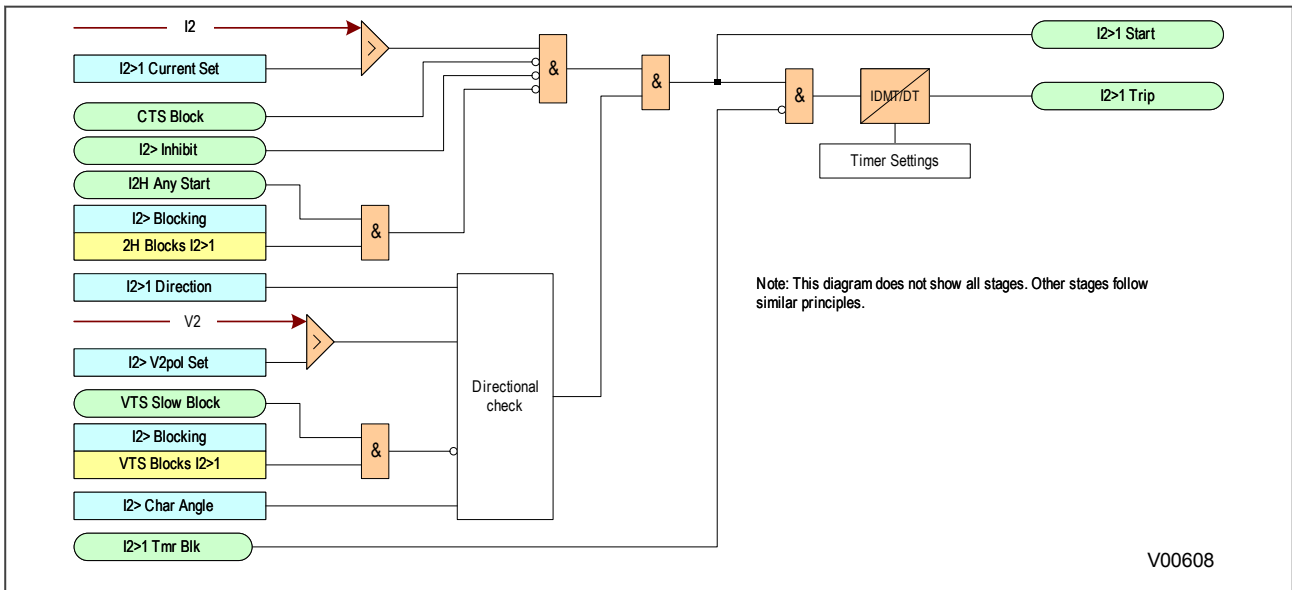
Figure 34: Negative Sequence Overcurrent logic - directional operation

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

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

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

6.4   PHASE ROTATION

A facility is provided in the P24xM to maintain correct operation of all the protection functions even when the motor is running in a reverse phase sequence. This is achieved through user configurable settings available for the four setting groups.

The default phase sequence for P24xM is the clockwise rotation ABC. However, some applications may require an intermediate anti-clockwise phase rotation of ACB.

In process industry there is often a common practice to reverse two phases to facilitate the process, using phase reversal switches. The following sections describe some common scenarios and their effects.

For such applications the correct phase rotation settings can be applied for a specific operating mode and phase configuration in different setting groups. The phase configuration can then be set by selecting the appropriate setting group. This method of selecting the phase configuration removes the need for external switching of CT circuits or the duplication of relays with connections to different CT phases. The phase rotation settings should only be changed when the motor is off-line so that transient differences in the phase rotation between the relay and power system due to the switching of phases don't cause operation of any of the protection functions. To ensure that setting groups are only changed when the machine is off-line the changing of the setting groups could be interlocked with the IA/IB/IC undercurrent start signals and an undervoltage start signal in the PSL.

All the protection functions that use the positive and negative sequence component of voltage and current are affected (Thermal Overload, 3 Ph Volt Check, Negative Sequence O/C, VT Supervision).

6.5 APPLICATION NOTES

6.5.1 NEGATIVE SEQUENCE PROTECTION

Negative phase sequence current is generated from an unbalanced current condition, such as unbalanced loading, loss of one phase or single phase faults.

Consider the equivalent circuits for positive and negative phase sequence currents shown in the figure below, the magnetizing impedance being neglected.
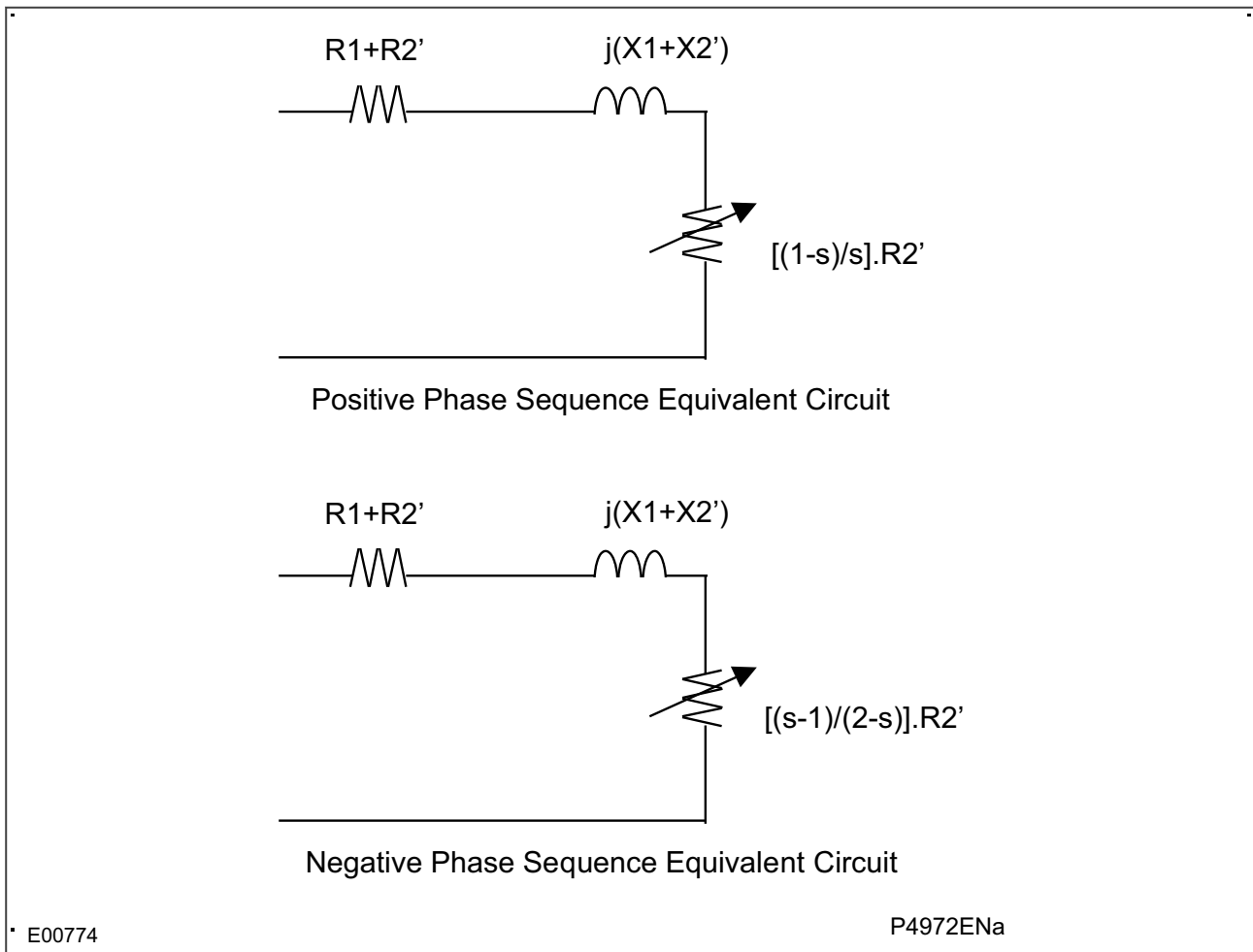
Figure 35: Equivalent circuits

With positive phase sequence voltages applied to the motor, a rotating field is set up between the stator and rotor. The resulting effect is that the direction of rotation of the rotor is equal to that of the applied field. With negative phase sequence voltages, the field rotates in the opposite direction, cutting a rotating rotor conductor at almost twice the system frequency. The actual frequency of negative phase sequence voltage and current in the rotor circuit is equal to (2-s)f.

From the equivalent circuits;

Motor positive sequence impedance at a given slip s by the formula:

$[(R1 + R'2/2-s)2 + (X1 + X'2)2]0.5$

That means: $[(R1 + R'2)2 + (X1 + X'2)2]0.5$ when s = 1 at standstill.

Motor negative sequence impedance at a given slip s by the formula:

[(R1 + R'2/s)2 + (X1 + X'2)2]0.5

That means: [(R1 + R'2/2)2 + (X1 + X'2)2]0.5 when s << 1 at normal running speed.

Where:

PPS = positive phase sequence

NPS = negative phase sequence

R1 = PPS Stator Resistance

R'1 = PPS Rotor Resistance Referred to Stator

X1 = PPS Rotor Reactance

X'1 = PPS Rotor Reactance Referred to Stator

R2 = NPS Stator Resistance

R'2 = NPS Rotor Resistance Referred to Stator

X2 = NPS Rotor Reactance

X'2 = NPS Rotor Reactance Referred to Stator

s = Slip

The value of resistance is generally much less than the leakage reactance. Therefore, neglecting the resistance term, the motor negative phase sequence impedance at normal running speed can be approximated to the positive phase sequence impedance at standstill.

At normal running speed:

$$\frac{\text{positive sequence impedance}}{\text{negative sequence impedance}} \cong \frac{\text{starting current}}{\text{normal load current}}$$

For example, if a motor has a starting current of six times the full load value, the negative sequence impedance would be about 1/6 the positive sequence impedance.

Therefore, the presence of 5% negative sequence voltage in the supply would result in approximately 30% of negative sequence current.

The a.c. resistance of the rotor conductor to the induced negative sequence current is greater due to the higher frequency [(2-s)f], causing skin effect. The heating effect of negative sequence current is therefore greater and increases the motor losses.

It is therefore essential to detect any negative sequence current present on the system and act accordingly before dangerous temperatures occur in the motor.

The P24xM relay includes several methods for the detection of negative phase sequence currents, depending on the cause of the unbalance. These methods are addressed in detail below.

6.5.1.1   THREE PHASE VOLTAGE CHECK (REVERSE PHASE DETECTION)

Principle

Incorrect phase rotation of the incoming supply to the motor results in the motor rotating in the opposite direction. For certain directionally sensitive applications, such as lifts and conveyor belts, this is a potentially dangerous condition and must be detected rapidly.

Although the above condition does not result in the flow of negative phase sequence current in the motor, 100% negative phase sequence current are presented to the measuring circuitry of the relay.

If the machine is allowed to rotate in the opposite direction, the thermal protection and negative phase sequence overcurrent element detects the condition and trips the circuit breaker in their respective time delays. However, it is sometimes better not to allow the motor to rotate at all.

For such applications, the P24xM relay includes a 3 phase voltage check detector. This element monitors the input voltage rotation and magnitude. The positive sequence voltage should be greater than the negative sequence voltage and the phase voltages VA, VB and VC should be greater than the user settable threshold. If the aforementioned conditions are not satisfied then an alarm is raised. This alarm contact can be interlocked with the motor contactor or circuit breaker to prevent the motor from being energized until correct phase rotation and sufficient voltage exist on the system.

This feature requires a 52a circuit breaker auxiliary contact mapped to an opto input to get the information CBclosed/CB open.

Setting guidelines

The undervoltage interlock (***Start Low V Set***) is provided to prevent the motor attempting to start on reduced voltage. The setting is system dependent but may typically be set to:

80% - 90% of Vn.

6.5.1.2   LOSS OF PHASE (WHILE STARTING AND RUNNING)

Principle

If a motor is started with one phase open, it remains stationary and it can draw a current equal to 0.866 times the normal starting current. Under these circumstances, the negative phase sequence component present in the current is equal to half the normal starting current value. This is an extreme condition, as this amount of negative phase sequence current rapidly overheats the motor, and unless corrective action is taken, the motor will be seriously damaged.

Loss of one phase of the supply to a motor during normal running conditions, results in the following conditions:

Heating increases considerably due to high rotor losses caused by the -ve sequence current now present

Output of the motor is reduced and, depending on the load, an induction motor may stall or a synchronous motor may pull out of synchronism,

The motor current will increase.

One common factor in the aforementioned conditions is the presence of negative phase sequence current. The P24xM relay therefore incorporates a negative phase sequence current element to detect such extreme operating conditions. This negative phase sequence current element operating time characteristic is of an inverse time nature and is governed by the following formula:

t = TMS * [1.2/(I2/Is)]

> *Note:*
> *If the I2/Is has to be limited, a fixed timer should be used for the threshold I2> value.*

The element may be selectively enabled or disabled.

In addition to this, an independent, definite time alarm stage is provided.

Setting guidelines

This element should be set in excess of the anticipated negative phase sequence current resulting from asymmetric CT saturation during starting, but less than the negative phase sequence current resulting from loss of one phase during starting.

A typical setting for the negative sequence overcurrent element is 30% of the anticipated negative sequence current resulting from loss of one phase during starting for a motor with a starting current to load current ratio of 6 to 1.

Therefore set:

I2>2 Current Set = 1/6 normal starting current or full load current

The setting for the alarm time delay is application dependent.

7   EARTH FAULT PROTECTION

Earth faults are overcurrent faults where the fault current flows to earth. Earth faults are the most common type of fault.

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

- A separate current Transformer (CT) located in a power system earth connection
- A separate Core Balance Current Transformer (CBCT), usually connected to the SEF transformer input
- A residual connection of the three line CTs, where 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. *EARTH FAULT 1* (EF1) is used for earth fault current that is measured directly from the system (measured). *EARTH FAULT 2* (EF2) uses quantities derived internally from summing 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 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
- I*N2>(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. 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: This diagram shows the logic for IN2 (derived earth fault). The logic for IN1 (measured earth fault) follows the same principles, but with no CTS blocking.
This diagram does not show all stages. Other stages follow similar principles.

V04003
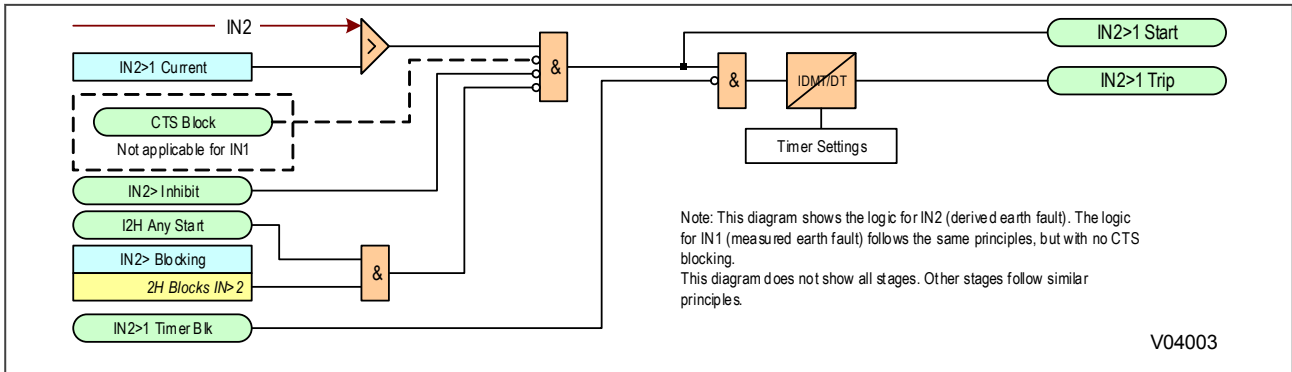
> Note:
> Non-directional EF logic (single stage)

> Note:
> 1 If a CLP condition exists, the **I>(n) Current Set** threshold is taken from the COLD LOAD PICKUP column
> 2 The CTS blocking is not applicable for IN1, however this can be achieved using the PSL

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 that 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.
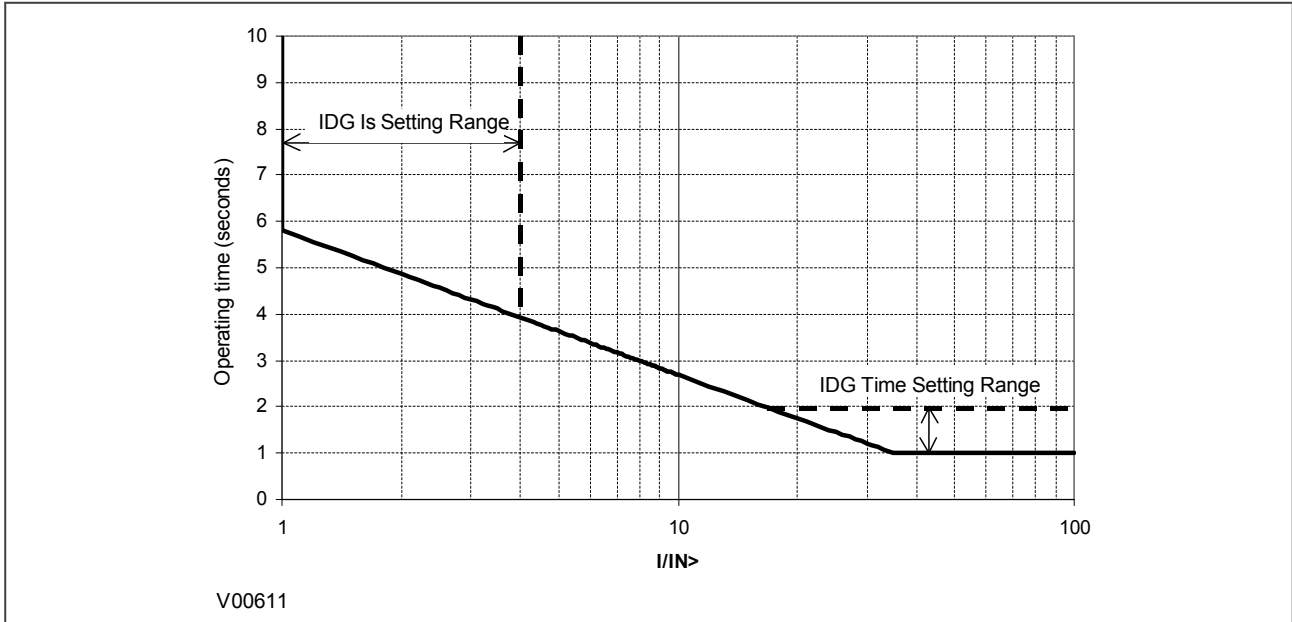
Figure 36: IDG Characteristic

7.4 DIRECTIONAL ELEMENT

If Earth fault current can flow in both directions through a protected location, you will need to use a directional overcurrent element to determine the direction of the fault. Typical systems that require such protection are parallel feeders and ring main systems.

A directional element is available for all of the Earth Fault stages. These are found in the direction setting cells for the relevant stage. They can be set to non-directional, directional forward, or directional reverse.

Directional control can be blocked by the VTS element if required.

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

7.4.1 RESIDUAL VOLTAGE POLARISATION

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

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

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

The directional criteria with residual voltage polarisation is given below:

Directional forward

(∠VN + 180°) + RCA - 90° + (180° - tripping angle)/2 < ∠IN < (∠VN +180°) + RCA +90° - (180° - tripping angle)/2

Directional reverse

(∠VN + 180°) + RCA - 90° - (180° - tripping angle)/2 > ∠IN > (∠VN +180°) + RCA +90° + (180° - tripping angle)/2

This can be best visualised with reference to the following diagram:

V00748
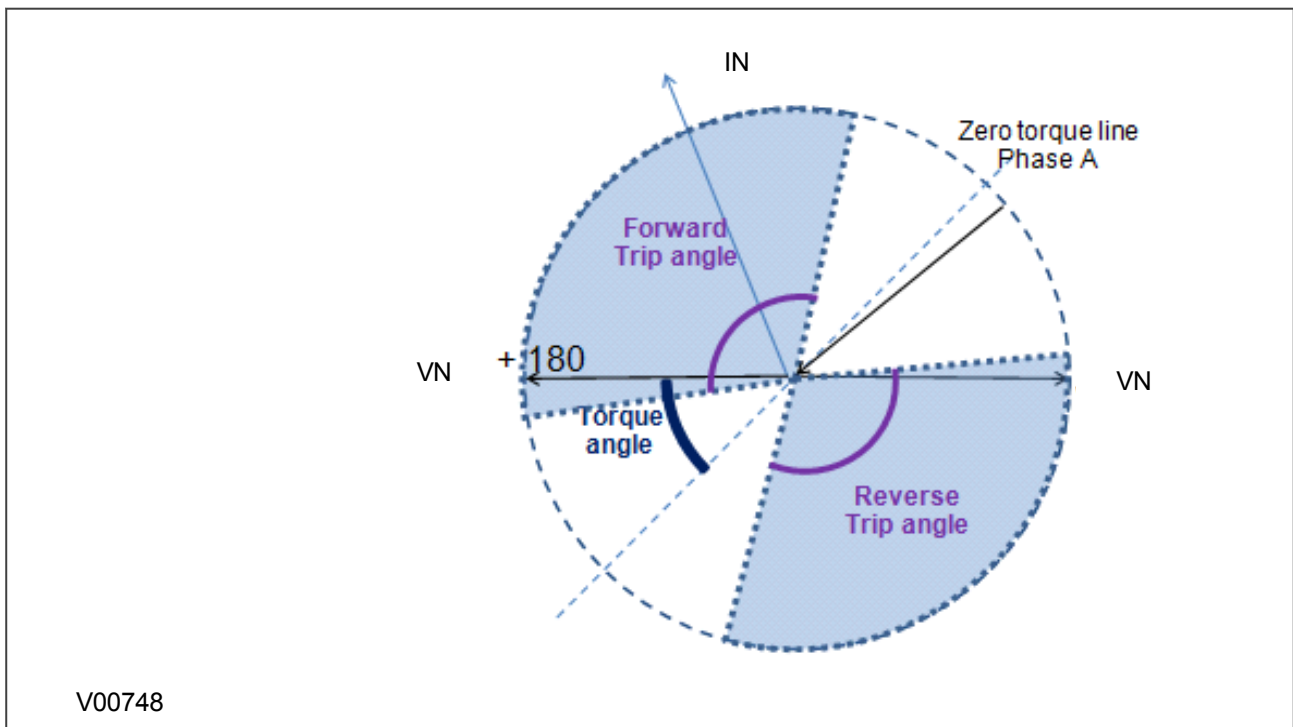
Figure 37: Directional angles

Some of the models derive the Residual Voltage quantity internally, from the 3-phase voltage input supplied from either a 5-limb or three single-phase VTs.On models with 4th VT input, this feature can be used for Check Sync or to measure the Residual Voltage VN. The 4th VT input can be configured for measured or derived voltage.

7.4.1.1   DIRECTIONAL EARTH FAULT LOGIC WITH RESIDUAL VOLTAGE POLARISATION
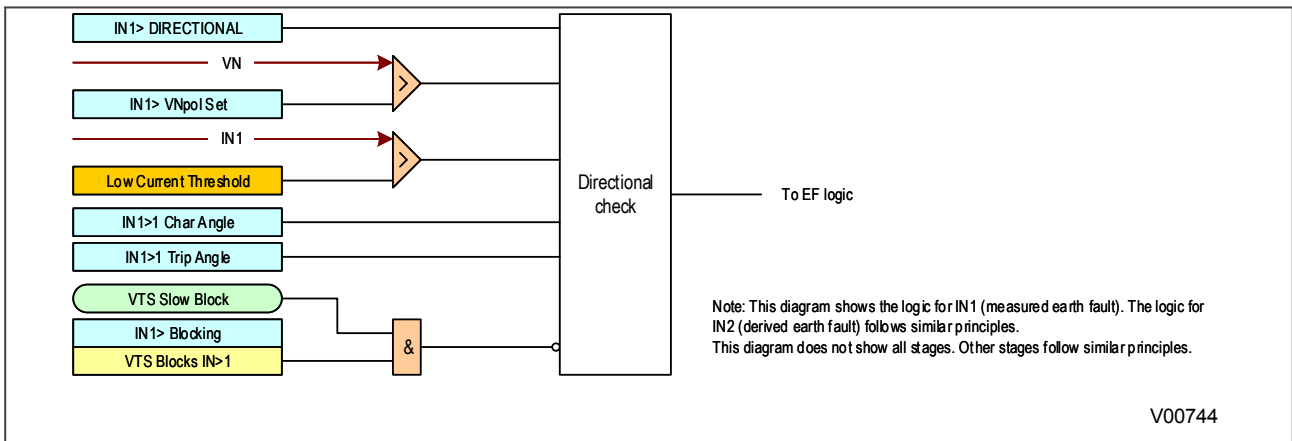
Figure 38: Directional EF logic with neutral voltage polarization (single stage)

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

7.4.2   NEGATIVE SEQUENCE POLARISATION

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

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

This can be used for both the derived and measured standard earth fault elements. It requires a suitable voltage and current threshold to be set in cells **IN> V2pol Set** and **IN> I2pol set** respectively.

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

The directional criteria with negative sequence polarisation is given below:

Directional forward

$(\angle V2 + 180°) + RCA - 90° + (180° - tripping\ angle)/2 < \angle I2 < (\angle V2 + 180°) + RCA + 90° - (180° - tripping\ angle)/2$

Directional reverse

$(\angle V2 + 180°) + RCA - 90° - (180° - tripping\ angle)/2 > \angle I2 > (\angle V2 + 180°) + RCA + 90° + (180° - tripping\ angle)/2$

This can be best visualised with reference to the following diagram:
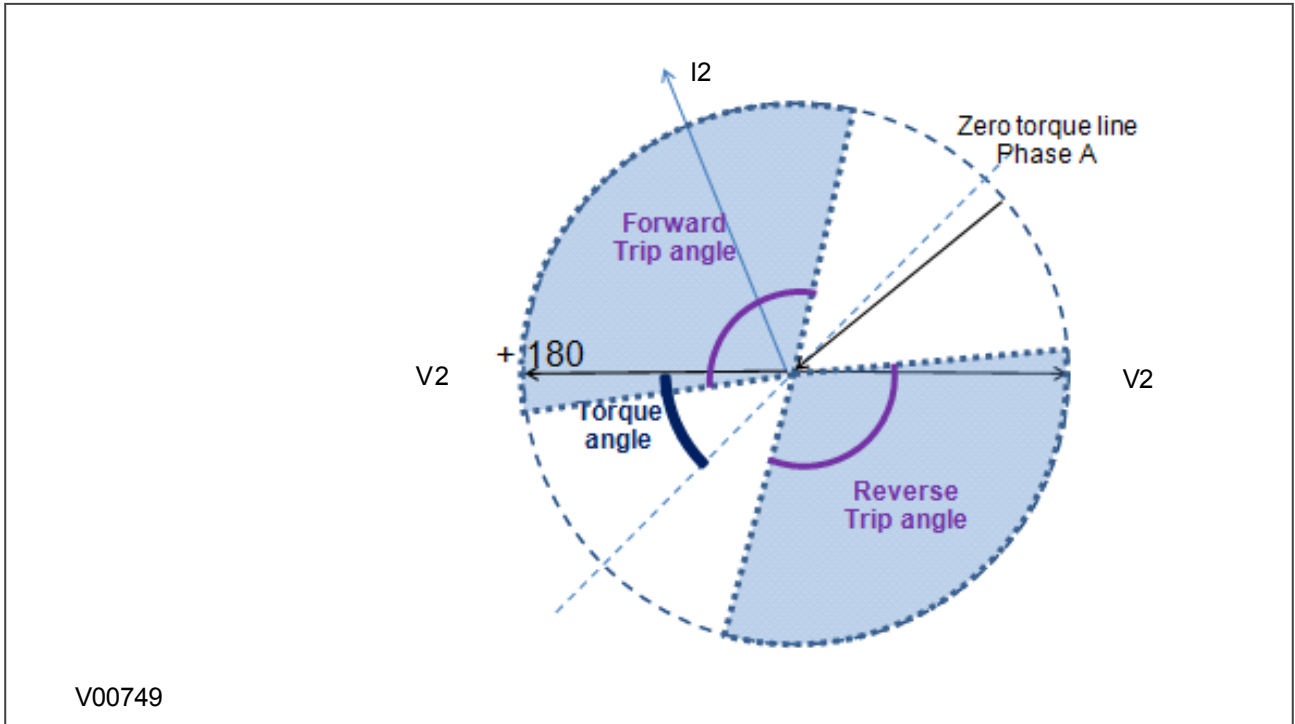
Figure 39: Directional angles

7.4.2.1   DIRECTIONAL EARTH FAULT LOGIC WITH NPS POLARISATION
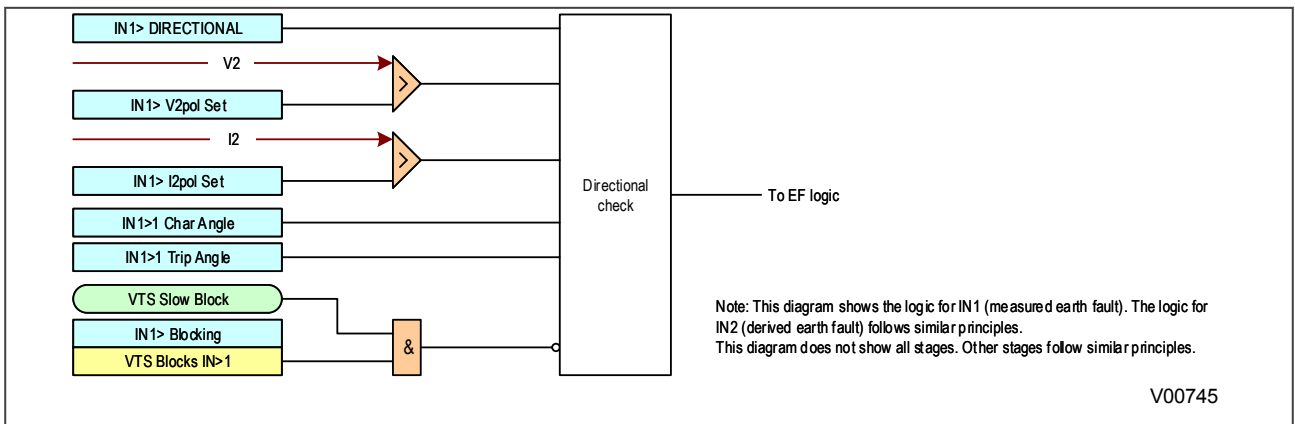
Figure 40: *Directional Earth Fault logic with negative sequence polarisation (single stage)

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

7.5   APPLICATION NOTES

7.5.1   SETTING GUIDELINES (DIRECTIONAL ELEMENT)

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

We recommend the following RCA settings:

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

7.5.2   PETERSON COIL EARTHED SYSTEMS

A Petersen Coil earthing system is used in compensated earthing systems, as well as being used in cases of high impedance earthing. Petersen Coil earthed systems (also called compensated or resonant systems) are commonly found in areas where the system consists mainly of rural overhead lines. They are particularly beneficial in locations which are subject to a high incidence of transient faults. In a Petersen Coil earthed system, the network is earthed via a reactor, whose reactance is tuned to be nominally equal to the total system capacitance to earth. Similar to insulated systems, if a single-phase to earth fault is applied to a Petersen Coil earthed system, under steady state conditions no earth fault current flows. The effectiveness of the method in reducing the current to zero is dependent on the accuracy of the tuning of the reactance value and any changes in system capacitance (for example due to system configuration changes) require changes to the coil reactance. In practice, perfect matching of the coil reactance to the system capacitance is difficult to achieve, so that a small earth fault current will flow.

In isolated and compensated earthed systems, if an earth fault current is below a certain level, then the fault will self-extinguish due to the low current magnitude. It therefore appears as a transient phenomenon. The figure below shows earth fault current levels, below which they self-extinguish on these types of system. Statistics demonstrate that around 80% of earth faults in Petersen Coil earthed systems self-extinguish. This, in part, explains their popularity.
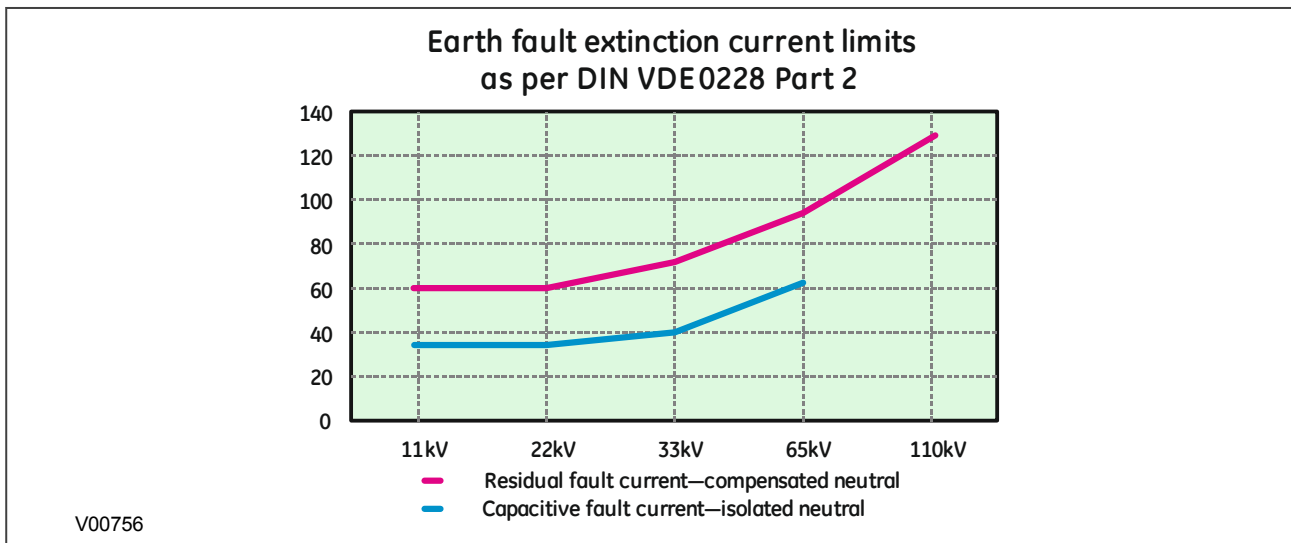
Figure 41: Current level (amps) at which transient faults are self-extinguishing

The following figure depicts a simple network earthed through a Petersen Coil reactance. It can be shown that if the reactor is correctly tuned, theoretically no earth fault current will flow.
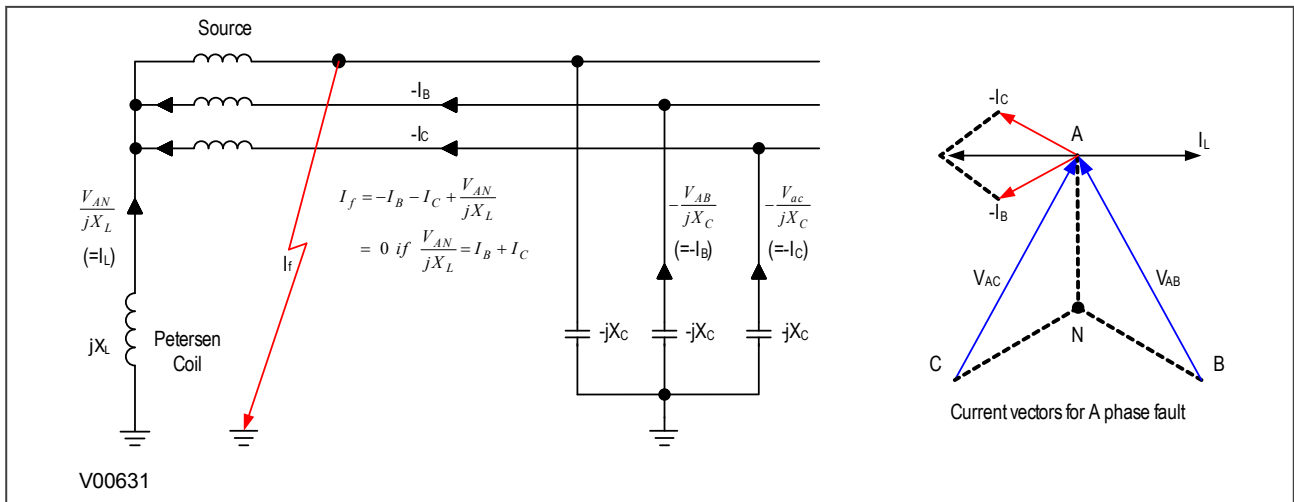
Figure 42: Earth fault in Petersen Coil earthed system

Consider a radial distribution system earthed using a Petersen Coil with a phase to earth fault on phase C, shown in the figure below:
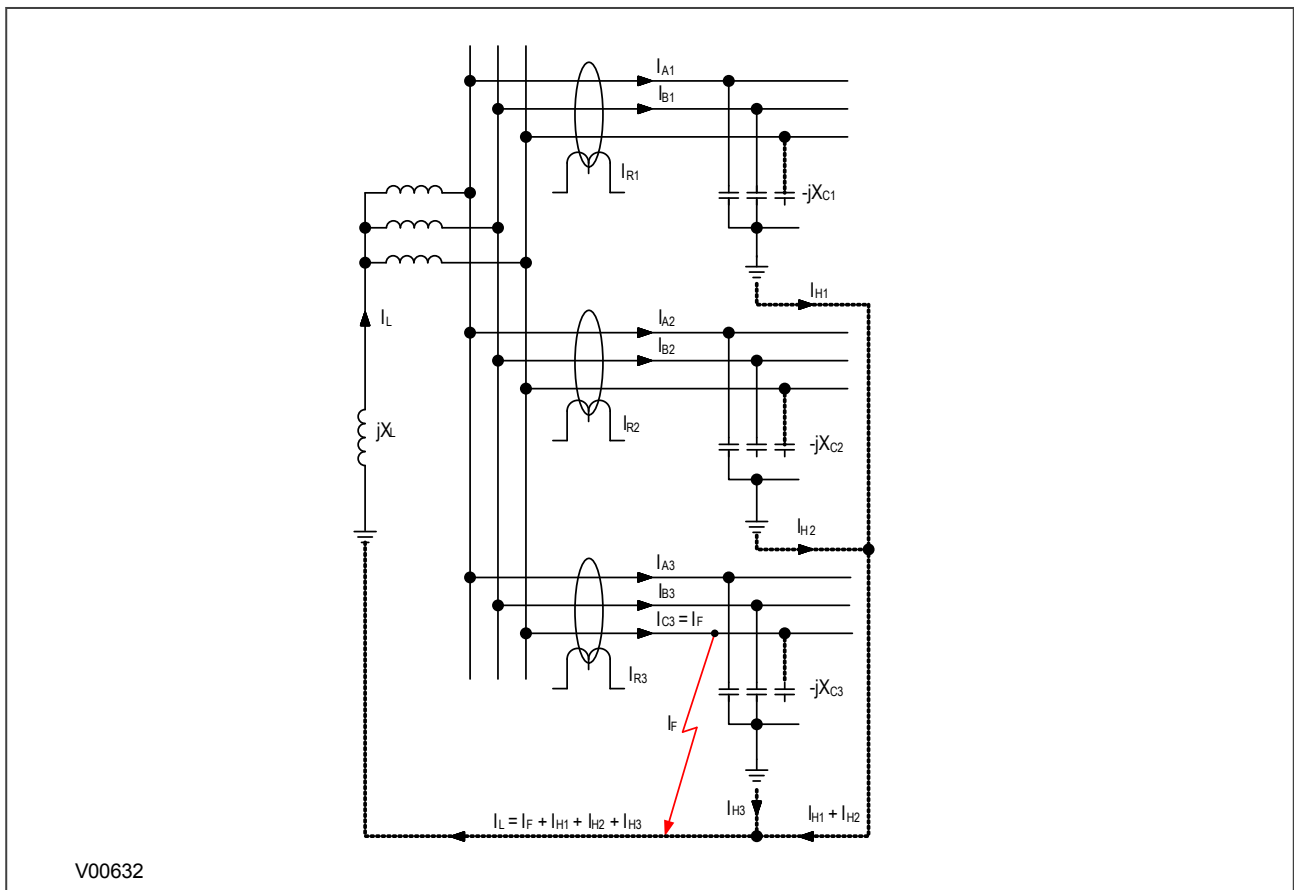
Figure 43: Distribution of currents during a Phase C fault

Assuming that no resistance is present in X_L or X_C, the resulting phasor diagrams will be as shown in the figure below:
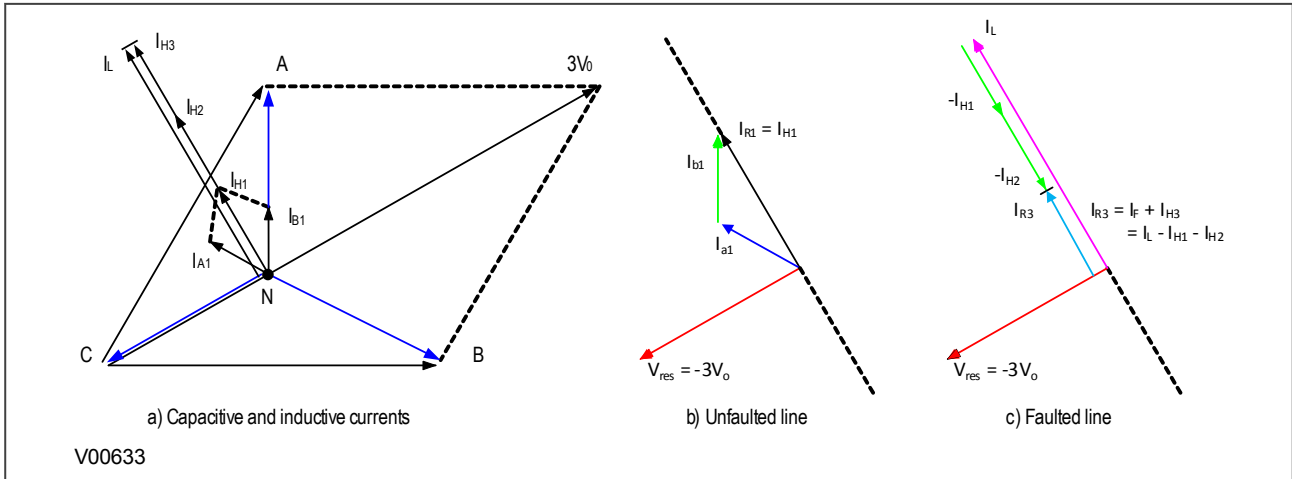
Figure 44: Phasors for a phase C earth fault in a Petersen Coil earthed system

It can be seen that:

- The voltage in the faulty phase reduces to almost 0V
- The healthy phases raise their phase to earth voltages by a factor of √3
- The triangle of voltages remains balanced
- The charging currents lead the voltages by 90°

Using a core-balance current transformer (CBCT), the current imbalances on the healthy feeders can be measured. They correspond to simple vector addition of I_{A1} and I_{B1}, I_{A2} and I_{B2}, I_{A3} and I_{B3}, and they lag the residual voltage by exactly 90º.

The magnitude of the residual current I_{R1} is equal to three times the steady-state charging current per phase. On the faulted feeder, the residual current is equal to $I_L - I_{H1} - I_{H2}$ (C). This is shown in the zero sequence network shown in the following figure:
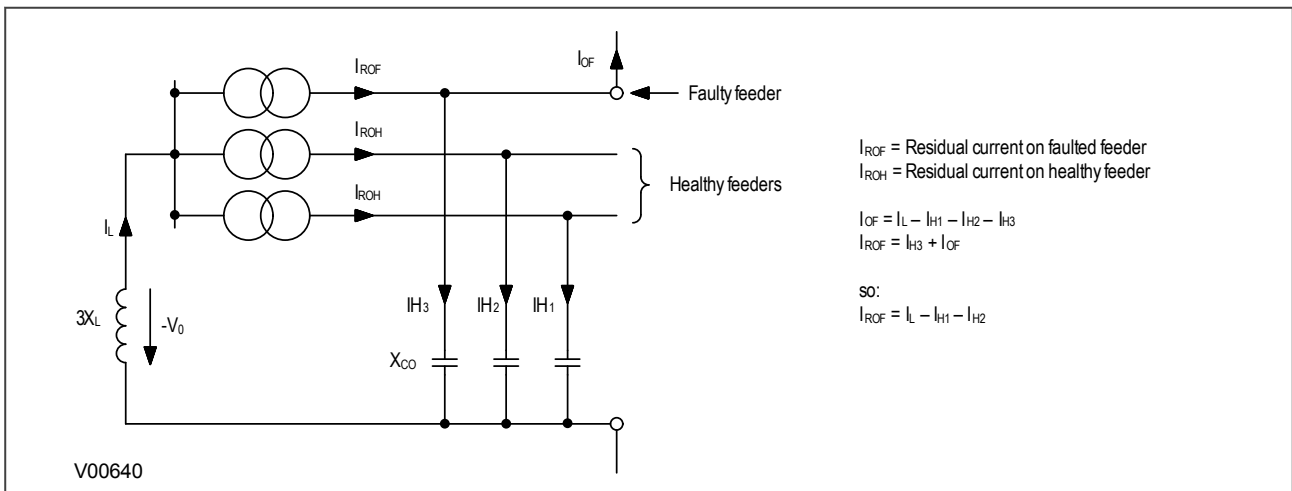
Figure 45: Zero sequence network showing residual currents

In practical cases, however, resistance is present, resulting in the following phasor diagrams:
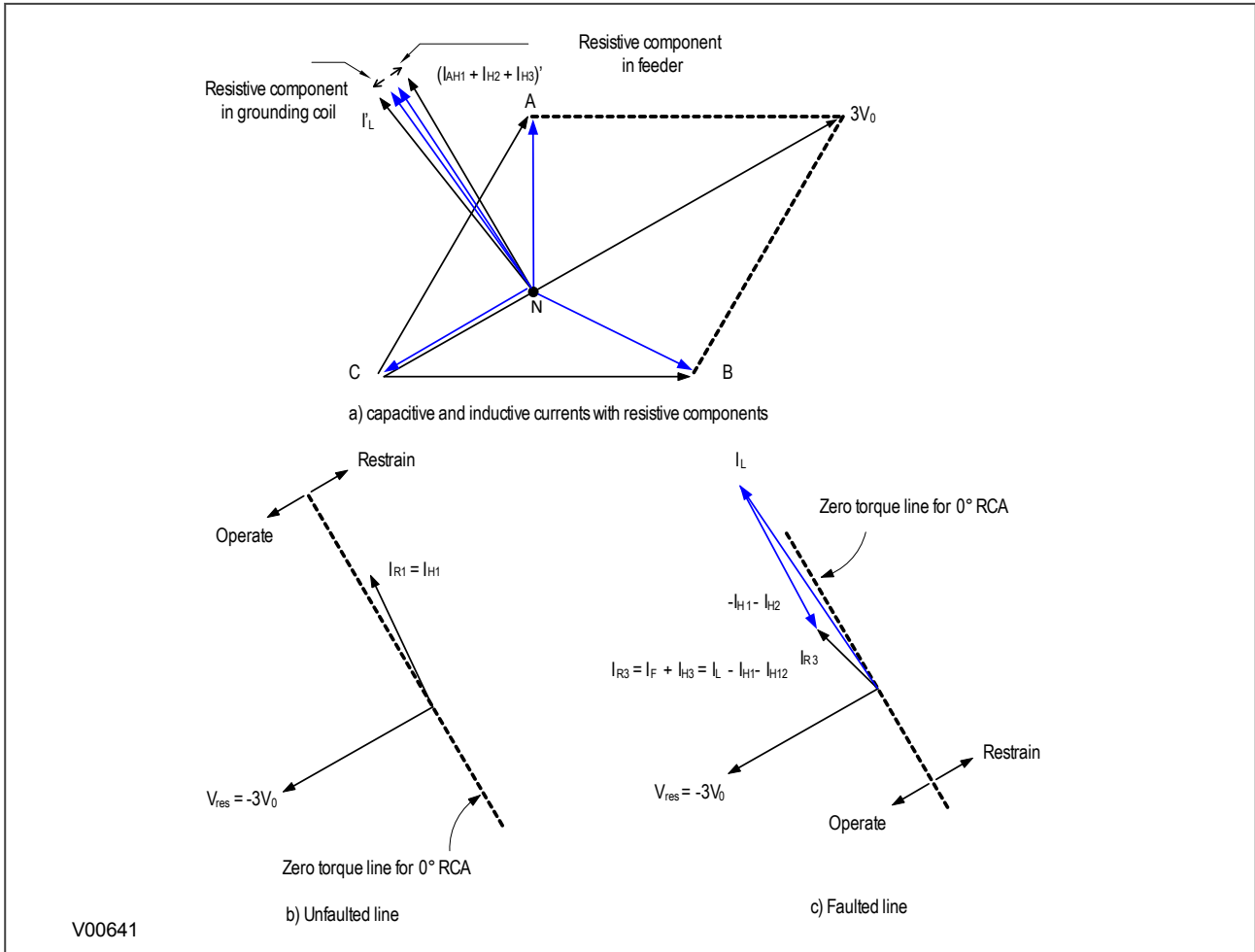
Figure 46: Phase C earth fault in Petersen Coil earthed system: practical case with resistance present

If the residual voltage is used as the polarising voltage, the residual current is phase shifted by an angle less than 90° on the faulted feeder, and greater than 90° on the healthy feeders. With an RCA of 0°, the healthy feeder residual current will fall in the 'restrain' area of the characteristic while the faulted feeder residual current falls in the 'operate' area.

Often, a resistance is deliberately inserted in parallel with the Petersen Coil to ensure a measurable earth fault current and increase the angular difference between the residual signals to reinforce the directional decision.

Directionality is usually implemented using a Wattmetric function, or a transient earth fault detection function (TEFD), rather than a simple directional function, since they are more sensitive. For further information about TEFD, refer to Transient Earth Fault Detection in the Current Protection Functions chapter.

7.5.3   SETTING GUIDELINES (COMPENSATED NETWORKS)

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

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

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

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

7.5.4   SOLIDLY EARTHED SYSTEM

Principle

For earth fault settings >20% of the motor continuous rated current you can use conventional residual CT connection for the detection of earth faults. Anything under this value the use of a core balance CT can be more applicable.

Care must be taken to ensure the relay does not operate from the spill current resulting from asymmetric CT saturation during starting. To achieve stability under these conditions, it is usual to insert a stabilizing resistor in series with the relay (when set for instantaneous operation) or use a time delay. The required value of resistor is calculated as follows:

R_{stab} =

$$\frac{I_{st}}{I_o}$$

$(R_{ct} + N. R_1 + R_r)$

Where:

I_o = earth fault setting in amps

I_{st} = motor starting current referred to CT secondary

R_{ct} = d.c. resistance of CT secondary

N = 1 for 4 wire CT connection (star point at CTS)

2 for 6 wire CT connection (both star points formed at relay panel).

R_1 = resistance of single lead from relay to CT

R_r = Relay resistance in ohms

> *Note:*
> *The value of the CT Knee-pint is calculated as Vk≥4 Io x Rs when Rs is the actual stabalizing resistence value.*

Typical settings

The earth fault element should be set non-directional with a setting of approximately 30% of the motor continuous rated current.

Where a stabilizing resistor is used the earthfault element should be set instantaneous. If not used, stability during asymmetric CT saturation can be achieved by time delaying the earth fault element. The actual timer setting is very much system dependent.

If the motor is supplied by a fused contactor, it is important to grade the earthfault protection to ensure that the contactor does not attempt to interrupt fault current in excess of its breaking capacity.
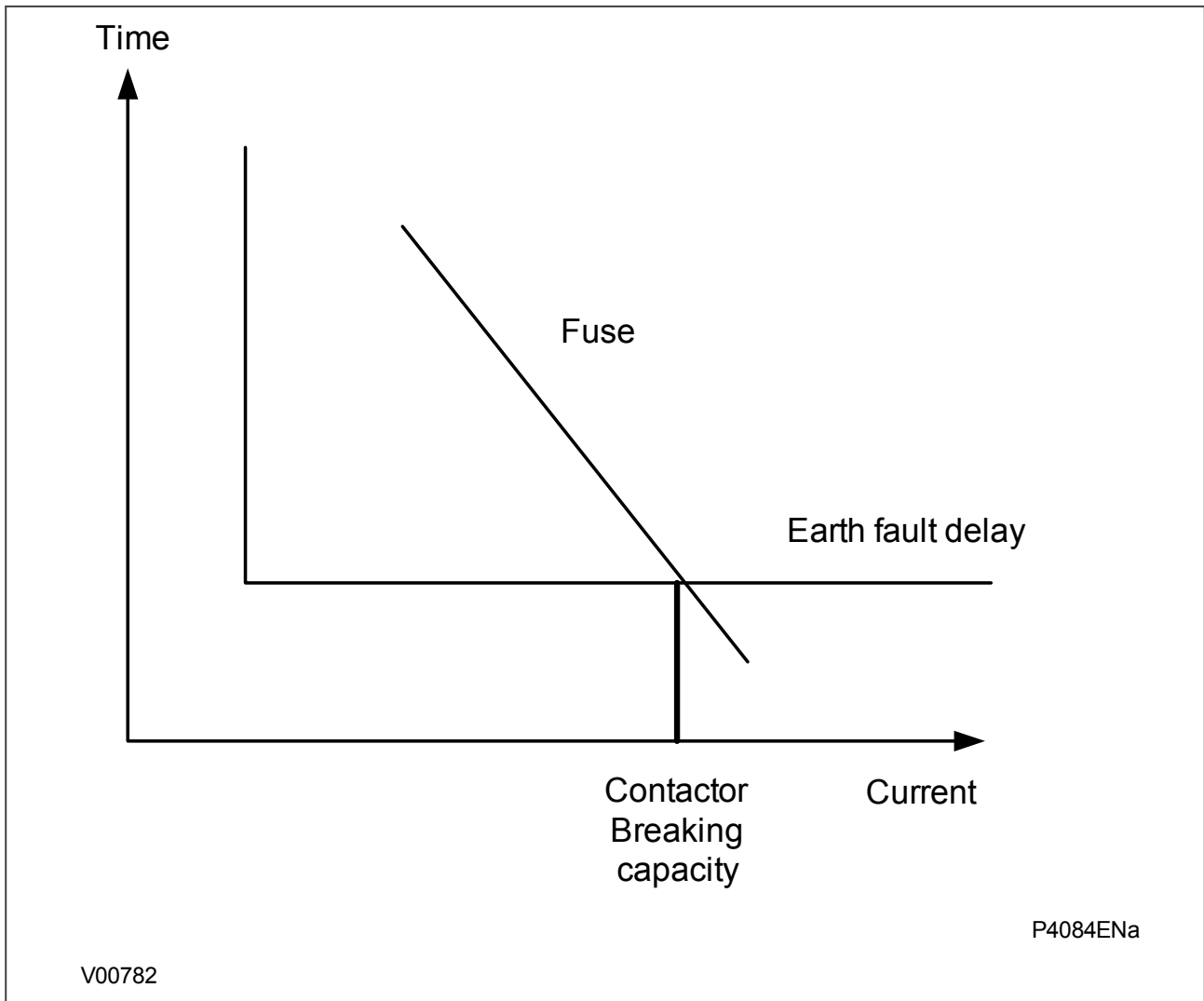
Figure 47: Fuse characteristic

7.5.5 INSULATED SYSTEM

Principle

The advantage gained by running a power system, which is insulated from earth, is that during a single phase to earth fault condition no earth fault current is allowed to flow. Therefore, you can maintain power flow on the system even when an earth fault condition is present. This advantage is offset by the fact that the resultant steady state and transient overvoltages on the sound phases can be very high.

Operational advantages can be gained by the use of insulated systems. However, it is vital that detection of the fault is achieved. This is not possible through standard current operated earth fault protection. One possibility for fault detection is through a residual overvoltage device. This functionality is included within the P24xM relay and is detailed in the Residual Overvoltage Protection section. However, fully discriminative earth fault protection on this type of system can be achieved by the application of a sensitive earth fault element. This type of relay is set to detect the resultant imbalance in the system charging currents that occurs under earth fault conditions. Therefore, it is essential that a core balance CT is used for this application.
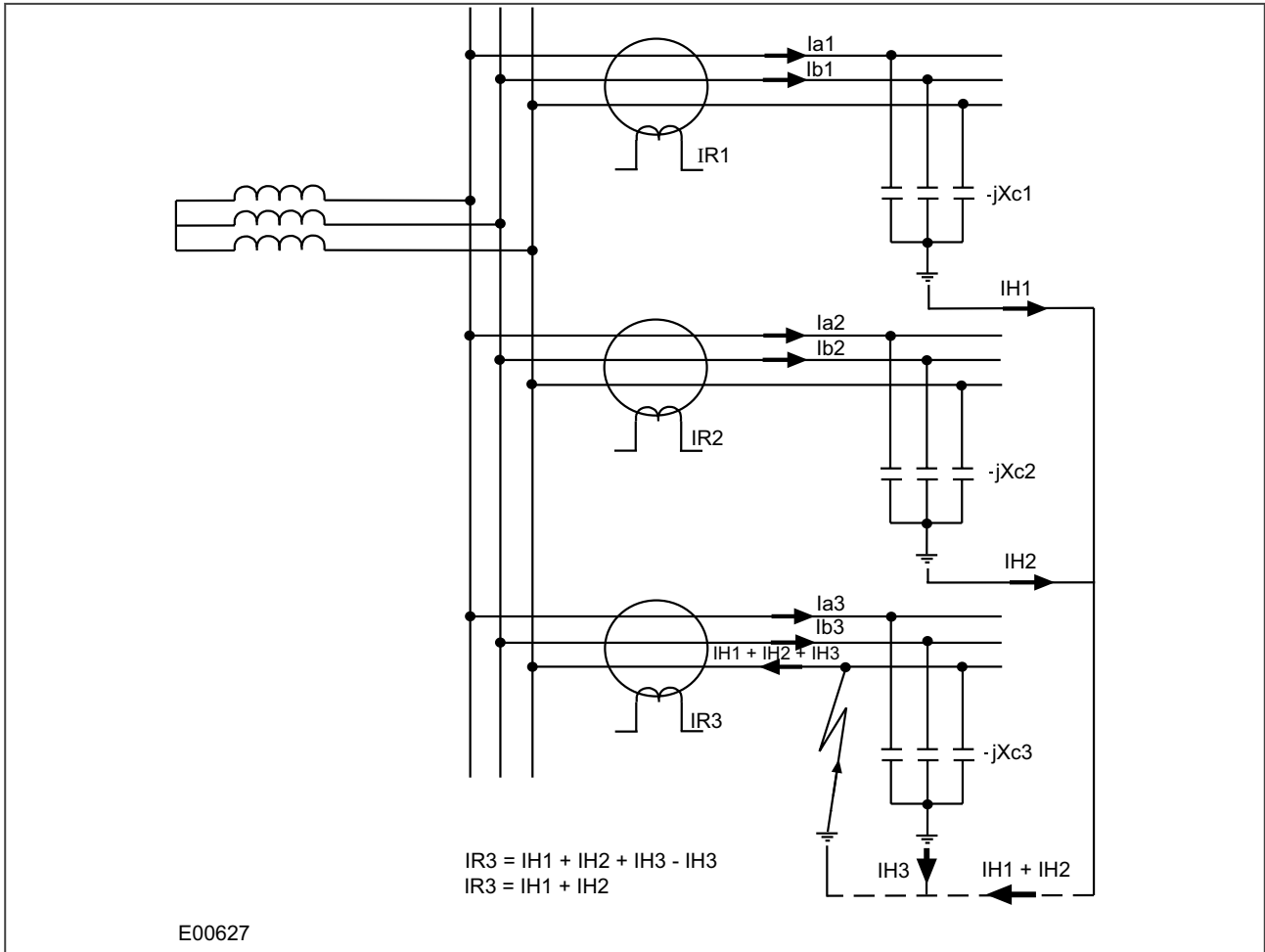
Figure 48: Current distribution in an insulated system with C phase fault

The figure above shows the relays on the healthy motor feeders see the unbalance in the charging currents for their own feeder.

The relay on the faulted feeder, however, sees the charging current from the rest of the system (IH1 and IH2 in this case), with its own feeders charging current (IH3) becoming cancelled out. This is further shown by the phasor diagrams in the next figure.
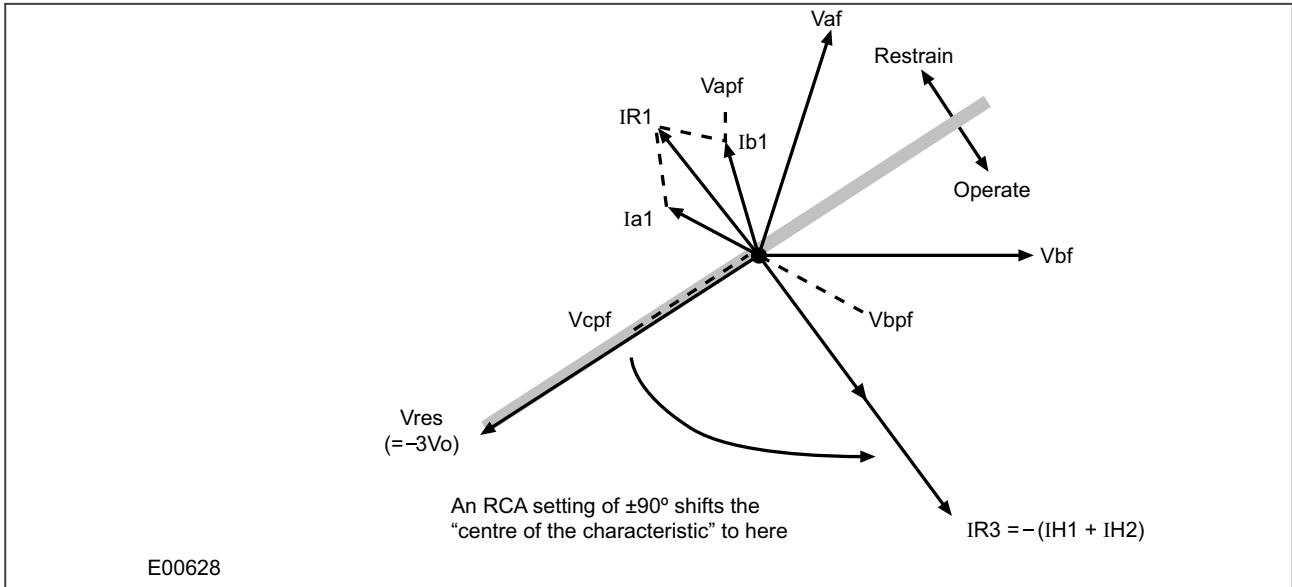
Figure 49: Phasor diagrams for insulated system with C phase fault

The diagram above shows 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 currents (Ia1), is then shown to be leading the resultant A phase voltage by 90°. Likewise, the B phase charging current leads the resultant Vb by 90°.

The unbalance current detected by a core balance current transformer on the healthy motor feeders can be seen to be a simple vector addition of Ia1 and Ib1, giving a residual current which lies at exactly 90° lagging the residual voltage (-3Vo). As the healthy phase voltages have risen by a factor of √3, the charging currents on these phases are ·3 times larger than their steady state values. Therefore, the magnitude of residual current, IR1, is equal to 3 × the steady state per phase charging current.

The phasor diagrams show that the residual currents on the healthy and faulted motor feeders, IR1 and IR3 respectively, are in antiphase. Therefore, a directional element can be used to provide discriminative earth fault protection.

If the polarizing voltage of this element, Vres (equal to -3Vo), is shifted through +90°, the residual current seen by the relay on the faulted feeder lies within the operate region of the directional characteristic and the current on the healthy feeders falls within the restrain region.

> *Note:*
> *The actual residual voltage used as a reference signal for the directional earth fault protection in the P24xM relay is internally phase shifted by 180° and is therefore shown as -3Vo in the vector diagrams.*

The required characteristic angle setting for the sensitive earth fault element when applied to insulated systems is +90°.

> *Note:*
> *The recommended setting corresponds to the relay being connected so that its direction of current flow for operation is from the motor feeder into the busbar.*

The P24xM relay internally derives the residual polarizing voltage for the directional earth fault element. Therefore, either a 5-limb or three single phase VTs should be applied to drive the relay, not a VT of the three-limb design. The former allows the passage of residual flux through the VT and permits the relay to derive the required residual voltage. A three limb VT provides no path for the flow of residual flux, so is unsuitable. Alternatively, the relay can be driven by a phase to phase connected VT with a broken delta winding connected to the residual voltage input.

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

Setting guidelines

The residual current detected by the relay on the faulted feeder is equal to the sum of the charging currents flowing from the rest of the system. 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 unbalance current detected by the relay is equal to three times the per phase charging current of the rest of the system. A typical relay setting can be 30% of this value, that is equal to the per phase charging current of the remaining system. In practice, the required setting can be determined on site, where system faults can be applied and suitable settings can be adopted based on practically obtained results. The use of P24xM relays comprehensive measurement and fault recording facilities can prove very useful in this respect.

The timer setting of this element is not critical, since for the first fault only capacitive current exists on the system. However, for subsequent faults, fast tripping is required. If the motor is operated using a fused contactor it is important to delay the protection sufficiently to ensure that the contactor does not attempt to interrupt fault current in excess of its breaking capacity.

7.5.6   RESISTANCE EARTHED SYSTEMS

Earthing the system using a resistor reduces both the fault current and transient overvoltages. Resistance earthing can sometimes be advantageous in hazardous environments such as in mines since the earthing resistance reduces touch and step potentials during earth faults.

Setting guidelines

On a resistance earthed system, it is common practice to limit the fault current to approximately full load current.

For this type of application the relay can be set non-directional with a current sensitivity of less than 30% of the minimum earth fault level, but greater than three times the steady state charging current of the motor feeder.

Guidelines given for solidly earthed systems are also applicable for the required time delay setting.

> *Note:*
> *If the setting guidelines for applying a non-directional relay cannot be achieved due to the current magnitudes, then a sensitive directional earth fault element is required. This eliminates the need to set the relay in excess of the charging current for the protected feeder.*

7.5.7   HIGH RESISTANCE EARTHING

For certain applications, the fault current can be severely limited by the use of very high resistance earthing. It is usual in this case to choose a value of resistor which limits the resistive fault current to a similar magnitude as the system charging current. Therefore, charging current has a marked influence on the angle of the fault current with respect to the polarizing voltage (-3 Vo).

In this application sensitive directional earthfault protection, operated from a core balance CT, is required. The relay characteristic angle setting should therefore be set to +45° (refer to the Phasor diagrams for insulated system with C phase fault figure).

> *Note:*
> *The recommended setting corresponds to the relay being connected so that its direction of current flow for operation is from the motor feeder into the busbar.*

The current sensitivity of the relay should be approximately 30% of √2 times the charging current for the rest of the system (3 × steady state value). The relay connections to give a defined direction for operation are shown on the relay connection diagram.

The timer setting of this element is not critical because minimal damage results from the first fault. However, for subsequent faults fast tripping is required.

> *Note:*
> *Similar comments regarding the VT requirements for the P24xM relay when directionalizing earth fault elements (R.C.A = relay characteristic angle) can be seen in the Insulated system section.*
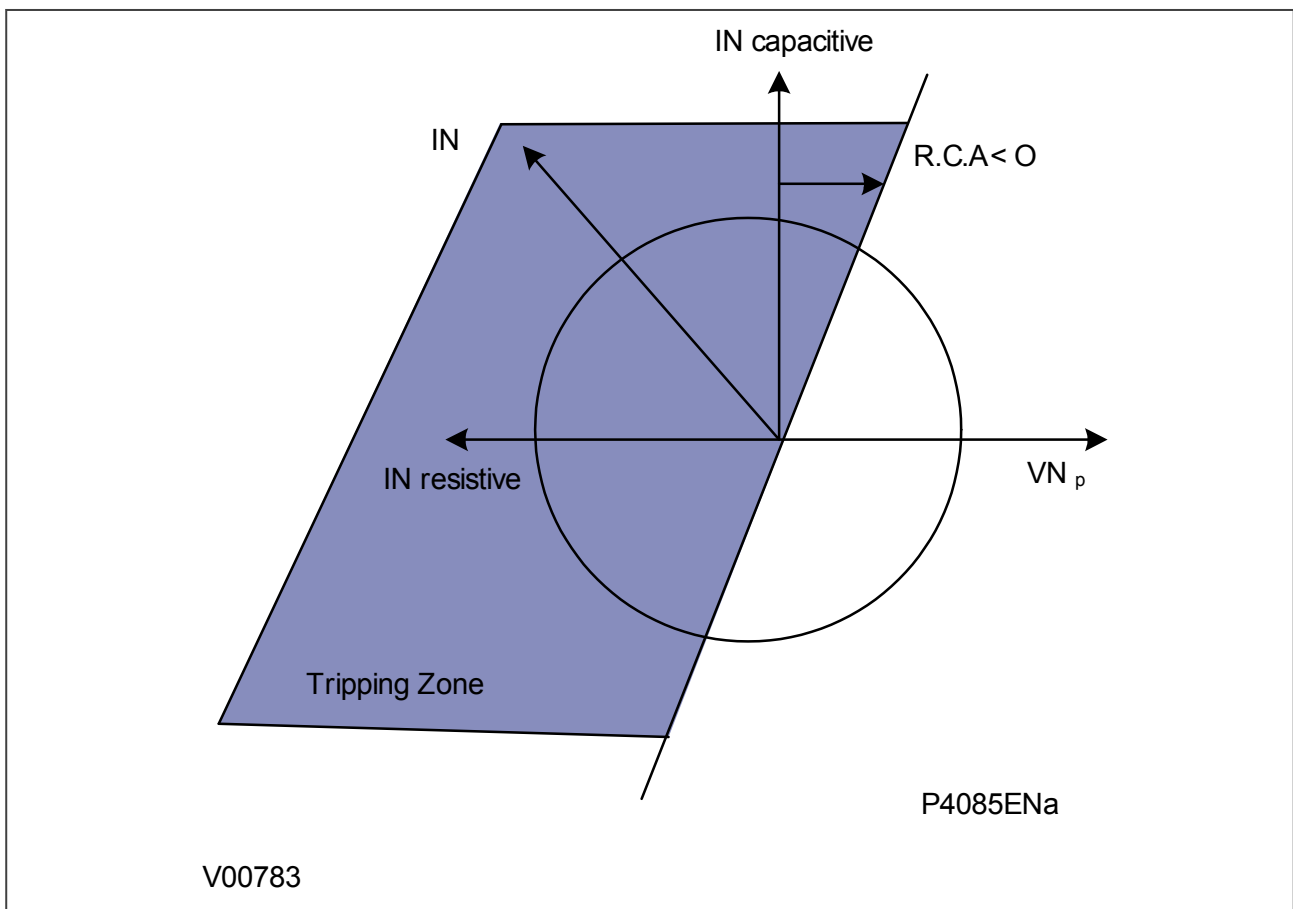
Figure 50: Directional tripping characteristic

7.5.8   PETERSEN COIL EARTHED SYSTEMS

Principle

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

If a high impedance device is used for earthing the system, or the system is unearthed, the earth fault current is reduced. However, the steady state and transient overvoltages on the sound phases can be very high. Therefore, high impedance earthing is only used in low or medium voltage networks where the necessary insulation against

such overvoltages is not too costly. Higher system voltages would normally be solidly earthed or earthed using a low impedance.

A special case of high impedance earthing using a reactor occurs when the inductive earthing reactance is made equal to the total system capacitive reactance to earth at system frequency. This practice is widely referred to as Petersen (or resonant) Coil Earthing. With a correctly tuned system, the steady state earthfault current is zero, so that earth faults become self-extinguishing. Such systems can, if designed, be run with one phase earthed for a long period until the cause of the fault is identified and rectified. With the effectiveness of this method being dependent on the correct tuning of the coil reactance to the system capacitive reactance, an expansion of the system at any time would necessitate an adjustment of the coil reactance.

Petersen coil earthed systems are commonly found in areas where the power system consists mainly of rural overhead lines and can be particularly beneficial in locations which are subject to a high incidence of transient faults. The Petersen coil, for example, can extinguish transient earth faults caused by lightning strikes without the need for outages.

The figure below shows a source of generation earthed through a Petersen Coil, with an earth fault applied on the A Phase. Under this situation you can see that the A phase shunt capacitance becomes short circuited by the fault. Therefore, the calculations show that if the reactance of the earthing coil is set correctly, the resulting earth fault current is zero.
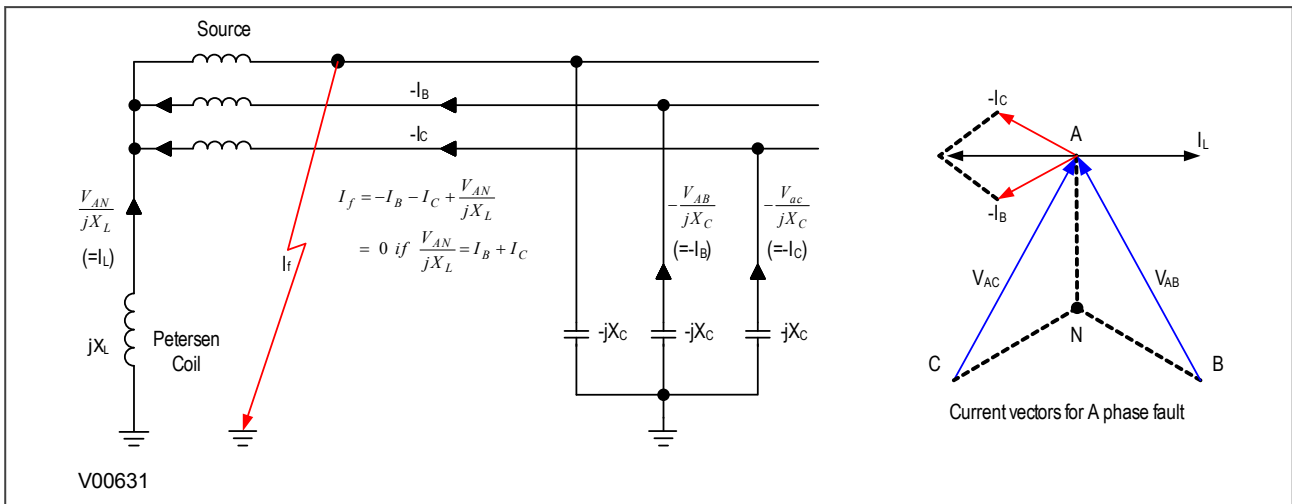
Figure 51: Current distribution in Petersen coil earthed system

Prior to actually applying protective relays to provide earth fault protection on systems which are earthed using a Petersen Coil, it is imperative to gain an understanding of the current distributions that occur under fault conditions on such systems. With this information you can decide on the type of relay that may be applied, ensuring that it is both set and connected correctly.

The figure below shows a radial distribution system having a source which is earthed using a Petersen Coil. Three outgoing feeders are present, the lower of which has a phase to earth fault applied on the C phase.
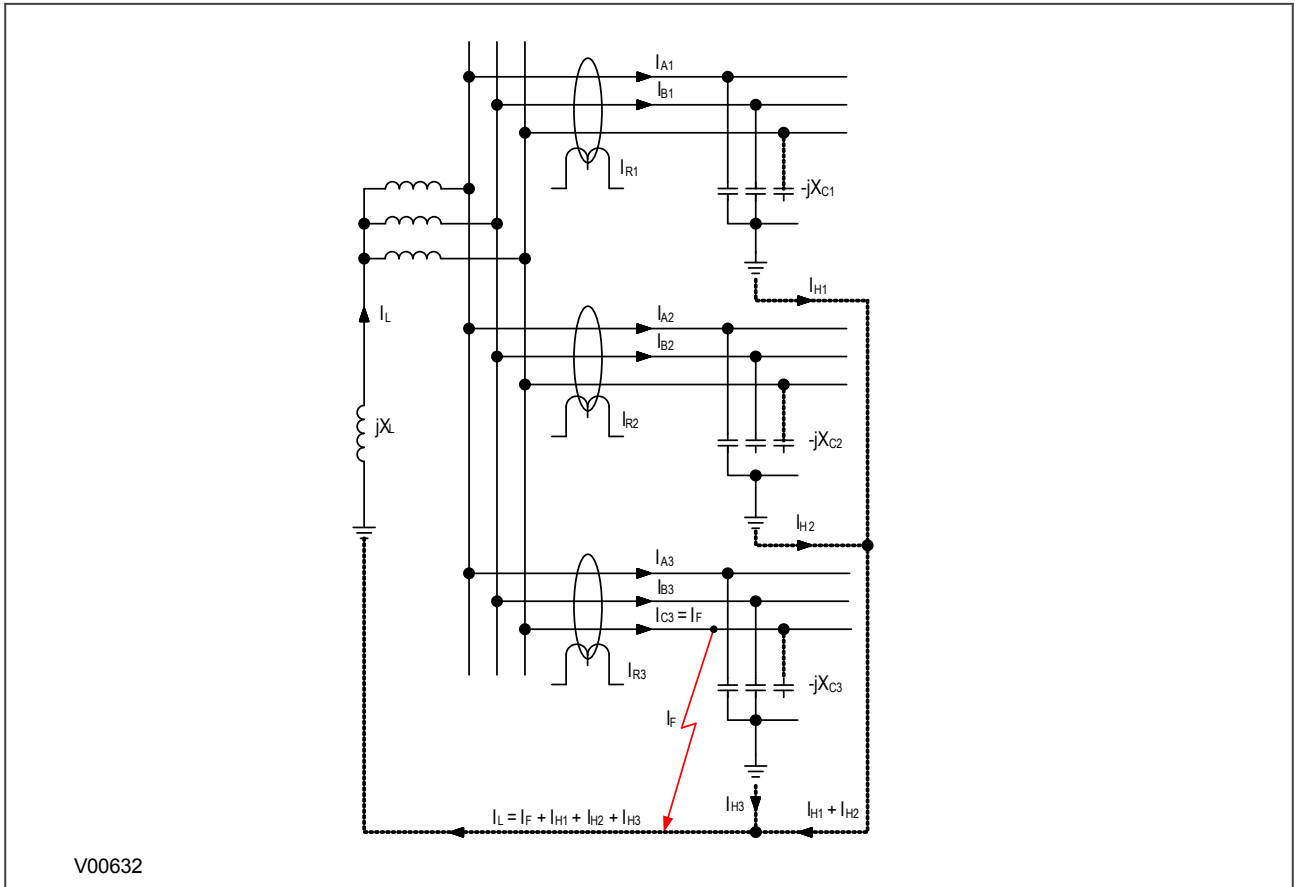
Figure 52: Distribution of currents during a C phase to earth fault

The figure below shows vector diagrams for the previous system, assuming that it is fully compensated (for example, coil reactance fully tuned to system capacitance), in addition to assuming a theoretical situation where no resistance is present either in the earthing coil or in the feeder cables.
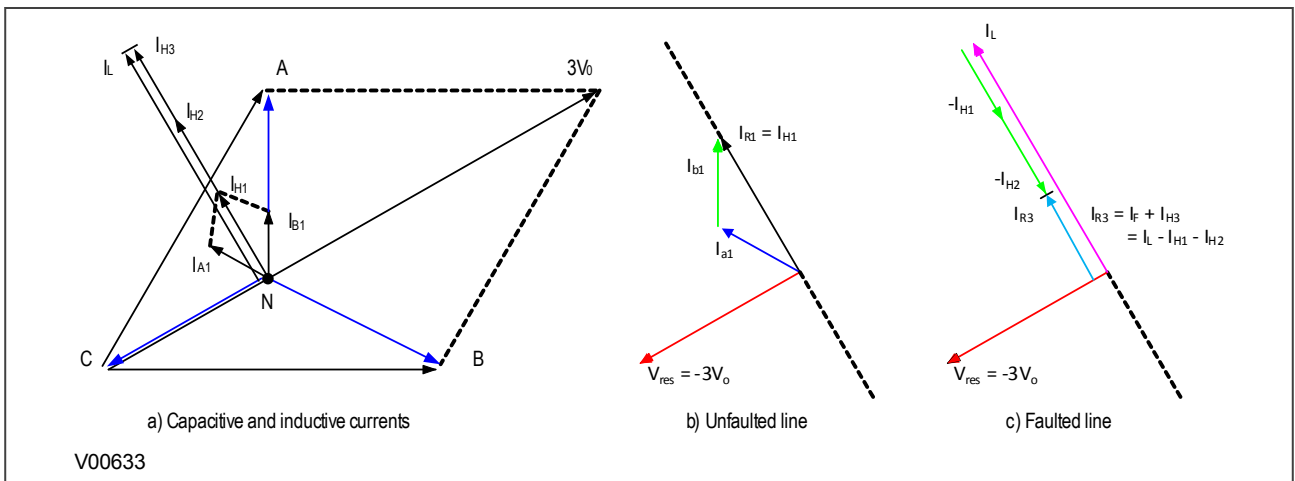
Figure 53: Theoretical case - no resistance present in XL or XC

With reference to the associated vector diagram, it can be seen that the the C-phase to earth fault causes the voltages on the healthy phases to rise by a factor of 3. The A phase charging currents (Ia1, Ia2 and Ia3), are then shown to be leading the resultant A phase voltage by 90° and likewise for the B phase charging currents with respect to the resultant Vb.

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

> *Note:*
> *The actual residual voltage used as a reference signal for directional earth fault relays is phase shifted by 180° and is therefore shown as -3 Vo in the vector diagrams. This phase shift is automatically introduced within the P24xM relays.*

On the faulted feeder, the residual current is the addition of the charging current on the healthy phases (Ih3) plus the fault current (If). The net unbalance is therefore equal to Il-Ih1-Ih2.

This situation is more readily observed by considering the zero sequence network for this fault condition. This is shown in figure below.
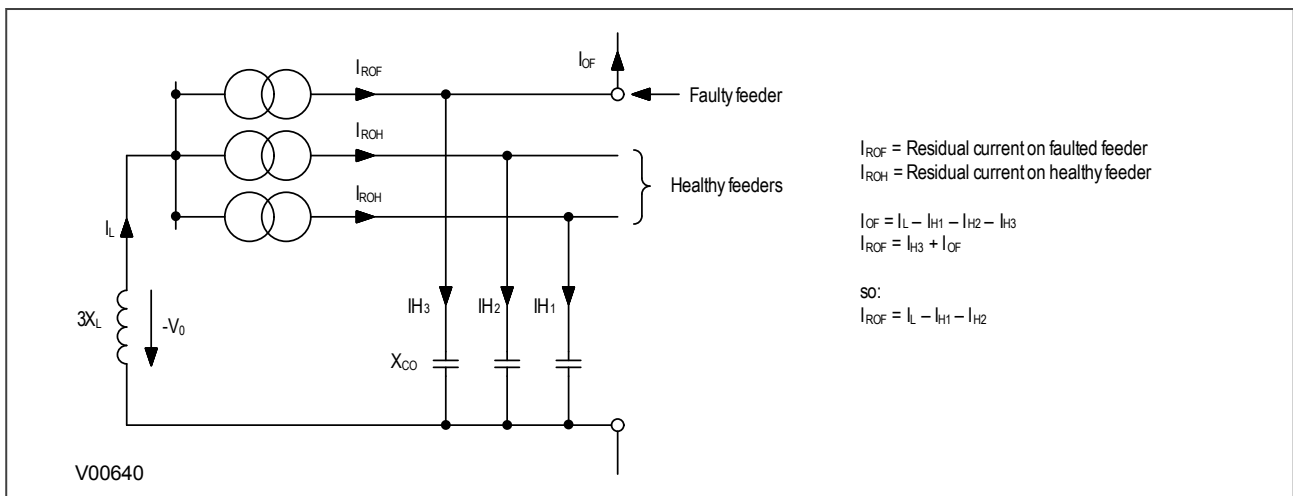
Figure 54: Zero sequence network showing residual currents

When comparing the residual currents occurring on the healthy and the faulted feeders the figure below shows that the currents would be similar in both magnitude and phase. Therefore, it is not possible to apply a relay which could provide discrimination.

However, the scenario of no resistance being present in the coil or feeder cables is purely theoretical. Further consideration needs to be given to a practical application in which the resistive component is no longer ignored.
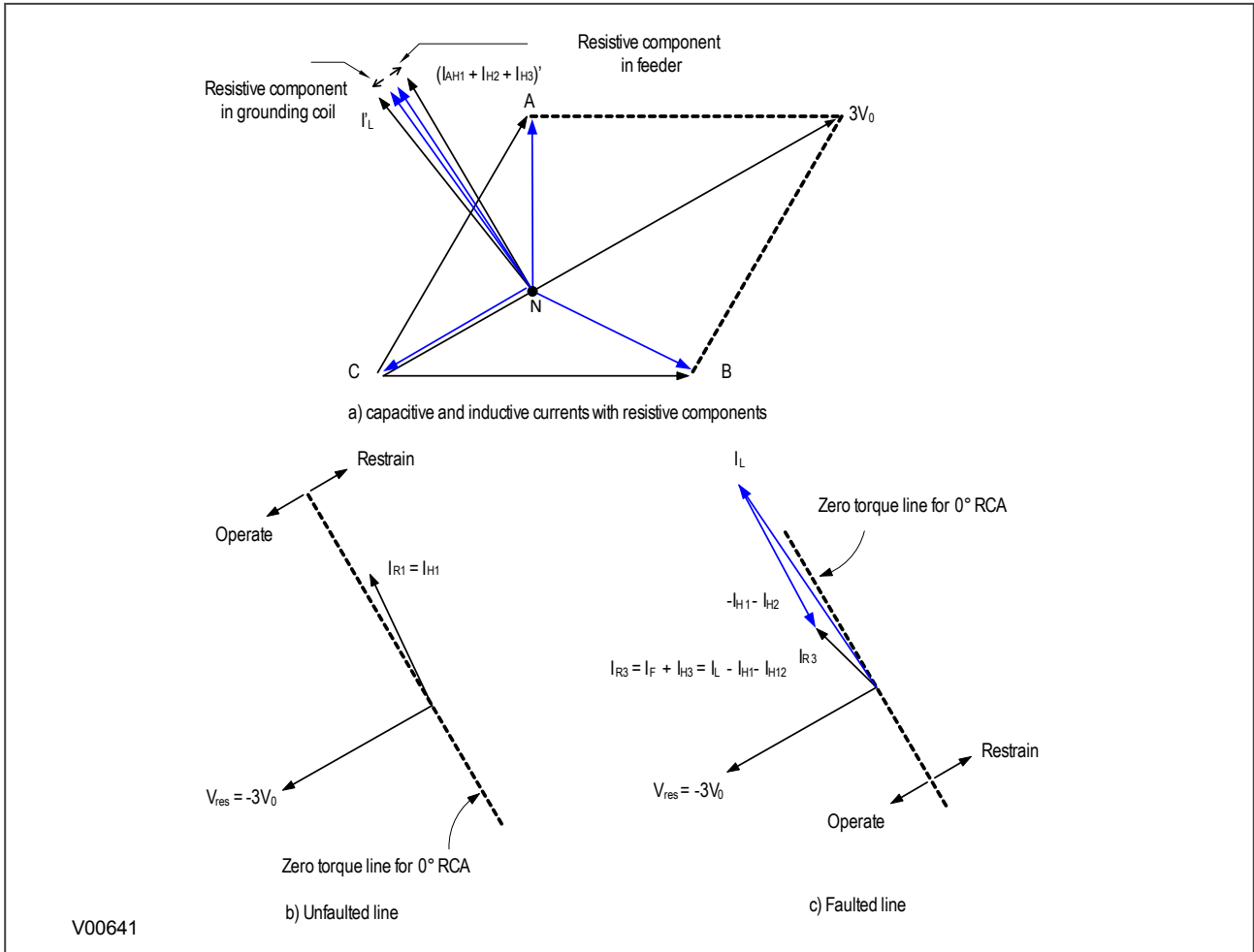
Figure 55: Practical case:- resistance present in XL and Xc

The figure above shows the relationship between the capacitive currents, coil current and residual voltage. Due to the presence of resistance in the feeders the healthy phase charging currents are now leading their respective phase voltages by less than 90°. In a similar manner, the resistance present in the earthing coil has the effect of shifting the current, IL, to an angle less than 90° lagging. The result of these slight shifts in angles can be seen in part b and c in the figure above.

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

In practical systems a resistance is inserted in parallel with the earthing coil. This increases the level of earth fault current to a more detectable level. It also increases the angular difference between the residual signals to help the application of discriminating protection.

7.5.9 OPERATION OF SENSITIVE EARTH FAULT ELEMENT

The angular difference between the residual currents on the healthy and faulted feeders allows a directional relay to be applied whose zero torque line passes between the two currents. The following types of protection elements may be applied for earth fault detection.

- A suitably sensitive directional earth fault relay having a relay characteristic angle setting (RCA) of zero degrees, with the possibility of fine adjustment about this threshold.
- A sensitive directional zero sequence wattmetric relay having similar requirements to the above with respect to the required RCA settings.

Stages 1 and 2 of the sensitive earth fault element of the P24xM relay are settable down to 0.2% of rated current and would fulfill the requirements of the first method (listed above) and could be applied successfully. However, many utilities (particularly in central Europe) have standardized on the wattmetric method of earth fault detection, which is described in the following section.

Zero sequence power measurement, as a derivative of Vo and Io, offers improved relay security against false operation with any spurious core balance CT output for non earth fault conditions. This is also the case for a sensitive directional earth fault relay having an adjustable Vo polarizing threshold.

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 the SEF input would normally be fed from a core balance current transformer (CBCT) mounted around the three phases of the feeder cable. The SEF transformer should be a special measurement class transformer.

8.1   SEF PROTECTION IMPLEMENTATION

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

Stages 3 and 4 have definite time characteristics only.

8.2   NON-DIRECTIONAL SEF LOGIC
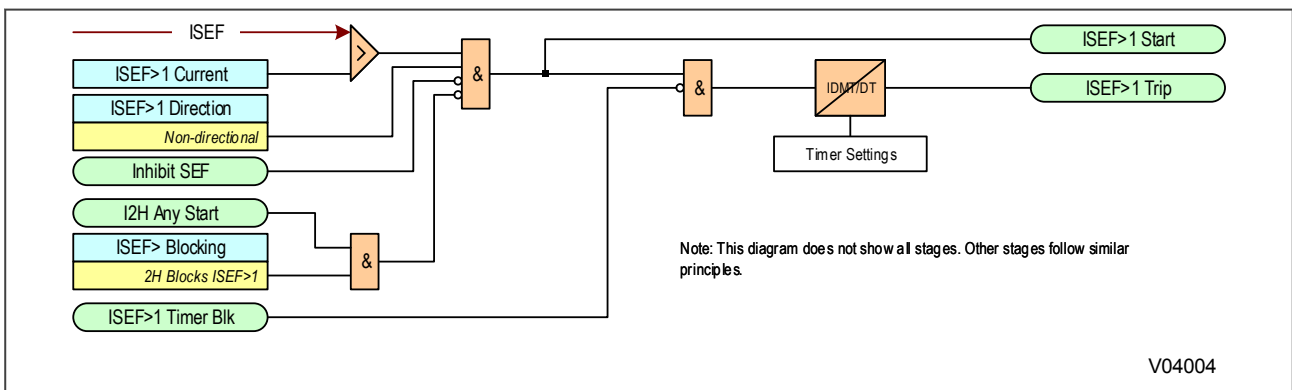
Figure 56: Non-directional SEF logic

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.
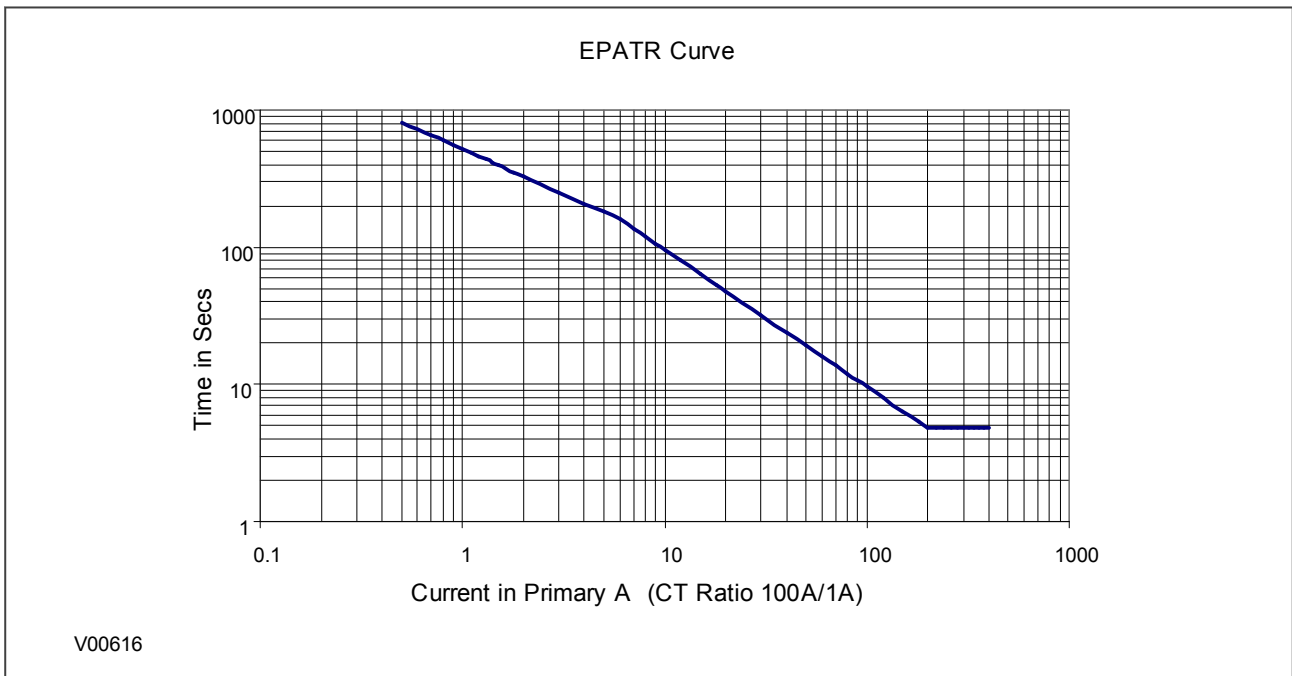
Figure 57: EPATR B characteristic shown for TMS = 1.0

> *Note:*
> *SEF CT ratios are user settable.*

8.4   DIRECTIONAL ELEMENT

Where current may flow in either direction, directional control should be used.

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

Directionality is achieved by using differet techniques depending on the application. The directional SEF can be used for:

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

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

If you are using directional SEF protection, you select the required polarisation using the **SEF Options** setting in the *SEF PROTECTION* column.

8.4.1 WATTMETRIC CHARACTERISTIC

Analysis has shown that a small angular difference exists between the spill current on healthy and faulted feeders for earth faults on compensated networks. This angular difference gives rise to active components of current which are in anti-phase to one another.
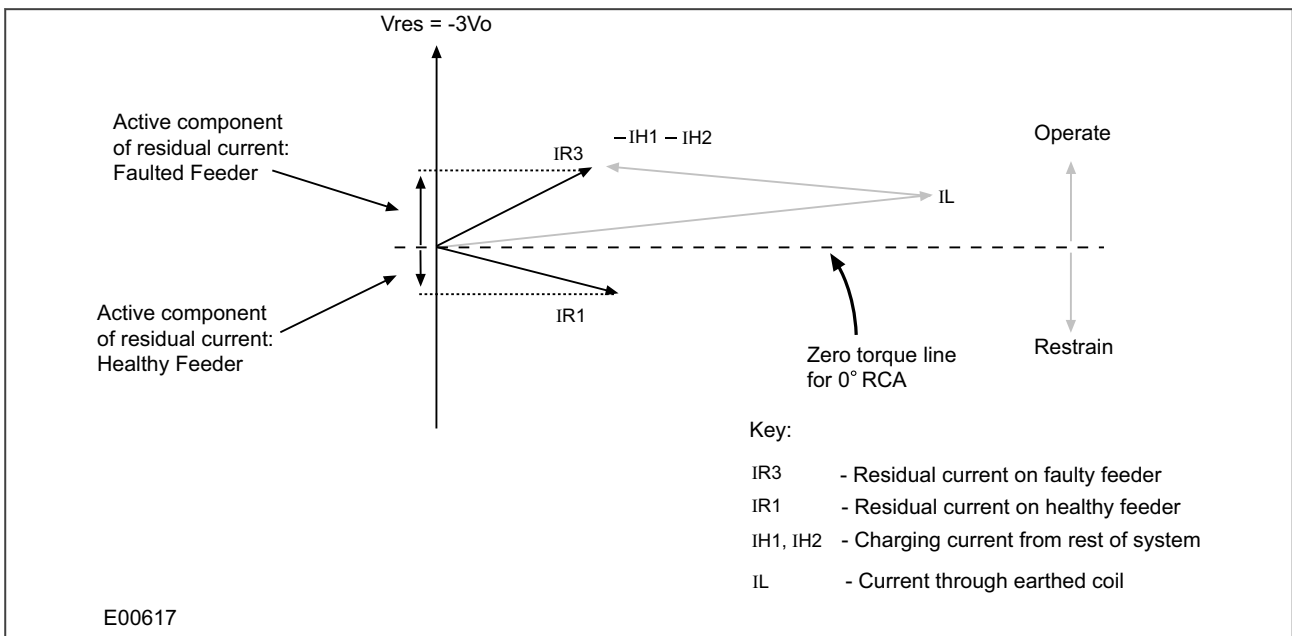
Figure 58: Resistive components of spill current

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

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

The power setting is called PN> and is calculated using residual quantities. The formula for operation is as follows:

The PN> setting corresponds to:

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

where:

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

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

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

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

The directional check criteria is as follows:

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

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

8.4.2   ICOS PHI / ISIN PHI CHARACTERISTIC

In some applications, the residual current on the healthy feeder can lie just inside the operating boundary following a fault condition. The residual current for the faulted feeder lies close to the operating boundary.
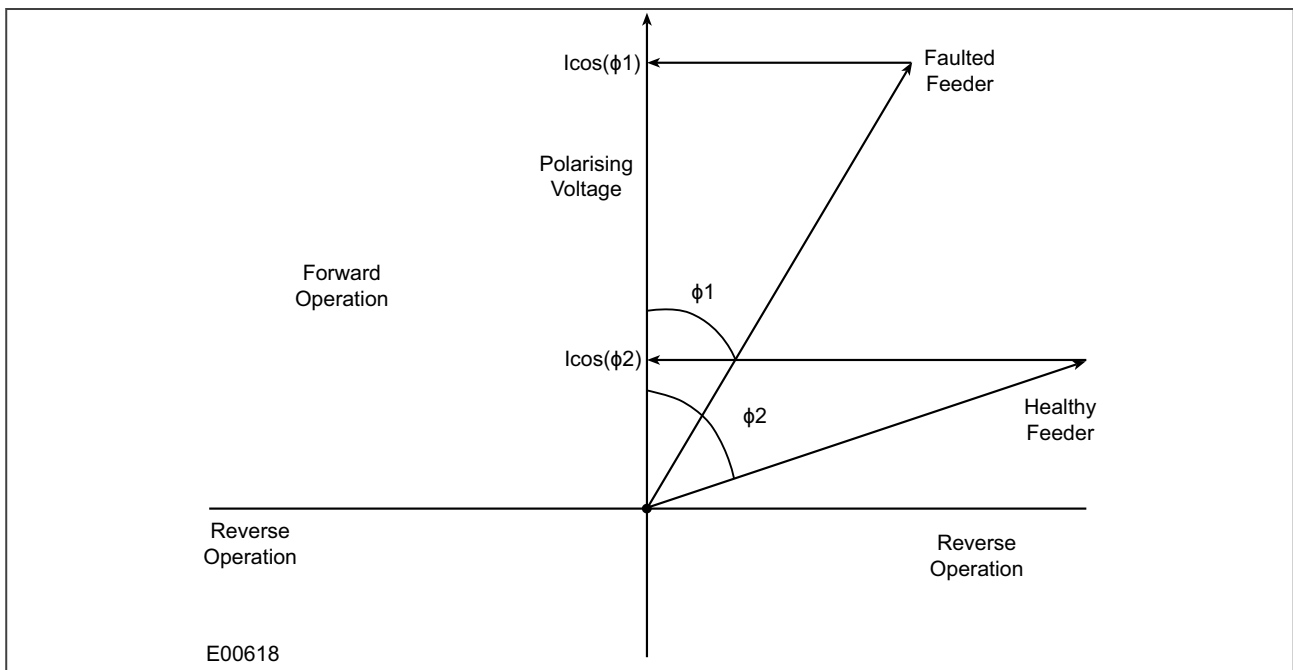
Figure 59: Operating characteristic for Icos

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

- For the active component Icos, the criterion for operation is: Icosφ > *ISEF>(n) current*
- For the reactive component Isin, the criterion for operation is: Isinφ > *ISEF>(n) current*

Where *ISEF>(n) current* is the sensitive earth fault current setting for the stage in question

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

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

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

8.4.3   DIRECTIONAL SEF LOGIC

Note: This diagram does not show all stages. Other stages follow similar principles.

V04005
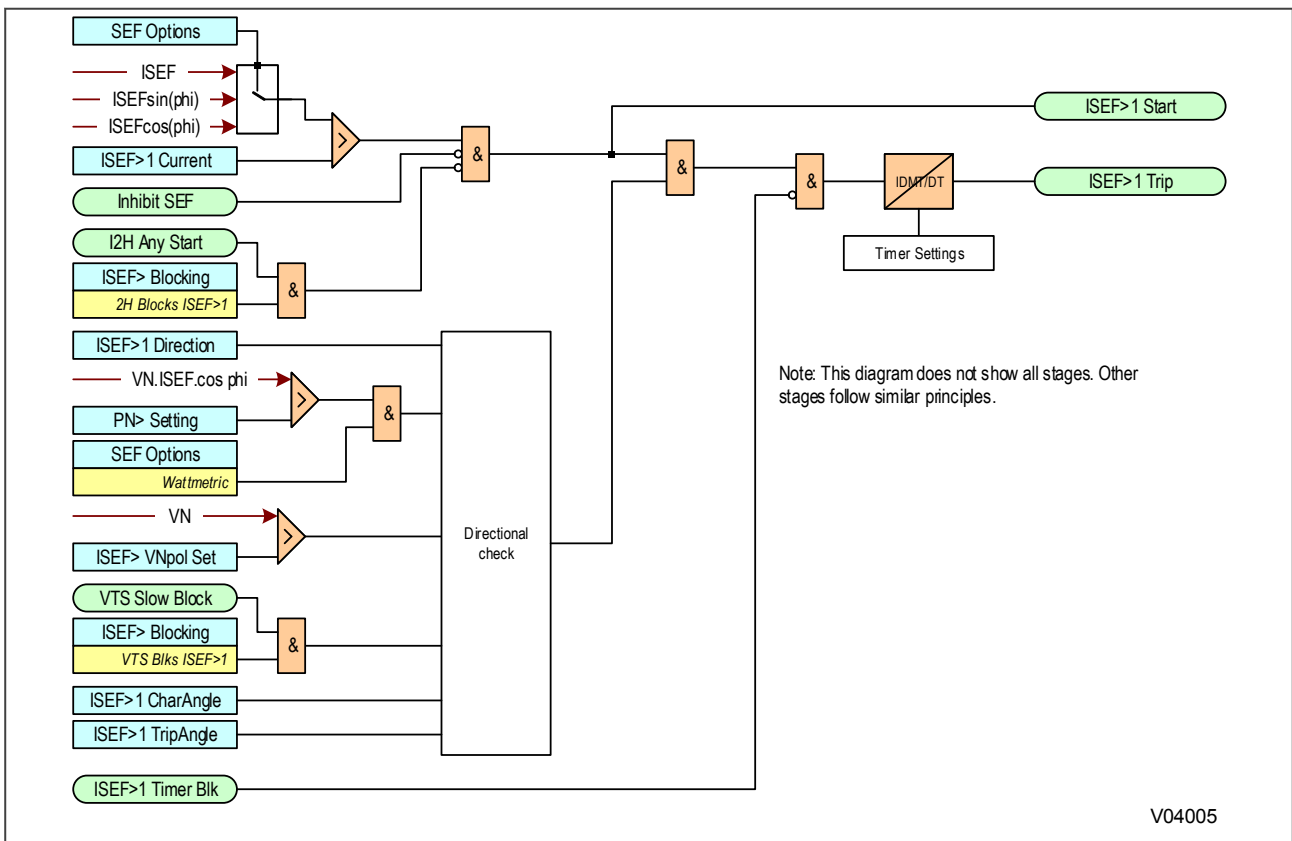
Figure 60: Directional SEF with VN polarisation (single stage)

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

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

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

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

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

All stages of the sensitive earth fault element can be set down to 0.5% of rated current.

8.5 APPLICATION NOTES

8.5.1 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.
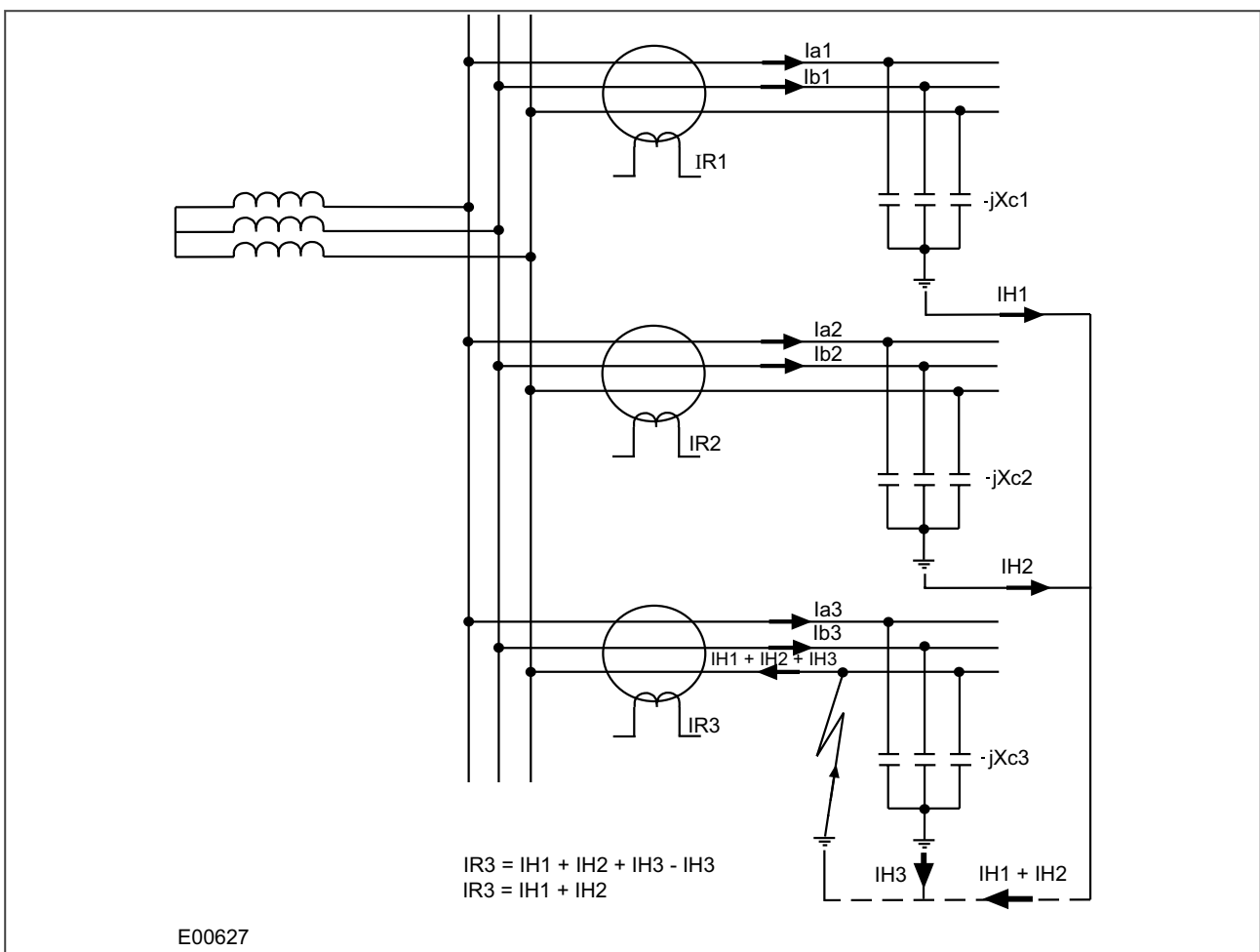
Figure 61: Current distribution in an insulated system with C phase fault

The protection elements on the healthy feeder see the charging current imbalance for their own feeder. The protection element 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°.
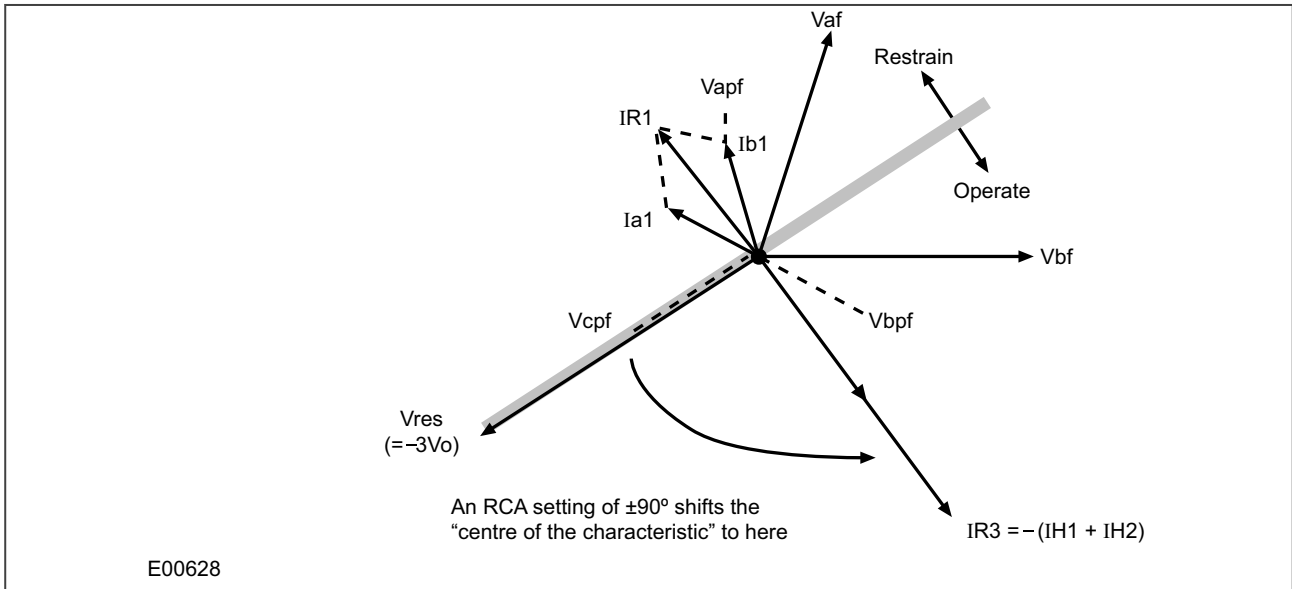
Figure 62: Phasor diagrams for insulated system with C phase fault

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 diagram indicates 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.

The required characteristic angle setting for the SEF element when applied to insulated systems, is +90°. This is for the case when the protection 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, 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.*

8.5.2   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:
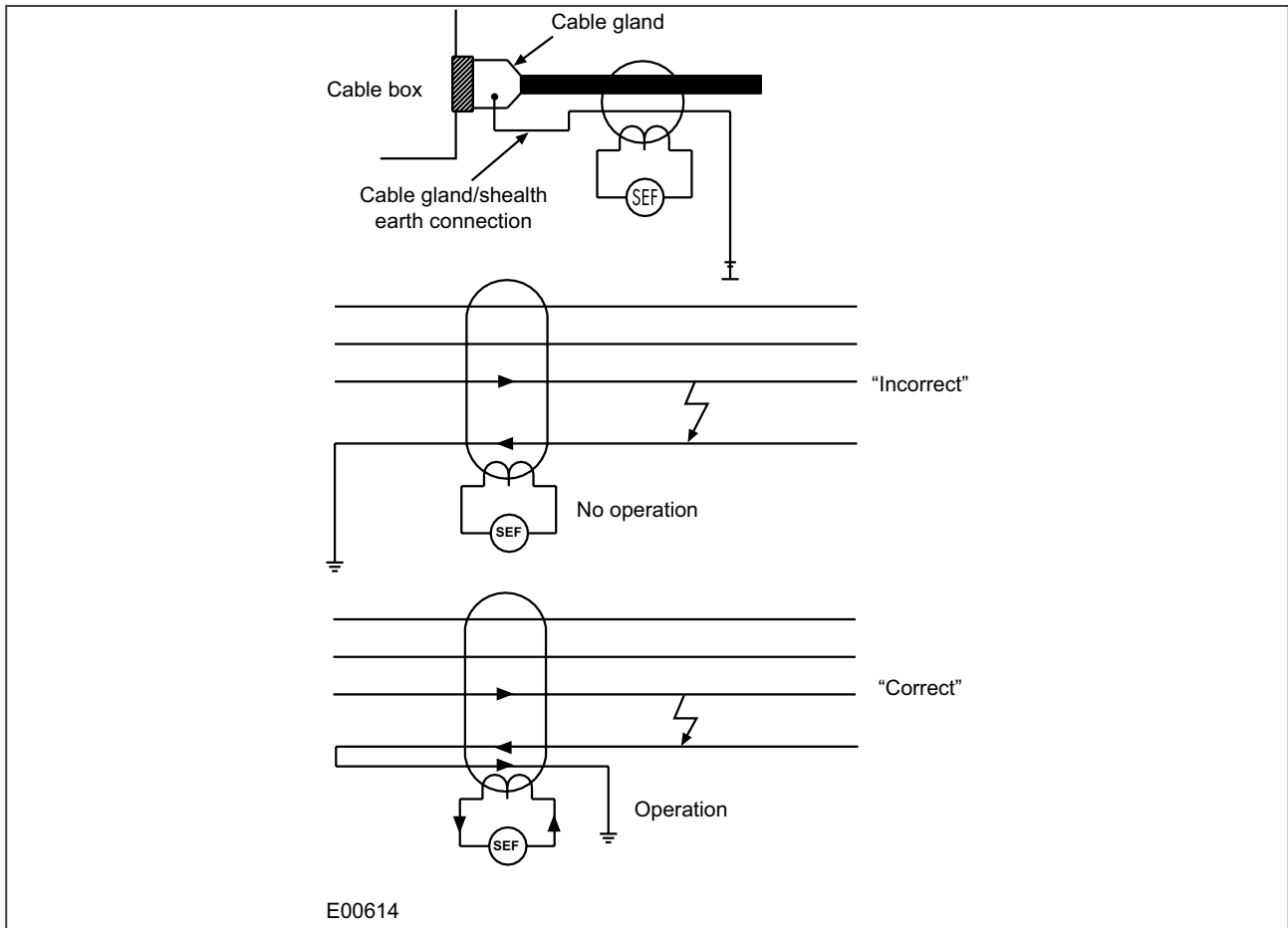
Figure 63: Positioning of core balance current transformers

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   COLD LOAD PICKUP

When a 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:

- Blocking 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.

9.1   IMPLEMENTATION

Cold Load Pickup Protection is configured 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)
- All Earth Fault 1 stages (both non-directional and directional if applicable)
- All Earth Fault 2 stages (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 function. 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.

9.2   CLP LOGIC
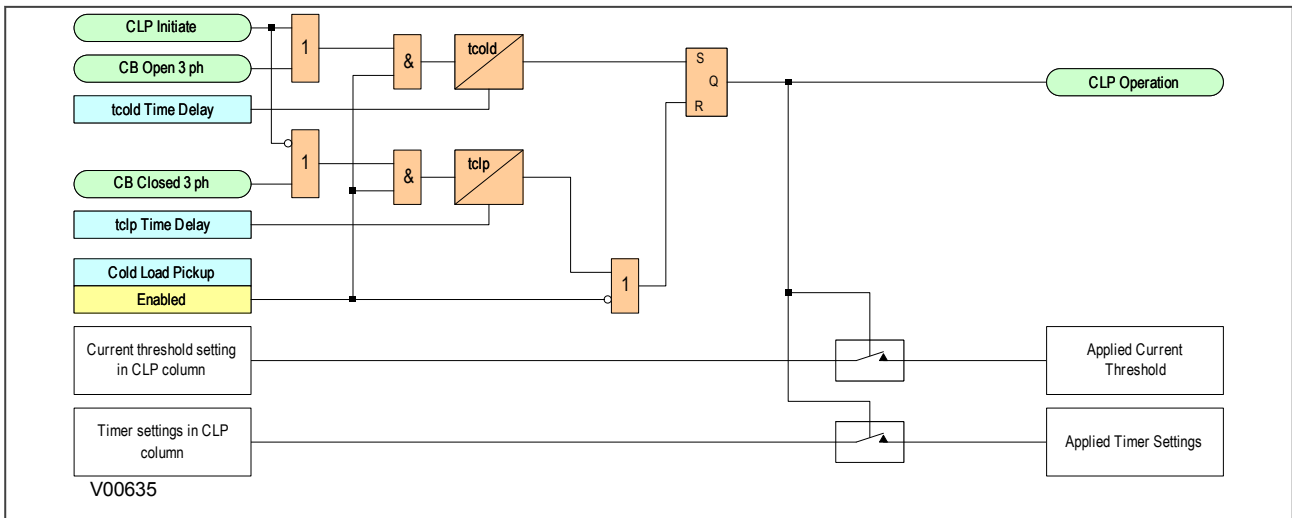
Figure 64: Cold Load Pickup logic

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`.

9.3   APPLICATION NOTES

9.3.1   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.

9.3.2   CLP FOR MOTOR FEEDERS

In general, a dedicated motor protection device would protect feeders supplying motor loads. However, if CLP logic is available, 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.

9.3.3   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.

10   SELECTIVE LOGIC

With Selective Logic you can use the Start signals 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.

10.1   SELECTIVE LOGIC IMPLEMENTATION

Selective Logic is set 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 issuing signals to an 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 and 4th stages)
- Non-Directional/Directional earth fault – 2 (3rd and 4th stages)
- Non-Directional/Directional sensitive earth fault (3rd and 4th stages)

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

10.2   SELECTIVE LOGIC DIAGRAM
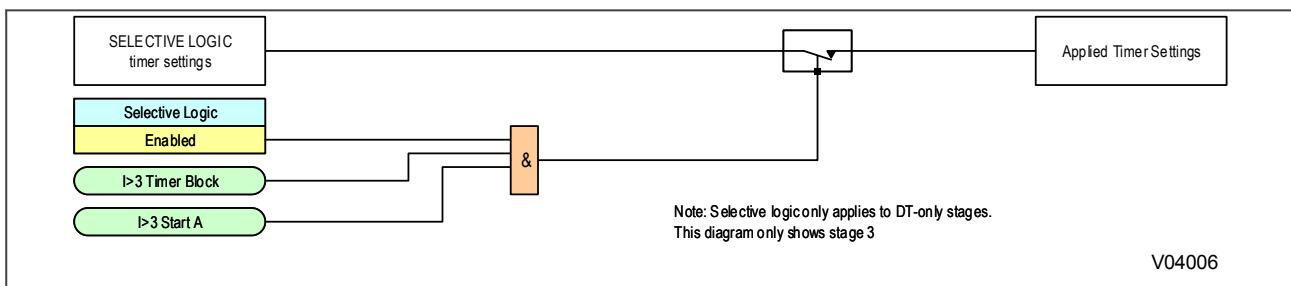
Figure 65: Selective Logic

The logic diagram is shown for overcurrent phase A, but is valid for all three phases for each of the stages. The principle of operation is also identical for earth fault protection.

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.

11   TIMER SETTING SELECTION

The timer settings used depend on whether there is a Selective Overcurrent condition or a Cold Load Pickup condition (if this functionality is used). The protection function selects the settings according to the following flow diagram:
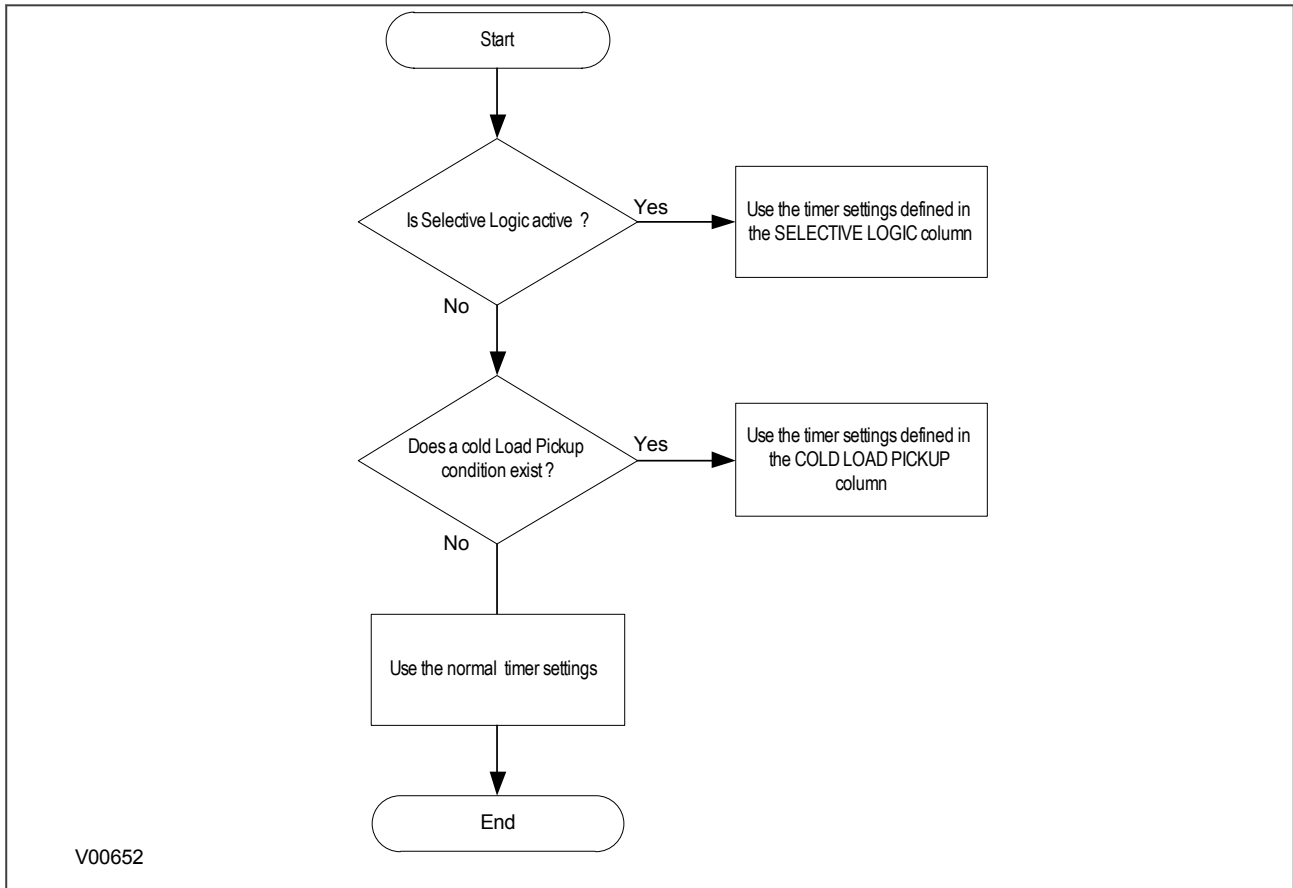
Figure 66: Selecting the timer settings

12   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 General Electric IEDs allows additional time-graded overcurrent protection for back-up purposes.

12.1   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.

12.2   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*:
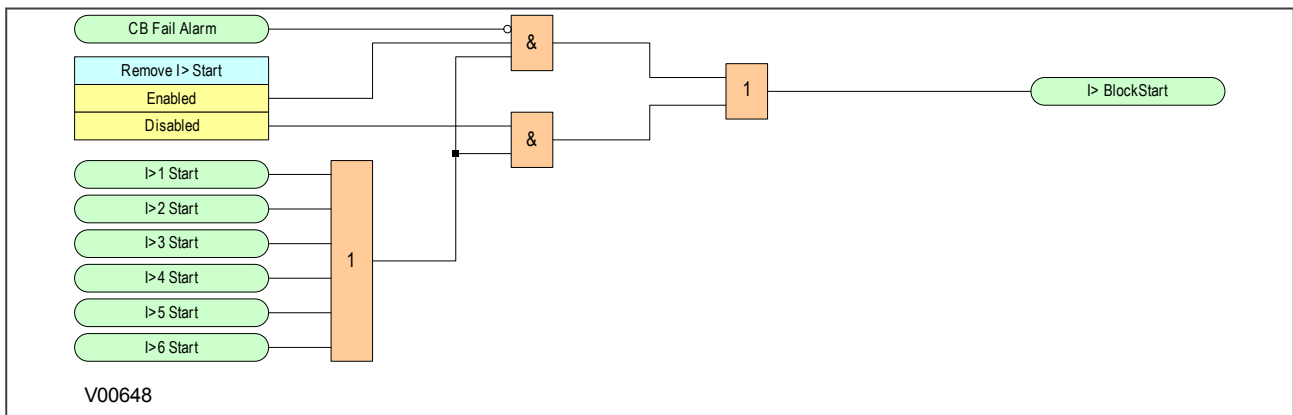
Figure 67: Blocked Overcurrent logic

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.

12.3   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/SEF>Blk Start*:
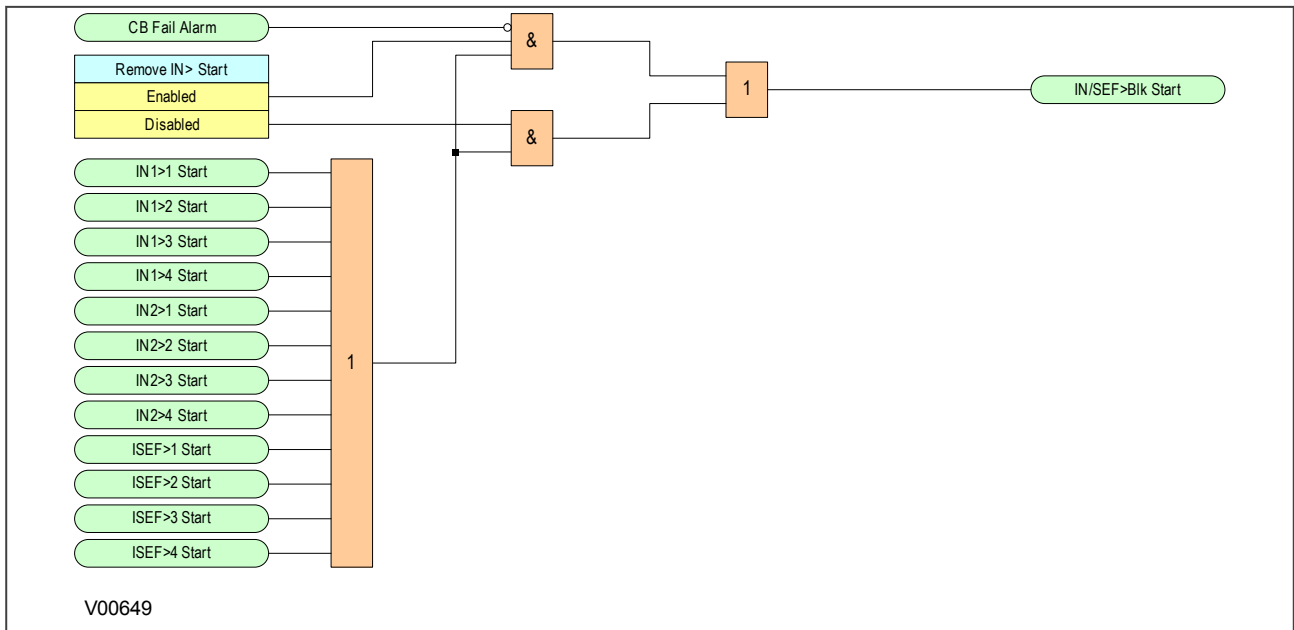
Figure 68: Blocked Earth Fault logic

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.

12.4 APPLICATION NOTES

12.4.1 BUSBAR BLOCKING SCHEME
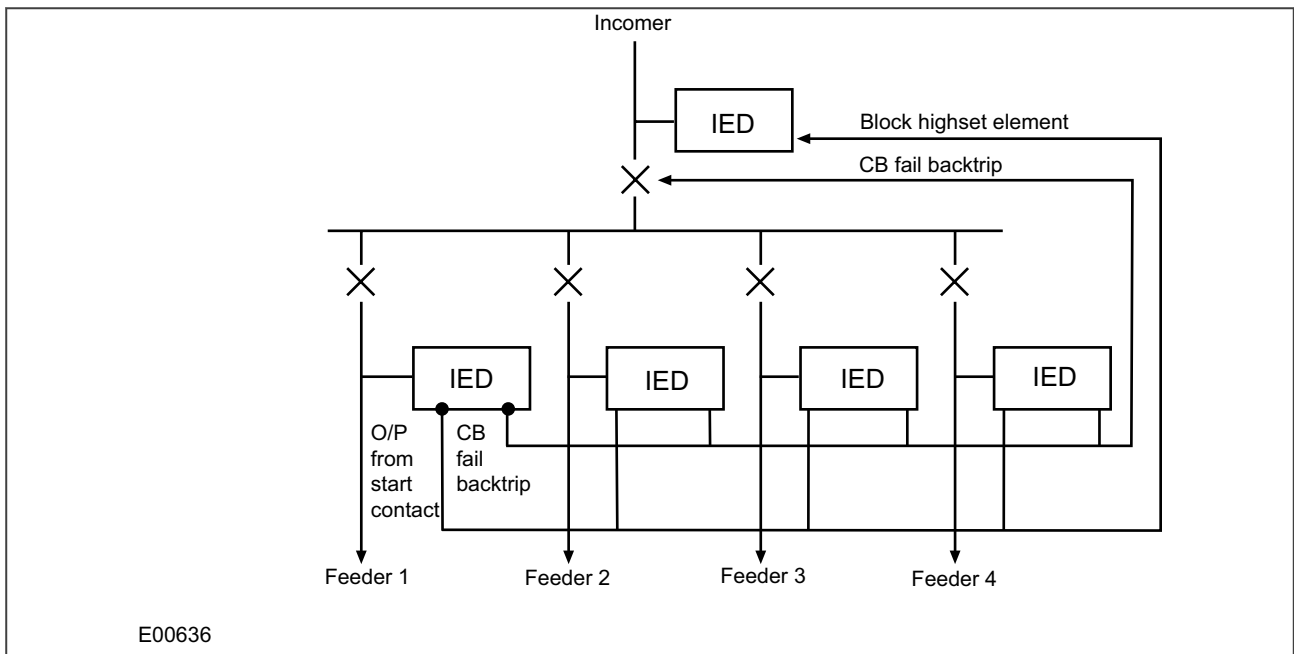
Figure 69: Simple busbar blocking scheme
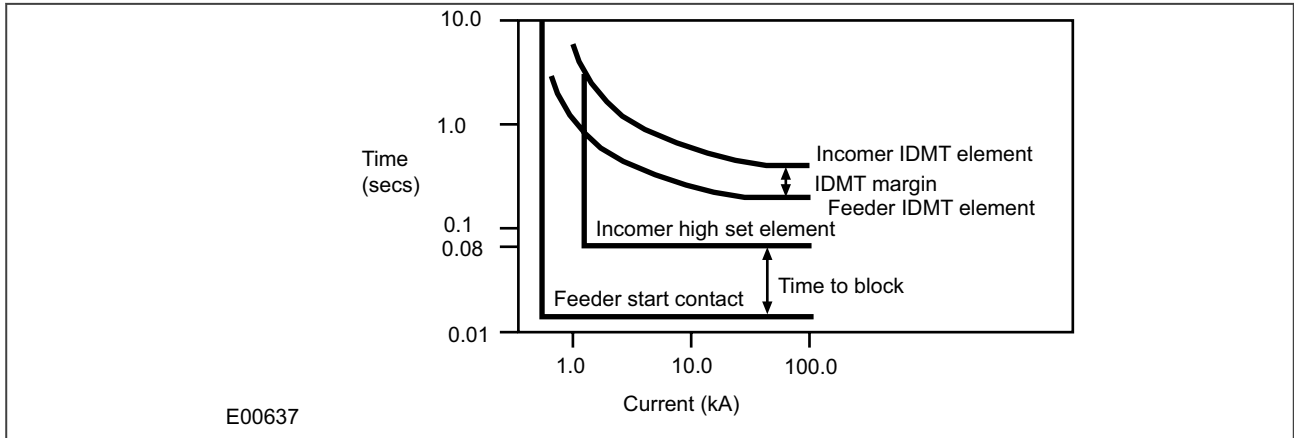
Figure 70: Simple busbar blocking scheme characteristics

For further guidance on the use of blocked busbar schemes, refer to General Electric.

13   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.

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 (particularly the second), 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.

13.1   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 *SECURITY CONFIG* column of the relevant setting group.

Second harmonic blocking is applicable to all stages of each of the elements. Each protection element has a relevant blocking setting with which the type of blocking is defined.

For phase overcurrent, 2nd harmonic blocking can be applied to each phase individually (phase segregated), or to all three phases at once (cross-block). This is determined by the **I> Blocking** setting.

13.2 SECOND HARMONIC BLOCKING LOGIC (POC INPUT)
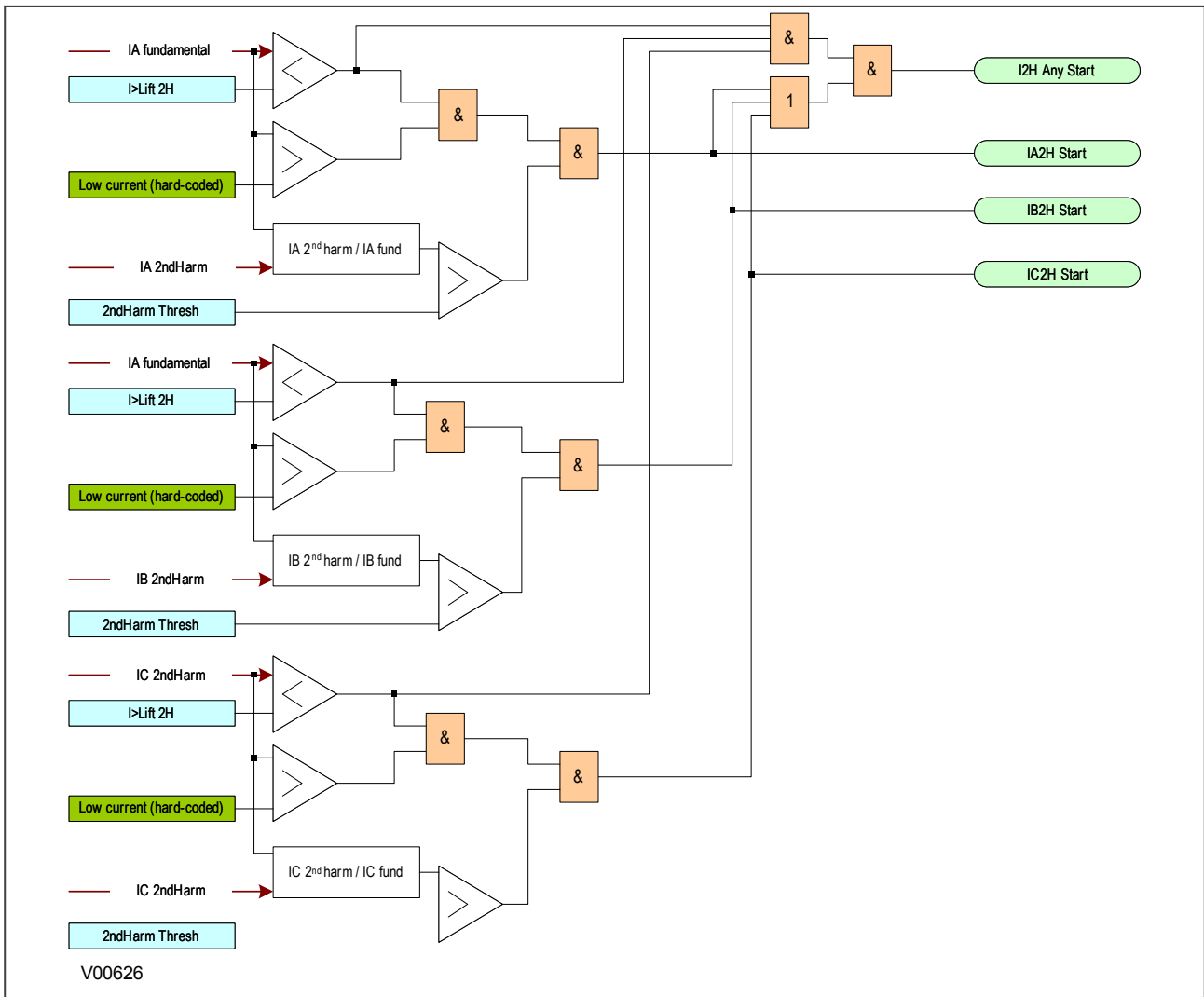
Figure 71: 2nd Harmonic Blocking Logic (POC Input)

The function works by identifying and measuring the inrush currents present in the phase currents 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.

13.3 APPLICATION NOTES

13.3.1 SETTING GUIDELINES

During the energization period, the second harmonic component of the inrush current may vary. 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 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.

14 STALL PROTECTION

Comprehensive features are available to protect the motor during the critical starting sequence. Measurements and diagnostics are also available to help you with the maintenance of the electrical process. For example, last start time and last start current can be displayed on the HMI of the relay.

14.1 PROLONGED START

The following criteria can be used to detect a motor start.

Single criteria: a change in the interrupting device position is detected. This is from open to closed or detection of a starting current of more than the starting current threshold. The start criteria is set to 52a or I in the *STALL DETECTION* menu settings.

Extended criteria: a change in the interrupting device position is detected, along with the detection of a starting current of more than the starting current threshold, 52A+I. Both criteria have to be present within a 90 ms time period.

Once a start has been detected, using one of these methods, and the current fails to fall below the current threshold before the normal starting time threshold, a trip is initialized.

The diagram below shows detection of a successful start with the use of the extended criteria.
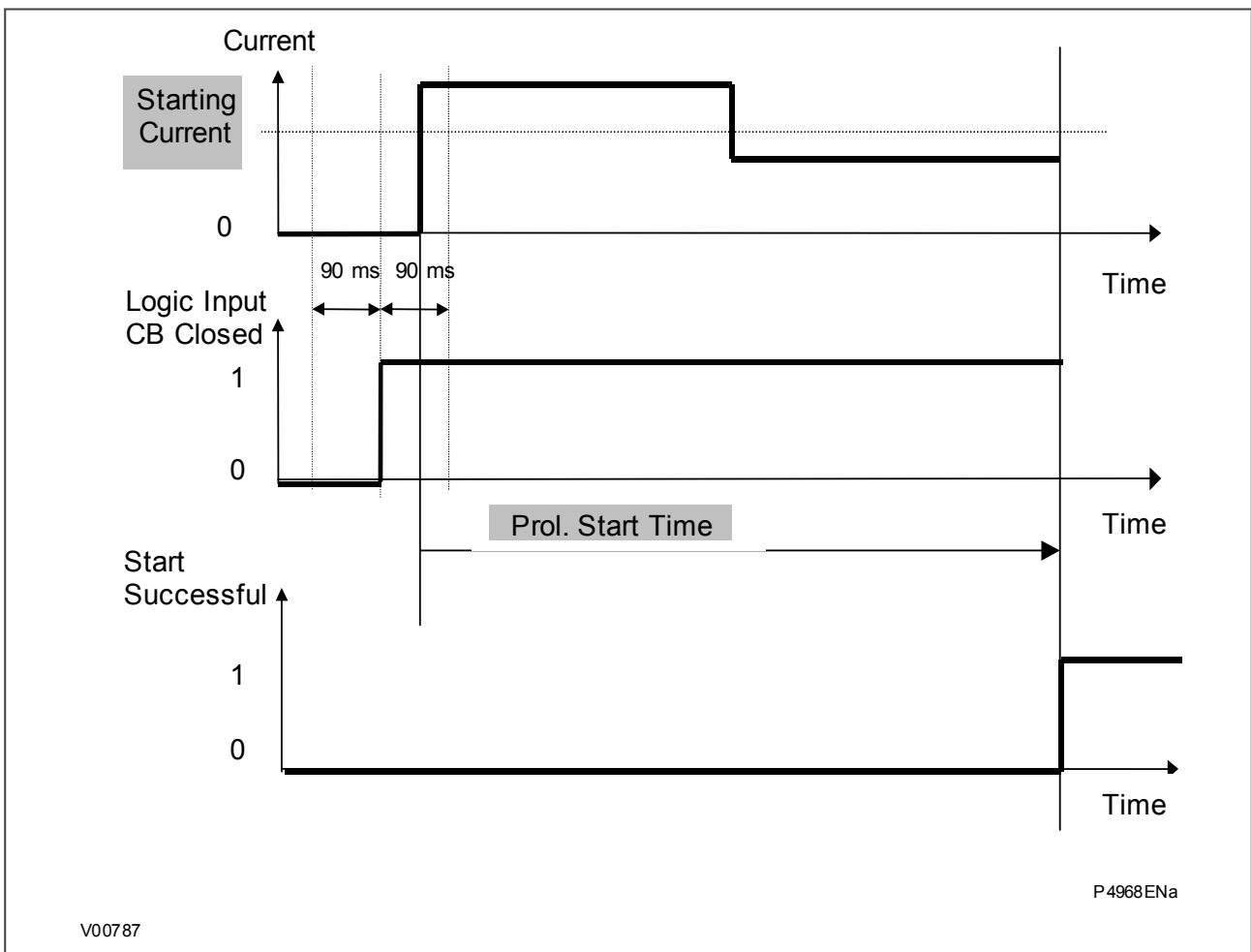
Figure 72: Start successful

An alarm (**Prolonged Start)** is generated if the current fails to fall below the starting current threshold before the end of the starting timer.

14.2   LOCKED ROTOR DURING STARTING – (STALL TIME < START TIME)

For applications such as motors driving high inertia loads, the stall withstand time can be safely exceeded during starting. This can be done without an over temperature condition within the motor. The stall withstand time is less than the start time, therefore time alone cannot be used to distinguish between a start and a stall condition.

The **P24xM** relay overcomes this problem by using a contact from a speed sensing device wired into a specified opto input (Speed Input). Change of state of this contact indicates successful acceleration of the motor. If the line current exceeds the value set in the Starting current and the speed of the motor is equal to zero, the relay trips following the programmed Stall Time (**Stall Rotor-Strt**).

> *Note:*
> *The breaker status must be mapped for this function and the breaker must be closed (52A input high) for the relay to operate if a locked rotor is detected.*

The figure below shows the principle of this feature:
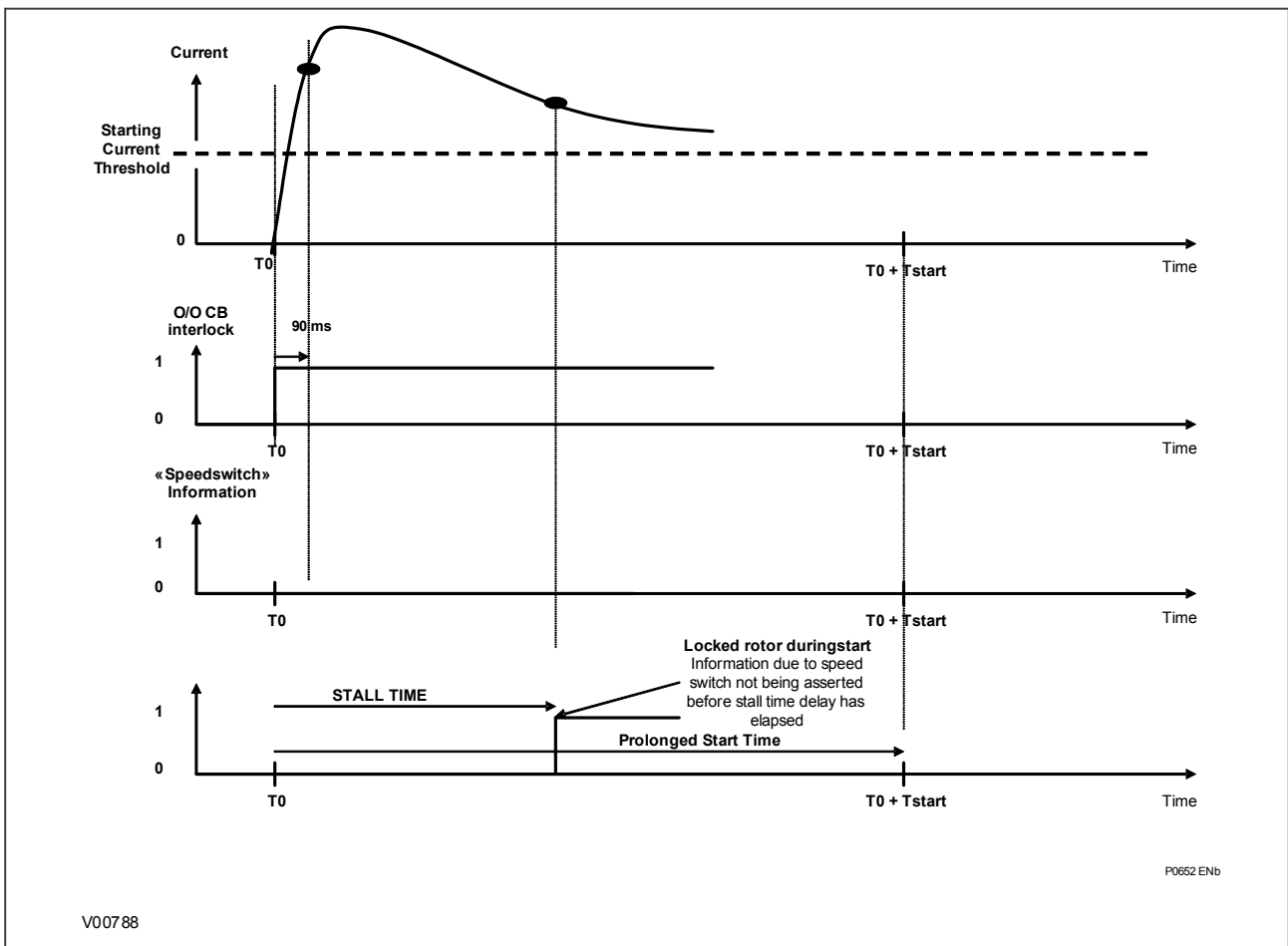
Figure 73: Locked rotor detection

The **Stall Rot-Strt** setting must be enabled. After the detection of the start, both timers **Prol.Start Time** and **Stall Time** are running. A typical setting could be 5 s for the prolonged start timer and 1 s for the stall timer.

If the current falls below the starting current threshold before the end of the Stall time and if the speed switch doesn't detect the rotation of the motor, this feature will NOT generate a tripping order.

14.3   STALL DURING RUNNING

A stall during running is given by a current exceeding the programmed current threshold, (Stall Setting) following a successful start. The Successful Start signal is issued if the current decreases below the starting current and/or CB still close (depending on start criteria) when **Prol. Start Time** is timed out). If the current fails to fall below the current threshold before the stall time delay has elapsed, a trip is initiated (**Stall Rotor-run**).

14.4   MOMENTARY REDUCTION IN SYSTEM VOLTAGE DURING RUNNING

To find Reacceleration, Low voltage Ride Through and Auto Restart protection functions, go to the relay menu Stall Detection.

14.5   REACCELERATION AFTER A REDUCTION IN SYSTEM VOLTAGE

If there is a low voltage condition on the system for more than 100 ms, once the voltage has recovered, the current exceeds the stalling current threshold within 5 seconds (**Reac in Progress**), the stall protection is disabled to allow for reacceleration. A settable undervoltage threshold **Reac. Low V Set** makes it possible to detect a voltage drop.
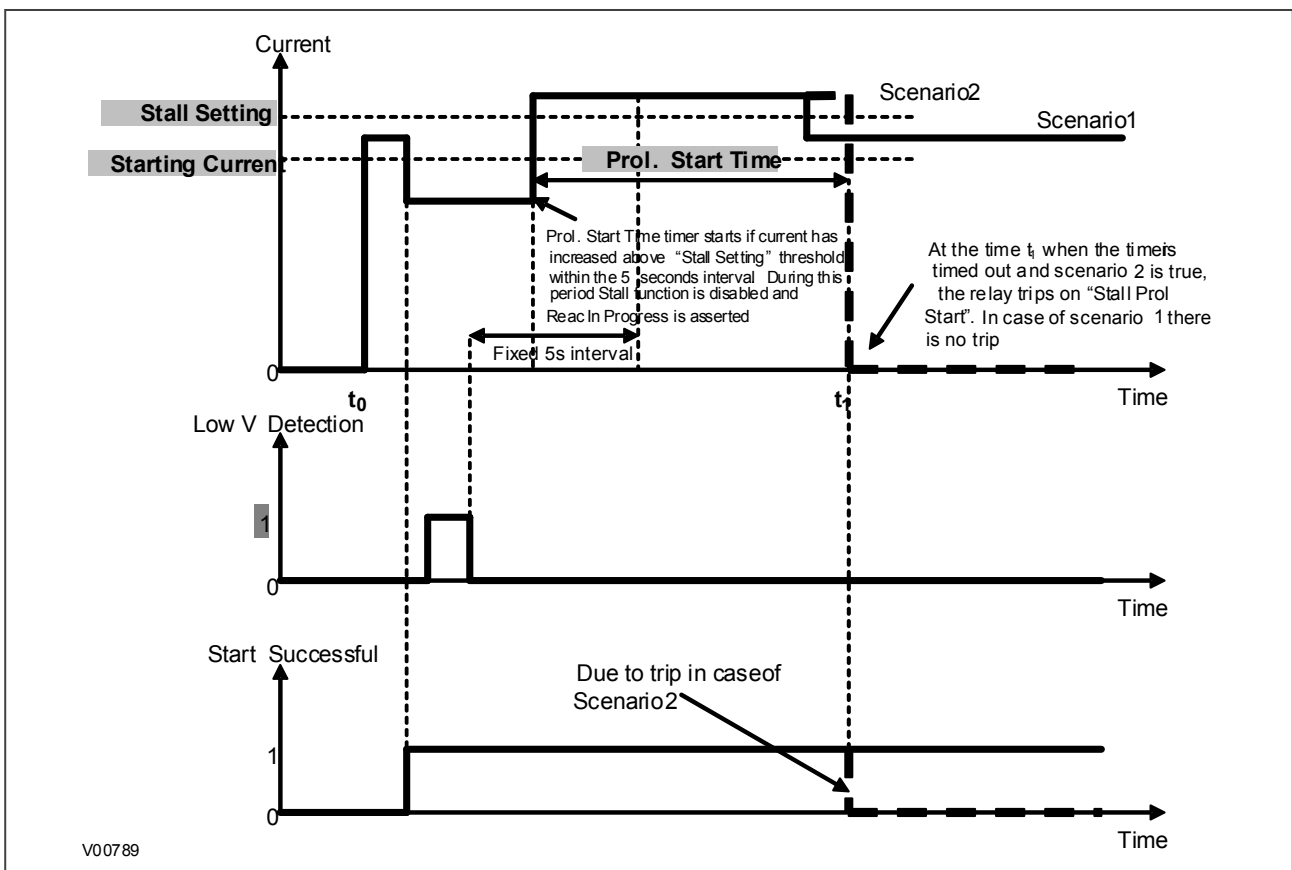
Figure 74: Reacceleration detection

The figure above shows the setting thresholds. If the current fails to fall below the stalling current threshold before the end of the **Prol.Start Time** (Scenario 2), the relay generates a tripping order (**Reacc Low Volt.**).

If the current exceeds the stall setting threshold after the 5 s window used for reacceleration criteria, the stall protection is enabled and a trip occurs. The Stall Rotor Run trips if the current stays above the stall setting threshold when the Stall Time timer has timed out.

This function is disabled during the starting period. This period begins when **Strt in progress** is asserted and ends when **Strt successful** is asserted.

14.6   LOW VOLTAGE RIDE THROUGH AUTHORIZATION

When *LV Ride Thru* is enabled, extra settings are available to define the restored voltage level and introduce an adjustable delay for reacceleration.

A settable overvoltage threshold *Reac. High V Set* makes it possible to detect pre-defined restoration of the voltage.

Adjust the time delay *Reac. Time*. This time delay corresponds to the maximum duration of voltage sag for which the motor reacceleration is authorized. On detection of a voltage drop, the relay initiates a time-delay Reac Time. The diagrams below show the relay behaviour under different conditions:
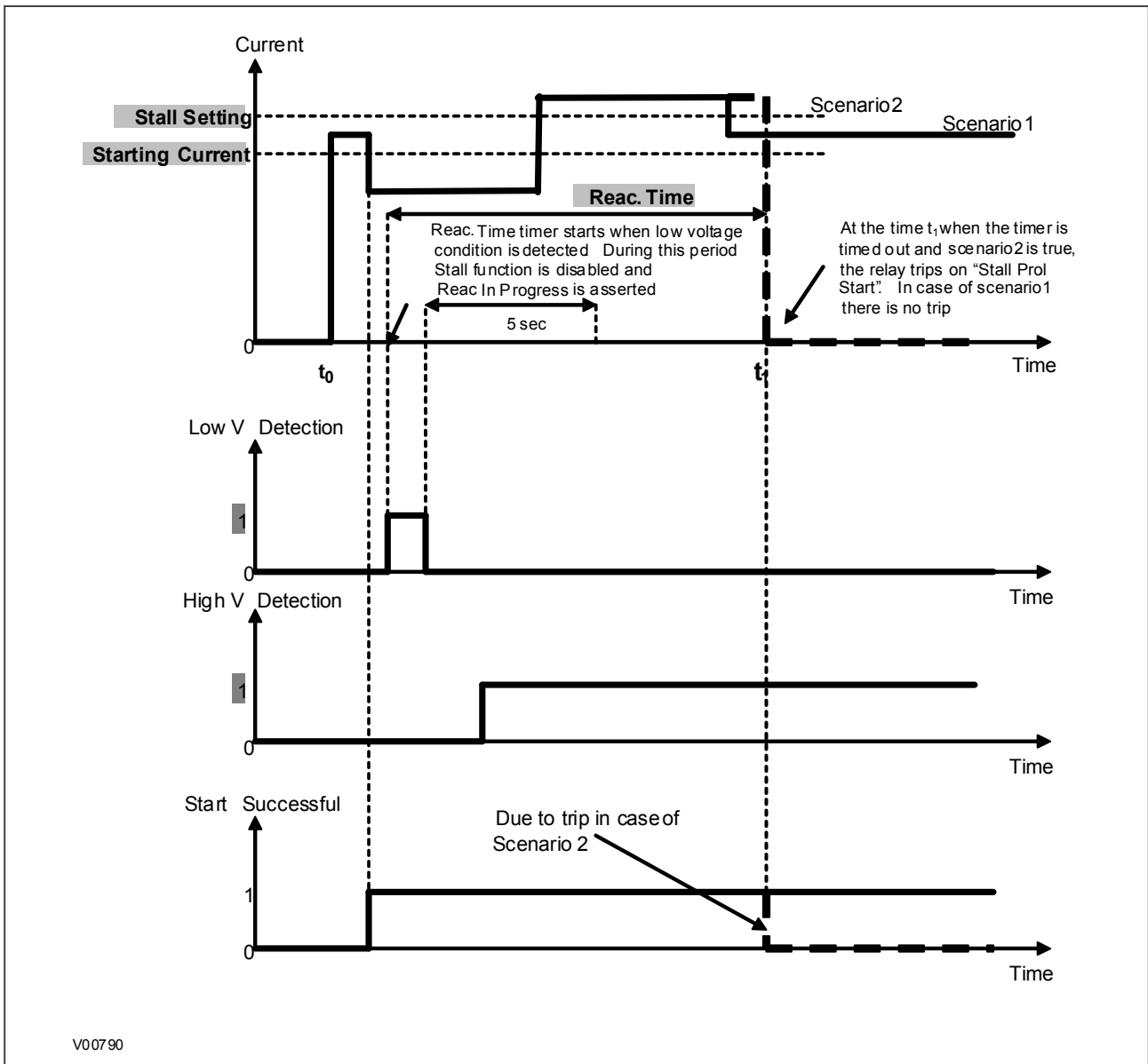
Figure 75: Adjustable reacceleration authorization - Voltage restored within the set time
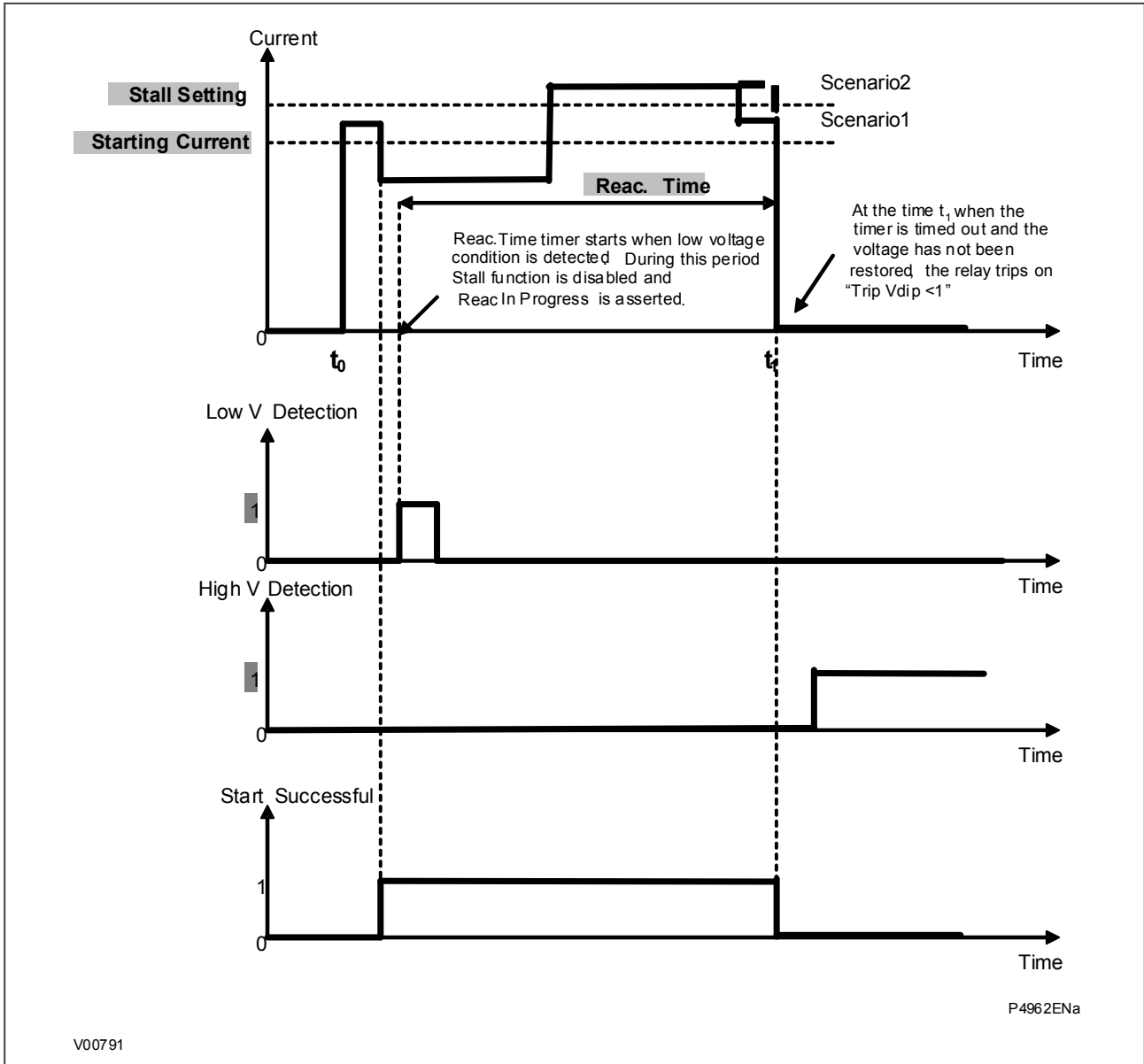
Figure 76: Adjustable reacceleration authorization - Voltage restored after the set time

14.7   AUTO RE-START AUTHORIZATION RESTORATION SEQUENCE

The Auto Re-start element controls the timing of controlled starts following interruptions. When **Auto Re-start** is `enabled`, two time delay settings (**Reac. Long Time** and **Reac. Shed Time**) become available. Automatic classical restart is carried out in a set time delay **Reac. Long Time** or after an extended time delay **Reac. Shed Time** when the voltage is restored. The **Reac. Long Time** threshold setting can be used when it is appropriate to restart the motor without any staged startup sequence. The **Reac. Shed Time** threshold setting can be used to cover cases when restoration is from backup power. There must be substantial intervals between starting different motors to maintain stability, and/or only critical motors can be started. The diagrams below show the relay behaviour under different conditions:
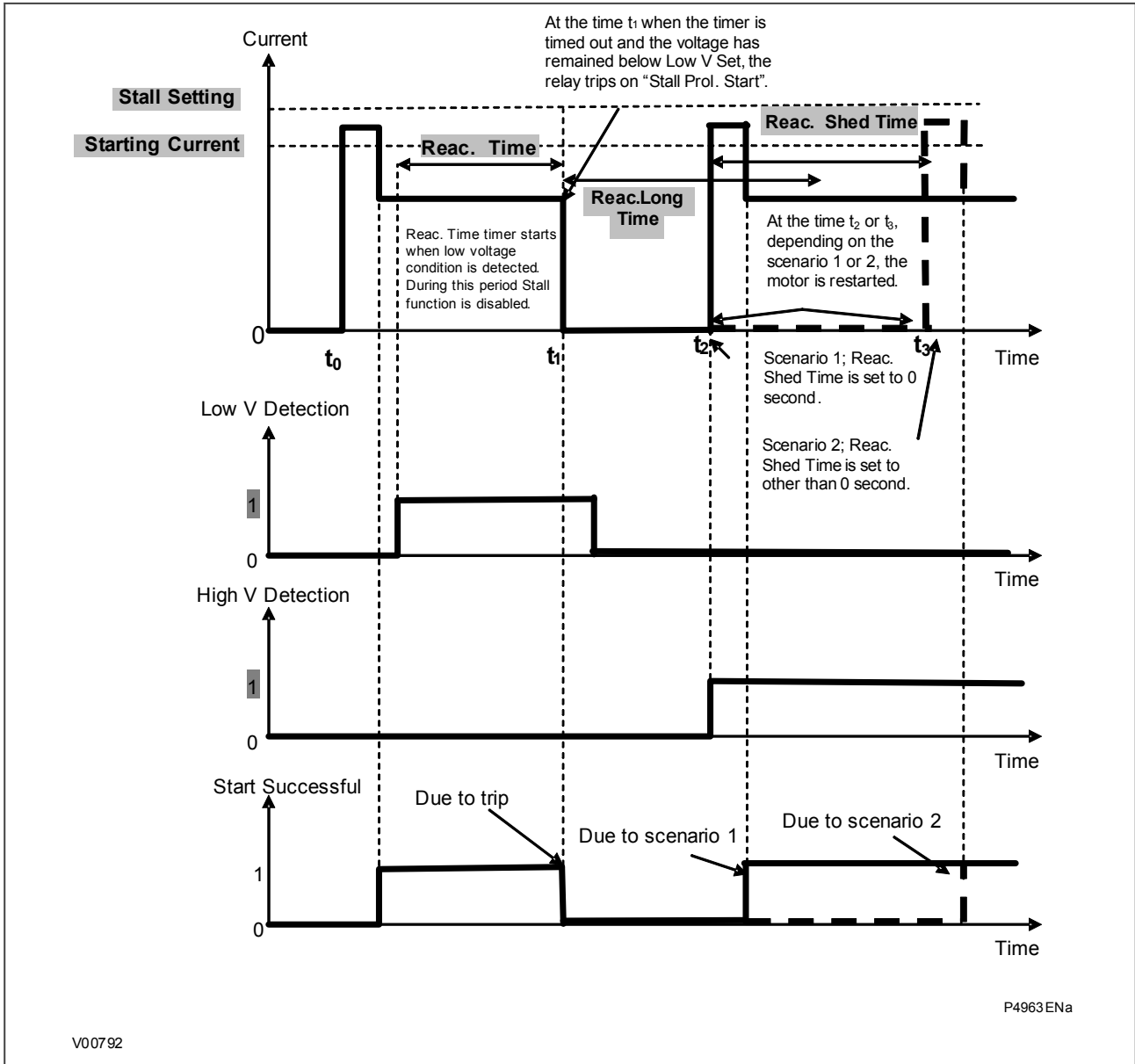
Figure 77: Automatic restart authorized- voltage restored within the set time

VT monitors the busbar voltage for automatic restart function to operate correctly. When restart is authorized, *Auto Re-Start* and *Auto Re-Start OK* are asserted.
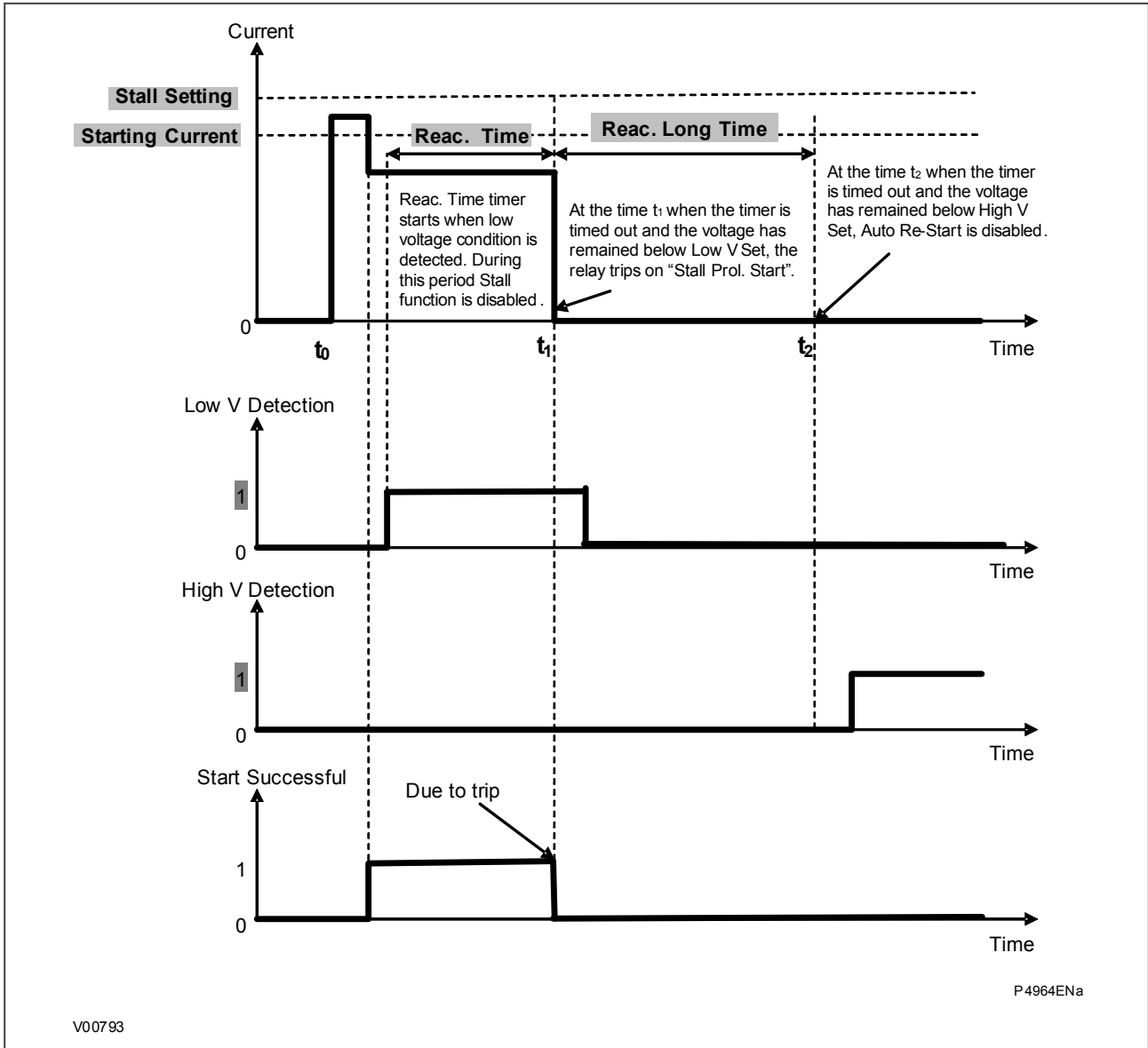
Figure 78: Automatic restart failed- voltage restored after the set time

If voltage is not restored within **Reac. Long Time** duration or if it falls below "High V Set" threshold before **Reac. Shed Time** timer has timed out (where **Reac. Shed Time** timer is set to a value other than zero for sequence start scheme), **Auto Re-Start KO** becomes asserted. For default LED and Output Relay management refer to the default PSL.

14.8 APPLICATION NOTES

14.8.1 START/STALL PROTECTION

When a motor starts it draws a value of current in excess of full load rating for a set period of time, namely the starting time. It is normal practice to assume a constant starting current for the whole of the starting time.

The starting current varies depending on the type and method of starting utilized. If the motor is started direct-on-line (DOL), the current could easily reach 6 times full load current. However, when star/delta starting is utilized, the starting current is $\sqrt{3}$ less than when DOL starting.

If a motor stalls while running, or is unable to start due to excessive loading, it draws a current equivalent to the locked rotor current. The level of starting current is equal to the level of locked rotor current. Therefore, it is not possible to distinguish between 3 phase stalling and healthy starting by monitoring current alone.

In the majority of cases the starting time of a normal induction motor is less than the maximum stall withstand time. Under these conditions you can discriminate on a time basis between the two conditions to provide protection against stalling.

However, where motors are used to drive high inertia loads, the stall withstand time may be less than the starting time. This means you cannot discriminate between start and stall conditions by time alone.

The P24xM relay provides extensive start and stall protection so that all of the aforementioned conditions can be accounted for. The methods used to achieve this are discussed in more detail below.

This feature requires a 52a circuit breaker auxiliary contact mapped to an opto input to get the information CBclosed/CB open.

14.8.2   EXCESSIVE START TIME/LOCKED ROTOR PROTECTION - STALL TIME > START TIME

A motor can fail to accelerate for a number of reasons. For example, loss of one supply phase, mechanical failure or insufficient supply voltage. Failure of a machine to accelerate results in excessive current being drawn by the motor. This current generates extremely high temperatures within the machine. The motor does not have the added cooling normally provided by rotation, therefore irreparable damage will result very quickly.

Where the stall withstand time is less than the starting time, it is possible to utilize a contact from a speed sensing device wired into a specified opto input (***Speed Input***) in conjunction with measurement of the phase current to detect a safe start.

Three methods are available for detecting a start and they are menu selectable.

Setting guidelines

The starting current threshold should be set greater than full load current, but less than motor starting current. Where the stall withstand time is greater than the starting time, timer – ***Prol. Start Time*** - should be set 1 or 2 seconds above the motor starting time and less than the cold stall withstand time. The ***Prolonged Start*** needs to be set to `Enabled` for this function to operate.

Setting example:

Utilizing the previously specified motor parameters;

Starting current = 3 × Ith = 882A

Prolonged start time = 12 seconds.

14.8.3   STALL PROTECTION (STALL WHILE RUNNING)

Principle

An induction motor can stall for a number of reasons, such as overloading or undervoltage. When a machine stalls it runs down while drawing a current equal to the locked rotor current.

Where the stall withstand time is greater than the starting time, a stall condition during running is simply detected by the line current exceeding the programmed threshold. If the current fails to fall back below this threshold before the programmed time delay has elapsed, a trip can be initiated.

> *Note:*
> *This function is disabled when the relay detects a start condition.*

Setting guidelines

The stall current threshold (**Stall Setting**) should be set greater than full load current, but less than motor stall current (which is usually equal to starting current). Its corresponding timer (**Stall Time**) should be set less than the motor hot stall withstand time. The **Stall Detection** needs to be set to `Enabled` for this function to operate.

Setting example:

Utilizing the previously specified motor parameters;

Stall Setting = 3 × I_{th} = 882 A

Stall Time = 6 seconds

14.8.4   EXCESSIVE START TIME/LOCKED ROTOR PROTECTION - STALL TIME < START TIME

As the rotor resistance of an induction motor is proportional to slip, it decreases during acceleration. When the motor is stationary, the rotating field in the air gap, set up by currents flowing in the stator winding will cut the rotor. This field travels at synchronous speed relative to the rotor and induces a voltage at system frequency, therefore generating circulating currents in the rotor bars. At this frequency, the reactance of the rotor causes the current to flow in the outer section of the rotor conductors, commonly known as the 'skin effect'. Since the current is occupying a smaller section of the rotor, the apparent impedance presented to it is increased, which means the I^2R heating is greatly increased. As the motor accelerates during starting the slip begins to decrease and the current is able to occupy more of the rotor conductor. The apparent impedance therefore reduces along with the heating effect. The motor is able to tolerate starting current for the starting time, but not locked rotor current.

This explains why, for certain applications, such as motors driving high inertia loads, the stall withstand time can be safely exceeded during starting, without resulting in an overtemperature condition within the motor. Since the stall withstand time is less than the start time, it is not possible to use time alone to distinguish between a start and a stall condition.

Where the stall withstand time is less than the starting time, it is possible to utilize a contact from a speed sensing device wired into a specified opto input (**Speed Input**) in conjunction with measurement of the phase current to detect a safe start.

Setting guidelines

The Starting current threshold (**Starting current**) should be set greater than full load current, but less than motor locked rotor current (usually equal to starting current). Its corresponding timer (**Stall Time**) should be set less than the motor cold stall withstand time. The **Stall Rotor-strt** needs to be set to `Enabled` for this function to operate.

14.8.5   MOMENTARY REDUCTION IN SYSTEM VOLTAGE DURING RUNNING OF THE MOTOR

When the supply voltage falls below a settable under voltage threshold, the duration of the fall in voltage can be classified as short, medium, or long. This corresponds with **Reac. Time**, **Reac. Long Time** and **Reac. Shed Time** respectively of P24DM relay designations.

- Short falls cover situations when it is appropriate to authorize reacceleration of the rotor and not to issue a trip order after voltage restoration is detected using a settable under voltage threshold.
- Medium falls cover situations when the voltage has not been recovered within a set short time. This is detected using a settable over voltage threshold and the motor has tripped as a result. Therefore, it is appropriate to automatically restart the motor within a set long time after the voltage has become restored. Detection of restored voltage is based on a settable over voltage threshold.
- Long falls cover cases when restoration is from back-up power and there must be substantial intervals between starting different motors to maintain stability, and/or only critical motors can be started.

A short fall in voltage from the electrical network causes a reduction in rotor speed. If the motor was running at the time a short fall occurred, a forced reacceleration occurs as soon as the relay detects healthy supply voltage. A forced reacceleration bypasses any pre-staged start-up sequence the starter type might otherwise provide.

When the voltage is restored, the rotor starts on a reacceleration phase to regain its nominal speed. This reacceleration manifests itself as an intake of current. This is approximately the same value as the locked rotor current, its duration being relative to the magnitude of the fall in voltage and the duration of the fall in voltage.

14.8.6   LOW VOLTAGE PROTECTION (REACCELERATION AUTHORIZATION)

Following a transient dip in the supply voltage, a motor will attempt to re-accelerate. Under these circumstances it draws a level of current exceeding the relay stall protection threshold, (**Stall Setting**). Therefore, for successful re-acceleration the P24DM relay can be configured to temporarily inhibit the stall protection.

If a low voltage condition exists on the system for a time in excess of 100 ms, on recovery of the voltage the relay will inhibit stall protection. Reacceleration is recognized if current above the set threshold is detected within 5 seconds of the voltage recovery. During this period the excessive start protection is enabled. This provides protection in the event of unsuccessful reacceleration. For example, a dip in the busbar voltage supplying several motors results in each of them attempting reacceleration. Afterwards a large current is drawn from the supply, further reducing the supply voltage, resulting in potential stalling of all machines. This does not occur during normal starting as a staggered approach is normally adopted.

This function is disabled during the starting period and requires a 52a circuit breaker auxiliary contact mapped to an opto input to get the information CBclosed/CB open.

Setting guidelines

The low voltage threshold (**Reac. Low V Set**) is very much system dependent, however a typical setting may be 0.8-0.9 Vn.

14.8.7   AUTO RE-START AUTHORIZATION

When enabled, the Auto-Restart feature is available to carry out automatic re-starting of the motor on restoration of supply for cases when duration of the voltage fall is medium or long.

The AUTO RE-START element provides for controlling the timing of controlled starts following interruptions.

The automatic re-start of the motor is carried out after a medium set time delay $T_{reac-long}$ or after an extended long time delay $T_{reac-shed}$. $T_{reac-long}$ threshold setting can be used when it is appropriate to restart the motor with any staged startup sequence the starter type might provide. $T_{reac-shed}$ threshold setting can be used to cover cases when restoration is from backup power, and there must be substantial delays between starting different motors to maintain stability, and/or only critical motors can be started. The Auto re-start feature, if enabled, becomes active after the relay has issued a trip signal due to a voltage sag condition with duration longer than T_{reacc} threshold.

If $T_{reac-long}$ is set to a value other than Zero (off) after a trip order has been issued, the P24DM initiates $T_{reac-long}$ time-delay. This is due to the supply voltage not being restored within the time interval of T_{reac}.

If the supply is restored within $T_{reac-long}$ time delay interval, a close order is issued by the relay and a normal start is allowed to initiate. If the supply is not restored within $T_{reac-long}$ time delay interval, AUTO RE-START will be deactivated.

It is possible extend the delay to start different motors and to arrange a load restoration sequence in cases where the system is weak or when restoration is from backup power. In this case $T_{reac-shed}$ time delay can be adjusted to perform a sequence start. If $T_{reac-shed}$ is set to a value other than Zero (off) re-start will be extended by $T_{reac-shed}$ time delay.

15   NUMBER OF STARTS

Motors can be started a limited number of times in a defined period without exceeding the permitted winding temperatures. The settings in the **Limit Nb Starts** protection menu monitors these starts.

Two types of starts are supervised:

- Hot Starts are defined by an initial thermal state greater than 50%
- Cold Starts are defined by an initial thermal state lower than 50%

The maximum allowed number of starts per period is an auto-reset inhibit function. This function monitors the number of motor starts in the set period. At the end of the period the number of starts is decremented.

Starts are detected using the 52a status from the breaker. Once the number of starts equals the user-defined setting, the start inhibit is enabled for the set period (inhibit time).

> *Note:*
> *If User Curve is enabled in the Thermal Overload protection, the thermal state remains at 0% for as long as I_{eq} is less than I_{th}. The number of hot starts and cold starts protections should be disabled as they can give an unexpected result.*

Example 1

When the maximum number of starts in the **Supervising Time** is reached the **Inhib.Start Time** is initiated. The remaining time Supervising Time - tn is greater than the **Inhib.Start Time** so the start inhibition remains for a duration equal to Supervising time – tn. Therefore, the inhibition time before a new start is 52 mins with the default settings and a tn of 8 mins.
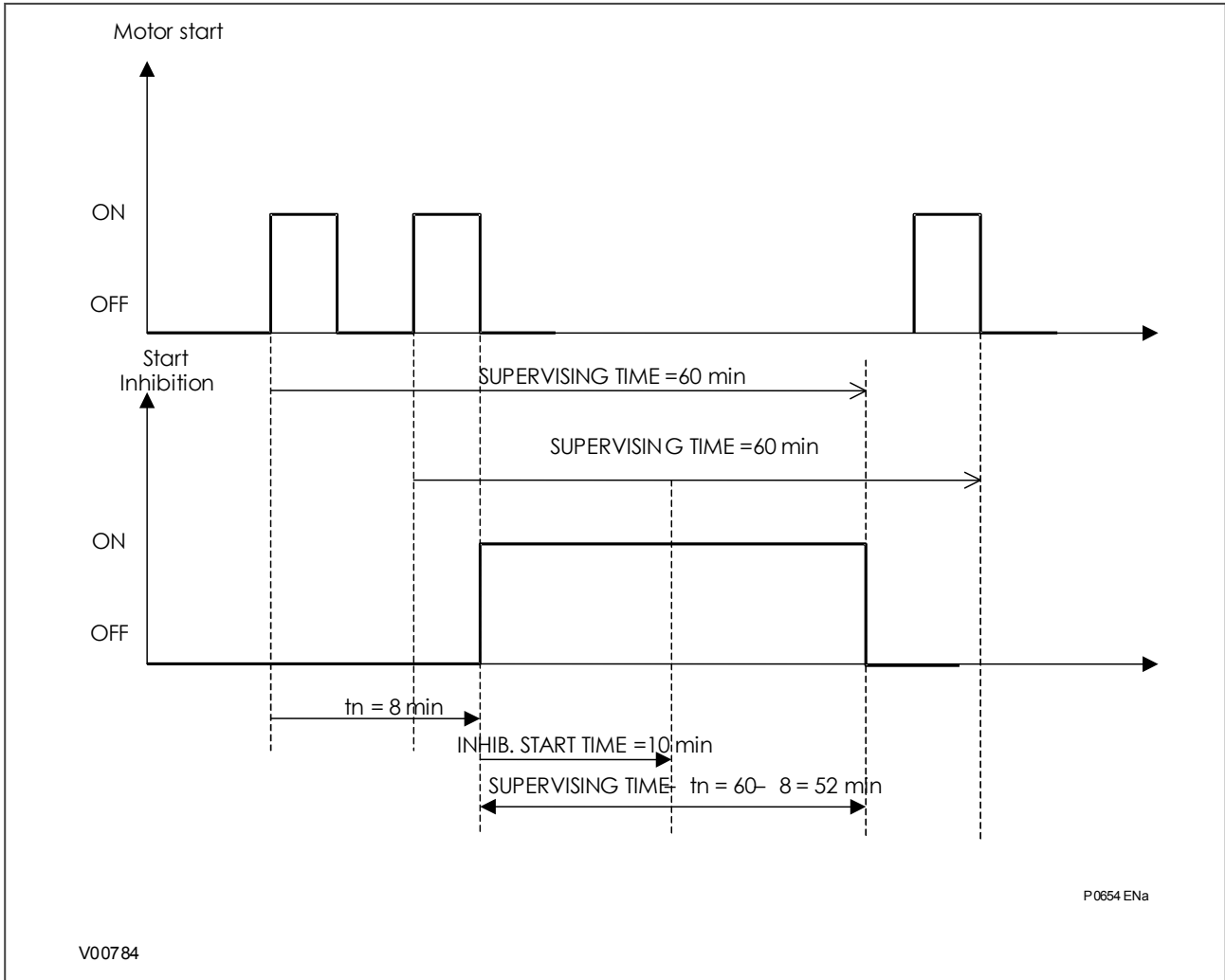
Figure 79: Start inhibition example 1

Example 2

When the maximum number of starts in the *Supervising Time* is reached the *Inhib. Start Time* is initiated. The remaining time Supervising Time – tn is shorter than the *Inhib. Start Time* so the start inhibition remains for a duration equal to *Inhib. Start Time*. Therefore, the inhibition time before a new start is 10 mins with the default settings and a tn of 55 mins.
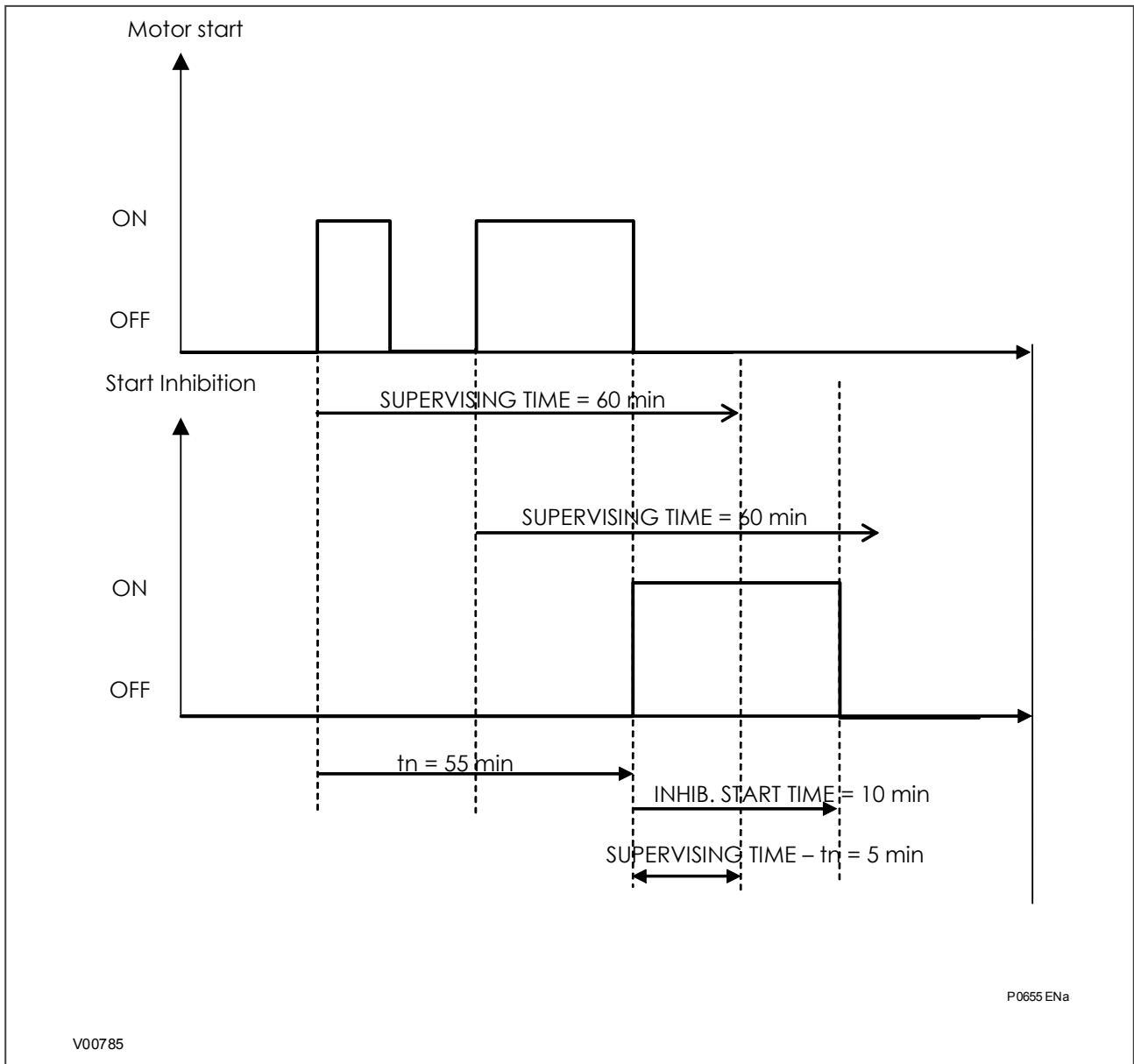
Figure 80: Start inhibition example 2

The Start Lockout information (**Hot Start Nb.** and **Cold Start Nb.**) is present until the end of the **Inhib.Start Time** or as long as the counter of the number of starts is equal to the maximum allowed starts.

15.1   TIME BETWEEN STARTS

Immediately after a start there is a start inhibit as soon as the interrupting device opens. This is for a period equal to the remaining time of the Time between start settings.

The Start Lockout information is present until the end of the greater time delay between **Inhib.Start Time** and **Time Betwe Start**.
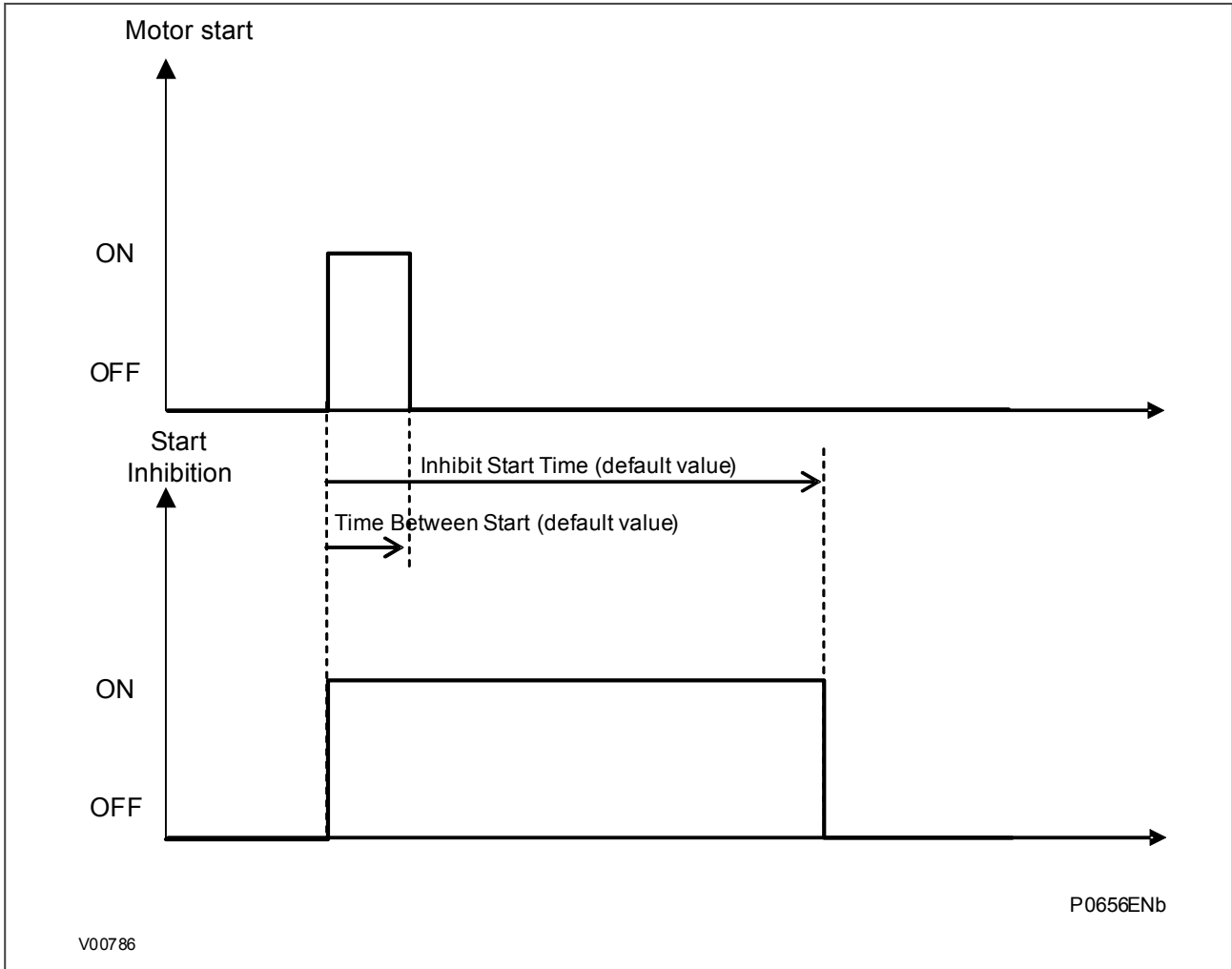
Figure 81: Time between starts

15.2   NUMBER OF STARTS LIMITATION

Repeated starting, or intermittent operation of a motor, can generate dangerously high temperatures within the motor, unless sufficient time is allowed for cooling between starts.

The P24xM relay incorporates several starts limitation facilities. This limitation is fully programmable.

Restarting the motor from a hot thermal state

For certain applications do not allow the motor time to cool down to a specified thermal state before a re-start is permitted. The P24xM relay incorporates several features which allow a subsequent start from a hot thermal state. These are discussed in the section on 'thermal overload protection'.

The motor accumulated run time displayed in the menu cell **Motor Run. Time** of the *MEASUREMENTS 3* menu is initiated each time the switching device is closed and remains closed.

16 ANTI-BACKSPIN PROTECTION

The anti-backspin function is mainly used for a motor with high inertia, or a synchronous motor in deceleration. This function is used to detect when the rotor has completely stopped, to allow restarting of the motor.

The operation of the function depends on the **VRemanent** setting in the *CT AND VT RATIOS* column. The **VRemanent** parameter is visible only if **VN Input** is configured as `Derived`. In this case, 4th VT is available for VPhase-Phase remanent.

If **VRemanent** is `Enabled`:

- The **Vr Antibacks Mag** value is visible in *MEASUREMENTS 1* column.
- The anti-backspin algorithm uses the **VRem Antibacks** setting (in the *MOTOR PROTECTION* Column) as a threshold for **Vr Antibacks Mag**.
- The **Anti-backs delay** setting is used as a delay.

If **VRemanent** is `Disabled`:

- The anti-backspin algorithm uses the **Anti-backs delay** setting as a delay

If the VPhase-Phase Remanent is connected:

When the remanent phase-phase voltage drops under the threshold during the delay, the signal **Antibkspin Alarm** is reset (and the delay is reset) and a new start is allowed. If the threshold is not reached and the delay expires, the **Antibkspin Alarm** signal is reset and a new start is allowed.

If the VPhase-Phase remanent is not connected:

- If the **Anti-backs delay** expires, the alarm signal **Antibkspin Alarm** is reset and a new start is allowed.
- The **Antibkspin Alarm** may be added to the PSL circuit breaker closing logic.
- VPhase-Phase remanent threshold has no impact.

As soon as the motor is stopped (**CB open 3 ph**), the delay set (maximum delay to stop) starts and the **Antibkspin Alarm** signal is set.
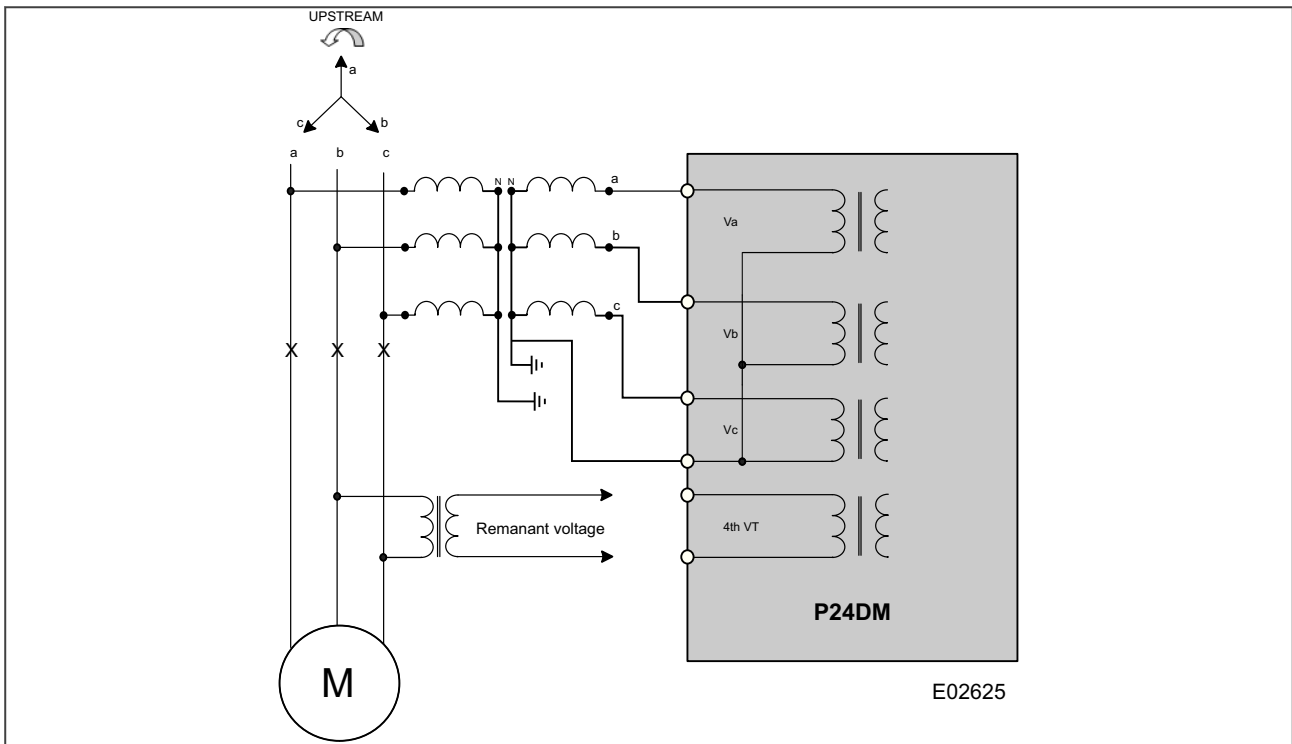
Figure 82: 3 phase VTs and Anti-Backspin (remanent phase-phase) VT configuration

16.1   APPLICATION NOTES

16.1.1   ANTI-BACKSPIN PROTECTION

A motor may be driving a very high inertia load. Once the CB/Contactor supplying power to the motor is switched off, the rotor may continue to turn for a considerable length of time as it decelerates. The motor now becomes a generator and applying supply voltage out of phase can result in catastrophic failure. In some other applications for example when a motor is on a down-hole pump, after the motor stops, the liquid may fall back down the pipe and spin the rotor backwards. Don't start the motor at this time. In these circumstances the anti-backspin function is used to detect when the rotor has stopped, to allow re-starting of the motor.

The operation of this function depends on the parameter VT connecting mode. If this is set to **_Vremanent_**, then the function uses an undervoltage with the connected Phase-Phase remanent voltage. If not, the function uses only a time delay.

Setting guidelines

The voltage threshold setting for the anti-backspin protection **_VRem Antibacks_** should be set to a low value to indicate that the motor is stopped. The default setting of 10 V secondary is adequate for most applications.

The **_Anti-backs Delay_** must be set to an adequate time for the motor to stop after the trip. The default setting of 3000 s is adequate for the majority of applications.

CHAPTER 7

RESTRICTED EARTH FAULT PROTECTION

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 can be caused by 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. 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 to protect the individual windings.

The following figure shows a REF protection arrangement for protecting the delta connected winding.
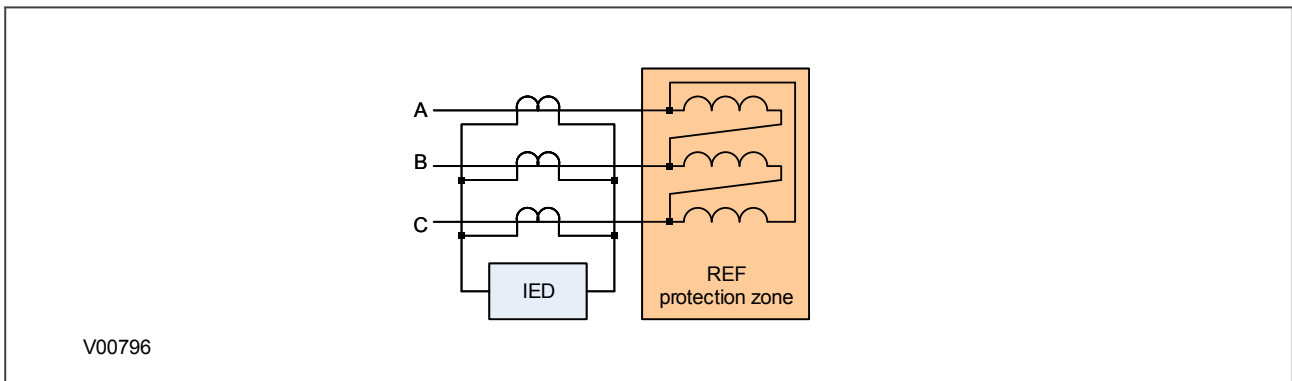
Figure 83: REF protection for delta connected winding

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. If the spill current is large enough, it will trigger a trip command.

The following figure shows a REF protection arrangement for the star connected winding.
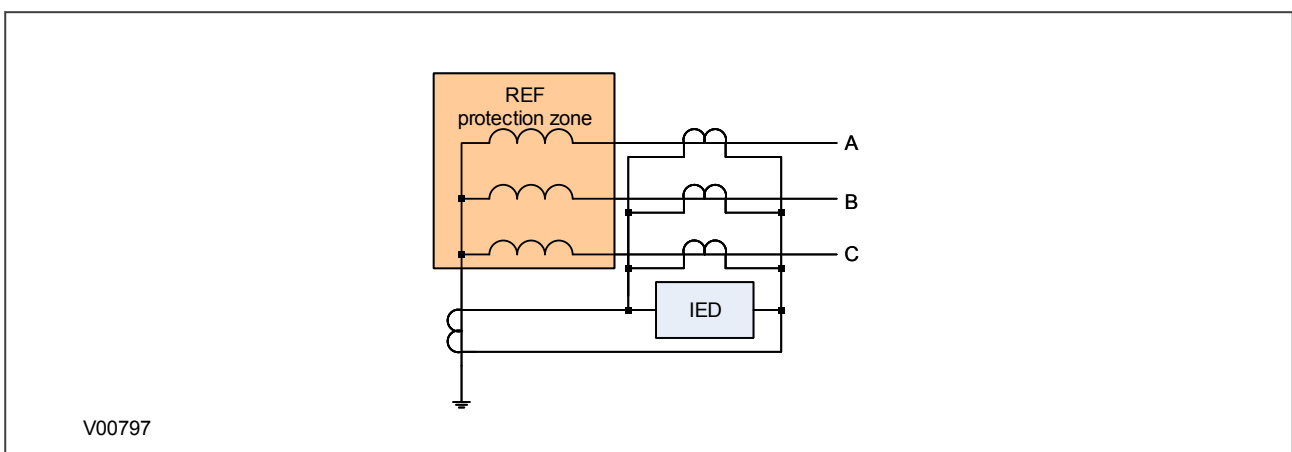
Figure 84: REF protection for star connected winding

Here we have a similar arrangement of current transformers connected in parallel. The difference is that we need to measure the zero sequence current in the neutral line as well. An external unbalanced fault causes zero sequence current to flow through the neutral line, resulting in uneven currents in the phases, which could cause the protection to maloperate. By measuring this zero sequence current and placing it in parallel with the other

three, the currents are balanced, resulting in stable operation. Now only a fault inside the star winding can create an imbalance sufficient to cause a trip.

2.1 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.

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.

Low impedance protection used to be considered less secure than high impedance protection. This is no longer true as numerical IEDs apply sophisticated algorithms to match the performance of high-impedance schemes. Some advantages of using Low Impedance REF are listed below:

- There is no need for dedicated CTs. As a result CT cost is substantially reduced.
- The wiring is simpler as it does not require an external resistor or Metrosil.
- Common phase current inputs can be used.
- It provides internal CT ratio mismatch compensation. It can match CT ratios up to 1:40 resulting flexibility in substation design and reduced cost.
- Advanced algorithms make the protection secure.

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.

High Impedance REF protection responds to a voltage across the differential junction points. During external faults, even with severe saturation of some of the CTs, the voltage does not rise above certain level, because the other CTs will provide a lower-impedance path compared with the device input impedance. The principle has been used for more than half a century. Some advantages of using High Impedance REF are listed below:

- It provides a simple proven algorithm, which is fast, robust and secure.
- It is less sensitive to CT saturation.

2.1.1 LOW IMPEDANCE BIAS CHARACTERISTIC

Usually, a triple slope biased characteristic is used as follows:
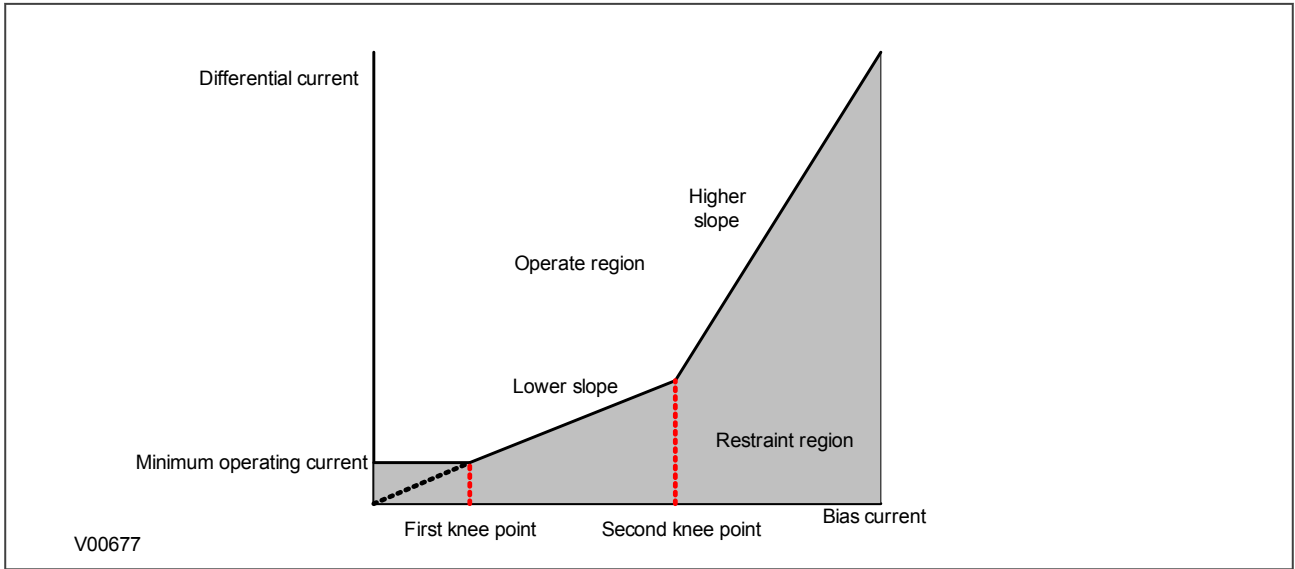
Figure 85: Three-slope REF bias characteristic

The flat area of the characteristic is the minimum differential current required to cause a trip (operate current) at low bias currents. From the first kneepoint onwards, the operate current increases linearly with bias current, as shown by the lower slope on the characteristic. This lower slope provides sensitivity for internal faults. From the second knee point onwards, the operate current further increases linearly with bias current, but at a higher rate. The second slope provides stability under through fault conditions.

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

2.1.2   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:
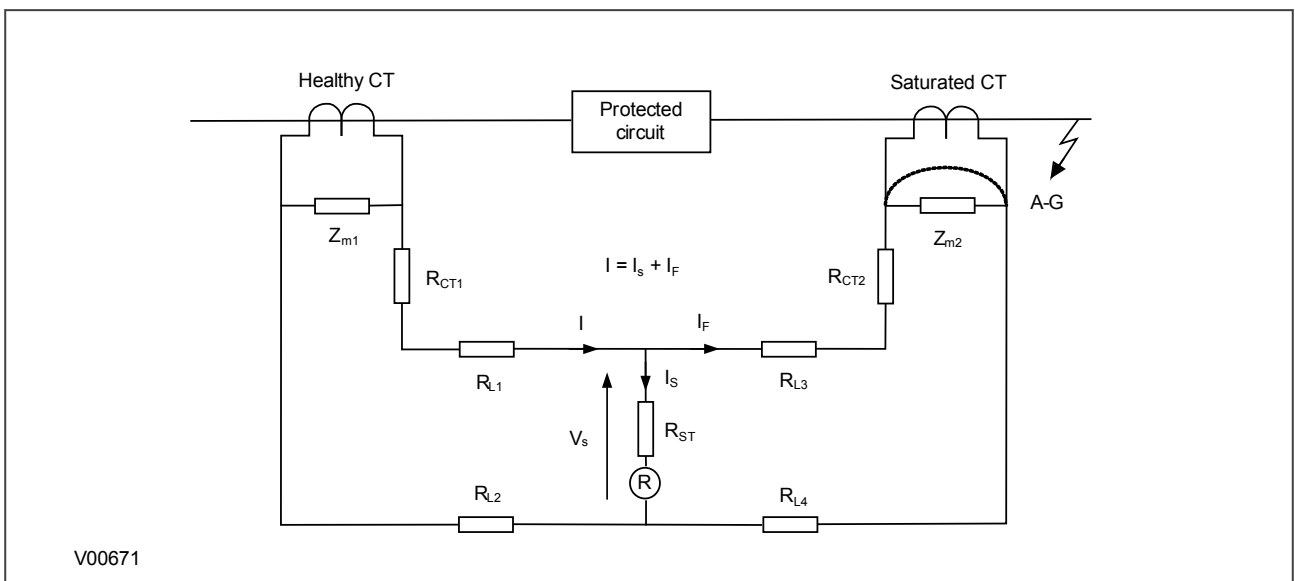
Figure 86: High Impedance REF principle

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/motor starting 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 connection is shown below:
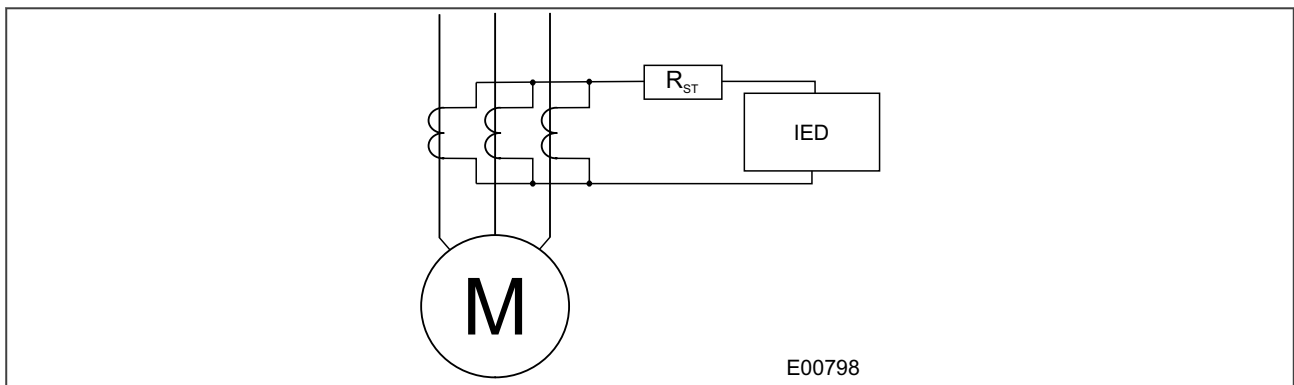
Figure 87: High impedance REF connection

3   RESTRICTED EARTH FAULT PROTECTION IMPLEMENTATION

3.1   RESTRICTED EARTH FAULT PROTECTION SETTINGS

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

3.2.1   SETTING THE BIAS CHARACTERISTIC

Low impedance REF uses a bias charactersitic for increasing sensitivity and stabilising for through faults. 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 according to the bias characteristic.

The differential current is defined as follows:

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

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 = Neutral CT ratio / Line CT ratio
- IN = current measured by the neutral CT

The allowable range for K is:

   0.05 < K < 15 for standard CTs

The operate current is calculated according to the following characteristic:
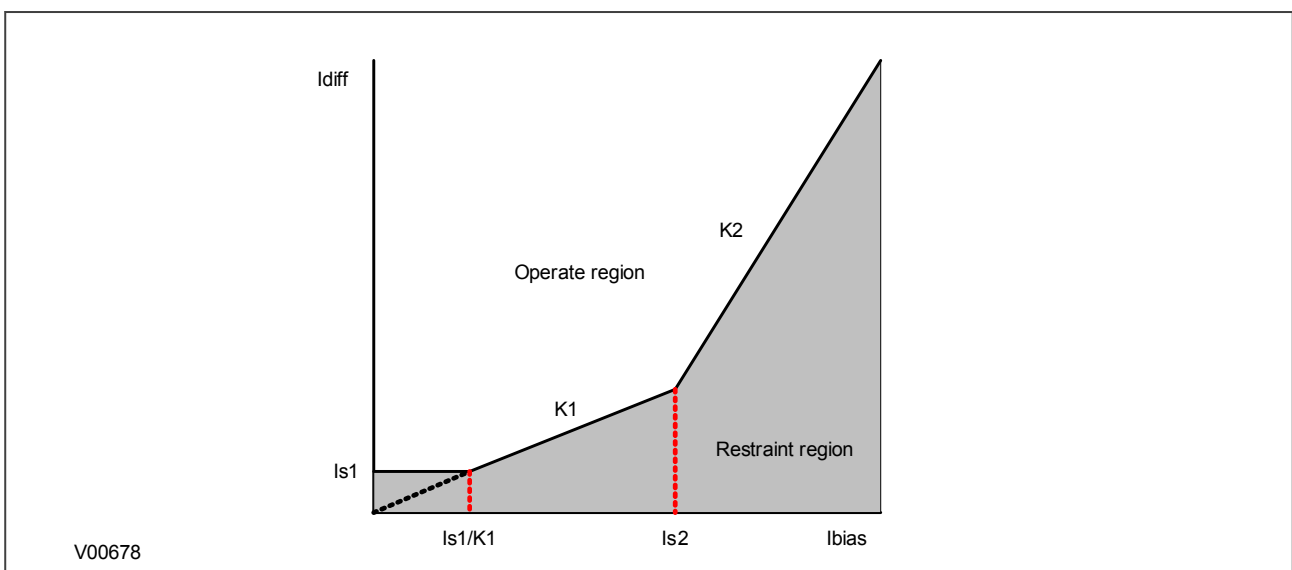
Figure 88: REF bias characteristic

The following settings are provided to define this 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.*

3.2.2 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.

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

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

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 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:

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

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

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

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

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

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 shown in item 2 above. You can calculate the value of the stabilising resistor (R_{ST}) in the following manner.

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

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   APPLICATION NOTES

4.1   LOW IMPEDANCE REF PROTECTION APPLICATION

4.1.1   SETTING GUIDELINES FOR BIASED OPERATION

For this configuration, settings must be modified in the *RESTRICTED E/F* column. The **REF Options** setting should be set to `Lo Z REF` (Low Impedance REF) protection.

To protect as much of the machine winding as possible, the differential current setting **IREF>Is1** should be adjusted to a low setting. A setting of 5% of the machine's rated current of is adequate.

If the conductors are placed reasonably concentrically within the window of the core balance current transformers, spill current can be kept to a minimum. This low spill current and a reasonable independence of CT ratio to full load, allows a lower fault setting than with conventional high impedance circulating current differential schemes.

The differential current setting, **IREF>Is2** should be set to 120% of the machine rated current, this is the threshold above which the second bias setting is applied.

To provide optimum sensitivity for internal faults, the initial bias slope setting **IREF>k1** should be set to 0%. And, to provide adequate stability for external faults, the second bias slope setting **IREF>ks** should be set to 150%.

The above settings can be increased where low accuracy class CTs are used to supply protection.

4.1.2   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.
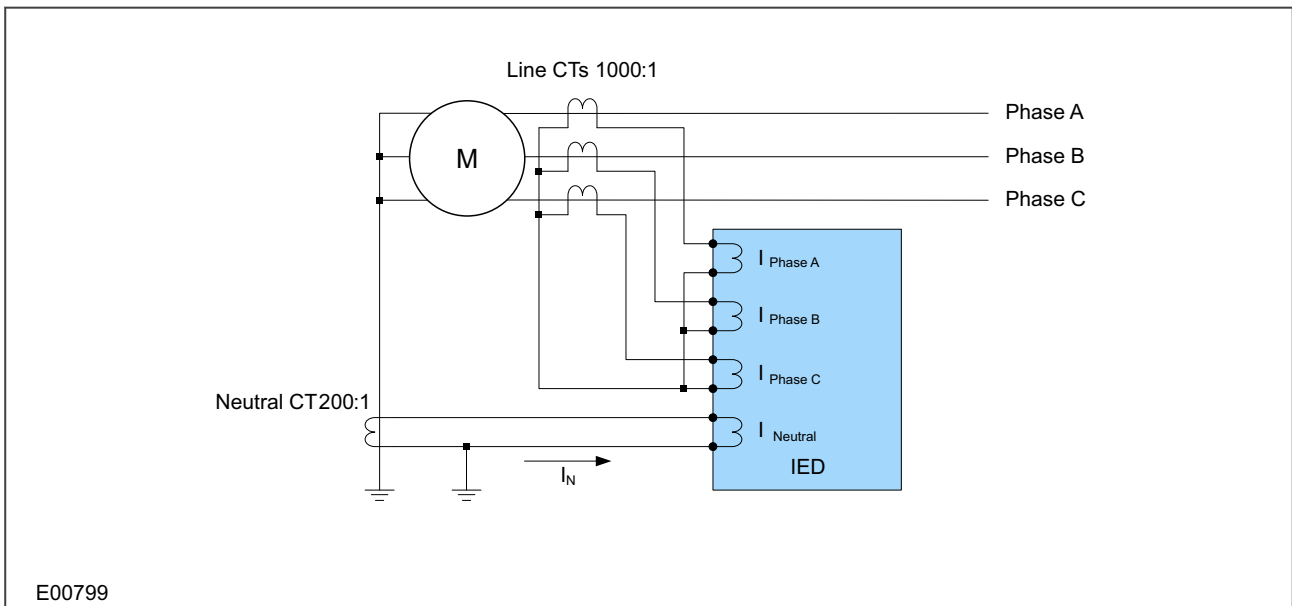
Figure 89: Low Impedance REF Scaling Factor

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 = Neutral CT ratio / Line CT ratio

This results in the following differential and bias current equations:

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

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

4.2   HIGH IMPEDANCE REF PROTECTION APPLICATION

4.2.1   SETTING GUIDELINES FOR HIGH IMPEDANCE OPERATION

For this configuration, settings must be modified in the *RESTRICTED E/F* column. The **REF Options** setting should be set to `Hi Z REF` (High Impedance REF) protection.

To protect as much of the machine winding as possible, the differential current setting **IREF>Is** should be set to a low setting. A setting of 5% of the machine's rated current is adequate, but this may need to be increased where low accuracy class CTs are used to supply the protection. Make sure the primary operating current of the element is less than the minimum fault current for which the protection should operate.

CHAPTER 8

CB FAIL PROTECTION

1   CHAPTER OVERVIEW

The device provides a Circuit Breaker Fail Protection function. This chapter describes the operation of this function 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 practice 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 column of the relevant settings group.

3.1   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 retripping 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 retripping. If retripping fails to open the circuit breaker, 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. Alternatively you can use an external protection trip by allocating one of the opto-inputs to the *External Trip* DDB signal in the PSL.

You can 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 if the undercurrent elements have also been reset. The resetting mechanism is determined by the settings *Volt Prot Reset* and *Ext Prot 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

3.2   ZERO CROSSING DETECTION

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. 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.

4 CIRCUIT BREAKER FAIL LOGIC
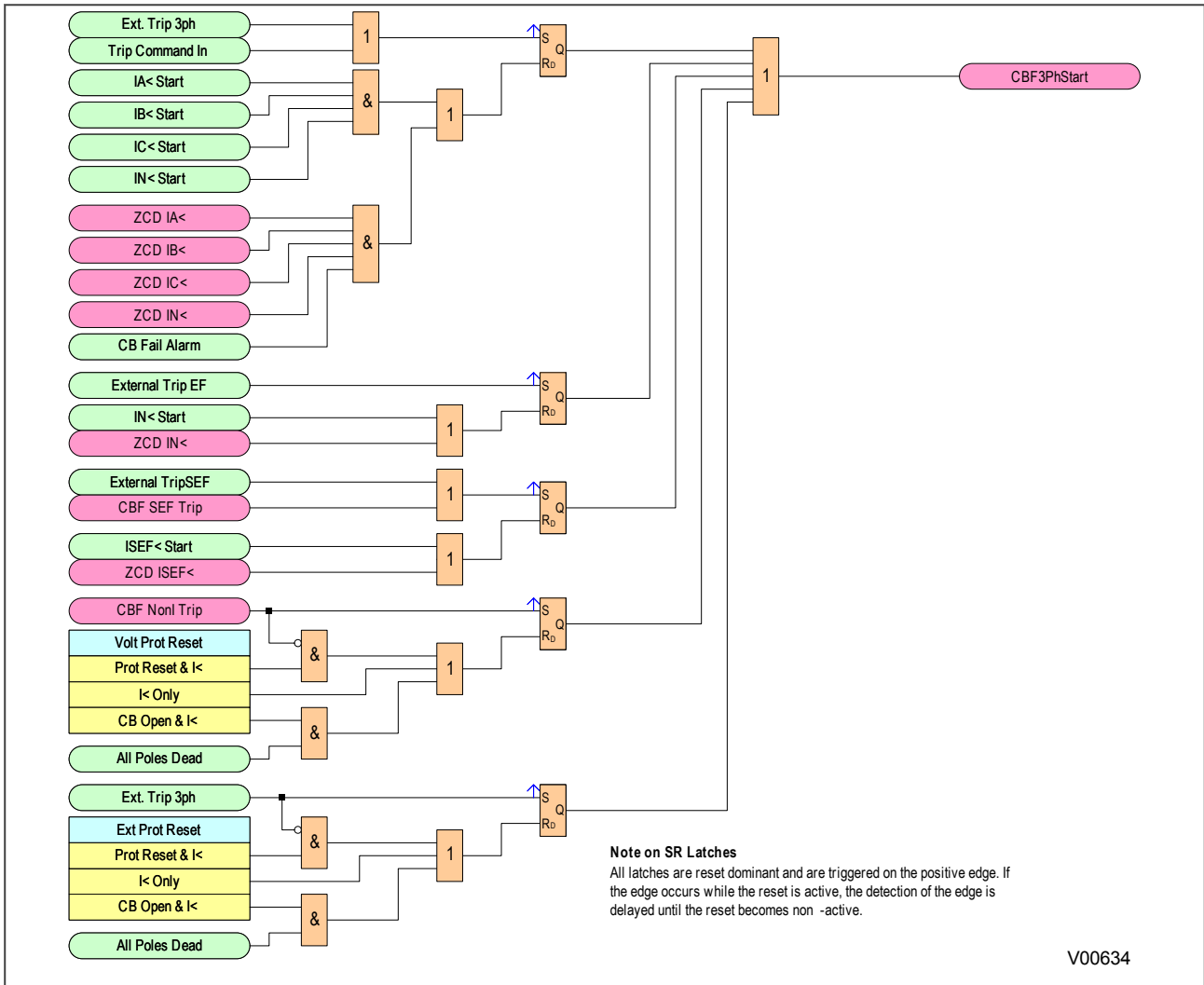
Figure 90: Circuit Breaker Fail logic - three phase start
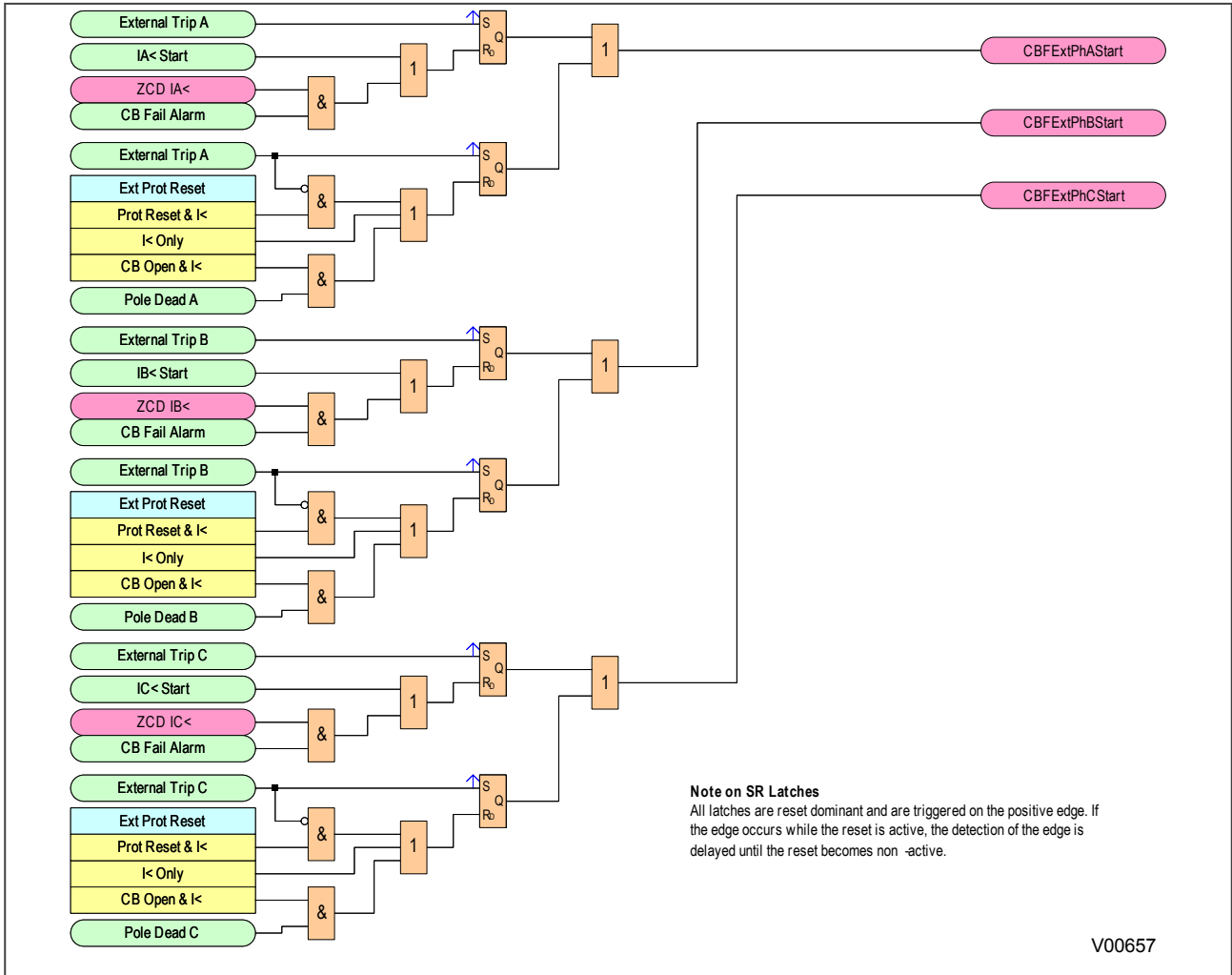
Figure 91: Circuit Breaker Fail logic - single phase start
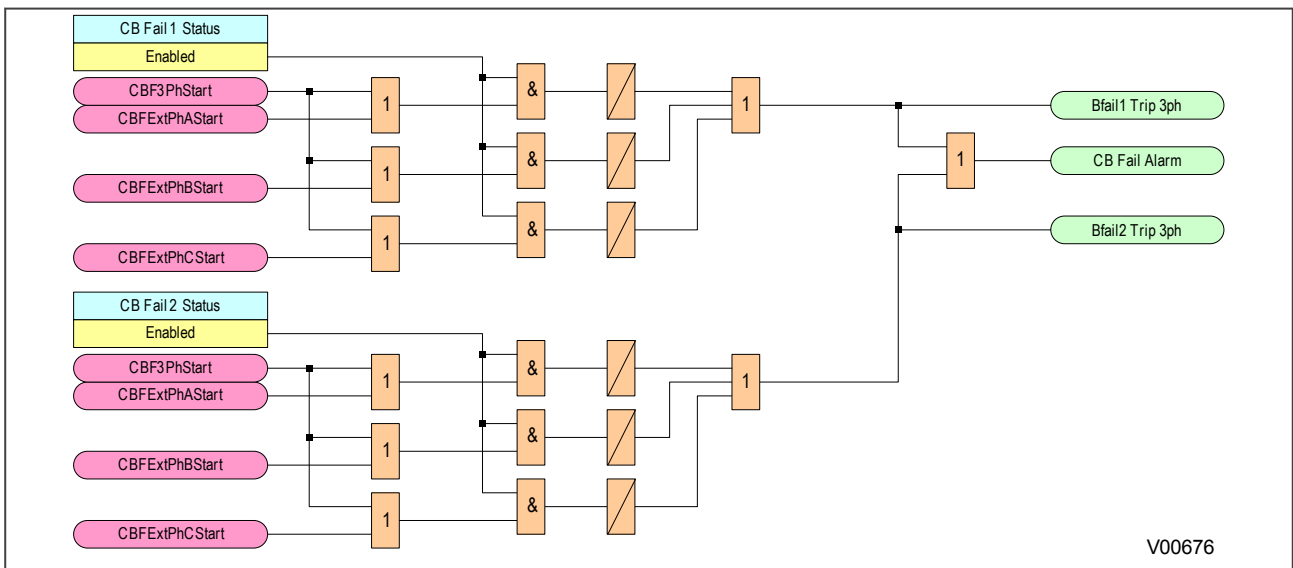
Figure 92: Circuit Breaker Fail Trip and Alarm

5   UNDERCURRENT AND ZCD LOGIC FOR CB FAIL
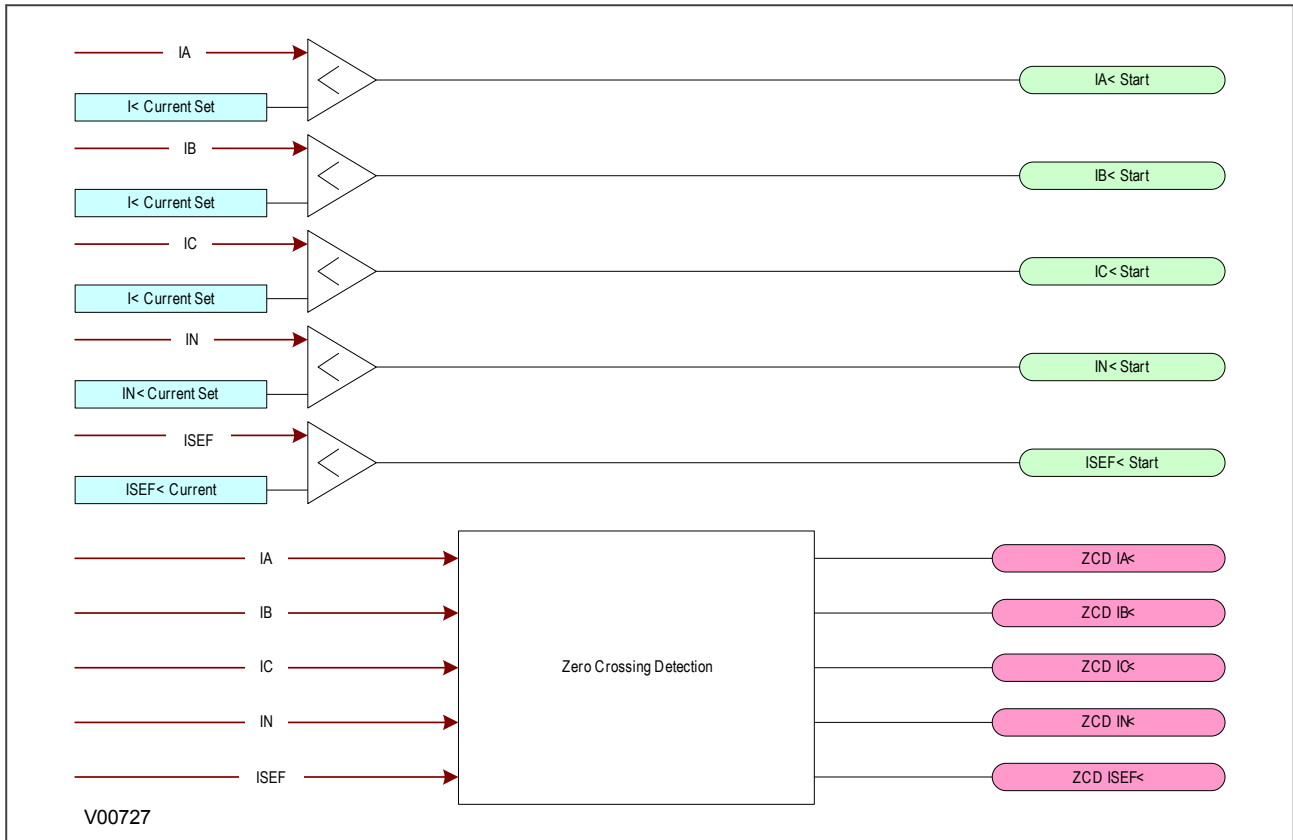
Figure 93: Undercurrent and Zero Crossing Detection Logic for CB Fail

6   CB FAIL SEF PROTECTION LOGIC
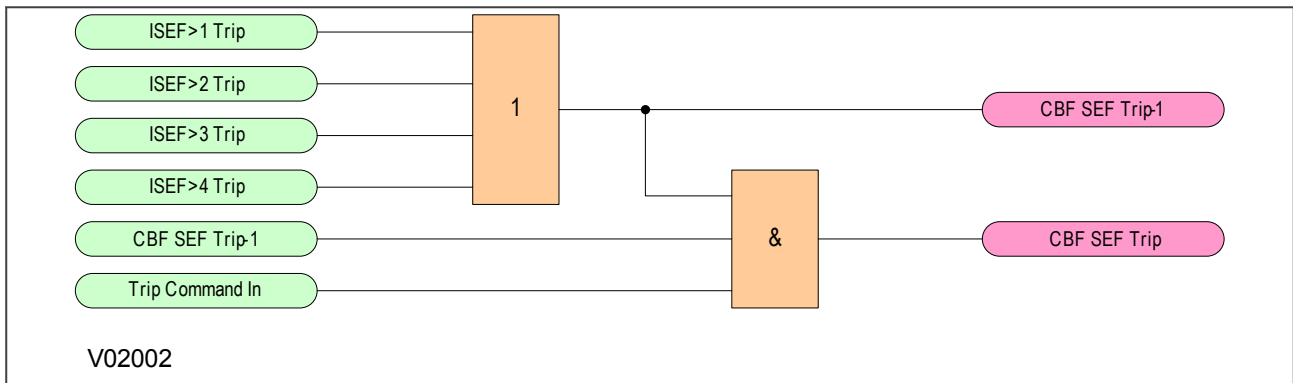
Figure 94: CB Fail SEF Protection Logic

7   CB FAIL NON CURRENT PROTECTION LOGIC
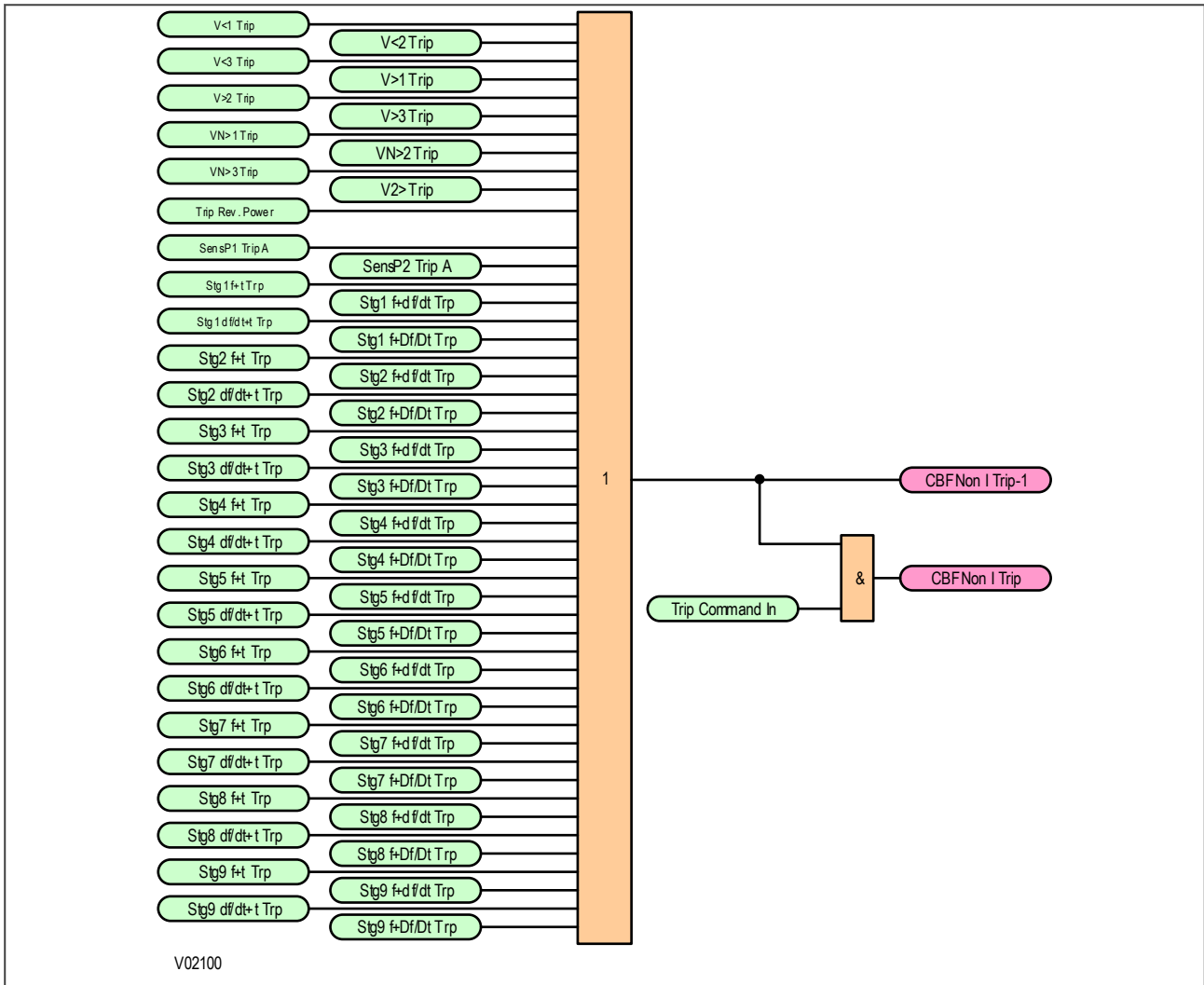
Figure 95: CB Fail Non Current Protection Logic

8   CIRCUIT BREAKER MAPPING
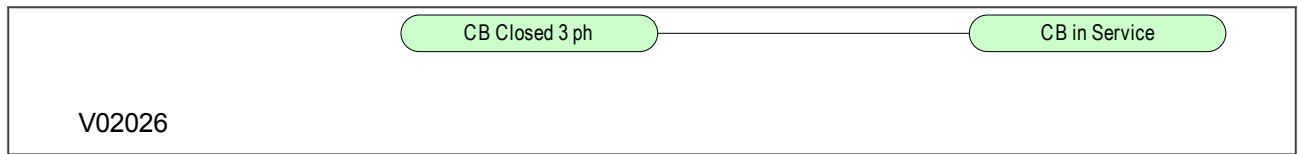
Figure 96: Circuit Breaker mapping

9 APPLICATION NOTES

9.1 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.

9.2 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.
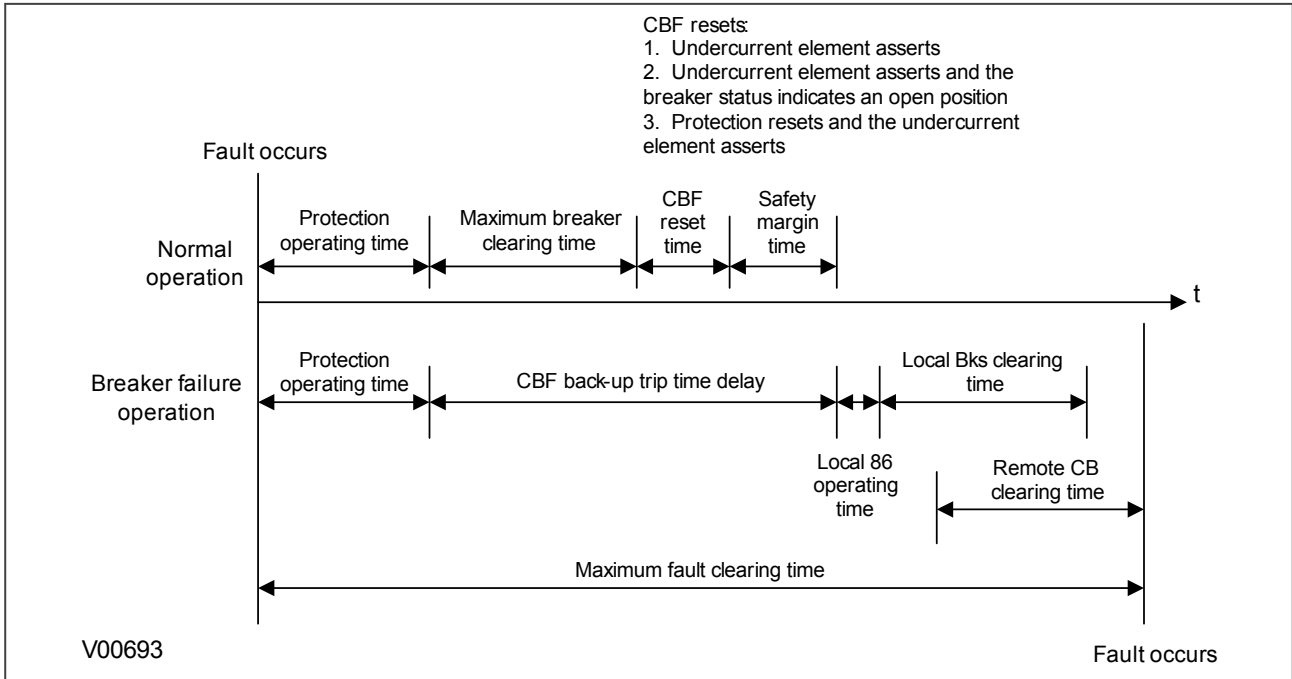
Figure 97: CB Fail timing

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.

9.3   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:

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

CHAPTER 9

CURRENT TRANSFORMER REQUIREMENTS

1   CHAPTER OVERVIEW

This chapter contains the following sections:

2   CT 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	2.5 VA	10P	20	1.3 ohms
5A	7.5 VA	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) / motor starting current

I_n = Rated secondary 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)

R_{CT} = Resistance of current transformer secondary winding (ohms)

R_L = Resistance of a single lead from relay to current transformer (ohms)

R_{st} = Value of stabilising resistor for REF applications (ohms)

I_s = Current setting of REF elements (amps)

V_S = Required stability voltage

2.1   PHASE OVERCURRENT PROTECTION

2.1.1   DIRECTIONAL ELEMENTS

Time-delayed phase overcurrent elements

$$V_K = \frac{I_{cp}}{2}(R_{CT} + R_L + R_p)$$

Instantaneous phase overcurrent elements

$$V_K = \frac{I_{fp}}{2}(R_{CT} + R_L + R_p)$$

2.1.2 NON-DIRECTIONAL ELEMENTS

Time-delayed phase overcurrent elements

$$V_K = \frac{I_{cp}}{2}(R_{CT} + R_L + R_p)$$

Instantaneous phase overcurrent elements

$$V_K = I_{sp}(R_{CT} + R_L + R_p)$$

2.2 EARTH FAULT PROTECTION

2.2.1 DIRECTIONAL ELEMENTS

Instantaneous earth fault overcurrent elements

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

2.2.2 NON-DIRECTIONAL ELEMENTS

Time-delayed earth fault overcurrent elements

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

Instantaneous earth fault overcurrent elements

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

2.3 SEF PROTECTION (RESIDUALLY CONNECTED)

2.3.1 DIRECTIONAL ELEMENTS

Time delayed SEF protection

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

Instantaneous SEF protection

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

2.3.2 NON-DIRECTIONAL ELEMENTS

Time delayed SEF protection

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

Instantaneous SEF protection

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

2.4 SEF PROTECTION (CORE-BALANCED CT)

2.4.1 DIRECTIONAL ELEMENTS

Instantaneous element

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

> *Note:*
> *Ensure that the phase error of the applied core balance current transformer is less than 90 minutes at 10% of rated current and less than 150 minutes at 1% of rated current.*

2.4.2 NON-DIRECTIONAL ELEMENTS

Time delayed element

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

Instantaneous element

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

> *Note:*
> *Ensure that the phase error of the applied core balance current transformer is less than 90 minutes at 10% of rated current and less than 150 minutes at 1% of rated current.*

2.5 LOW IMPEDANCE REF PROTECTION

For X/R < 40 and I_f < 15I_n

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

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

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

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

2.6 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:

$$R_{st} = \frac{I_f(R_{CT} + 2R_L)}{I_s}$$

$$V_K \geq 4I_s R_{st}$$

> *Note:*
> *Class x CTs should be used for high impedance REF applications.*

2.7 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 stabilising 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 × 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:

Device Voltage Setting	Nominal Characteristic		Recommended Metrosil Type	
	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

Secondary Internal Fault Current	Recommended Metrosil types for various voltage settings			
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 General Electric for detailed applications.

> *Note:*
> *The Metrosils recommended for use with 5 Amp CTs can also be used with triple pole devices 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.*

2.8   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:

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

CHAPTER 10

VOLTAGE PROTECTION FUNCTIONS

# 1		CHAPTER OVERVIEW

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

This chapter contains the following sections:

2   UNDERVOLTAGE PROTECTION

Undervoltage conditions may occur on a power system for a variety of reasons, some of which are outlined below:

- Undervoltage conditions can be related to increased loads, whereby the supply voltage will decrease in magnitude. This situation would normally be rectified by voltage regulating equipment such as AVRs (Auto Voltage Regulators) or On Load Tap Changers. However, failure of this equipment to bring the system voltage back within permitted limits leaves the system with an undervoltage condition, which must be cleared.

- If the regulating equipment is unsuccessful in restoring healthy system voltage, then tripping by means of an undervoltage element is required.

- Faults occurring on the power system result in a reduction in voltage of the faulty phases. The proportion by which the voltage decreases is dependent on the type of fault, method of system earthing and its location. Consequently, co-ordination with other voltage and current-based protection devices is essential in order to achieve correct discrimination.

- Complete loss of busbar voltage. This may occur due to fault conditions present on the incomer or busbar itself, resulting in total isolation of the incoming power supply. For this condition, it may be necessary to isolate each of the outgoing circuits, such that when supply voltage is restored, the load is not connected. Therefore, the automatic tripping of a feeder on detection of complete loss of voltage may be required. This can be achieved by a three-phase undervoltage element.

- Where outgoing feeders from a busbar are supplying induction motor loads, excessive dips in the supply may cause the connected motors to stall, and should be tripped for voltage reductions that last longer than a pre-determined time.

2.1   UNDERVOLTAGE PROTECTION IMPLEMENTATION

Undervoltage Protection is implemented in the *VOLT PROTECTION* column of the relevant settings group. The Undervoltage parameters are contained within the sub-heading *UNDERVOLTAGE*.

The product provides three stages of Undervoltage protection with independent time delay characteristics.

Stages 1 and 3 provide a choice of operate characteristics, where you can select between:

- An IDMT characteristic
- A range of user-defined curves
- DT (Definite Time)

You set this using the **V<1 Function** and **V<3 Function** cells depending on the stage.

The IDMT characteristic is defined by the following formula:

$$t = K/(M-1)$$

where:

- K = Time multiplier setting
- t = Operating time in seconds
- M = Measured voltage / IED setting voltage

The undervoltage stages can be configured either as phase-to-neutral or phase-to-phase voltages in the **V< Measure't mode** cell.

There is no Timer Hold facility for Undervoltage.

Stage 2 can have definite time characteristics only. This is set in the **V<2** status cell.

Three stages are included in order to provide multiple output types, such as alarm and trip stages. Alternatively, different time settings may be required depending upon the severity of the voltage dip. For example, motor loads will be able to cope with a small voltage dip for a longer time than a major one.

Outputs are available for single or three-phase conditions via the **V< Operate Mode** cell for each stage.

2.2   UNDERVOLTAGE PROTECTION LOGIC
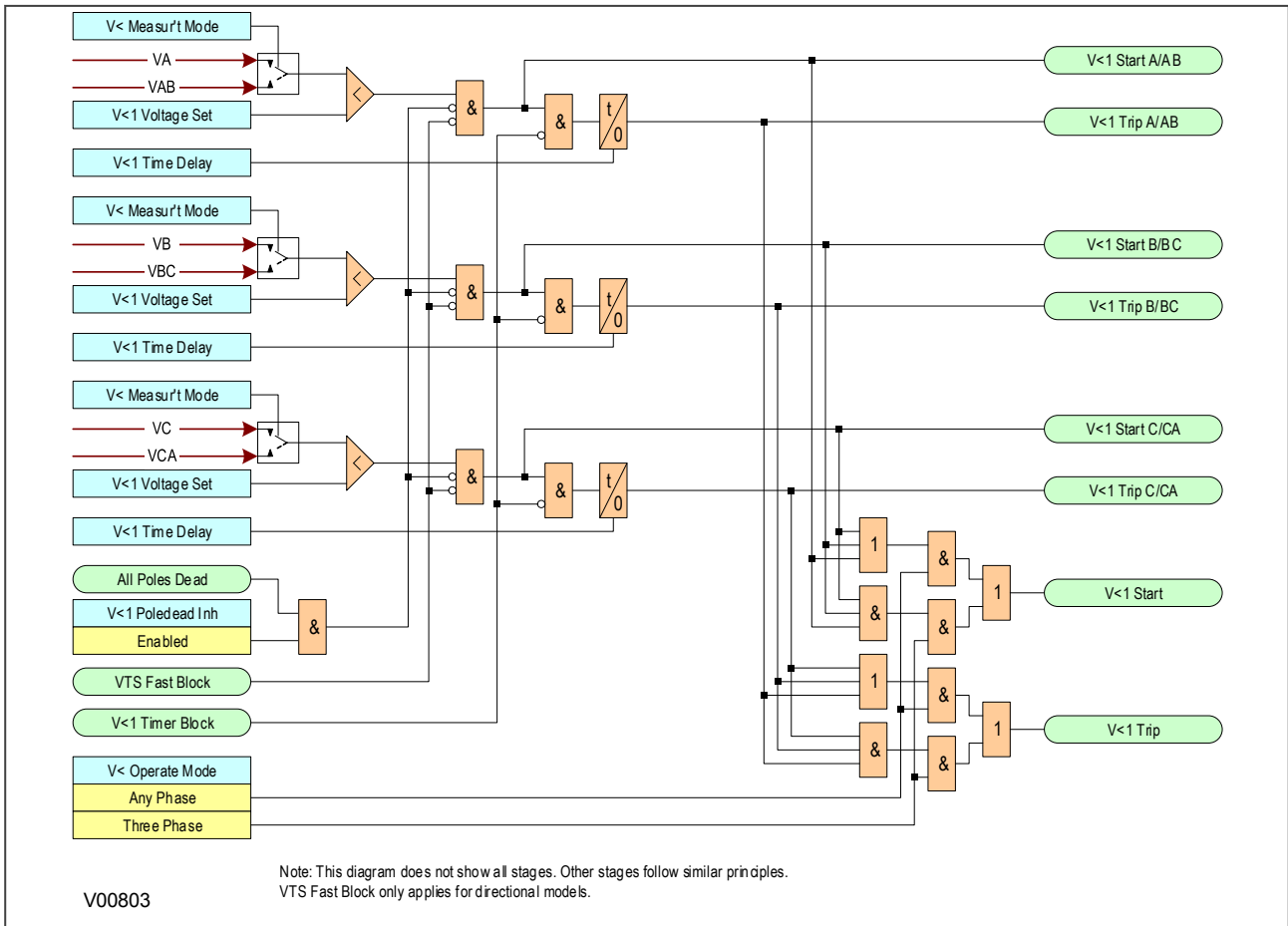
Figure 98: Undervoltage - single and three phase tripping mode (single stage)

The Undervoltage protection function detects when the voltage magnitude for a certain stage falls short of a set threshold. If this happens a **Start** signal, signifying the "Start of protection", is produced. This Start signal can be blocked by the **VTS Fast Block** signal and an **All Poles Dead** signal. This **Start** signal is applied to the timer module to produce the **Trip** signal, which can be blocked by the undervoltage timer block signal (**V<(n) Timer Block**). For each stage, there are three Phase undervoltage detection modules, one for each phase. The three **Start** signals from each of these phases are OR'd together to create a 3-phase Start signal (**V<(n) Start**), which can be be activated when any of the three phases start (Any Phase), or when all three phases start (Three Phase), depending on the chosen **V< Operate Mode** setting.

The outputs of the timer modules are the trip signals which are used to drive the tripping output relay. These tripping signals are also OR'd together to create a 3-phase Trip signal, which are also controlled by the **V< Operate Mode** setting.

If any one of the above signals is low, or goes low before the timer has counted out, the timer module is inhibited (effectively reset) until the blocking signal goes high.

In some cases, we do not want the undervoltage element to trip; for example, when the protected feeder is de-energised, or the circuit breaker is opened, an undervoltage condition would obviously be detected, but we would not want to start protection. To cater for this, an **All Poles Dead** signal blocks the **Start** signal for each phase. This is controlled by the **V<Poledead Inh** cell, which is included for each of the stages. If the cell is enabled, the relevant stage will be blocked by the integrated pole dead logic. This logic produces an output when it detects either an

open circuit breaker via auxiliary contacts feeding the opto-inputs or it detects a combination of both undercurrent and undervoltage on any one phase.

2.3   APPLICATION NOTES

2.3.1   UNDERVOLTAGE PROTECTION

Principle

Undervoltage conditions can occur on a power system as a result of increased loading, fault conditions or incorrect regulation. Transient voltage dips can allow successful motor re-acceleration. However, sustained undervoltage conditions will result in the motor stalling. Time delayed undervoltage protection is commonly applied.

The undervoltage protection included in the P24DM relays consists of three independent measuring stages.

Multiple stages are included to provide both alarm and trip stages, where required. Depending on the severity of the voltage dip different time settings may be needed so that motor loads are able to withstand a small voltage depression for longer than if a major voltage excursion occurs. Therefore, two stages can be used; one with a higher setting and a longer time delay and vice versa for the second stage.

Setting guidelines

The voltage threshold setting for the undervoltage protection should be set at some value below the voltage excursions that may be expected under normal system operating conditions. This threshold is dependent on the system in question but typical healthy system voltage excursions may be -10% of nominal value.

The same applies to the time setting. The required time delay is dependent on the time for which the system is able to withstand a reduced voltage. A typical time setting may be 0.5 seconds.

The setting **Inhib.During St.** must be set to `Enabled` to allow the voltage decrease during motor starting.

This feature must be interlocked with the motor control gear to ensure that it is disabled when the motor is stopped. The interlock is made by the CB Close signal.

3   OVERVOLTAGE PROTECTION

Overvoltage conditions are generally related to loss of load conditions, whereby the supply voltage increases in magnitude. This situation would normally be rectified by voltage regulating equipment such as AVRs (Auto Voltage Regulators) or On Load Tap Changers. However, failure of this equipment to bring the system voltage back within permitted limits leaves the system with an overvoltage condition which must be cleared.

> *Note:*
> *During earth fault conditions on a power system there may be an increase in the healthy phase voltages. Ideally, the system should be designed to withstand such overvoltages for a defined period of time.*

3.1   OVERVOLTAGE PROTECTION IMPLEMENTATION

Overvoltage Protection is implemented in the *VOLT PROTECTION* column of the relevant settings group. The Overvoltage parameters are contained within the sub-heading *OVERVOLTAGE*.

The product provides three stages of overvoltage protection with independent time delay characteristics.

Stages 1 and 3 provide a choice of operate characteristics, where you can select between:

- An IDMT characteristic
- A range of user-defined curves
- DT (Definite Time)

You set this using the **V>1 Function** and **V>3 Function** cells depending on the stage.

The IDMT characteristic is defined by the following formula:

$$t = K/(M - 1)$$

where:

- K = Time multiplier setting
- t = Operating time in seconds
- M = Measured voltage setting voltage (**V> Voltage Set**)

The overvoltage stages can be configured either as phase-to-neutral or phase-to-phase voltages in the **V> Measure't mode** cell.

There is no Timer Hold facility for Overvoltage.

Stage 2 has definite time characteristics only. This is set in the **V>2 status** cell.

Three stages are included in order to provide multiple output types, such as alarm and trip stages. Alternatively, different time settings may be required depending upon the severity of the voltage increase.

Outputs are available for single or three-phase conditions via the **V> Operate Mode** cell for each stage.

3.2   OVERVOLTAGE PROTECTION LOGIC
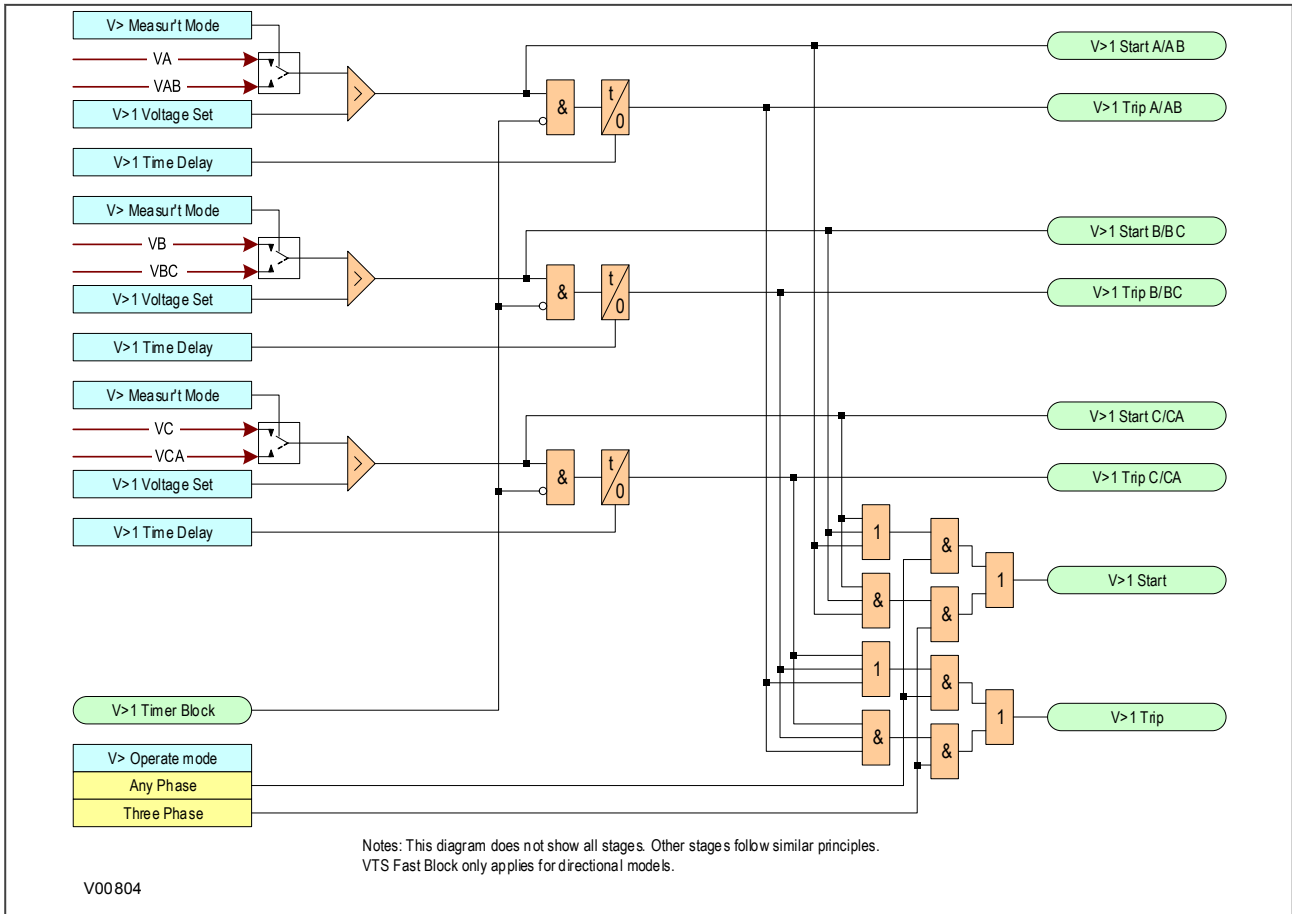
Figure 99: Overvoltage - single and three phase tripping mode (single stage)

The Overvoltage protection function detects when the voltage magnitude for a certain stage exceeds a set threshold. If this happens a **Start** signal, signifying the "Start of protection", is produced. This Start signal can be blocked by the **VTS Fast Block** signal. This start signal is applied to the timer module to produce the **Trip** signal, which can be blocked by the overvoltage timer block signal (**V>(n) Timer Block**). For each stage, there are three Phase overvoltage detection modules, one for each phase. The three **Start** signals from each of these phases are OR'd together to create a 3-phase Start signal (**V>(n) Start**), which can then be activated when any of the three phases start (Any Phase), or when all three phases start (Three Phase), depending on the chosen **V> Operate Mode** setting.

The outputs of the timer modules are the trip signals which are used to drive the tripping output relay. These tripping signals are also OR'd together to create a 3-phase Trip signal, which are also controlled by the **V> Operate Mode** setting.

If any one of the above signals is low, or goes low before the timer has counted out, the timer module is inhibited (effectively reset) until the blocking signal goes high.

3.3   APPLICATION NOTES

3.3.1   OVERVOLTAGE SETTING GUIDELINES

The provision of multiple stages and their respective operating characteristics allows for a number of possible applications:

- Definite Time can be used for both stages to provide the required alarm and trip stages.
- Use of the IDMT characteristic allows grading of the time delay according to the severity of the overvoltage. As the voltage settings for both of the stages are independent, the second stage could then be set lower than the first to provide a time-delayed alarm stage.
- If only one stage of overvoltage protection is required, or if the element is required to provide an alarm only, the remaining stage may be disabled.

This type of protection must be co-ordinated with any other overvoltage devices at other locations on the system.

4   RESIDUAL OVERVOLTAGE PROTECTION

On a healthy three-phase power system, the sum of the three-phase to earth voltages is nominally zero, as it is the vector sum of three balanced vectors displaced from each other by 120°. However, when an earth fault occurs on the primary system, this balance is upset and a residual voltage is produced. This condition causes a rise in the neutral voltage with respect to earth. Consequently this type of protection is also commonly referred to as 'Neutral Voltage Displacement' or NVD for short.

This residual voltage may be derived (from the phase voltages) or measured (from a measurement class open delta VT). Derived values will normally only be used where the model does not support measured functionality (a dedicated measurement class VT).

This offers an alternative means of earth fault detection, which does not require any measurement of current. This may be particularly advantageous in high impedance earthed or insulated systems, where the provision of core balanced current transformers on each feeder may be either impractical, or uneconomic, or for providing earth fault protection for devices with no current transformers.

4.1   RESIDUAL OVERVOLTAGE PROTECTION IMPLEMENTATION

Residual Overvoltage Protection is implemented in the *RESIDUAL O/V NVD* column of the relevant settings group.

Some applications require more than one stage. For example an insulated system may require an alarm stage and a trip stage. It is common in such a case for the system to be designed to withstand the associated healthy phase overvoltages for a number of hours following an earth fault. In such applications, an alarm is generated soon after the condition is detected, which serves to indicate the presence of an earth fault on the system. This gives time for system operators to locate and isolate the fault. The second stage of the protection can issue a trip signal if the fault condition persists.

The product provides three stages of Residual Overvoltage protection with independent time delay characteristics.

Stages 1 and 3 provide a choice of operate characteristics, where you can select between:

- An IDMT characteristic
- A range of user-defined curves
- DT (Definite Time)

The IDMT characteristic is defined by the following formula:

$$t = K/(M - 1)$$

where:

- K= Time multiplier setting
- t = Operating time in seconds
- M = Derived residual voltage setting voltage (***VN> Voltage Set***)

You set this using the ***VN>1 Function*** and ***VN>3 Function*** cells depending on the stage.

Stages 1 and 3 also provide a Timer Hold facility as described in

Stage 2 can have definite time characteristics only. This is set in the ***VN>2 status*** cell

The residual voltage may be derived from the phase voltages (Vres = Va + Vb +Vc) or measured from the 4th VT input.

In the *CT AND VT RATIOS* column, the ***VN Input*** setting may be set to `Measured` or `Derived`, this is used to select the type of neutral voltage.

The device derives the residual voltage internally from the three-phase voltage inputs supplied from either a 5-limb VT or three single-phase VTs. These types of VT design provide a path for the residual flux and consequently permit the device to derive the required residual voltage. In addition, the primary star point of the VT must be earthed. Three-limb VTs have no path for residual flux and are therefore unsuitable for this type of protection.

4.2   RESIDUAL OVERVOLTAGE LOGIC
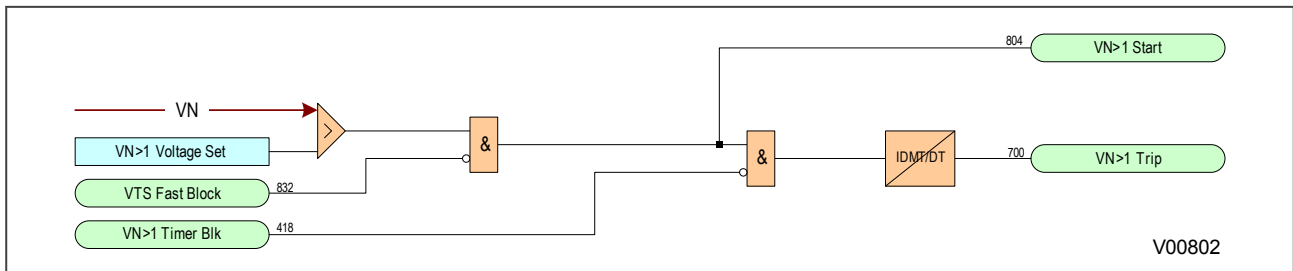
Figure 100: Residual Overvoltage logic

The Residual Overvoltage module (VN>) is a level detector that detects when the voltage magnitude exceeds a set threshold, for each stage. When this happens, the comparator output produces a **Start** signal (**VN>(n) Start**), which signifies the "Start of protection". This can be blocked by a **VTS Fast block** signal. This **Start** signal is applied to the timer module. The output of the timer module is the **VN> (n) Trip** signal which is used to drive the tripping output relay.

4.3   APPLICATION NOTES

4.3.1   CALCULATION FOR SOLIDLY EARTHED SYSTEMS

Consider a Phase-A to Earth fault on a simple radial system.
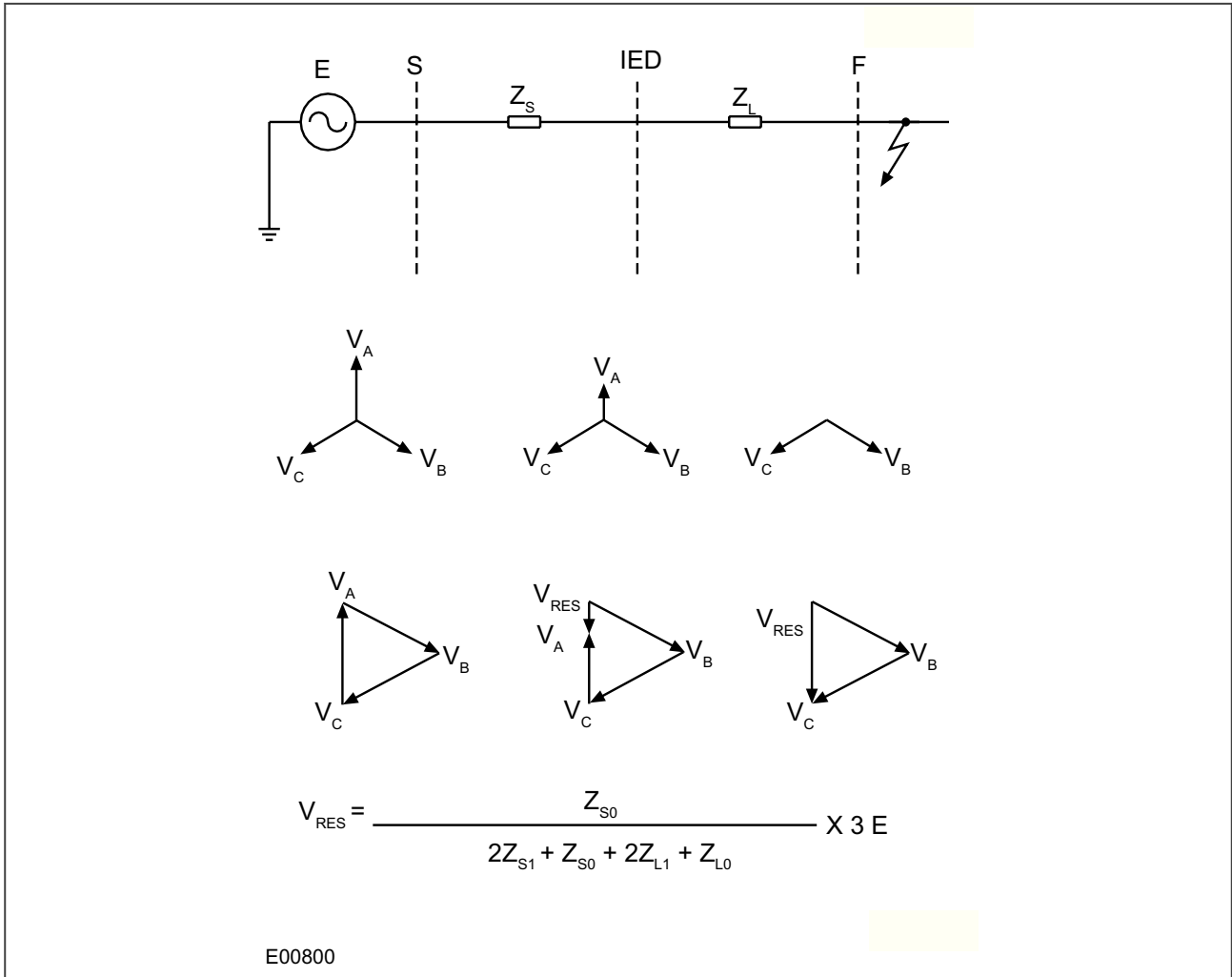
Figure 101: Residual voltage for a solidly earthed system

As can be seen from the above diagram, the residual voltage measured on a solidly earthed system is solely dependent on the ratio of source impedance behind the protection to the line impedance in front of the protection, up to the point of fault. For a remote fault far away, the Z_S/Z_L: ratio will be small, resulting in a correspondingly small residual voltage. Therefore, the protection only operates for faults up to a certain distance along the system. The maximum distance depends on the device setting.

4.3.2   CALCULATION FOR IMPEDANCE EARTHED SYSTEMS

Consider a Phase-A to Earth fault on a simple radial system.
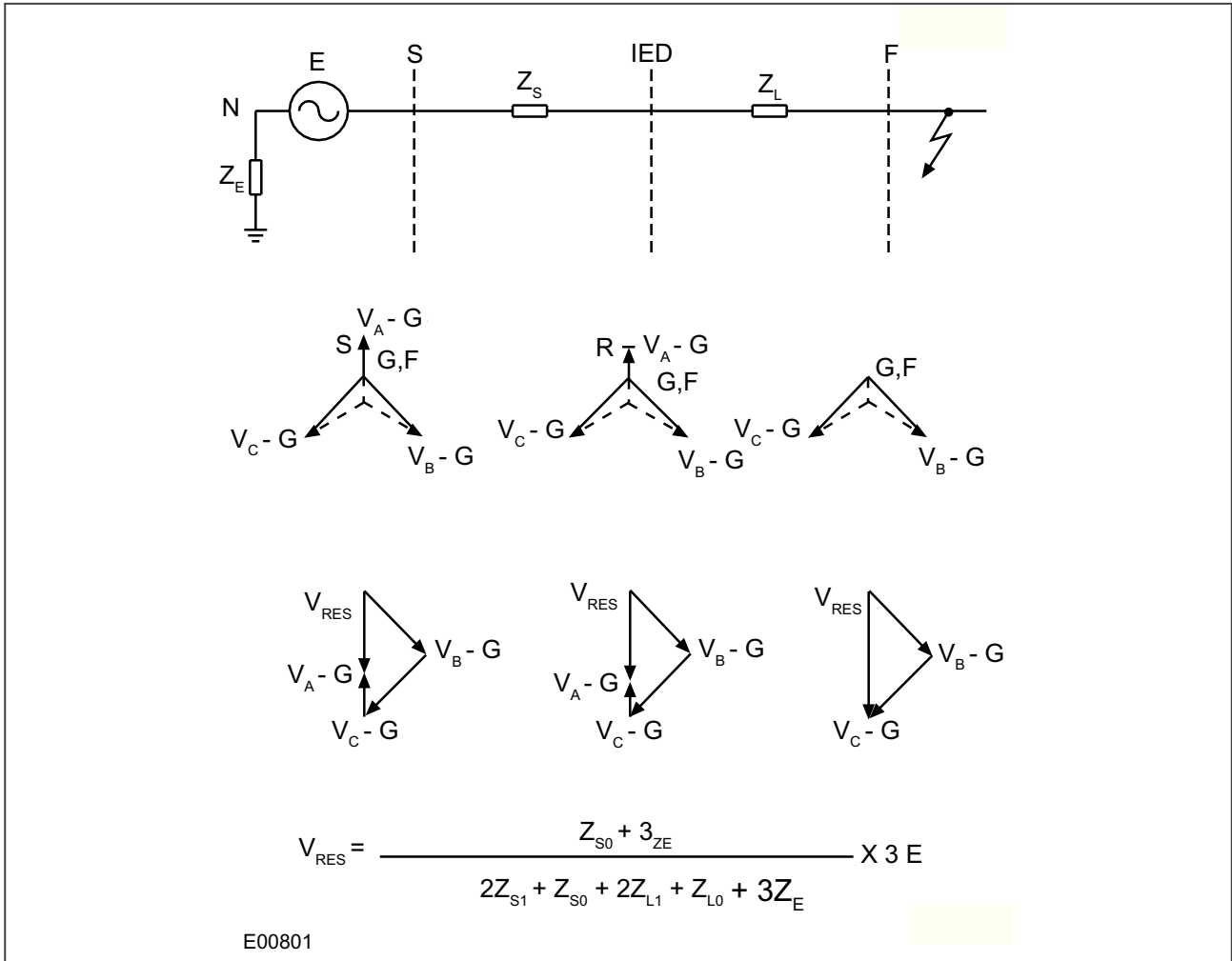
Figure 102: Residual voltage for an impedance earthed system

An impedance earthed system will always generate a relatively large degree of residual voltage, as the zero sequence source impedance now includes the earthing impedance. It follows then that the residual voltage generated by an earth fault on an insulated system will be the highest possible value (3 × phase-neutral voltage), as the zero sequence source impedance is infinite.

4.3.3   SETTING GUIDELINES

The voltage setting applied to the elements is dependent on the magnitude of residual voltage that is expected to occur during the earth fault condition. This in turn is dependent on the method of system earthing employed.

Also, you must ensure that the protection setting is set above any standing level of residual voltage that is present on the system.

5   NEGATIVE SEQUENCE OVERVOLTAGE PROTECTION

Where an incoming feeder is supplying rotating plant equipment such as an induction motor, correct phasing and balance of the supply is essential. Incorrect phase rotation will result in connected motors rotating in the wrong direction. For directionally sensitive applications, such as elevators and conveyor belts, it is unacceptable to allow this to happen.

Imbalances on the incoming supply cause negative phase sequence voltage components. In the event of incorrect phase rotation, the supply voltage would effectively consist of 100% negative phase sequence voltage only.

5.1   NEGATIVE SEQUENCE OVERVOLTAGE IMPLEMENTATION

Negative Sequence Overvoltage Protection is implemented in the *NEG SEQUENCE O/V* column of the relevant settings group.

The device includes one Negative Phase Sequence Overvoltage element with two stages. Only Definite time is possible.

This element monitors the input voltage rotation and magnitude (normally from a bus connected voltage transformer) and may be interlocked with the motor contactor or circuit breaker to prevent the motor from being energised whilst incorrect phase rotation exists.

The element is enabled using the **V2>1 status** and **V2>2 status** cells.

5.2   NEGATIVE SEQUENCE OVERVOLTAGE LOGIC
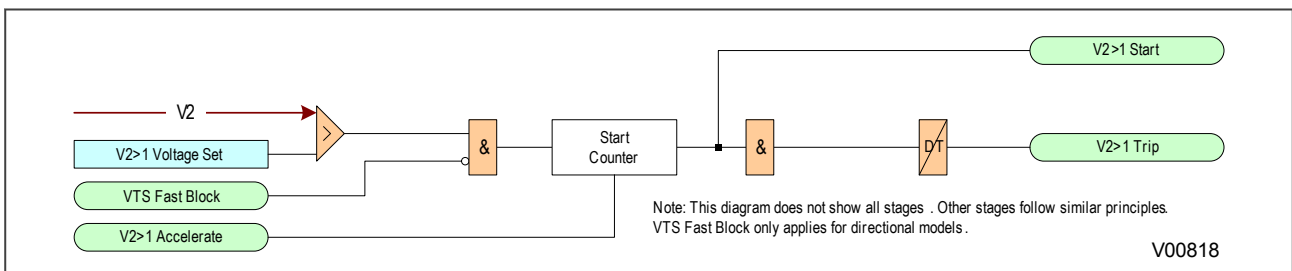
Figure 103: Negative Sequence Overvoltage logic

The Negative Voltage Sequence Overvoltage module detects when the voltage magnitude exceeds a set threshold. When this happens, the comparator output Overvoltage Module produces a **Start** signal (e.g. for stage 1: **V2>1 Start**), which signifies the "Start of protection". This can be blocked by a **VTS Fast block** signal. This **Start** signal is applied to the DT timer module. The output of the DT timer module is the trip signal which is used to drive the tripping output relay.

The **V2>1 Accelerate** signal accelerates the operating time of the function, by reducing the number of confirmation cycles needed to start the function. At 50 Hz, this means the protection Start is reduced by 20 ms.

5.3   APPLICATION NOTES

5.3.1   SETTING GUIDELINES

The primary concern is usually the detection of incorrect phase rotation (rather than small imbalances), therefore a sensitive setting is not required. The setting must be higher than any standing NPS voltage, which may be present due to imbalances in the measuring VT, device tolerances etc.

A setting of approximately 15% of rated voltage may be typical.

> *Note:*
> *Standing levels of NPS voltage (V2) are displayed in the **V2 Magnitude** cell of the MEASUREMENTS 1 column.*

The operation time of the element depends on the application, but a typical setting would be in the region of 5 seconds.

6   POSITIVE SEQUENCE UNDERVOLTAGE PROTECTION

6.1   POSITIVE SEQUENCE UNDERVOLTAGE IMPLEMENTATION

Positive Sequence Undervoltage Protection is implemented under the *POS SEQ U/V* heading in the *VOLT PROTECTION* Voltage column of the relevant settings group.

The product provides two stages of Positive Sequence Undervoltage protection with independent time delay characteristics.

Stage 1 provides a choice of operate characteristics, where you can select between:

- An IDMT characteristic
- DT (Definite Time)

You set this using the **V1<1 Function** cell.

The IDMT characteristic is defined by the following formula:

$$t = K/(M-1)$$

where:

- K = Time multiplier setting
- t = Operating time in seconds
- M = Measured voltage / IED setting voltage

There is no Timer Hold facility for Undervoltage.

Stage 2 can have definite time characteristics only. This is set in the **V1<2** status cell.

Two stages are included in order to provide multiple output types, such as alarm and trip stages.

6.2   POSITIVE SEQUENCE UNDERVOLTAGE LOGIC
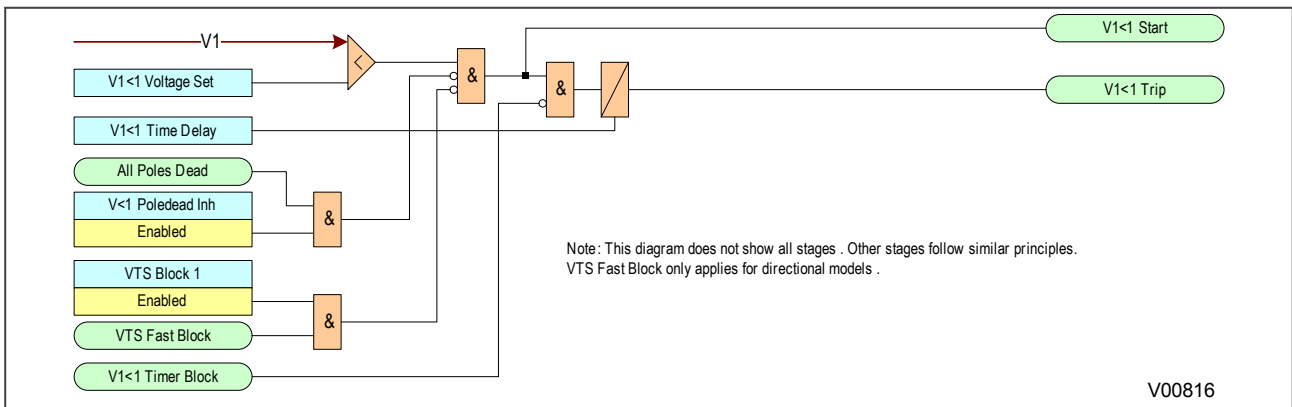
Figure 104: Positive Sequence Undervoltage logic

7   POSITIVE SEQUENCE OVERVOLTAGE PROTECTION

7.1   POSITIVE SEQUENCE OVERVOLTAGE IMPLEMENTATION

Positive Sequence Overvoltage Protection is implemented under the *POS SEQ O/V* heading in the *VOLT PROTECTION* Voltage column of the relevant settings group.

The product provides two stages of Positive Sequence Overvoltage protection with independent time delay characteristics.

Stage 1 provides a choice of operate characteristics, where you can select between:

- An IDMT characteristic
- DT (Definite Time)

You set this using the **V1>1 Function** cell.

The IDMT characteristic is defined by the following formula:

$$t = K/(M-1)$$

where:

- K = Time multiplier setting
- t = Operating time in seconds
- M = Measured voltage / IED setting voltage

There is no Timer Hold facility for Positive Sequence Overvoltage.

Stage 2 can have definite time characteristics only. This is set in the **V1>2 status** cell.

Two stages are included in order to provide multiple output types, such as alarm and trip stages.

7.2   POSITIVE SEQUENCE OVERVOLTAGE LOGIC
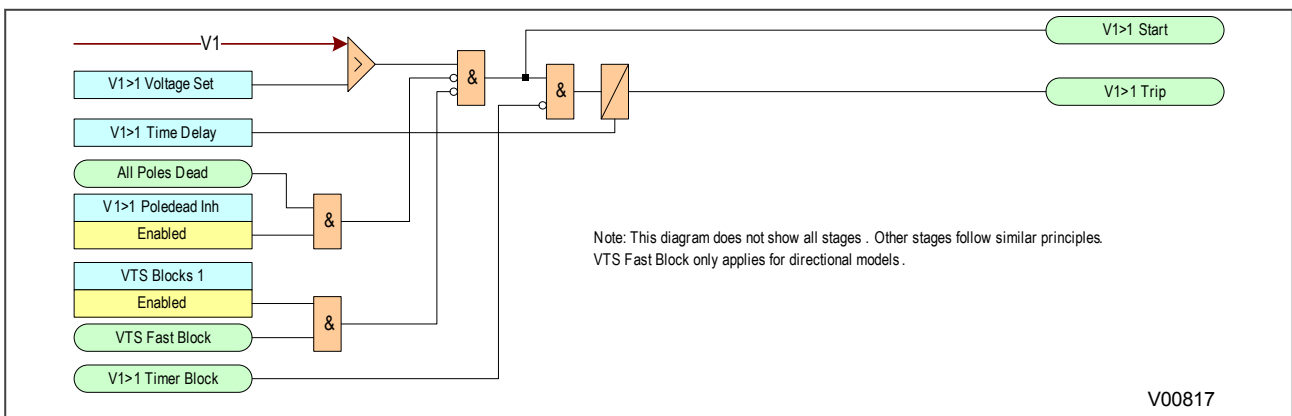
Figure 105: Positive Sequence Overvoltage logic

8   MOVING AVERAGE VOLTAGE FUNCTIONS

Moving average voltage functions are available for:

- Undervoltage (Vavg<)
- Overvoltage (Vavg>)
- Zero Sequence Voltage (V0avg>)
- Positive Sequence Voltage (V1Avg>)
- Negative Sequence Voltage (V2Avg>)

The voltage is sampled at 5 Hz (one sample every 200 ms for a 50 Hz system). The refresh period is 3 seconds, meaning 15 samples are collected every refresh period. The average voltage for the previous 10 minutes is calculated, displayed as measurements and used as energising quantities for the protection functions. The folllowing quantities are provided:

VA Mov Average: A-phase RMS average voltage

VB Mov Average: B-phase RMS average voltage

VC Mov Average: C-phase RMS average voltage

V0 Mov Average: Zero Sequence average voltage magnitude

V1 Mov Average: Positive Sequence average voltage magnitude

V2 Mov Average: Negative Sequence average voltage magnitude

8.1   MOVING AVERAGE UNDERVOLTAGE LOGIC
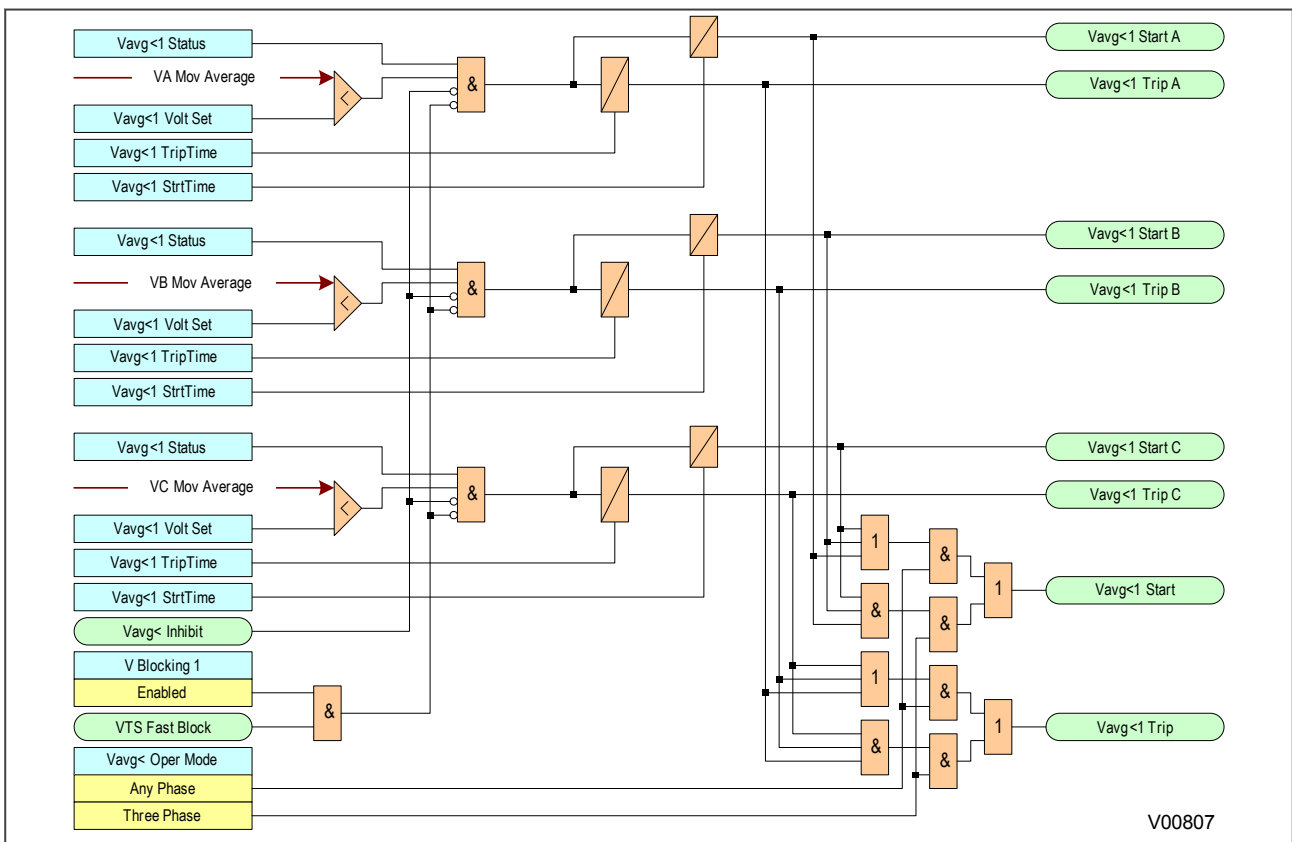
Figure 106: Moving Average undervoltage logic

8.2   MOVING AVERAGE OVERVOLTAGE LOGIC
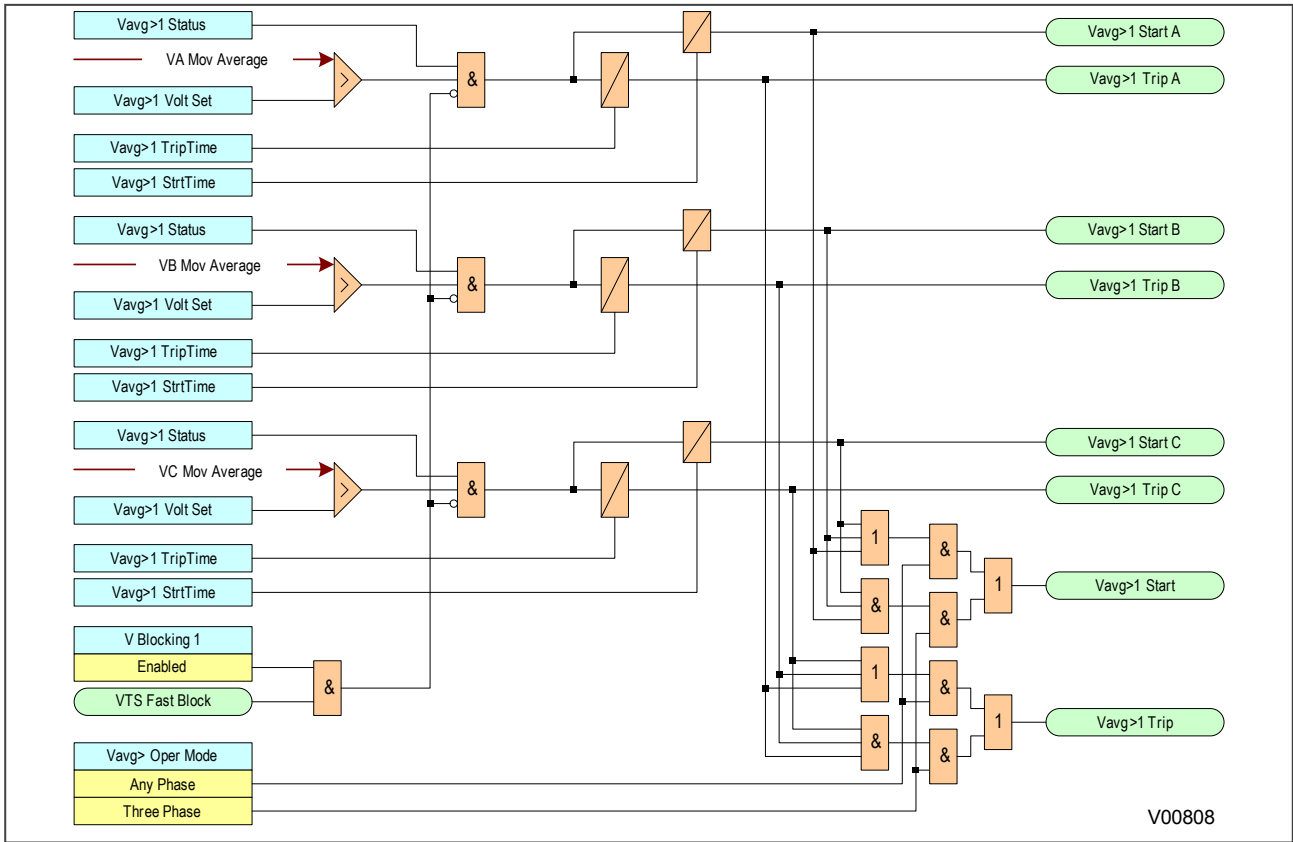
Figure 107: Moving Average overvoltage logic

8.3   MOVING AVERAGE ZERO SEQUENCE VOLTAGE LOGIC
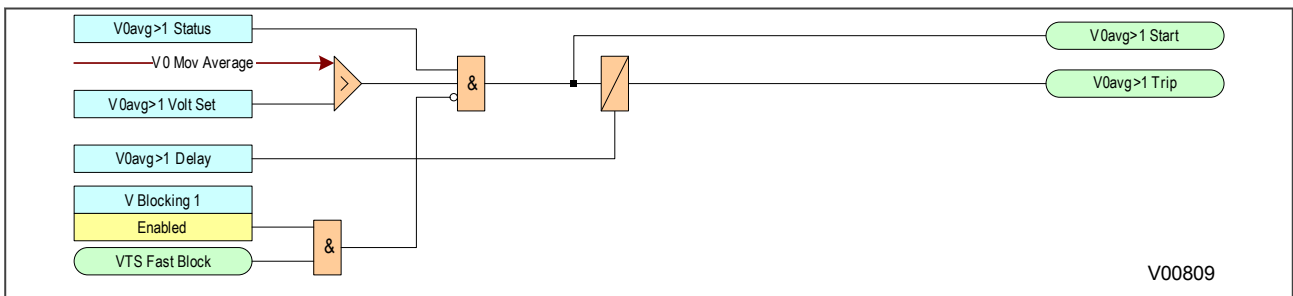
Figure 108: Moving Average zero sequence voltage logic

8.4   MOVING AVERAGE POSITIVE SEQUENCE VOLTAGE LOGIC
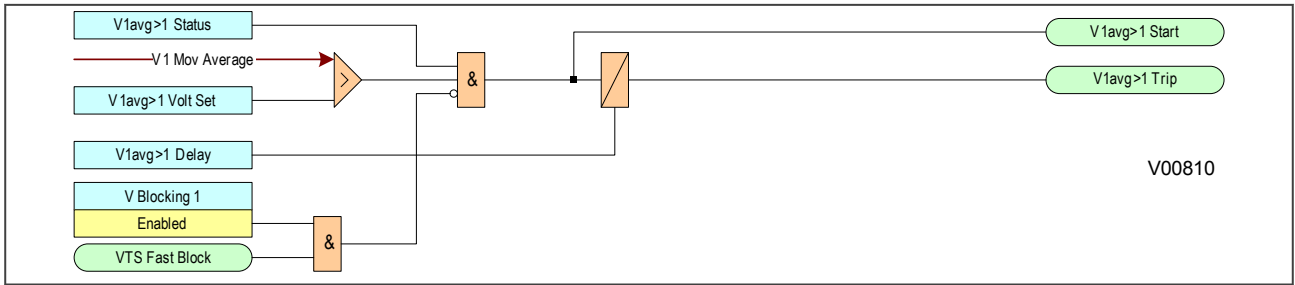
Figure 109: Moving Average positive sequence voltage logic

8.5   MOVING AVERAGE NEGATIVE SEQUENCE VOLTAGE LOGIC
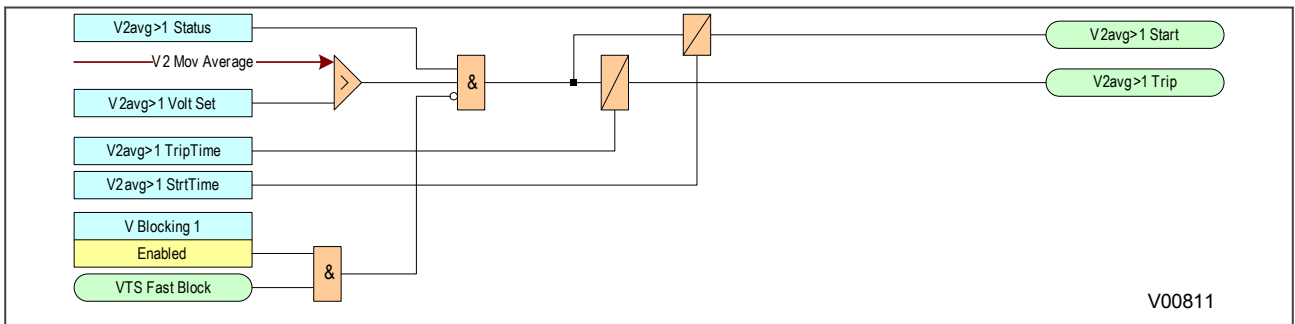
Figure 110: Moving Average negative sequence voltage logic

8.6   MOVING AVERAGE UNDERVOLTAGE BLOCKING PSL

The Moving Average Undervoltage Protection function does not provide internal blocking for Pole Dead conditions. To achieve this you must configure this in PSL as follows:
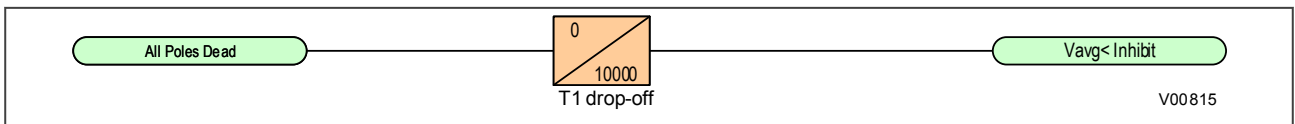
Figure 111: Average Voltage Protection blocking

CHAPTER 11

FREQUENCY PROTECTION FUNCTIONS

1   CHAPTER OVERVIEW

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

This chapter contains the following sections:

2   FREQUENCY PROTECTION OVERVIEW

Power generation and utilisation needs to be well balanced in any industrial, distribution or transmission network. These electrical networks are dynamic entities, with continually varying loads and supplies, which are continually affecting the system frequency. Increased loading reduces the system frequency and generation needs to be increased to maintain the frequency of the supply. Conversely decreased loading increases the system frequency and generation needs to be reduced. Sudden fluctuations in load can cause rapid changes in frequency, which need to be dealt with quickly.

Unless corrective measures are taken at the appropriate time, frequency decay can go beyond the point of no return and cause widespread network collapse, which has dire consequences.

Protection devices capable of detecting low frequency conditions are generally used to disconnect unimportant loads in order to re-establish the generation-to-load balance. However, with such devices, the action is initiated only after the event and this form of corrective action may not be effective enough to cope with sudden load increases that cause large frequency decays in very short times. In such cases a device that can anticipate the severity of frequency decay and act to disconnect loads before the frequency reaches dangerously low levels, are very effective in containing damage. This is called instantaneous rate of change of frequency protection (ROCOF).

During severe disturbances, the frequency of the system oscillates as various generators try to synchronise to a common frequency. The measurement of instantaneous rate of change of frequency can be misleading during such a disturbance. The frequency decay needs to be monitored over a longer period of time to make the correct decision for load shedding. This is called average rate of change of frequency protection.

Normally, generators are rated for a particular band of frequency. Operation outside this band can cause mechanical damage to the turbine blades. Protection against such contingencies is required when frequency does not improve even after load shedding steps have been taken. This type of protection can be used for operator alarms or turbine trips in case of severe frequency decay.

2.1   FREQUENCY PROTECTION IMPLEMENTATION

Frequency Protection is implemented in the *FREQ PROTECTION* column of the relevant settings group.

The device includes 9 stages for the following frequency protection methods:

- Underfrequency Protection: abbreviated to f+t<
- Overfrequency Protection: abbreviated to f+t>
- Independent Rate of Change of Frequency Protection: abbreviated to Independent R.O.C.O.F, or df/dt+t
- Frequency-supervised Rate of Change of Frequency Protection: abbreviated to Frequency-supervised R.O.C.O.F, or f+df/dt
- Average Rate of Change of Frequency Protection: abbreviated to Average R.O.C.O.F, or f+Df/Dt (note the uppercase 'D')
- Load Shedding and Restoration

Each stage can be disabled or enabled with the **Stage (n)** setting. The frequency protection can also be blocked by an undervoltage condition if required.

3   UNDERFREQUENCY PROTECTION

A reduced system frequency implies that the net load is in excess of the available generation. Such a condition can arise, when an interconnected system splits, and the load left connected to one of the subsystems is in excess of the capacity of the generators in that particular subsystem. Industrial plants that are dependent on utilities to supply part of their loads will experience underfrequency conditions when the incoming lines are lost.

Many types of industrial loads have limited tolerances on the operating frequency and running speeds (e.g. synchronous motors). Sustained underfrequency has implications on the stability of the system, whereby any subsequent disturbance may damage equipment and even lead to blackouts. It is therefore essential to provide protection for underfrequency conditions.

3.1   UNDERFREQUENCY PROTECTION IMPLEMENTATION

The following settings are relevant for underfrequency:

- **Stg (n) f+t Status**: determines whether the stage is underfrequency, overfrequency, or disabled
- **Stg (n) f+t Freq**: defines the frequency pickup setting
- **Stg (n) f+t Time**: sets the time delay

3.2   UNDERFREQUENCY PROTECTION LOGIC
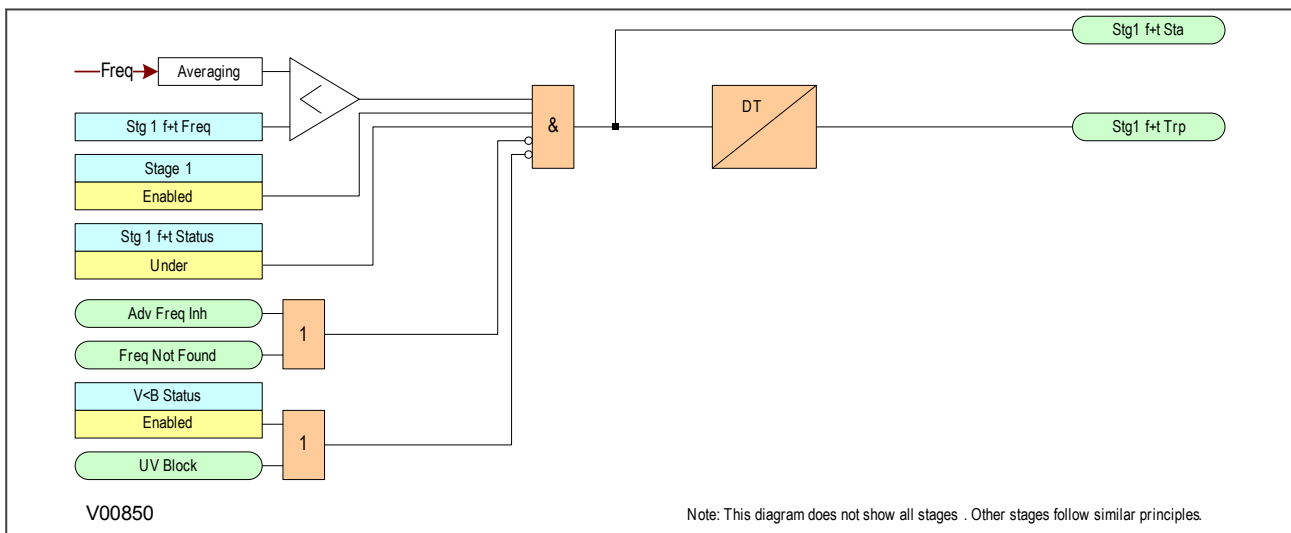
Figure 112: Underfrequency logic (single stage)

If the frequency is below the setting and not blocked the DT timer is started. If the frequency cannot be determined, the function is blocked.

3.3   APPLICATION NOTES

3.3.1   SETTING GUIDELINES

In order to minimise the effects of underfrequency, a multi-stage load shedding scheme may be used with the plant loads prioritised and grouped. During an underfrequency condition, the load groups are disconnected sequentially, with the highest priority group being the last one to be disconnected.

The effectiveness of each load shedding stage depends on the proportion of power deficiency it represents. If the load shedding stage is too small compared with the prevailing generation deficiency, then there may be no improvement in the frequency. This should be taken into account when forming the load groups.

Time delays should be sufficient to override any transient dips in frequency, as well as to provide time for the frequency controls in the system to respond. These should not be excessive as this could jeopardize system stability. Time delay settings of 5 - 20 s are typical.

An example of a four-stage load shedding scheme for 50 Hz systems is shown below:

Stage	Element	Frequency Setting (Hz)	Time Setting (Sec)
1	Stage 1(f+t)	49.0	20 s
2	Stage 2(f+t)	48.6	20 s
3	Stage 3(f+t)	48.2	10 s
4	Stage 4(f+t)	47.8	10 s

The relatively long time delays are intended to provide sufficient time for the system controls to respond. This will work well in a situation where the decline of system frequency is slow. For situations where rapid decline of frequency is expected, this load shedding scheme should be supplemented by rate of change of frequency protection elements.

4   OVERFREQUENCY PROTECTION

An increased system frequency arises when the mechanical power input to a generator exceeds the electrical power output. This could happen, for instance, when there is a sudden loss of load due to tripping of an outgoing feeder from the plant to a load centre. Under such conditions, the governor would normally respond quickly to obtain a balance between the mechanical input and electrical output, thereby restoring normal frequency. Overfrequency protection is required as a backup to cater for cases where the reaction of the control equipment is too slow.

4.1   OVERFREQUENCY PROTECTION IMPLEMENTATION

The following settings are relevant for overfrequency:

- *Stg (n) f+t Status*: determines whether the stage is underfrequency, overfrequency, or disabled
- *Stg (n) f+t Freq*: defines the frequency pickup setting
- *Stg (n) f+t Time*: sets the time delay

4.2   OVERFREQUENCY PROTECTION LOGIC
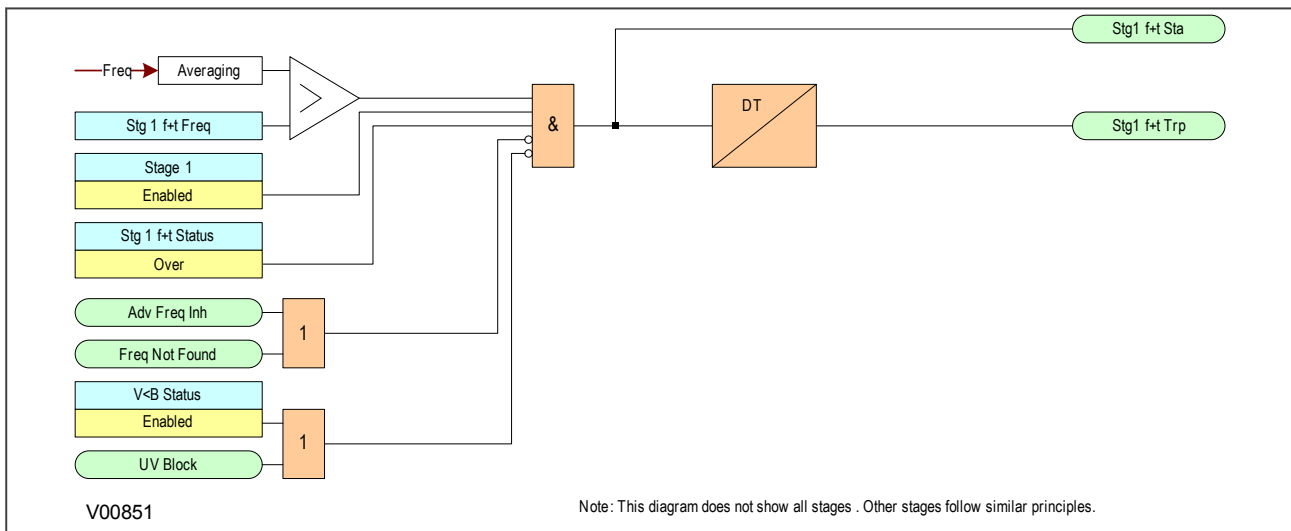
Figure 113: Overfrequency logic (single stage)

If the frequency is above the setting and not blocked, the DT timer is started and after this has timed out, the trip is produced. If the frequency cannot be determined, the function is blocked.

4.3   APPLICATION NOTES

4.3.1   SETTING GUIDELINES

Following changes on the network caused by faults or other operational requirements, it is possible that various subsystems will be formed within the power network. It is likely that these subsystems will suffer from a generation/load imbalance. The "islands" where generation exceeds the existing load will be subject to overfrequency conditions. Severe over frequency conditions may be unacceptable to many industrial loads, since running speeds of motors will be affected. The overfrequency element can be suitably set to sense this contingency.

An example of two-stage overfrequency protection is shown below using stages 5 and 6 of the f+t elements. However, settings for a real system will depend on the maximum frequency that equipment can tolerate for a given period of time.

Stage	Element	Frequency Setting (Hz)	Time Setting (Sec.)
1	Stage 5(f+t)	50.5	30
2	Stage 6(f+t)	51.0	20

The relatively long time delays are intended to provide time for the system controls to respond and will work well in a situation where the increase of system frequency is slow.

For situations where rapid increase of frequency is expected, the protection scheme above could be supplemented by rate of change of frequency protection elements.

In the system shown below, the generation in the MV bus is sized according to the loads on that bus, whereas the generators linked to the HV bus produce energy for export to utility. If the links to the grid are lost, the generation will cause the system frequency to rise. This rate of rise could be used to isolate the MV bus from the HV system.
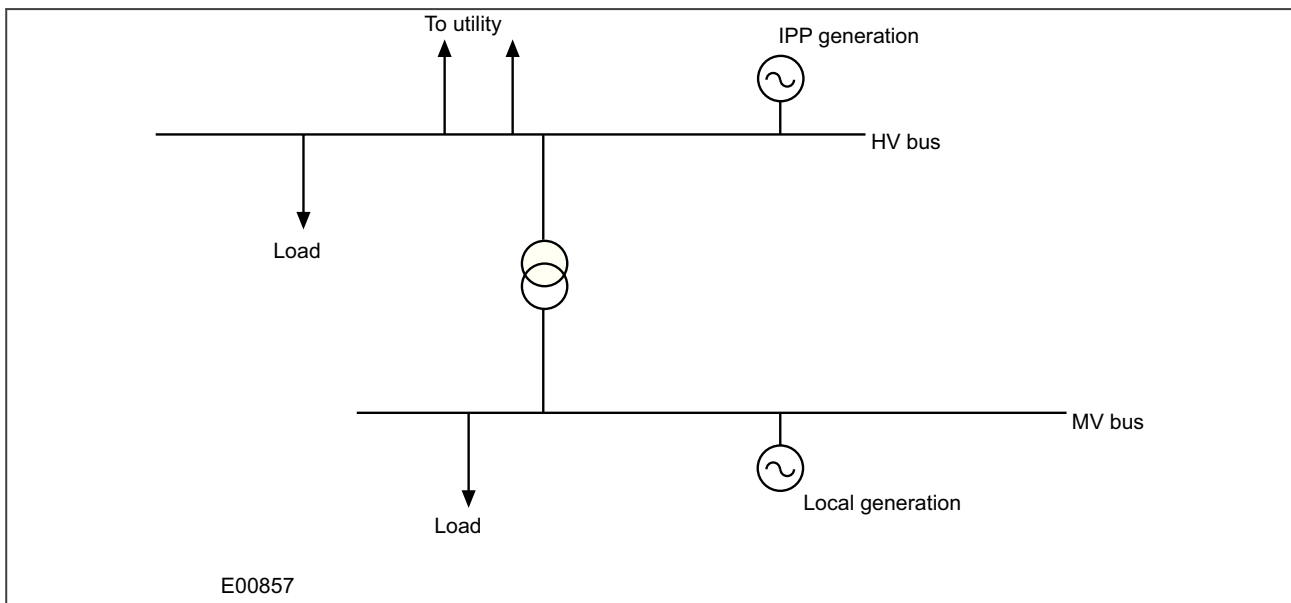
Figure 114: Power system segregation based upon frequency measurements

5   INDEPENDENT R.O.C.O.F PROTECTION

Where there are very large loads, imbalances may occur that result in rapid decline in system frequency. The situation could be so bad that shedding one or two stages of load is unlikely to stop this rapid frequency decline. In such a situation, standard underfrequency protection will normally have to be supplemented with protection that responds to the rate of change of frequency. An element is therefore required which identifies the high rate of decline of frequency, and adapts the load shedding scheme accordingly.

Such protection can identify frequency variations occurring close to nominal frequency thereby providing early warning of a developing frequency problem. The element can also be used as an alarm to warn operators of unusually high system frequency variations.

5.1   INDEPENENT R.O.C.O.F PROTECTION IMPLEMENTATION

The device provides nine independent stages of protection. Each stage can respond to either rising or falling frequency conditions. This depends on whether the frequency threshold is set above or below the system nominal frequency. For example, if the frequency threshold is set above nominal frequency, the rate of change of frequency setting is considered as positive and the element will operate for rising frequency conditions. If the frequency threshold is set below nominal frequency, the setting is considered as negative and the element will operate for falling frequency conditions.

The following settings are relevant for df/dt+t protection:

- **df/dt+t (n) Status**: determines whether the stage is for falling or rising frequency conditions
- **df/dt+t (n) Set**: defines the rate of change of frequency pickup setting
- **df/dt+t (n) Time**: sets the time delay

5.2   INDEPENDENT R.O.C.O.F PROTECTION LOGIC
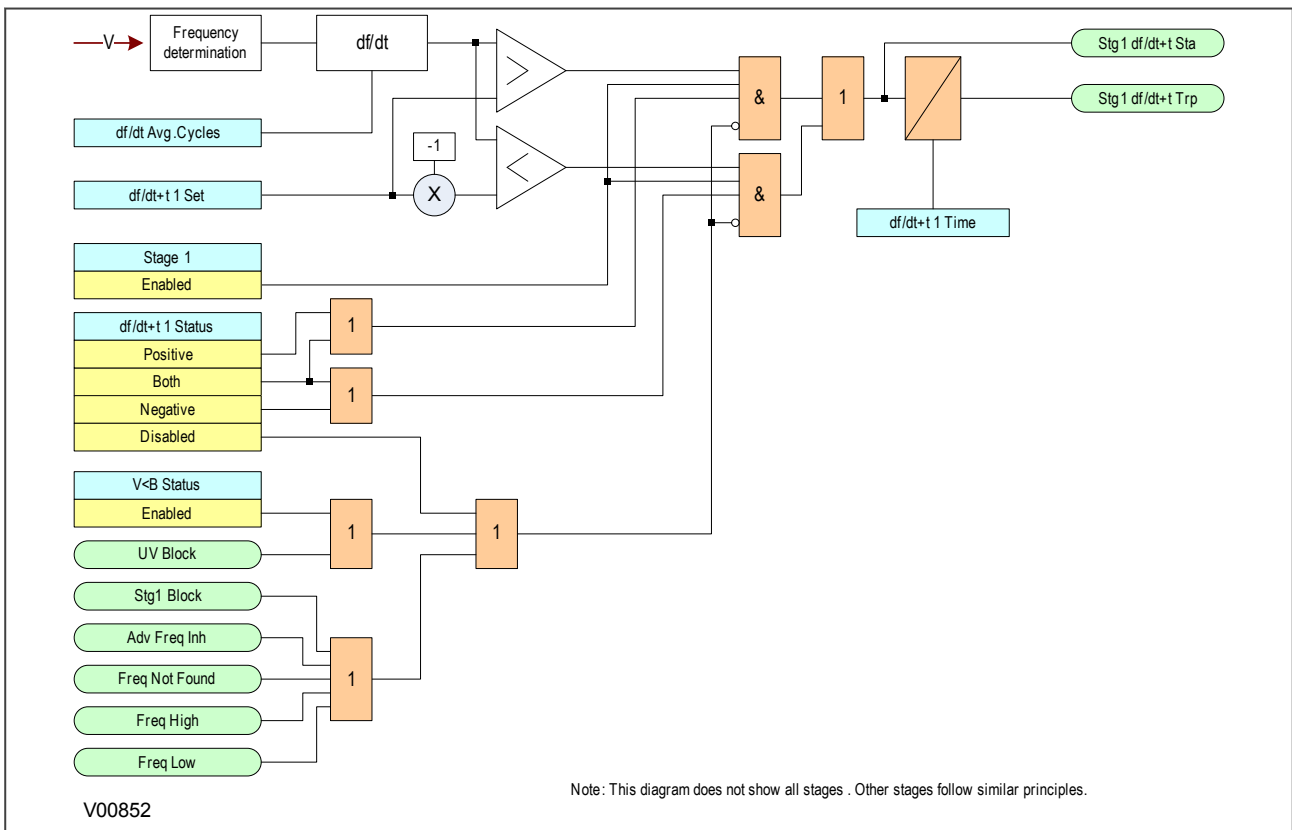
Figure 115: Independent rate of change of frequency logic (single stage)

5.3   APPLICATION NOTES

5.3.1   SETTING GUIDELINES

Considerable care should be taken when setting this element because it is not supervised by a frequency setting. Setting of the time delay or increasing the number of df/dt averaging cycles will improve stability but this is traded against reduced tripping times.

It is likely that this element would be used in conjunction with other frequency based protection elements to provide a scheme that accounts for severe frequency fluctuations. An example scheme is shown below:

Stage	Frequency "f+t [81U/81O]" Elements		Frequency Supervised Rate of Change of Frequency "f+df/dt [81RF]" Elements	
	Frequency Setting (Hz)	Time Setting (Sec.)	Frequency Setting (Hz)	Rate of Change of Frequency Setting (Hz/Sec.)
1	49	20	49.2	1.0
2	48.6	20	48.8	1.0
3	48.2	10	48.4	1.0
4	47.8	10	48.0	1.0
5	-	-	-	-

Stage	Rate of Change of Frequency "df/dt+t [81R]" Elements	
	Rate of Change of Frequency Setting (Hz/Sec.)	Time Setting (Sec.)
1	-	-
2	-	-
3	-3.0	0.5
4	-3.0	0.5
5	-3.0	0.1

In this scheme, tripping of the last two stages is accelerated by using the independent rate of change of frequency element. If the frequency starts falling at a high rate (> 3 Hz/s in this example), then stages 3 & 4 are shed at around 48.5 Hz, with the objective of improving system stability. Stage 5 serves as an alarm and gives operators advance warning that the situation is critical.

6   FREQUENCY-SUPERVISED R.O.C.O.F PROTECTION

Frequency-supervised Rate of Change of Frequency protection works in a similar way to Independent Rate of change of Frequency Protection. The only difference is that with frequency supervision, the actual frequency itself is monitored and the protection operates when both the rate of change of frequency AND the frequency itself go outside the set limits.

Frequency-supervised Rate of Change of Frequency protection is also known as f+df/dt protection.

6.1   FREQUENCY-SUPERVISED R.O.C.O.F IMPLEMENTATION

The device provides nine independent stages of protection. Each stage can respond to either rising or falling frequency conditions. This depends on whether the frequency threshold is set above or below the system nominal frequency. For example, if the frequency threshold is set above nominal frequency, the rate of change of frequency setting is considered as positive and the element will operate for rising frequency conditions. If the frequency threshold is set below nominal frequency, the setting is considered as negative and the element will operate for falling frequency conditions.

The following settings are relevant for f+ df/dt protection:

- *f+df/dt 1 Status*: determines whether the stage is for falling or rising frequency conditions
- *f+df/dt 1 freq*: defines the frequency pickup setting
- *f+df/dt 1 df/dt*: defines the rate of change of frequency pickup setting

The device will also indicate when an incorrect setting has been applied if the frequency threshold is set to the nominal system frequency. There is no intentional time delay associated with this element, but time delays could be applied using the PSL if required.

6.2   FREQUENCY-SUPERVISED R.O.C.O.F LOGIC
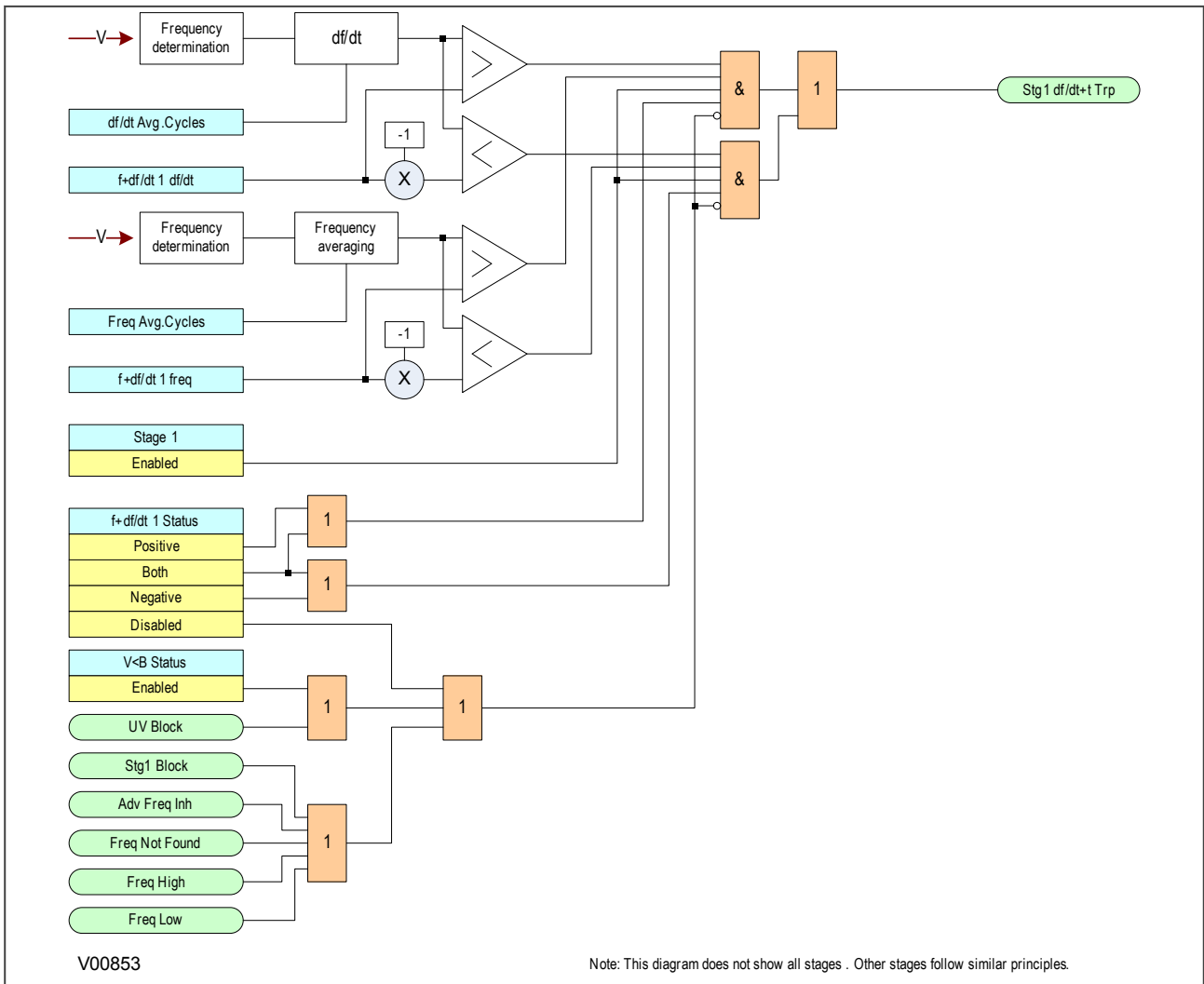
Figure 116: Frequency-supervised rate of change of frequency logic (single stage)

6.3   APPLICATION NOTES

6.3.1   FREQUENCY-SUPERVISED R.O.C.O.F EXAMPLE

In the load shedding scheme below, we assume that for falling frequency conditions, the system can be stabilised at frequency f2 by shedding a stage of load. For slow rates of decay, this can be achieved using the underfrequency protection element set at frequency f1 with a suitable time delay. However, if the generation deficit is substantial, the frequency will rapidly decrease and it is possible that the time delay imposed by the underfrequency protection will not allow for frequency stabilisation. In this case, the chance of system recovery will be enhanced by disconnecting the load stage based on a measurement of rate of change of frequency and bypassing the time delay.
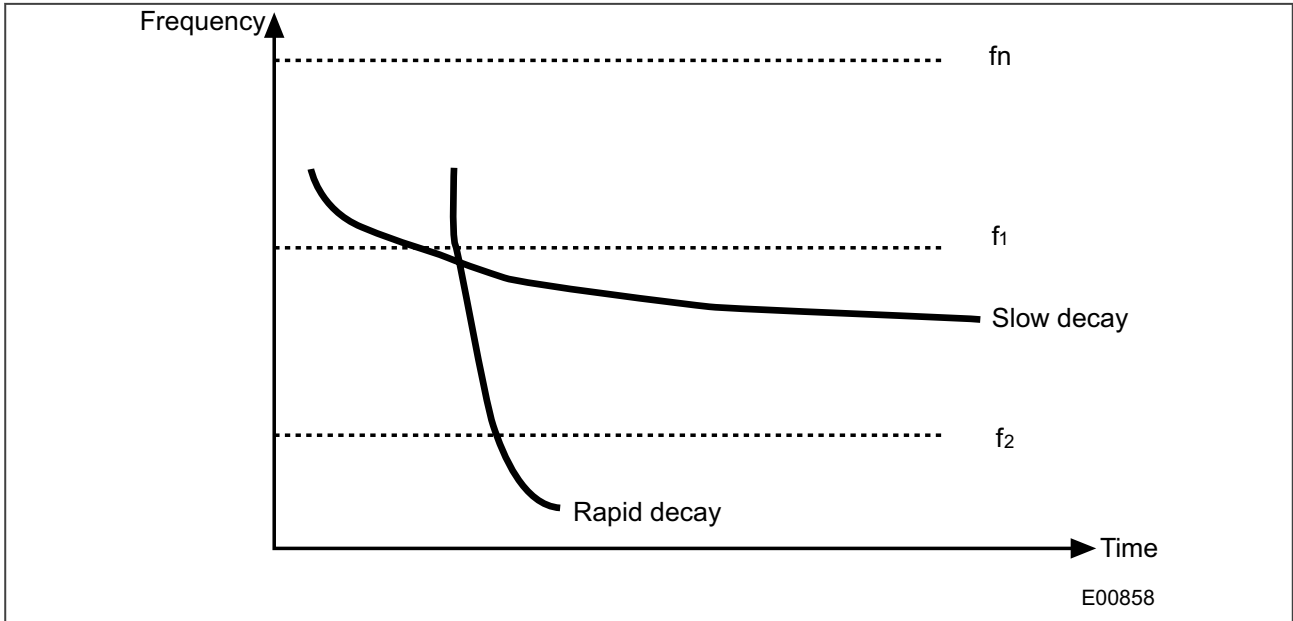
Figure 117: Frequency supervised rate of change of frequency protection

6.3.2   SETTING GUIDELINES

We recommend that the frequency supervised rate of change of frequency protection (f+df/dt) element be used in conjunction with the time delayed frequency protection (f+t) elements.

A four stage high speed load shedding scheme may be configured as indicated below, noting that in each stage, both the "f+t" and the "f+df/dt" elements are enabled.

	Frequency "f+t [81U/81O]" Elements		Frequency Supervised Rate of Change of Frequency "f+df/dt [81RF]" Elements	
Stage	Frequency Setting (Hz)	Time Setting (Sec.)	Frequency Setting (Hz)	Rate of Change of Frequency Setting (Hz/ sec.)
1	49	20	49	1.0
2	48.6	20	48.6	1.0
3	48.2	10	48.2	1.0
4	47.8	10	47.8	1.0

It may be possible to further improve the speed of load shedding by changing the frequency setting on the f+df/dt element. In the settings outlined below, the frequency settings for this element have been set slightly higher than the frequency settings for the f+t element. This difference will allow for the measuring time, and will result in the tripping of the two elements at approximately the same frequency value. Therefore, the slow frequency decline and fast frequency decline scenarios are independently monitored and optimised without sacrificing system security.

	Frequency "f+t [81U/81O]" Elements		Frequency Supervised Rate of Change of Frequency "f+df/dt [81RF]" Elements	
Stage	Frequency Setting (Hz)	Time Setting (Sec.)	Frequency Setting (Hz)	Rate of Change of Frequency Setting (Hz/ sec.)
1	49	20	49.2	1.0
2	48.6	20	48.8	1.0
3	48.2	10	48.4	1.0
4	47.8	10	48.0	1.0

7 AVERAGE RATE OF CHANGE OF FREQUENCY PROTECTION

Owing to the complex dynamics of power systems, variations in frequency during times of generation-to-load imbalance are highly non-linear. Oscillations will occur as the system seeks to address the imbalance, resulting in frequency oscillations typically in the order of 0.1 Hz to 1 Hz, in addition to the basic change in frequency.

The independent and frequency-supervised rate of change of frequency elements use an instantaneous measurement of the rate of change of frequency, based on a 3-cycle, filtered, rolling average technique. Due to the oscillatory nature of frequency excursions, this instantaneous value can sometimes be misleading, either causing unexpected operation or excessive instability. For this reason, the device also provides an element for monitoring the longer term frequency trend, thereby reducing the effects of non-linearity in the system.

Average Rate of Change of Frequency protection is also known as f+Df/Dt protection (note the upper-case "D").

7.1 AVERAGE R.O.C.O.F PROTECTION IMPLEMENTATION

The device provides nine independent stages of average rate of change of frequency protection. Each stage can respond to either rising or falling frequency conditions. This depends on whether the frequency threshold is set above or below the system nominal frequency. For example, if the frequency threshold is set above nominal frequency, the rate of change of frequency setting is considered as positive and the element will operate for rising frequency conditions. If the frequency threshold is set below nominal frequency, the setting is considered as negative and the element will operate for falling frequency conditions.

When the measured frequency crosses the supervising frequency threshold, a timer is initiated. At the end of this time period, the frequency difference is evaluated and if this exceeds the setting, a trip output is given.
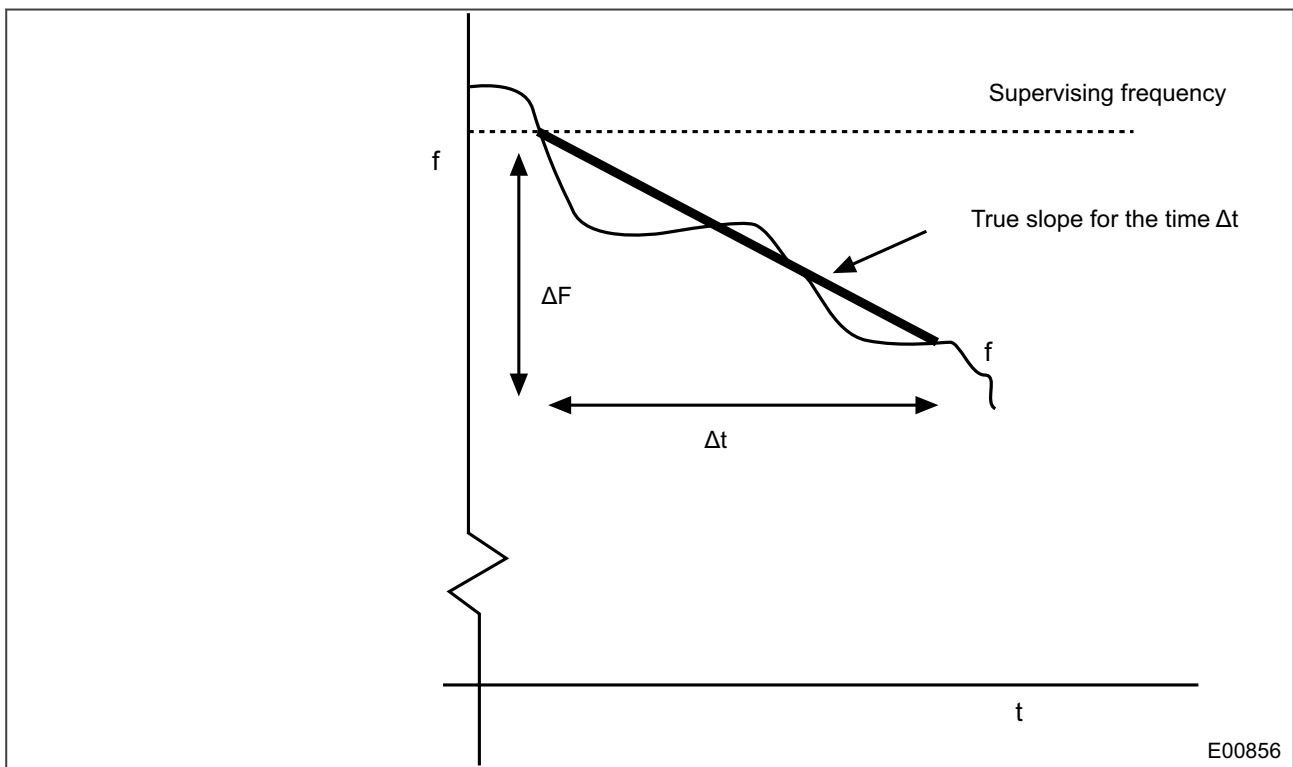
Figure 118: Average rate of change of frequency characteristic

After time Δt, the element is blocked from further operation until the frequency recovers to a value above the supervising frequency threshold. If the element has operated, the trip DDB signal will be ON until the frequency recovers to a value above the supervising frequency threshold.

The average rate of change of frequency is then measured based on the frequency difference, Δf over the settable time period, Δt.

The following settings are relevant for Df/Dt protection:

- *f+Df/Dt (n) Status*: determines whether the stage is for falling or rising frequency conditions
- *f+Df/Dt (n) Freq*: defines the frequency pickup setting
- *f+Df/Dt (n) Dfreq*: defines the change in frequency that must be measured in a set time period
- *f+Df/Dt (n) Dtime*: sets the time period over which the frequency is monitiored

7.2   AVERAGE R.O.C.O.F LOGIC

V00859

Note: This diagram does not show all stages . Other stages follow similar principles.
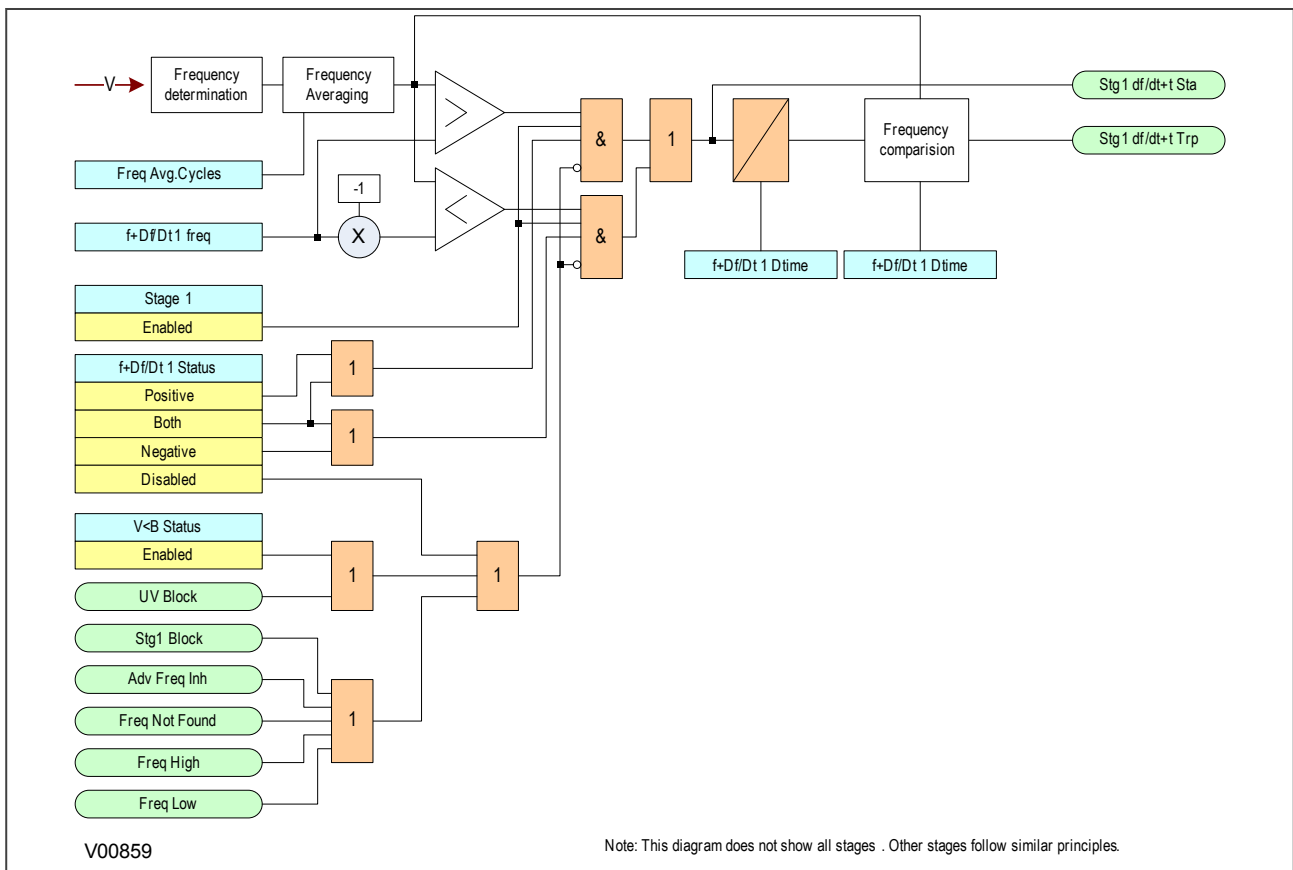
Figure 119: Average rate of change of frequency logic (single stage)

7.3   APPLICATION NOTES

7.3.1   SETTING GUIDELINES

The average rate of change of frequency element can be set to measure the rate of change over a short period as low as 20 ms (1 cycle @ 50 Hz) or a relatively long period up to 2 s (100 cycles @ 50 Hz). With a time setting, Dt, towards the lower end of this range, the element becomes similar to the frequency supervised rate of change function, "f+df/dt". With high Dt settings, the element acts as a frequency trend monitor.

Although the element has a wide range of setting possibilities we recommend that the Dt setting is set greater than 100 ms to ensure the accuracy of the element.

A possible four stage load shedding scheme using the average rate of change frequency element is shown in the following table:

Stage	Frequency "f+t [81U/81O]" Elements		Average Rate of Change of Frequency "f+Df/Dt [81RAV]" Elements		
	(f+t) f Frequency Setting (Hz)	(f+t) t Time Setting (Sec.)	(f+Df/Dt) f Frequency Setting (Hz)	(f+Df/Dt) Df Frequency Diff Setting, (Hz)	(f+Df/Dt) Dt Time Period, (Sec.)
1	49	20	49	0.5	0.5
2	48.6	20	48.6	0.5	0.5
3	48.2	10	48.2	0.5	0.5
4	47.8	10	47.8	0.5	0.5

In the above scheme, the faster load shed decisions are made by monitoring the frequency change over 500 ms. Therefore tripping takes place more slowly than in schemes employing frequency-supervised df/dt, but the difference is not very much at this setting. If the delay jeopardises system stability, then the scheme can be improved by increasing the independent "f" setting. Depending on how much this value is increased, the frequency at which the "f+Df/Dt" element will trip also increases and so reduces the time delay under more severe frequency fluctuations. For example, with the settings shown below, the first stage of load shedding would be tripped approximately 300 msecs after 49.0 Hz is reached and at a frequency of approximately 48.7 Hz.

Stage	Frequency "f+t [81U/81O]" Elements		Average Rate of Change of Frequency "f+Df/Dt [81RAV]" Elements		
	(f+t) f Frequency Setting (Hz)	(f+t) t Time Setting (Sec)	(f+Df/Dt) f Frequency Setting (Hz)	(f+Df/Dt) Df Frequency Diff Setting (Hz)	(f+Df/Dt) Dt Time Period, (Sec.)
1	49	20	49.2	0.5	0.5 s
2	48.6	20	48.8	0.5	0.5 s
3	48.2	10	48.4	0.5	0.5 s
4	47.8	10	48.0	0.5	0.5 s

CHAPTER 12

POWER PROTECTION FUNCTIONS

1   CHAPTER OVERVIEW

Reverse power protection is used to detect the inverse flow of energy and to ensure that the motor does not feed the fault which has appeared on the network.

This chapter contains the following sections:

2   REVERSE POWER PROTECTION

When a power supply failure occurs on the feeder, synchronous motors become generators due to the inertia of their load and induction motors become generators.

The aim of the reverse power protection is to detect the inverse flow of energy and to ensure that the motor does not feed the fault which has appeared on the network.

The Reverse Power protection in the P24DM has a single reverse power threshold Rev P< Power Set. If this setting is reached, the reverse power protection trips in a time equal to the time delay setting Rev P< Time Delay. A drop-off time, Rev P< Drop-of Ti during the motor start time can be used to avoid tripping orders during starts.

Trip Rev. Power indicates the trip of the reverse power protection. This signal is used to operate the output relays and trigger the disturbance recorder as programmed into the programmable Scheme Logic (PSL). The state of the DDB signals can also be programmed to be viewed in *COMMISSION TESTS* > ***Monitor Bit x***.

This feature is only enabled when the circuit breaker is closed, therefore it requires a 52a circuit breaker auxiliary contact mapped to an opto input to obtain the CB closed / CB open information.

2.1   REVERSE POWER IMPLEMENTATION

Reverse power Protection is implemented in the *POWER PROTECTION* column of the relevant settings group, under the sub-heading *REVERSE POWER*.

The reverse power protection element provides 1 stage of directional reverse power.

The Start and Trip timer resets if the power falls below the drop-off level or if an inhibit condition occurs. The reset mechanism is similar to the overcurrent functionality for a pecking fault condition, where the percentage of elapsed time for the operate timer is memorised for a set reset time delay. If the Start condition returns before the reset timer has timed out, the operate time initialises from the memorised travel value. Otherwise the memorised value is reset to zero after the reset time times out.

CHAPTER 13

MONITORING AND CONTROL

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

General Electric devices record 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. Each event is time tagged.

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.

The event records are detailed 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 menu database.

Field in Event Viewer	Equivalent cell in menu 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

The device is capable of storing up to 2048 event records.

In addition to the event log, there are two additional logs which contain duplicates of the last 10 maintenance records and the last 10 fault records. The purpose of this is to provide convenient access to the most recent fault and maintenance events.

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

> *Note:*
> *The first event in the list (event 0) is the most recent event to have occurred.*

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 (which runs at several times per cycle), 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 opto-inputs and '2' for the second batch of 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 Least Significant Bit (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 (which runs at several times per cycle), 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 output contacts and '2' for the second batch of 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.

Alarm Status 1

Bit No.	Bit Mask 2nd register, 1st register	Alarm Description
Bit 0	0x0000, 0x0001	Thermal Lockout
Bit 1	0x0000, 0x0002	Unused
Bit 2	0x0000, 0x0004	SG-opto Invalid ON/OFF
Bit 3	0x0000, 0x0008	Prot'n Disabled ON/OFF
Bit 4	0x0000, 0x0010	F out of Range ON/OFF
Bit 5	0x0000, 0x0020	VT Fail Alarm ON/OFF
Bit 6	0x0000, 0x0040	CT Fail Alarm ON/OFF
Bit 7	0x0000, 0x0080	CB Fail Alarm ON/OFF
Bit 8	0x0000, 0x0100	I^ Maint Alarm ON/OFF
Bit 9	0x0000, 0x0200	I^ Lockout Alarm ON/OFF
Bit 10	0x0000, 0x0400	CB Ops Maint ON/OFF
Bit 11	0x0000, 0x0800	CB Ops Lockout ON/OFF
Bit 12	0x0000, 0x1000	CB Op Time Maint ON/OFF
Bit 13	0x0000, 0x2000	CB Op Time Lock ON/OFF
Bit 14	0x0000, 0x4000	Fault Freq Lock ON/OFF
Bit15	0x0000, 0x8000	CB Status Alarm ON/OFF
Bit 16	0x0001, 0x0000	Man CB Trip Fail ON/OFF
Bit17	0x0002, 0x0000	Man CB Cls Fail ON/OFF
Bit 18	0x0004, 0x0000	Man CB Unhealthy ON/OFF
Bit 19	0x0008, 0x0000	Unused
Bit 20	0x0010, 0x0000	Unused
Bit 21	0x0020, 0x0000	Unused
Bit 22	0x0040, 0x0000	Unused
Bit 23	0x0080, 0x0000	Unused
Bit 24	0x0100, 0x0000	UV Block ON/OFF
Bit 25	0x0200, 0x0000	User Alarm 1 ON/OFF
Bit 26	0x0400, 0x0000	User Alarm 2 ON/OFF
Bit 27	0x0800, 0x0000	User Alarm 3 ON/OFF
Bit 28	0x1000, 0x0000	User Alarm 4 ON/OFF
Bit 29	0x2000, 0x0000	User Alarm 5 ON/OFF
Bit 30	0x4000, 0x0000	User Alarm 6 ON/OFF
Bit 31	0x8000, 0x0000	User Alarm 7 ON/OFF

Alarm Status 2

Bit No.	Bit Mask 2nd register, 1st register	Alarm Description
Bit 1	0x0000, 0x0001	Time Betwe Start (motor protection models only)
Bit 2	0x0000, 0x0002	Hot Start Nb. (motor protection models only)
Bit 3	0x0000, 0x0004	Cold Start Nb. (motor protection models only)

Bit No.	Bit Mask 2nd register, 1st register	Alarm Description
Bit 4	0x0000, 0x0008	Antibkspin Alarm (motor protection models only)
Bit 5	0x0000, 0x0010	User Alarm 8
Bit 6	0x0000, 0x0020	User Alarm 9
Bit 7	0x0000, 0x0040	User Alarm 10
Bit 8	0x0000, 0x0080	User Alarm 11
Bit 9	0x0000, 0x0100	User Alarm 12
Bit 10	0x0000, 0x0200	User Alarm 13
Bit 11	0x0000, 0x0400	User Alarm 14
Bit 12	0x0000, 0x0800	User Alarm 15
Bit 13	0x0000, 0x1000	User Alarm 16
Bit 14	0x0000, 0x2000	User Alarm 17
Bit 15	0x0000, 0x4000	User Alarm 18
Bit 16	0x0000, 0x8000	User Alarm 19
Bit 17	0x0001, 0x0000	User Alarm 20
Bit 18	0x0002, 0x0000	User Alarm 21
Bit 19	0x0004, 0x0000	User Alarm 22
Bit 20	0x0008, 0x0000	User Alarm 23
Bit 21	0x0010, 0x0000	User Alarm 24
Bit 22	0x0020, 0x0000	User Alarm 25
Bit 23	0x0040, 0x0000	User Alarm 26
Bit 24	0x0080, 0x0000	User Alarm 27
Bit 25	0x0100, 0x0000	User Alarm 28
Bit 26	0x0200, 0x0000	User Alarm 29
Bit 27	0x0400, 0x0000	User Alarm 30
Bit 28	0x0800, 0x0000	User Alarm 31
Bit 29	0x1000, 0x0000	User Alarm 32
Bit 30	0x2000, 0x0000	MR User Alarm 33
Bit 31	0x4000, 0x0000	MR User Alarm 34
Bit 32	0x8000, 0x0000	MR User Alarm 35

Alarm Status 3

Bit No.	Bit Mask 2nd register, 1st register	Alarm Description
Bit 1	0x00000001	DC Supply Fail
Bit 2	0x00000002	Unused
Bit 3	0x00000004	Unused
Bit 4	0x00000008	GOOSE IED Absent
Bit 5	0x00000010	NIC Not Fitted
Bit 6	0x00000020	NIC No Response
Bit 7	0x00000040	NIC Fatal Error

Bit No.	Bit Mask 2nd register, 1st register	Alarm Description
Bit 8	0x00000080	Unused
Bit 9	0x00000100	Bad TCP/IP Cfg.
Bit 10	0x00000200	Unused
Bit 11	0x00000400	NIC Link Fail
Bit 12	0x00000800	NIC SW Mis-Match
Bit 13	0x00001000	IP Addr Conflict
Bit 14	0x00002000	Port A Link Fail
Bit 15	0x00004000	Port B Link Fail
Bit 16	0x00008000	DREB Set.Invalid
Bit 17	0x00010000	Unused
Bit 18	0x00020000	Unused
Bit 19	0x00040000	Bad DNP Settings
Bit 20	0x00080000	Unused
Bit 21	0x00100000	Unused
Bit 22	0x00200000	Unused
Bit 23	0x00400000	Unused
Bit 24	0x00800000	Unused
Bit 25	0x01000000	Unused
Bit 26	0x02000000	Unused
Bit 27	0x04000000	Unused
Bit 28	0x08000000	Unused
Bit 29	0x10000000	Unused
Bit 30	0x20000000	Unused
Bit 31	0x40000000	Unused
Bit 32	0x80000000	Unused

Alarm Status 4

Bit No.	Bit Mask 2nd register, 1st register	Alarm Description
Bit 1	0x00000001	Hour Run Alarm 1
Bit 2	0x00000002	Hour Run Alarm 2
Bit 3	0x00000004	Hour Run Alarm 3
Bit 4	0x00000008	Unused
Bit 17	0x00010000	Unused
Bit 18	0x00020000	Unused
Bit 19	0x00040000	Unused
Bit 20	0x00080000	Unused
Bit 21	0x00100000	Unused
Bit 22	0x00200000	Unused

Bit No.	Bit Mask 2nd register, 1st register	Alarm Description
Bit 23	0x00400000	Unused
Bit 24	0x00800000	Unused
Bit 25	0x01000000	Unused
Bit 26	0x02000000	Unused
Bit 27	0x04000000	Unused
Bit 28	0x08000000	Unused
Bit 29	0x10000000	Unused
Bit 30	0x20000000	Unused
Bit 31	0x40000000	Unused
Bit 32	0x80000000	Unused

User Alarms

Bit No.	Bit Mask 2nd register, 1st register	Alarm Description
Bit 1	0x0000,0x0001	User Alarm 1
Bit 2	0x0000,0x0002	User Alarm 2
Bit 3	0x0000,0x0004	User Alarm 3
Bit 4	0x0000,0x0008	User Alarm 4
Bit 5	0x0000,0x0010	User Alarm 5
Bit 6	0x0000,0x0020	User Alarm 6
Bit 7	0x0000,0x0040	User Alarm 7
Bit 8	0x0000,0x0080	User Alarm 8
Bit 9	0x0000,0x0100	User Alarm 9
Bit 10	0x0000,0x0200	User Alarm 10
Bit 11	0x0000,0x0400	User Alarm 11
Bit 12	0x0000,0x0800	User Alarm 12
Bit 13	0x0000,0x1000	User Alarm 13
Bit 14	0x0000,0x2000	User Alarm 14
Bit 15	0x0000,0x4000	User Alarm 15
Bit 16	0x0000,0x8000	User Alarm 16
Bit 17	0x0001,0x0000	User Alarm 17
Bit 18	0x0002,0x0000	User Alarm 18
Bit 19	0x0004,0x0000	User Alarm 19
Bit 20	0x0008,0x0000	User Alarm 20
Bit 21	0x0010,0x0000	User Alarm 21
Bit 22	0x0020,0x0000	User Alarm 22
Bit 23	0x0040,0x0000	User Alarm 23
Bit 24	0x0080,0x0000	User Alarm 24
Bit 25	0x0100,0x0000	User Alarm 25

Bit No.	Bit Mask 2nd register, 1st register	Alarm Description
Bit 26	0x0200,0x0000	User Alarm 26
Bit 27	0x0400,0x0000	User Alarm 27
Bit 28	0x0800,0x0000	User Alarm 28
Bit 29	0x1000,0x0000	User Alarm 29
Bit 30	0x2000,0x0000	User Alarm 30
Bit 31	0x4000,0x0000	User Alarm 31
Bit 32	0x8000,0x0000	User Alarm 32

> *Note:*
> *User Alarms 1 to 32 are fully settable in the USER ALARMS column:*
> *Alarm texts can be changed via menu*
> *Alarm types can changed via menu (0=Self-reset or 1=Manual reset)*

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:
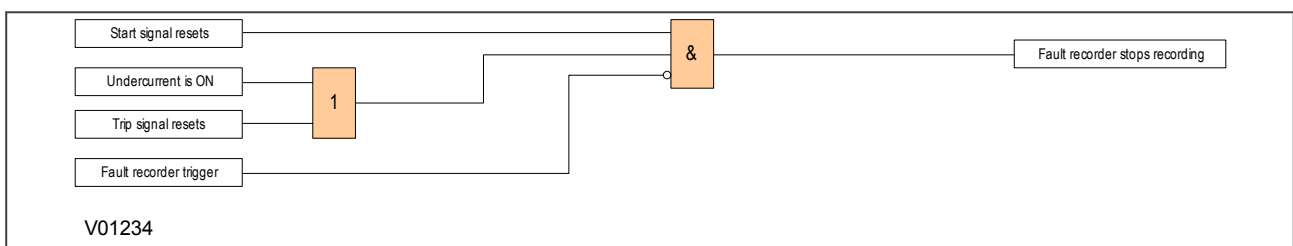
Figure 120: Fault recorder stop conditions

The event is logged as soon as the fault recorder stops. The time stamp assigned to the fault corresponds to the start of the fault. The timestamp assigned to the fault record event corresponds to the time when the fault recorder stops.

> *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   SECURITY EVENTS

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

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

2.1.6   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 **Event Value** cell also provides a unique binary code.

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 menu 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.

2.1.7   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.

2.1.8   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.

3   DISTURBANCE RECORDER

The disturbance recorder feature allows you to record selected current and voltage inputs to the protection elements, together with selected digital signals. The digital signals may be inputs, outputs, or internal DDB signals. 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.

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.

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 relevant MEASUREMENT 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 and calculated analogue current and voltage values
● Power and energy quantities
● Peak, fixed and rolling demand values
● Frequency measurements
● Thermal 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 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.

These measurements are contained in the *MEASUREMENTS 1* column.

4.1.2   MEASURED AND CALCULATED VOLTAGES

The device measures phase-to-phase and phase-to-neutral voltage values. The values are produced by sampling the analogue input quantities, converting them to digital quantities 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.

These measurements are contained in the *MEASUREMENTS 1* column.

4.1.3   POWER AND ENERGY QUANTITIES

Using the measured voltages and currents the device calculates the apparent, real and reactive power quantities. These are produced on a phase by phase basis together with three-phase values based on the sum of the three individual phase values. The signing of the real and reactive power measurements can be controlled using the measurement mode setting. The four options are defined in the following table:

Measurement Mode	Parameter	Signing
0 (Default)	Export Power Import Power Lagging Vars Leading VArs	+ − + −
1	Export Power Import Power Lagging Vars Leading VArs	− + + −
2	Export Power Import Power Lagging Vars Leading VArs	+ − − +

Measurement Mode	Parameter	Signing
3	Export Power Import Power Lagging Vars Leading VArs	– + – +

The device also calculates the per-phase and three-phase power factors.

These power values increment the total real and total reactive energy measurements. Separate energy measurements are maintained for the total exported and imported energy. The energy measurements are incremented up to maximum values of 1000 GWhr or 1000 GVARhr at which point they reset to zero. It is possible to reset these values using the menu or remote interfaces using the Reset demand cell.

These measurements are contained in the *MEASUREMENTS 2* column.

4.1.4   DEMAND VALUES

The device produces fixed, rolling, and peak demand values. You reset these quantities using the **Reset demand** cell.

The fixed demand value is the average value of a quantity over the specified interval. Values are produced for three phase real and reactive power. The fixed demand values displayed are those for the previous interval. The values are updated at the end of the fixed demand period according to the **Fix Dem Period** setting in the *MEASURE'T SETUP* column.

The rolling demand values are similar to the fixed demand values, but a sliding window is used. The rolling demand window consists of a number of smaller sub-periods. The resolution of the sliding window is the sub-period length, with the displayed values being updated at the end of each of the sub-periods according to the **Roll Sub Period** setting in the *MEASURE'T SETUP* column.

Peak demand values are produced for each phase current and the real and reactive power quantities. These display the maximum value of the measured quantity since the last reset of the demand values.

These measurements are contained in the *MEASUREMENTS 2* column.

> *Note:*
> *A **Reset Demand** opto-input DDB signal is available.*

4.1.5   FREQUENCY MEASUREMENTS

The device produces a range of frequency statistics and measurements relating to the Frequency Protection function. These include Check synchronisation and Slip frequency measurements found in the *MEASUREMENTS 1* column, Rate of Change of Frequency measurements found in the *MEASUREMENTS 3* column, and Frequency Protection statistics found in the *FREQUENCY STAT.* column.

The device produces the slip frequency measurement by measuring the rate of change of phase angle between the bus and line voltages, over a one-cycle period. The slip frequency measurement assumes the bus voltage to be the reference phasor.

4.1.6   OTHER MEASUREMENTS

Depending on the model, the device produces a range of other measurements such as thermal 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 and the measurements are shown in the relevant MEASUREMENTS tables.

4.3   OPTO-INPUT 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 multiple opto-inputs change state at the same sampling interval, these state changes are reported as a single event.

5   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. The menu cells 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.*

5.1   APPLICATION NOTES

5.1.1   SETTING THE THRESHOLDS FOR THE TOTAL BROKEN CURRENT

Where power lines use 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.*

5.1.2   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.

5.1.3   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.

5.1.4   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.

6   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

This device can be set to monitor both of these types of circuit breaker state indication. 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 opposite to 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

6.1   CB STATE MONITORING LOGIC
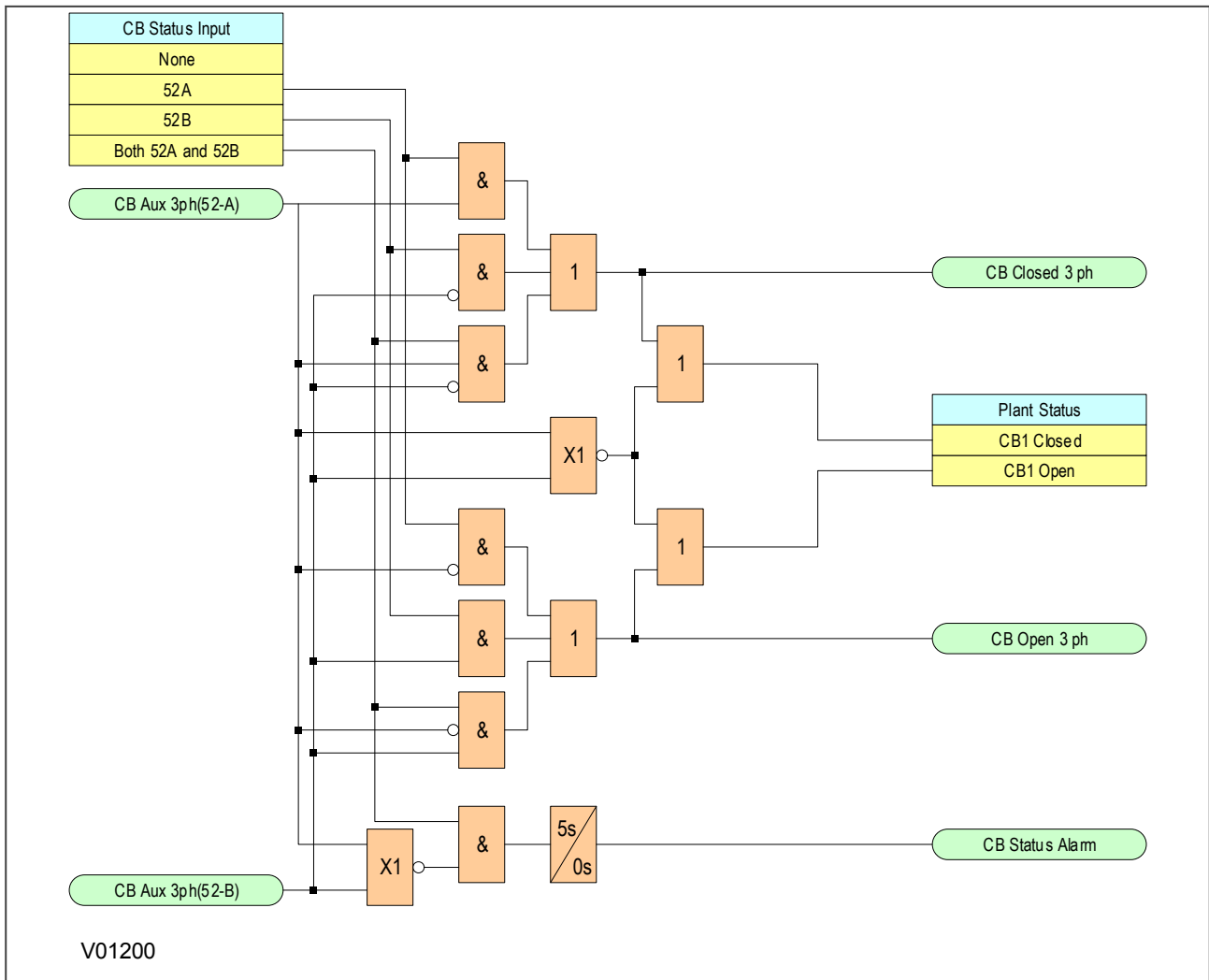
Figure 121: CB State Monitoring logic

7   CIRCUIT BREAKER CONTROL

Although some circuit breakers do not provide auxiliary contacts, most provide auxiliary contacts to reflect the state of the circuit breaker. These are:

- 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 from 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 control close cycle can be cancelled at any time before the output contact operates by any appropriate trip signal, or by activating the **Reset Close Dly** DDB signal.

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) an 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:

- The IED menu (local control)
- The Hotkeys (local control)
- The function keys (local control)
- The opto-inputs (local control)
- SCADA communication (remote control)

7.1   CB 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 3 `Local + Remote`, option 5 `Opto+Local`, or option 7 `Opto+Local+Remote` in the *CB CONTROL* column.

7.2   CB CONTROL USING THE HOTKEYS

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 3 `Local+Remote`, 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 5 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 hotkey functionality is summarised graphically below:
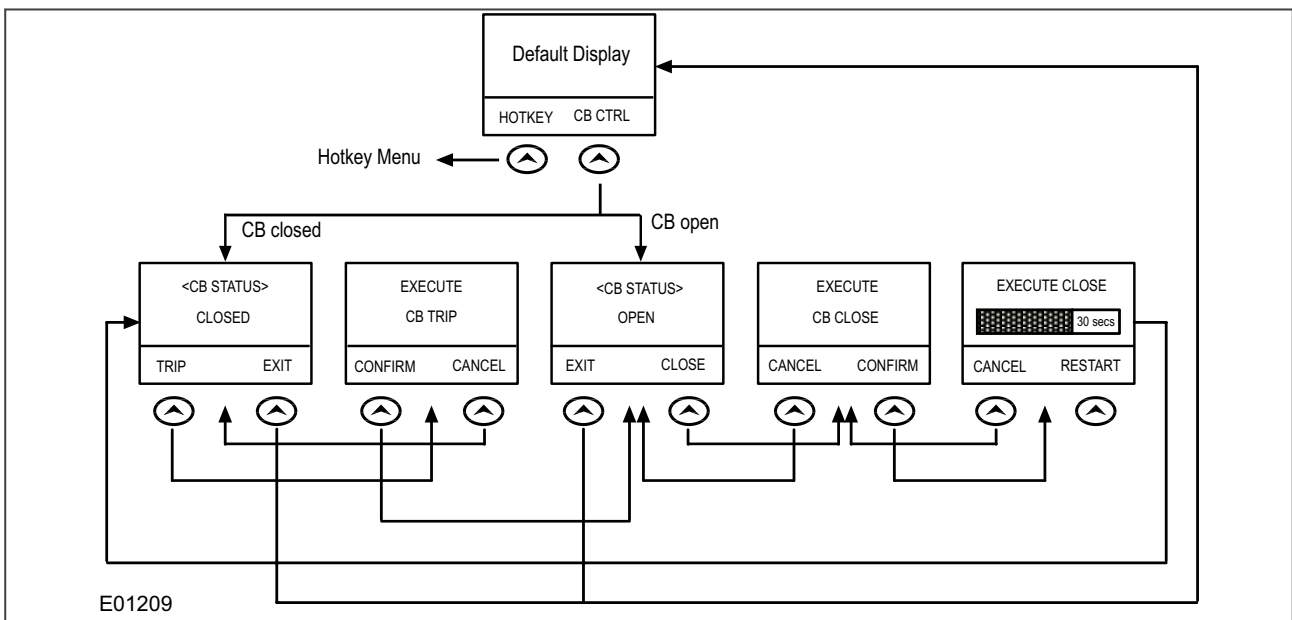
Figure 122: Hotkey menu navigation

7.3   CB CONTROL USING THE FUNCTION KEYS

For most models, 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.

As shown below, function keys 2 and 3 have already been assigned to CB control in the default PSL.
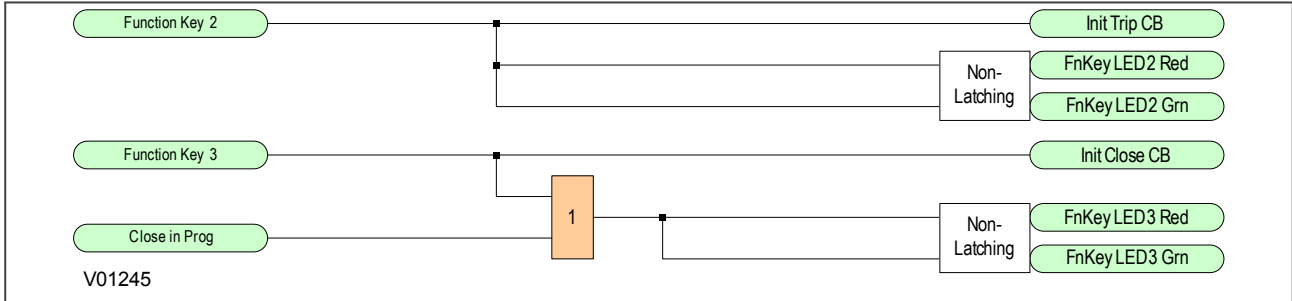
Figure 123: Default function key PSL

The programmable function key LEDs have been mapped such that they will indicate yellow whilst the keys are activated.

Note:
Not all models provide function keys.

7.4   CB 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 4 *opto*, option 5 *Opto+Local*, option 6 *Opto+Remote*, or option 7 *Opto+Local+Remote* in the *CB CONTROL* column.

7.5   REMOTE CB 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 command over a communication link.

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.
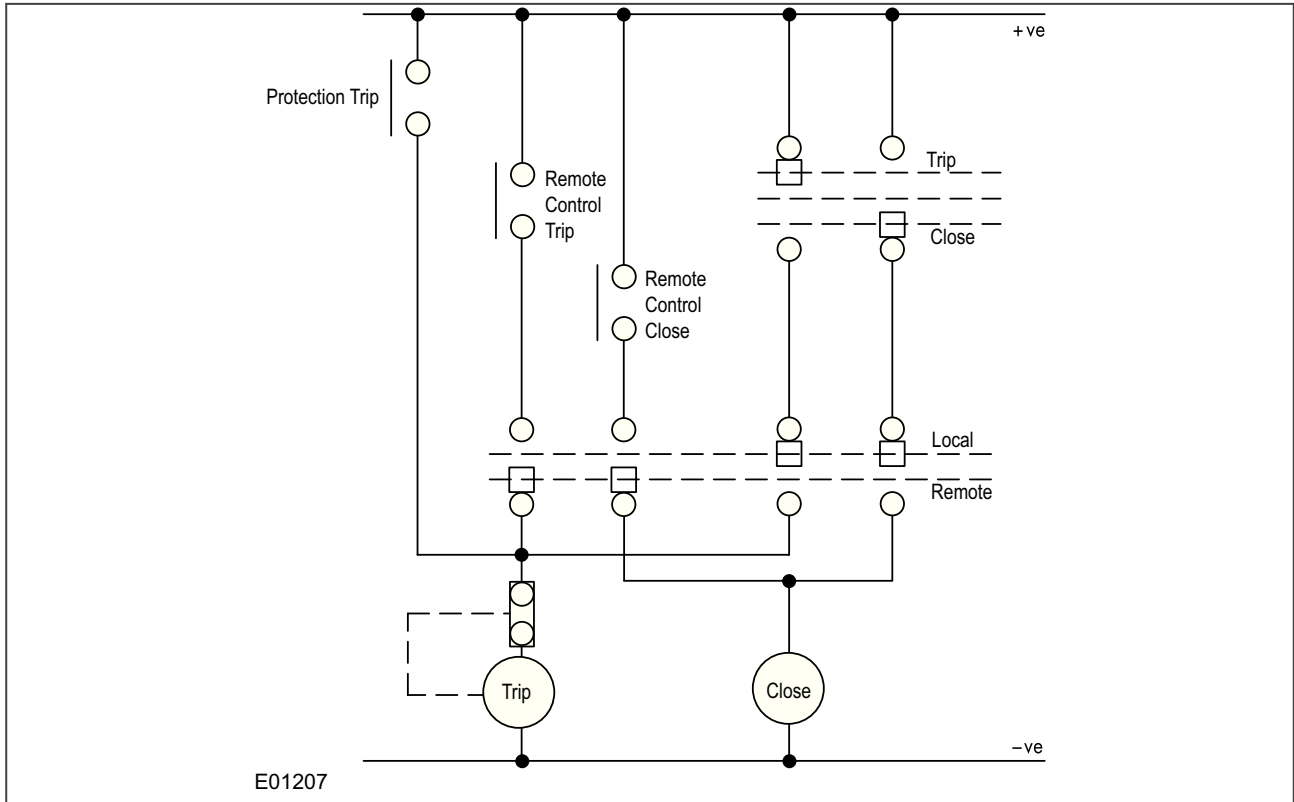
Figure 124: Remote Control of Circuit Breaker

7.6   CB HEALTHY CHECK

A CB Healthy check is 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
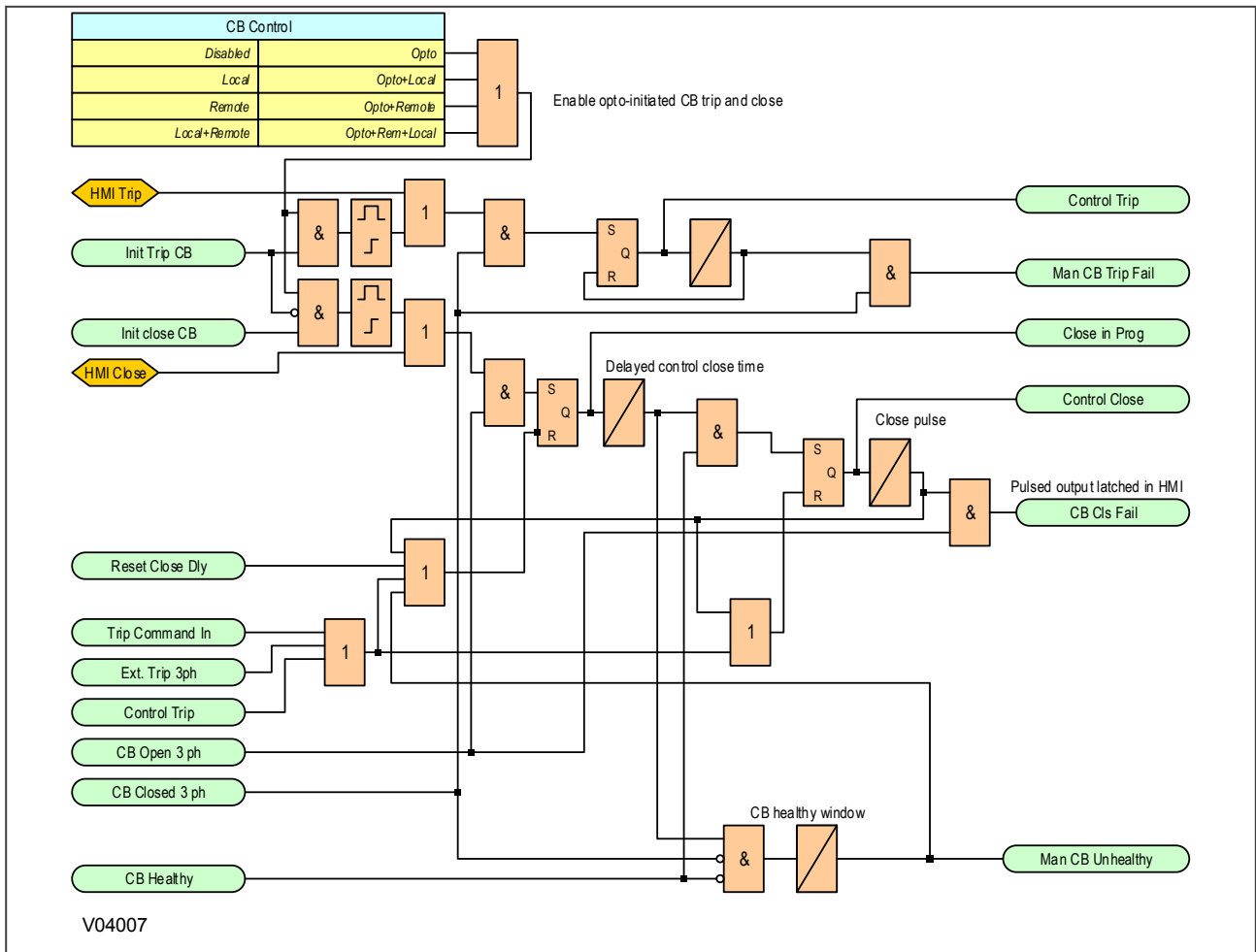
Figure 125: CB Control logic

8   POLE DEAD FUNCTION

The Pole Dead Logic is used to determine and indicate that one or more phases of the line are not energised. A Pole Dead condition is determined either by measuring:

- the line currents and/or voltages, or
- by monitoring the status of the circuit breaker auxiliary contacts, as shown by dedicated DDB signals.

It can also be used to block operation of underfrequency and undervoltage elements where applicable.

8.1   POLE DEAD LOGIC
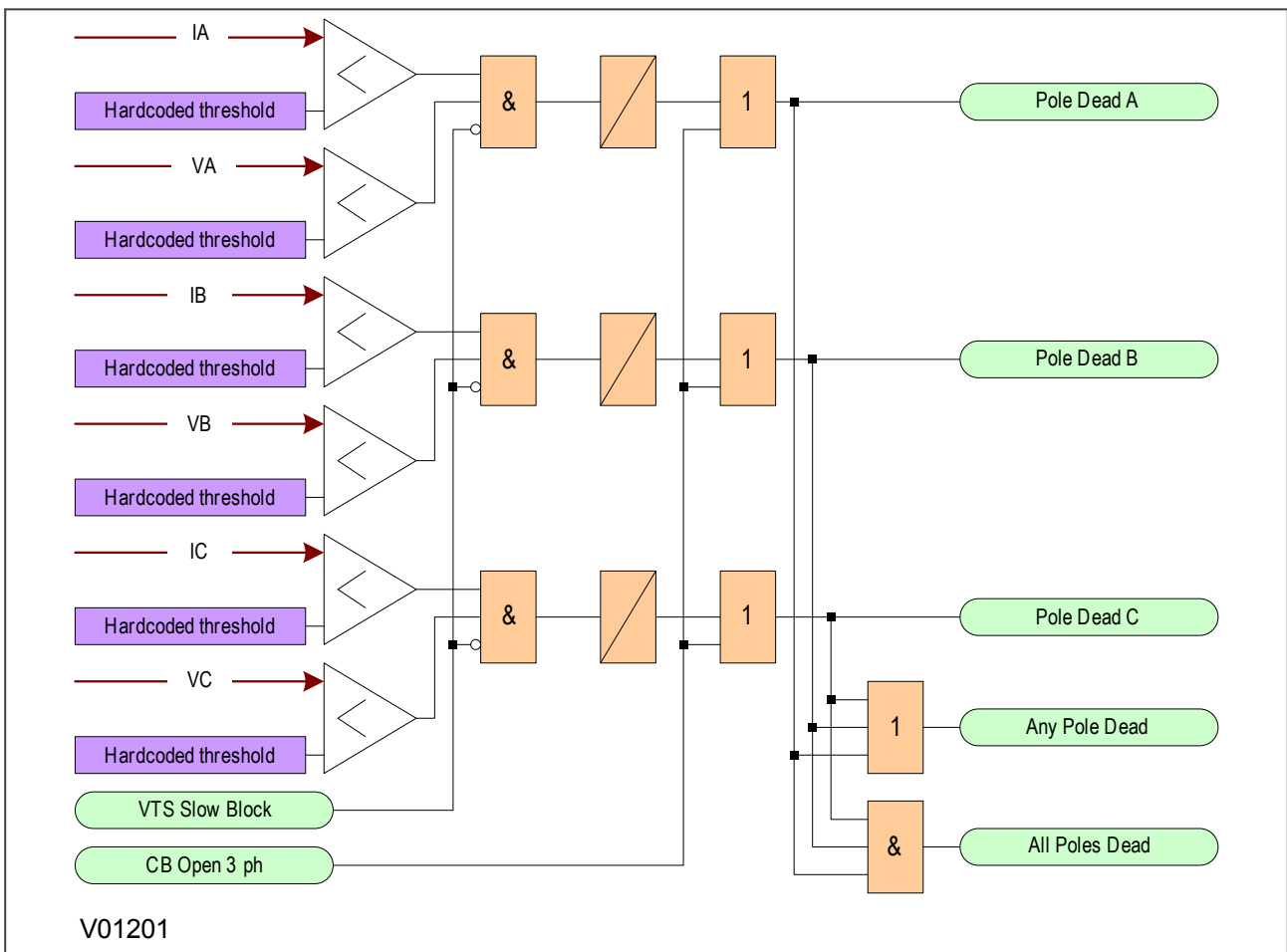
Figure 126: Pole Dead logic

If both the line current and voltage fall below certain thresholds, the device will initiate a Pole Dead condition. The undervoltage (V<) and undercurrent (I<) thresholds are hardcoded internally.

If one or more poles are dead, the device will indicate which phase is dead and will also assert the **Any Pole Dead** DDB signal. If all phases are dead the **Any Pole Dead** signal would be accompanied by the **All Poles Dead** signal.

If a VT fails, a **VTS Slow Block** signal is generated to block the Pole Dead indications that would be generated by the undervoltage and undercurrent thresholds. However, the VTS logic will not block the Pole Dead indications if they are initiated by a **CB Open 3 ph** signal. A **CB Open 3 ph** signal automatically initiates a Pole Dead condition regardless of the current and voltage measurement.

9   SYSTEM CHECKS

In some situations it is necessary to check that the network conditions are suitable for some protection functions (unbalance conditions, blocking conditions). The System Checks functionality involves monitoring the voltages on the source side of a circuit breaker and indicate live line or dead line accordingly.

9.1   SYSTEM CHECKS IMPLEMENTATION

The **System Checks** function is `enabled` or `disabled` by the **System Checks** setting in the *CONFIGURATION* column. If **System Checks** is `disabled`, the **SYSTEM CHECKS** menu becomes invisible, and a **SysChks Inactive** DDB signal is set.

9.1.1   VT CONNECTIONS

The device provides inputs for a three-phase "Main VT" for detecting Live line/dead line condition.

9.1.2   VOLTAGE MONITORING

The settings in the *VOLTAGE MONITORS* sub-heading in the *SYSTEM CHECKS* column allow you to define the threshold at which a voltage is considered live, and a threshold at which the voltage is considered dead. If the measured voltage falls below the **Dead Voltage** setting, a DDB signal is generated (**Dead Line**). If the measured voltage exceeds the **Live Voltage** setting, a DDB signal is generated (**Live Line**).

10   SWITCH STATUS AND CONTROL

All P40 Agile products support Switch Status and Control for up to 8 switchgear elements in an IEC61850 substation. The device is able to monitor the status of and control up to eight switches. The types of switch that can be controlled are:

● Load Break switch

● Disconnector

● Earthing Switch

● High Speed Earthing Switch

Consider the following feeder bay:
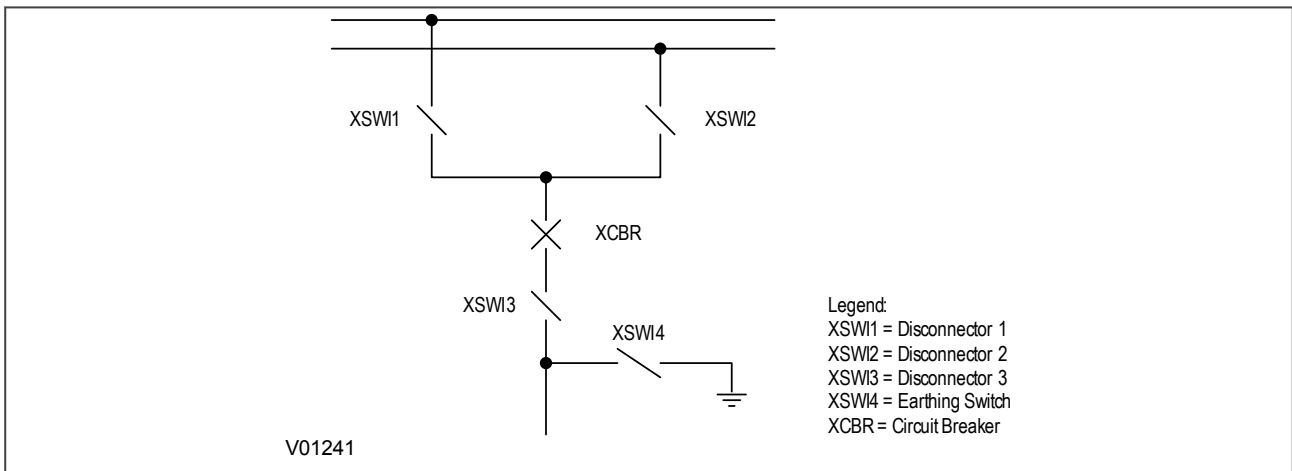
Figure 127: Representation of typical feeder bay

This bay shows four switches of the type LN XSWI and one circuit breaker of type LN XCBR. In this example, the switches XSWI1 – XSWI3 are disconnectors and XCSWI4 is an earthing switch.

For the device to be able to control the switches, the switches must provide auxiliary contacts to indicate the switch status. For convenience, the device settings refer to the auxiliary contacts as 52A and 52B, even though they are not circuit breakers.

There are eight sets of settings in the *SWITCH CONTROL* column, which allow you to set up the Switch control, one set for each switch. These settings are as follows:

SWITCH1 Type

This setting defines the type of switch. It can be a load breaking switch, a disconnector, an earthing switch or a high speed earthing switch.

SWI1 Status Inpt

This setting defines the type of auxiliary contacts that will be used for the control logic. For convenience, the device settings refer to the auxiliary contacts as 52A and 52B, even though they are not circuit breakers. "A" contacts match the status of the primary contacts, whilst "B" contacts are of the opposite polarity.

SWI1 Control by

This setting determines how the switch is to be controlled. This can be Local (using the device directly) remote (using a communications link), or both.

SWI1 Trip/Close

This is a command to directly trip or close the switch.

SWI1 Trp Puls T and SWI1 Cls Puls T

These settings allow you to control the width of the open and close pulses.

SWI1 Sta Alrm T

This setting allows you to define the duration of wait timer before the relay raises a status alarm.

SWI1 Trp Alrm T and SWI1 Cls Alrm T

These settings allow you to control the delay of the open and close alarms when the final switch status is not in line with expected status.

SWI1 Operations

This is a data cell, which displays the number of switch operations that have taken place. It is an accumulator, which you can reset using the **Reset SWI1 Data** setting

Reset SWI1 Data

This setting resets the switch monitoring data.

> *Note:*
> *Settings for switch 1 are shown, but settings for all other switch elements are the same.*

10.1   SWITCH STATUS LOGIC
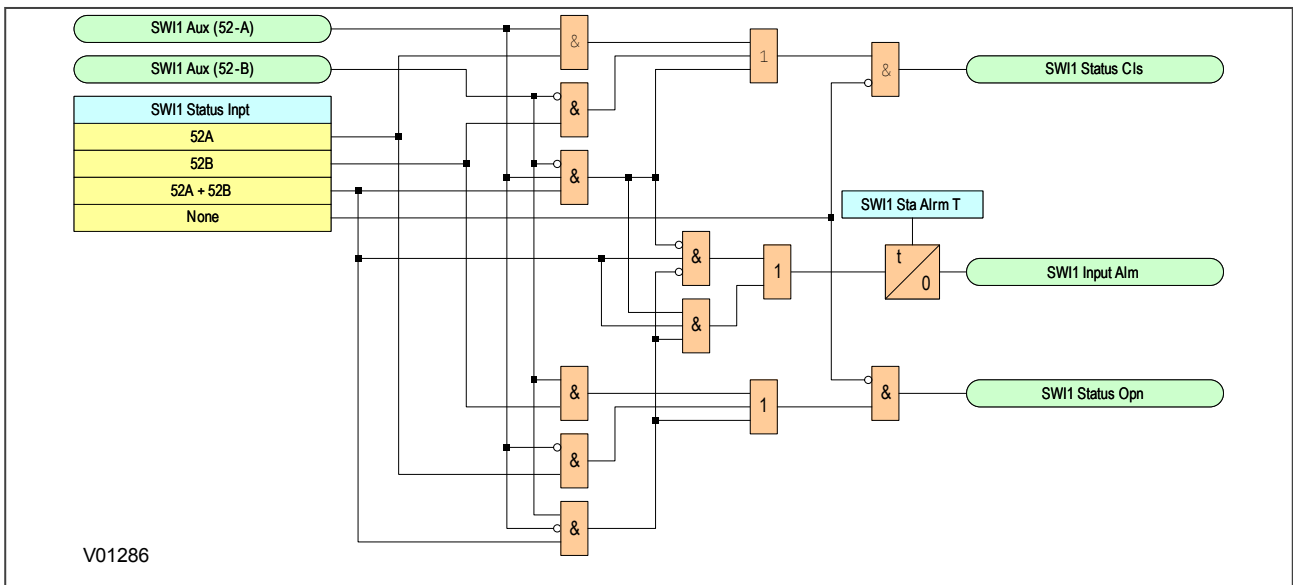
Figure 128: Switch Status logic

10.2   SWITCH CONTROL LOGIC
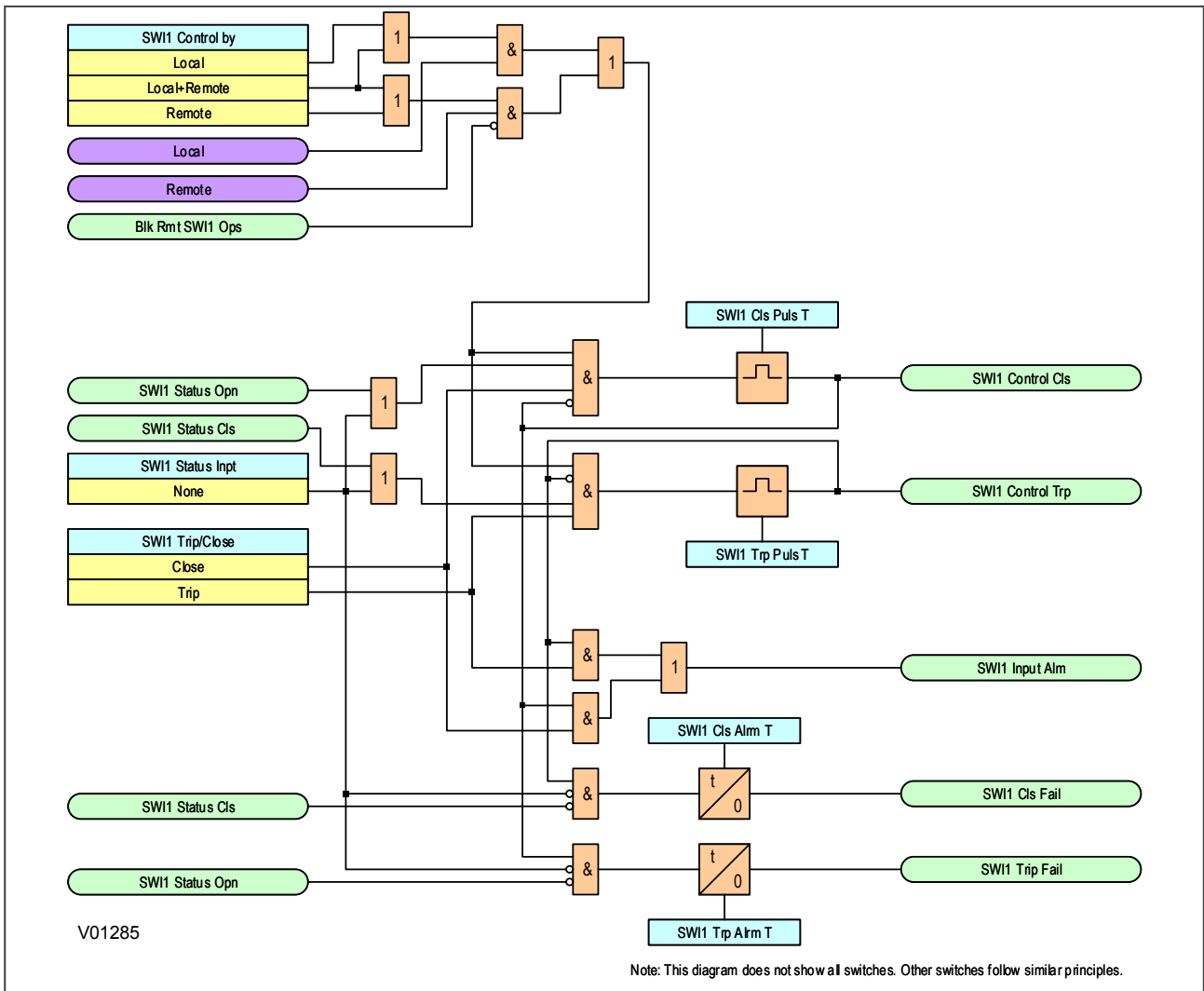
Figure 129: Switch Control logic

CHAPTER 14

SUPERVISION

1   CHAPTER OVERVIEW

This chapter describes the supervison functions.

This chapter contains the following sections:

2   DC SUPPLY MONITOR

This product can be powered using either a DC or AC supply. As a DC supply is normally used, a DC Supply Monitoring feature is included to indicate the DC supply status. The nominal DC Station supply is 48 V DC, which is provided by a bank of batteries. It is sometimes possible for this nominal supply to fall below or rise above acceptable operational limits. If the voltage is too high, it may indicate overcharging. If the voltage is too low, it may indicate a failing battery.

In such cases it is very useful to have DC supply monitoring functionality. 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.

2.1   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:
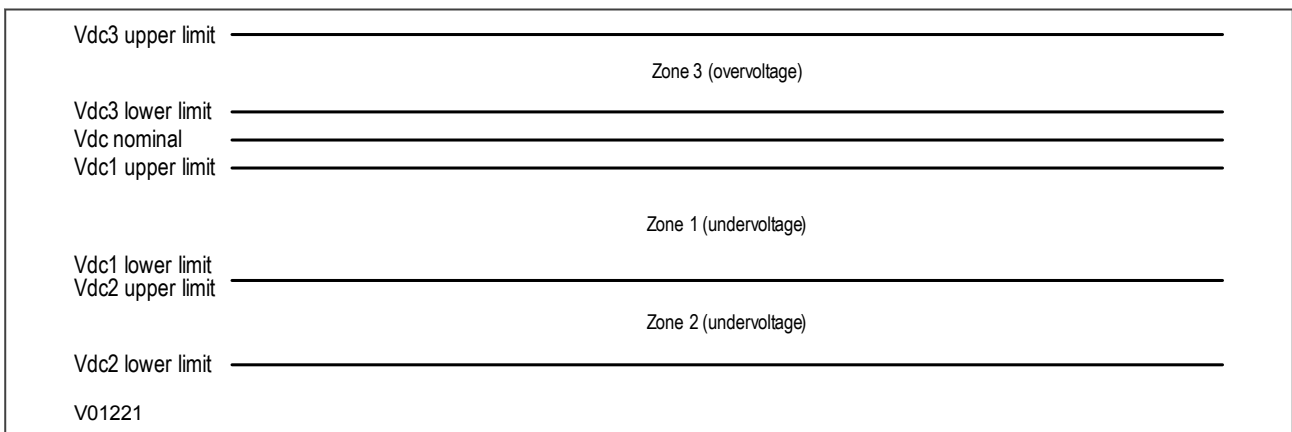
Figure 130: DC Supply Monitor zones

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

2.2   DC SUPPLY MONITOR LOGIC
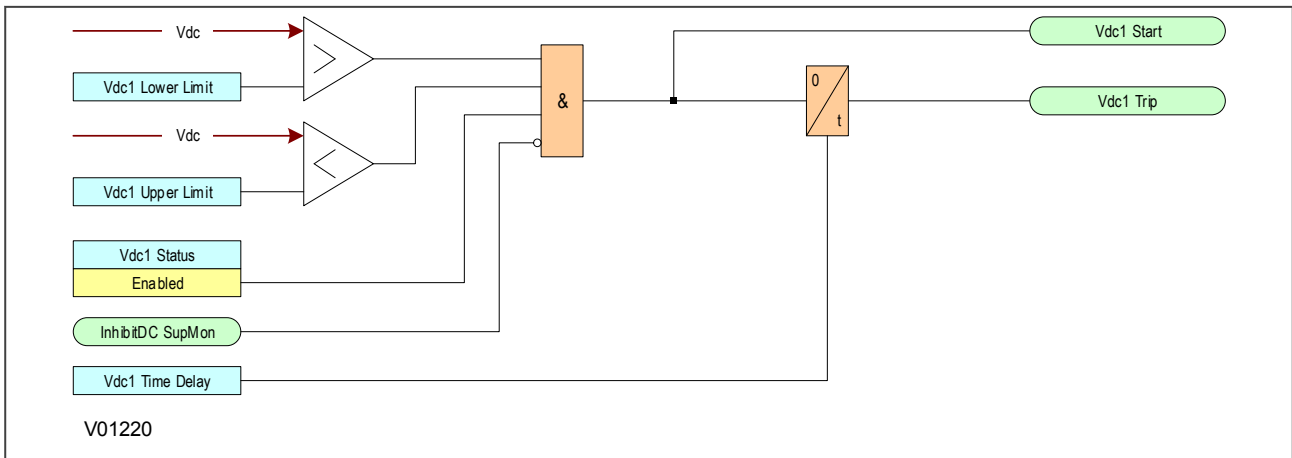
Figure 131: DC Supply Monitor logic

The diagram above 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 **Vdc1 status** setting cell is `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 healthy 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**.

> *Note:*
> *The device's supercapacitor uses Vdc to provide charge and so may cause the voltage to dip below the Vdc lower limit (19.2 V) during a system power-up sequence if fully discharged. This will trigger a lockout error. In this case, it will be necessary to allow the supercapacitor to charge before attempting another power-up sequence. The supercapacitor may take several minutes to become fully charged, depending on the AC/DC supply specification. With the supercapacitor charged, the next relay power cycle will clear the lockout and the relay will boot and operate normally.*

3   VOLTAGE TRANSFORMER SUPERVISION

The Voltage Transformer Supervision (VTS) function is used to detect failure of the AC voltage inputs to the protection. This may be caused by voltage transformer faults, overloading, or faults on the wiring, which usually results in one or more of the voltage transformer fuses blowing.

If there is a failure of the AC voltage input, the IED could misinterpret this as a failure of the actual phase voltages on the power system, which could result in unnecessary tripping of a circuit breaker.

The VTS logic is designed to prevent such a situation by detecting voltage input failures, which are NOT caused by power system phase voltage failure, and automatically blocking associated voltage dependent protection elements. A time-delayed alarm output is available to warn of a VTS condition.

The following scenarios are possible with respect to the failure of the VT inputs.

- Loss of one or two-phase voltages
- Loss of all three-phase voltages under load conditions
- Absence of three-phase voltages upon line energisation

3.1   LOSS OF ONE OR TWO PHASE VOLTAGES

If the power system voltages are healthy, no Negative Phase Sequence (NPS) current will be present. If however, one or two of the AC voltage inputs are missing, there will be Negative Phase Sequence voltage present, even if the actual power system phase voltages are healthy. VTS works by detecting Negative Phase Sequence (NPS) voltage without the presence of Negative Phase Sequence current. So if there is NPS voltage present, but no NPS current, it is certain that there is a problem with the voltage transformers and a VTS block should be applied to voltage dependent protection functions to prevent maloperation. The use of negative sequence quantities ensures correct operation even where three-limb or V-connected VTs are used.

3.2   LOSS OF ALL THREE PHASE VOLTAGES

If all three voltage inputs are lost, there will be no Negative Phase Sequence quantities present, but the device will see that there is no voltage input. If this is caused by a power system failure, there will be a step change in the phase currents. However, if this is not caused by a power system failure, there will be no change in any of the phase currents. So if there is no measured voltage on any of the three phases and there is no change in any of the phase currents, this indicates that there is a problem with the voltage transformers and a VTS block should be applied to voltage dependent protection functions to prevent maloperation.

3.3   ABSENCE OF ALL THREE PHASE VOLTAGES ON LINE ENERGISATION

On line energization there should be a change in the phase currents as a result of loading or line charging current. Under this condition we need an alternative method of detecting three-phase VT failure.

If there is no measured voltage on all three phases during line energization, two conditions might apply:

- A three-phase VT failure
- A close-up three-phase fault.

The first condition would require VTS to block the voltage-dependent functions.

In the second condition, voltage dependent functions should not be blocked, as tripping is required.

To differentiate between these two conditions overcurrent level detectors are used (***VTS I> Inhibit*** and ***VTS I2> Inhibit***). These prevent a VTS block from being issued in case of a genuine fault. These elements should be set in excess of any non-fault based currents on line energisation (load, line charging current, transformer inrush current if applicable), but below the level of current produced by a close-up three-phase fault.

If the line is closed where a three-phase VT failure is present, the overcurrent detector will not operate and a VTS block will be applied. Closing onto a three-phase fault will result in operation of the overcurrent detector and prevent a VTS block being applied.

3.4   VTS IMPLEMENTATION

VTS is implemented in the *SUPERVISION* column of the relevant settings group.

The following settings are relevant for VT Supervision:

- **VTS Status**: determines whether the VTS Operate output will be a blocking output or an alarm indication only
- **VTS PickupThresh**: determines the threshold at which the phase voltage detectors pick up
- **VTS Reset Mode**: determines whether the Reset is to be manual or automatic
- **VTS Time delay**: determines the operating time delay
- **VTS I> Inhibit**: inhibits VTS operation in the case of a phase overcurrent fault
- **VTS I2> Inhibit**: inhibits VTS operation in the case of a negative sequence overcurrent fault

VTS is only enabled during a live line condition (as indicated by the pole dead logic) to prevent operation under dead system conditions.

3.5   VTS LOGIC

This logic will only be enabled during a live line condition (as indicated by the pole dead logic) to prevent operation under dead system conditions (i.e. where no voltage will be present and the **VTS I> Inhibit** overcurrent element will not be picked up).
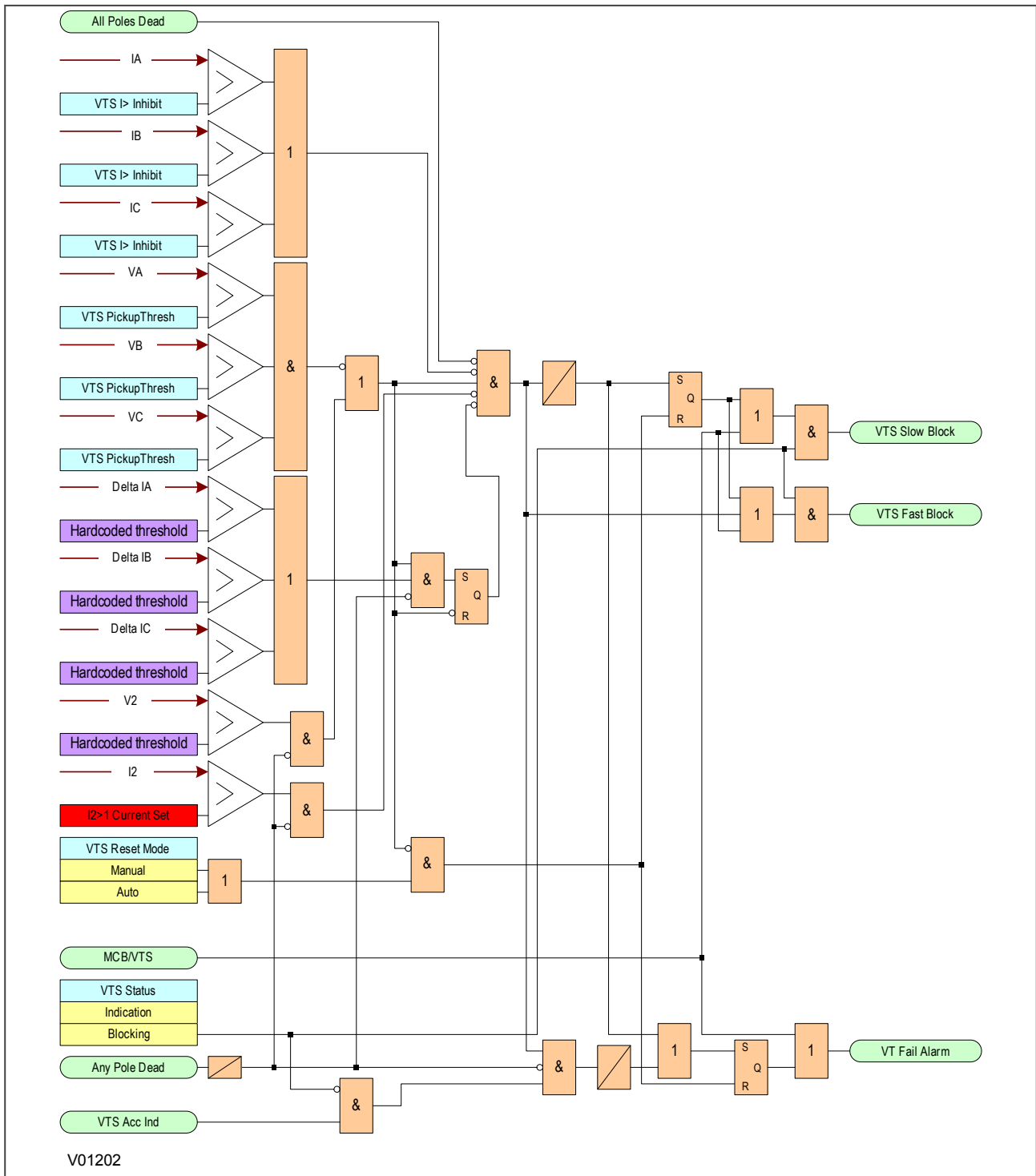
Figure 132: VTS logic

As can be seen from the diagram, the VTS function is inhibited if:

- An **All Poles Dead** DDB signal is present
- Any phase overcurrent condition exists
- A Negative Phase Sequence current exists
- If the phase current changes over the period of 1 cycle

3.6   VTS ACCELERATION INDICATION LOGIC
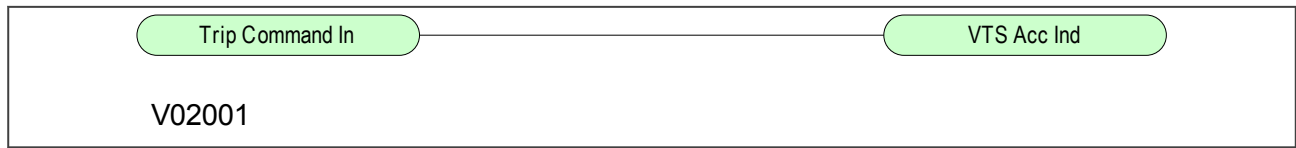
Figure 133: VTS Acceleration Indication Logic

4 CURRENT TRANSFORMER SUPERVISION

The Current Transformer Supervision function (CTS) is used to detect failure of the AC current inputs to the protection. This may be caused by internal current transformer faults, overloading, or faults on the wiring. If there is a failure of the AC current input, the protection could misinterpret this as a failure of the actual phase currents on the power system, which could result in maloperation. Also, interruption in the AC current circuits can cause dangerous CT secondary voltages to be generated.

4.1 CTS IMPLEMENTATION

If the power system currents are healthy, no zero sequence voltage are derived. However, if one or more of the AC current inputs are missing, a zero sequence current would be derived, even if the actual power system phase currents are healthy. Standard CTS works by detecting a derived zero sequence current where there is no corresponding derived zero sequence voltage.

The voltage transformer connection used must be able to refer zero sequence voltages from the primary to the secondary side. Therefore, this element should only be enabled where the VT is of a five-limb construction, or comprises three single-phase units with the primary star point earthed.

The CTS function is implemented in the *SUPERVISION* column of the relevant settings group, under the sub-heading *CT SUPERVISION*.

The following settings are relevant for CT Supervision:

- **CTS Status**: to disable or enable CTS
- **CTS VN< Inhibit**: inhibits CTS if the zero sequence voltage exceeds this setting
- **CTS IN> Set**: determines the level of zero sequence current
- **CTS Time Delay**: determines the operating time delay

4.2 CTS LOGIC
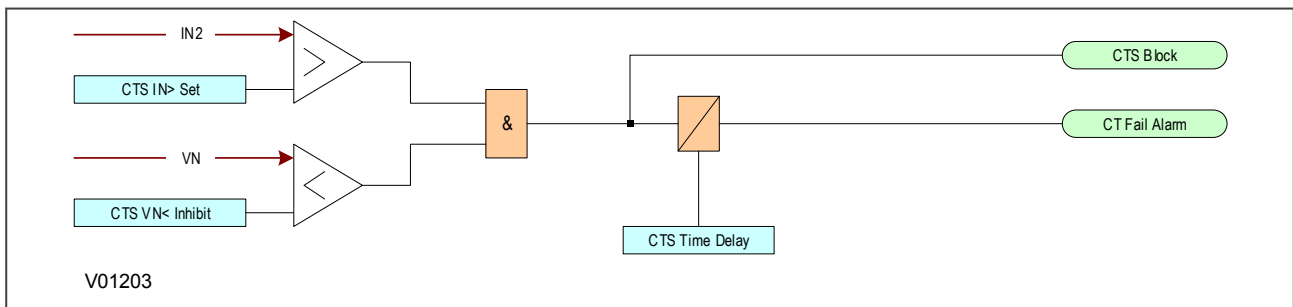
Figure 134: CTS logic diagram

If the derived earth fault current (zero sequence current) exceeds the threshold set by **CTS IN> Set**, a CTS block DDB signal is produced, provided it is not inhibited. the signal is inhibited if the residual voltage is less than the threshold set by **CTS VN< Inhibit**. A CTS alarm is generated after a short time delay defined by the setting **CTS Time Delay**.

4.3   APPLICATION NOTES

4.3.1   SETTING GUIDELINES

The residual voltage setting, *CTS VN< Inhibit* and the residual current setting, *CTS IN> Set*, should be set to avoid unwanted operation during healthy system conditions. For example:

- *CTS VN< Inhibit* should be set to 120% of the maximum steady state residual voltage.
- *CTS IN> Set* will typically be set below minimum load current.
- *CTS Time Delay* is generally set to 5 seconds.

Where the magnitude of residual voltage during an earth fault is unpredictable, the element can be disabled to prevent protection elements being blocked during fault conditions.

5   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.

This product supports a number of trip circuit supervision (TCS) schemes.

5.1   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. 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.*
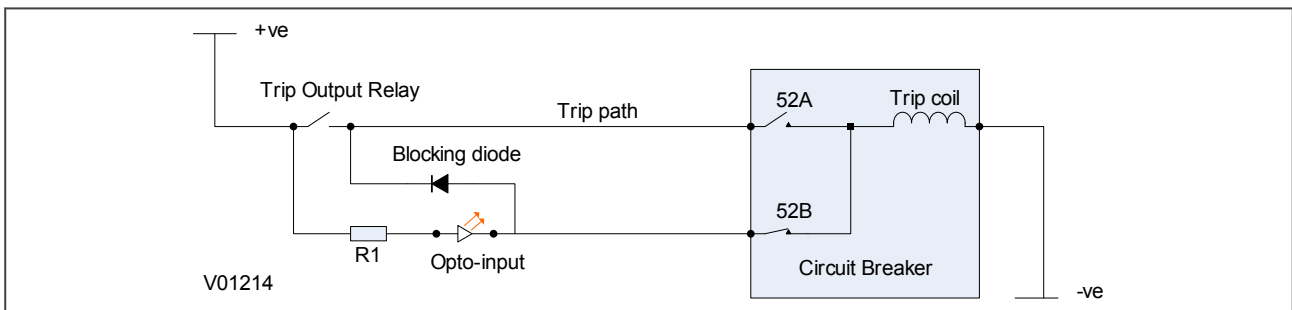
Figure 135: TCS Scheme 1

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.

5.1.1   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 available in the *OPTO CONFIG* column, these
> MUST be set to `TCS` for any corresponding Opto Inputs(s) used for Trip Circuit
> Supervision.

5.1.2 PSL FOR TCS SCHEME 1
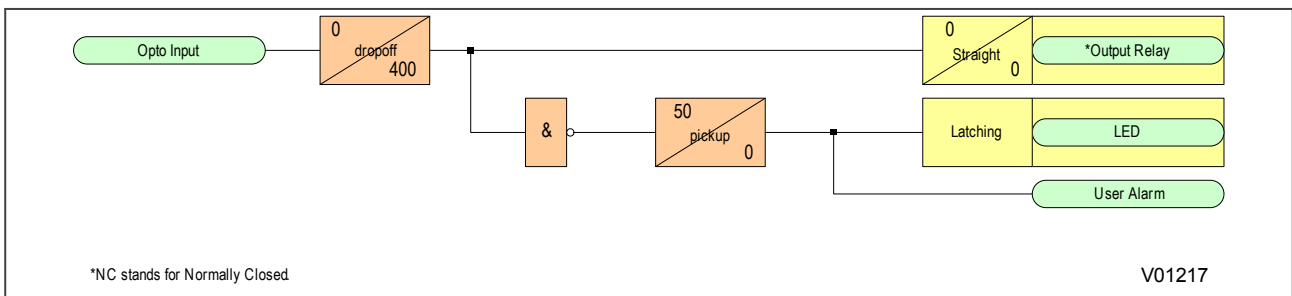
Figure 136: PSL for TCS Scheme 1

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.

5.2 TRIP CIRCUIT SUPERVISION SCHEME 2

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 one opto-input to the 52a contact and another opto-input to the 52b contact. Provided the **CB Status** setting in the *CB CONTROL* column is set to `Both 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.
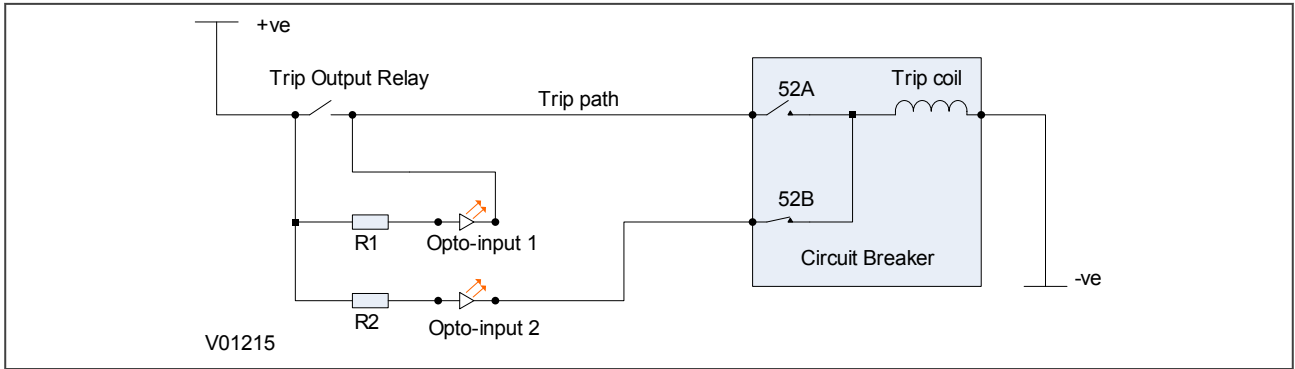
Figure 137: TCS Scheme 2

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. 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.

5.2.1   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 available in the *OPTO CONFIG* column, these MUST be set to `TCS` for any corresponding Opto Inputs(s) used for Trip Circuit Supervision.

5.2.2   PSL FOR TCS SCHEME 2
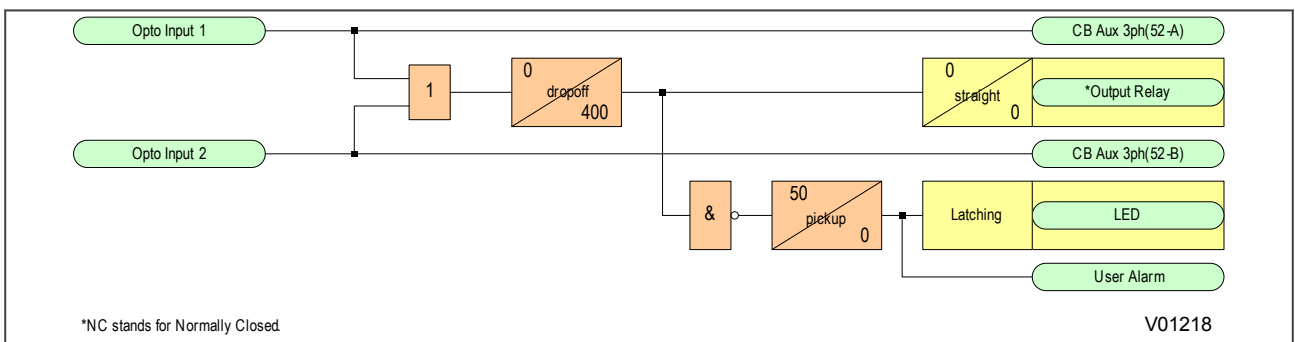
Figure 138: PSL for TCS Scheme 2

In TCS scheme 2, both opto-inputs must be low before a trip circuit fail alarm is given.

5.3   TRIP CIRCUIT SUPERVISION SCHEME 3

TCS Scheme 3 is designed to provide supervision of the trip coil with the breaker open or closed. It 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.
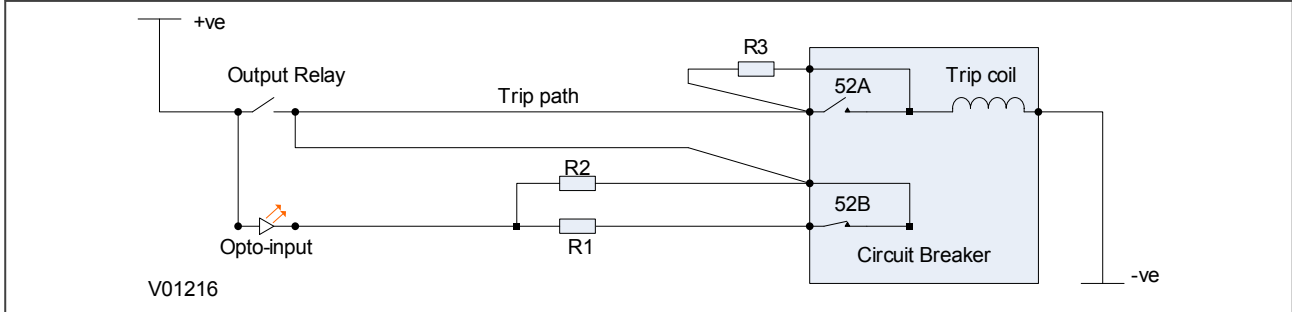
Figure 139: TCS Scheme 3

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. The supervision current is maintained through the trip path with the breaker in either state, therefore providing pre-closing supervision.

5.3.1   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 available in the *OPTO CONFIG* column, these MUST be set to TCS for any corresponding Opto Inputs(s) used for Trip Circuit Supervision.

5.3.2   PSL FOR TCS SCHEME 3
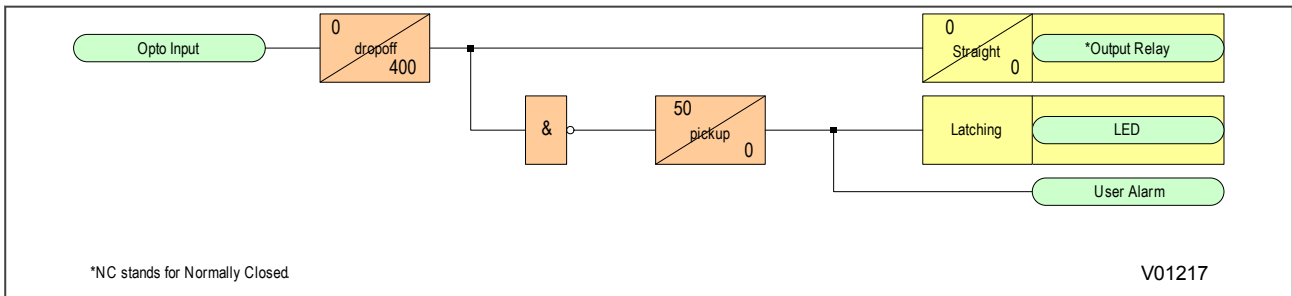
Figure 140: PSL for TCS Scheme 3

5.4   TRIP CIRCUIT SUPERVISION SCHEME 4

Scheme 4 is identical to that offered by MVAX31 (a Trip Circuit Supervision relay) and consequently is fully compliant with ENA Specification H7. To achieve this compliance, there are eight settings in the *OPTO CONFIG* column. Two of these settings (**Opto 1 Mode** to **Opto 11 Mode**--dependant on I/O option chosen) must be set to `TCS` before the scheme can be used, with any remaining opto-input set to `Normal` as required.

In the diagram below, Opto-input 1 and Opto-input 2 would correlate to one of the above-mentioned opto-inputs.
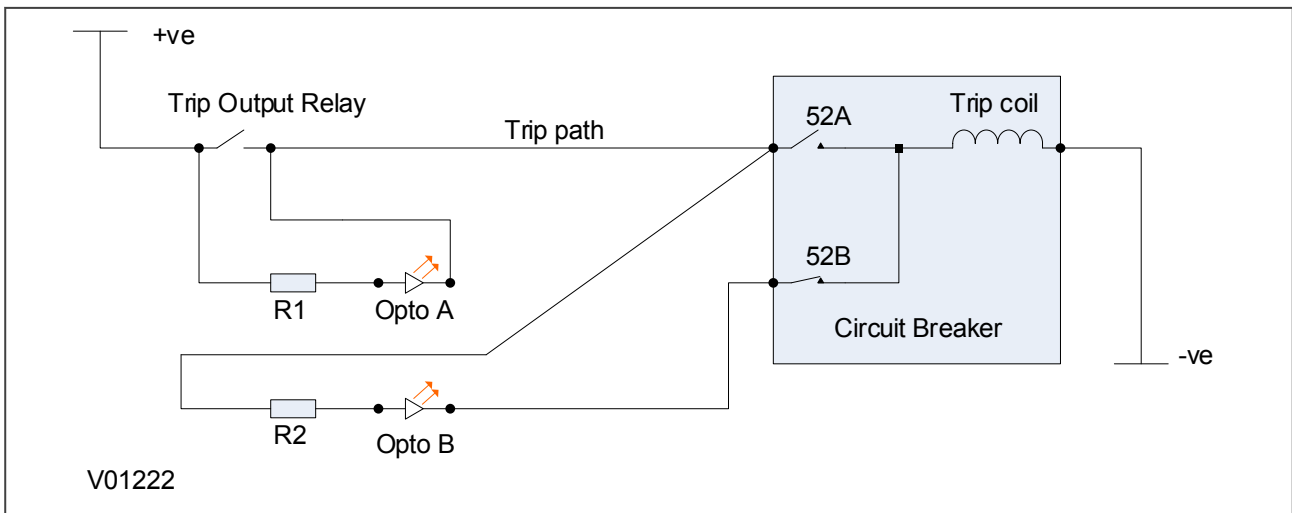
Figure 141: TCS Scheme 4

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 A, Contact 52A and the trip coil.

b) Pre-close Supervision: When the CB is in an open state, the current flows through R1, Opto A, Contact 52B, Opto B 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 B 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.

Recommended Scheme Opto Connections and Settings

I/O option G or J		I/O Option F			I/O Option C		
Opto Input 1 (Mode Setting)	Opto Input 2 (Mode Setting)	Opto Input 4 (Mode Setting)	Opto Input 5 (Mode Setting)	Opto Input 6 (Mode Setting)	Opto Input 9 (Mode Setting)	Opto Input 10 (Mode Setting)	Opto Input 11 (Mode Setting)
Opto A (TCS)	Opto B (TCS)	Opto A (TCS)	Opto B (TCS)	- (NORMAL)	Opto A (TCS)	Opto B (TCS)	- (NORMAL)
					I/O Option H		

5.4.1   RESISTOR VALUES

The TCS opto-inputs sink a constant current of 2 mA.The values of external resistors R1 and R2 are chosen to limit the current to a maximum of 60 mA in the event that an opto-input becomes shorted. The values of these resistors depend on the trip circuit voltage. To achieve compliance with ENA Specification H7, we have carried out extensive testing and we recommended the following resistors values.

Trip Circuit Voltage	Resistor R1 and R2 (ohms)
24/27	620 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 available in the *OPTO CONFIG* column, these MUST be set to *TCS* for any corresponding Opto Inputs(s) used for Trip Circuit Supervision.

5.4.2   PSL FOR TCS SCHEME 4
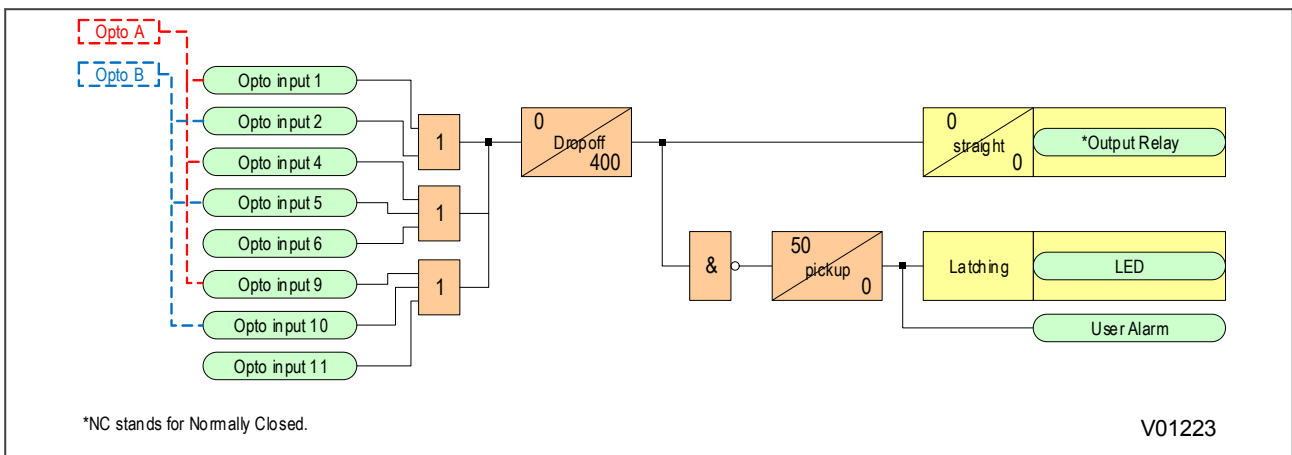
Figure 142: PSL for TCS Scheme 4

CHAPTER 15

DIGITAL I/O AND PSL CONFIGURATION

1   CHAPTER OVERVIEW

This chapter introduces the PSL (Programmable Scheme Logic) Editor, and describes the configuration of the digital inputs and outputs. It provides an outline of scheme logic concepts and the PSL Editor. This is followed by details about allocation of the digital inputs and outputs, which require the use of the PSL Editor. A separate "Settings Application Software" document is available that gives a comprehensive description of the PSL, but enough information is provided in this chapter to allow you to allocate the principal digital inputs and outputs.

This chapter contains the following sections:

2   CONFIGURING DIGITAL INPUTS AND OUTPUTS

Configuration of the digital inputs and outputs in this product is very flexible. You can use a combination of settings and programmable logic to customise them to your application. You can access some of the settings using the keypad on the front panel, but you will need a computer running the settings application software to fully interrogate and configure the properties of the digital inputs and outputs.

The settings application software includes an application called the PSL Editor (Programmable Scheme Logic Editor). The PSL Editor lets you allocate inputs and outputs according to your specific application. It also allows you to apply attributes to some of the signals such as a drop-off delay for an output contact.

In this product, digital inputs and outputs that are configurable are:

- Optically isolated digital inputs (opto-inputs). These can be used to monitor the status of associated plant.
- Output relays. These can be used for purposes such as initiating the tripping of circuit breakers, providing alarm signals, etc..
- Programmable LEDs. The number and colour of the programmable LEDs varies according to the particular product being applied.
- Function keys and associated LED indications. These are not provided on all products, but where they are, each function key has an associated tri-colour LED.
- IEC 61850 GOOSE inputs and outputs. These are only provided on products that have been specified for connection to an IEC61850 system, and the details of the GOOSE are presented in the documentation on IEC61850.

3   SCHEME LOGIC

The product is supplied with pre-loaded Fixed Scheme Logic (FSL) and Programmable Scheme Logic (PSL).

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). It is built around a concept called the digital data bus (DDB). The DDB encompasses all of the digital signals (DDBs) which are used in the FSL and PSL. The DDBs included digital inputs, outputs, and internal signals.

The FSL is logic that has been hard-coded in the product. It is fundamental to correct interaction between various protection and/or control elements. It is fixed and cannot be changed.

The PSL gives you a facility to develop custom schemes to suit your application if the factory-programmed default PSL schemes do not meet your needs. Default PSL schemes are programmed before the product leaves the factory. These default PSL schemes have been designed to suit typical applications and 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.

The PSL consists of components such as logic gates and timers, which combine and condition DDB signals.

The logic gates can be programmed to perform a range of different logic functions. The number of inputs to a logic gate are not limited. The timers can be used either to create a programmable delay or to condition the logic outputs. Output contacts and programmable LEDs have dedicated conditioners.

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 minimises the amount of processing time used by the PSL ensuring industry leading performance.

The following diagram shows how the scheme logic interacts with the rest of the IED.
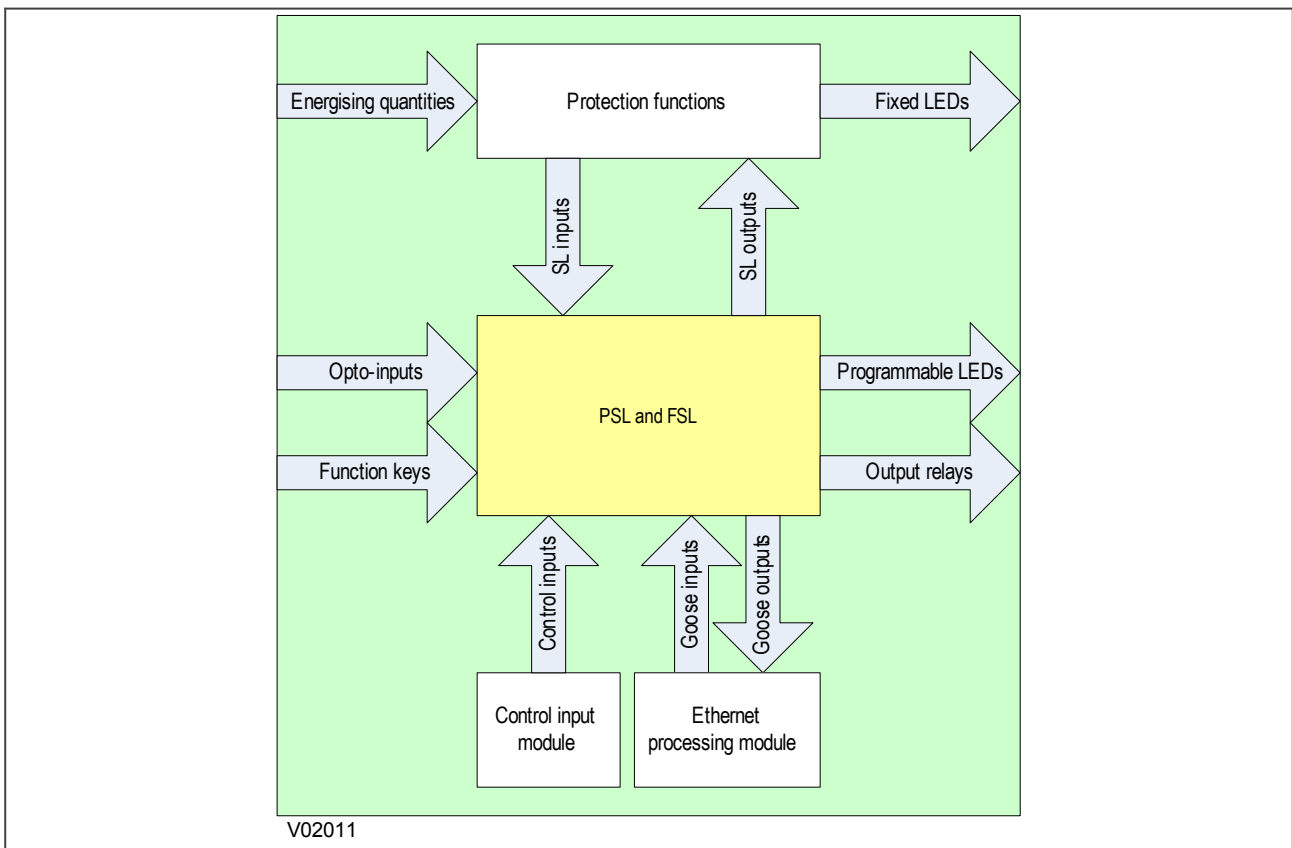
Figure 143: Scheme Logic Interfaces

3.1   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 logic to qualify how the product manages its response to system conditions. The IED's digital inputs are combined with internally generated digital signals using logic gates, timers, and conditioners. The resultant signals are then mapped to digital outputs signals including output relays and LEDs.

The PSL Editor is a tool in the settings application software that allows you to create and edit scheme logic diagrams. You can use the default scheme logic which has been designed to suit most applications, but if it does not suit your application you can change it. If you create a different scheme logic with the software, you need to upload it to the device to apply it.

3.2   PSL SCHEMES

Your product is shipped with default scheme files. These can be used without modification for most applications, or you can choose to use them as a starting point to design your own scheme. You can also create a new scheme from scratch. To create a new scheme, or to modify an existing scheme, you will need to launch the settings application software. You then need to open an existing PSL file, or create a new one, for the particular product that you are using, and then open a PSL file. If you want to create a new PSL file, you should select **File** then **New** then **Blank scheme...** This action opens a default file appropriate for the device in question, but deletes the diagram components from the default file to leave an empty diagram with configuration information loaded. To open an existing file, or a default file, simply double-click on it.

3.3   PSL SCHEME VERSION CONTROL

To help you keep track of the PSL loaded into products, a version control feature is included. The user interface 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(n)  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(n)  PSL ID
ID - 2062813232
```

4   CONFIGURING THE OPTO-INPUTS

The number of optically isolated status inputs (opto-inputs) depends on the specific model supplied. The use of the inputs will depend on the application, and their allocation is defined in the programmable scheme logic (PSL). In addition to the PSL assignment, you also need to specify the expected input voltage. Generally, all opto-inputs will share the same input voltage range, but if different voltage ranges are being used, this device can accommodate them.

In the *OPTO CONFIG* column there is a global nominal voltage setting. If all opto-inputs are going to be energised from the same voltage range, you select the appropriate value with this setting. If you select `Custom` in the setting, then the cells **Opto Input 1**, **Opto Input 2**, etc. become visible. You use these cells to set the voltage ranges for each individual opto-input.

If you are using the recommended settings application software (MiCOM S1 Agile), the product's DC supply monitoring function detects the DC supply voltage and provides some automation for setting for the global nominal voltage. This feature is found by right clicking on **Device**, then selecting **Supervise Device → Auto-setup of Opto Voltage**. This automatic detection only works for DC inputs.

Within the *OPTO CONFIG* column there are also settings to control the filtering applied to the inputs, as well as the pick-up/drop-off characteristic.

The filter control setting provides a bit string with a bit associated with all opto-inputs. Setting the bit to '1' means that a half-cycle filter is applied to the inputs. This helps to prevent incorrect operation in the event of power system frequency interference on the wiring. Setting the field to '0' removes the filter and provides for faster operation. You should note that removing the filter reduces the AC immunity. that means it is less effective at filtering out-of-band interference.

The **Characteristic** setting is a single setting that applies to all the opto-inputs. It is used to set the pick-up/drop-off ratios of the input signals.

By default the drop-off is 60% of the maximum DC input value and the pick-up threshold is 80% of the minimum DC input value. You can change this to other available thresholds if required. Other available thresholds are 50% - 70% and 58% - 75%.

5   ASSIGNING THE OUTPUT RELAYS

Relay contact action is controlled using the PSL. DDB signals are mapped in the PSL and drive the output relays. The driving of an output relay is controlled by means of a relay output conditioner. Several choices are available for how output relay contacts are conditioned. For example, you can choose whether operation of an output relay contact is latched, has delay on pick-up, or has a delay on drop-off. You make this choice in the **Contact Properties** window associated with the output relay conditioner.

To map an output relay in the PSL you should use the Contact Conditioner button in the toolbar to import it. You then condition it according to your needs. The output of the conditioner respects the attributes you have assigned.

The toolbar button for a Contact Conditioner looks like this:

The PSL contribution that it delivers looks like this:
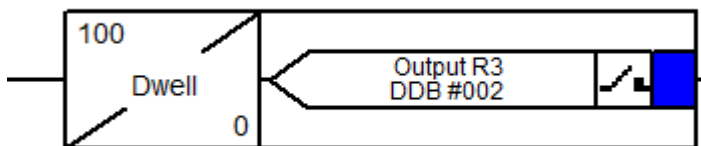
> Note:
> Contact Conditioners are only available if they have not all been used. In some default PSL schemes, all Contact Conditioners might have been used. If that is the case, and you want to use them for something else, you will need to re-assign them.

On the toolbar there is another button associated with the relay outputs. The button looks like this:

This is the "Contact Signal" button. It allows you to put replica instances of a conditioned output relay into the PSL, preventing you having to make cross-page connections which might detract from the clarity of the scheme.

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 functions are 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.

6.1   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.

The Trip LED logic is as follows:
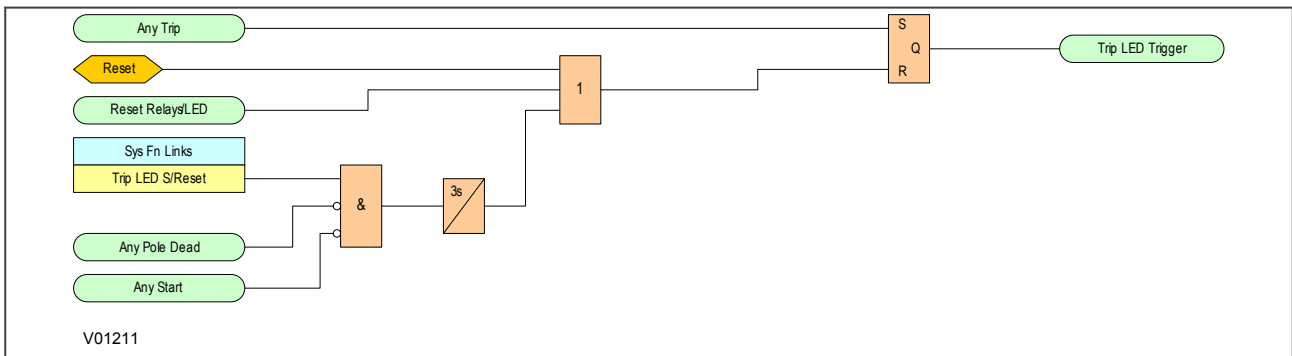
Figure 144: Trip LED logic

7 CONFIGURING PROGRAMMABLE LEDS

There are three types of programmable LED signals which vary according to the model being used. These are:

- Single-colour programmable LED. These are red when illuminated.
- Tri-colour programmable LED. These can be illuminated red, green, or amber.
- Tri-colour programmable LED associated with a Function Key. These can be illuminated red, green, or amber.

DDB signals are mapped in the PSL and used to illuminate the LEDs. For single-coloured programmable LEDs there is one DDB signal per LED. For tri-coloured LEDs there are two DDB signals associated with the LED. Asserting **LED # Grn** will illuminate the LED green. Asserting **LED # Red** will illuminate the LED red. Asserting both DDB signals will illuminate the LED amber.

The illumination of an LED is controlled by means of a conditioner. Using the conditioner, you can decide whether the LEDs reflect the real-time state of the DDB signals, or whether illumination is latched pending user intervention.

To map an LED in the PSL you should use the LED Conditioner button in the toolbar to import it. You then condition it according to your needs. The output(s) of the conditioner respect the attribute you have assigned.

The toolbar button for a tri-colour LED looks like this:

The PSL contribution that it delivers looks like this:
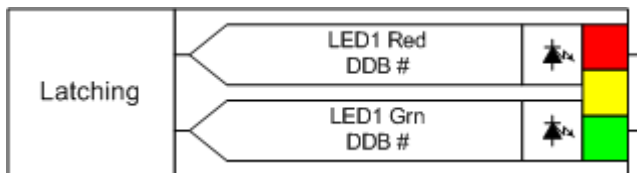
The toolbar button for a single-colour LED looks like this:

The PSL contribution that it delivers looks like this.
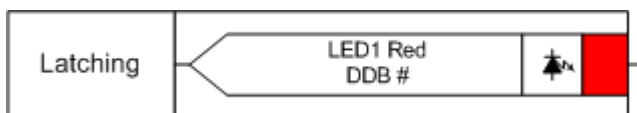
> *Note:*
> *LED Conditioners are only available if they have not all been used up, and in some default PSL schemes they might be. If that is the case and you want to use them for something else, you will need to re-assign them.*

On the toolbar there is another button associated with the LEDs. For a tri-coloured LED the button looks like this:

For a single-colour LED it looks like this:

It is the "LED Signal" button. It allows you to put replica instances of a conditioned LED into the PSL, preventing you having to make cross-page connections which might detract from the clarity of the scheme.

Note:
All LED DDB signals are always shown in the PSL Editor. However, the actual number of LEDs depends on the device hardware. For example, if a small 20TE device has only 4 programmable LEDs, LEDs 5-8 will not take effect even if they are mapped in the PSL.

8   FUNCTION KEYS

For most models, 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 are 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)**, which enables or disables the function key
- **Fn Key (n) Mode**, which allows you to configure the key as toggled or normal
- **Fn Key (n) label**, which allows you to define the function key text that is displayed

The **Fn Key (n)** cell is used to enable (unlock) or disable (unlock) 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.

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 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 their status will be maintained.

> *Note:*
> *All function key DDB signals are always shown in the PSL Editor. However, the actual number of function keys depends on the device hardware. For example, if a small 20TE device has no function keys, the function key DDBs mapped in the PSL will not take effect.*

9   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: *CONTROL INPUTS*, *CTRL I/P CONFIG* and *CTRL I/P LABELS*. These are listed in the Settings and Records appendix at the end of this manual.

10   INTER-PSL INPUTS AND OUTPUTS

To make the design of PSL schemes easier, P40 Agile provides a range of DDB signals for conncting PSL Inputs to PSL Outputs. these are called Inter-PSL inputs and outputs. This facility allows you to map many PSL input signals to a single Inter-PSL output signal, many PSL output signals to a single Inter-PSL input signal, and to join the Inter-PSL input signal to an Inter-PSL output signal. The Inter-PSL input signals can also be used to directly trigger the Disturbance Recorder.

CHAPTER 16

COMMUNICATIONS

1   CHAPTER OVERVIEW

This product supports Substation Automation System (SAS), and Supervisory Control and Data Acquisition (SCADA) communication. The support embraces the evolution of communications technologies that have taken place since microprocessor technologies were introduced into protection, control, and monitoring devices which are now ubiquitously known as Intelligent Electronic Devices for the substation (IEDs).

As standard, all products support rugged serial communications for SCADA and SAS applications. By option, any product can support Ethernet communications for more advanced SCADA and SAS applications.

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 page308) and General Electric'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.*
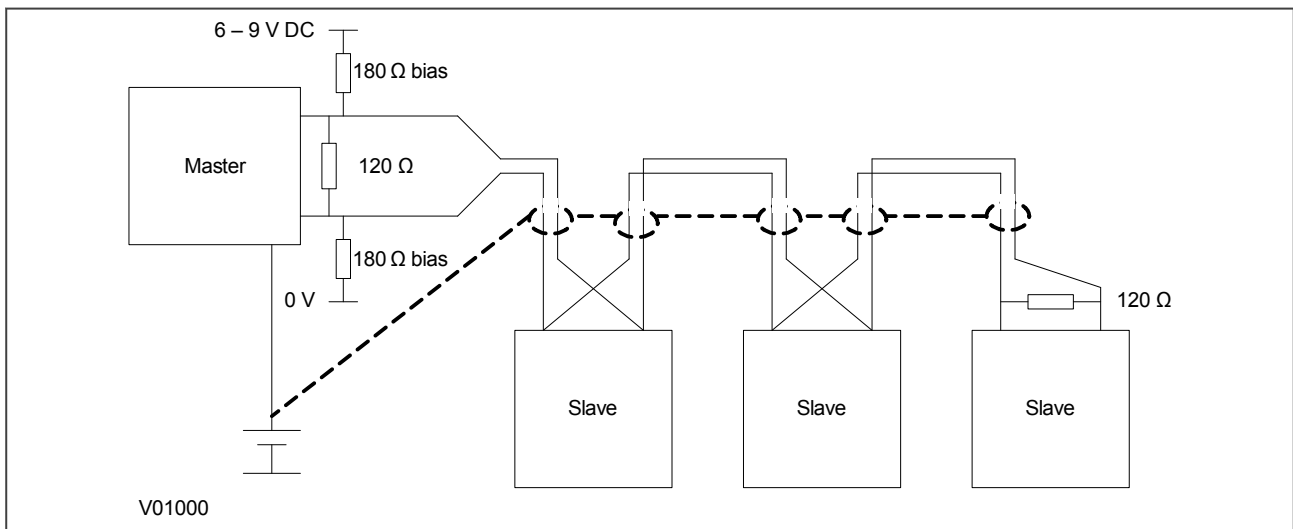
Figure 145: RS485 biasing circuit

> ⚠️ **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.

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 General Electric for information regarding the specification and supply of KITZ devices. The following figure demonstrates a typical K-Bus connection.
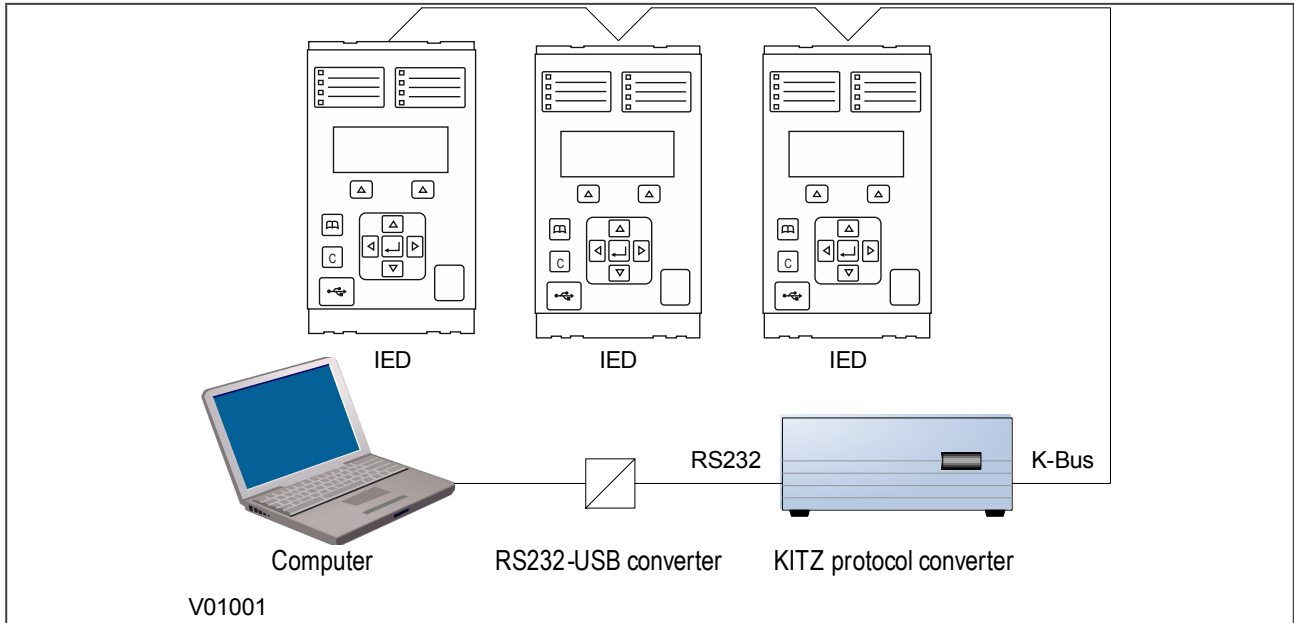
Figure 146: Remote communication using K-Bus

> *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 and/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 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   REDUNDANT ETHERNET COMMUNICATION

Redundancy is required where a single point of failure cannot be tolerated. It is required in critical applications such as substation automation. Redundancy acts as an insurance policy, providing an alternative route if one route fails.

Ethernet communication redundancy is available for most General Electric products, using a Redundant Ethernet facility. This is an in-built Network Interface Card (NIC), which incorporates an integrated Ethernet switch. The interface provides two Ethernet transmitter/receiver pairs, both of which are for the same physical medium (two copper, or two fibre). In addition to the two Ethernet transmitter/receiver pairs, the REB provides link activity indication.

Both industry standard PRP (Parallel Redundancy Protocol) and HSR (High-availability Seamless Redundancy) protocols are available by ordering option.

5.1   SUPPORTED PROTOCOLS

One of the key requirements of substation redundant communications is "bumpless" redundancy. This means the ability to transfer from one communication path to another without noticeable consequences. Standard protocols of the time could not meet the demanding requirements of network availability for substation automation solutions. Switch-over times were unacceptably long. For this reason, companies developed proprietary protocols. More recently, however, standard protocols, which support bumpless redundancy (namely PRP and HSR) have been developed and ratified.

P40Agile version 56 onwards supports redundant Ethernet. Variants for each of the following protocols are available:

- PRP (Parallel Redundancy Protocol)
- HSR (High-availability Seamless Redundancy)

PRP and HSR are open standards, so their implementation is compatible with any standard PRP or HSR device respectively. PRP provides "bumpless" redundancy.

> *Note:*
> *The protocol you require must be selected at the time of ordering.*

5.2   PARALLEL REDUNDANCY PROTOCOL

PRP (Parallel Reundancy Protocol) is defined in IEC 62439-3. PRP provides bumpless redundancy and meets the most demanding needs of substation automation. The PRP implementation of the REB is compatible with any standard PRP device.

PRP uses two independent Ethernet networks operating in parallel. PRP systems are designed so that there should be no common point of failure between the two networks, so the networks have independent power sources and are not connected together directly.

Devices designed for PRP applications have two ports attached to two separate networks and are called Doubly Attached Nodes (DAN). A DAN has two ports, one MAC address and one IP address.

The sending node replicates each frame and transmits them over both networks. The receiving node processes the frame that arrives first and discards the duplicate. Therefore there is no distinction between the working and backup path. The receiving node checks that all frames arrive in sequence and that frames are correctly received on both ports.

Devices such as printers that have a single Ethernet port can be connected to either of the networks but will not directly benefit from the PRP principles. Such devices are called Singly Attached Nodes (SAN). For devices with a single Ethernet port that need to connect to both LANs, this can be achieved by employing Ethernet Redundancy

Boxes (sometimes abbreviated to RedBox). Devices with a single Ethernet port that connect to both LANs by means of a RedBox are known as Virtual DAN (VDAN).

The figure below summarises DAN, SAN, VDAN, LAN, and RedBox connectivity.
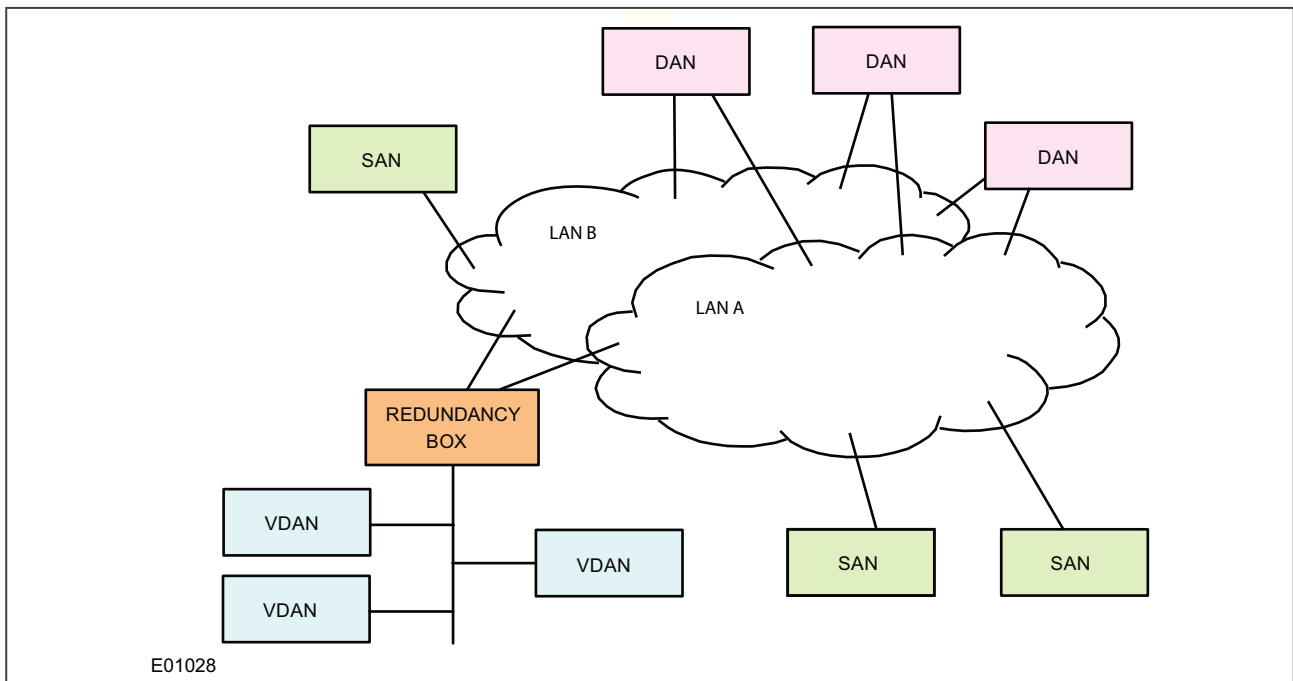
Figure 147: IED attached to separate LANs

In a DAN, both ports share the same MAC address so it does not affect the way devices talk to each other in an Ethernet network (Address Resolution Protocol at layer 2). Every data frame is seen by both ports.

When a DAN sends a frame of data, the frame is duplicated on both ports and therefore on both LAN segments. This provides a redundant path for the data frame if one of the segments fails. Under normal conditions, both LAN segments are working and each port receives identical frames.

5.3 HIGH-AVAILABILITY SEAMLESS REDUNDANCY (HSR)

HSR is standardized in IEC 62439-3 (clause 5) for use in ring topology networks. Similar to PRP, HSR provides bumpless redundancy and meets the most demanding needs of substation automation. HSR has become the reference standard for ring-topology networks in the substation environment. The HSR implementation of the redundancy Ethernet board (REB) is compatible with any standard HSR device.

HSR works on the premise that each device connected in the ring is a doubly attached node running HSR (referred to as DANH). Similar to PRP, singly attached nodes such as printers are connected via Ethernet Redundancy Boxes (RedBox).

5.3.1 HSR MULTICAST TOPOLOGY

When a DANH is sending a multicast frame, the frame (C frame) is duplicated (A frame and B frame), and each duplicate frame A/B is tagged with the destination MAC address and the sequence number. The frames A and B differ only in their sequence number, which is used to identify one frame from the other. Each frame is sent to the network via a separate port. The destination DANH receives two identical frames, removes the HSR tag of the first frame received and passes this (frame D) on for processing. The other duplicate frame is discarded. The nodes forward frames from one port to the other unless it was the node that injected it into the ring.
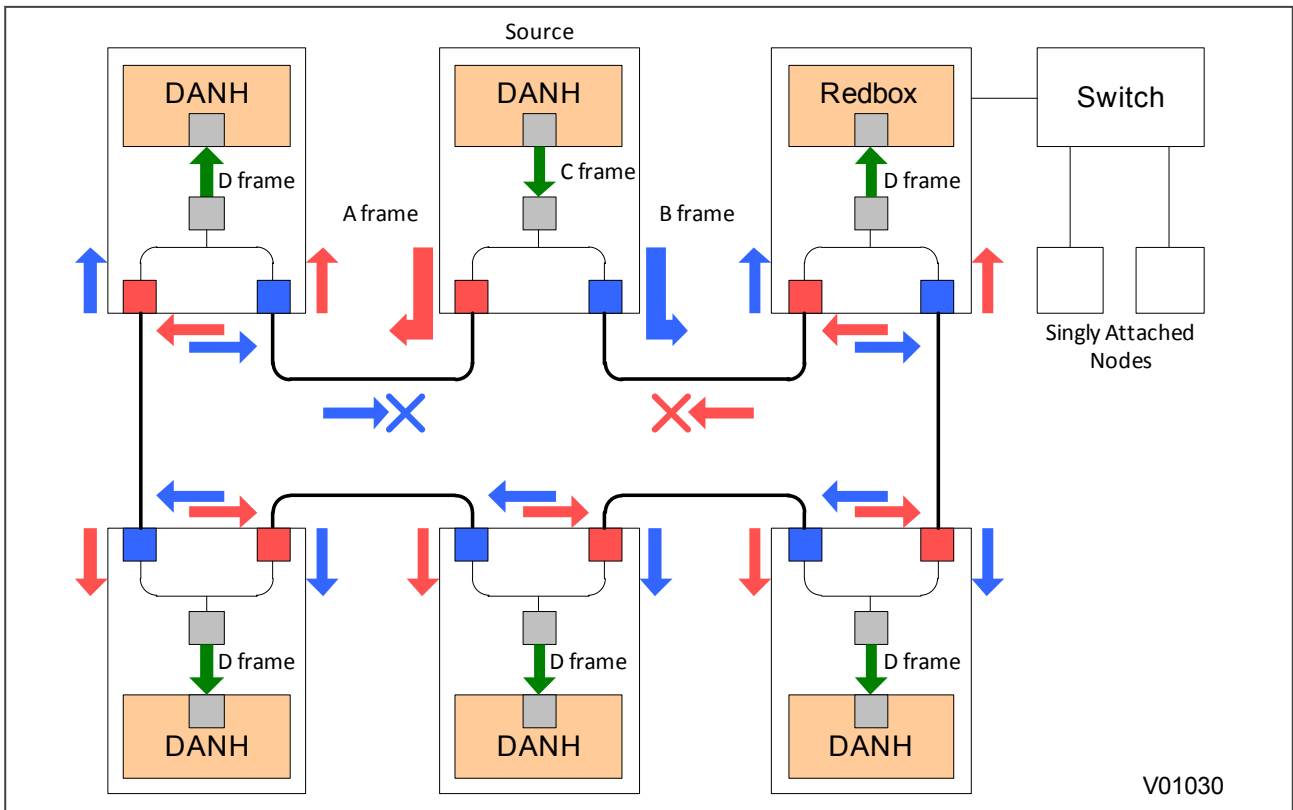
Figure 148: HSR multicast topology

Only about half of the network bandwidth is available in HSR for multicast or broadcast frames because both duplicate frames A & B circulate the full ring.

5.3.2   HSR UNICAST TOPOLOGY

With unicast frames, there is just one destination and the frames are sent to that destination alone. All non-recipient devices simply pass the frames on. They do not process them in any way. In other words, D frames are produced only for the receiving DANH. This is illustrated below.
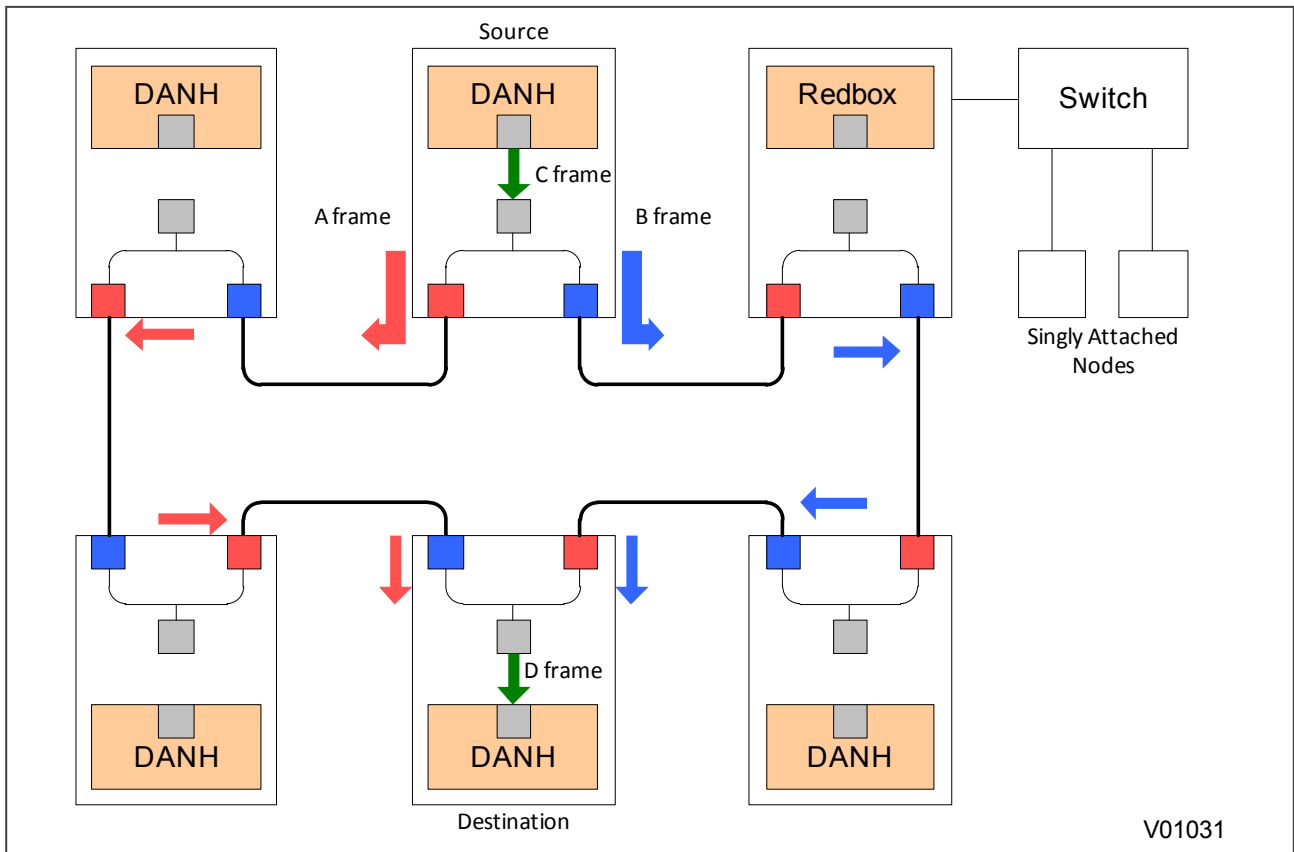
Figure 149: HSR unicast topology

For unicast frames, the whole bandwidth is available as both frames A & B stop at the destination node.

5.3.3   HSR APPLICATION IN THE SUBSTATION
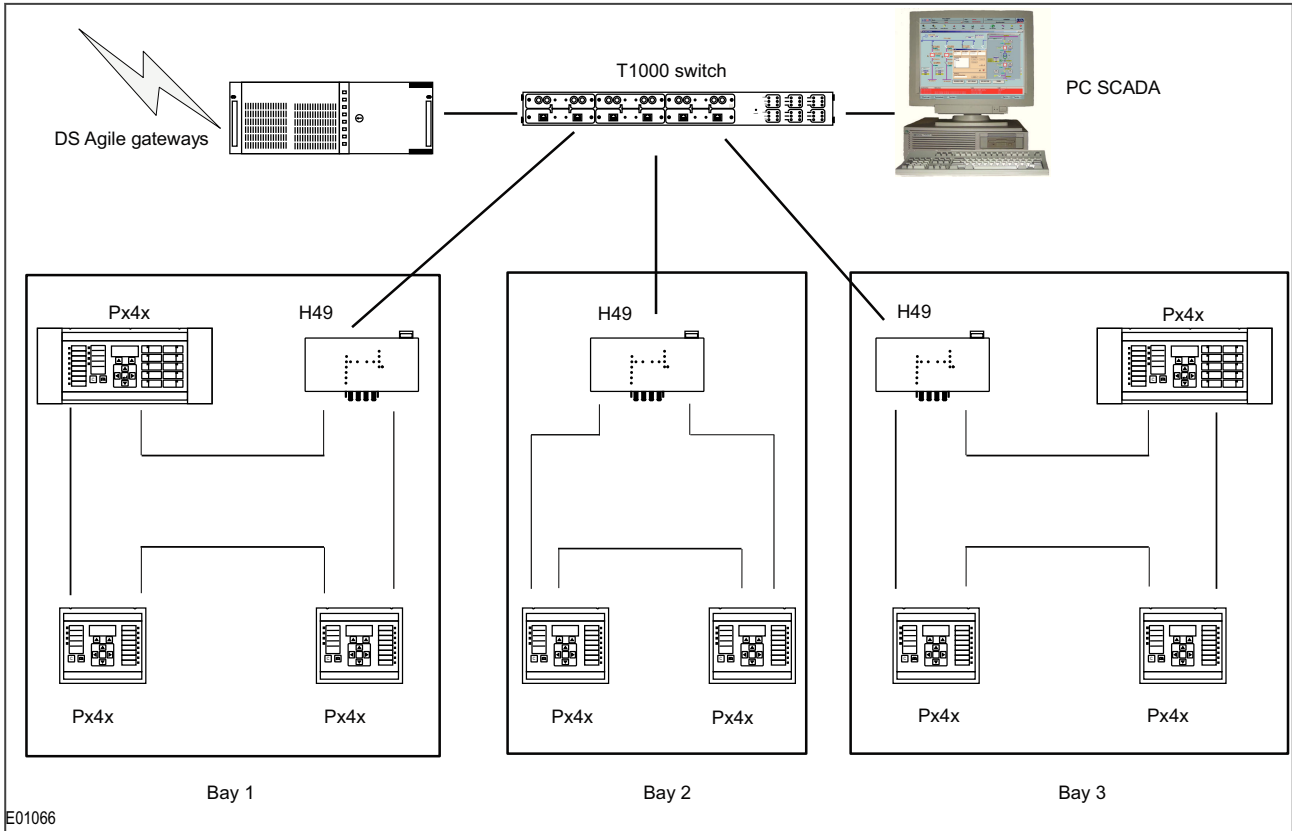
Figure 150: HSR application in the substation

5.4 RAPID SPANNING TREE PROTOCOL

RSTP is a standard used to quickly reconnect a network fault by finding an alternative path. It stops network loops whilst enabling redundancy. It can be used in star or ring connections as shown in the following figure.
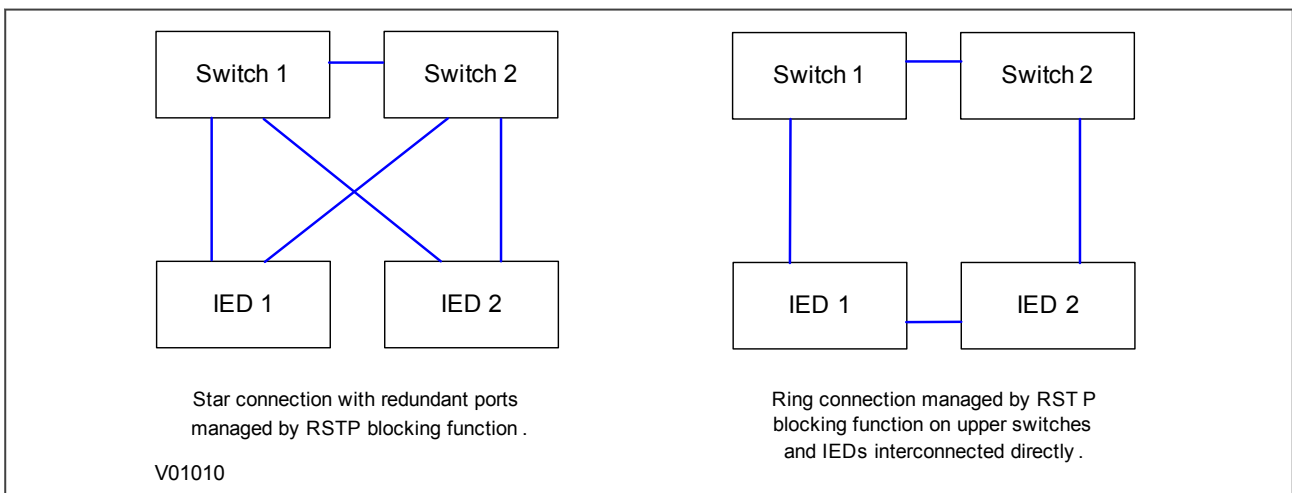
Figure 151: IED attached to redundant Ethernet star or ring circuit

The RSTP implementation in this product is compatible with any devices that use RSTP.

RSTP can recover network faults quickly, but the fault recovery time depends on the number of devices on the network and the network topology. A typical figure for the fault recovery time is 300ms. Therefore, RSTP cannot achieve the "bumpless" redundancy that some other protocols can.

Refer to IEEE 802.1D 2004 standard for detailed information about the opration of the protocol.

5.5   CONFIGURING IP ADDRESS

The redundant Ethernet facility does not have any special IP address configuration requirements. There is just one IP address for the device, which can be configured using the IEC61850 configurator as for a standard Ethernet device.

The IED configurator will automatically display the PRP/HSR configuration parameters.

6   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 General Electric.
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:

Data Protocols	IEC 60870-5-103 MODBUS DNP3.0 Courier	IEC 61850 DNP3.0 Courier	Courier	Courier
Data Link Layer	EIA(RS)485	Ethernet	USB	K-Bus
Physical Layer	Copper or Optical Fibre			

6.1   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 General Electric 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.

6.1.1   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.

6.1.2   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.

6.1.3 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.

6.1.4 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.

6.1.5 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 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.

6.1.5.1 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.

6.1.5.2   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 column B4. Row 01 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.

6.1.6   DISTURBANCE RECORD EXTRACTION

The stored disturbance records are accessible through the Courier interface. The records are extracted using 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.

6.1.7   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 must be used to edit the settings. It also performs checks on the validity of the settings before they are transferred to the IED.

6.1.8   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.

6.1.9   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 RP1 port on thje device. 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 Relay 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 revoking any password access that was enabled and discarding any changes. 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 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
```

6.2 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

6.2.1 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.

6.2.2   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 General Electric separately if required.

In addition to the above identification message, it will also produce a power up event.

6.2.3   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.

6.2.4   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.

6.2.5   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.

6.2.6   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.

6.2.7   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'.

6.2.8   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'.

6.2.9 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.*

6.2.10 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 CS103Blcking** in the *COMMUNICATIONS* column
- The DDB signals Monitor Blocked and Command Blocked

6.2.11 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 address. It is important that no two IEDs have the same IEC 60870 5 103 address. The IEC 60870-5-103 address is then used by the master station to communicate with the IED.

```
COMMUNICATIONS
RP1 address
162
```

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

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

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

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

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

```
COMMUNICATIONS
RP1 PhysicalLink
Copper
```

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

```
COMMUNICATIONS
RP1 CS103Blcking
Disabled
```

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

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

6.3   DNP 3.0

This section describes how the DNP 3.0 standard is applied in the product. 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).

6.3.1   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

With DNP3 Over Ethernet, a maximum of 10 Clients can be configured. They are configured using the DNP3 Configurator

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.

6.3.2   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.

6.3.3   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.
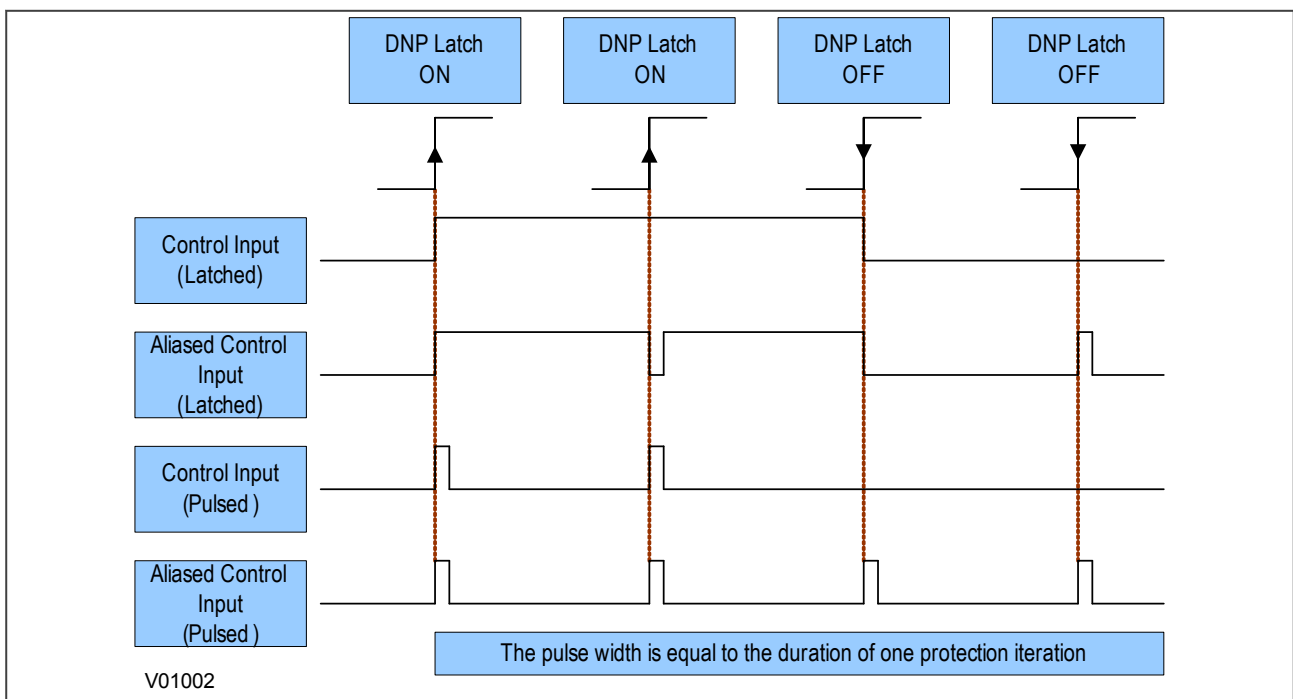
Figure 152: Control input behaviour

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

6.3.4   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.

6.3.5   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).

6.3.6   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.

6.3.7   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.

6.3.8   DNP3 DEVICE PROFILE

This section describes the specific implementation of DNP version 3.0 within General Electric MiCOM P40 Agile IEDs for both compact and modular ranges.

The devices use the DNP 3.0 Slave Source Code Library version 3 from Triangle MicroWorks Inc.

This document, in conjunction with the DNP 3.0 Basic 4 Document Set, and the DNP Subset Definitions Document, provides complete information on how to communicate with the devices using the DNP 3.0 protocol.

This implementation of DNP 3.0 is fully compliant with DNP 3.0 Subset Definition Level 2. It also contains many Subset Level 3 and above features.

6.3.8.1   DNP3 DEVICE PROFILE TABLE

The following table provides the device profile in a similar format to that defined in the DNP 3.0 Subset Definitions Document. While it is referred to in the DNP 3.0 Subset Definitions as a "Document", it is just one component of a total interoperability guide. This table, in combination with the subsequent Implementation and Points List tables should provide a complete interoperability/configuration guide for the device.

The following table provides the device profile in a similar format to that defined in the DNP 3.0 Subset Definitions Document. While it is referred to in the DNP 3.0 Subset Definitions as a "Document", it is just one component of a total interoperability guide. This table, in combination with the subsequent Implementation and Points List tables should provide a complete interoperability/configuration guide for the device.

DNP 3.0 Device Profile Document	
Vendor Name:	General Electric
Device Name:	MiCOM P40Agile Protection Relays – compact and modular range
Models Covered:	All models
Highest DNP Level Supported*: *This is the highest DNP level FULLY supported. Parts of level 3 are also supported	For Requests: Level 2 For Responses: Level 2
Device Function:	Slave
Notable objects, functions, and/or qualifiers supported in addition to the highest DNP levels supported (the complete list is described in the DNP 3.0 Implementation Table): For static (non-change event) object requests, request qualifier codes 00 and 01 (start-stop), 07 and 08 (limited quantity), and 17 and 28 (index) are supported in addition to the request qualifier code 06 (no range (all points)) Static object requests sent with qualifiers 00, 01, 06, 07, or 08 will be responded with qualifiers 00 or 01 Static object requests sent with qualifiers 17 or 28 will be responded with qualifiers 17 or 28 For change-event object requests, qualifiers 17 or 28 are always responded 16-bit and 32-bit analogue change events with time may be requested The read function code for Object 50 (time and date) variation 1 is supported Analogue Input Deadbands, Object 34, variations 1 through 3, are supported Floating Point Analogue Output Status and Output Block Objects 40 and 41 are supported Sequential file transfer, Object 70, variations 2 through 7, are supported Device Attribute Object 0 is supported	
Maximum Data Link Frame Size (octets):	Transmitted: 292 Received: 292
Maximum Application Fragment Size (octets)	Transmitted: Configurable (100 to 2048). Default 2048 Received: 249

DNP 3.0 Device Profile Document	
Maximum Data Link Retries:	Fixed at 2
Maximum Application Layer Retries:	None
Requires Data Link Layer Confirmation:	Configurable to Never or Always
Requires Application Layer Confirmation:	When reporting event data (Slave devices only) When sending multi-fragment responses (Slave devices only)
Timeouts while waiting for:	
Data Link Confirm:	Configurable
Complete Application Fragment:	None
Application Confirm:	Configurable
Complete Application Response:	None
Others:	
Data Link Confirm Timeout:	Configurable from 0 (Disabled) to 120s, default 10s.
Application Confirm Timeout:	Configurable from 1 to 120s, default 2s.
Select/Operate Arm Timeout:	Configurable from 1 to 10s, default 10s.
Need Time Interval (Set IIN1-4):	Configurable from 1 to 30, default 10min.
Application File Timeout	60 s
Analog Change Event Scan Period:	Fixed at 0.5s
Counter Change Event Scan Period	Fixed at 0.5s
Frozen Counter Change Event Scan Period	Fixed at 1s
Maximum Delay Measurement Error:	2.5 ms
Time Base Drift Over a 10-minute Interval:	7 ms
Sends/Executes Control Operations:	
Write Binary Outputs:	Never
Select/Operate:	Always
Direct Operate:	Always
Direct Operate - No Ack:	Always
Count > 1	Never
Pulse On	Always
Pulse Off	Sometimes
Latch On	Always
Latch Off	Always
Queue	Never
Clear Queue	Never
Note: Paired Control points will accept Pulse On/Trip and Pulse On/Close, but only single point will accept the Pulse Off control command.	
Reports Binary Input Change Events when no specific variation requested:	Configurable to send one or the other
Reports time-tagged Binary Input Change Events when no specific variation requested:	Binary input change with time
Sends Unsolicited Responses:	Never
Sends Static Data in Unsolicited Responses:	Never No other options are permitted
Default Counter Object/Variation:	Configurable, Point-by-point list attached Default object: 20 Default variation: 1

DNP 3.0 Device Profile Document	
Counters Roll Over at:	32 bits
Sends multi-fragment responses:	Yes
Sequential File Transfer Support:	
Append File Mode	No
Custom Status Code Strings	No
Permissions Field	Yes
File Events Assigned to Class	No
File Events Send Immediately	Yes
Multiple Blocks in a Fragment	No
Max Number of Files Open	1

6.3.8.2   DNP3 IMPLEMENTATION TABLE

The implementation table provides a list of objects, variations and control codes supported by the device:

Object			Request (Library will parse)				Response (Library will respond with)			
Object Number	Variation Number	Description	Function Codes (dec)		Qualifier Codes (hex)		Function Codes (dec)		Qualifier Codes (hex)	
1	0	Binary Input (Variation 0 is used to request default variation)	1 22	(read) (assign class)	00, 01 06 07, 08 17, 27, 28	(start-stop) (no range, or all) (limited qty) (index)				
1	1 (default - see note 1)	Binary Input	1	(read)	00, 01 06 07, 08 17, 27, 28	(start-stop) (no range, or all) (limited qty) (index)	129	response	00, 01 17, 28	(start-stop) (index - see note 2)
1	2	Binary Input with Flag	1	(read)	00, 01 06 07, 08 17, 28	(start-stop) (no range, or all) (limited qty) (index)	129	response	00, 01 17, 28	(start-stop) (index - see note 2)
2	0	Binary Input Change - Any Variation	1	(read)	06 07, 08	(no range, or all) (limited qty)				
2	1	Binary Input Change without Time	1	(read)	06 07, 08	(no range, or all) (limited qty)	129	response	17, 28	(index)
2	2	Binary Input Change with Time	1	(read)	06 07, 08	(no range, or all) (limited qty)	129	response	17, 28	(index)
10	0	Binary Output Status - Any Variation	1	(read)	00, 01 06 07, 08 17, 27, 28	(start-stop) (no range, or all) (limited qty) (index)				
10	2 (default - see note 1)	Binary Output Status	1	(read)	00, 01 06 07, 08 17, 28	(start-stop) (no range, or all) (limited qty) (index)	129	response	00, 01 17, 28	(start-stop) (index - see note 2)
12	1	Control Relay Output Block	3 4 5 6	(select) (operate) (direct op) (dir. op, noack)	17, 28	(index)	129	response		echo of request
20	0	Binary Counter - Any Variation	1 22	(read) (assign class)	00, 01 06 07, 08 17, 27, 28	(start-stop) (no range, or all) (limited qty) (index)				
			7 8 9 10	(freeze) (freeze noack) (freeze clear) (frz. cl. Noack)	00, 01 06 07, 08	(start-stop) (no range, or all) (limited qty)				
20	1	32-Bit Binary Counter with Flag	1	(read)	00, 01 06 07, 08 17, 27, 28	(start-stop) (no range, or all) (limited qty) (index)	129	response	00, 01 17, 28	(start-stop) (index - see note 2)

Object			Request (Library will parse)				Response (Library will respond with)			
Object Number	Variation Number	Description	Function Codes (dec)		Qualifier Codes (hex)		Function Codes (dec)		Qualifier Codes (hex)	
20	2	16-Bit Binary Counter with Flag	1	(read)	00, 01 06 07, 08 17, 27, 28	(start-stop) (no range, or all) (limited qty) (index)	129	response	00, 01 17, 28	(start-stop) (index - see note 2)
20	5 (default - see note 1)	32-Bit Binary Counter without Flag	1	(read)	00, 01 06 07, 08 17, 27, 28	(start-stop) (no range, or all) (limited qty) (index)	129	response	00, 01 17, 28	(start-stop) (index - see note 2)
20	6	16-Bit Binary Counter without Flag	1	(read)	00, 01 06 07, 08 17, 27, 28	(start-stop) (no range, or all) (limited qty) (index)	129	response	00, 01 17, 28	(start-stop) (index - see note 2)
21	0	Frozen Counter - Any Variation	1	(read)	00, 01 06 07, 08 17, 27, 28	(start-stop) (no range, or all) (limited qty) (index)				
21	1	32-Bit Frozen Counter with Flag	1	(read)	00, 01 06 07, 08 17, 27, 28	(start-stop) (no range, or all) (limited qty) (index)	129	response	00, 01 17, 28	(start-stop) (index - see note 2)
21	2	16-Bit Frozen Counter with Flag	1	(read)	00, 01 06 07, 08 17, 27, 28	(start-stop) (no range, or all) (limited qty) (index)	129	response	00, 01 17, 28	(start-stop) (index - see note 2)
21	5	32-Bit Frozen Counter with Time of Freeze	1	(read)	00, 01 06 07, 08 17, 27, 28	(start-stop) (no range, or all) (limited qty) (index)	129	response	00, 01 17, 28	(start-stop) (index - see note 1)
21	6	16-Bit Frozen Counter with Time of Freeze	1	(read)	00, 01 06 07, 08 17, 27, 28	(start-stop) (no range, or all) (limited qty) (index)	129	response	00, 01 17, 28	(start-stop) 17, 28 (index - see note 1)
21	9 (default - see note 1)	32-Bit Frozen Counter without Flag	1	(read)	00, 01 06 07, 08 17, 27, 28	(start-stop) (no range, or all) (limited qty) (index)	129	response	00, 01 17, 28	(start-stop) (index - see note 2)
21	10	16-Bit Frozen Counter without Flag	1	(read)	00, 01 06 07, 08 17, 27, 28	(start-stop) (no range, or all) (limited qty) (index)	129	response	00, 01 17, 28	(start-stop) (index - see note 2)
`22	0	Counter Change Event - Any Variation	1	(read)	06 07, 08	(no range, or all) (limited qty)				
22	1 (default - see note 1)	32-Bit Counter Change Event without Time	1	(read)	06 07, 08	(no range, or all) (limited qty)	129	response	17, 28	(index)
22	2	16-Bit Counter Change Event without Time	1	(read)	06 07, 08	(no range, or all) (limited qty)	129	response	17, 28	(index)
22	5	32-Bit Counter Change Event with Time	1	(read)	06 07, 08	(no range, or all) (limited qty)	129	response	17, 28	(index)
22	6	16-Bit Counter Change Event with Time	1	(read)	06 07, 08	(no range, or all) (limited qty)	129	response	17, 28	(index)
23	0	Frozen Counter Event (Variation 0 is used to request default variation)	1	(read)	06 07, 08	(no range, or all) (limited qty)				
23	1 (default - see note 1)	32-Bit Frozen Counter Event	1	(read)	06 07, 08	(no range, or all) (limited qty)	129	response	17, 28	(index)
23	2	16-Bit Frozen Counter Event	1	(read)	06 07, 08	(no range, or all) (limited qty)	129	response	17, 28	(index)
23	5	32-Bit Frozen Counter Event with Time	1	(read)	06 07, 08	(no range, or all) (limited qty)	129	response	17, 28	(index)
23	6	16-Bit Frozen Counter Event with Time	1	(read)	06 07, 08	(no range, or all) (limited qty)	129	response	17, 28	(index)
30	0	Analog Input - Any Variation	1 22	(read) (assign class)	00, 01 06 07, 08 17, 27, 28	(start-stop) (no range, or all) (limited qty) (index)				

Object			Request (Library will parse)				Response (Library will respond with)			
Object Number	Variation Number	Description	Function Codes (dec)		Qualifier Codes (hex)		Function Codes (dec)		Qualifier Codes (hex)	
30	1	32-Bit Analog Input	1	(read)	00, 01 06 07, 08 17, 27, 28	(start-stop) (no range, or all) (limited qty) (index)	129	response	00, 01 17, 28	(start-stop) (index - see note 2)
30	2	16-Bit Analog Input	1	(read)	00, 01 06 07, 08 17, 27, 28	(start-stop) (no range, or all) (limited qty) (index)	129	response	00, 01 17, 28	(start-stop) (index - see note 2)
30	3 (default - see note 1)	32-Bit Analog Input without Flag	1	(read)	00, 01 06 07, 08 17, 27, 28	(start-stop) (no range, or all) (limited qty) (index)	129	response	00, 01 17, 28	(start-stop) (index - see note 2)
30	4	16-Bit Analog Input without Flag	1	(read)	00, 01 06 07, 08 17, 27, 28	(start-stop) (no range, or all) (limited qty) (index)	129	response	00, 01 17, 28	(start-stop) (index - see note 2)
30	5	Short floating point	1	(read)	00, 01 06 07, 08 17, 27, 28	(start-stop) (no range, or all) (limited qty) (index)	129	response	00, 01 17, 28	(start-stop) (index - see note 2)
32	0	Analog Change Event - Any Variation	1	(read)	06 07, 08	(no range, or all) (limited qty)				
32	1 (default - see note 1)	32-Bit Analog Change Event without Time	1	(read)	06 07, 08	(no range, or all) (limited qty)	129	response	17, 28	(index)
32	2	16-Bit Analog Change Event without Time	1	(read)	06 07, 08	(no range, or all) (limited qty)	129	response	17, 28	(index)
32	3	32-Bit Analog Change Event with Time	1	(read)	06 07, 08	(no range, or all) (limited qty)	129	response	17, 28	(index)
32	4	16-Bit Analog Change Event with Time	1	(read)	06 07, 08	(no range, or all) (limited qty)	129	response	17, 28	(index)
32	5	Short floating point Analog Change Event without Time	1	(read)	06 07, 08	(no range, or all) (limited qty)	129	response	17, 28	(index)
32	7	Short floating point Analog Change Event with Time	1	(read)	06 07, 08	(no range, or all) (limited qty)	129	response	17, 28	(index)
34	0	Analog Input Deadband (Variation 0 is used to request default variation)	1	(read)	00, 01 06 07, 08 17, 27, 28	(start-stop) (no range, or all) (limited qty) (index)				
34	1	16 Bit Analog Input Deadband	1	(read)	00, 01 06 07, 08 17, 27, 28	(start-stop) (no range, or all) (limited qty) (index)	129	response	00, 01 17, 28	(start-stop) (index - see note 2)
			2	(write)	00, 01 07, 08 17, 27, 28	(start-stop) (limited qty) (index)				
34	2 (default - see note 1)	32 Bit Analog Input Deadband	1	(read)	00, 01 06 07, 08 17, 27, 28	(start-stop) (no range, or all) (limited qty) (index)	129	response	00, 01 17, 28	(start-stop) (index - see note 2)
			2	(write)	00, 01 07, 08 17, 27, 28	(start-stop) (limited qty) (index)				
34	3	Short Floating Point Analog Input Deadband	1	(read)	00, 01 06 07, 08 17, 27, 28	(start-stop) (no range, or all) (limited qty) (index)	129	response	00, 01 17, 28	(start-stop) (index - see note 2)
			2	(write)	00, 01 07, 08 17, 27, 28	(start-stop) (limited qty) (index)				
40	0	Analog Output Status (Variation 0 is used to request default variation)	1	(read)	00, 01 06 07, 08 17, 27, 28	(start-stop) (no range, or all) (limited qty) (index)				

Object			Request (Library will parse)				Response (Library will respond with)			
Object Number	Variation Number	Description	Function Codes (dec)		Qualifier Codes (hex)		Function Codes (dec)		Qualifier Codes (hex)	
40	1 (default - see note 1)	32-Bit Analog Output Status	1	(read)	00, 01 06 07, 08 17, 27, 28	(start-stop) (no range, or all) (limited qty) (index)	129	response	00, 01 17, 28	(start-stop) (index - see note 2)
40	2	16-Bit Analog Output Status	1	(read)	00, 01 06 07, 08 17, 27, 28	(start-stop) (no range, or all) (limited qty) (index)	129	response	00, 01 17, 28	(start-stop) (index - see note 2)
40	3	Short Floating Point Analog Output Status	1	(read)	00, 01 06 07, 08 17, 27, 28	(start-stop) (no range, or all) (limited qty) (index)	129	response	00, 01 17, 28	(start-stop) (index - see note 2)
41	1	32-Bit Analog Output Block	3 4 5 6	(select) (operate) (direct op) (dir. op, noack)	17, 28 27	(index) (index)	129	response		echo of request
41	2	16-Bit Analog Output Block	3 4 5 6	(select) (operate) (direct op) (dir. op, noack)	17, 28 27	(index) (index)	129	response		echo of request
41	3	Short Floating Point Analog Output Block	3 4 5 6	(select) (operate) (direct op) (dir. op, noack)	17, 27, 28	(index)	129	response		echo of request
50	1 (default - see note 1)	Time and Date	1	(read)	07	(limited qty = 1)	129	response	07	(limited qty = 1)
			2	(write)	07	(limited qty = 1)				
60	0	Not defined								
60	1	Class 0 Data	1	(read)	06	(no range, or all)				
60	2	Class 1 Data	1	(read)	06 07, 08	(no range, or all) (limited qty)				
			22	(assign class)	06	(no range, or all)				
60	3	Class 2 Data	1	(read)	06 07, 08	(no range, or all) (limited qty)				
			22	(assign class)	06	(no range, or all)				
60	4	Class 3 Data	1	(read)	06 07, 08	(no range, or all) (limited qty)				
			22	(assign class)	06	(no range, or all)				
70	0	File Event - Any Variation	1	(read)	06 07, 08	(no range, or all) (limited qty)				
			22	(assign class)	06	(no range, or all)				
70	2	File Authentication	29	(authenticate)	5b	(free-format)	129	response		5B (free-format)
70	3	File Command	25 27	(open) (delete)	5b	(free-format)				
70	4	File Command Status	26 30	(close) (abort)	5b	(free-format)	129	response		5B (free-format)
70	5	File Transfer	1	(read)	5b	(free-format)	129	response		5B (free-format)
70	6	File Transfer Status					129	response		5B (free-format)
70	7	File Descriptor	28	(get file info)	5b	(free-format)	129	response		5B (free-format)
80	1	Internal Indications	1	(read)	00, 01	(start-stop)	129	response	00, 01	(start-stop)
		No Object (function code only)	13	(cold restart)						
		No Object (function code only)	14	(warm restart)						
		No Object (function code only)	23	(delay meas.)						

> *Note:*
> *A Default variation refers to the variation responded to when variation 0 is requested and/or in class 0, 1, 2, or 3 scans.*

> *Note:*
> *For static (non-change-event) objects, qualifiers 17 or 28 are only responded to when a request is sent with qualifiers 17 or 28, respectively. Otherwise, static object requests sent with qualifiers 00, 01, 06, 07, or 08, will be responded to with qualifiers 00 or 01. For change-event objects, qualifiers 17 or 28 are always responded to.*

6.3.8.3   DNP3 INTERNAL INDICATIONS

The following table lists the DNP3.0 Internal Indications (IIN) and identifies those that are supported by the device.

The IIN form an information element used to convey the internal states and diagnostic results of a device. This information can be used by a receiving station to perform error recovery or other suitable functions. The IIN is a two-octet field that follows the function code in all responses from the device. When a request cannot be processed due to formatting errors or the requested data is not available, the IIN is always returned with the appropriate bits set.

Bit	Indication	Description	Supported
Octet 1			
0	All stations message received	Set when a request is received with the destination address of the all stations address (6553510). It is cleared after the next response (even if a response to a global request is required). This IIN is used to let the master station know that a "broadcast" message was received by the relay.	Yes
1	Class 1 data available	Set when data that has been configured as Class 1 data is ready to be sent to the master. The master station should request this class data from the relay when this bit is set in a response.	Yes
2	Class 2 data available	Set when data that has been configured as Class 2 data is ready to be sent to the master. The master station should request this class data from the relay when this bit is set in a response.	Yes
3	Class 3 data available	Set when data that has been configured as Class 3 data is ready to be sent to the master. The master station should request this class data from the relay when this bit is set in a response.	Yes
4	Time-synchronization required	The relay requires time synchronization from the master station (using the Time and Date object). This IIN is cleared once the time has been synchronized. It can also be cleared by explicitly writing a 0 into this bit of the Internal Indication object.	Yes
5	Local	Set when some or all of the relays digital output points (Object 10/12) are in the Local state. That is, the relays control outputs are NOT accessible through the DNP protocol. This IIN is clear when the relay is in the Remote state. That is, the relays control outputs are fully accessible through the DNP protocol.	No
6	Device in trouble	Set when an abnormal condition exists in the relay. This IIN is only used when the state cannot be described by a combination of one or more of the other IIN bits.	No
7	Device restart	Set when the device software application restarts. This IIN is cleared when the master station explicitly writes a 0 into this bit of the Internal Indications object.	Yes
Octet 2			
0	Function code not implemented	The received function code is not implemented within the relay.	Yes

Bit	Indication	Description	Supported
1	Requested object(s) unknown	The relay does not have the specified objects or there are no objects assigned to the requested class. This IIN should be used for debugging purposes and usually indicates a mismatch in device profiles or configuration problems.	Yes
2	Out of range	Parameters in the qualifier, range or data fields are not valid or out of range. This is a 'catch-all' for application request formatting errors. It should only be used for debugging purposes. This IIN usually indicates configuration problems.	Yes
3	Buffer overflow	Event buffer(s), or other application buffers, have overflowed. The master station should attempt to recover as much data as possible and indicate to the user that there may be lost data. The appropriate error recovery procedures should be initiated by the user.	Yes
4	Already executing	The received request was understood but the requested operation is already executing.	
5	Bad configuration	Set to indicate that the current configuration in the relay is corrupt. The master station may download another configuration to the relay.	Yes
6	Reserved	Always returned as zero.	
7	Reserved	Always returned as zero.	

6.3.8.4   DNP3 RESPONSE STATUS CODES

When the device processes Control Relay Output Block (Object 12) requests, it returns a set of status codes; one for each point contained within the original request. The complete list of codes appears in the following table:

Code Number	Identifier Name	Description
0	Success	The received request has been accepted, initiated, or queued.
1	Timeout	The request has not been accepted because the 'operate' message was received after the arm timer (Select Before Operate) timed out. The arm timer was started when the select operation for the same point was received.
2	No select	The request has not been accepted because no previous matching 'select' request exists. (An 'operate' message was sent to activate an output that was not previously armed with a matching 'select' message).
3	Format error	The request has not been accepted because there were formatting errors in the control request ('select', 'operate', or 'direct operate').
4	Not supported	The request has not been accepted because a control operation is not supported for this point.
5	Already active	The request has not been accepted because the control queue is full or the point is already active.
6	Hardware error	The request has not been accepted because of control hardware problems.
7	Local	The request has not been accepted because local access is in progress.
8	Too many operations	The request has not been accepted because too many operations have been requested.
9	Not authorized	The request has not been accepted because of insufficient authorization.
127	Undefined	The request not been accepted because of some other undefined reason.

> Note:
> Code numbers 10 through to 126 are reserved for future use.

6.3.9   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 Relay 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 affects 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 on the IED.

```
COMMUNICATIONS
RP1 Time Sync
Enabled
```

6.3.9.1   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.

If the device supports DNP Over Ethernet, the configuration related settings are done in the folder **DNP Over Ethernet**.

6.3.10 DNP3 UNSOLICITED REPORTING

In previous versions, DNP3 only supports data transmission based on poll requests from the master station. From this version onwards, a new mode of transmission called Unsolicited Reporting is supported. This is a mode of operation where the outstation spontaneously transmits a response without having received a specific request for data. This mode is useful when the system has many outstations and the master requires notification as soon as possible after a change occurs. Rather than waiting for a master station polling cycle, the outstation transmits the change immediately. It is thus event driven rather than poll driven.

This feature requires a new group of settings, which are found under the DNP SETTINGS column (Courier cell range 1B). These can be found in the settings tables available as an interactive PDF at the back of the manual.

> *Note:*
> *We advise you not to enable Unsolicited Reporting on a serial multi-drop line. This is due the fact that collisions may result from multiple IEDs reporting concurrent events. If Unsolicited Reporting is enabled on a serial line, we recommend connecting only one IED per master link. This restriction is not applicable if DNP3 Over Ethernet is used.*

6.4 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 see the Modbus web site (www.modbus.org).

6.4.1 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).

6.4.2 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)

6.4.3   RESPONSE CODES

MCode	MODBUS Description	MiCOM Interpretation
01	Illegal Function Code	The function code transmitted is not supported by the slave.
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.

6.4.4   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.*

6.4.5 EVENT EXTRACTION

The device supports two methods of event extraction providing either automatic or manual extraction of the stored event, fault, and maintenance records.

6.4.5.1 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.

6.4.5.2 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.

6.4.5.3 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.

Event Description	MODBUS Address	Length	Comments
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.

6.4.6 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.

MODBUS Register	Name	Description
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.

6.4.6.1   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.
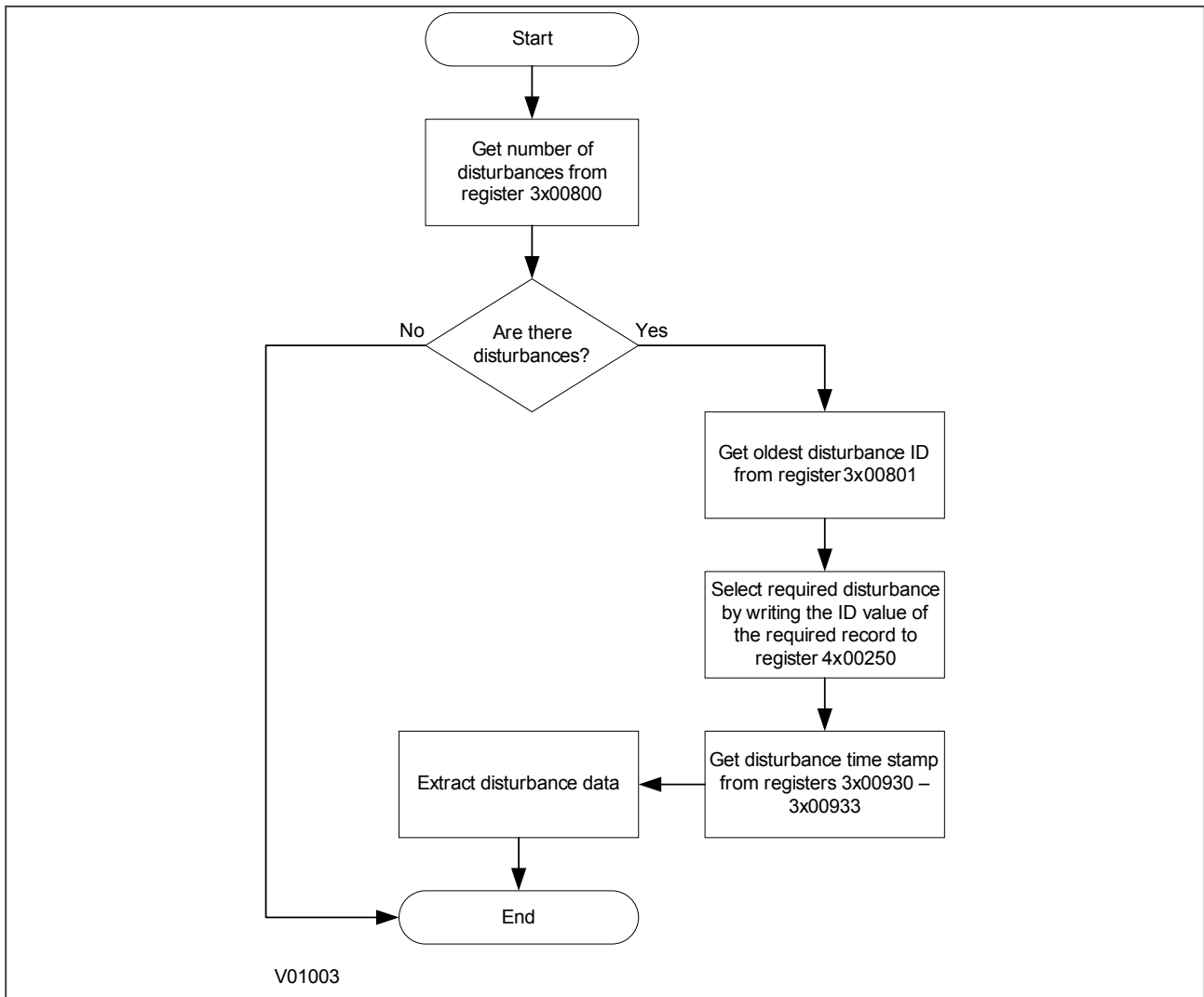
Figure 153: Manual selection of a disturbance record

6.4.6.2   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).
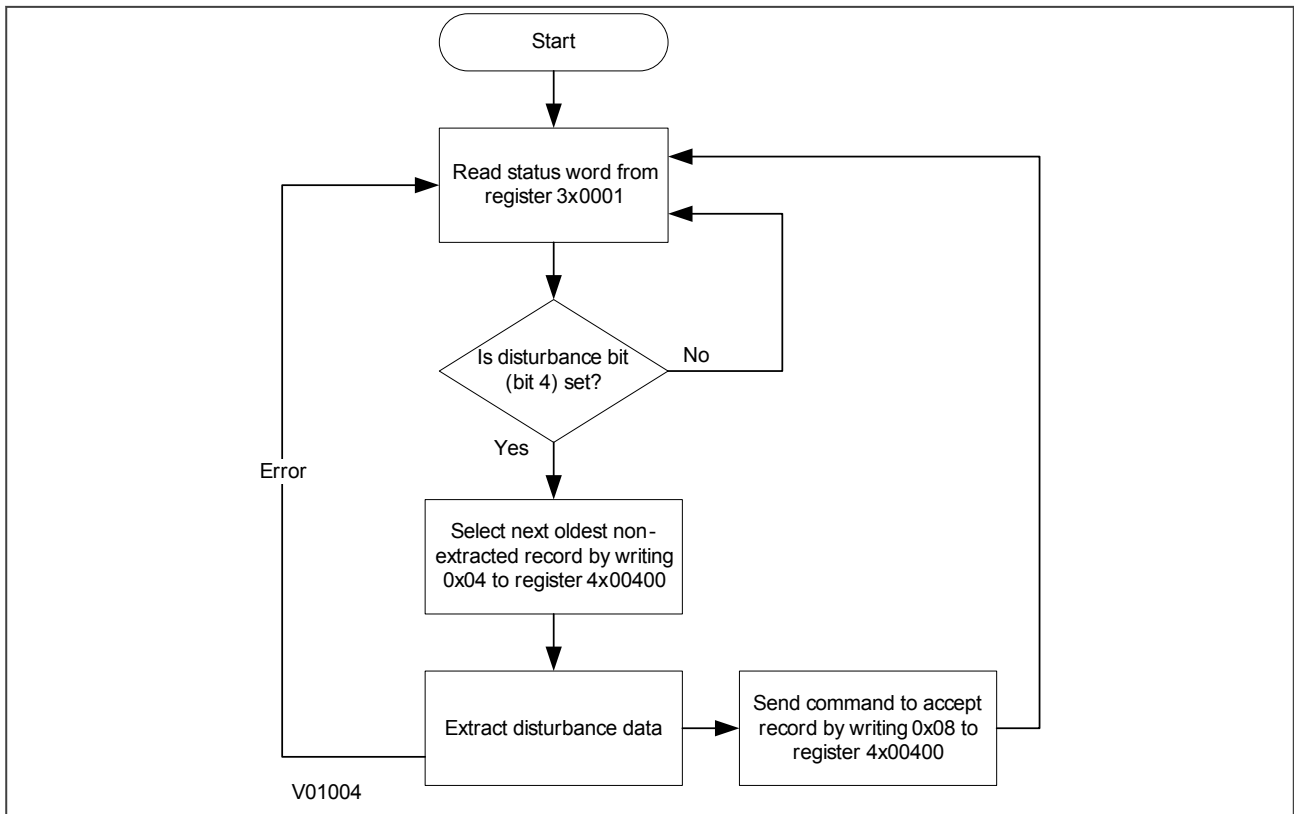
Figure 154: Automatic selection of disturbance record - method 1

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.
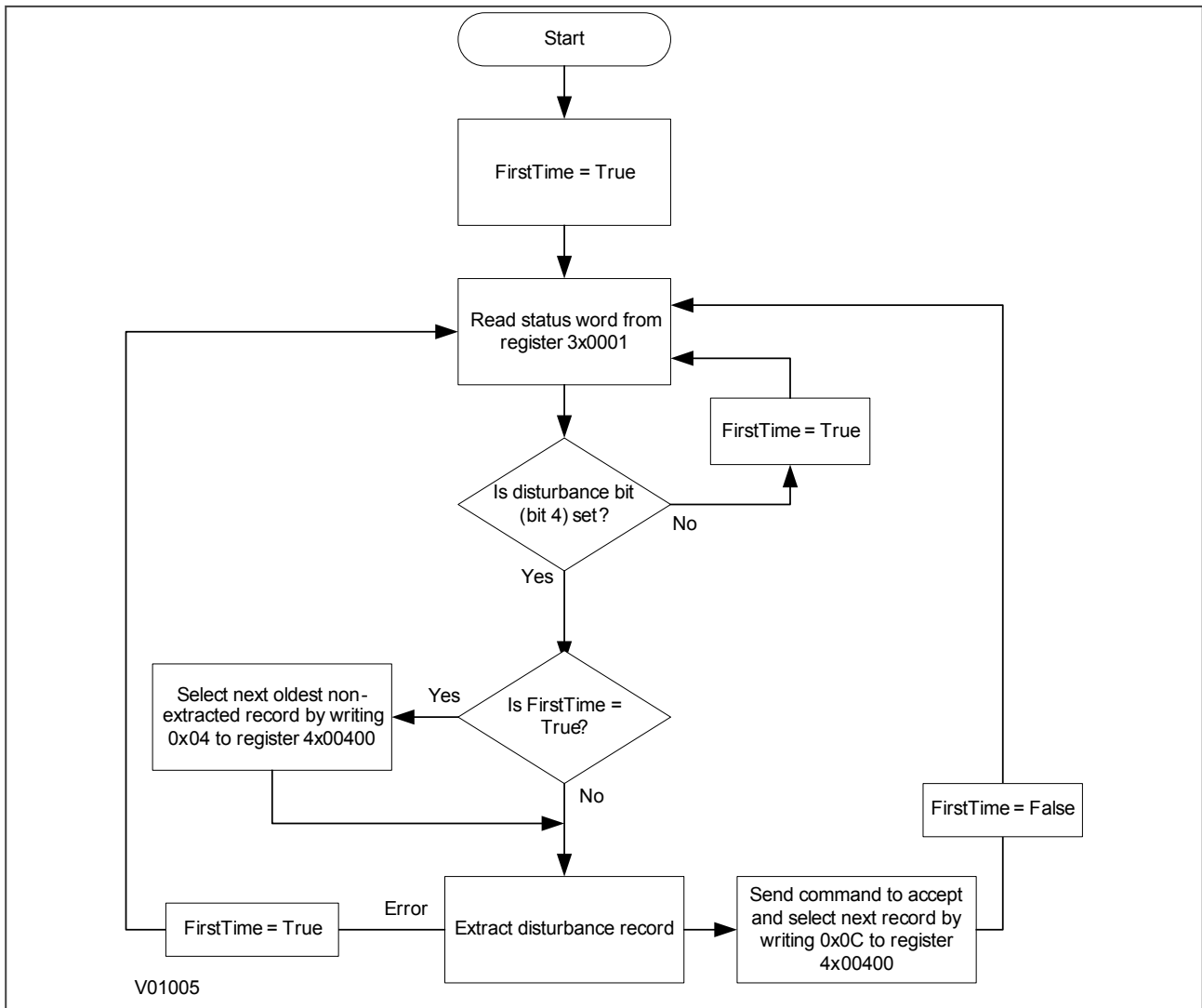
Figure 155: Automatic selection of disturbance record - method 2

6.4.6.3   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
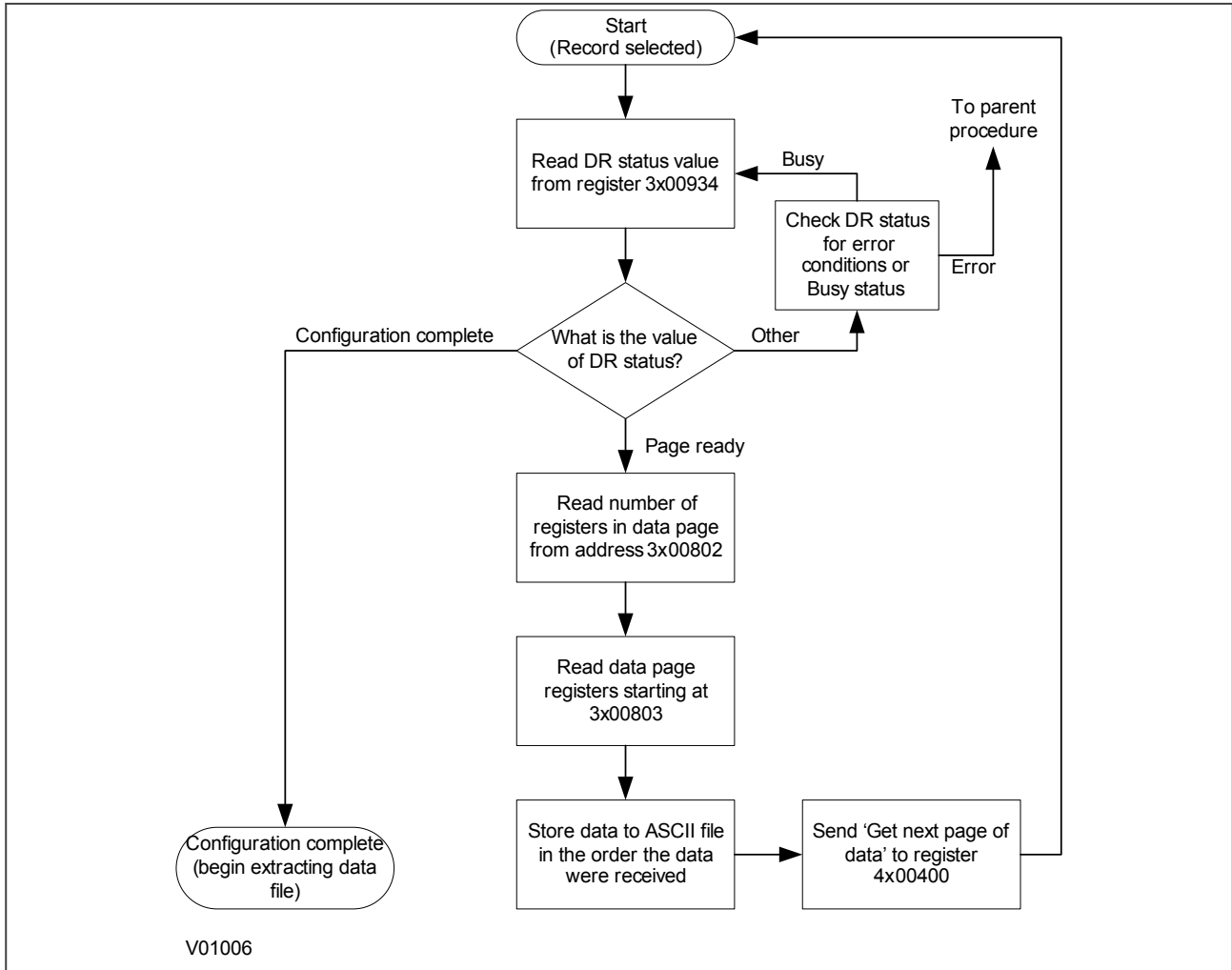
Figure 156: Configuration file extraction

Extracting the comtrade data file
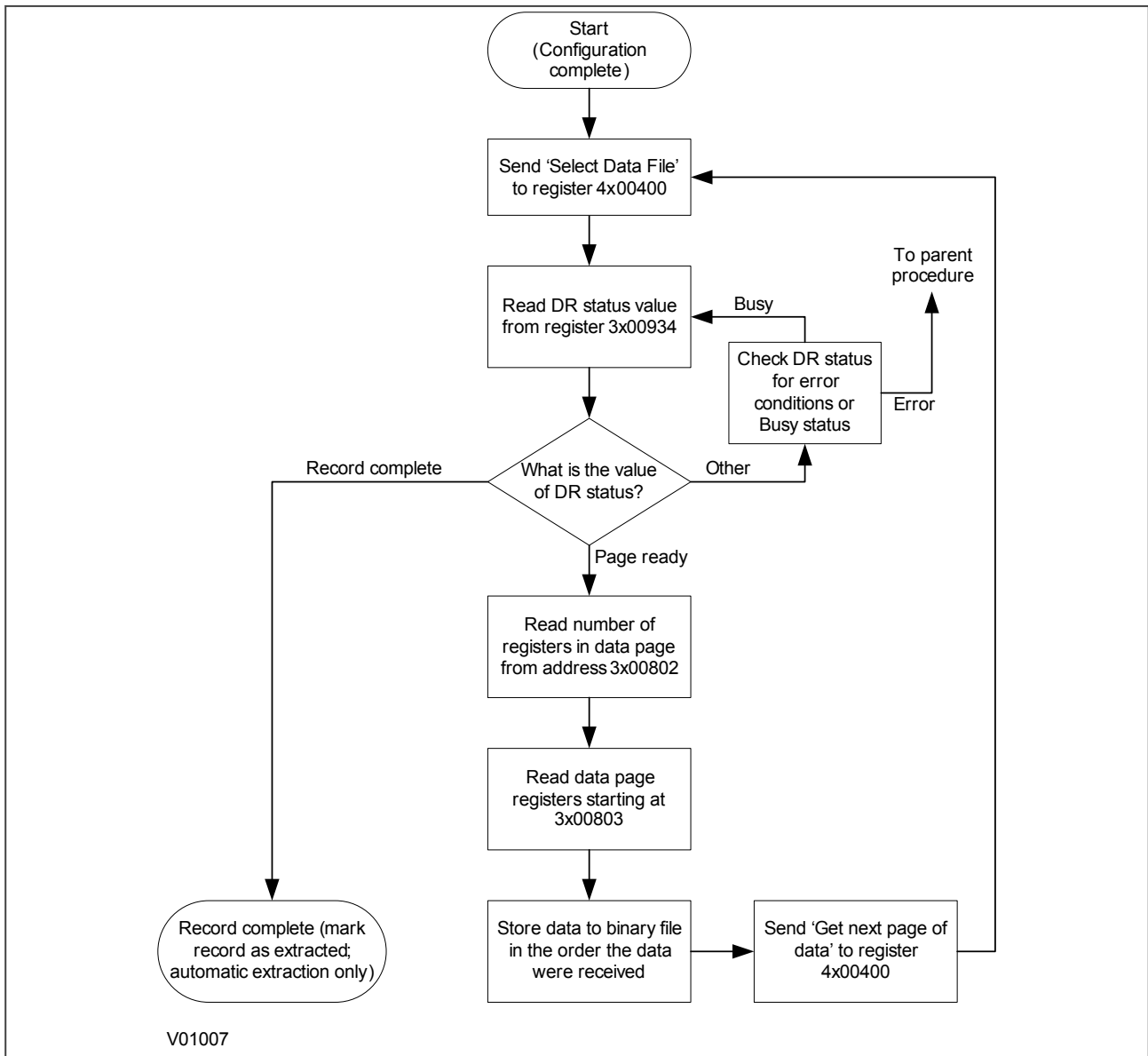
Figure 157: Data file extraction

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.

6.4.7   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.

6.4.8   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

6.4.9   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.

6.4.10   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

Byte	Bit Position							
	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).

6.4.11   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 × 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

Register Address	Data read from these registers	Format of the data
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.

6.4.12   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 Relay 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
```

6.5   IEC 61850

This section describes how the IEC 61850 standard is applied to General Electric 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.

There are two editions of IEC 61850; IEC 61850 edition 1 and IEC 61850 edition 2. The edition which this product supports depends on your exact model.

6.5.1   BENEFITS OF IEC 61850

The standard provides:

- Standardised models for IEDs and other equipment within the substation
- Standardised communication services (the methods used to access and exchange data)
- Standardised 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)

6.5.2   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.

6.5.3   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.
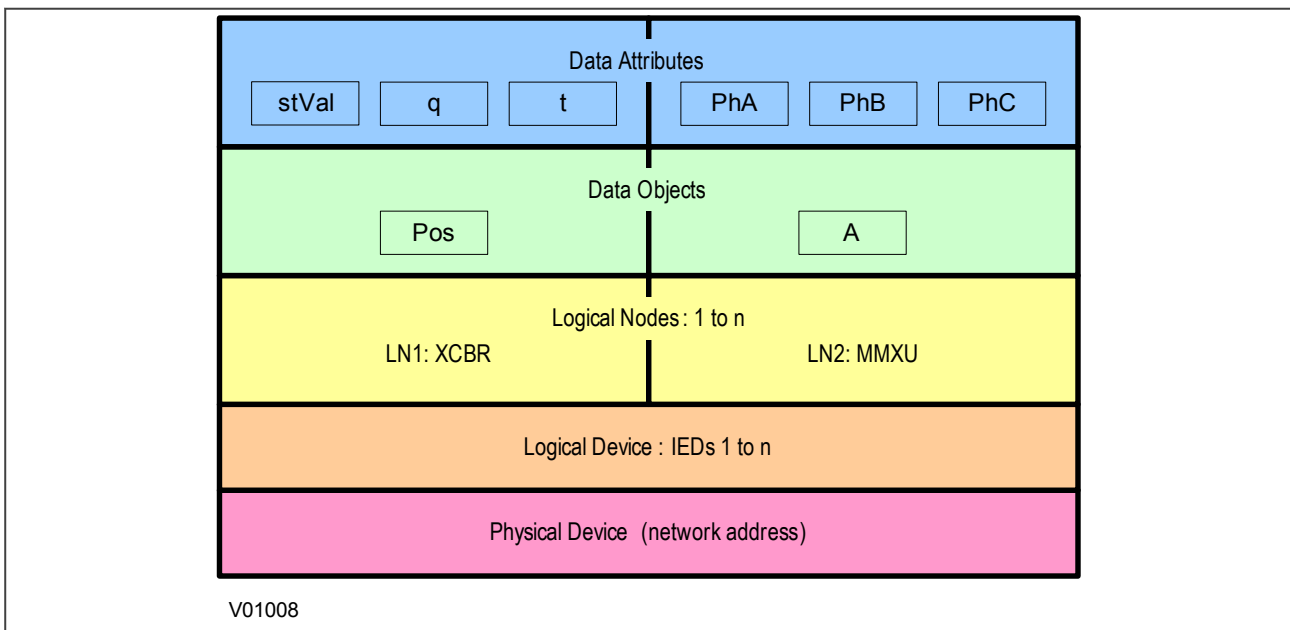
Figure 158: Data model layers in IEC 61850

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.

Layer	Description
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.

6.5.4   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 the settings application software.*

6.5.5   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.

6.5.6   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.

6.5.7   IEC 61850 PEER-TO-PEER (GOOSE) 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 selected devices on the network. 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.

6.5.8   MAPPING GOOSE MESSAGES TO VIRTUAL INPUTS

Each GOOSE signal contained in a subscribed GOOSE message can be mapped to any of the 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

6.5.8.1   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.

6.5.9   ETHERNET FUNCTIONALITY

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.

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.

6.5.9.1   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.

6.5.9.2   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.

6.5.10   IEC 61850 CONFIGURATION

You cannot configure the device for IEC 61850 edition 1 using the HMI panel on the product. For this you must use the IEC 61850 Configurator, which is part of the settings application software. If the device is compatible with edition 2, however, you can configure it with the HMI. To configure IEC61850 edition 2 using the HMI, you must first enable the IP From HMI setting, after which you can set the media (copper or fibre), IP address, subnet mask and gateway address.

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.*

6.5.10.1   IEC 61850 CONFIGURATION BANKS

There are two configuration banks:

- 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.

Following an upgrade, 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 available in the *IEC61850 CONFIG.* column of the HMI.

6.5.10.2   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.

6.6   CONCURRENT IEC 61850 AND DNP3.0 OPERATION

No Redundancy

Simultaneous IEC 61850 and DNP3.0 operation may be achieved using single or dual IP addresses.

Where concurrent IEC61850 & DNP3 uses a dual IP address configuration (defined via ordering option), Port A is dedicated to IEC 61850 (configured with or without SNTP), and Port B is dedicated to DNP3.0. Configuration settings are applied via IED Configurator Communications and DNP Over Ethernet Settings respectively. In this case, no Redundancy option is available.

> *Note:*
> *SNTP may only be configured via the IED Configurator tool.*

> *Note:*
> *When concurrent IEC61850 & DNP3 uses a dual IP address configuration, the Redundancy list in the IED Configurator tool is visible but ineffective.*

Where concurrent IEC61850 & DNP3 uses a single IP address setup with no redundancy required, configuration settings are applied via the IED Configurator and DNP3 settings respectively, with Redundancy set to NONE.

With Redundancy

Simultaneous IEC 61850 and DNP3.0 with FAILOVER, RSTP, PRP or HSP Redundancy is only possible where concurrent IEC61850 & DNP3 uses a single IP address. With Redundancy set to FAILOVER, either Port A or B may be selected, but when set to RSTP, PRP or HSR redundancy protocols, IEC 61850 and DNP3.0 communications (configured with or without SNTP) no port is specified.

> *Note:*
> *Redundancy and SNTP may only be configured via the IED Configurator tool.*

> *Note:*
> *The IP address, Subnet and Gateway may be set with either configuration tool, (IED Configurator Communications or DNP3 Over Ethernet settings), but only the last values sent will be configured, as only one IP address/Subnet/Gateway is used in a single IP Address setup. It is therefore recommended that the same IP address is entered into both configuration tools.*

To confirm the network interface protocol is set to concurrent IEC 61850 and DNP3, navigate to the device's *COMMUNICATIONS* column and check that **NIC Protocol** is set to `IEC61850 & DNP3`:

```
COMMUNICATIONS
NIC Protocol
IEC61850 & DNP3
```

To confirm the IP address setting for IEC 61850, navigate to the Device's *IEC61850 CONFIG.* column and check the **IP Address** setting:

```
IEC61850 CONFIG.
IP Address
192.168.1.1
```

To confirm the IP address setting for DNP, navigate to the Device's *DNP SETTINGS* column and check the **IP Address** setting:

```
DNP SETTINGS
IP Address
192.168.1.1
```

Note:
It is recommended that a maximum of two communication protocols are configured to operate concurrently.

7   READ ONLY MODE

With IEC 61850 and Ethernet/Internet communication capabilities, security has become an important issue. For this reason, all relevant General Electric IEDs have been adapted to comply with the latest cyber-security standards.

In addition to this, a facility is provided which allows you to enable or disable the communication interfaces. This feature is available for products using Courier, IEC 60870-5-103, or IEC 61850.

7.1   IEC 60870-5-103 PROTOCOL BLOCKING

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

Note:
For IEC 60870-5-103, Read Only Mode function is different from the existing Command block feature.

7.2   COURIER PROTOCOL BLOCKING

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

7.3 IEC 61850 PROTOCOL BLOCKING

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

7.4 READ-ONLY SETTINGS

The following settings are available for enabling or disabling Read Only Mode.

- RP1 Read Only
- RP2 Read Only (only for products that have RP2)
- NIC Read Only (where Ethernet is available)

7.5 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 (only for products that have RP2)
- 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.

8   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

8.1   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.
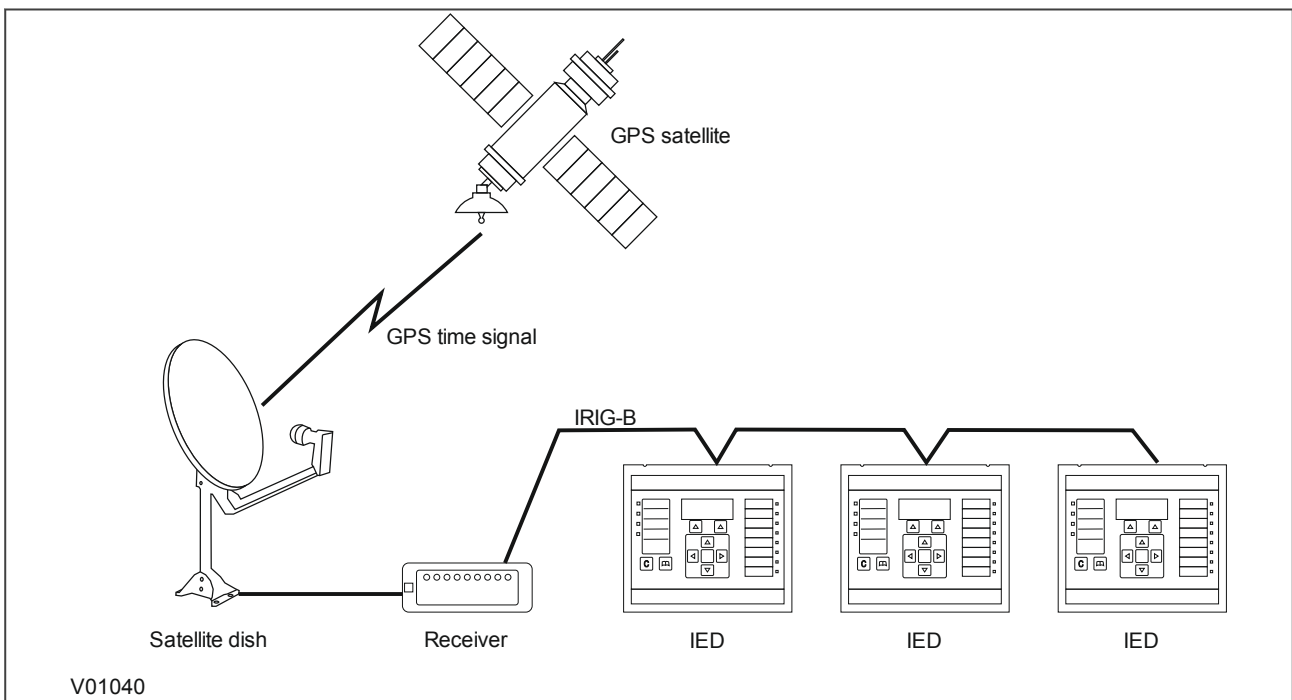
Figure 159: GPS Satellite timing signal

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).

8.1.1   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 and 40TE 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.

8.2   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 settings application software manual. A second server is also configured with a different IP address for backup purposes.

This function issues an alarm when there is a loss of time synchronisation on the SNTP server. This could be because there is no response or no valid clock signal.

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.

8.3   TIME SYNCHRONSIATION USING THE COMMUNICATION PROTOCOLS

All communication protocols have in-built time synchronisation mechanisms. If an external time synchronisation mechanism such as IRIG-B, SNTP, or IEEE 1588 PTP is not 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 section.

CHAPTER 17

CYBER-SECURITY

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 General Electric 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:	General Electric'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:	General Electric'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:	General Electric'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:	General Electric'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:	General Electric's contribution:
Provide physical security controls and perimeter monitoring. Ensure that people who have access to critical cyber assets don't have criminal records.	General Electric 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:	General Electric'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:	General Electric's contribution:
To provide an incident response team and have appropriate processes in place.	General Electric 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:	General Electric'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 General Electric 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:
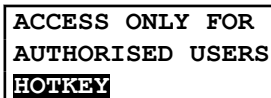
- NERC-compliant default display
- Four-level access
- Enhanced password security
- Password recovery procedure
- Disabling of unused physical and logical ports
- Inactivity timer
- Security events management

External to the IEDs, the following cyber-security measures have been implemented:

- Antivirus
- Security patch management
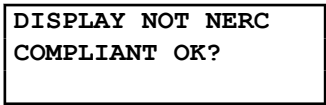
4.1   NERC-COMPLIANT DISPLAY

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.
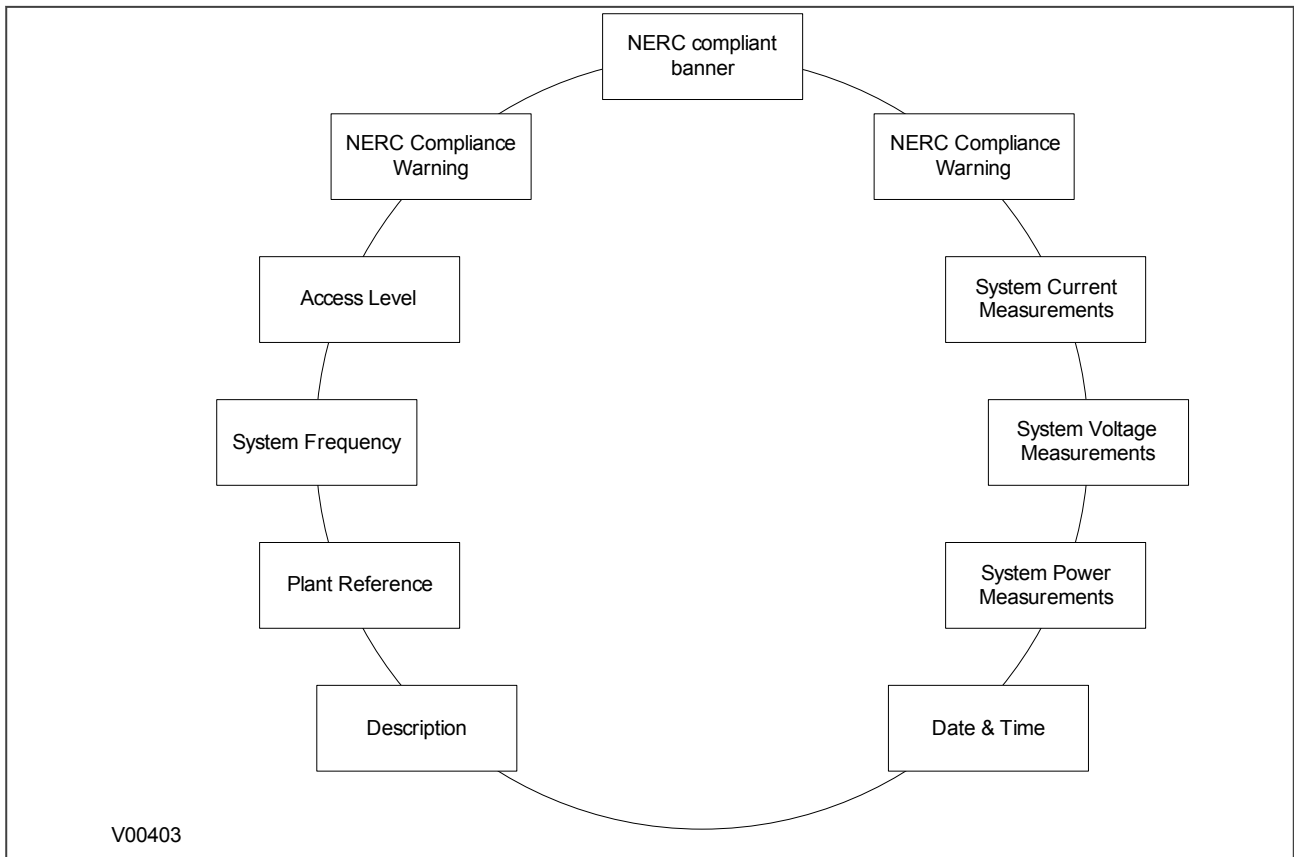
Figure 160: Default display navigation

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 addition 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
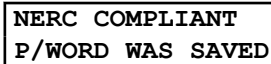
NERC compliant passwords have the following requirements:

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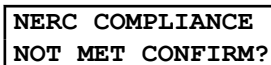
If the entered password is NERC compliant, the following text is displayed.

```
NERC COMPLIANT
P/WORD WAS SAVED
```
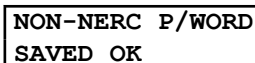
If the password entered is not NERC-compliant, the user is required to actively confirm this, in which case the non-compliance is logged.

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 Limit**, **Attempts Timer** and **Blocking Timer** settings in the *SECURITY 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   ENTRY OF THE RECOVERY PASSWORD

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 # 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.

CHAPTER 18

INSTALLATION

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 –25° to +70°C 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
- 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).

⚠ **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.

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).

⚠ **Caution:**
Risk of damage to the front cover molding. Do not use conventional self-tapping screws, including those supplied for mounting MiDOS products because they have slightly larger heads.

Once the tier is complete, the frames are fastened into the racks using mounting angles at each end of the tier.

R01400
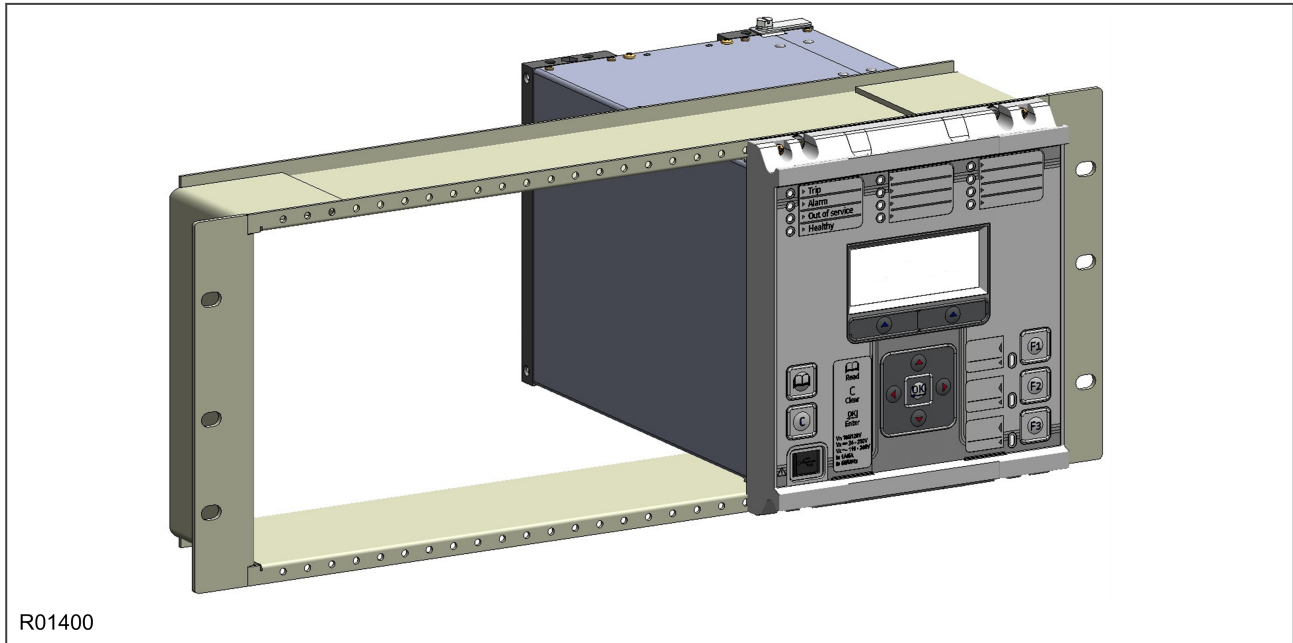
Figure 161: Rack mounting of products

Products can be mechanically grouped into single tier (4U) or multi-tier arrangements using the rack frame. This enables schemes using products from different product ranges to be pre-wired together before mounting.

Use blanking plates to fill any empty spaces. The spaces may be used for installing future products or because the total size is less than 80TE on any tier. Blanking plates can also be used to mount ancillary components. The part numbers are as follows:

Case size summation	Blanking plate part number
5TE	GJ2028 101
10TE	GJ2028 102
15TE	GJ2028 103
20TE	GJ2028 104
25TE	GJ2028 105
30TE	GJ2028 106
35TE	GJ2028 107
40TE	GJ2028 108

3.2   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 General Electric 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 162: 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

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:
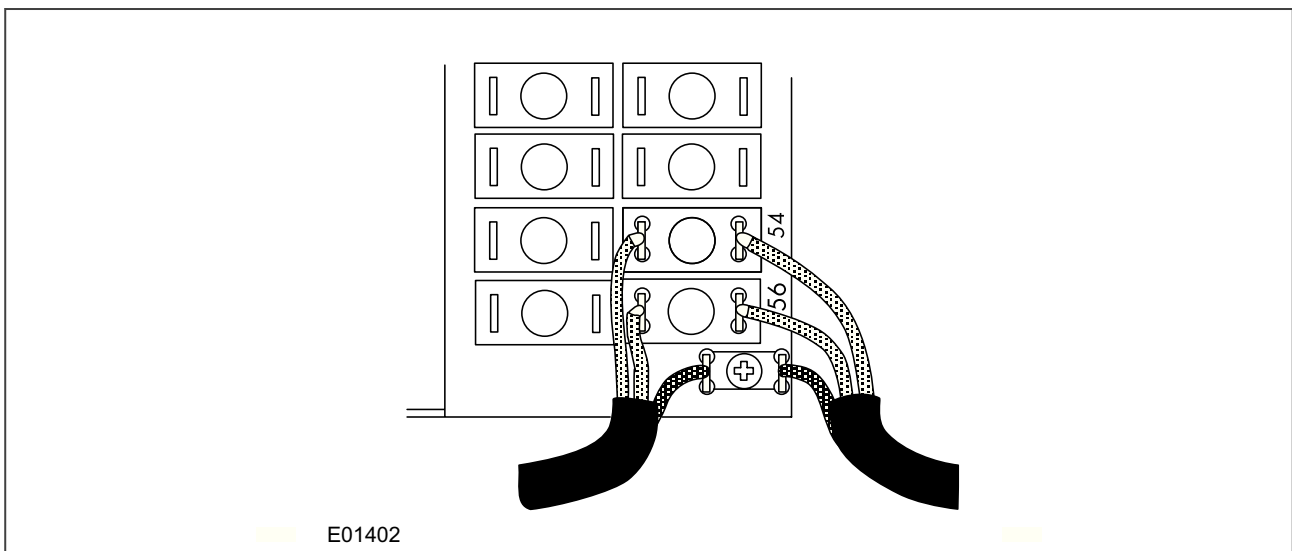
Figure 163: Earth link for cable screen

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
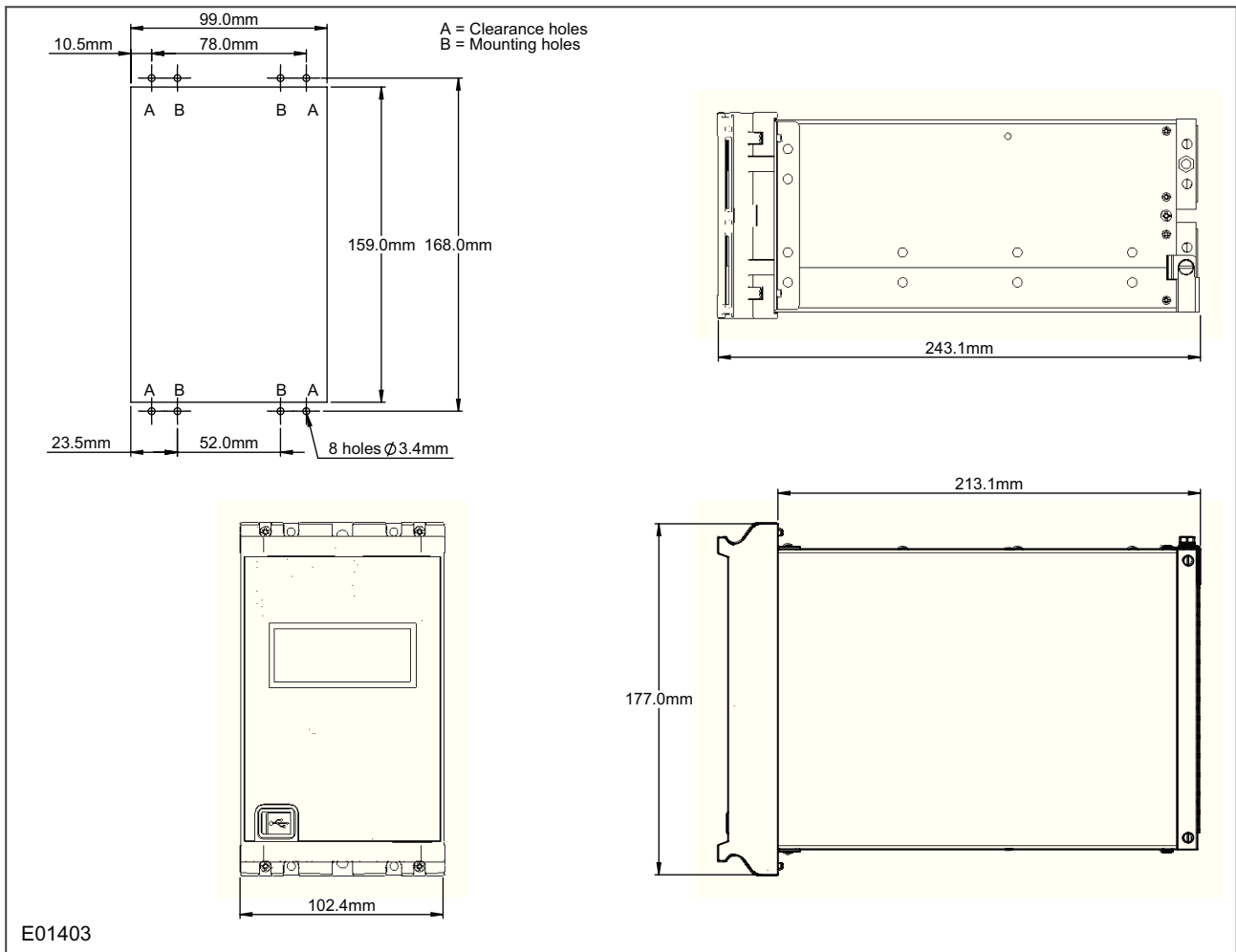
Figure 164: 20TE case dimensions
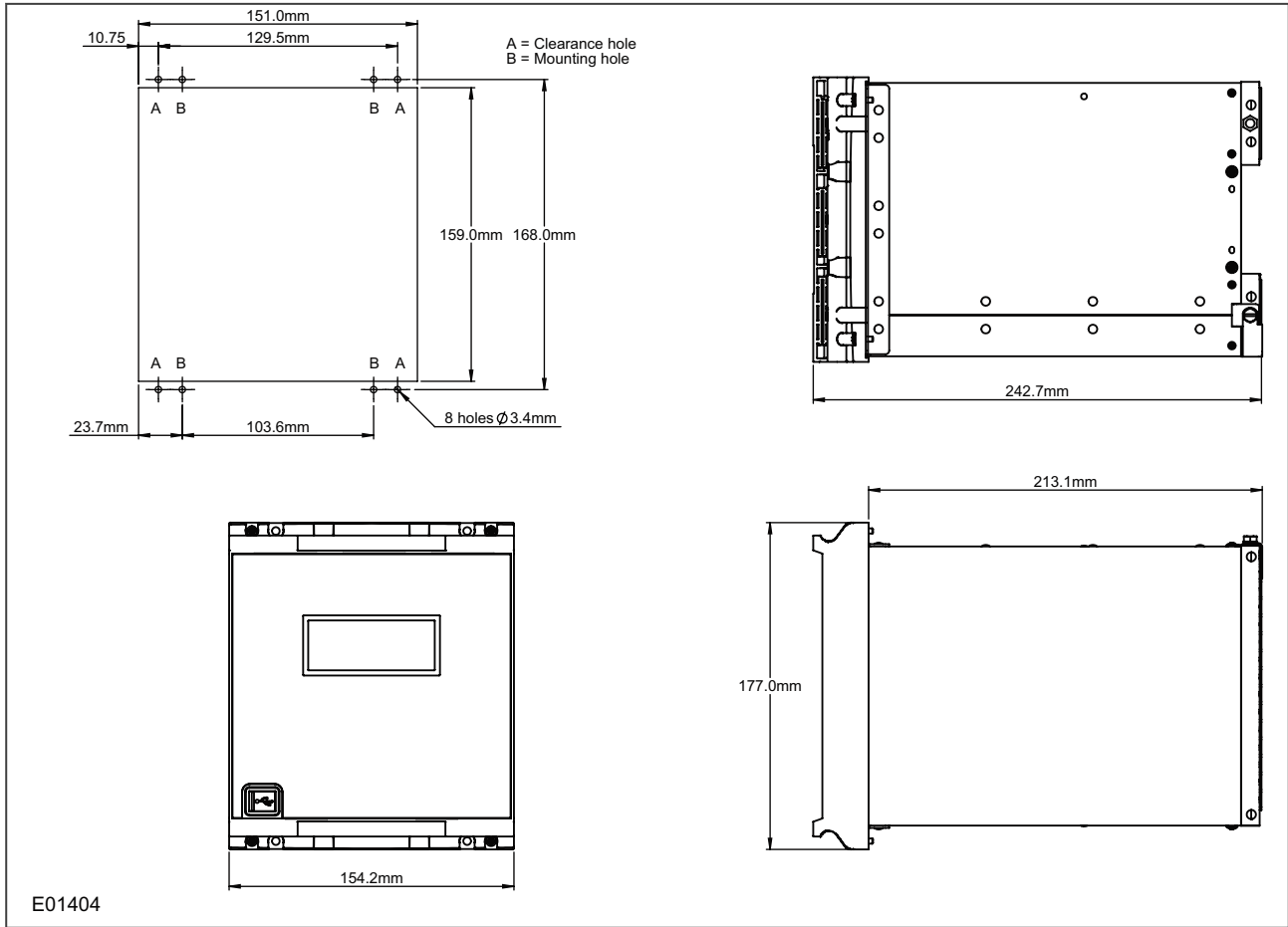
Figure 165: 30TE case dimensions
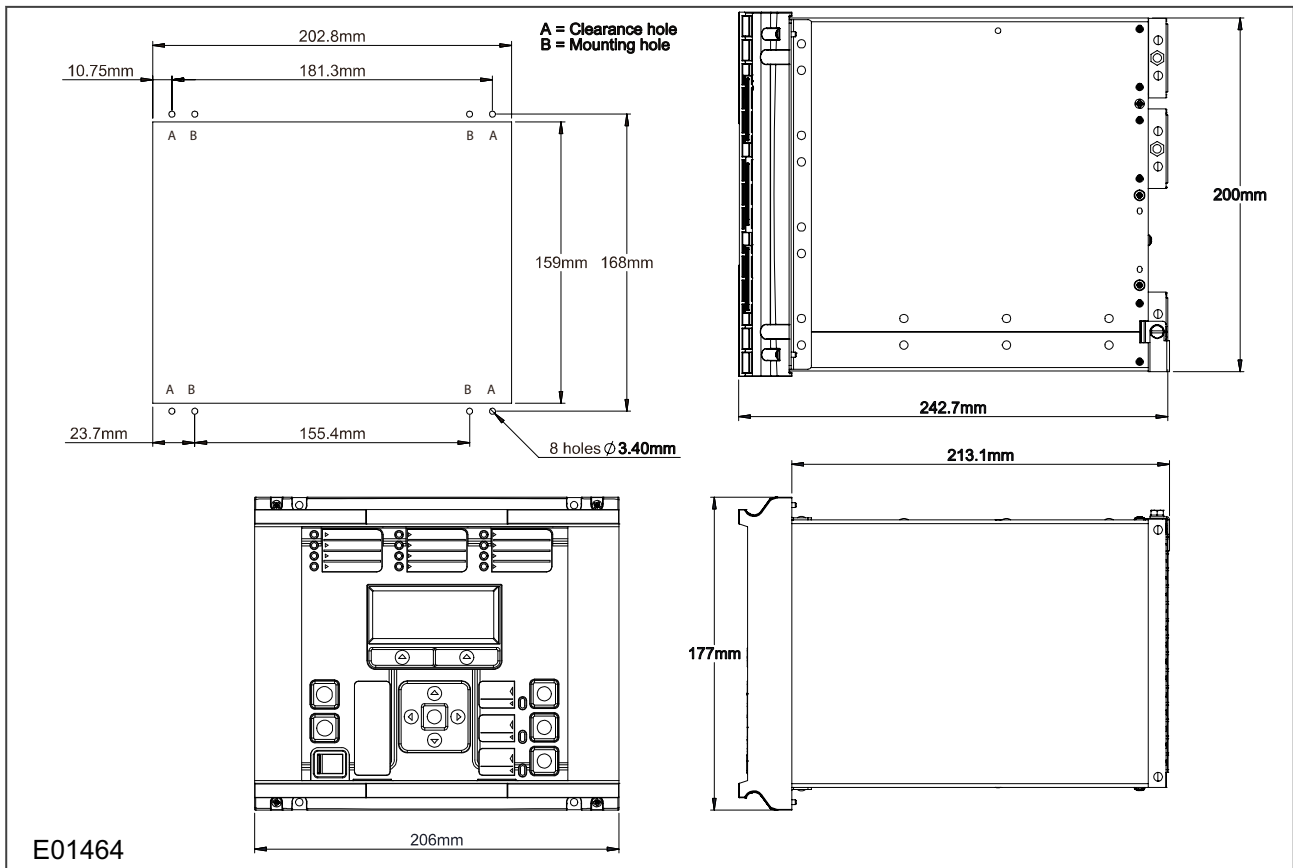
Figure 166: 40TE case dimensions

CHAPTER 19

COMMISSIONING INSTRUCTIONS

1   CHAPTER OVERVIEW

This chapter contains the following sections:

2   GENERAL GUIDELINES

General Electric 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 devices, you (the commissioning engineer) do not need to test every 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 the settings application software, or by means of the front panel interface (HMI panel).

The menu language is user-selectable, so you 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:** **With the exception of the CT shorting contacts check, do not disassemble the device 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 these commissioning test facilities.

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 is a binary string that displays the status of the opto-inputs where '1' means energised and '0' means 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 can be used to monitor the status of the relay outputs. The cell is a binary string that displays the status of the relay outputs where '1' means energised and '0' means de-energised. If you move the cursor along the binary numbers, the corresponding label text is displayed for each relay output.

The cell indicates the status of the output relays when the IED is in service. You can 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`*, the relay output status indicates which contacts would operate if the IED was in-service. It does not show the actual status of the output relays, as they are blocked.*

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 Autoreclose` 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

Specialist test equipment is required to commission this product. We recognise three classes of equipment for commissioning :

- Recommended
- Essential
- Advisory

Recommended equipment constitutes equipment that is both necessary, and sufficient, to verify correct performance of the principal protection functions.

Essential equipment represents the minimum necessary to check that the product includes the basic expected protection functions and that they operate within limits.

Advisory equipment represents equipment that is needed to verify satisfactory operation of features that may be unused, or supplementary, or which may, for example, be integral to a distributed control/automation scheme. Operation of such features may, perhaps, be more appropriately verified as part of a customer defined commissioning requirement, or as part of a system-level commissioning regime.

4.1   RECOMMENDED COMMISSIONING EQUIPMENT

The minimum recommended equipment is a multifunctional three-phase AC current and voltage injection test set featuring :

- Controlled three-phase AC current and voltage sources,
- Transient (dynamic) switching between pre-fault and post-fault conditions (to generate delta conditions),
- Dynamic impedance state sequencer (capable of sequencing through 4 impedance states),
- Integrated or separate variable DC supply (0 - 250 V)
- Integrated or separate AC and DC measurement capabilities (0-440V AC, 0-250V DC)
- Integrated and/or separate timer,
- Integrated and/or separate test switches.

In addition, you will need :

- A portable computer, installed with appropriate software to liaise with the equipment under test (EUT). Typically this software will be proprietary to the product's manufacturer (for example MiCOM S1 Agile).
- Suitable electrical test leads.
- Electronic or brushless insulation tester with a DC output not exceeding 500 V
- Continuity tester
- Verified application-specific settings files

4.2   ESSENTIAL COMMISSIONING EQUIPMENT

As an absolute minimum, the following equipment is required:

- AC current source coupled with AC voltage source
- Variable DC supply (0 - 250V)
- Multimeter capable of measuring AC and DC current and voltage (0-440V AC, 0-250V DC)
- Timer
- Test switches
- Suitable electrical test leads
- Continuity tester

4.3   ADVISORY TEST EQUIPMENT

Advisory test equipment may be required for extended commissioning procedures:

- Current clamp meter
- 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
- EIA(RS)485 to EIA(RS)232 converter for testing EIA(RS)485 Courier/MODBUS/IEC60870-5-103/DNP3 port
- A portable printer (for printing a setting record from the portable PC) and or writeable, detachable memory device.
- Phase angle meter
- Phase rotation meter
- Fibre-optic power meter.
- Fibre optic test leads (minimum 2). 10m minimum length, multimode 50/125 µm or 62.5µm terminated with BFOC (ST) 2.5 connectors for testing the fibre-optic RP1 port.

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 General Electric.*

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.**

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/RT430), 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.

5.2.5   TEST ALARM AND OUT-OF-SERVICE LEDS

The alarm and out of service LEDs can be tested using the *COMMISSION TESTS* menu column.

1.   Set the **Test Mode** cell to `Contacts Blocked`.
2.   Check that the out of service LED illuminates continuously and the alarm LED flashes.

It is not necessary to return the **Test Mode** cell to `Disabled` at this stage because the test mode will be required for later tests.

5.2.6   TEST TRIP LED

The trip LED can be tested by initiating a manual circuit breaker trip. However, the trip LED will operate during the setting checks performed later. Therefore no further testing of the trip LED is required at this stage.

5.2.7   TEST USER-PROGRAMMABLE LEDS

To test these LEDs, set the Test LEDs cell to `Apply Test`. Check that all user-programmable LEDs illuminate.

5.2.8   TEST OPTO-INPUTS

This test checks that all the opto-inputs on the IED are functioning correctly.

The opto-inputs should be energised one at a time. For terminal numbers, please see the external connection diagrams in the "Wiring Diagrams" chapter. Ensuring correct polarity, connect the supply voltage to the appropriate terminals for the input being tested.

The status of each opto-input can be viewed using either the **Opto I/P Status** cell in the *SYSTEM DATA* column, or the **Opto I/P Status** cell in the *COMMISSION TESTS* column.

A '1' indicates an energised input and a '0' indicates a de-energised input. When each opto-input is energised, one of the characters on the bottom line of the display changes to indicate the new state of the input.

5.2.9   TEST OUTPUT RELAYS

This test checks that all the output relays are functioning correctly.

1.   Ensure that the IED is still in test mode by viewing the **Test Mode** cell in the *COMMISSION TESTS* column. Ensure that it is set to `Contacts 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 with a permanent serial connection to the communications port. The scope of this test does not extend to verifying operation with

connected equipment beyond any suppied protocol converter. It verifies operation of the rear communication port (and if applicable the protocol converter) and varies according to the protocol fitted.

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:

E01402
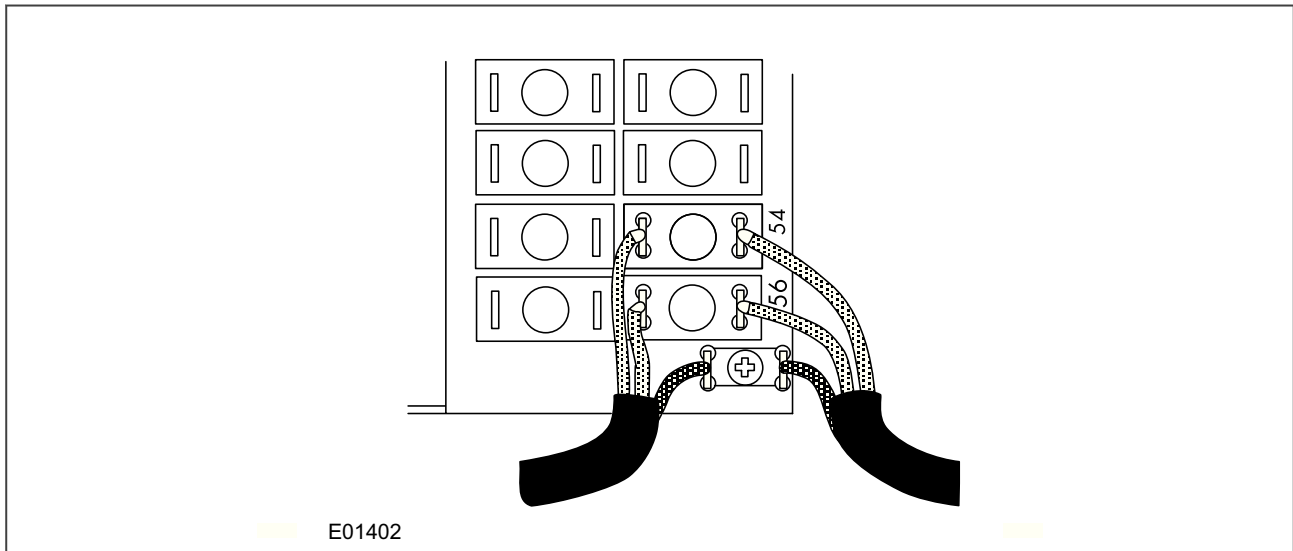
Figure 167: RP1 physical connection

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.
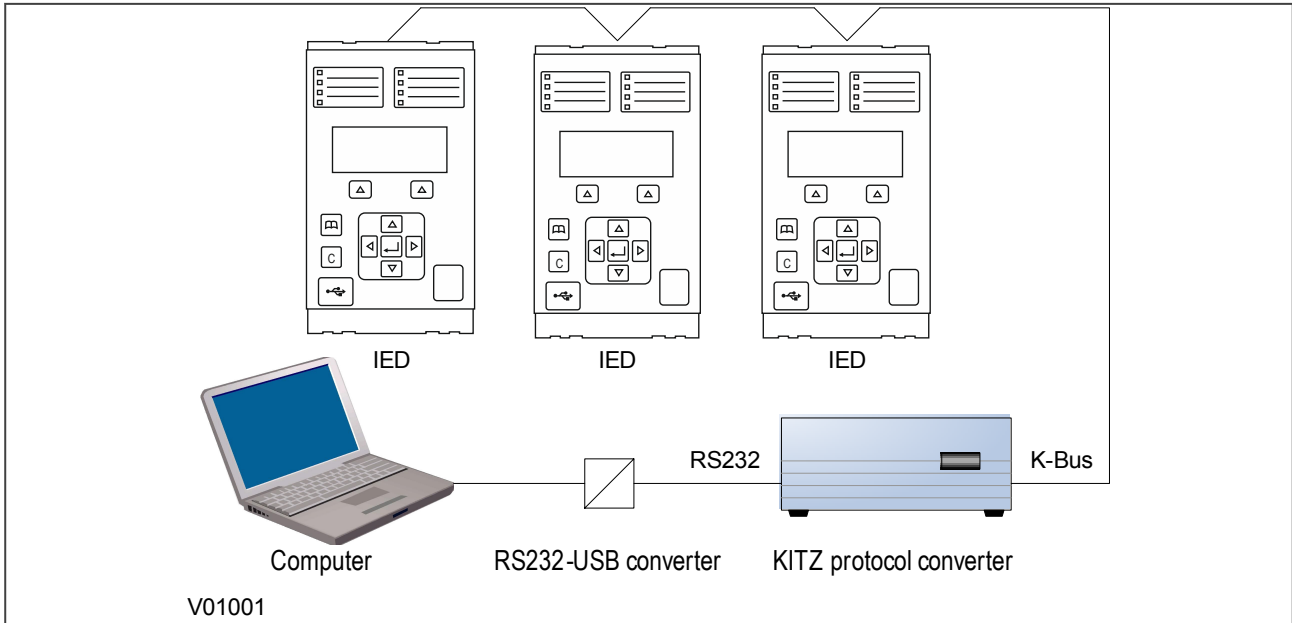
Figure 168: Remote communication using K-bus

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

For products that employ Ethernet communications, we recommend that testing be limited to a visual check that the correct ports are fitted and that there is no sign of physical damage.

If there is no board fitted or the board is faulty, a NIC link alarm will be raised (providing this option has been set in the *NIC Link Report* cell in the *COMMUNICATIONS* column).

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 *CT AND VT 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 CT AND VT 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
IN measured RMS	E/F CT Primary / E/F CT Secondary
ISEF magnitude	SEF CT Primary / SEF CT Secondary

5.2.14   TEST VOLTAGE INPUTS

This test verifies that the voltage measurement inputs are configured correctly.

1.   Apply rated voltage to each voltage transformer input in turn

2.   Check its magnitude using a multimeter or test set readout. The corresponding reading can then be checked in the *MEASUREMENTS 1* column.

3.   Record the value displayed. The measured voltage values will either be in primary or secondary Volts. If the Local Values cell in the *MEASURE'T SETUP* column is set to `Primary`, the values displayed should be equal to the applied voltage multiplied by the corresponding voltage transformer ratio (set in the *CT AND VT RATIOS* column) as shown below. If the Local Values cell is set to `Secondary`, the value displayed should be equal to the applied voltage.

> *Note:*
> *If a PC connected to the IED using the rear communications port is being used to display the measured current, the process will be similar. However, the setting of the Remote Values cell in the MEASURE'T SETUP column will determine whether the displayed values are in primary or secondary Amperes.*

Cell in MEASUREMENTS 1	Corresponding VT ratio (in *CT AND VT RATIOS* column)
VAN magnitude VBN magnitude VCN magnitude	Main VT Primary / Main VT Sec'y

Cell in MEASUREMENTS 1	Corresponding VT ratio (in *CT AND VT RATIOS* column)
4th VT Voltage Mag	4th VT Primary / 4th VT Secondary

6   SETTING CHECKS

The setting checks ensure that all of the application-specific settings (both the IED's function and programmable scheme logic settings) have been correctly applied.

> *Note:*
> *If applicable, the trip circuit should remain isolated during these checks to prevent accidental operation of the associated circuit breaker.*

6.1   APPLY APPLICATION-SPECIFIC SETTINGS

There are two different methods of applying the settings to the IED

- Transferring settings to the IED from a pre-prepared setting file using MiCOM S1 Agile
- Enter the settings manually using the IED's front panel HMI

6.1.1   TRANSFERRING SETTINGS FROM A SETTINGS FILE

This is the preferred method for transferring function settings. It is much faster and there is a lower margin for error.

1.   Connect a PC running the Settings Application Software to the IED's front port, or a rear Ethernet port. Alternatively connect to the rear Courier communications port, using a KITZ protocol converter if necessary.
2.   Power on the IED
3.   Enter the IP address of the device if it is Ethernet enabled
4.   Right-click the appropriate device name in the System Explorer pane and select **Send**
5.   In the **Send to** dialog select the setting files and click **Send**

> *Note:*
> *The device name may not already exist in the system shown in **System Explorer**. In this case, perform a **Quick Connect** to the IED, then manually add the settings file to the device name in the system. Refer to the Settings Application Software help for details of how to do this.*

6.1.2   ENTERING SETTINGS USING THE HMI

1.   Starting at the default display, press the Down cursor key to show the first column heading.
2.   Use the horizontal cursor keys to select the required column heading.
3.   Use the vertical cursor keys to view the setting data in the column.
4.   To return to the column header, either press the Up cursor key for a second or so, or press the **Cancel** key once. It is only possible to move across columns at the column heading level.
5.   To return to the default display, press the Up cursor key or the Cancel key from any of the column headings. If you use the auto-repeat function of the Up cursor key, you cannot go straight to the default display from one of the column cells because the auto-repeat stops at the column heading.
6.   To change the value of a setting, go to the relevant cell in the menu, then press the **Enter** key to change the cell value. A flashing cursor on the LCD shows that the value can be changed. You may be prompted for a password first.
7.   To change the setting value, press the vertical cursor keys. If the setting to be changed is a binary value or a text string, select the required bit or character to be changed using the left and right cursor keys.

8.   Press the **Enter** key to confirm the new setting value or the **Clear** key to discard it. The new setting is automatically discarded if it is not confirmed within 15 seconds.

9.   For protection group settings and disturbance recorder settings, the changes must be confirmed before they are used. When all required changes have been entered, return to the column heading level and press the down cursor key. Before returning to the default display, the following prompt appears.

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

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

Note:
If the menu time-out occurs before the setting changes have been confirmed, the setting values are also discarded.
Control and support settings are updated immediately after they are entered, without the Update settings prompt.
It is not possible to change the PSL using the IED's front panel HMI.

⚠ **Caution:**
Where the installation needs application-specific PSL, the relevant .psl files, must be transferred to the IED, for each and every setting group that will be used. If you do not do this, the factory default PSL will still be resident. This may have severe operational and safety consequences.

7   PROTECTION TIMING CHECKS

There is no need to check every protection function. Only one protection function needs to be checked as the purpose is to verify the timing on the processor is functioning correctly.

7.1   OVERCURRENT CHECK

If the overcurrent protection function is being used, test the overcurrent protection for stage 1.

1.   Check for any possible dependency conditions and simulate as appropriate.
2.   In the *CONFIGURATION* column, disable all protection elements other than the one being tested.
3.   Make a note of which elements need to be re-enabled after testing.
4.   Connect the test circuit.
5.   Perform the test.
6.   Check the operating time.

7.2   CONNECTING THE TEST CIRCUIT

1.   Use the PSL to determine which output relay will operate when an overcurrent trip occurs.
2.   Use the output relay assigned to ***Trip Output A***.
3.   Use the PSL to map the protection stage under test directly to an output relay.

> *Note:*
> *If using the default PSL, use output relay 3 as this is already mapped to the DDB signal **Trip Command Out**.*

4.   Connect the output relay so that its operation will trip the test set and stop the timer.
5.   Connect the current output of the test set to the A-phase current transformer input.

       If the ***I>1 Directional*** cell in the *OVERCURRENT* column is set to `Directional Fwd`, the current should flow out of terminal 21. If set to `Directional Rev`, it should flow into terminal 21.

       If the ***I>1 Directional*** cell in the *OVERCURRENT* column has been set to `Directional Fwd` or 'Directional Rev', the rated voltage should be applied to terminals 18 and 19.
6.   Ensure that the timer starts when the current is applied.

> *Note:*
> *If the timer does not stop when the current is applied and stage 1 has been set for directional operation, the connections may be incorrect for the direction of operation set. Try again with the current connections reversed.*

7.3   PERFORMING THE TEST

1.   Ensure that the timer is reset.
2.   Apply a current of twice the setting shown in the ***I>1 Current Set*** cell in the *OVERCURRENT* column.
3.   Note the time displayed when the timer stops.
4.   Check that the red trip LED has illuminated.

7.4   CHECK THE OPERATING TIME

Check that the operating time recorded by the timer is within the range shown below.

For all characteristics, allowance must be made for the accuracy of the test equipment being used.

Characteristic	Operating time at twice current setting and time multiplier/ time dial setting of 1.0	
	Nominal (seconds)	Range (seconds)
DT	I>1 Time Delay setting	Setting ±2%
IEC S Inverse	10.03	9.53 - 10.53
IEC V Inverse	13.50	12.83 - 14.18
IEC E Inverse	26.67	24.67 - 28.67
UK LT Inverse	120.00	114.00 - 126.00
IEEE M Inverse	3.8	3.61 - 4.0
IEEE V Inverse	7.03	6.68 - 7.38
IEEE E Inverse	9.50	9.02 - 9.97
US Inverse	2.16	2.05 - 2.27
US ST Inverse	12.12	11.51 - 12.73

Note:
With the exception of the definite time characteristic, the operating times given are for a Time Multiplier Setting (TMS) or Time Dial Setting (TDS) of 1. For other values of TMS or TDS, the values need to be modified accordingly.

Note:
For definite time and inverse characteristics there is an additional delay of up to 0.02 second and 0.08 second respectively. You may need to add this the IED's acceptable range of operating times.

Caution:
On completion of the tests, you must restore all settings to customer specifications.

8   ONLOAD CHECKS

Warning:
Onload checks are potentially very dangerous and may only be carried out by qualified and authorised personnel.

Onload checks can only be carried out if there are no restrictions preventing the energisation of the plant, and the other devices in the group have already been commissioned.

Remove all test leads and temporary shorting links, then replace any external wiring that has been removed to allow testing.

Warning:
If any external wiring has been disconnected for the commissioning process, replace it in accordance with the relevant external connection or scheme diagram.

8.1   CONFIRM CURRENT CONNECTIONS

1.   Measure the current transformer secondary values for each input using a multimeter connected in series with the corresponding current input.
2.   Check that the current transformer polarities are correct by measuring the phase angle between the current and voltage, either against a phase meter already installed on site and known to be correct or by determining the direction of power flow by contacting the system control centre.
3.   Ensure the current flowing in the neutral circuit of the current transformers is negligible.
4.   Compare the values of the secondary phase currents and phase angle with the measured values, which can be found in the *MEASUREMENTS 1* column.

If the **Local Values** cell is set to `Secondary`, the values displayed should be equal to the applied secondary voltage. The values should be within 1% of the applied secondary voltages. However, an additional allowance must be made for the accuracy of the test equipment being used.

If the **Local Values** cell is set to `Primary`, the values displayed should be equal to the applied secondary voltage multiplied the corresponding voltage transformer ratio set in the *CT AND VT RATIOS* column. The values should be within 1% of the expected values, plus an additional allowance for the accuracy of the test equipment being used.

8.2   CONFIRM VOLTAGE CONNECTIONS

1.   Using a multimeter, measure the voltage transformer secondary voltages to ensure they are correctly rated.
2.   Check that the system phase rotation is correct using a phase rotation meter.
3.   Compare the values of the secondary phase voltages with the measured values, which can be found in the *MEASUREMENTS 1* menu column.

Cell in MEASUREMENTS 1 Column	Corresponding VT ratio in CT AND VT RATIOS column
VAB Magnitude *VBC Magnitude* *VCA Magnitude* *VAN Magnitude* *VBN Magnitude* *VCN Magnitude*	Main VT Primary / Main VT Sec'y
C/S Voltage Mag.	4th VT Primary / 4th VT Secondary

If the **Local Values** cell is set to `Secondary`, the values displayed should be equal to the applied secondary voltage. The values should be within 1% of the applied secondary voltages. However, an additional allowance must be made for the accuracy of the test equipment being used.

If the **Local Values** cell is set to `Primary`, the values displayed should be equal to the applied secondary voltage multiplied the corresponding voltage transformer ratio set in the *CT AND VT RATIOS* column. The values should be within 1% of the expected values, plus an additional allowance for the accuracy of the test equipment being used.

8.3   ON-LOAD DIRECTIONAL TEST

This test ensures that directional overcurrent and fault locator functions have the correct forward/reverse response to fault and load conditions. For this test you must first know the actual direction of power flow on the system. If you do not already know this you must determine it using adjacent instrumentation or protection already in-service.

- For load current flowing in the Forward direction (power export to the remote line end), the **A Phase Watts** cell in the *MEASUREMENTS 2* column should show positive power signing.
- For load current flowing in the Reverse direction (power import from the remote line end), the **A Phase Watts** cell in the *MEASUREMENTS 2* column should show negative power signing.

> *Note:*
> *This check applies only for Measurement Modes 0 (default), and 2. This should be checked in the MEASURE'T SETUP column (**Measurement Mode** = 0 or 2). If measurement modes 1 or 3 are used, the expected power flow signing would be opposite to that shown above.*

In the event of any uncertainty, check the phase angle of the phase currents with respect to their phase voltage.

9   FINAL CHECKS

1.   Remove all test leads and temporary shorting leads.

2.   If you have had to disconnect any of the external wiring in order to perform the wiring verification tests, replace all wiring, fuses and links in accordance with the relevant external connection or scheme diagram.

3.   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.

4.   Ensure that all protection elements required have been set to `Enabled` in the *CONFIGURATION* column.

5.   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`.

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.

> *Note:*
> *Remember to restore the language setting to the customer's preferred language on completion.*

CHAPTER 20

MAINTENANCE AND TROUBLESHOOTING

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, General Electric products should be checked at regular intervals to confirm they are operating correctly. General Electric 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 General Electric 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.

Test	Check	Action
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. 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.
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:
    contact.centre@ge.com
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, email us at:
        contact.centre@ge.com
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.

CHAPTER 21

TECHNICAL SPECIFICATIONS

---

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
Accuracy	< +/- 1 s per day

2.5   REAR ETHERNET PORT COPPER

Rear Ethernet port using CAT 5/6/7 wiring	
Main Use	Substation Ethernet communications
Communication protocol	10BaseT/100BaseTX
Connector	RJ45
Cable type	Screened twisted pair (STP)
Isolation	1 kV
Supported Protocols	IEC 61850, DNP3.0 OE
Constraints	Maximum cable length 100 m

2.6   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)
Communication protocol	100 BaseFX
Fibre type	Multimode 50/125 µm or 62.5/125 µm
Supported Protocols	IEC 61850, DNP3.0 OE
Wavelength	1300 nm

2.6.1   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

2.6.2   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

3   PERFORMANCE OF CURRENT PROTECTION FUNCTIONS

3.1   THREE-PHASE OVERCURRENT PROTECTION

IDMT pick-up	1.05 × Setting +/-5%
DT Pick-up	Setting +/- 5%
Drop-off (IDMT and DT)	0.95 × setting +/- 5%
IDMT operation (for IEC and UK curves)	+/- 5% or 60 ms, whichever is greater (1.05 – <2) Is +/- 5% or 40 ms, whichever is greater (2 – 20) Is
IDMT operation (IEEE and US curves) For TD setting < 100s	+/- 5% or 60 ms, whichever is greater (1.05 – <2) Is +/- 5% or 40 ms, whichever is greater (2 – 20) Is
IDMT operation (IEEE and US curves) For TD setting > 100s	+/- 15% (1.05 - 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

3.1.1   THREE-PHASE OVERCURRENT DIRECTIONAL PARAMETERS

Directional boundary accuracy (RCA +/-90%)	+/-2° with hysteresis <3°
IDMT operate	+/- 5% 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 80 ms, whichever is greater (1.05 – <2) Is +/- 2% or 60 ms, whichever is greater (2 – 20) Is
DT reset	Setting +/-5%

3.1.2   THERMAL OVERLOAD PROTECTION

Setting accuracy	±5%
Reset	97% of thermal setting ±5%
Thermal alarm Pick-up	Calculated trip time ±5% or 40 ms whichever is greater
Cooling time constant typical accuracy	±5% of theoretical
Repeatability	<2.5%

3.2   EARTH FAULT PROTECTION

Measured and Derived	
IDMT pick-up	1.05 × Setting +/-5%

Measured and Derived	
DT Pick-up	Setting +/- 5%
Drop-off (IDMT and DT) for IN1	0.95 × Setting +/-5%
Drop-off (IDMT and DT) for IN2	0.9 × 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)

3.2.1   EARTH FAULT DIRECTIONAL PARAMETERS

Zero Sequence Polarising accuracy	
Directional boundary pick-up (RCA +/- 90°)	+/-2°
Hysteresis	<3°
VN> pick-up	Setting+/-10%
VN> drop-off	0.9 × Setting +/-10%

Negative Sequence Polarising accuracy	
Directional boundary pick-up (RCA +/- 90°)	+/-2°
Hysteresis	<3°
VN2> pick-up	Setting+/-10%
VN2> drop-off	0.9 × Setting +/-10%
IN2> pick-up	Setting+/-10%
IN2> drop-off	0.9 × Setting +/-10%

3.3   SENSITIVE EARTH FAULT PROTECTION

IDMT pick-up	1.05 × Setting +/-5%
DT Pick-up	Setting +/- 5%
Drop-off (IDMT + DT)	0.95 × 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.*

3.3.1   SEF DIRECTIONAL PARAMETERS

Wattmetric SEF accuracy	
Pick-up for P = 0 W	ISEF > +/-5% or 5 mA
Pick-up for P > 0 W	P > +/-5%
Drop-off for P = 0 W	0.95 x ISEF> +/- 5% or 5 mA
Drop-off for P > 0 W	0.9 x P> +/- 5% or 5 mA
Boundary accuracy	+/-5% with hysteresis < 1°
Repeatability	+/- 5%

SEF CosΦ accuracy	
Pick-up	Setting +/-5% for angles RCA+/-60°
Drop-off	0.9 x setting
Repeatability	+/- 2%

SEF SinΦ accuracy	
Pick-up	Setting +/-5% for angles RCA+/-60° to RCA+/-90°
Drop-off	0.9 x setting
Repeatability	+/- 2%

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	< 30 ms
High pick-up	Setting +/- 10%
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%
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%

3.5.1 NPSOC DIRECTIONAL PARAMETERS

Directional boundary pick-up (RCA +/-90%)	+/- 2°
Directional boundary hysteresis	< 1°
IDMT operate	+/- 5% or 70 ms, whichever is greater (1.05 – <2) Is +/- 5% or 50 ms, whichever is greater (2 – 20) Is
IDMT reset	< 40 ms
DT operate	+/- 2% or 80 ms, whichever is greater (1.05 – <2) Is +/- 2% or 60 ms, whichever is greater (2 – 20) Is
DT reset	Setting +/- 5%

3.6 STALL PROTECTION

Pick-up	Setting ±5%
Timer	± 2% or 40ms, whichever is greater

3.7 CIRCUIT BREAKER FAIL AND UNDERCURRENT PROTECTION

I< Pick-up	Setting +/- 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

3.8 BROKEN CONDUCTOR PROTECTION

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

3.9 SELECTIVE OVERCURRENT PROTECTION

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

3.10   COLD LOAD PICKUP PROTECTION

I> Pick-up	Setting +/- 1.5%
IN> Pick-up	Setting +/- 1.5%
I> Drop-off	0.95 × Setting +/- 1.5%
IN> Drop-off	0.95 × Setting +/- 1.5%
DT operate	+/- 0.5% or 50 ms, whichever is greater
Repeatability	+/- 1%

4 PERFORMANCE OF VOLTAGE PROTECTION FUNCTIONS

4.1 UNDERVOLTAGE PROTECTION

Pick-up (IDMT and DT)	Setting +/- 5%
Drop-off (IDMT and DT)	1.02 x Setting +/-5%
IDMT operate	+/- 3.5% or 40 ms, whichever is greater (<10 V) +/- 5% or 40 ms, whichever is greater (>10 V)
Disnegagement	<40 ms
DT operate	+/- 2% or 50 ms, whichever is greater
DT reset	Setting +/- 5%
Repeatability	+/- 1%

4.2 OVERVOLTAGE PROTECTION

IDMT pick-up	Setting +/- 2%
DT pick-up	Setting +/- 1%
Drop-off (IDMT and DT)	0.98 x Setting +/-5%
IDMT operate	+/-5% or 50 ms
Disengagement	< 40 ms
DT operate	+/- 2% or 50 ms, whichever is greater
DT reset	Setting +/- 5%
Repeatability	+/- 5%

4.3 RESIDUAL OVERVOLTAGE 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 65 ms, whichever is greater
Disengagement	< 35 ms
DT operate	+/- 2% or 70 ms or whichever is greater
DT reset	Setting +/- 5%
Repeatability	<10%

4.4 NEGATIVE SEQUENCE VOLTAGE PROTECTION

Accuracy	
Pick-up	Setting +/- 5%
Drop-off	0.95 x Setting +/-5%

Accuracy	
DT operate (normal operation)	+/- 5% or 70 ms, whichever is greater (<45 Hz) +/- 2% or 65 ms, whichever is greater (45 Hz - 70 Hz)
DT operate (accelerated)	+/- 5% or 50 ms, whichever is greater (<45 Hz) +/- 2% or 45 ms, whichever is greater (45 Hz - 70 Hz)
Repeatability	+/- 1%

4.5   RATE OF CHANGE OF VOLTAGE PROTECTION

Accuracy for 110 V VT	
Tolerance	1% or 0.07, whichever is greater
Pick-up	Setting +/- tolerance
Drop-off for positive direction	(Setting – 0.07)+/- tolerance
Drop-off for negative direction	(Setting + 0.07)+/- tolerance
Operating time at 50 Hz	(Average cycle x 20) +60 ms
Reset time at 50 Hz	40 ms

5   PERFORMANCE OF FREQUENCY PROTECTION FUNCTIONS

5.1   OVERFREQUENCY PROTECTION

Accuracy	
Pick-up	Setting +/- 10 mHz
Drop-off	Setting -20 mHz +/- 10 mHz
Operating timer	+/- 2% or 50 ms, whichever is greater

Operating and Reset time	
Operating time (Fs/Ff ratio less than 2)	<125 ms
Operating time (Fs/Ff ratio between 2 and 30)	<150 ms
Operating time (Fs/Ff ratio greater than 30)	<200 ms
Reset time	<200 ms

Reference conditions: Tested using step changed in frequency with Freq. Av Cycles setting = 0 and no intentional time delay.

Fs = start frequency – frequency setting

Ff = frequency setting – end frequency

5.2   UNDERFREQUENCY PROTECTION

Accuracy	
Pick-up	Setting +/- 10 mHz
Drop-off	Setting + 20 mHz +/- 10 mHz
Operating timer	+/- 2% or 50 ms, whichever is greater

Operating and Reset time	
Operating time (Fs/Ff ratio less than 2)	<100 ms
Operating time (Fs/Ff ratio between 2 and 6)	<160 ms
Operating time (Fs/Ff ratio greater than 6)	<230 ms
Reset time	<200 ms

Reference conditions: Tested using step changed in frequency with Freq. Av Cycles setting = 0 and no intentional time delay.

Fs = start frequency – frequency setting

Ff = frequency setting – end frequency

5.3   SUPERVISED RATE OF CHANGE OF FREQUENCY PROTECTION

Accuracy	
Pick-up (f)	Setting +/- 10 mHz
Pick-up (df/dt)	Setting +/- 3% or +/- 10 mHz/s, whichever is greater

Accuracy	
Drop-off (f, underfrequency)	(Setting + 20 mHz) +/- 10 mHz
Drop-off (f, overfrequency)	(Setting - 20 mHz) +/- 10 mHz
Drop-off (df/dt, falling, for settings between 10 mHz/s and 100 mHz/s)	(Setting + 5 mHz/s) +/- 10 mHz/s
Drop-off (df/dt, falling, for settings greater than 100 mHz/s)	(Setting + 50 mHz/s) +/- 5% or +/- 55 mHz/s, whichever is greater
Drop-off (df/dt, rising, for settings between 10 mHz/s and 100 mHz/s)	(Setting - 5 mHz/s) +/- 10 mHz/s
Drop-off (df/dt, rising, for settings greater than 100 mHz/s)	(Setting - 50 mHz/s) +/- 5% or +/- 55 mHz/s, whichever is greater

Operating and Reset time	
Instantaneous operating time (Freq AvCycles setting = 0)	<125 ms
Reset time time (df/dt AvCycles setting = 0)	<400 ms

5.4   INDEPENDENT RATE OF CHANGE OF FREQUENCY PROTECTION

Accuracy	
Pick-up (df/dt)	Setting +/- 3% or +/- 10 mHz/s, whichever is greater
Drop-off (df/dt, falling, for settings between 10 mHz/s and 100 mHz/s)	(Setting + 5 mHz/s) +/- 10 mHz/s
Drop-off (df/dt, falling, for settings greater than 100 mHz/s)	(Setting + 50 mHz/s) +/- 5% or +/- 55 mHz/s, whichever is greater
Drop-off (df/dt, rising, for settings between 10 mHz/s and 100 mHz/s)	(Setting - 5 mHz/s) +/- 10 mHz/s
Drop-off (df/dt, rising, for settings greater than 100 mHz/s)	(Setting - 50 mHz/s) +/- 5% or +/- 55 mHz/s, whichever is greater
Operating timer	+/- 2% or 50 ms, whichever is greater

Operating and Reset time	
Operating time (for ramps 2 x seting or greater)	<200 ms
Operating time (for ramps 1.3 x seting or greater)	<300 ms
Reset time time (df/dt AvCycles setting = 0 for df/dt settings greater than 0.1 Hz/s and no intentional time delay)	<250 ms

Referecne Conditions: Tested with df/dt Average Cycles = 0 for df/dt settings greater than 0.1 Hz/s, and no intentional time delay.

5.5   AVERAGE RATE OF CHANGE OF FREQUENCY PROTECTION

Accuracy	
Pick-up (f)	Setting +/- 10 mHz
Pick-up (Df/Dt)	Setting +/- 100 mHz/s
Drop-off (falling)	(Setting + 20 mHz) +/- 10 mHz
Drop-off (rising)	(Setting - 20 mHz) +/- 10 mHz
Operating timer	+/- 2% or 30 ms, whichever is greater

Operating time	
Operating time (Freq. Av Cycles setting = 0)	<125 ms

Reference conditions: To maintain accuracy, the minimum time delay setting should be:

Dt> 0.375 × Df + 0.23 (f0r Df setting <1 Hz)

Dt> 0.156 × Df + 0.47 (for Df setting >= 1 Hz)

5.6   LOAD RESTORATION

Pick-up	Setting +/- 2.5%
Drop-off	0.95% × Setting +/- 2.5%
Restoration timer	+/- 2% or 50 ms, whichever is greater
Holding timer	+/- 2% or 50 ms, whichever is greater

5.7   ANTI-BACKSPIN

Pick-up	Setting ±5%
DT operation	±2% or 50 ms whichever is greater
Repeatability	<1%

6   POWER PROTECTION FUNCTIONS

6.1   REVERSE POWER PROTECTION

Pick-up	Setting +/- 10%
Reverse power drop-off	0.95 × Setting +/- 10%
Angle variation pick-up	+/- 2°
Angle variation drop-off	+/- 2.5°
Operating time	+/- 2% or 50 ms, whichever is greater
Repeatability	< 5%
Disengagement time	<50 ms
tRESET	+/- 5%
Instantaneous operating time	< 50 ms

7   PERFORMANCE OF MONITORING AND CONTROL FUNCTIONS

7.1   VOLTAGE TRANSFORMER SUPERVISION

Fast block operation	< 25 ms
Fast block reset	< 40 ms
Time delay	+/- 2% or 40 ms, whichever is greater

7.2   CURRENT TRANSFORMER SUPERVISION

IN> Pick-up	Setting +/- 5%
VN< Pick-up	Setting +/- 5%
IN> Drop-off	0.9 x setting +/- 5%
VN< Drop-off	1.05 x setting +/-5% or 1 V, whichever is greater
Time delay operation	Setting +/-2% or 20 ms, whichever is greater
CTS block operation	< 1.1 cycles
CTS reset	< 40 ms

7.3   CB STATE AND CONDITION MONITORING

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

7.4   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

7.5   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

8   MEASUREMENTS AND RECORDING

8.1   GENERAL

General Measurement Accuracy at 20° C	
General measurement accuracy	Typically +/- 1%, but +/- 0.5% between 0.2 - 2 In/Vn
Current magnitude	0.05 to 4 In +/- 0.5% of reading (1A input) 0.05 to 4 In +/- 1.0% of reading (5A input)
Voltage magnitude	0.05 to 2 Vn +/- 1.0% of reading
Current phase	0° to 360° +/- 0.5° (0.05 to 4 In for 1A input) 0° to 360° +/- 1° (0.05 to 4 In for 5A input)
Voltage phase	0° to 360° +/- 0.5° (0.2 to 2 Vn) 0° to 360° +/- 1° (0.05 to 2 Vn)
Frequency	40 to 70 Hz +/- 0.025 Hz
Power (W)	0.2 to 2 Vn and 0.05 to 3 In +/- 5.0% of reading at unity power factor
Reactive power (Vars)	0.2 to 2 Vn and 0.05 to 3 In +/- 5.0% of reading at zero power factor
Apparent power (VA)	0.2 to 2 Vn and 0.05 to 3 In +/- 5.0% of reading
Energy (Wh)	0.2 to 2 Vn and 0.2 to 3 In +/- 5.0% of reading at zero power factor
Energy (Varh)	0.2 to 2 Vn and 0.2 to 3 In +/- 5.0% of reading at zero power factor

8.2   MEASURED OPERATING DATA

Local Values	Primary/Secondary
Remote Values	Primary/Secondary
Measurement Reference	VA/VB/VC/IA/IB/IC
Demand Interval	1...99 mins
Alarm Fix Demand	Invisible/Visible
3 Phase Watt Threshold	1 In......120 In W
3 Phase Var Threshold	1 In......120 In VAr
Alarm Energies	Invisible/Visible
W Fwd Threshold	1 In......1000 In Wh
W Rev Threshold	1 In......1000 In Wh
Var Fwd Threshold	1 In......1000 In VAr
Var Rev Threshold	1 In......1000 In VAr
Motor Hour Run >1	Disable/Enable
Motor Hour Run >1	1...9999 Hours
Motor Hour Run >2	Disable/Enable
Motor Hour Run >2	1...9999 Hours
Remote 2 Values	Primary/Secondary

8.3   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)

8.4   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

9   REGULATORY COMPLIANCE

Compliance with the European Commission Directive on EMC and LVD is demonstrated using a technical file.

CE

9.1   EMC COMPLIANCE: 2014/30/EU

The product specific Declaration of Conformity (DoC) lists the relevant harmonised standard(s) or conformity assessment used to demonstrate compliance with the EMC directive.

9.2   LVD COMPLIANCE: 2014/35/EU

The product specific Declaration of Conformity (DoC) lists the relevant harmonized standard(s) or conformity assessment used to demonstrate compliance with the LVD directive.

Safety related information, such as the installation I overvoltage category, pollution degree and operating temperature ranges are specified in the Technical Data section of the relevant product documentation and/or on the product labelling.

Unless otherwise stated in the Technical Data section of the relevant product documentation, the equipment is intended for indoor use only. Where the equipment is required for use in an outdoor location, it must be mounted in a specific cabinet or housing to provide the equipment with the appropriate level of protection from the expected outdoor environment.

9.3   R&TTE COMPLIANCE: 2014/53/EU

Radio and Telecommunications Terminal Equipment (R&TTE) directive 2014/53/EU.

Conformity is demonstrated by compliance to both the EMC directive and the Low Voltage directive, to zero volts.

9.4   UL/CUL COMPLIANCE

If marked with this logo, the product is compliant with the requirements of the Canadian and USA Underwriters Laboratories.

The relevant UL file number and ID is shown on the equipment.

c(UL)us

9.5   ATEX COMPLIANCE: 2014/34/EU

Products marked with the 'explosion protection' Ex symbol (shown in the example, below) are compliant with the ATEX directive. The product specific Declaration of Conformity (DoC) lists the Notified Body, Type Examination Certificate, and relevant harmonized standard or conformity assessment used to demonstrate compliance with the ATEX directive.

The ATEX Equipment Protection level, Equipment group, and Zone definition will be marked on the

product.

For example:

⟨Ex⟩ II (2) G

Where:

'II'   Equipment Group: Industrial.

'(2)G'   High protection equipment category, for control of equipment in gas atmospheres in Zone 1 and 2. This equipment (with parentheses marking around the zone number) is not itself suitable for operation within a potentially explosive atmosphere.

10 MECHANICAL SPECIFICATIONS

10.1 PHYSICAL PARAMETERS

Physical Measurements	
Case Types	20TE 30TE 40TE
Weight (20TE case)	2 kg – 3 kg (depending on chosen options)
Weight (30TE case)	3 kg – 4 kg (depending on chosen options)
Weight (40TE case)	5.5 kg
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
Dimensions in mm (w x h x l) (40TE case)	W: 206.0mm H: 177.0mm D: 243.1mm
Mounting	Panel or rack

10.2 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

10.3 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 1, Bump withstand: class 1
Seismic test per EN 60255-21-3: 1995	Class 2

10.4 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

11   RATINGS

11.1   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

11.2   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 × In 10 s: 30 × In 1 s: 100 × In Linear to 40 × 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.*

11.3   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 × Vn, 10 s: 2.6 × Vn

12   POWER SUPPLY

12.1   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)

12.2   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.
	40TE	8 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.

12.3   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 V dc	19.2 V – 110 V dc	>110 V dc
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
30TE with Redundant Ethernet Board	50 ms	100 ms	10 ms	100 ms
40TE with 2nd rear communications	20 ms	100 ms	10 ms*	50 ms

* for voltages > 48 V dc

Note:
Maximum loading = all inputs/outputs energised. Quiescent or 1/2 loading = 1/2 of all inputs/outputs energised.

13 INPUT / OUTPUT CONNECTIONS

13.1 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

13.1.1 NOMINAL PICKUP AND RESET THRESHOLDS

Nominal battery voltage	Logic levels: 60-80% DO/PU	Logic Levels: 50-70% DO/PU	Logic Levels: 58-75% DO/PU
24/27 V	Logic 0 < 16.2V, Logic 1 > 19.2V	Logic 0 <12V, Logic 1 > 16.8V	Logic 0 <15.7V, Logic 1 > 18V
30/34	Logic 0 < 20.4V, Logic 1 > 24V	Logic 0 < 15V, Logic 1 > 21V	Logic 0 < 19.7V, Logic 1 > 22.5V
48/54	Logic 0 < 32.4V, Logic 1 > 38.4V	Logic 0 < 24V, Logic 1 > 33.6V	Logic 0 < 31.3V, Logic 1 > 36V
110/125	Logic 0 < 75V, Logic 1 > 88V	Logic 0 < 55.V, Logic 1 > 77V	Logic 0 < 72.5V, Logic 1 > 82.5V
220/250	Logic 0 < 150V, Logic 1 > 176V	Logic 0 < 110V, Logic 1 > 154V	Logic 0 < 145V, Logic 1 > 165V

Note:
Filter is required to make the opto-inputs immune to induced AC voltages.

13.2 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 phi = unity)
Make and break, ac inductive	2500 VA inductive (cos phi = 0.7)
Make and carry, dc resistive	30 A for 3 s, 10000 operations (subject to a maximum load of 7500W))
Make, carry and break, dc resistive	4 A for 1.5 s, 10000 operations (subject to the above limit for make and break, dc resistive load)
Make, carry and break, dc inductive	0.5 A for 1 s, 10000 operations (subject to the above limit for make and break, dc inductive load)
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	10000 operations min.
Unloaded contact	100000 operations min.
Operate time	< 5 ms
Reset time	< 10 ms

13.3   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 phi = 0.7)

13.4   SHORTING LINK

Maximum operating voltage	300Vrms, 300Vdc
Maximum operating current	20A

14   ENVIRONMENTAL CONDITIONS

14.1   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)

14.2   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)

14.3   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

14.4   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 SO_2 at 75% relative humidity and +25°C
Industrial corrosive environment/poor environmental control, Hydrogen Sulphide	21 days exposure to elevated concentrations (10ppm) of H_2S at 75% relative humidity and +25°C
Salt mist	IEC 60068-2-52: 1996 KB severity 3

15   TYPE TESTS

15.1   INSULATION

Compliance	IEC 60255-27: 2005
Insulation resistance	> 100 M ohm at 500 V DC (Using only electronic/brushless insulation tester)

15.2   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

15.3   HIGH VOLTAGE (DIELECTRIC) WITHSTAND

IEC Compliance	IEC 60255-27: 2005
Between independent opto-inputs or Vx and other circuits	2.82kV dc for 1 minute
Between all other independent circuits	2 kV ac rms for 1 minute
Between Vx or opto-inputs, and protective earth terminal	2.82kV dc for 1 minute
Between all other independent circuits and protective earth terminal	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 terminal	1 kV ac rms for 1 minute
Between all screw-type EIA(RS)485 contacts and protective earth terminal	1 kV ac rms for 1 minute
ANSI/IEEE Compliance	ANSI/IEEE C37.90-2005
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

15.4   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.*

16   ELECTROMAGNETIC COMPATIBILITY

16.1   1 MHZ BURST HIGH FREQUENCY DISTURBANCE TEST

Compliance	IEC 60255-22-1: 2008, Class III, IEC 60255-26:2013
Common-mode test voltage (level 3)	2.5 kV
Differential test voltage (level 3)	1.0 kV

16.2   DAMPED OSCILLATORY TEST

Compliance	EN61000-4-18: 2011: Level 3, 100 kHz and 1 MHz. Level 4: 3 MHz, 10 MHz and 30 MHz, IEC 60255-26:2013
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

16.3   IMMUNITY TO ELECTROSTATIC DISCHARGE

Compliance	IEC 60255-22-2: 2009 Class 3 and Class 4, IEC 60255-26:2013
Class 4 Condition (20TE, 30TE)	15 kV discharge in air to user interface, display, and exposed metalwork 8 kV contact discharge to communication ports and exposed metalwork
Class 3 Condition (40TE)	6 kV contact discharge to communication ports and exposed metalwork

16.4   ELECTRICAL FAST TRANSIENT OR BURST REQUIREMENTS

Compliance	IEC 60255-22-4: 2008 and EN61000-4-4:2004. Test severity level lll and lV, IEC 60255-26:2013
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)

16.5   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

16.6   SURGE IMMUNITY TEST

Compliance	IEC 61000-4-5: 2005 Level 4, IEC 60255-26:2013
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

16.7   IMMUNITY TO RADIATED ELECTROMAGNETIC ENERGY

Compliance	IEC 60255-22-3: 2007, Class III, IEC 60255-26:2013
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

16.8   RADIATED IMMUNITY FROM DIGITAL COMMUNICATIONS

Compliance	IEC 61000-4-3: 2006, Level 4, IEC 60255-26:2013
Frequency bands	800 to 960 MHz, 1.4 to 2.0 GHz
Test field strength	30 V/m
Test using AM	1 kHz / 80%

16.9   RADIATED IMMUNITY FROM DIGITAL RADIO TELEPHONES

Compliance	IEC 61000-4-3: 2006, IEC 60255-26:2013
Frequency bands	900 MHz and 1.89 GHz
Test field strength	10 V/m

16.10   IMMUNITY TO CONDUCTED DISTURBANCES INDUCED BY RADIO FREQUENCY FIELDS

Compliance	IEC 61000-4-6: 2008, Level 3, IEC 60255-26:2013
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

16.11   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

16.12   CONDUCTED EMISSIONS

Compliance	EN 55022: 2010, IEC 60255-26:2013
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)

16.13   RADIATED EMISSIONS

Compliance	EN 55022: 2010, IEC 60255-26:2013
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

16.14   POWER FREQUENCY

Compliance	IEC 60255-22-7:2003, IEC 60255-26:2013
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.*

APPENDIX A

ORDERING OPTIONS

Variants	Order Number										
	1 - 4	5	6	7	8	9	10	11	12-13	14	15
Model Type											
Motor Protection IED - Directional	P24D										
Application											
Motor		M									
Small Generator		G									
Load / Line Management		L									
Current transformer											
Standard Earth CT			1								
SEF CT			2								
Hardware Options											
EIA RS485/IRIG-B (demodulated)	20TE/30TE			1							
EIA RS485/IRIG-B (demodulated) and Ethernet - Single channel Fibre/Copper (setting configurable as Failover*)	30TE			6							
EIA RS485/IRIG-B (demodulated) and EIA RS485	30TE			8							
EIA RS485/IRIG-B (demodulated) and Dual Redundant Copper Ethernet - 2x RJ45 Copper (setting configurable as Failover)	30TE/40TE			A							
EIA RS485/IRIG-B (demodulated) and Dual Redundant Fibre Ethernet - 2x multimode fibre (setting configurable as Failover)	30TE/40TE			B							
EIA RS485/IRIG-B (demodulated) and Dual Redundant Copper Ethernet - 2x RJ45 Copper (setting configurable as RSTP)	30TE/40TE			C							
EIA RS485/IRIG-B (demodulated) and Dual Redundant Fibre Ethernet - 2x multimode fibre (setting configurable as RSTP)	30TE/40TE			D							
EIA RS485/IRIG-B (demodulated) and Dual Redundant Copper Ethernet - 2x RJ45 Copper (setting configurable as PRP or HSR)	30TE/40TE			E							
EIA RS485/IRIG-B (demodulated) and Dual Redundant Fibre Ethernet - 2x multimode fibre (setting configurable as PRP or HSR)	30TE/40TE			F							
40TE only - EIA RS485, EIA RS485/IRIG-B (demodulated) and Dual Redundant Copper Ethernet - 2x RJ45 Copper (setting configurable as Failover)	40TE			G							
40TE only - EIA RS485, EIA RS485/IRIG-B (demodulated) and Dual Redundant Fibre Ethernet - 2x multimode fibre (setting configurable as Failover)	40TE			H							
40TE only - EIA RS485, EIA RS485/IRIG-B (demodulated) and Dual Redundant Copper Ethernet - 2x RJ45 Copper (setting configurable as RSTP)	40TE			J							
40TE only - EIA RS485, EIA RS485/IRIG-B (demodulated) and Dual Redundant Fibre Ethernet - 2x multimode fibre (setting configurable as RSTP)	40TE			K							
40TE only - EIA RS485, EIA RS485/IRIG-B (demodulated) and Dual Redundant Copper Ethernet - 2x RJ45 Copper (setting configurable as PRP or HSR)	40TE			L							
40TE only - EIA RS485, EIA RS485/IRIG-B (demodulated) and Dual Redundant Fibre Ethernet - 2x multimode fibre (setting configurable as PRP or HSR)	40TE			M							
EIA RS485/IRIG-B (demodulated) and Dual Copper Ethernet - 2x RJ45 Copper (dual IP)	30TE/40TE			N							
EIA RS485/IRIG-B (demodulated) and Dual Redundant Fibre Ethernet - 2x multimode fibre (dual IP)	30TE/40TE			P							
EIA RS485, EIA RS485/IRIG-B (demodulated) and Dual Copper Ethernet - 2x RJ45 Copper (dual IP)	40TE			Q							
EIA RS485, EIA RS485/IRIG-B (demodulated) and Dual Redundant Fibre Ethernet - 2x multimode fibre (dual IP)	40TE			R							
I/O Options	**Case**										
Standard (8 logic inputs + 8 relay outputs)	20TE/30TE				A						
Total (11 logic inputs + 12 relay outputs)	30TE/40TE				B						
Total (11 logic inputs + 12 relay outputs) suitable for trip circuit supervision	30TE/40TE				C						
Total (13 logic inputs + 12 relay outputs)	30TE/40TE				D						
Total (3 logic inputs + 4 relay outputs)	20TE				E						
Total (6 logic inputs + 8 relay outputs) suitable for trip circuit supervision	30TE				F						
Total (10 logic inputs + 12 relay outputs) suitable for trip circuit supervision	40TE				H						
Total (12 logic inputs + 12 relay outputs) suitable for trip circuit supervision	40TE				J						
Communication protocol											
Courier						1					
Modbus						2					
IEC60870-5-103 (VDEW)						3					
DNP3.0						4					
IEC 61850 over Ethernet and Courier via rear RS485						6					
IEC 61850 over Ethernet and IEC60870-5-103 via rear RS485						7					
DNP3.0 over Ethernet and Courier via rear RS485						8					
IEC 61850 over Ethernet and Modbus via rear RS485						9					
IEC 61850 over Ethernet and DNP3.0 via rear RS485						A					
IEC61850 over Ethernet + DNP3.0 over Ethernet and Courier via RS485						B					
IEC61850 over Ethernet + DNP3.0 over Ethernet and Modbus via RS485						C					
IEC61850 over Ethernet + DNP3.0 over Ethernet and IEC60870-5-103 via RS485						D					
Case											
20TE Flush (no function keys, 4 programmable LEDs)							B				
30TE Flush (3 function keys with LEDs, 8 programmable LEDs)							C				
40TE Flush (3 function keys with LEDs, 8 programmable LEDs)							D				
Software only							0				
20TE Flush (Adapted field voltage for KCGG retrofit)							2				
20TE Flush (without field voltage jumpering for KCGG retrofit)							4				
30TE Flush (Additional shorting link)							6				
Language											
Multilingual (English, French, German, Spanish)								0			
Multilingual (English, Russian, Italian, Portuguese)								6			
Chinese, English or French via HMI, with English or French only via Communications port								C			
Software Reference											
Unless specified the latest version will be delivered									**		
Customisation / Regionalisation											
Default										0	
Customer specific										A	
Hardware design suffix											
Initial release											A

Variants	Order Number										
	1 - 4	5	6	7	8	9	10	11	12-13	14	15
Model Type											
Motor Protection IED - Non-directional	P24N										
Application											
Motor		M									
Small Generator		G									
Load / Line Management		L									
Current transformer											
Standard Earth CT			1								
SEF CT			2								
Hardware Options											
EIA RS485/IRIG-B (demodulated)	20TE/30TE			1							
EIA RS485/IRIG-B (demodulated) and Ethernet - Single channel Fibre/Copper (setting configurable as Failover*)	30TE			6							
EIA RS485/IRIG-B (demodulated) and EIA RS485	30TE			8							
EIA RS485/IRIG-B (demodulated) and Dual Redundant Copper Ethernet - 2x RJ45 Copper (setting configurable as Failover)	30TE/40TE			A							
EIA RS485/IRIG-B (demodulated) and Dual Redundant Fibre Ethernet - 2x multimode fibre (setting configurable as Failover)	30TE/40TE			B							
EIA RS485/IRIG-B (demodulated) and Dual Redundant Copper Ethernet - 2x RJ45 Copper (setting configurable as RSTP)	30TE/40TE			C							
EIA RS485/IRIG-B (demodulated) and Dual Redundant Fibre Ethernet - 2x multimode fibre (setting configurable as RSTP)	30TE/40TE			D							
EIA RS485/IRIG-B (demodulated) and Dual Redundant Copper Ethernet - 2x RJ45 Copper (setting configurable as PRP or HSR)	30TE/40TE			E							
EIA RS485/IRIG-B (demodulated) and Dual Redundant Fibre Ethernet - 2x multimode fibre (setting configurable as PRP or HSR)	30TE/40TE			F							
40TE only - EIA RS485, EIA RS485/IRIG-B (demodulated) and Dual Redundant Copper Ethernet - 2x RJ45 Copper (setting configurable as Failover)	40TE			G							
40TE only - EIA RS485, EIA RS485/IRIG-B (demodulated) and Dual Redundant Fibre Ethernet - 2x multimode fibre (setting configurable as Failover)	40TE			H							
40TE only - EIA RS485, EIA RS485/IRIG-B (demodulated) and Dual Redundant Copper Ethernet - 2x RJ45 Copper (setting configurable as RSTP)	40TE			J							
40TE only - EIA RS485, EIA RS485/IRIG-B (demodulated) and Dual Redundant Fibre Ethernet - 2x multimode fibre (setting configurable as RSTP)	40TE			K							
40TE only - EIA RS485, EIA RS485/IRIG-B (demodulated) and Dual Redundant Copper Ethernet - 2x RJ45 Copper (setting configurable as PRP or HSR)	40TE			L							
40TE only - EIA RS485, EIA RS485/IRIG-B (demodulated) and Dual Redundant Fibre Ethernet - 2x multimode fibre (setting configurable as PRP or HSR)	40TE			M							
EIA RS485/IRIG-B (demodulated) and Dual Copper Ethernet - 2x RJ45 Copper (dual IP)	30TE/40TE			N							
EIA RS485/IRIG-B (demodulated) and Dual Redundant Fibre Ethernet - 2x multimode fibre (dual IP)	30TE/40TE			P							
EIA RS485, EIA RS485/IRIG-B (demodulated) and Dual Copper Ethernet - 2x RJ45 Copper (dual IP)	40TE			Q							
EIA RS485, EIA RS485/IRIG-B (demodulated) and Dual Redundant Fibre Ethernet - 2x multimode fibre (dual IP)	40TE			R							
I/O Options	**Case**										
Standard (8 logic inputs + 8 relay outputs)	20TE/30TE				A						
Total (11 logic inputs + 12 relay outputs)	30TE/40TE				B						
Total (11 logic inputs + 12 relay outputs) suitable for trip circuit supervision	30TE/40TE				C						
Total (13 logic inputs + 12 relay outputs)	30TE/40TE				D						
Total (3 logic inputs + 4 relay outputs)	20TE				E						
Total (6 logic inputs + 8 relay outputs) suitable for trip circuit supervision	30TE				F						
Total (10 logic inputs + 12 relay outputs) suitable for trip circuit supervision	40TE				H						
Total (12 logic inputs + 12 relay outputs) suitable for trip circuit supervision	40TE				J						
Communication protocol											
Courier						1					
Modbus						2					
IEC60870-5-103 (VDEW)						3					
DNP3.0						4					
IEC 61850 over Ethernet and Courier via rear RS485						6					
IEC 61850 over Ethernet and IEC60870-5-103 via rear RS485						7					
DNP3.0 over Ethernet and Courier via rear RS485						8					
IEC 61850 over Ethernet and Modbus via rear RS485						9					
IEC 61850 over Ethernet and DNP3.0 via rear RS485						A					
IEC61850 over Ethernet + DNP3.0 over Ethernet and Courier via RS485						B					
IEC61850 over Ethernet + DNP3.0 over Ethernet and Modbus via RS485						C					
IEC61850 over Ethernet + DNP3.0 over Ethernet and IEC60870-5-103 via RS485						D					
Case											
20TE Flush (no function keys, 4 programmable LEDs)							B				
30TE Flush (3 function keys with LEDs, 8 programmable LEDs)							C				
40TE Flush (3 function keys with LEDs, 8 programmable LEDs)							D				
Software only							0				
20TE Flush (Adapted field voltage for KCGG retrofit)							2				
20TE Flush (without field voltage jumpering for KCGG retrofit)							4				
30TE Flush (Additional shorting link)							6				
Language											
Multilingual (English, French, German, Spanish)								0			
Multilingual (English, Russian, Italian, Portuguese)								6			
Chinese, English or French via HMI, with English or French only via Communications port								C			
Software Reference											
Unless specified the latest version will be delivered									**		
Customisation / Regionalisation											
Default										0	
Customer specific										A	
Hardware design suffix											
Initial release											A

APPENDIX B

SETTINGS AND SIGNALS

Tables, containing a full list of settings, measurement data and DDB signals for each product model, are provided in a separate interactive PDF file attached as an embedded resource.

Tables are organized into a simple menu system allowing selection by language (where available), model and table type, and may be viewed and/or printed using an up-to-date version of Adobe Reader.

APPENDIX C

WIRING DIAGRAMS

MODEL	CORTEC OPTION*	EXTERNAL CONNECTION DIAGRAM TITLE	DRAWING-SHEET	ISSUE
BP24DM	IO option A	MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS AND E/F (8 I/P & 8 O/P)	10P24D01-1	B
	IO option A	MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS AND SEF (8 I/P & 8 O/P)	10P24D02-1	B
	IO option A	MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS AND E/F (8 I/P & 8 O/P) WITH ETHERNET MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS AND E/F (8 I/P & 8 O/P) WITH DUAL COPPER ETHERNET MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS AND E/F (8 I/P & 8 O/P) WITH DUAL FIBRE ETHERNET	10P24D03-1 10P24D03-2 10P24D03-3	B B B
	IO option A	MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS AND SEF (8 I/P & 8 O/P) WITH ETHERNET MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS AND SEF (8 I/P & 8 O/P) WITH DUAL COPPER ETHERNET MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS AND SEF (8 I/P & 8 O/P) WITH DUAL FIBRE ETHERNET	10P24D04-1 10P24D04-2 10P24D04-3	B B B
	IO option B	MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS AND E/F (11 I/P & 12 O/P) WITH 2 RS485 MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS AND E/F (11 I/P & 12 O/P) WITH 2 RS485 & ETHERNET MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT I/Ps AND E/F (11 I/P & 12 O/P) WITH 2 RS485 & DUAL COPPER ETHERNET MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT I/Ps AND E/F (11 I/P & 12 O/P) WITH 2 RS485 & DUAL FIBRE ETHERNET	10P24D05-1 10P24D05-2 10P24D05-3 10P24D05-4	B B B B
	IO option B	MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS AND SEF (11 I/P & 12 O/P) WITH 2 RS485 MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS AND SEF (11 I/P & 12 O/P) WITH 2 RS485 & ETHERNET MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT I/Ps AND SEF (11 I/P & 12 O/P) WITH 2 RS485 & DUAL COPPER ETHERNET MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT I/Ps AND SEF (11 I/P & 12 O/P) WITH 2 RS485 & DUAL FIBRE ETHERNET	10P24D06-1 10P24D06-2 10P24D06-3 10P24D06-4	B B B B
	IO option C	MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS AND E/F (11 I/P & 12 O/P) WITH TCS MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS AND E/F (11 I/P & 12 O/P) WITH TCS & ETHERNET MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS AND E/F (11 I/P & 12 O/P) WITH TCS & DUAL COPPER ETHERNET MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS AND E/F (11 I/P & 12 O/P) WITH TCS & DUAL FIBRE ETHERNET	10P24D07-1 10P24D07-2 10P24D07-3 10P24D07-4	B B B B
	IO option C	MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS AND SEF (11 I/P & 12 O/P) WITH TCS MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS AND SEF (11 I/P & 12 O/P) WITH TCS & ETHERNET MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS AND SEF (11 I/P & 12 O/P) WITH TCS & DUAL COPPER ETHERNET MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS AND SEF (11 I/P & 12 O/P) WITH TCS & DUAL FIBRE ETHERNET	10P24D08-1 10P24D08-2 10P24D08-3 10P24D08-4	B B B B
	IO option D	MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS AND E/F (13 I/P & 12 O/P) MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS AND E/F (13 I/P & 12 O/P) WITH ETHERNET MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS AND E/F (13 I/P & 12 O/P) WITH DUAL COPPER ETHERNET MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS AND E/F (13 I/P & 12 O/P) WITH DUAL FIBRE ETHERNET	10P24D09-1 10P24D09-2 10P24D09-3 10P24D09-4	B B B B
	IO option D	MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS AND SEF (13 I/P & 12 O/P) MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS AND SEF (13 I/P & 12 O/P) WITH ETHERNET MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS AND SEF (13 I/P & 12 O/P) WITH DUAL COPPER ETHERNET MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS AND SEF (13 I/P & 12 O/P) WITH DUAL FIBRE ETHERNET	10P24D10-1 10P24D10-2 10P24D10-3 10P24D10-4	B B B B
	IO option A	MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS AND E/F WITH SEPERATE RESIDUAL VOLTAGE INPUT 8I/P + 8O/P	10P24D12-1	B
	IO option E	MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS AND E/F (3 I/P & 4 O/P)	10P24D13-1	B
	IO option F	MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS AND E/F (6 I/P & 8 O/P) WITH TCS	10P24D14-1	B
	IO option H	MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & E/F (10 I/P & 12 O/P) WITH 2 RS485 MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & E/F (10 I/P & 12 O/P) WITH 2 RS485 & ETHERNET MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & E/F (10 I/P & 12 O/P) WITH 2 RS485 & DUAL COPPER ETHERNET MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & E/F (10 I/P & 12 O/P) WITH 2 RS485 & DUAL FIBRE ETHERNET	10P24D16-1 10P24D16-2 10P24D16-3 10P24D16-4	B B B B
	IO option H	MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & SEF (10 I/P & 12 O/P) WITH 2 RS485 MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & SEF (10 I/P & 12 O/P) WITH 2 RS485 & ETHERNET MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT I/Ps & SEF (10 I/P & 12 O/P) WITH 2 RS485 & DUAL COPPER ETHERNET MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & SEF (10 I/P & 12 O/P) WITH 2 RS485 & DUAL FIBRE ETHERNET	10P24D17-1 10P24D17-2 10P24D17-3 10P24D17-4	B B B B
	IO option J	MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & E/F (12 I/P & 12 O/P) MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & E/F (12 I/P & 12 O/P) WITH ETHERNET MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & E/F (12 I/P & 12 O/P) WITH DUAL COPPER ETHERNET MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & E/F (12 I/P & 12 O/P) WITH DUAL FIBRE ETHERNET	10P24D18-1 10P24D18-2 10P24D18-3 10P24D18-4	B B B B
	IO option J	MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & SEF (12 I/P & 12 O/P) MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & SEF (12 I/P & 12 O/P) WITH ETHERNET MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & SEF (12 I/P & 12 O/P) WITH DUAL COPPER ETHERNET MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & SEF (12 I/P & 12 O/P) WITH DUAL FIBRE ETHERNET	10P24D19-1 10P24D19-2 10P24D19-3 10P24D19-4	B B B B

* When selecting applicable connection diagram(s), it may be helpful to reference the appropriate model's CORTEC.

MODEL	CORTEC OPTION*	EXTERNAL CONNECTION DIAGRAM TITLE	DRAWING-SHEET	ISSUE
P24NM	IO option A	MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND E/F (8 I/P & 8 O/P)	10P24N01-1	B
	IO option A	MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND SEF (8 I/P & 8 O/P)	10P24N02-1	B
	IO option A	MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND E/F (8 I/P & 8 O/P) WITH ETHERNET MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND E/F (8 I/P & 8 O/P) WITH DUAL COPPER ETHERNET MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND E/F (8 I/P & 8 O/P) WITH DUAL FIBRE ETHERNET	10P24N03-1 10P24N03-2 10P24N03-3	B B B
	IO option A	MOTOR PROTECTION WITH PHASE CURRENT INPUTS & SEF (8 I/P 8 O/P) WITH ETHERNET & OPTIONAL SHORTING LINK MOTOR PROTECTION WITH PHASE CURRENT INPUTS & SEF (8 I/P 8 O/P) WITH DUAL COPPER ETHERNET MOTOR PROTECTION WITH PHASE CURRENT INPUTS & SEF (8 I/P 8 O/P) WITH DUAL FIBRE ETHERNET	10P24N04-1 10P24N04-2 10P24N04-3	B B B
	IO option B	MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND E/F (11 I/P & 12 O/P) WITH 2 RS485 MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND E/F (11 I/P & 12 O/P) WITH 2 RS485 & ETHERNET MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND E/F (11 I/P & 12 O/P) WITH 2 RS485 & DUAL COPPER ETHERNET MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND E/F (11 I/P & 12 O/P) WITH 2 RS485 & DUAL FIBRE ETHERNET	10P24N05-1 10P24N05-2 10P24N05-3 10P24N05-4	B B B B
	IO option B	MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND SEF (11 I/P & 12 O/P) WITH 2 RS485 MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND SEF (11 I/P & 12 O/P) WITH 2 RS485 & ETHERNET MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND SEF (11 I/P & 12 O/P) WITH 2 RS485 & DUAL COPPER ETHERNET MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND SEF (11 I/P & 12 O/P) WITH 2 RS485 & DUAL FIBRE ETHERNET	10P24N06-1 10P24N06-2 10P24N06-3 10P24N06-4	B B B B
	IO option C	MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND E/F (11 I/P & 12 O/P) WITH TCS MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND E/F (11 I/P & 12 O/P) WITH TCS & ETHERNET MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND E/F (11 I/P & 12 O/P) WITH TCS & DUAL COPPER ETHERNET MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND E/F (11 I/P & 12 O/P) WITH TCS & DUAL FIBRE ETHERNET	10P24N07-1 10P24N07-2 10P24N07-3 10P24N07-4	B B B B
	IO option C	MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND SEF (11 I/P & 12 O/P) WITH TCS MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND SEF (11 I/P & 12 O/P) WITH TCS & ETHERNET MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND SEF (11 I/P & 12 O/P) WITH TCS & DUAL COPPER ETHERNET MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND SEF (11 I/P & 12 O/P) WITH TCS & DUAL FIBRE ETHERNET	10P24N08-1 10P24N08-2 10P24N08-3 10P24N08-4	B B B B
	IO option D	MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND E/F (13 I/P & 12 O/P) MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND E/F (13 I/P & 12 O/P) & ETHERNET MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND E/F (13 I/P & 12 O/P) & DUAL COPPER ETHERNET MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND E/F (13 I/P & 12 O/P) & DUAL FIBRE ETHERNET	10P24N09-1 10P24N09-2 10P24N09-3 10P24N09-4	B B B B
	IO option D	MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND SEF (13 I/P & 12 O/P) MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND SEF (13 I/P & 12 O/P) & ETHERNET MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND SEF (13 I/P & 12 O/P) & DUAL COPPER ETHERNET MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND SEF (13 I/P & 12 O/P) & DUAL FIBRE ETHERNET	10P24N10-1 10P24N10-2 10P24N10-3 10P24N10-4	B B B B
	IO option E	MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND EARTH FAULT (3 I/P & 4 O/P)	10P24N12-1	B
	IO option F	MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND EARTH FAULT (6 I/P & 8 O/P) WITH TCS	10P24N13-1	B
	IO option H	MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND E/F (10 I/P & 12 O/P) WITH 2 RS485 MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND E/F (10 I/P & 12 O/P) WITH 2 RS485 & ETHERNET MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND E/F (10 I/P & 12 O/P) WITH 2 RS485 & DUAL COPPER ETHERNET MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND E/F (10 I/P & 12 O/P) WITH 2 RS485 & DUAL FIBRE ETHERNET	10P24N14-1 10P24N14-2 10P24N14-3 10P24N14-4	B B B B
	IO option H	MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND SEF (10 I/P & 12 O/P) WITH 2 RS485 MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND SEF (10 I/P & 12 O/P) WITH 2 RS485 & ETHERNET MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND SEF (10 I/P & 12 O/P) WITH 2 RS485 & DUAL COPPER ETHERNET MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND SEF (10 I/P & 12 O/P) WITH 2 RS485 & DUAL FIBRE ETHERNET	10P24N15-1 10P24N15-2 10P24N15-3 10P24N15-4	B B B B
	IO option J	MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND E/F (12 I/P & 12 O/P) MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND E/F (12 I/P & 12 O/P) & ETHERNET MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND E/F (12 I/P & 12 O/P) & DUAL COPPER ETHERNET MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND E/F (12 I/P & 12 O/P) & DUAL FIBRE ETHERNET	10P24N16-1 10P24N16-2 10P24N16-3 10P24N16-4	B B B B
	IO option J	MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND SEF (12 I/P & 12 O/P) MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND SEF (12 I/P & 12 O/P) & ETHERNET MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND SEF (12 I/P & 12 O/P) & DUAL COPPER ETHERNET MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND SEF (12 I/P & 12 O/P) & DUAL FIBRE ETHERNET	10P24N17-1 10P24N17-2 10P24N17-3 10P24N17-4	B B B B

* When selecting applicable connection diagram(s), it may be helpful to reference the appropriate model's CORTEC.

DIRECTION OF FORWARD CURRENT FLOW

P2   P1

M

A
B
C

A
B
C

S2   S1

PHASE ROTATION

4th VT
(OPEN DELTA)

P24D
8I + 8O

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

IA
IB
IC
IN

VA
VB
VC

CASE EARTH CONNECTION

EIARS485/K BUS COMMUNICATIONS

A.C./D.C. SUPPLY Vx

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 -
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8 -

OPTO ISOLATED BINARY INPUTS

CASE EARTH

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE
EARTH STRAP)

NOTES:

1.
  (a)   C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
  (b)   SHORT TERMINALS BREAK BEFORE (c).
  (c)   LONG TERMINAL.
  (d)   PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.

3. EARTH CONNECTIONS ARE TYPICAL ONLY.

4. RESIDUAL VOLTAGE MEASUREMENT REQUIRE A 5 LIMB VT OR 3*1PH VT

Date: 03/10/2017	Name: V.SIVASAMBO	Drg Title: MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & E/F (8 I/P & 8 O/P)	Next Stage: -	Drg No: 10P24D01-1	ECN No: CID005225	Revision: B	Iteration: 2
Date: 03/10/2017	Chkd: S WOOTTON						
Sub-contractor reference: -		CAD DATA 1:1 DIMENSIONS: mm	Linear Tol mm: -		PLM No: A20028370	Sht: 1	Status: IN WORK
Finish: -		DO NOT SCALE	Angular Tol deg: -	Grid Solutions		Next Sht: -	

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

P24D
8I + 80

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

4th VT (OPEN DELTA)

IA
IB
IC
IN SENSITIVE
VA
VB
VC

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 −
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8 −

OPTO ISOLATED BINARY INPUTS

CASE EARTH CONNECTION

EIARS485/K BUS COMMUNICATIONS

A.C./D.C. SUPPLY Vx

CASE EARTH

MODULE TERMINAL BLOCKS VIEWED FROM REAR (WITH INTEGRAL CASE EARTH STRAP)

NOTES:

1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.

3. CT/VT EARTH CONNECTIONS ARE TYPICAL ONLY.

4. RESIDUAL VOLTAGE MEASUREMENT REQUIRE A 5 LIMB VT OR 3*1PH VT

Date: 03/10/2017	Name: V.SIVASAMBO	Drg Title: MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & SEF (8 I/P & 8 O/P)	Next Stage: -	Drg No: 10P24D02-1	ECN No: CID005225	Revision: B	Iteration: 2
Date: 03/10/2017	Chkd: S WOOTTON						
Sub-contractor reference: -		CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: - Angular Tol deg: -	Grid Solutions	PLM No: A20028435	Sht: 1 Next Sht: -	Status: IN WORK
Finish: -							

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

P24D
8I + 8O
+ Ethernet

4th VT
(OPEN DELTA)

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 −
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8 −

OPTO ISOLATED BINARY INPUTS

EIARS485/K BUS COMMUNICATIONS

A.C./D.C. SUPPLY Vx

TX+
TX−
RX+
RX−
RJ45
10 BASE−T/
100 BASE−TX

TX
RX
LC
10 BASE−FL
OR
100 BASE−FX

NOTES:

1.
(a)   C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b)   SHORT TERMINALS BREAK BEFORE (c).
(c)   LONG TERMINAL.
(d)   PIN TERMINAL (P.C.B. TYPE).

2. C.T. CONNECTIONS ARE TYPICAL ONLY.
3. CT/VT EARTH CONNECTIONS ARE TYPICAL ONLY.
4. RESIDUAL VOLTAGE MEASUREMENT REQUIRE A 5 LIMB VT OR 3*1PH VT

CASE EARTH

LINK
ACTIVITY
PORT A
(SK2) TX
RX

ACTIVITY
PORT B
(SK3)
LINK

SCN

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE
EARTH STRAP)

| Date: | 03/10/2017 | Name: | V.SIVASAMBO | Drg Title: | MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT - INPUTS & E/F (8 I/P & 8 O/P) WITH ETHERNET | Next Stage: - | Drg No: | 10P24D03-1 | ECN No: CID005225 | Revision: B | Iteration: 2 |
| Date: | 03/10/2017 | Chkd: | S WOOTTON | | | | | | | | |

CAD DATA 1:1 DIMENSIONS: mm
DO NOT SCALE

Linear Tol mm: -
Angular Tol deg: -

GE Grid Solutions

PLM No: A20028437

Sht: 1
Next Sht: 2

Status: IN WORK

Sub-contractor reference: -
Finish: -

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

4th VT
(OPEN DELTA)

P24D
8I + 8O
+ Ethernet

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 –
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8 –

OPTO ISOLATED BINARY INPUTS

EIARS485/K BUS COMMUNICATIONS

SCN

NOTES:

1.
(a)   C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b)   SHORT TERMINALS BREAK BEFORE (c).
(c)   LONG TERMINAL.
(d)   PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.

3. CT/VT EARTH CONNECTIONS ARE TYPICAL ONLY.

4. RESIDUAL VOLTAGE MEASUREMENT REQUIRE A 5 LIMB VT OR 3*1PH VT

CASE EARTH

ACTIVITY
PORT A
(SK2)
LINK

ACTIVITY
PORT B
(SK3)
LINK

SCN

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE EARTH STRAP)

A.C./D.C. SUPPLY Vx

SK2
TX+
TX–
RX+
RX–

RJ45
10 BASE–T/
100 BASE–TX

SK3
TX+
TX–
RX+
RX–

RJ45
10 BASE–T/
100 BASE–TX

Date: 03/10/2017	Name: V.SIVASAMBO	Drg Title: MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & E/F (8 I/P & 8 O/P) WITH DUAL COPPER ETHERNET	Next Stage: -	Drg No: 10P24D03-2	ECN No: CID005225	Revision: B	Iteration: 2
Date: 03/10/2017	Chkd: S WOOTTON						
Sub-contractor reference: -		CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: - / Angular Tol deg: -	GE Grid Solutions	PLM No: A20028471	Sht: 2 / Next Sht: 3	Status: IN WORK
Finish: -							

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

4th VT
(OPEN DELTA)

P24D
8I + 8O
+ Ethernet

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 −
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8 −

OPTO ISOLATED BINARY INPUTS

EIARS485/K BUS COMMUNICATIONS

NOTES:
1.
(a)   C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b)   SHORT TERMINALS BREAK BEFORE (c).
(c)   LONG TERMINAL.
(d)   PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.
3. CT/VT EARTH CONNECTIONS ARE TYPICAL ONLY.
4. RESIDUAL VOLTAGE MEASUREMENT REQUIRE A 5 LIMB VT OR 3*1PH VT

CASE EARTH

PORT A (SK2)   RX TX   ACTIVITY LINK

PORT B (SK3)   RX TX   ACTIVITY LINK

SCN

MODULE TERMINAL BLOCKS VIEWED FROM REAR (WITH INTEGRAL CASE EARTH STRAP)

A.C./D.C. SUPPLY Vx

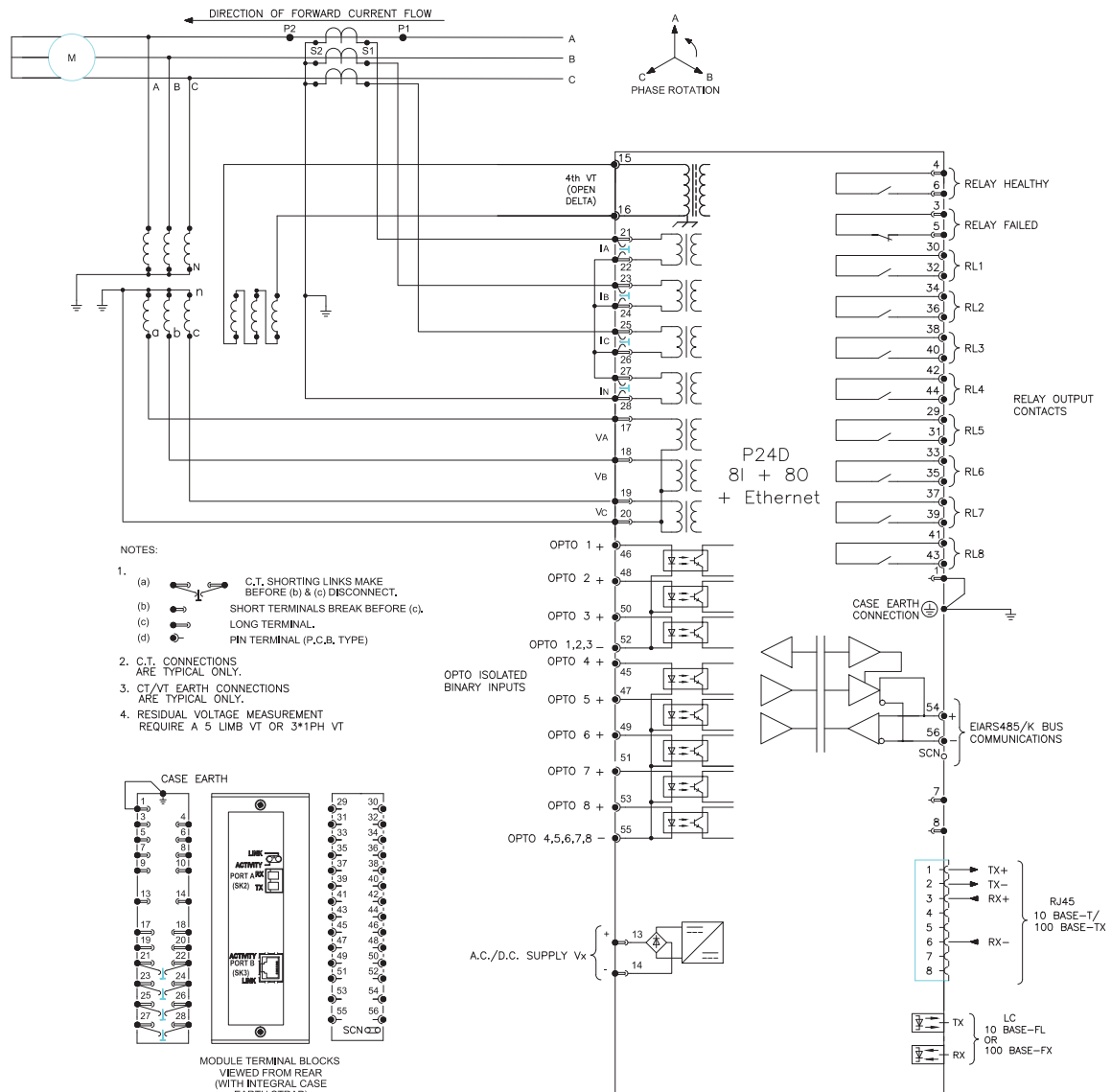SK2   TX RX   LC 10 BASE−FL OR 100 BASE−FX

SK3   TX RX   LC 10 BASE−FL OR 100 BASE−FX

Date: 05/10/2017	Name: V.SIVASAMBO	Drg Title: MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & E/F (8 I/P & 8 O/P) WITH DUAL FIBRE ETHERNET	Next Stage: -	Drg No: 10P24D03-3	ECN No: CID005225	Revision: B	Iteration: 2
Date: 05/10/2017	Chkd: S WOOTTON						
Sub-contractor reference: -		CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: -	Grid Solutions	PLM No: A20028489	Sht: 3	Status: IN WORK
Finish: -			Angular Tol deg: -			Next Sht: -	

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

4th VT (OPEN DELTA)

OPTIONAL FEATURE SEE NOTE 4

IA
IB
IC
IN SENSITIVE
VA
VB
Vc

P24D
8I + 8O
+ Ethernet

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

EIARS485/K BUS COMMUNICATIONS

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8

OPTO ISOLATED BINARY INPUTS

A.C./D.C. SUPPLY Vx

TX+
TX−
RX+
RX−

RJ45
10 BASE−T/
100 BASE−TX

TX
RX

LC
10 BASE−FL
OR
100 BASE−FX

CASE EARTH

LINK
ACTIVITY
PORT A RX
(SK2) TX

ACTIVITY
PORT B
(SK3) LINK

SCN

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE
EARTH STRAP)

NOTES:

1.
(a)   C.T. SHORTING LINKS MAKE
        BEFORE (b) & (c) DISCONNECT.
(b)   SHORT TERMINALS BREAK BEFORE (c).
(c)   LONG TERMINAL.
(d)   PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS
   ARE TYPICAL ONLY.

3. CT/VT EARTH CONNECTIONS
   ARE TYPICAL ONLY.

4. TERMINALS 9 & 10: OPTIONAL SHORTING LINK (ORDERING OPTION). ONLY
   AVAILABLE FOR THE 30TE MODEL VARIANTS.
   THESE TERMINALS ARE USED FOR CAPACITOR CONE APPLICATIONS. PLEASE
   REFER TO ALSTOM GRID APPLICATION GUIDE AG013 FOR GUIDANCE.

5. RESIDUAL VOLTAGE MEASUREMENT
   REQUIRE A 5 LIMB VT OR 3*1PH VT

Date: 05/10/2017	Name: V.SIVASAMBO	Drg Title: MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & SEF (8 I/P & 8 O/P) WITH ETHERNET	Next Stage: -	Drg No: 10P24D04-1	ECN No: CID005225	Revision: B	Iteration: 2
Date: 05/10/2017	Chkd: S WOOTTON						
Sub-contractor reference: -		CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: - Angular Tol deg: -	Grid Solutions	PLM No: A20028491	Sht: 1	Status: IN WORK
Finish: -						Next Sht: 2	

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

4th VT (OPEN DELTA)

IA
IB
IC
IN SENSITIVE
VA
VB
Vc

P24D
8I + 8O
+ Ethernet

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8

OPTO ISOLATED BINARY INPUTS

EIARS485/K BUS COMMUNICATIONS

CASE EARTH

ACTIVITY PORT A (SK2) LINK

ACTIVITY PORT B (SK3) LINK

MODULE TERMINAL BLOCKS VIEWED FROM REAR (WITH INTEGRAL CASE EARTH STRAP)

NOTES:
1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.
3. CT/VT EARTH CONNECTIONS ARE TYPICAL ONLY.
4. RESIDUAL VOLTAGE MEASUREMENT REQUIRE A 5 LIMB VT OR 3*1PH VT

A.C./D.C. SUPPLY Vx

SK2
1 TX+
2 TX-
3 RX+
4
5
6 RX-
7
8

RJ45 10 BASE-T/ 100 BASE-TX

SK3
1 TX+
2 TX-
3 RX+
4
5
6 RX-
7
8

RJ45 10 BASE-T/ 100 BASE-TX

Date: 05/10/2017	Name: V.SIVASAMBO	Drg Title: MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & SEF (8 I/P & 8 O/P) WITH DUAL COPPER ETHERNET	Next Stage: -	Drg No: 10P24D04-2	ECN No: CID005225	Revision: B	Iteration: 2
Date: 05/10/2017	Chkd: S WOOTTON						
Sub-contractor reference: -		CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: - / Angular Tol deg: -	Grid Solutions	PLM No: A20028493	Sht: 2	Status: IN WORK
Finish: -						Next Sht: 3	

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

4th VT (OPEN DELTA)

P24D
8I + 8O
+ Ethernet

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

IA
IB
IC
IN SENSITIVE
VA
VB
VC

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 -
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8 -

OPTO ISOLATED BINARY INPUTS

CASE EARTH CONNECTION

EIARS485/K BUS COMMUNICATIONS
SCN

CASE EARTH

PORT A (SK2)
ACTIVITY LINK

PORT B (SK3)
ACTIVITY LINK

MODULE TERMINAL BLOCKS VIEWED FROM REAR (WITH INTEGRAL CASE EARTH STRAP)

NOTES:
1.
(a)   C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b)   SHORT TERMINALS BREAK BEFORE (c).
(c)   LONG TERMINAL.
(d)   PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.
3. CT/VT EARTH CONNECTIONS ARE TYPICAL ONLY.
4. RESIDUAL VOLTAGE MEASUREMENT REQUIRE A 5 LIMB VT OR 3*1PH VT

A.C./D.C. SUPPLY Vx

SK2
TX
RX
LC 10 BASE-FL OR 100 BASE-FX
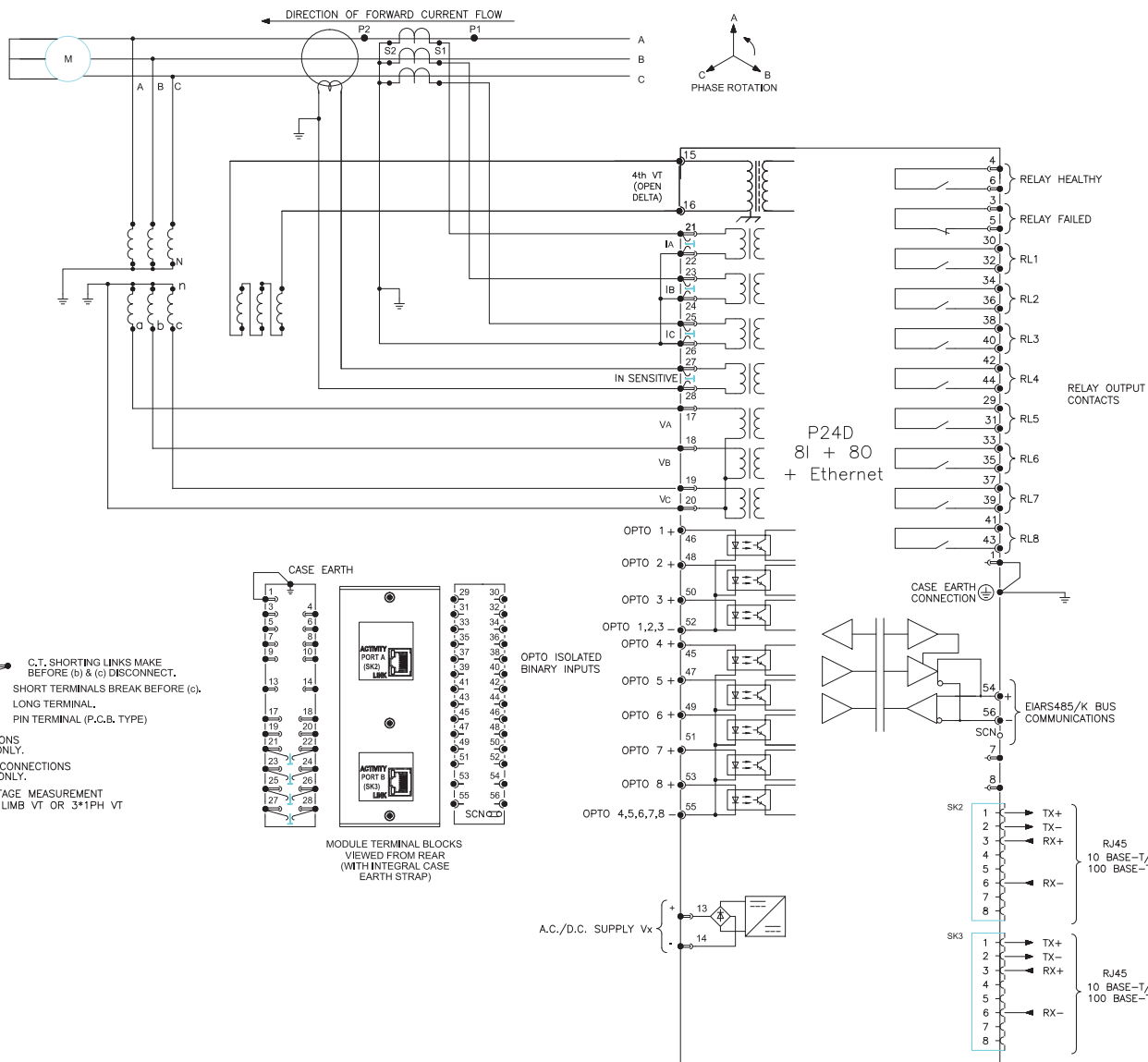
SK3
TX
RX
LC 10 BASE-FL OR 100 BASE-FX

Date: 05/10/2017	Name: V.SIVASAMBO	Drg Title: MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & SEF (8 I/P & 8 O/P) WITH DUAL FIBRE ETHERNET	Next Stage: -	Drg No: 10P24D04-3	ECN No: CID005225	Revision: B	Iteration: 2
Date: 05/10/2017	Chkd: S WOOTTON						
Sub-contractor reference: -		CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: - / Angular Tol deg: -	GE Grid Solutions	PLM No: A20028495	Sht: 3	Status: IN WORK
Finish: -						Next Sht: -	

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

4th VT
(OPEN DELTA)

P24D
11I + 12O
+ 2 RS485

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 −
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8 −
OPTO 9 +
OPTO 10+
OPTO 11+
OPTO 9,10,11 −

OPTO ISOLATED BINARY INPUTS

CASE EARTH

MODULE TERMINAL BLOCKS VIEWED FROM REAR (WITH INTEGRAL CASE EARTH STRAP)

RP−1 EIARS485/K BUS COMMUNICATIONS

A.C./D.C. SUPPLY Vx

RL9
RL10
RL11
RL12

RELAY OUTPUT CONTACTS

RP−2 EIARS485/K BUS COMMUNICATIONS

NOTES:

1. (a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
   (b) SHORT TERMINALS BREAK BEFORE (c).
   (c) LONG TERMINAL.
   (d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.

3. EARTH CONNECTIONS ARE TYPICAL ONLY.

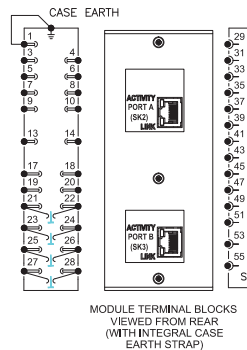4. RESIDUAL VOLTAGE MEASUREMENT REQUIRE A 5 LIMB VT OR 3*1PH VT

Date: 05/10/2017	Name: V.SIVASAMBO	Drg Title: MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & E/F (11 I/P & 12 O/P) WITH 2 RS485	Next Stage: -	Drg No: 10P24D05-1	ECN No: CID005225	Revision: B	Iteration: 2
Date: 05/10/2017	Chkd: S WOOTTON						
Sub-contractor reference: -		CAD DATA 1:1 DIMENSIONS: mm	Linear Tol mm: -	PLM No: A20028497	Sht: 1	Status: IN WORK	
Finish: -		DO NOT SCALE	Angular Tol deg: -		Next Sht: -		

Grid Solutions

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

4th VT (OPEN DELTA)

P24D
11I + 12O
+ 2 RS485
+ ETHERNET

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8
RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

RP-1
EIARS485/K BUS
COMMUNICATIONS

RP-2
EIARS485/K BUS
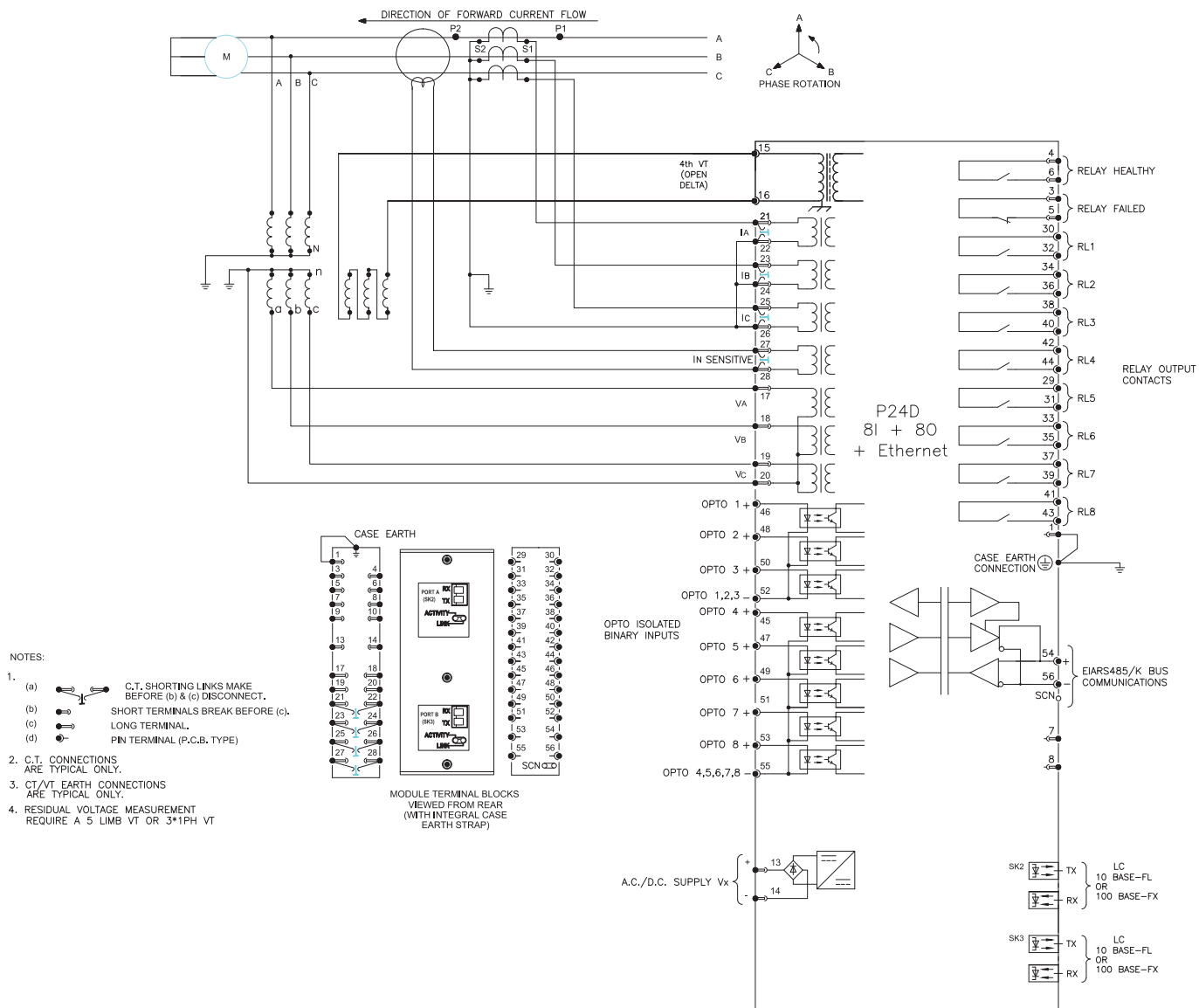COMMUNICATIONS

RL9
RL10
RL11
RL12
RELAY OUTPUT CONTACTS

CASE EARTH

NOTES:
1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.
3. EARTH CONNECTIONS ARE TYPICAL ONLY.
4. RESIDUAL VOLTAGE MEASUREMENT REQUIRE A 5 LIMB VT OR 3*1PH VT

OPTO ISOLATED BINARY INPUTS

OPTO 1+
OPTO 2+
OPTO 3+
OPTO 1,2,3 -
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8 -
OPTO 9 +
OPTO 10+
OPTO 11+
OPTO 9,10,11 -

A.C./D.C. SUPPLY Vx

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE
EARTH STRAP)

LINK
ACTIVITY
PORT A RX
(SK2) TX

ACTIVITY
PORT B
(SK3)
LINK

SCN
SCN

TX+
TX-
RX+

RX-

RJ45
10 BASE-T/
100 BASE-TX

TX
RX

LC
10 BASE-FL
OR
100 BASE-FX

Date: 05/10/2017	Name: V.SIVASAMBO	Drg Title: MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & E/F (11 I/P & 12 O/P) WITH 2 RS485 & ETHERNET	Next Stage: -	Drg No: 10P24D05-2	ECN No: CID005225	Revision: B	Iteration: 2
Date: 05/10/2017	Chkd: S WOOTTON						
Sub-contractor reference: -		CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: - Angular Tol deg: -	GE Grid Solutions	PLM No: A20028500	Sht: 2	Status: IN WORK
Finish: -						Next Sht: 3	

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

4th VT
(OPEN
DELTA)

P24D
11I + 12O
+ 2 RS485
+ ETHERNET

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT
CONTACTS

CASE EARTH
CONNECTION

OPTO 1+
OPTO 2+
OPTO 3+
OPTO 1,2,3−
OPTO 4+
OPTO 5+
OPTO 6+
OPTO 7+
OPTO 8+
OPTO 4,5,6,7,8−
OPTO 9+
OPTO 10+
OPTO 11+
OPTO 9,10,11−

OPTO ISOLATED
BINARY INPUTS

RP−1
EIARS485/K BUS
COMMUNICATIONS

RL9
RL10
RL11
RL12

RELAY OUTPUT
CONTACTS

CASE EARTH

ACTIVITY
PORT A
(SK2)
LINK

ACTIVITY
PORT B
(SK3)
LINK

SCN
SCN

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE
EARTH STRAP)

A.C./D.C. SUPPLY Vx

RP−2
EIARS485/K BUS
COMMUNICATIONS

SK2
TX+
TX−
RX+
RX−
RJ45
10 BASE−T/
100 BASE−TX

SK3
TX+
TX−
RX+
RX−
RJ45
10 BASE−T/
100 BASE−TX

NOTES:

1.
(a) C.T. SHORTING LINKS MAKE
     BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS
   ARE TYPICAL ONLY.

3. EARTH CONNECTIONS
   ARE TYPICAL ONLY.

4. RESIDUAL VOLTAGE MEASUREMENT
   REQUIRE A 5 LIMB VT OR 3*1PH VT

Date:	05/10/2017	Name:	V.SIVASAMBO	Drg Title:	MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & E/F (11 I/P & 12 O/P) WITH 2 RS485 & DUAL COPPER ETHERNET	Next Stage: -	Drg No:	10P24D05-3	ECN No: CID005225	Revision: B	Iteration: 2
Date:	05/10/2017	Chkd:	S WOOTTON							
Sub-contractor reference: -				CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: - / Angular Tol deg: -	Grid Solutions	PLM No:	A20028505	Sht: 3	Status: IN WORK
Finish: -									Next Sht: 4	

DIRECTION OF FORWARD CURRENT FLOW

M

P2 P1
S2 S1

A
B
C

PHASE ROTATION

4th VT
(OPEN DELTA)

IA
IB
IC
IN
VA
VB
Vc

P24D
11I + 12O
+ 2 RS485
+ ETHERNET

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 -
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8 -
OPTO 9 +
OPTO 10+
OPTO 11+
OPTO 9,10,11 -

OPTO ISOLATED
BINARY INPUTS

RP-1
EIARS485/K BUS
COMMUNICATIONS
SCN

RL9
RL10
RL11
RL12

RELAY OUTPUT CONTACTS

A.C./D.C. SUPPLY Vx

RP-2
EIARS485/K BUS
COMMUNICATIONS
SCN

SK2   TX   LC
10 BASE-FL
OR
100 BASE-FX
RX

SK3   TX   LC
10 BASE-FL
OR
100 BASE-FX
RX

CASE EARTH

PORT A RX
(SK2)   TX
ACTIVITY
LINK

PORT B RX
(SK3)   TX
ACTIVITY
LINK

SCN   SCN   SCN

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE
EARTH STRAP)

NOTES:
1.
(a)   C.T. SHORTING LINKS MAKE
        BEFORE (b) & (c) DISCONNECT.
(b)   SHORT TERMINALS BREAK BEFORE (c).
(c)   LONG TERMINAL.
(d)   PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS
   ARE TYPICAL ONLY.
3. EARTH CONNECTIONS
   ARE TYPICAL ONLY.
4. RESIDUAL VOLTAGE MEASUREMENT
   REQUIRE A 5 LIMB VT OR 3*1PH VT

Date: 05/10/2017	Name: V.SIVASAMBO	Drg Title: MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & E/F (11 I/P & 12 O/P) WITH 2 RS485 & DUAL FIBRE ETHERNET	Next Stage: -	Drg No: 10P24D05-4	ECN No: CID005225	Revision: B	Iteration: 2
Date: 05/10/2017	Chkd: S WOOTTON						

Sub-contractor reference: -	CAD DATA 1:1 DIMENSIONS: mm	Linear Tol mm: -	Grid Solutions	PLM No: A20028507	Sht: 4	Status:
Finish: -	DO NOT SCALE	Angular Tol deg: -			Next Sht: -	IN WORK

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

4th VT (OPEN DELTA)

IA
IB
IC
IN SENSITIVE
VA
VB
VC

P24D
11I + 12O + 2 RS485

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 −
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8 −
OPTO 9 +
OPTO 10+
OPTO 11+
OPTO 9,10,11−

OPTO ISOLATED BINARY INPUTS

RP−1 EIARS485/K BUS COMMUNICATIONS
SCN

A.C./D.C. SUPPLY Vx

RL9
RL10
RL11
RL12

RELAY OUTPUT CONTACTS

RP−2 EIARS485/K BUS COMMUNICATIONS
SCN

CASE EARTH

NOTES:
1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.
3. CT/VT EARTH CONNECTIONS ARE TYPICAL ONLY.
4. RESIDUAL VOLTAGE MEASUREMENT REQUIRE A 5 LIMB VT OR 3*1PH VT

MODULE TERMINAL BLOCKS VIEWED FROM REAR (WITH INTEGRAL CASE EARTH STRAP)

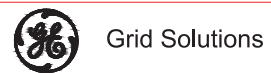| Date: 06/10/2017 | Name: V.SIVASAMBO | Drg Title: MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & SEF (11 I/P & 12 O/P) WITH 2 RS485 | Next Stage: - | Drg No: 10P24D06-1 | ECN No: CID005225 | Revision: B | Iteration: 2 |
Date: 06/10/2017	Chkd: S WOOTTON						
Sub-contractor reference: -		CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: - / Angular Tol deg: -	Grid Solutions	PLM No: A20028509	Sht: 1	Status: IN WORK
Finish: -						Next Sht: -	

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

4th VT (OPEN DELTA)

IA
IB
IC
IN SENSITIVE
VA
VB
VC

P24D
11I + 12O
+ 2 RS485
+ ETHERNET

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 −
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8 −
OPTO 9 +
OPTO 10+
OPTO 11+
OPTO 9,10,11−

OPTO ISOLATED BINARY INPUTS

RP−1 EIARS485/K BUS COMMUNICATIONS
SCN

RP−2 EIARS485/K BUS COMMUNICATIONS
SCN

RL9
RL10
RL11
RL12

RELAY OUTPUT CONTACTS

A.C./D.C. SUPPLY Vx

TX+
TX−
RX+
RX−
RJ45
10 BASE−T/ 100 BASE−TX

TX
RX
LC
10 BASE−FL OR 100 BASE−FX

CASE EARTH

LINK
ACTIVITY
PORT A RX
(SK2)   TX

ACTIVITY
PORT B
(SK3) LINK

SCN

MODULE TERMINAL BLOCKS VIEWED FROM REAR (WITH INTEGRAL CASE EARTH STRAP)

NOTES:
1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.
3. CT/VT EARTH CONNECTIONS ARE TYPICAL ONLY.
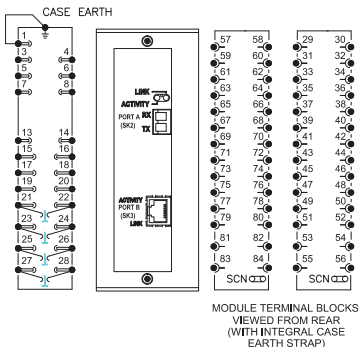4. RESIDUAL VOLTAGE MEASUREMENT REQUIRE A 5 LIMB VT OR 3*1PH VT

Date: 06/10/2017	Name: V.SIVASAMBO	Drg Title: MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & SEF (11 I/P & 12 O/P) WITH 2 RS485 & ETHERNET	Next Stage:	Drg No: 10P24D06-2	ECN No: CID005225	Revision: B	Iteration: 2
Date: 06/10/2017	Chkd: S WOOTTON						
Sub-contractor reference: -		CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: - / Angular Tol deg: -	Grid Solutions	PLM No: A20028511	Sht: 2	Status: IN WORK
Finish: -						Next Sht: 3	

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

NOTES:

1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.

3. CT/VT EARTH CONNECTIONS ARE TYPICAL ONLY.

4. RESIDUAL VOLTAGE MEASUREMENT REQUIRE A 5 LIMB VT OR 3*1PH VT

CASE EARTH

ACTIVITY PORT A (SK2) LINK

ACTIVITY PORT B (SK3) LINK

MODULE TERMINAL BLOCKS VIEWED FROM REAR (WITH INTEGRAL CASE EARTH STRAP)

4th VT (OPEN DELTA)

IN SENSITIVE

P24D
11I + 12O
+ 2 RS485
+ ETHERNET

OPTO ISOLATED BINARY INPUTS

A.C./D.C. SUPPLY Vx

RELAY HEALTHY

RELAY FAILED

RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

RP-1
EIARS485/K BUS COMMUNICATIONS

RL9
RL10
RL11
RL12

RELAY OUTPUT CONTACTS

RP-2
EIARS485/K BUS COMMUNICATIONS

SK2
1 TX+
2 TX-
3 RX+
4
5
6 RX-
7
8
RJ45 10 BASE-T/ 100 BASE-TX

SK3
1 TX+
2 TX-
3 RX+
4
5
6 RX-
7
8
RJ45 10 BASE-T/ 100 BASE-TX

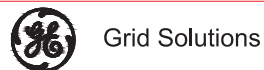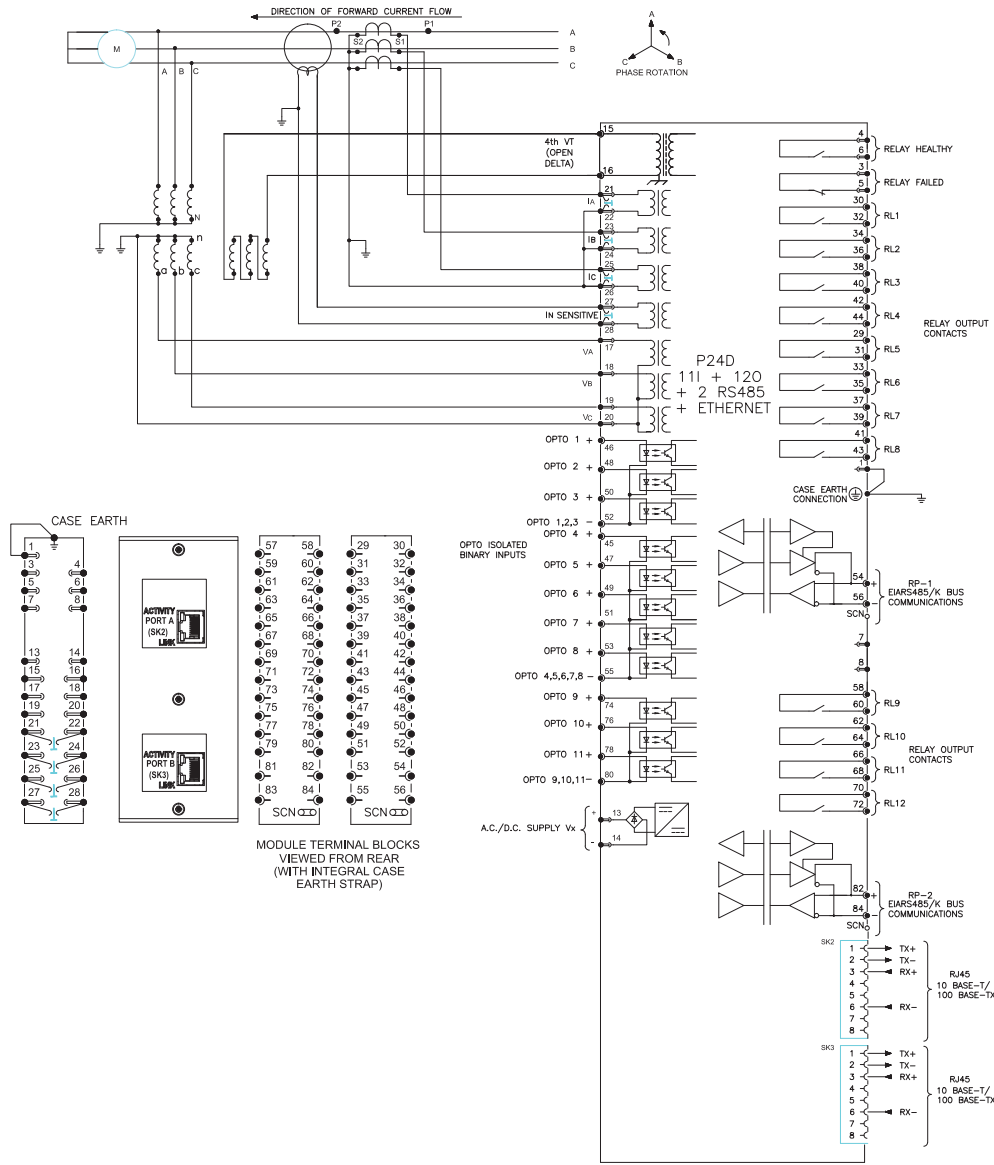| Date: | 06/10/2017 | Name: | V.SIVASAMBO | Drg Title: | MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & SEF (11 I/P & 12 O/P) WITH 2 RS485 & DUAL COPPER ETHERNET | Next Stage: - | | Drg No: | 10P24D06-3 | ECN No: CID005225 | Revision: B | Iteration: 2 |
Date:	06/10/2017	Chkd:	S WOOTTON									
Sub-contractor reference: -				CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: - Angular Tol deg: -	GE Grid Solutions		PLM No:	A20028513	Sht: 3	Status: IN WORK	
Finish: -										Next Sht: 4		

NOTES:

1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.

3. CT/VT EARTH CONNECTIONS ARE TYPICAL ONLY.

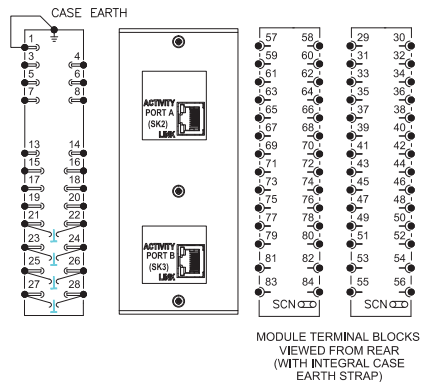4. RESIDUAL VOLTAGE MEASUREMENT REQUIRE A 5 LIMB VT OR 3*1PH VT

P24D
11I + 12O
+ 2 RS485
+ ETHERNET

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE
EARTH STRAP)

Date: 06/10/2017	Name: V.SIVASAMBO	Drg Title: MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & SEF (11 I/P & 12 O/P) WITH 2 RS485 & DUAL FIBRE ETHERNET	Next Stage: -	Drg No: 10P24D06-4	ECN No: CID005225	Revision: B	Iteration: 2
Date: 06/10/2017	Chkd: S WOOTTON						
Sub-contractor reference: -		CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: - / Angular Tol deg: -	GE Grid Solutions	PLM No: A20028515	Sht: 4	Status: IN WORK
Finish: -						Next Sht: -	

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

4th VT (OPEN DELTA)

P24D
11I + 12O
TCS

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 _
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8 _
OPTO 9
OPTO 10
OPTO 11

OPTO ISOLATED BINARY INPUTS

RP-1 EIARS485/K BUS COMMUNICATIONS

A.C./D.C. SUPPLY Vx

RL9
RL10
RL11
RL12

RELAY OUTPUT CONTACTS

CASE EARTH

MODULE TERMINAL BLOCKS VIEWED FROM REAR (WITH INTEGRAL CASE EARTH STRAP)
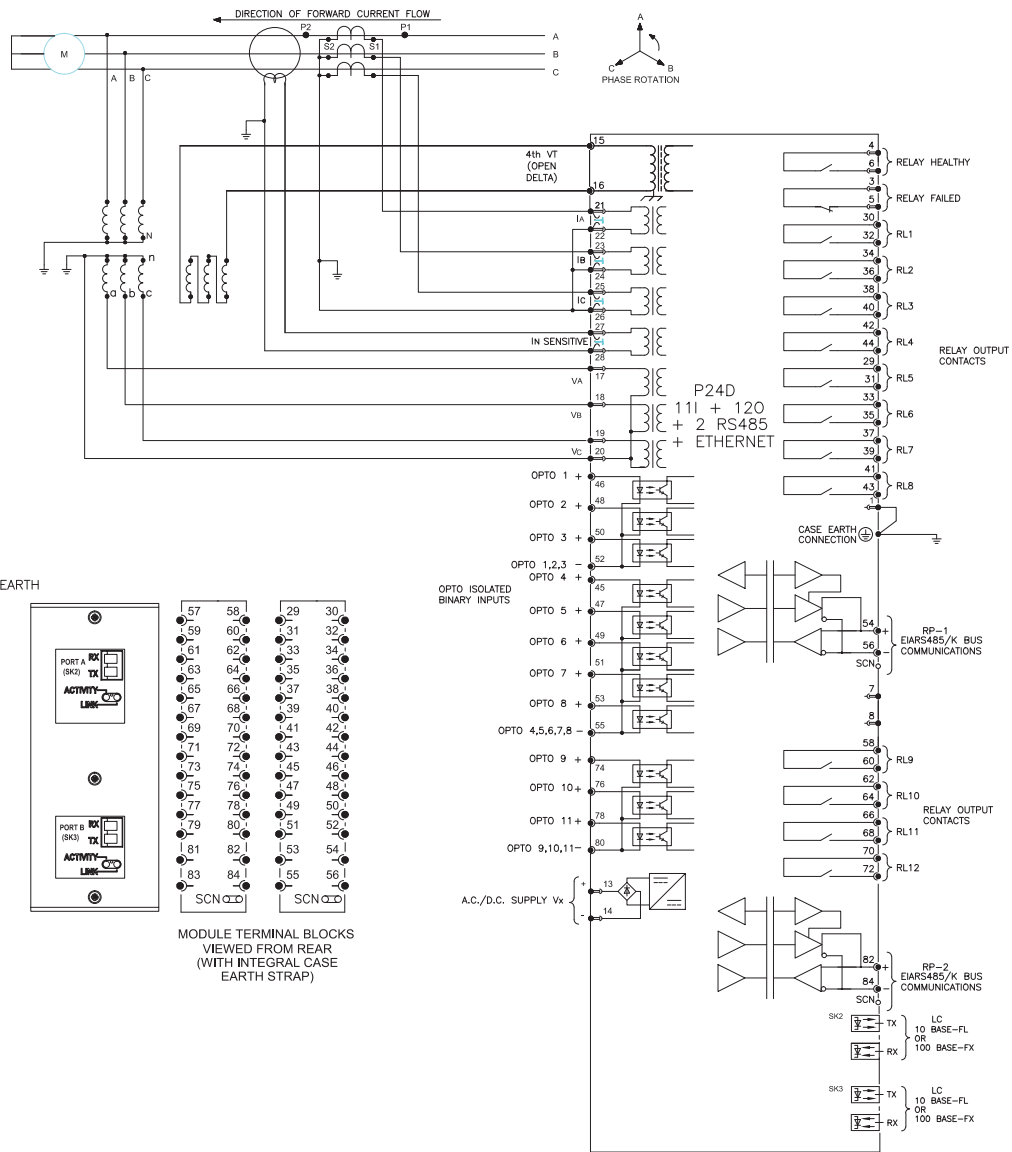
NOTES:
1.
(a)   C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b)   SHORT TERMINALS BREAK BEFORE (c).
(c)   LONG TERMINAL.
(d)   PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.

3. EARTH CONNECTIONS ARE TYPICAL ONLY.

4. RESIDUAL VOLTAGE MEASUREMENT REQUIRE A 5 LIMB VT OR 3*1PH VT

Date: 06/10/2017	Name: V.SIVASAMBO	Drg Title: MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & E/F (11 I/P & 12 O/P) WITH TCS	Next Stage: -	Drg No: 10P24D07-1	ECN No: CID005225	Revision: B	Iteration: 2
Date: 06/10/2017	Chkd: S WOOTTON						
Sub-contractor reference: -		CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: -	GE Grid Solutions	PLM No: A20028518	Sht: 1	Status: IN WORK
Finish: -			Angular Tol deg: -			Next Sht: -	

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

4th VT (OPEN DELTA)

P24D
11I + 12O
TCS +
ETHERNET

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 −
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8 −

OPTO ISOLATED BINARY INPUTS

OPTO 9
OPTO 10
OPTO 11

A.C./D.C. SUPPLY Vx

RP−1
EIARS485/K BUS
COMMUNICATIONS

RL9
RL10
RL11
RL12

RELAY OUTPUT CONTACTS

TX+
TX−
RX+
RX−

RJ45
10 BASE−T/
100 BASE−TX

TX
RX
LC
10 BASE−FL
OR
100 BASE−FX

CASE EARTH

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE
EARTH STRAP)

LINK
ACTIVITY
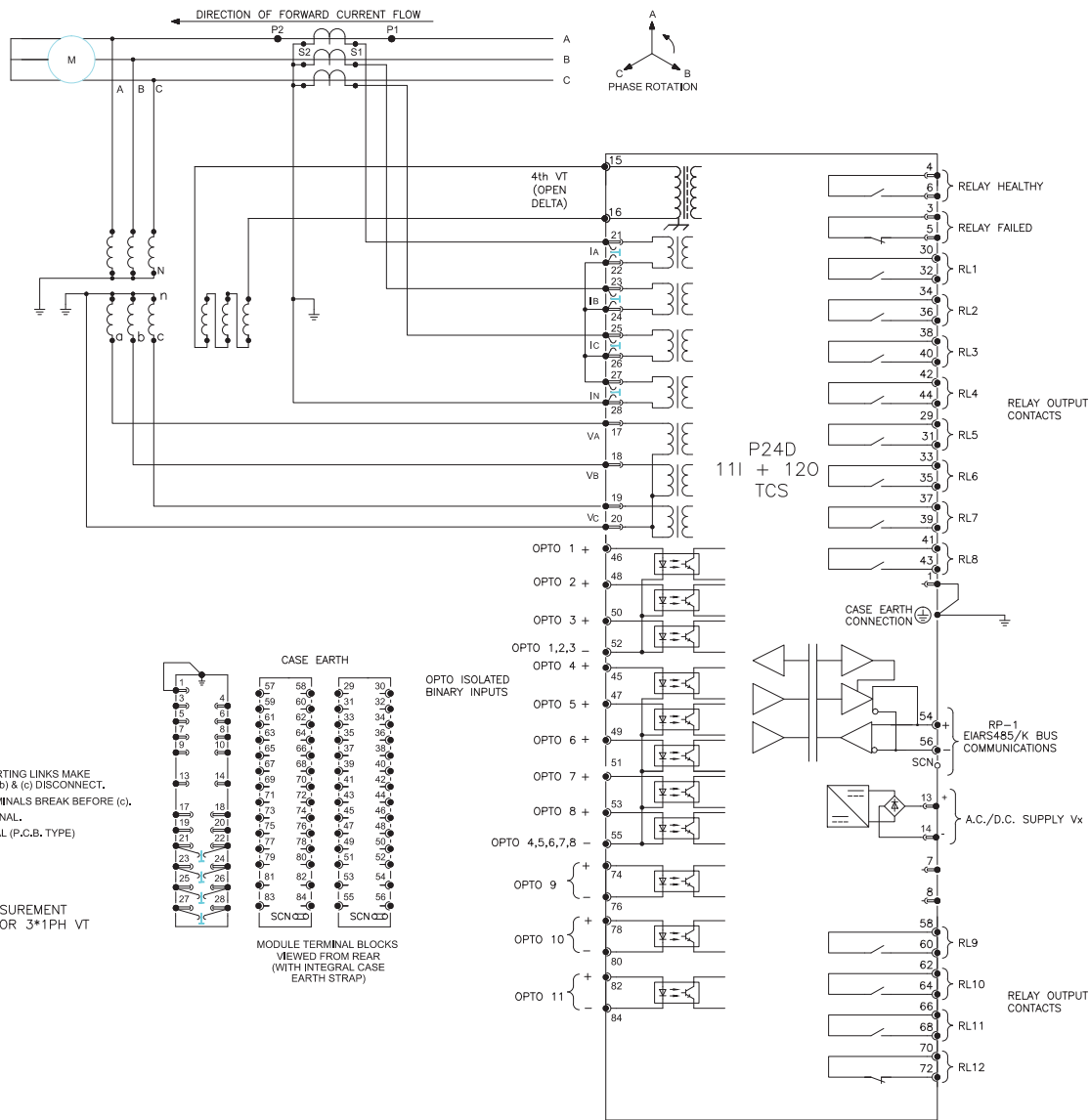PORT A RX
(SK2) TX

ACTIVITY
PORT B
(SK3) LINK

SCN

NOTES:

1.
(a)   C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b)   SHORT TERMINALS BREAK BEFORE (c).
(c)   LONG TERMINAL.
(d)   PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.

3. EARTH CONNECTIONS ARE TYPICAL ONLY.

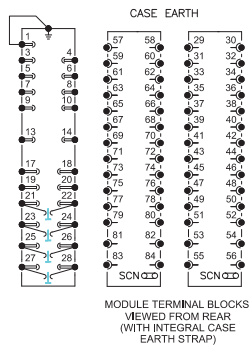4. RESIDUAL VOLTAGE MEASUREMENT REQUIRE A 5 LIMB VT OR 3*1PH VT

Date: 06/10/2017	Name: V.SIVASAMBO	Drg Title: MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & E/F (11 I/P & 12 O/P) WITH TCS & ETHERNET	Next Stage: -	Drg No: 10P24D07-2	ECN No: CID005225	Revision: B	Iteration: 2
Date: 06/10/2017	Chkd: S WOOTTON						
Sub-contractor reference: -		CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: - Angular Tol deg: -	GE Grid Solutions	PLM No: A20028521	Sht: 2	Status: IN WORK
Finish: -					Next Sht: 3		

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

4th VT (OPEN DELTA)

P24D
11I + 12O
TCS +
ETHERNET

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RELAY OUTPUT CONTACTS
RL5
RL6
RL7
RL8

CASE EARTH CONNECTION

RP-1
EIARS485/K BUS
COMMUNICATIONS

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 _
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8 _
OPTO 9
OPTO 10
OPTO 11

OPTO ISOLATED
BINARY INPUTS

A.C./D.C. SUPPLY Vx

RL9
RL10
RL11
RL12
RELAY OUTPUT CONTACTS

SK2
TX+
TX-
RX+
RX-
RJ45
10 BASE-T/
100 BASE-TX

SK3
TX+
TX-
RX+
RX-
RJ45
10 BASE-T/
100 BASE-TX

CASE EARTH

ACTIVITY PORT A (SK2) LINK
ACTIVITY PORT B (SK3) LINK

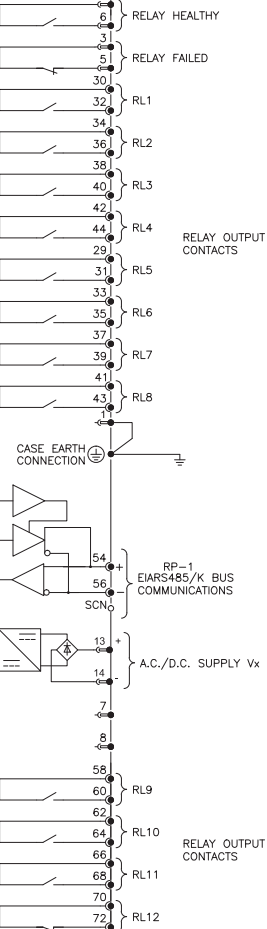MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE
EARTH STRAP)

NOTES:

1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.

3. EARTH CONNECTIONS ARE TYPICAL ONLY.

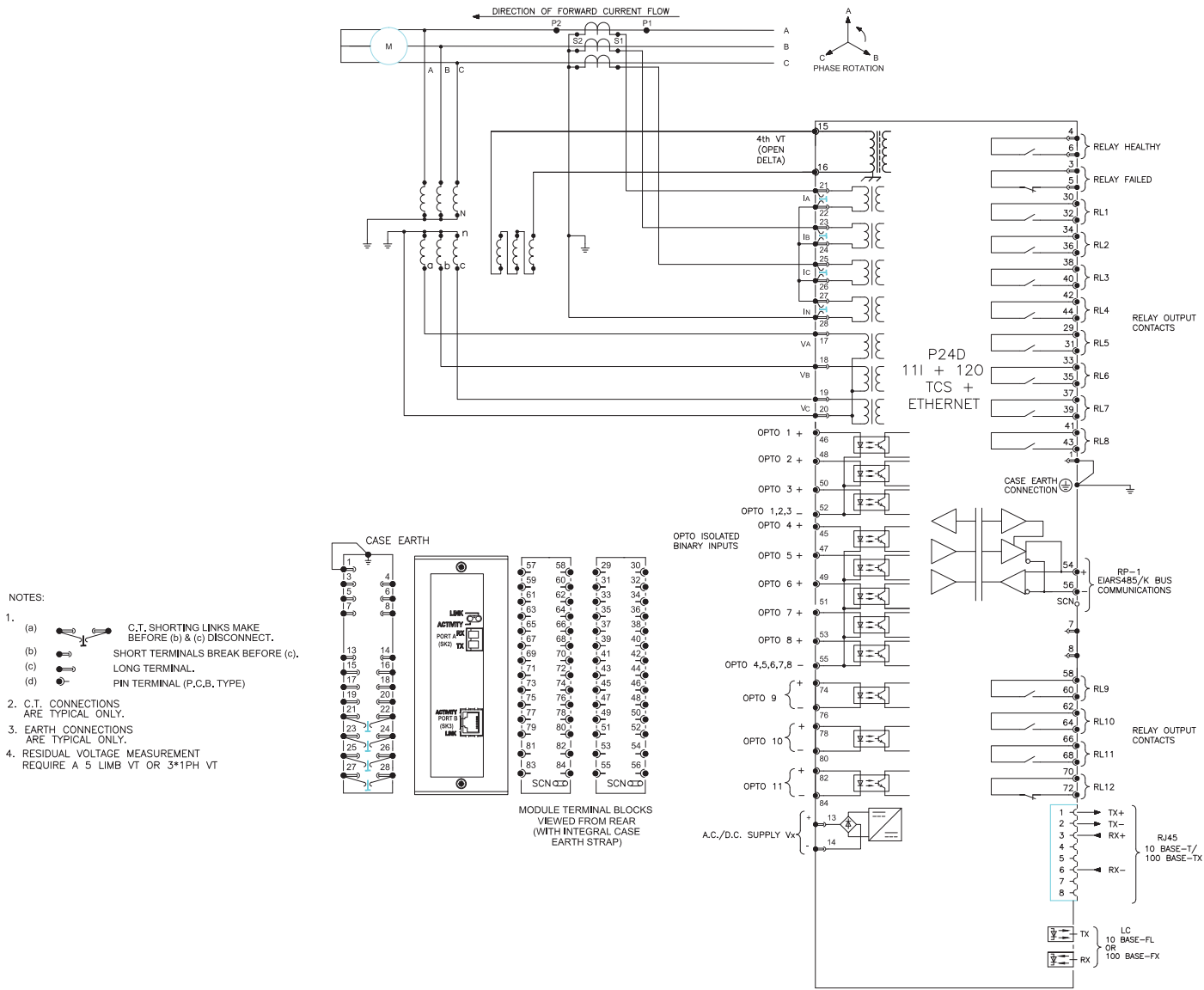4. RESIDUAL VOLTAGE MEASUREMENT REQUIRE A 5 LIMB VT OR 3*1PH VT

Date: 09/10/2017	Name: V.SIVASAMBO	Drg Title: MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & E/F (11 I/P & 12 O/P) WITH TCS & DUAL COPPER ETHERNET	Next Stage: -	Drg No: 10P24D07-3	ECN No: CID005225	Revision: B	Iteration: 2
Date: 09/10/2017	Chkd: S WOOTTON						
Sub-contractor reference: -		CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: - Angular Tol deg: -	Grid Solutions	PLM No: A20028529	Sht: 3	Status: IN WORK
Finish: -						Next Sht: 4	

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

4th VT (OPEN DELTA)

P24D
11I + 12O
TCS +
ETHERNET

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RELAY OUTPUT CONTACTS
RL5
RL6
RL7
RL8

CASE EARTH CONNECTION

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 −
OPTO 4 +
OPTO ISOLATED BINARY INPUTS
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8 −
OPTO 9
OPTO 10
OPTO 11

A.C./D.C. SUPPLY Vx

RP−1
EIARS485/K BUS COMMUNICATIONS
SCN

RL9
RL10
RL11
RL12
RELAY OUTPUT CONTACTS

SK2 TX LC 10 BASE−FL OR 100 BASE−FX
     RX

SK3 TX LC 10 BASE−FL OR 100 BASE−FX
     RX

CASE EARTH

PORT A (SK2) RX TX ACTIVITY LINK

PORT B (SK3) RX TX ACTIVITY LINK

MODULE TERMINAL BLOCKS VIEWED FROM REAR (WITH INTEGRAL CASE EARTH STRAP)

NOTES:
1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.
3. EARTH CONNECTIONS ARE TYPICAL ONLY.
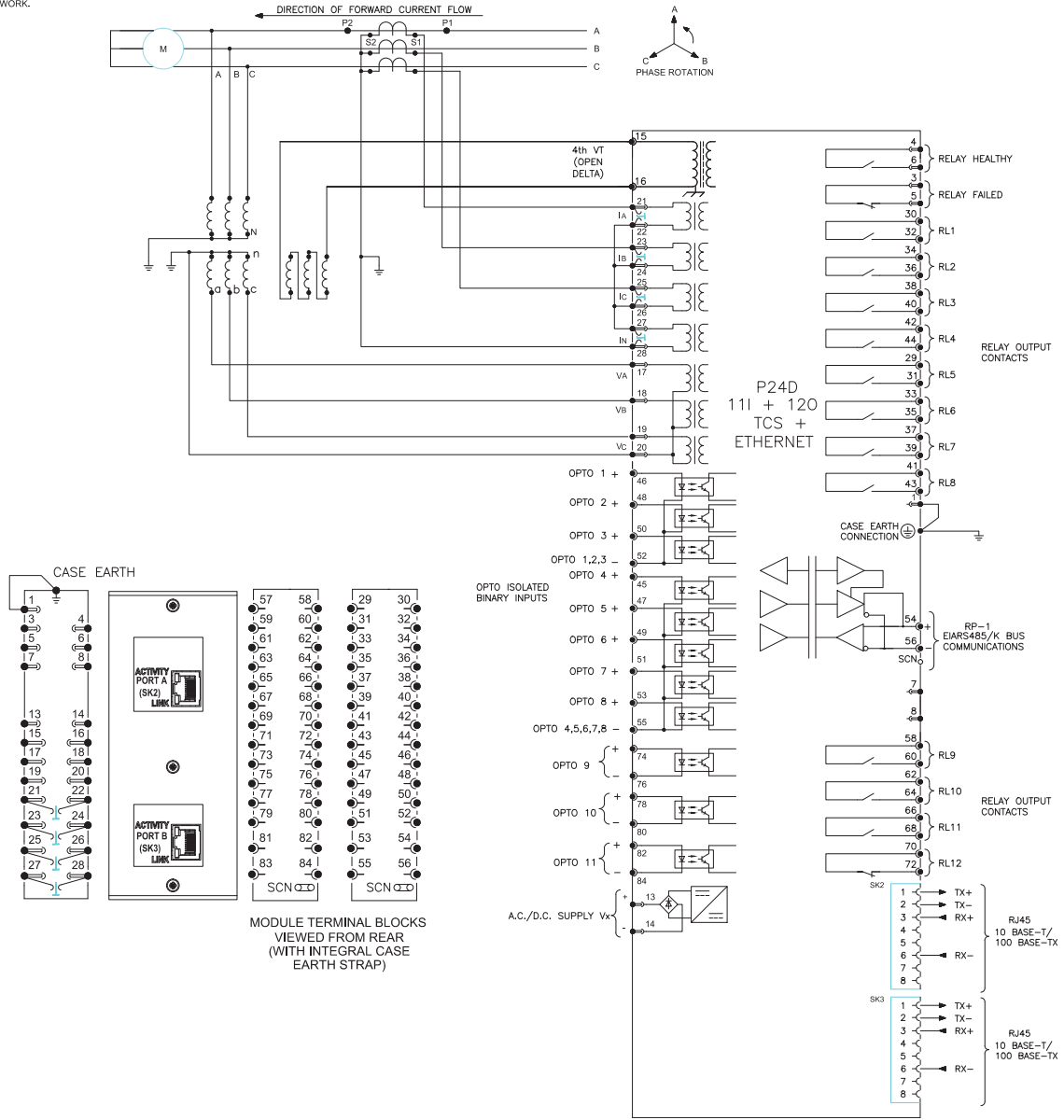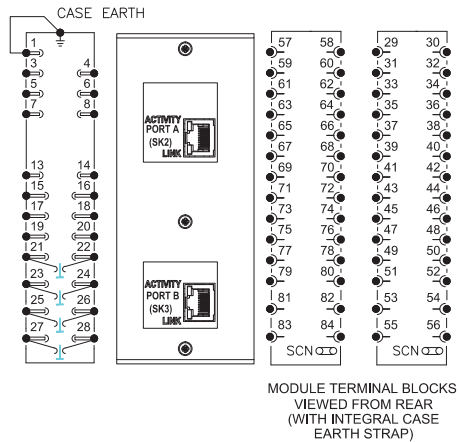4. RESIDUAL VOLTAGE MEASUREMENT REQUIRE A 5 LIMB VT OR 3*1PH VT

Date:	09/10/2017	Name:	V.SIVASAMBO	Drg Title:	MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & E/F (11 I/P & 12 O/P) WITH TCS & DUAL FIBRE ETHERNET	Next Stage:	-	Drg No:	10P24D07-4	ECN No:	CID005225	Revision:	B	Iteration:	2
Date:	09/10/2017	Chkd:	S WOOTTON												
Sub-contractor reference:	-			CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm:	-		Grid Solutions	PLM No:	A20028531	Sht:	4	Status:	IN WORK
Finish:	-				Angular Tol deg:	-				Next Sht:	-		

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

4th VT
(OPEN DELTA)

RELAY HEALTHY
RELAY FAILED

RELAY OUTPUT CONTACTS

RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

P24D
11I + 12O
TCS

CASE EARTH CONNECTION

OPTO ISOLATED BINARY INPUTS

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 _
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8 _
OPTO 9
OPTO 10
OPTO 11

RP-1
EIARS485/K BUS COMMUNICATIONS

A.C./D.C. SUPPLY Vx

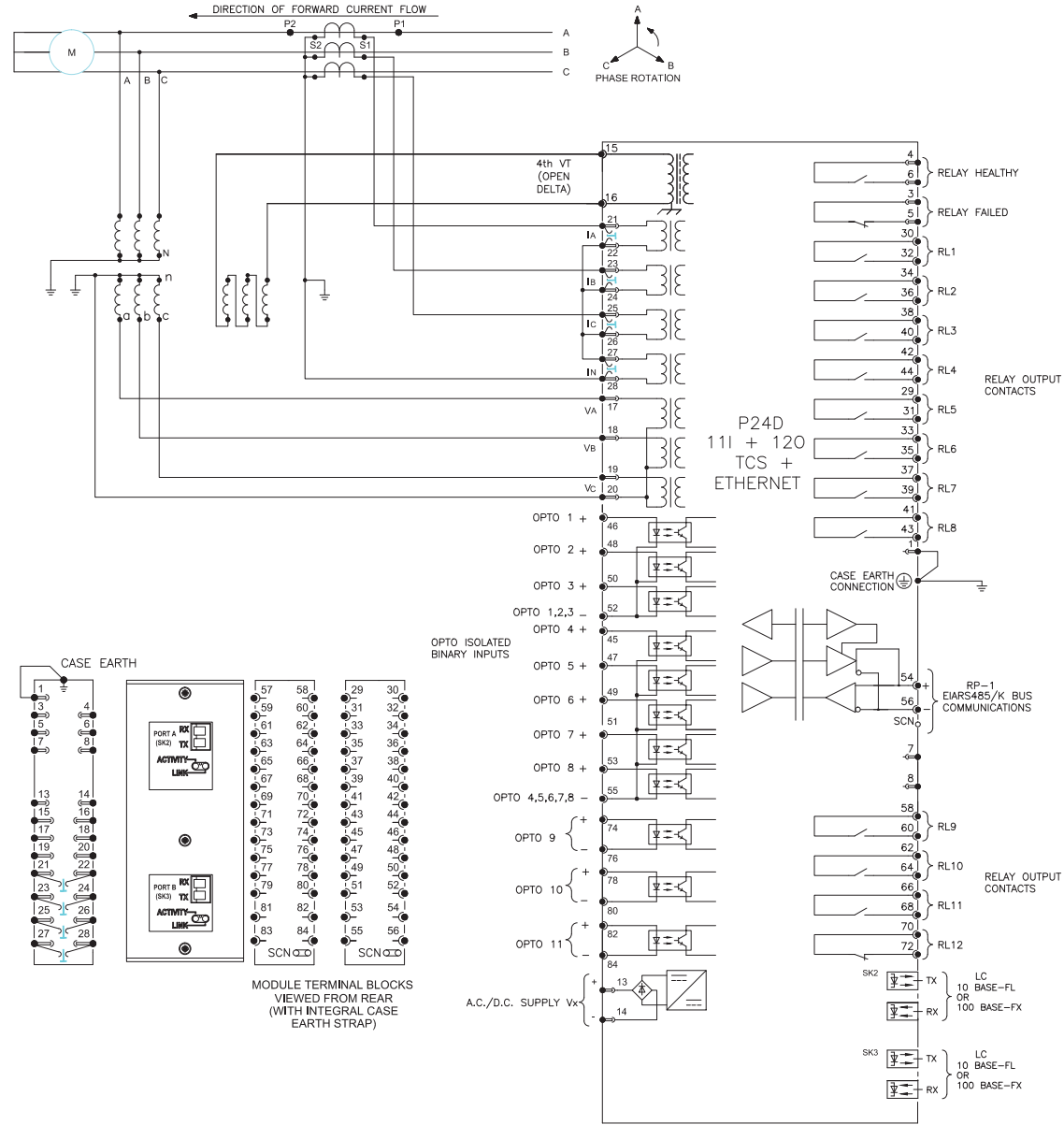RL9
RL10
RL11
RL12

RELAY OUTPUT CONTACTS

NOTES:
1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.
3. CT/VT EARTH CONNECTIONS ARE TYPICAL ONLY.
4. RESIDUAL VOLTAGE MEASUREMENT REQUIRE A 5 LIMB VT OR 3*1PH VT

CASE EARTH

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE EARTH STRAP)

Date: 09/10/2017	Name: V.SIVASAMBO	Drg Title: MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & SEF (11 I/P & 12 O/P) WITH TCS	Next Stage: -	Drg No: 10P24D08-1	ECN No: CID005225	Revision: B	Iteration: 2
Date: 09/10/2017	Chkd: S WOOTTON						
Sub-contractor reference: -		CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: -		PLM No: A20028533	Sht: 1	Status: IN WORK
Finish: -			Angular Tol deg: -	Grid Solutions		Next Sht: 2	

DIRECTION OF FORWARD CURRENT FLOW

P2   S2   S1   P1

A
B
C

PHASE ROTATION

4th VT
(OPEN DELTA)

15
16
21
22   IA
23
24   IB
25
26   IC
27
28   IN SENSITIVE

17   VA
18
19   VB
20   VC

P24D
11I + 12O
TCS +
ETHERNET

RELAY HEALTHY
RELAY FAILED

4
6
3
5
30   RL1
32
34   RL2
36
38   RL3
40
42
44   RL4
29
31   RL5
33
35   RL6
37
39   RL7
41
43   RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

OPTO 1 +   46
OPTO 2 +   48
OPTO 3 +   50
OPTO 1,2,3 _ 52
OPTO 4 +   45
OPTO ISOLATED BINARY INPUTS
OPTO 5 +   47
OPTO 6 +   49
OPTO 7 +   51
OPTO 8 +   53
OPTO 4,5,6,7,8 _ 55

OPTO 9   74   76
OPTO 10   78   80
OPTO 11   82   84

A.C./D.C. SUPPLY Vx   13   14

RP-1
EIARS485/K BUS COMMUNICATIONS
54
56
SCN
7
8

58
60   RL9
62
64   RL10
66
68   RL11
70
72   RL12

RELAY OUTPUT CONTACTS

RJ45
10 BASE-T/
100 BASE-TX
1   TX+
2   TX-
3   RX+
4
5
6   RX-
7
8

LC
10 BASE-FL
OR
100 BASE-FX
TX
RX

CASE EARTH

1
3
5
7
13
15
17
19
21
23
25
27

4
6
8
14
16
18
20
22
24
26
28

LINK
ACTIVITY
PORT A RX
(SK2)   TX

ACTIVITY
PORT B
(SK3) LINK

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE
EARTH STRAP)

57 58
59 60
61 62
63 64
65 66
67 68
69 70
71 72
73 74
75 76
77 78
79 80
81 82
83 84 SCN

29 30
31 32
33 34
35 36
37 38
39 40
41 42
43 44
45 46
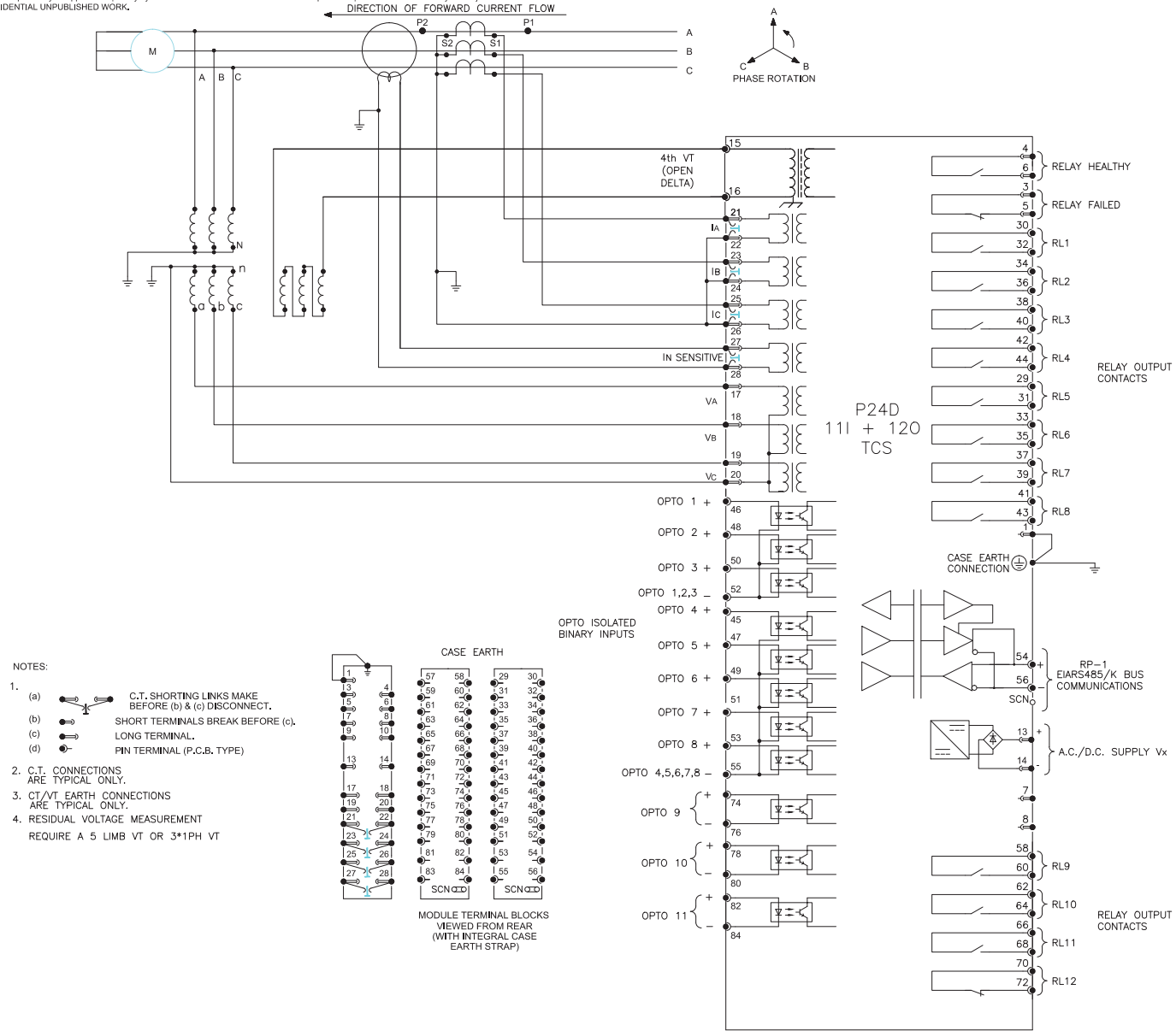47 48
49 50
51 52
53 54
55 56 SCN

NOTES:

1.
(a)   C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b)   SHORT TERMINALS BREAK BEFORE (c).
(c)   LONG TERMINAL.
(d)   PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.

3. CT/VT EARTH CONNECTIONS ARE TYPICAL ONLY.

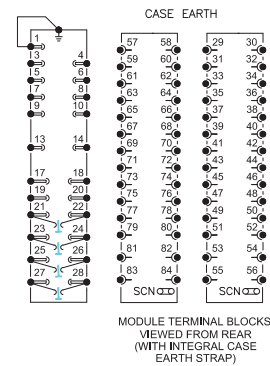4. RESIDUAL VOLTAGE MEASUREMENT REQUIRE A 5 LIMB VT OR 3*1PH VT

Date: 09/10/2017	Name: V.SIVASAMBO	Drg Title: MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & SEF (11 I/P & 12 O/P) WITH TCS & ETHERNET	Next Stage: -	Drg No: 10P24D08-2	ECN No: CID005225	Revision: B	Iteration: 2
Date: 09/10/2017	Chkd: S WOOTTON						
Sub-contractor reference: -		CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: - Angular Tol deg: -	GE Grid Solutions	PLM No: A20028535	Sht: 2 Next Sht: 3	Status: IN WORK
Finish: -							

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

4th VT
(OPEN DELTA)

IA
IB
IC
IN SENSITIVE
VA
VB
VC

P24D
11I + 12O
TCS +
ETHERNET

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 −
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8 −
OPTO 9
OPTO 10
OPTO 11

OPTO ISOLATED BINARY INPUTS

RP−1
EIARS485/K BUS
COMMUNICATIONS
SCN

RL9
RL10
RL11
RL12

RELAY OUTPUT CONTACTS

A.C./D.C. SUPPLY Vx

SK2
1 TX+
2 TX−
3 RX+
4
5
6 RX−
7
8
RJ45
10 BASE−T/
100 BASE−TX

SK3
1 TX+
2 TX−
3 RX+
4
5
6 RX−
7
8
RJ45
10 BASE−T/
100 BASE−TX

CASE EARTH

ACTIVITY
PORT A
(SK2)
LINK

ACTIVITY
PORT B
(SK3)
LINK

MODULE TERMINAL BLOCKS
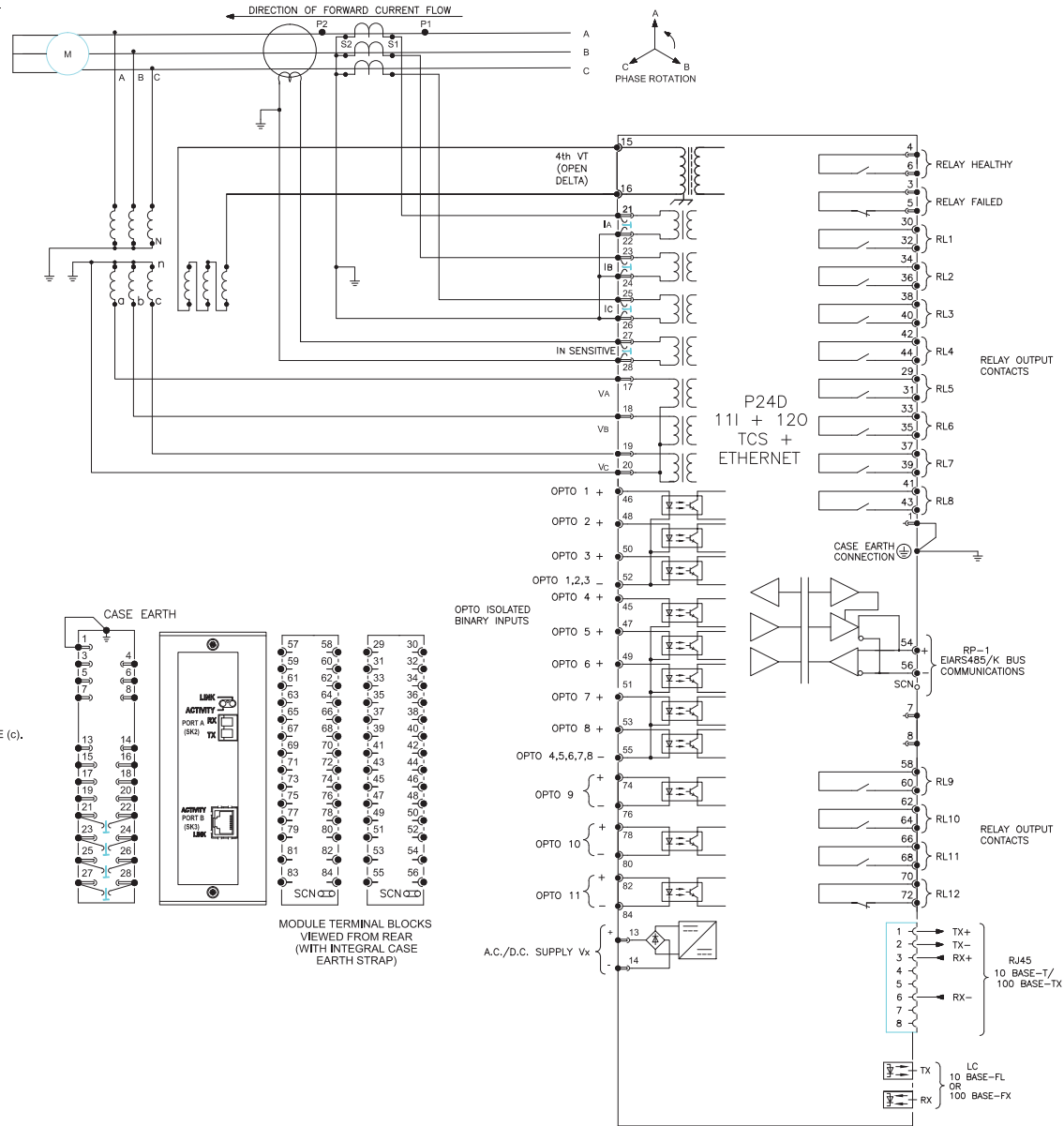VIEWED FROM REAR
(WITH INTEGRAL CASE
EARTH STRAP)

NOTES:
1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.
3. CT/VT EARTH CONNECTIONS ARE TYPICAL ONLY.
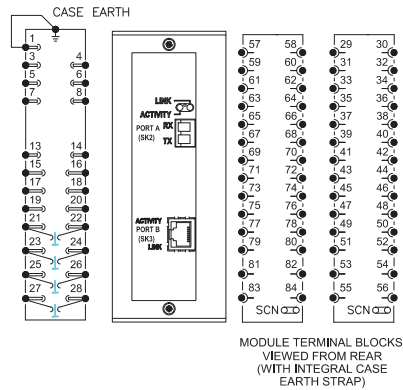4. RESIDUAL VOLTAGE MEASUREMENT REQUIRE A 5 LIMB VT OR 3*1PH VT

Date: 09/10/2017	Name: V.SIVASAMBO	Drg Title: MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & SEF (11 I/P & 12 O/P) WITH TCS & DUAL COPPER ETHERNET	Next Stage: -	Drg No: 10P24D08-3	ECN No: CID005225	Revision: B	Iteration: 2
Date: 09/10/2017	Chkd: S WOOTTON						
Sub-contractor reference: -		CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: - Angular Tol deg: -	Grid Solutions	PLM No: A20028540	Sht: 3 Next Sht: 4	Status: IN WORK
Finish: -							

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

4th VT
(OPEN DELTA)

IA
IB
IC
IN SENSITIVE

VA
VB
VC

P24D
11I + 12O
TCS +
ETHERNET

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 −
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8 −

OPTO ISOLATED BINARY INPUTS

RP−1
EIARS485/K BUS
COMMUNICATIONS
SCN

OPTO 9
OPTO 10
OPTO 11

RL9
RL10
RL11
RL12

RELAY OUTPUT CONTACTS

A.C./D.C. SUPPLY Vx

CASE EARTH

PORT A
(SK2)   RX
         TX
ACTIVITY
LINK

PORT B
(SK3)   RX
         TX
ACTIVITY
LINK

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE
EARTH STRAP)

SK2   TX   LC
             10 BASE−FL
             OR
       RX   100 BASE−FX

SK3   TX   LC
             10 BASE−FL
             OR
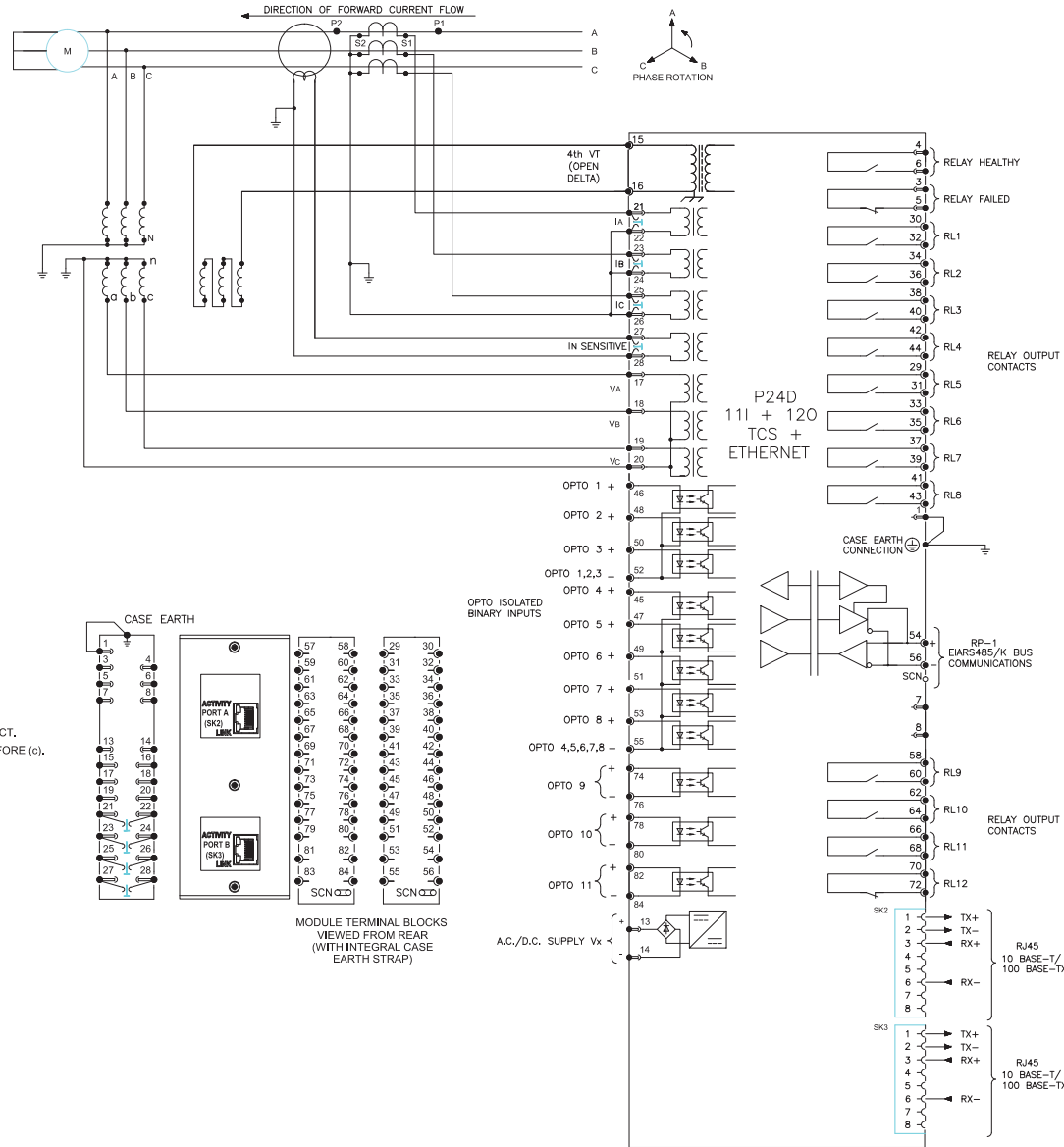   RX   100 BASE−FX

NOTES:

1.
(a)   C.T. SHORTING LINKS MAKE
             BEFORE (b) & (c) DISCONNECT.
(b)   SHORT TERMINALS BREAK BEFORE (c).
(c)   LONG TERMINAL.
(d)   PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS
   ARE TYPICAL ONLY.
3. CT/VT EARTH CONNECTIONS
   ARE TYPICAL ONLY.
4. RESIDUAL VOLTAGE MEASUREMENT
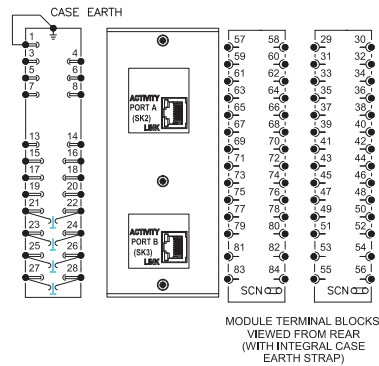   REQUIRE A 5 LIMB VT OR 3*1PH VT

Date: 09/10/2017	Name: V.SIVASAMBO	Drg Title: MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & SEF (11 I/P & 12 O/P) WITH TCS & DUAL FIBRE ETHERNET	Next Stage: -	Drg No: 10P24D08-4	ECN No: CID005225	Revision: B	Iteration: 2
Date: 09/10/2017	Chkd: S WOOTTON						
Sub-contractor reference: -		CAD DATA 1:1 DIMENSIONS: mm	Linear Tol mm: -	Grid Solutions	PLM No: A20028543	Sht: 4	Status:
Finish: -		DO NOT SCALE	Angular Tol deg: -			Next Sht: -	IN WORK

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

4th VT
(OPEN DELTA)

P24D
13I + 120

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8
RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 −
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8 −
OPTO 9 +
OPTO 10+
OPTO 11+
OPTO 12+
OPTO 13 +
OPTO 9,10,11,12,13 −

OPTO ISOLATED BINARY INPUTS

CASE EARTH

RP-1
EIARS485/K BUS
COMMUNICATIONS

A.C./D.C. SUPPLY Vx

RL9
RL10
RL11
RL12
RELAY OUTPUT CONTACTS

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE
EARTH STRAP)

NOTES:
1.
(a)   C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b)   SHORT TERMINALS BREAK BEFORE (c).
(c)   LONG TERMINAL.
(d)   PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.
3. EARTH CONNECTIONS ARE TYPICAL ONLY.
4. RESIDUAL VOLTAGE MEASUREMENT REQUIRE A 5 LIMB VT OR 3*1PH VT

Date: 09/10/2017	Name: V.SIVASAMBO	Drg Title: MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & E/F (13 I/P & 12 O/P)	Next Stage: -	Drg No: 10P24D09-1	ECN No: CID005225	Revision: B	Iteration: 2
Date: 09/10/2017	Chkd: S WOOTTON						
Sub-contractor reference: -		CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: - / Angular Tol deg: -	Grid Solutions	PLM No: A20028546	Sht: 1	Status: IN WORK
Finish: -						Next Sht: -	

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

4th VT (OPEN DELTA)

P24D
13I + 12O
+ ETHERNET

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RELAY OUTPUT CONTACTS
RL5
RL6
RL7
RL8

CASE EARTH CONNECTION

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 −
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8 −
OPTO 9 +
OPTO 10+
OPTO 11+
OPTO 12+
OPTO 13 +
OPTO 9,10,11,12,13 −

OPTO ISOLATED BINARY INPUTS

RP−1
EIARS485/K BUS COMMUNICATIONS
SCN

RL9
RL10
RELAY OUTPUT CONTACTS
RL11
RL12

A.C./D.C. SUPPLY Vx

TX+
TX−
RX+
RX−
RJ45
10 BASE−T/
100 BASE−TX

TX
RX
LC
10 BASE−FL
OR
100 BASE−FX

CASE EARTH

LINK
ACTIVITY
PORT A RX
(SK2) TX

ACTIVITY
PORT B
(SK3)
LINK

SCN   SCN

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
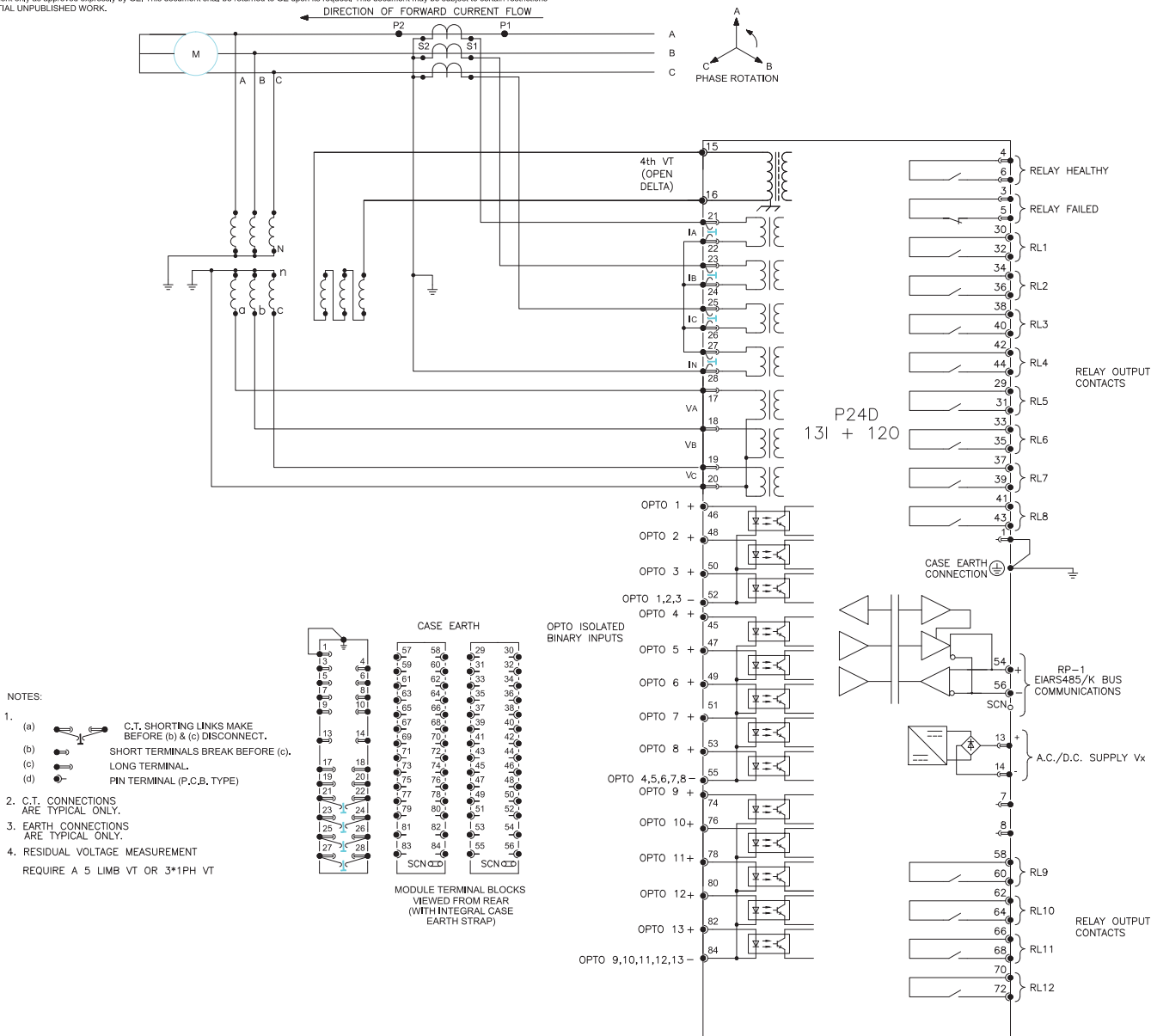(WITH INTEGRAL CASE
EARTH STRAP)

NOTES:
1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.

3. EARTH CONNECTIONS ARE TYPICAL ONLY.

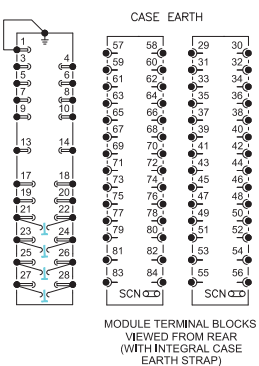4. RESIDUAL VOLTAGE MEASUREMENT REQUIRE A 5 LIMB VT OR 3*1PH VT

Date: 09/10/2017	Name: V.SIVASAMBO	Drg Title: MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & E/F (13 I/P & 12 O/P) WITH ETHERNET	Next Stage: -	Drg No: 10P24D09-2	ECN No: CID005225	Revision: B	Iteration: 2
Date: 09/10/2017	Chkd: S WOOTTON						
Sub-contractor reference: -		CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: -	GE Grid Solutions	PLM No: A20028549	Sht: 2	Status: IN WORK
Finish: -			Angular Tol deg: -			Next Sht: 3	

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

4th VT (OPEN DELTA)

P24D
13I + 12O
+ ETHERNET

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 −
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8 −
OPTO 9 +
OPTO 10+
OPTO 11+
OPTO 12+
OPTO 13 +
OPTO 9,10,11,12,13 −

OPTO ISOLATED BINARY INPUTS

A.C./D.C. SUPPLY Vx

RP−1
EIARS485/K BUS
COMMUNICATIONS

RL9
RL10
RL11
RL12

RELAY OUTPUT CONTACTS

SK2
TX+
TX−
RX+
RX−
RJ45
10 BASE−T/
100 BASE−TX

SK3
TX+
TX−
RX+
RX−
RJ45
10 BASE−T/
100 BASE−TX

CASE EARTH

ACTIVITY PORT A (SK2) LINK
ACTIVITY PORT B (SK3) LINK

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
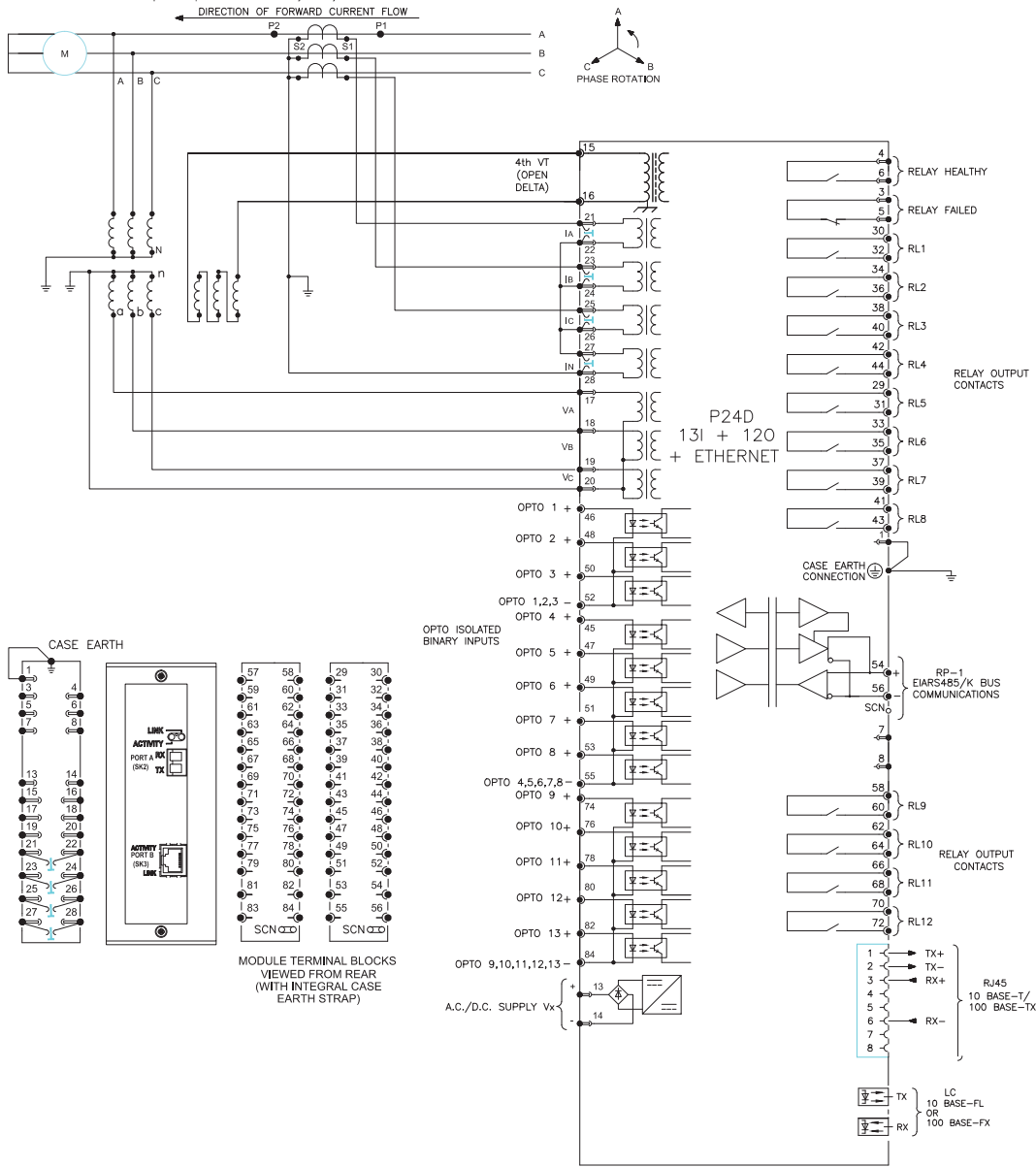(WITH INTEGRAL CASE
EARTH STRAP)

NOTES:
1.
(a)   C.T. SHORTING LINKS MAKE
      BEFORE (b) & (c) DISCONNECT.
(b)   SHORT TERMINALS BREAK BEFORE (c).
(c)   LONG TERMINAL.
(d)   PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS
   ARE TYPICAL ONLY.

3. EARTH CONNECTIONS
   ARE TYPICAL ONLY.

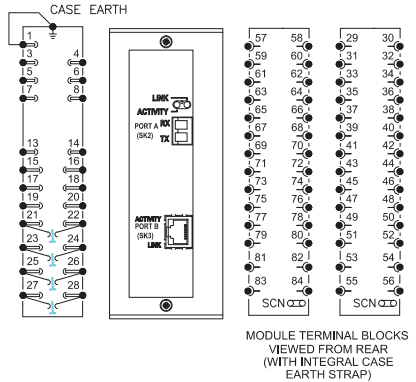4. RESIDUAL VOLTAGE MEASUREMENT
   REQUIRE A 5 LIMB VT OR 3*1PH VT

Date: 10/10/2017	Name: V.SIVASAMBO	Drg Title: MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & E/F (13 I/P & 12 O/P) WITH DUAL COPPER ETHERNET	Next Stage: -	Drg No: 10P24D09-3	ECN No: CID005225	Revision: B	Iteration: 2
Date: 10/10/2017	Chkd: S WOOTTON						
Sub-contractor reference: -		CAD DATA 1:1 DIMENSIONS: mm	Linear Tol mm: -		PLM No: A20028552	Sht: 3	Status: IN WORK
Finish: -		DO NOT SCALE	Angular Tol deg: -	Grid Solutions		Next Sht: 4	

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

4th VT (OPEN DELTA)

P24D
13I + 12O
+ ETHERNET

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8
RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

RP-1
EIARS485/K BUS COMMUNICATIONS

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 -
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8 -
OPTO 9 +
OPTO 10+
OPTO 11+
OPTO 12+
OPTO 13 +
OPTO 9,10,11,12,13 -

OPTO ISOLATED BINARY INPUTS

RL9
RL10
RL11
RL12
RELAY OUTPUT CONTACTS

A.C./D.C. SUPPLY Vx

SK2 TX / RX LC 10 BASE-FL OR 100 BASE-FX
SK3 TX / RX LC 10 BASE-FL OR 100 BASE-FX

CASE EARTH

PORT A (SK2) RX TX ACTIVITY LINK
PORT B (SK3) RX TX ACTIVITY LINK

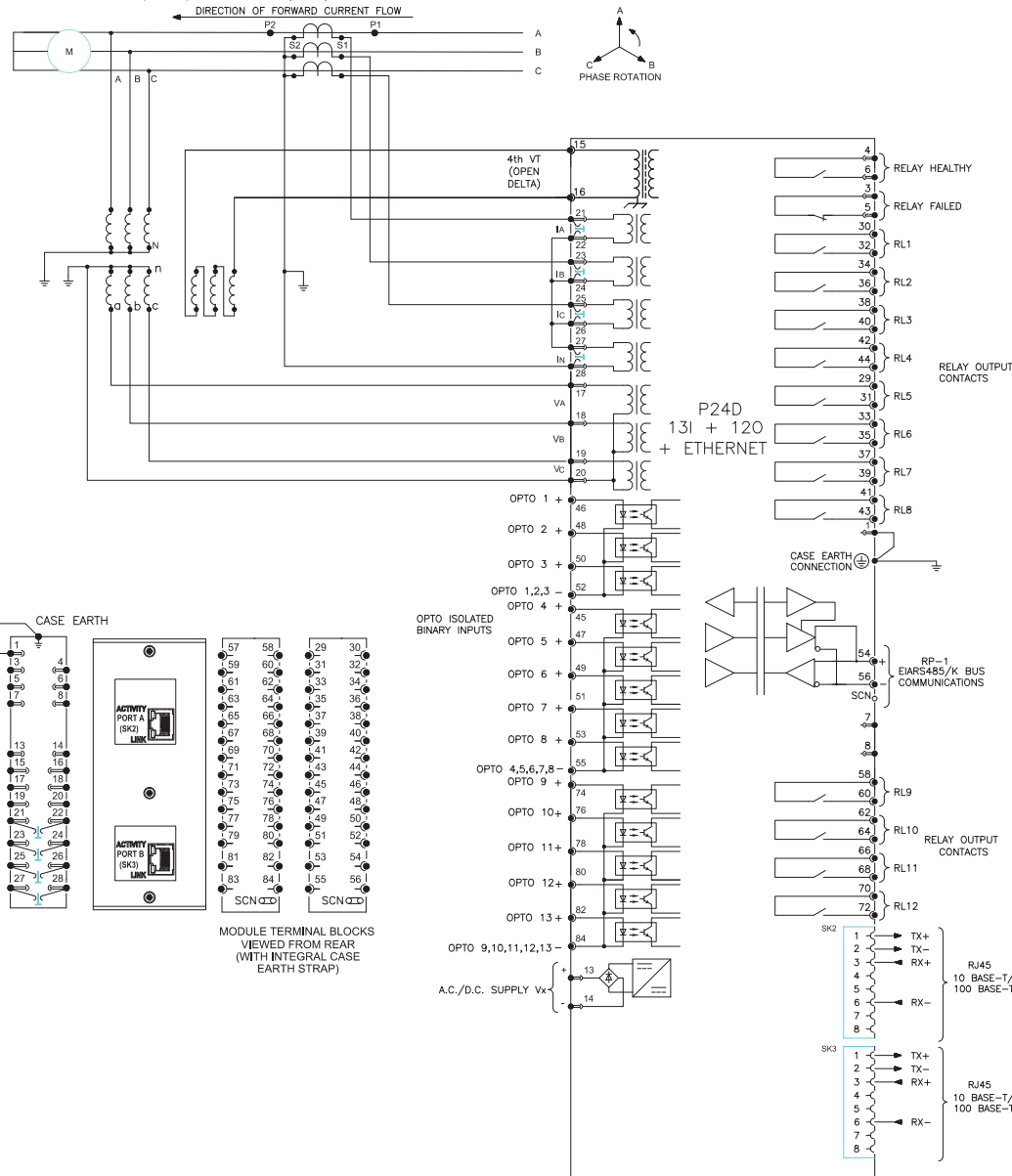MODULE TERMINAL BLOCKS VIEWED FROM REAR (WITH INTEGRAL CASE EARTH STRAP)

NOTES:
1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.

3. EARTH CONNECTIONS ARE TYPICAL ONLY.

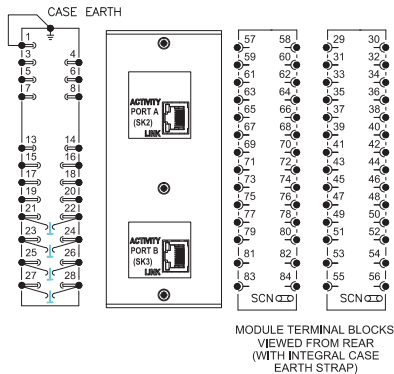4. RESIDUAL VOLTAGE MEASUREMENT REQUIRE A 5 LIMB VT OR 3*1PH VT

Date: 10/10/2017	Name: V.SIVASAMBO	Drg Title: MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & E/F (13 I/P & 12 O/P) WITH DUAL FIBRE ETHERNET	Next Stage: -	Drg No: 10P24D09-4	ECN No: CID005225	Revision: B	Iteration: 2
Date: 10/10/2017	Chkd: S WOOTTON						
Sub-contractor reference: -		CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: -	GE Grid Solutions	PLM No: A20028554	Sht: 4	Status: IN WORK
Finish: -			Angular Tol deg: -			Next Sht: -	

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

P24D
13I + 12O

4th VT (OPEN DELTA)

IA
IB
IC

IN SENSITIVE

VA
VB
VC

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RELAY OUTPUT CONTACTS
RL5
RL6
RL7
RL8

CASE EARTH CONNECTION

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 –
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8 –
OPTO 9 +
OPTO 10+
OPTO 11+
OPTO 12+
OPTO 13 +
OPTO 9,10,11,12,13 –

OPTO ISOLATED BINARY INPUTS

RP-1
EIARS485/K BUS COMMUNICATIONS
SCN

A.C./D.C. SUPPLY Vx

RL9
RL10
RL11
RL12
RELAY OUTPUT CONTACTS

CASE EARTH

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
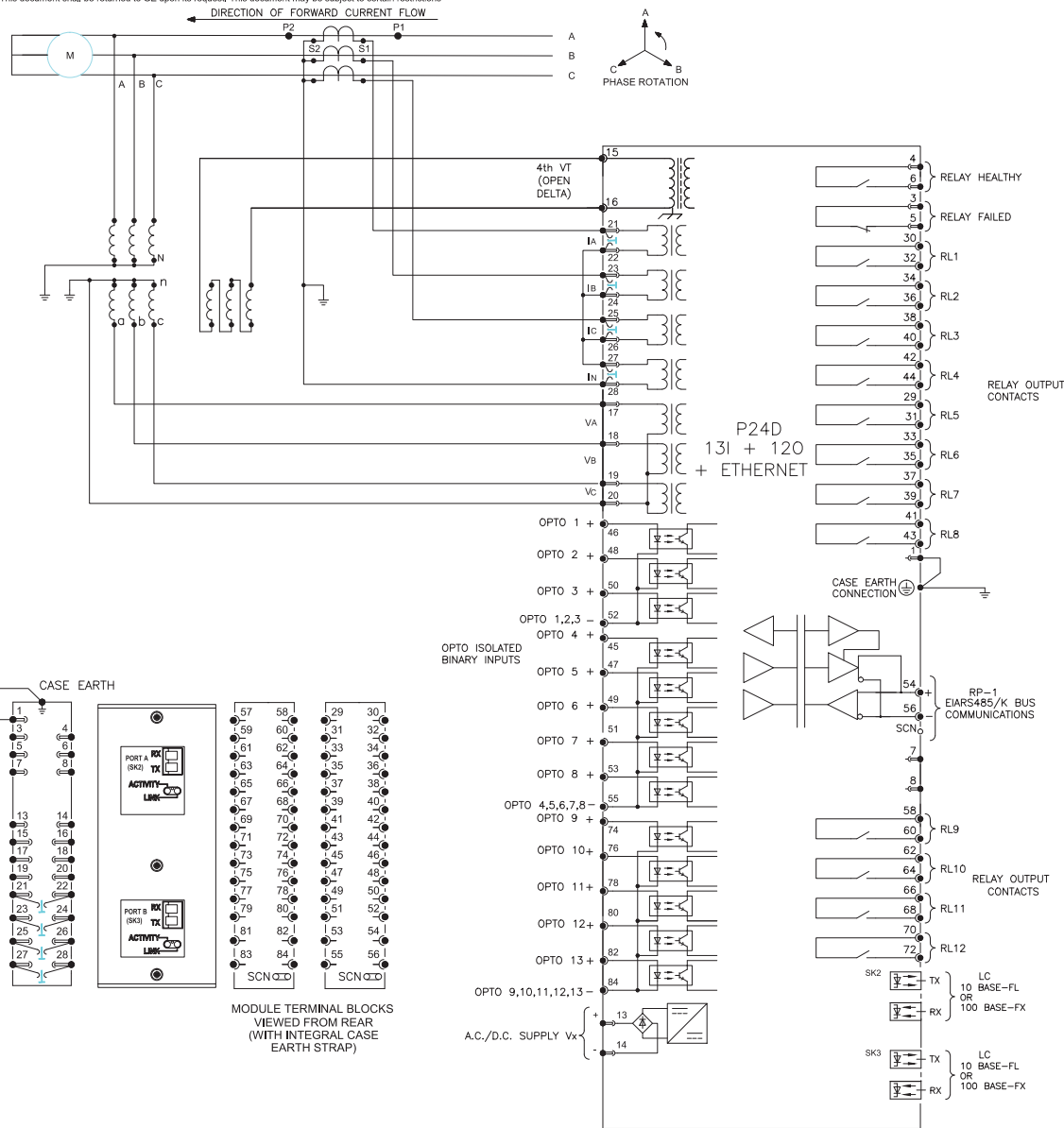(WITH INTEGRAL CASE EARTH STRAP)

SCN   SCN

NOTES:

1.
(a)   C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b)   SHORT TERMINALS BREAK BEFORE (c).
(c)   LONG TERMINAL.
(d)   PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.

3. CT/VT EARTH CONNECTIONS ARE TYPICAL ONLY.

4. RESIDUAL VOLTAGE MEASUREMENT REQUIRE A 5 LIMB VT OR 3*1PH VT

Date:	10/10/2017	Name:	V.SIVASAMBO	Drg Title:	MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & SEF (13 I/P & 12 O/P)	Next Stage:	–	Drg No:	10P24D10-1	ECN No: CID005225	Revision: B	Iteration: 2
Date:	10/10/2017	Chkd:	S WOOTTON									
Sub-contractor reference:	–			CAD DATA 1:1 DIMENSIONS: mm	Linear Tol mm: –		Grid Solutions	PLM No:	A20028556	Sht: 1	Status: IN WORK	
Finish:	–			DO NOT SCALE	Angular Tol deg: –					Next Sht: –		

DIRECTION OF FORWARD CURRENT FLOW

P2   P1
S2   S1

A
B
C

M

A B C

PHASE ROTATION

4th VT
(OPEN
DELTA)

15
16

21
IA
22
23
IB
24
25
IC
26
27
IN SENSITIVE
28

17
VA
18
VB
19
Vc
20

P24D
13I + 12O
+ ETHERNET

4
6   RELAY HEALTHY
3
5   RELAY FAILED
30
32   RL1
34
36   RL2
38
40   RL3
42
44   RL4
29
31   RL5
33
35   RL6
37
39   RL7
41
43   RL8

RELAY OUTPUT
CONTACTS

CASE EARTH
CONNECTION

OPTO 1 +   46
OPTO 2 +   48
OPTO 3 +   50
OPTO 1,2,3 - 52
OPTO 4 +   45
OPTO 5 +   47
OPTO 6 +   49
OPTO 7 +   51
OPTO 8 +   53
OPTO 4,5,6,7,8 - 55
OPTO 9 +   74
OPTO 10+   76
OPTO 11+   78
OPTO 12+   80
OPTO 13 +   82
OPTO 9,10,11,12,13 - 84

OPTO ISOLATED
BINARY INPUTS

54
56   RP-1
EIARS485/K BUS
COMMUNICATIONS
SCN
7
8

58
60   RL9
62
64   RL10
66
68   RL11
70
72   RL12

RELAY OUTPUT
CONTACTS

A.C./D.C. SUPPLY Vx
13
14

1   TX+
2   TX-
3   RX+
4
5
6   RX-
7
8

RJ45
10 BASE-T/
100 BASE-TX

TX
RX

LC
10 BASE-FL
OR
100 BASE-FX

CASE EARTH

1
3   4
5   6
7   8

LINK
ACTIVITY
PORT A
(SK2)
RX
TX

ACTIVITY
PORT B
(SK3)
LINK

13   14
15   16
17   18
19   20
21   22
23   24
25   26
27   28

57   58
59   60
61   62
63   64
65   66
67   68
69   70
71   72
73   74
75   76
77   78
79   80
81   82
83   84
SCN

29   30
31   32
33   34
35   36
37   38
39   40
41   42
43   44
45   46
47   48
49   50
51   52
53   54
55   56
SCN

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
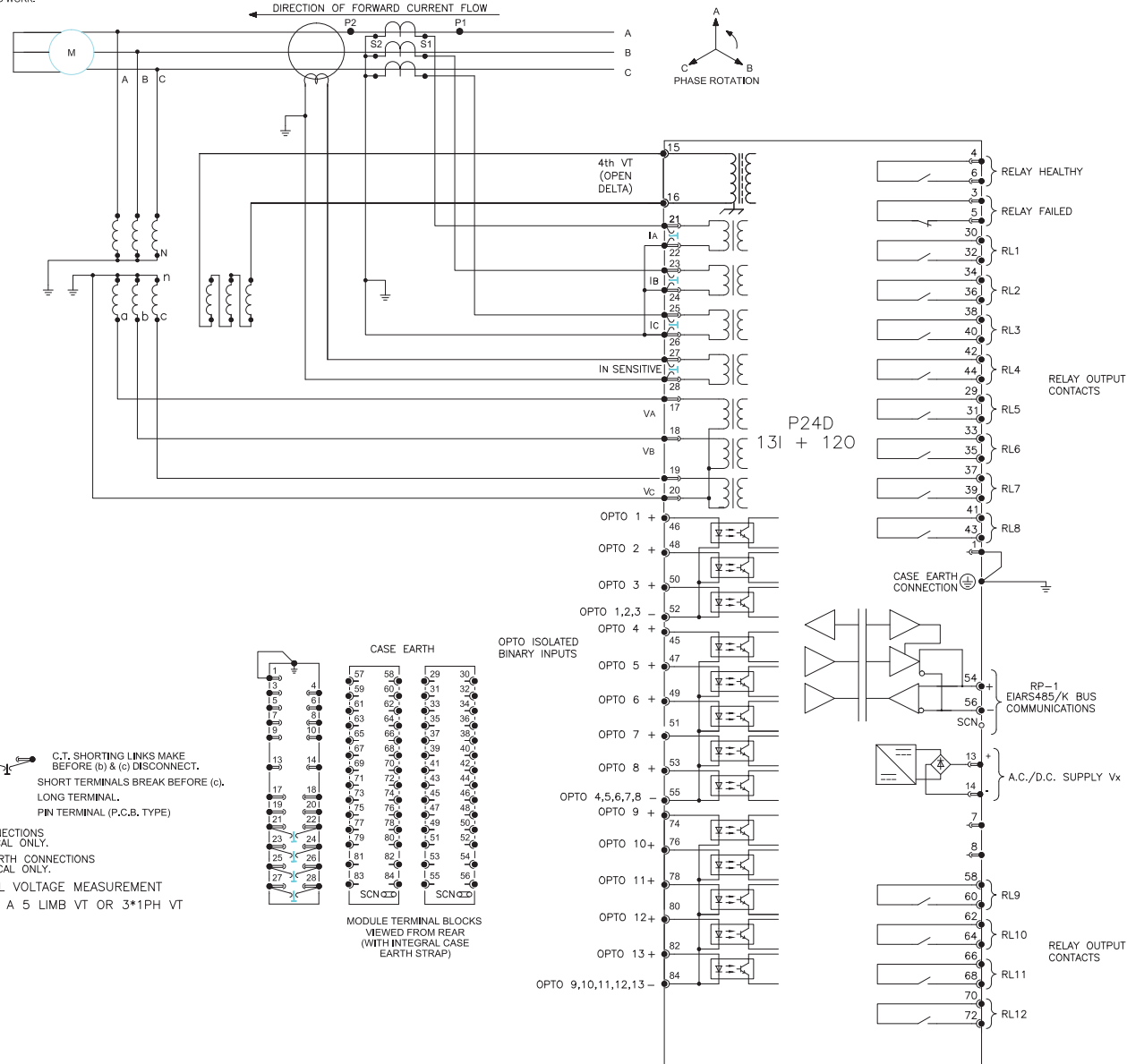(WITH INTEGRAL CASE
EARTH STRAP)

NOTES:

1.
(a)   C.T. SHORTING LINKS MAKE
       BEFORE (b) & (c) DISCONNECT.
(b)   SHORT TERMINALS BREAK BEFORE (c).
(c)   LONG TERMINAL.
(d)   PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS
   ARE TYPICAL ONLY.
3. CT/VT EARTH CONNECTIONS
   ARE TYPICAL ONLY.
4. RESIDUAL VOLTAGE MEASUREMENT
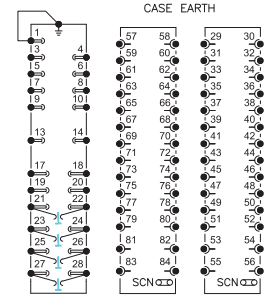   REQUIRE A 5 LIMB VT OR 3*1PH VT

Date: 10/10/2017	Name: V.SIVASAMBO	Drg Title: MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & SEF (13 I/P & 12 O/P) WITH ETHERNET	Next Stage: -	Drg No: 10P24D10-2	ECN No: CID005225	Revision: B	Iteration: 2
Date: 10/10/2017	Chkd: S WOOTTON						
Sub-contractor reference: -		CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: -		Grid Solutions	PLM No: A20028558	Sht: 2	Status: IN WORK
Finish: -			Angular Tol deg: -			Next Sht: 3	

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

4th VT
(OPEN DELTA)

IA
IB
IC
IN SENSITIVE

VA
VB
VC

P24D
13I + 12O
+ ETHERNET

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 –
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8 –
OPTO 9 +
OPTO 10+
OPTO 11+
OPTO 12+
OPTO 13 +
OPTO 9,10,11,12,13 –

OPTO ISOLATED BINARY INPUTS

A.C./D.C. SUPPLY Vx

CASE EARTH CONNECTION

RP-1
EIARS485/K BUS
COMMUNICATIONS
SCN

RL9
RL10
RL11
RL12

RELAY OUTPUT CONTACTS

SK2
TX+
TX–
RX+
RX–
RJ45
10 BASE-T/
100 BASE-TX

SK3
TX+
TX–
RX+
RX–
RJ45
10 BASE-T/
100 BASE-TX

CASE EARTH

ACTIVITY
PORT A
(SK2)
LBK

ACTIVITY
PORT B
(SK3)
LBK

SCN   SCN

MODULE TERMINAL BLOCKS
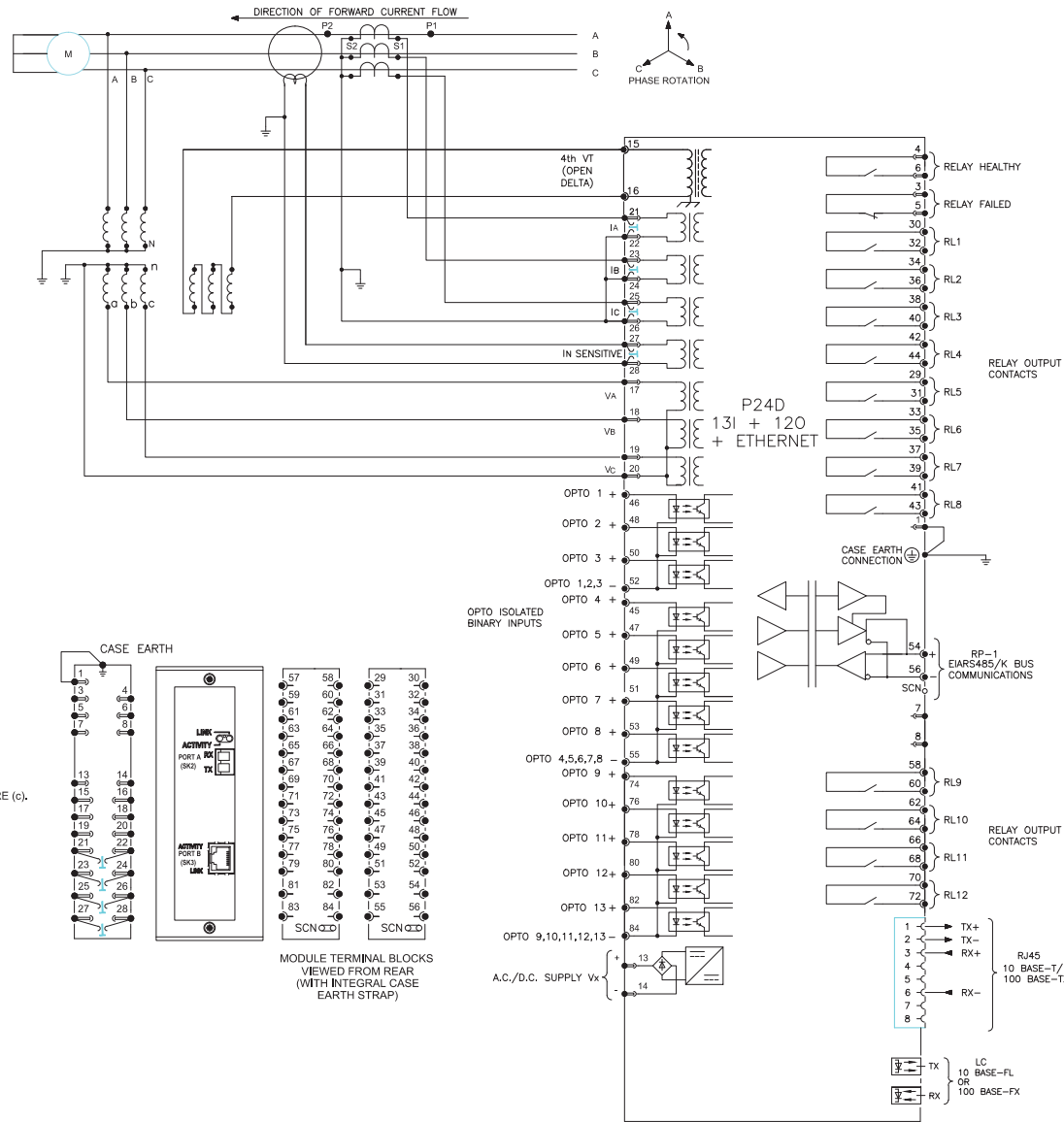VIEWED FROM REAR
(WITH INTEGRAL CASE
EARTH STRAP)

NOTES:
1.
(a) C.T. SHORTING LINKS MAKE
     BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS
   ARE TYPICAL ONLY.

3. CT/VT EARTH CONNECTIONS
   ARE TYPICAL ONLY.

4. RESIDUAL VOLTAGE MEASUREMENT
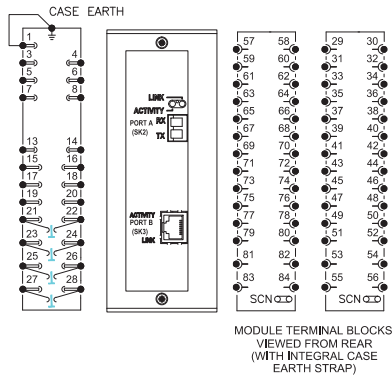   REQUIRE A 5 LIMB VT OR 3*1PH VT

Date:	10/10/2017	Name:	V.SIVASAMBO	Drg Title:	MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & SEF (13 I/P & 12 O/P) WITH DUAL COPPER ETHERNET	Next Stage:	-	Drg No:	10P24D10-3	ECN No: CID005225	Revision: B	Iteration: 2
Date:	10/10/2017	Chkd:	S WOOTTON									

Sub-contractor reference: -	CAD DATA 1:1 DIMENSIONS: mm	Linear Tol mm: -		PLM No:	A20028560	Sht: 3	Status:
Finish: -	DO NOT SCALE	Angular Tol deg: -	Grid Solutions			Next Sht: 4	IN WORK

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

4th VT (OPEN DELTA)

P24D
13I + 12O
+ ETHERNET

IA
IB
IC
IN SENSITIVE
VA
VB
VC

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 −
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8 −
OPTO 9 +
OPTO 10+
OPTO 11+
OPTO 12+
OPTO 13 +
OPTO 9,10,11,12,13 −

OPTO ISOLATED BINARY INPUTS

RP−1
EIARS485/K BUS
COMMUNICATIONS
SCN

RL9
RL10
RL11
RL12

RELAY OUTPUT CONTACTS

SK2 TX / RX   LC 10 BASE−FL OR 100 BASE−FX
SK3 TX / RX   LC 10 BASE−FL OR 100 BASE−FX

A.C./D.C. SUPPLY Vx

CASE EARTH

PORT A (SK2) RX TX ACTIVITY LINK

PORT B (SK3) RX TX ACTIVITY LINK

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
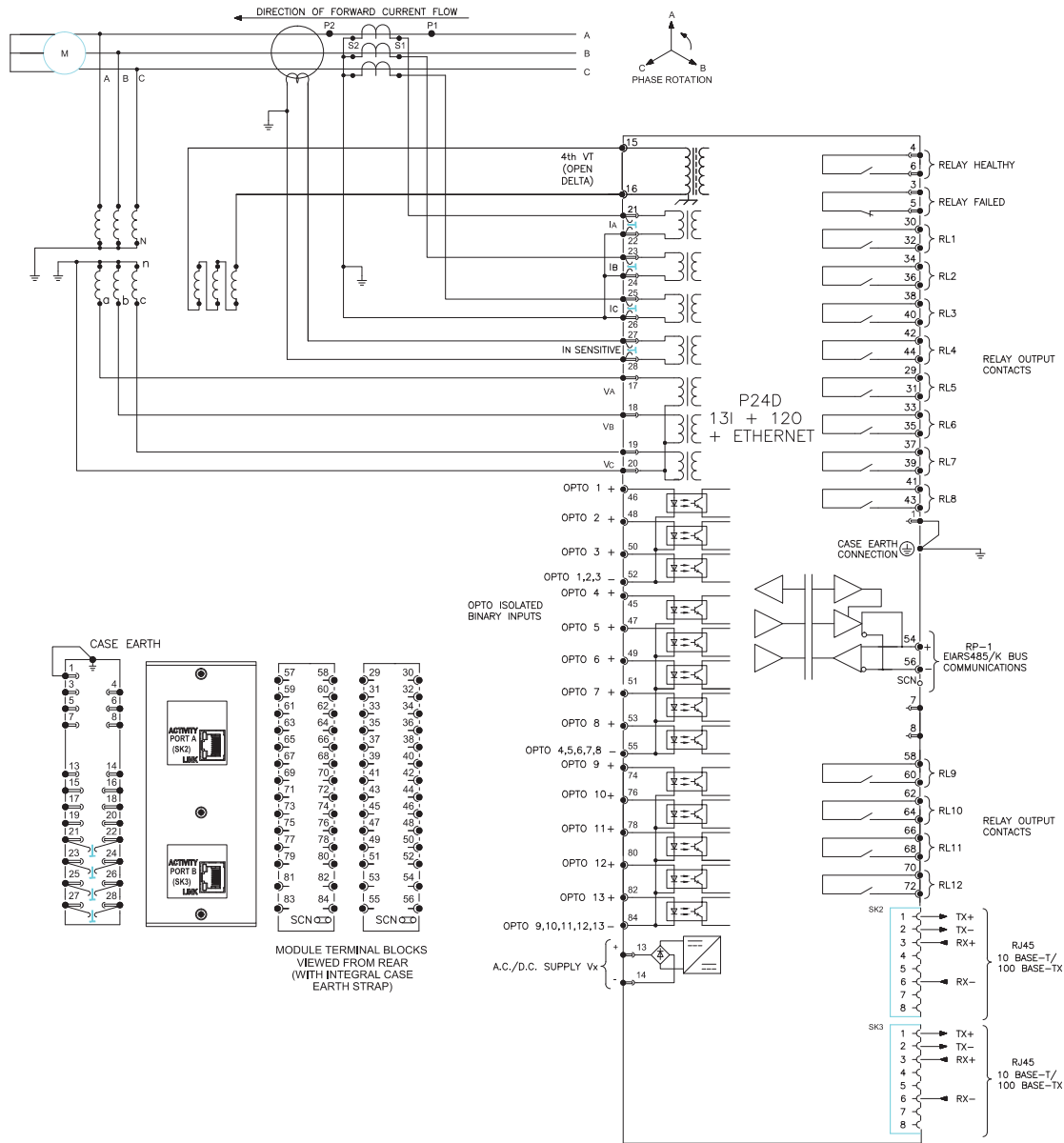(WITH INTEGRAL CASE
EARTH STRAP)

SCN   SCN

NOTES:

1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.

3. CT/VT EARTH CONNECTIONS ARE TYPICAL ONLY.

4. RESIDUAL VOLTAGE MEASUREMENT REQUIRE A 5 LIMB VT OR 3*1PH VT

| Date: | 10/10/2017 | Name: | V.SIVASAMBO | Drg Title: | MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & SEF (13 I/P & 12 O/P) WITH DUAL FIBRE ETHERNET | Next Stage: | | Drg No: | 10P24D10-4 | ECN No: CID005225 | Revision: B | Iteration: 2 |
| Date: | 10/10/2017 | Chkd: | S WOOTTON | | | | | | | | | |

Sub-contractor reference: -

Finish: -

CAD DATA 1:1 DIMENSIONS: mm
DO NOT SCALE

Linear Tol mm: -
Angular Tol deg: -

GE Grid Solutions

PLM No: A20028564

Sht: 4
Next Sht: -

Status: IN WORK

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

4th VT
(OPEN DELTA)

P24D
8I + 8O

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 -
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8 -

OPTO ISOLATED BINARY INPUTS

EIARS485/K BUS COMMUNICATIONS

A.C./D.C. SUPPLY Vx

CASE EARTH
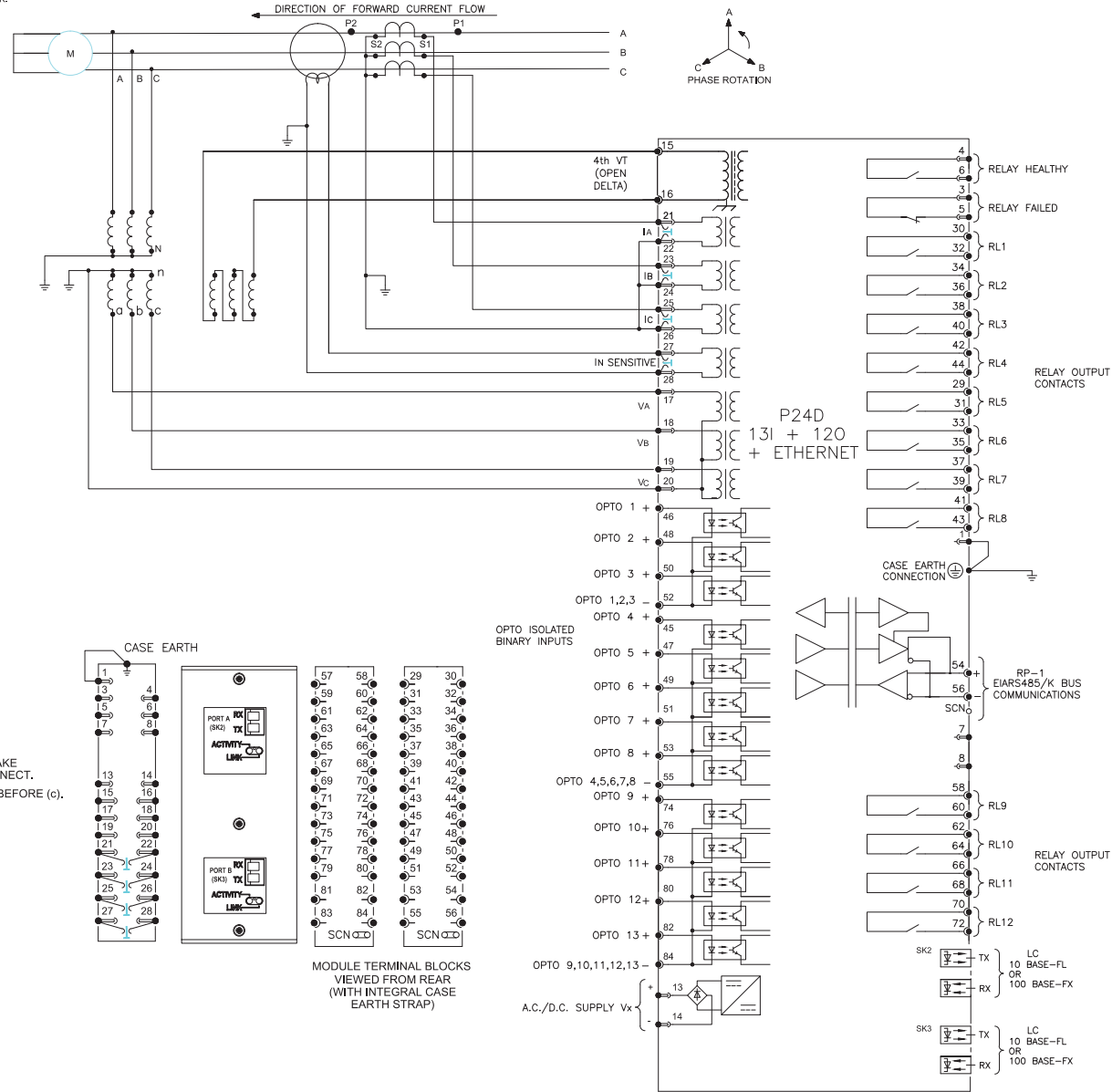
NOTES:
1.
(a)   C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b)   SHORT TERMINALS BREAK BEFORE (c).
(c)   LONG TERMINAL.
(d)   PIN TERMINAL (P.C.B. TYPE)
2. C.T. CONNECTIONS ARE TYPICAL ONLY.
3. EARTH CONNECTIONS ARE TYPICAL ONLY.
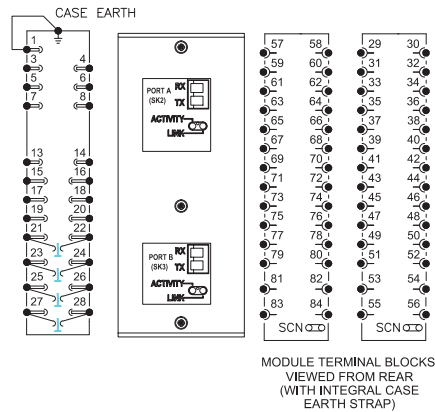4. RESIDUAL VOLTAGE MEASUREMENT REQUIRE A 5 LIMB VT OR 3*1PH VT

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE EARTH STRAP)

Date:	13/11/2017	Name:	V.SIVASAMBO	Drg Title:	MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & E/F (8I/P + 8O/P)	Next Stage:	-	Drg No:	10P24D12-1	ECN No: CID005225	Revision: B	Iteration: 3
Date:	13/11/2017	Chkd:	S WOOTTON									
Sub-contractor reference:	-			CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: - Angular Tol deg: -		Grid Solutions	PLM No:	A20028566	Sht: 1 Next Sht: -	Status: IN WORK	
Finish:	-											

DIRECTION OF FORWARD CURRENT FLOW

P2   P1   A
S2   S1   B
            C

PHASE ROTATION
A
C   B

M

A B C

SEE NOTES 2 & 3

N

n

a b c

4th VT
(OPEN
DELTA)

15
16

21
IA
22
23
IB
24
25
IC
26
27
IN
28

17
VA
18
VB
19
VC
20

OPTO 1 +   46
OPTO 2 +   48
OPTO 3 +   50
OPTO 1,2,3 - 52

P24D
3I + 40

4
6   RELAY HEALTHY
3
5   RELAY FAILED
30
32   RL1
34
36   RL2   RELAY OUTPUT
38   CONTACTS
40   RL3
42
44   RL4

OPTO ISOLATED
BINARY INPUTS

CASE EARTH
CONNECTION

54
56   EIARS485/K BUS
     COMMUNICATIONS
SCN

13 +
     A.C./D.C. SUPPLY Vx
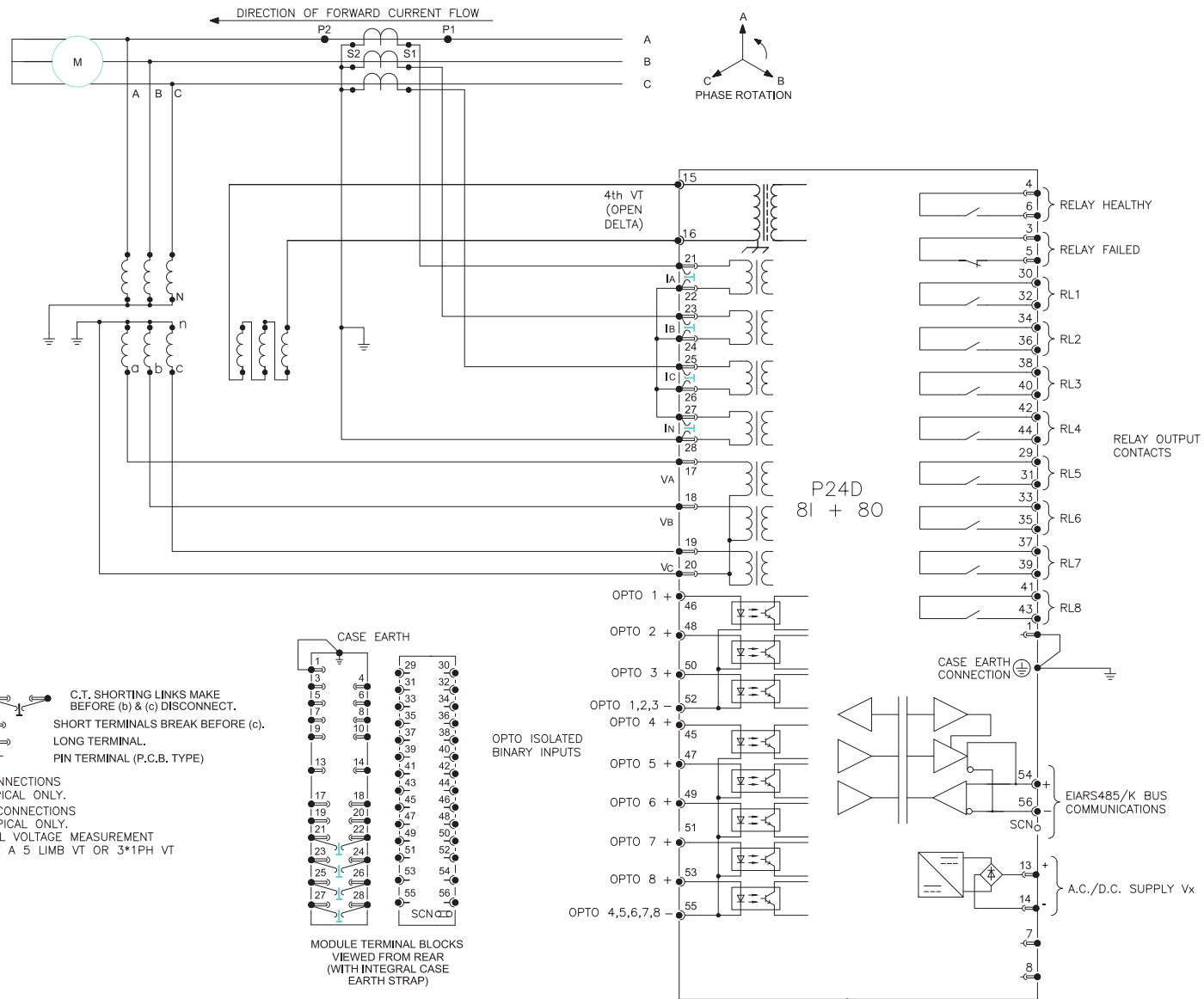14

7

8

CASE EARTH

NOTES:

1.
(a)   C.T. SHORTING LINKS MAKE
       BEFORE (b) & (c) DISCONNECT.
(b)   SHORT TERMINALS BREAK BEFORE (c).
(c)   LONG TERMINAL.
(d)   PIN TERMINAL (P.C.B. TYPE)

2. CT/VT CONNECTIONS
   ARE TYPICAL ONLY.

3. CT/VT EARTH CONNECTIONS
   ARE TYPICAL ONLY.

4. RESIDUAL VOLTAGE MEASUREMENT
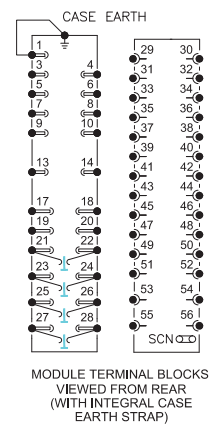   REQUIRE A 5 LIMB VT OR 3*1PH VT

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE
EARTH STRAP)

| Date: | 10/10/2017 | Name: | V.SIVASAMBO | Drg Title: | MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & E/F (3 I/P & 4 O/P) | Next Stage: - | Drg No: | 10P24D13-1 | ECN No: CID005225 | Revision: B | Iteration: 2 |
| Date: | 10/10/2017 | Chkd: | S WOOTTON | | | | | | | | |

Sub-contractor reference: -

Finish: -

CAD DATA 1:1 DIMENSIONS: mm
DO NOT SCALE

Linear Tol mm: -
Angular Tol deg: -

GE Grid Solutions

PLM No: A20028573

Sht: 1
Next Sht: -

Status: IN WORK

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

SEE NOTES 2 & 3

4th VT (OPEN DELTA)

P24D
6I + 8O
TCS

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 −

OPTO ISOLATED BINARY INPUTS

OPTO 4
OPTO 5
OPTO 6

CASE EARTH

CASE EARTH CONNECTION

RP-1
EIARS485/K BUS
COMMUNICATIONS

SCN

A.C./D.C. SUPPLY Vx

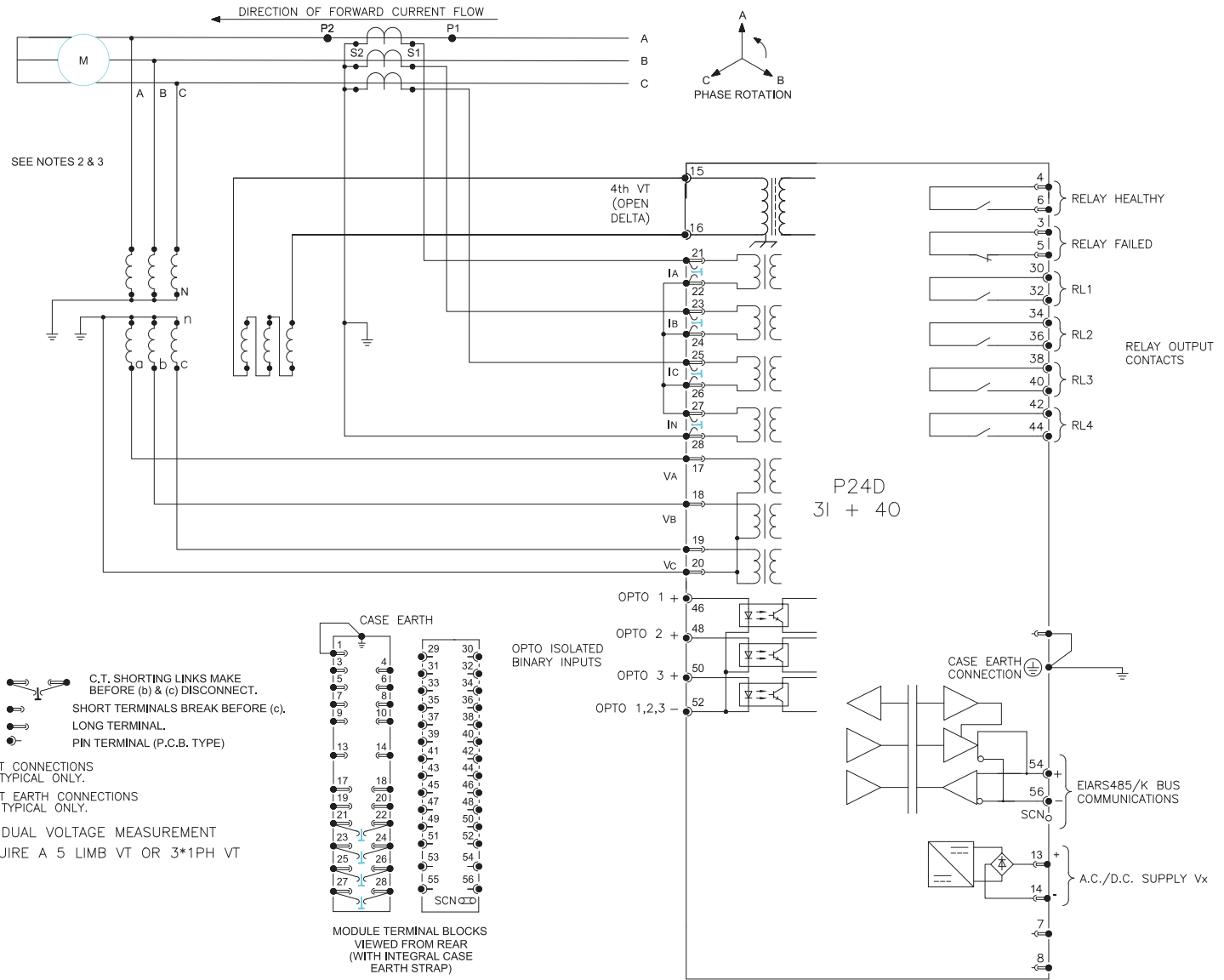MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE
EARTH STRAP)

NOTES:

1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. CT/VT CONNECTIONS ARE TYPICAL ONLY.

3. CT/VT EARTH CONNECTIONS ARE TYPICAL ONLY.

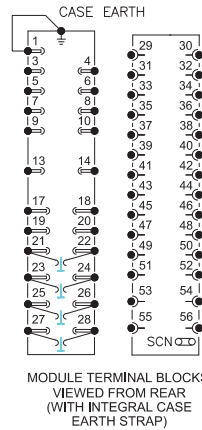4. RESIDUAL VOLTAGE MEASUREMENT REQUIRE A 5 LIMB VT OR 3*1PH VT

| Date: | 10/10/2017 | Name: | V.SIVASAMBO | Drg Title: | MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & E/F (6 I/P & 8 O/P) WITH TCS | Next Stage: | | Drg No: | 10P24D14-1 | ECN No: CID005225 | Revision: B | Iteration: 2 |
| Date: | 10/10/2017 | Chkd: | S WOOTTON | | | | | | | | | |

Sub-contractor reference: -

Finish: -

CAD DATA 1:1 DIMENSIONS: mm
DO NOT SCALE

Linear Tol mm: -
Angular Tol deg: -

Grid Solutions

PLM No: A20028575

Sht: 1
Next Sht: -

Status: IN WORK

DIRECTION OF FORWARD CURRENT FLOW

M

P2 P1
S2 S1

A
B
C

A B C

PHASE ROTATION

4th VT
(OPEN
DELTA)

N
n
a b c

15
16
21
IA 22
23
IB 24
25
IC 26
27
IN 28
VA 17
18
VB 19
Vc 20

P24D
10I + 12O
+ 2 RS485

4
6   RELAY HEALTHY
3
5   RELAY FAILED
30
32   RL1
34
36   RL2
38
40   RL3
42
44   RL4
29
31   RL5
33
35   RL6
37
39   RL7
41
43   RL8
1

RELAY OUTPUT
CONTACTS

CASE EARTH
CONNECTION

OPTO 1 +   46
OPTO 2 +   48
OPTO 3 +   50
OPTO 1,2,3 – 52

OPTO 4 +   45
OPTO 5 +   47
OPTO 6 +   49
OPTO 7 +   51
OPTO 8 +   53
OPTO 4,5,6,7,8 – 55

OPTO 9 +   74
OPTO 9 –   76
OPTO 10 +   78
OPTO 10 –   80

54
56   RP–1
SCN   EIARS485/K BUS
      COMMUNICATIONS

13
14   A.C./D.C. SUPPLY Vx
7
8

58
60   RL9
62
64   RL10
66
68   RL11
70
72   RL12

RELAY OUTPUT
CONTACTS

82
84   RP–2
SCN   EIARS485/K BUS
      COMMUNICATIONS

NOTES:

1.
(a)   C.T. SHORTING LINKS MAKE   OPTO ISOLATED
       BEFORE (b) & (c) DISCONNECT BINARY INPUTS
(b)   SHORT TERMINALS BREAK BEFORE (c).
(c)   LONG TERMINAL.
(d)   PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS
   ARE TYPICAL ONLY.

3. EARTH CONNECTIONS
   ARE TYPICAL ONLY.

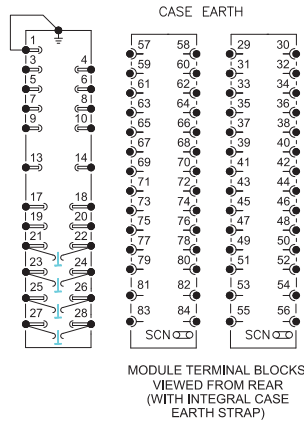4. RESIDUAL VOLTAGE MEASUREMENT
   REQUIRE A 5 LIMB VT OR 3*1PH VT

CASE EARTH

1 2
3 4
5 6
7 8
...
57 58
59 60
61 62
63 64
65 66
67 68
69 70
71 72
73 74
75 76
77 78
79 80
81 82
83 84
SCN

29 30
31 32
33 34
35 36
37 38
39 40
41 42
43 44
45 46
47 48
49 50
51 52
53 54
55 56
SCN

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE
EARTH STRAP)

Date: 11/10/2017	Name: V.SIVASAMBO	Drg Title: MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & E/F (10 I/P & 12 O/P) WITH 2 RS485	Next Stage:	Drg No: 10P24D16-1	ECN No: CID005225	Revision: B	Iteration: 2
Date: 11/10/2017	Chkd: S WOOTTON						
Sub-contractor reference: -		CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: - / Angular Tol deg: -	Grid Solutions	PLM No: A20028585	Sht: 1 / Next Sht: 2	Status: IN WORK
Finish: -							

DIRECTION OF FORWARD CURRENT FLOW

P2   S2   S1   P1

A
B
C

PHASE ROTATION

M

A B C

N

n

a b c

4th VT
(OPEN
DELTA)

15
16

21
22
IA
23
24
IB
25
26
Ic
27
IN
28

17
VA
18
VB
19
VC
20

P24D
10I + 12O
+ 2 RS485
+ ETHERNET

4
6   RELAY HEALTHY
3
5   RELAY FAILED
30
32   RL1
34
36   RL2
38
40   RL3
42
44   RL4
29
31   RL5
33
35   RL6
37
39   RL7
41
43   RL8

RELAY OUTPUT
CONTACTS

CASE EARTH
CONNECTION

OPTO 1 +   46
OPTO 2 +   48
OPTO 3 +   50
OPTO 1,2,3 – 52

OPTO 4 +   45
OPTO 5 +   47
OPTO 6 +   49
OPTO 7 +   51
OPTO 8 +   53
OPTO 4,5,6,7,8 55
OPTO 9 +   74
OPTO 9 –   76
OPTO 10 +   78
OPTO 10 –   80

54
56   RP-1
       EIARS485/K BUS
SCN   COMMUNICATIONS

7
8

58
60   RL9
62
64   RL10
66
68   RL11
70
72   RL12

RELAY OUTPUT
CONTACTS

A.C./D.C. SUPPLY Vx
+ 13
– 14

82
84   RP-2
       EIARS485/K BUS
SCN   COMMUNICATIONS

1   TX+
2   TX–
3   RX+
4
5   RX–
6
7
8

RJ45
10 BASE-T/
100 BASE-TX

TX   LC
       10 BASE-FL
RX   OR
       100 BASE-FX

CASE EARTH

LINK
ACTIVITY
PORT A   RX
(SK2)   TX

ACTIVITY
PORT B
(SK3)   LINK

57 58
59 60
61 62
63 64
65 66
67 68
69 70
71 72
73 74
75 76
77 78
79 80
81 82
83 84

SCN

29 30
31 32
33 34
35 36
37 38
39 40
41 42
43 44
45 46
47 48
49 50
51 52
53 54
55 56

SCN

1
13 4
15 6
17 8

13 14
15 16
17 18
19 20
21 22
23 24
25 26
27 28

MODULE TERMINAL BLOCKS
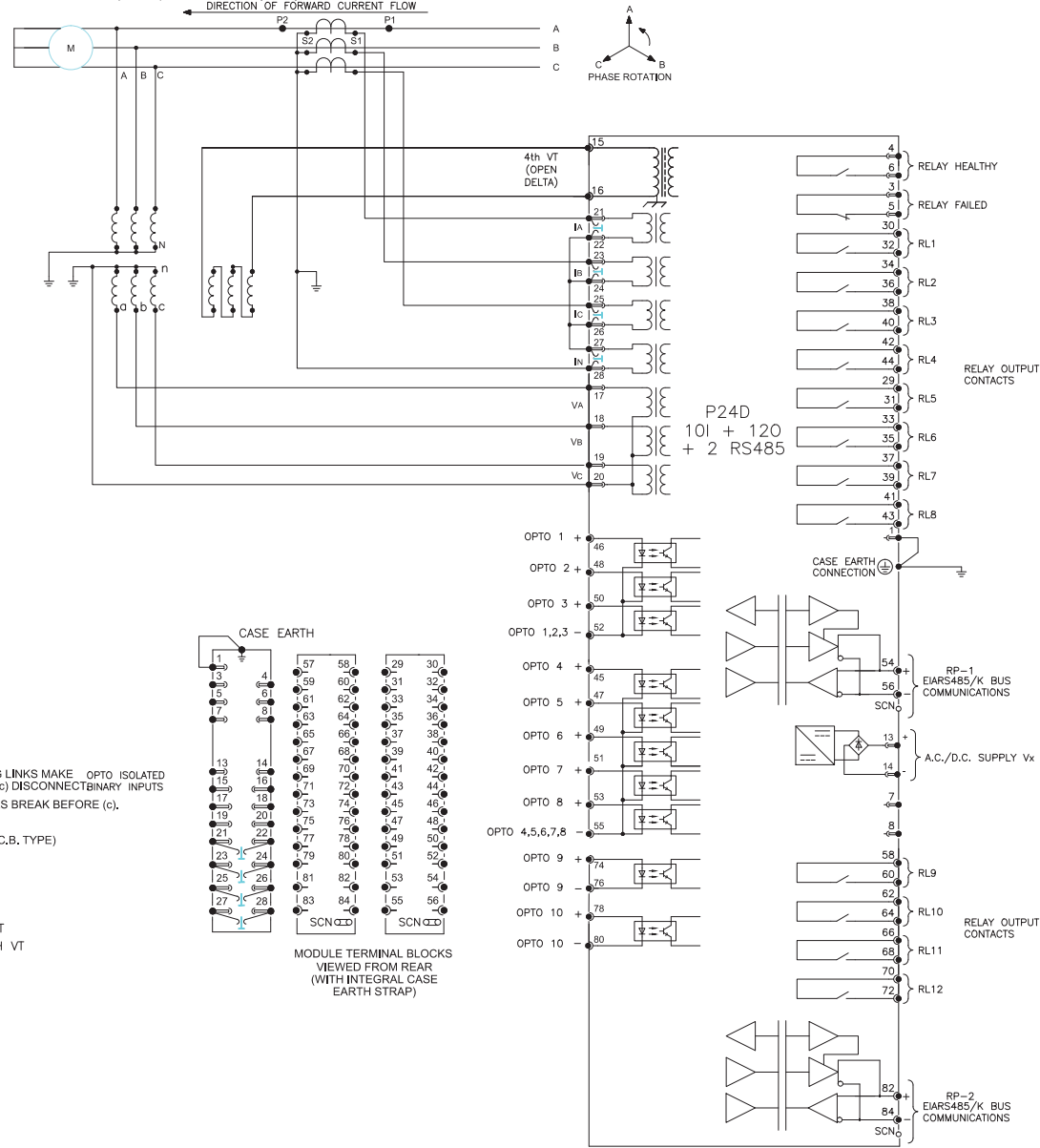VIEWED FROM REAR
(WITH INTEGRAL CASE
EARTH STRAP)

NOTES:
1.
(a)   C.T. SHORTING LINKS MAKE
       BEFORE (b) & (c) DISCONNECT.
(b)   SHORT TERMINALS BREAK BEFORE (c).
(c)   LONG TERMINAL.
(d)   PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS
   ARE TYPICAL ONLY.
3. EARTH CONNECTIONS
   ARE TYPICAL ONLY.
4. RESIDUAL VOLTAGE MEASUREMENT
   REQUIRE A 5 LIMB VT OR 3*1PH VT
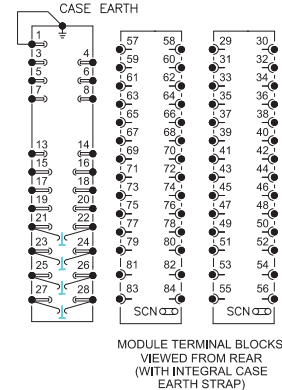
| Date: | 11/10/2017 | Name: | V.SIVASAMBO | Drg Title: | MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & E/F (10 I/P & 12 O/P) WITH 2 RS485 & ETHERNET | Next Stage: | - | Drg No: | 10P24D16-2 | ECN No: CID005225 | Revision: B | Iteration: 2 |
| Date: | 11/10/2017 | Chkd: | S WOOTTON | | | | | | | | | |

Sub-contractor reference: -
Finish: -

CAD DATA 1:1 DIMENSIONS: mm
DO NOT SCALE

Linear Tol mm: -
Angular Tol deg: -

Grid Solutions

PLM No: A20028587

Sht: 2
Next Sht: 3

Status: IN WORK

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

4th VT (OPEN DELTA)

P24D
10I + 12O
+ 2 RS485
+ ETHERNET

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 -

OPTO ISOLATED BINARY INPUTS

OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8 -
OPTO 9 +
OPTO 9 -
OPTO 10 +
OPTO 10 -

RP-1
EIARS485/K BUS
COMMUNICATIONS

RL9
RL10
RL11
RL12

RELAY OUTPUT CONTACTS

A.C./D.C. SUPPLY Vx

RP-2
EIARS485/K BUS
COMMUNICATIONS

SK2
TX+
TX-
RX+
RX-
RJ45
10 BASE-T/
100 BASE-TX

SK3
TX+
TX-
RX+
RX-
RJ45
10 BASE-T/
100 BASE-TX

CASE EARTH

ACTIVITY PORT A (SK2) LINK
ACTIVITY PORT B (SK3) LINK

MODULE TERMINAL BLOCKS VIEWED FROM REAR (WITH INTEGRAL CASE EARTH STRAP)

NOTES:
1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE).

2. C.T. CONNECTIONS ARE TYPICAL ONLY.

3. EARTH CONNECTIONS ARE TYPICAL ONLY.

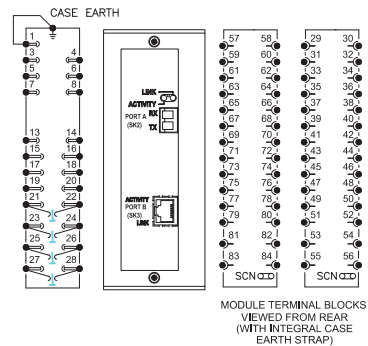4. RESIDUAL VOLTAGE MEASUREMENT REQUIRE A 5 LIMB VT OR 3*1PH VT

| Date: | 11/10/2017 | Name: | V.SIVASAMBO | Drg Title: | MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & E/F (10 I/P & 12 O/P) WITH 2 RS485 & DUAL COPPER ETHERNET | Next Stage: - | Drg No: 10P24D16-3 | ECN No: CID005225 | Revision: B | Iteration: 2 |
| Date: | 11/10/2017 | Chkd: | S WOOTTON |

Sub-contractor reference: -

Finish: -

CAD DATA 1:1 DIMENSIONS: mm
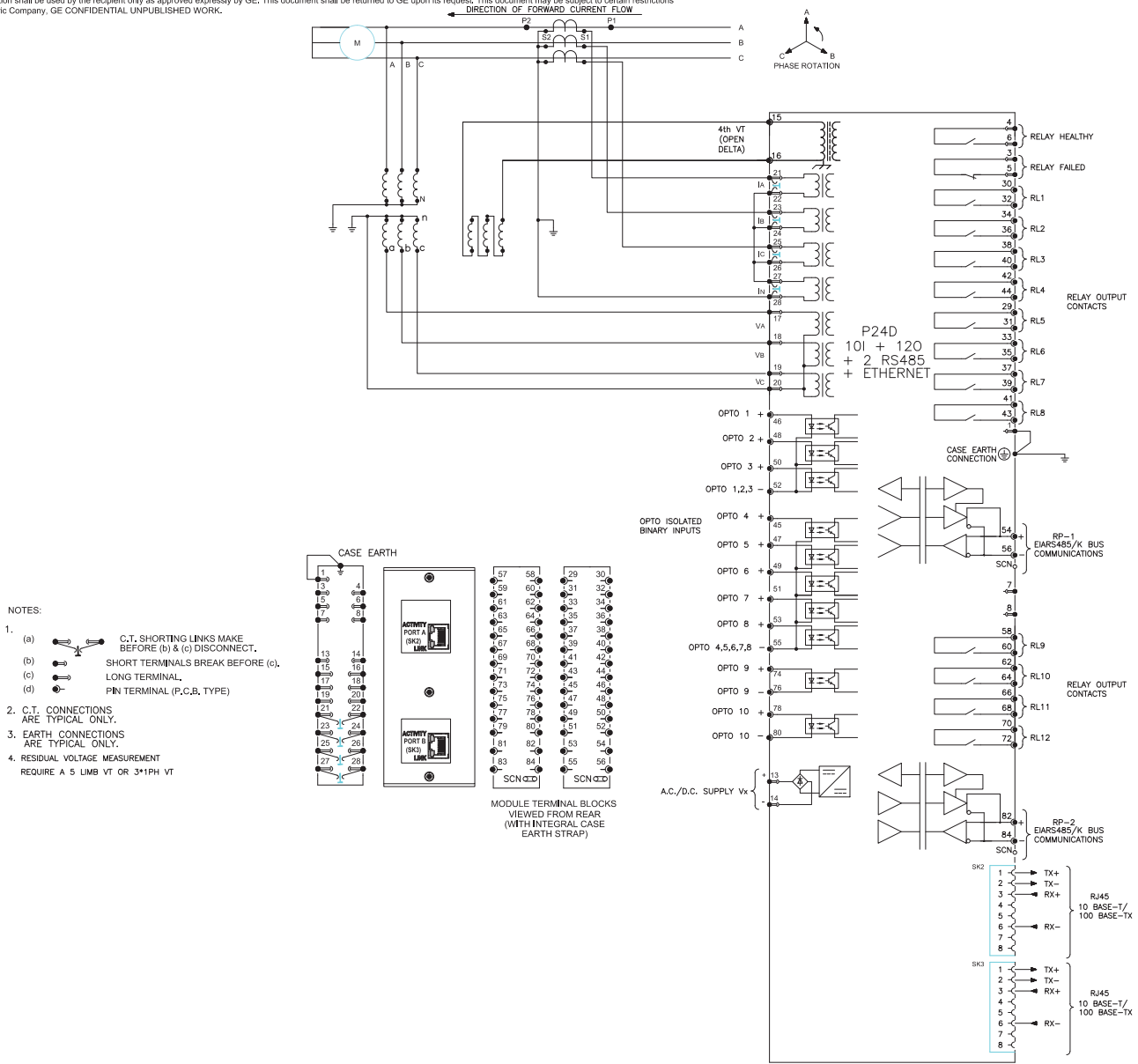DO NOT SCALE

Linear Tol mm: -
Angular Tol deg: -

Grid Solutions

PLM No: A20028589

Sht: 3
Next Sht: 4

Status: IN WORK

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

4th VT
(OPEN
DELTA)

P24D
10I + 12O
+ 2 RS485
+ ETHERNET

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT
CONTACTS

CASE EARTH
CONNECTION

OPTO ISOLATED
BINARY INPUTS

RP-1
EIARS485/K BUS
COMMUNICATIONS

RL9
RL10
RL11
RL12

RELAY OUTPUT
CONTACTS

A.C./D.C. SUPPLY Vx

RP-2
EIARS485/K BUS
COMMUNICATIONS

LC
10 BASE-FL
OR
100 BASE-FX

LC
10 BASE-FL
OR
100 BASE-FX

CASE EARTH

PORT A RX
(SK2)   TX
ACTIVITY
LINK

PORT B RX
(SK3)   TX
ACTIVITY
LINK

SCN   SCN

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE
EARTH STRAP)

NOTES:
1.
(a)   C.T. SHORTING LINKS MAKE
            BEFORE (b) & (c) DISCONNECT.
(b)   SHORT TERMINALS BREAK BEFORE (c).
(c)   LONG TERMINAL.
(d)   PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS
   ARE TYPICAL ONLY.
3. EARTH CONNECTIONS
   ARE TYPICAL ONLY.
4. RESIDUAL VOLTAGE MEASUREMENT
   REQUIRE A 5 LIMB VT OR 3*1PH VT

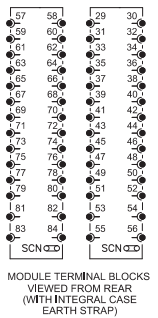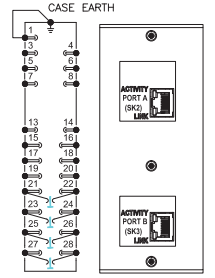| Date: 11/10/2017 | Name: V.SIVASAMBO | Drg Title: MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & E/F (10 I/P & 12 O/P) WITH 2 RS485 & DUAL FIBRE ETHERNET | Next Stage: - | Drg No: 10P24D16-4 | ECN No: CID005225 | Revision: B | Iteration: 2 |
Date: 11/10/2017	Chkd: S WOOTTON						
Sub-contractor reference: -		CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: - Angular Tol deg: -	Grid Solutions	PLM No: A20028591	Sht: 4	Status: IN WORK
Finish: -						Next Sht: -	

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

15
16
4th VT
(OPEN DELTA)

21
22 IA
23
24 IB
25
26 IC
27 IN SENSITIVE
28
17 VA
18 VB
19
20 Vc

P24D
10I + 12O
+ 2 RS485

4
6 RELAY HEALTHY
3
5 RELAY FAILED
30
32 RL1
34
36 RL2
38
40 RL3
42
44 RL4
29
31 RL5
33
35 RL6
37
39 RL7
41
43 RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

OPTO 1 +   46
OPTO 2 +   48
OPTO 3 +   50
OPTO 1,2,3 52

OPTO ISOLATED BINARY INPUTS

OPTO 4 +   45
OPTO 5 +   47
OPTO 6 +   49
OPTO 7 +   51
OPTO 8 +   53
OPTO 4,5,6,7,8 55

OPTO 9 +   74
OPTO 9 −   76
OPTO 10 + 78
OPTO 10 − 80

54
56 SCN
RP−1
EIARS485/K BUS
COMMUNICATIONS

13 +
14 −
A.C./D.C. SUPPLY Vx

7
8

58
60 RL9
62
64 RL10
66
68 RL11
70
72 RL12

RELAY OUTPUT CONTACTS

82 +
84 −
SCN
RP−2
EIARS485/K BUS
COMMUNICATIONS

CASE EARTH

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE
EARTH STRAP)

NOTES:
1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.

3. CT/VT EARTH CONNECTIONS ARE TYPICAL ONLY.

4. RESIDUAL VOLTAGE MEASUREMENT REQUIRE A 5 LIMB VT OR 3*1PH VT

Date: 11/10/2017	Name: V.SIVASAMBO	Drg Title: MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & SEF (10 I/P & 12 O/P) WITH 2 RS485	Next Stage: -	Drg No: 10P24D17-1	ECN No: CID005225	Revision: B	Iteration: 2
Date: 11/10/2017	Chkd: S WOOTTON						
Sub-contractor reference: -		CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: -	Grid Solutions	PLM No: A20028593	Sht: 1	Status: IN WORK
Finish: -			Angular Tol deg: -			Next Sht: 2	

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

4th VT (OPEN DELTA)

IN SENSITIVE

P24D
10I + 12O
+ 2 RS485
+ ETHERNET

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 −
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8 −
OPTO 9 +
OPTO 9 −
OPTO 10 +
OPTO 10 −

OPTO ISOLATED BINARY INPUTS

RP−1 EIARS485/K BUS COMMUNICATIONS

RL9
RL10
RL11
RL12

RELAY OUTPUT CONTACTS

A.C./D.C. SUPPLY Vx

RP−2 EIARS485/K BUS COMMUNICATIONS

TX+
TX−
RX+
RX−

RJ45
10 BASE−T/
100 BASE−TX

LC
10 BASE−FL
OR
100 BASE−FX

CASE EARTH

LINK
ACTIVITY
PORT A
(SK2)
RX
TX

ACTIVITY
PORT B
(SK3)
LINK

MODULE TERMINAL BLOCKS VIEWED FROM REAR (WITH INTEGRAL CASE EARTH STRAP)

NOTES:

1.
   (a)   C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
   (b)   SHORT TERMINALS BREAK BEFORE (c).
   (c)   LONG TERMINAL.
   (d)   PIN TERMINAL (P.C.B. TYPE).

2. C.T. CONNECTIONS ARE TYPICAL ONLY.

3. CT/VT EARTH CONNECTIONS ARE TYPICAL ONLY.

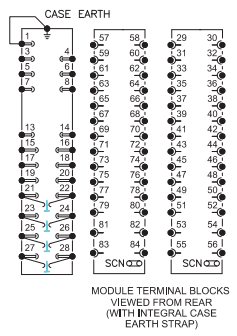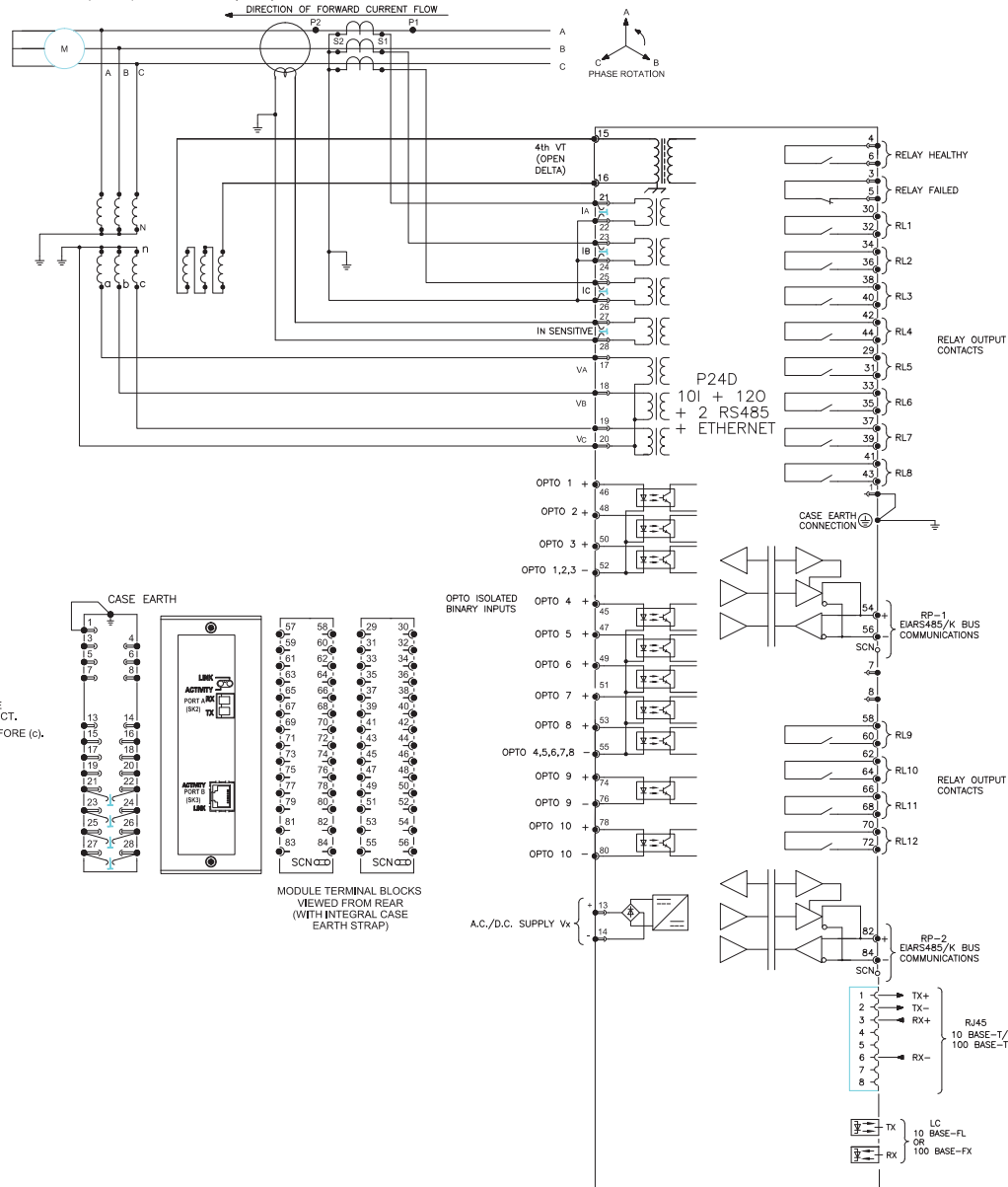4. RESIDUAL VOLTAGE MEASUREMENT REQUIRE A 5 LIMB VT OR 3*1PH VT

Date: 11/10/2017	Name: V.SIVASAMBO	Drg Title: MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & SEF (10 I/P & 12 O/P) WITH 2 RS485 & ETHERNET	Next Stage: -	Drg No: 10P24D17-2	ECN No: CID005225	Revision: B	Iteration: 2
Date: 11/10/2017	Chkd: S WOOTTON						
Sub-contractor reference: -		CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: - Angular Tol deg: -	Grid Solutions	PLM No: A20028596	Sht: 2 Next Sht: 3	Status: IN WORK
Finish: -							

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

15
4th VT (OPEN DELTA)
16

21 IA
22
23 IB
24
25 IC
26
27 IN
28

VA 17
VB 18
VC 19 20

P24D
11I + 120
TCS +
ETHERNET

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

OPTO 1 + 46
OPTO 2 + 48
OPTO 3 + 50
OPTO 1,2,3 _ 52
OPTO 4 + 45
OPTO 5 + 47
OPTO 6 + 49
OPTO 7 + 51
OPTO 8 + 53
OPTO 4,5,6,7,8 _ 55

OPTO ISOLATED BINARY INPUTS

OPTO 9 { + 74
         _ 76
OPTO 10 { + 78
          _ 80
OPTO 11 { + 82
          _ 84

A.C./D.C. SUPPLY Vx { + 13
                       14

RP-1
EIARS485/K BUS
COMMUNICATIONS
54
56
SCN

7
8

RL9 58 60
RL10 62 64 66
RL11 68
RL12 70 72

RELAY OUTPUT CONTACTS

CASE EARTH

ACTIVITY PORT A (SK2) LINK

ACTIVITY PORT B (SK3) LINK

1 2 3 4
5 6 7 8
13 14
15 16
17 18
19 20
21 22
23 24
25 26
27 28

57 58
59 60
61 62
63 64
65 66
67 68
69 70
71 72
73 74
75 76
77 78
79 80
81 82
83 84
SCN

29 30
31 32
33 34
35 36
37 38
39 40
41 42
43 44
45 46
47 48
49 50
51 52
53 54
55 56
SCN

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE EARTH STRAP)

SK2
1 TX+
2 TX-
3 RX+
4
5
6 RX-
7
8
RJ45
10 BASE-T/
100 BASE-TX

SK3
1 TX+
2 TX-
3 RX+
4
5
6 RX-
7
8
RJ45
10 BASE-T/
100 BASE-TX

NOTES:
1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.
3. EARTH CONNECTIONS ARE TYPICAL ONLY.
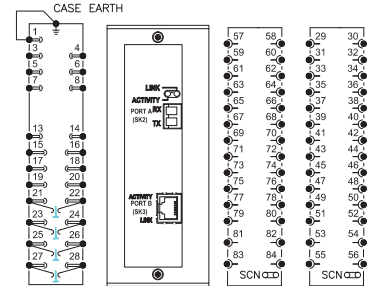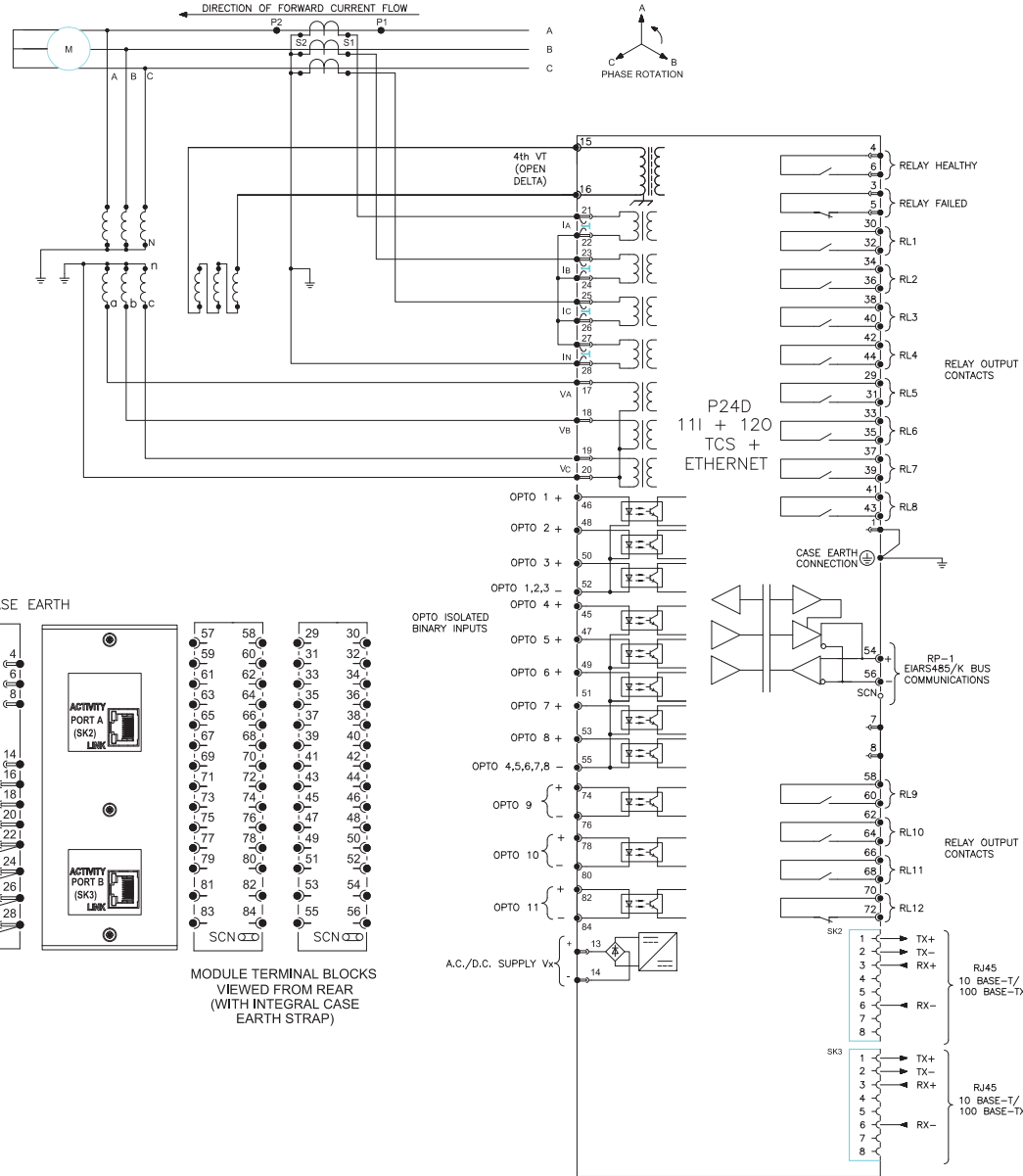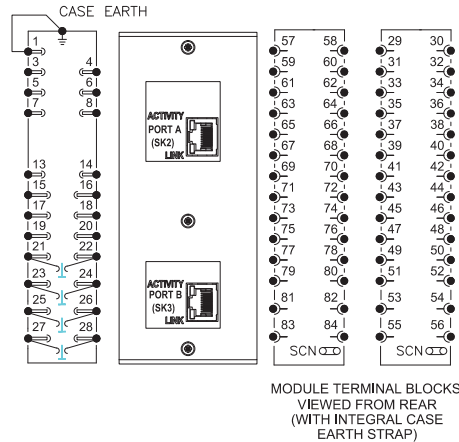4. RESIDUAL VOLTAGE MEASUREMENT REQUIRE A 5 LIMB VT OR 3*1PH VT

| Date: | 11/10/2017 | Name: | V.SIVASAMBO | Drg Title: | MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & SEF (10 I/P & 12 O/P) WITH 2 RS485 & DUAL COPPER ETHERNET | Next Stage: | | Drg No: | 10P24D17-3 | ECN No: CID005225 | Revision: B | Iteration: 2 |
| Date: | 11/10/2017 | Chkd: | S WOOTTON | | | | | | | | | |

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

4th VT (OPEN DELTA)

IN SENSITIVE

P24D
10I + 12O
+ 2 RS485
+ ETHERNET

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 -
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8 -
OPTO 9 +
OPTO 9 -
OPTO 10 +
OPTO 10 -

OPTO ISOLATED BINARY INPUTS

CASE EARTH CONNECTION

RP-1 EIARS485/K BUS COMMUNICATIONS
SCN

RL9
RL10
RL11
RL12

RELAY OUTPUT CONTACTS

A.C./D.C. SUPPLY Vx

RP-2 EIARS485/K BUS COMMUNICATIONS
SCN

SK2 TX LC 10 BASE-FL OR 100 BASE-FX
RX

SK3 TX LC 10 BASE-FL OR 100 BASE-FX
RX

CASE EARTH

PORT A (SK2) RX TX ACTIVITY LINK
PORT B (SK3) RX TX ACTIVITY LINK

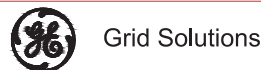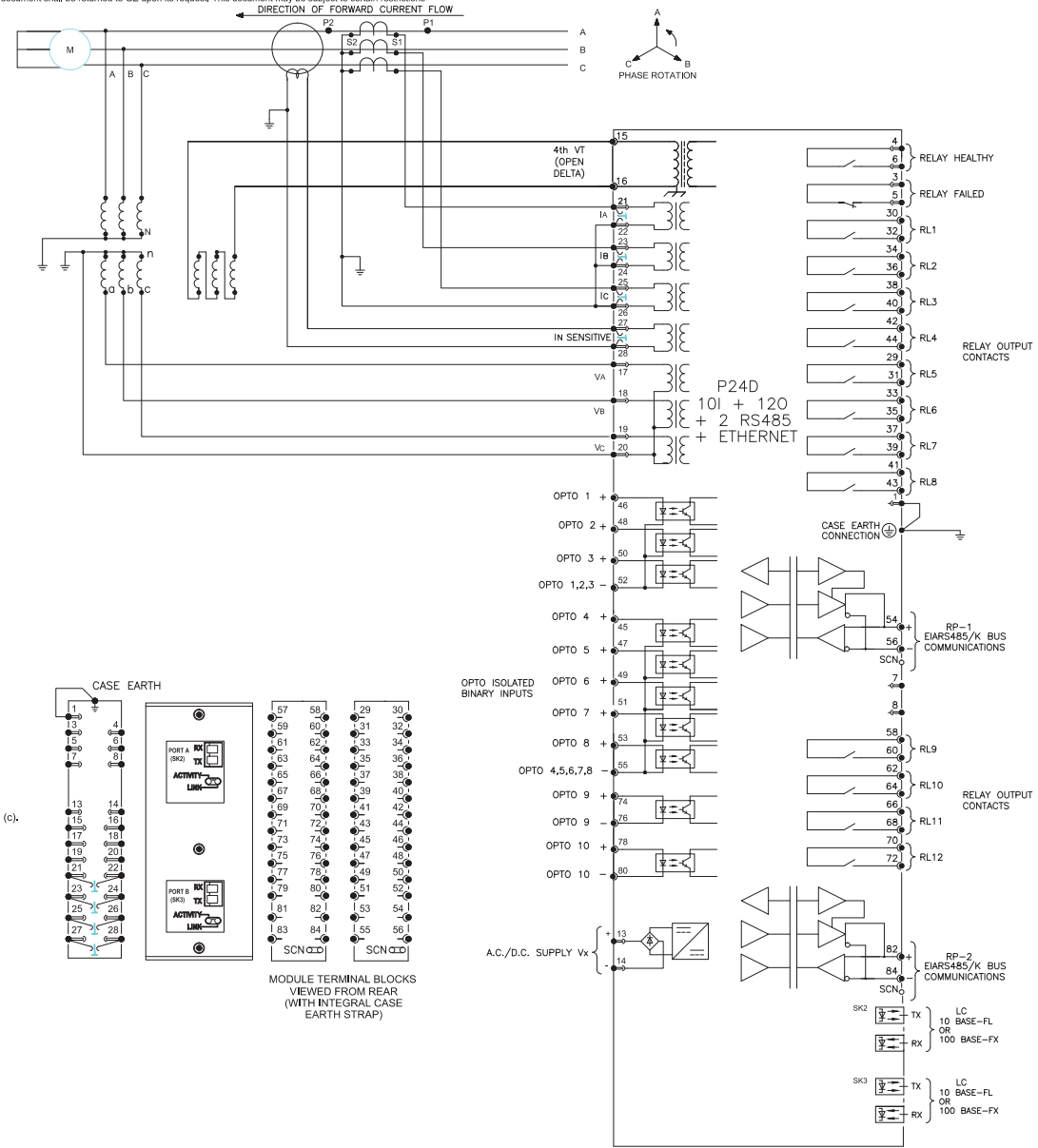MODULE TERMINAL BLOCKS VIEWED FROM REAR (WITH INTEGRAL CASE EARTH STRAP)

NOTES:

1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.

3. CT/VT EARTH CONNECTIONS ARE TYPICAL ONLY.

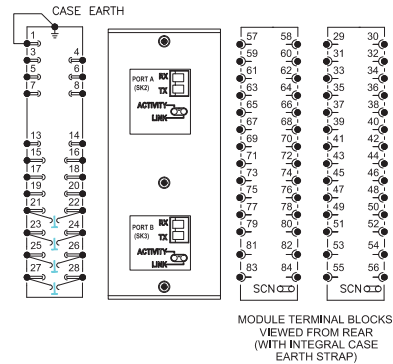4. RESIDUAL VOLTAGE MEASUREMENT REQUIRE A 5 LIMB VT OR 3*1PH VT

Date:	11/10/2017	Name:	V.SIVASAMBO	Drg Title:	MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & SEF (10 I/P & 12 O/P) WITH 2 RS485 & DUAL FIBRE ETHERNET	Next Stage:	-	Drg No:	10P24D17-4	ECN No: CID005225	Revision: B	Iteration: 2
Date:	11/10/2017	Chkd:	S WOOTTON									
Sub-contractor reference: -				CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE		Linear Tol mm: - Angular Tol deg: -		Grid Solutions	PLM No: A20028600	Sht: 4	Status: IN WORK	
Finish: -									Next Sht: -		

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

4th VT (OPEN DELTA)

P24D
12I + 12O

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

RP−1 EIARS485/K BUS COMMUNICATIONS

A.C./D.C. SUPPLY Vx

OPTO ISOLATED BINARY INPUTS

OPTO 1 +
OPTO 1 −
OPTO 2 +
OPTO 2 −
OPTO 3 +
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 3,4,5,6,7 −
OPTO 8 +
OPTO 9 +
OPTO 10 +
OPTO 11 +
OPTO 12 +
OPTO 8,9,10,11,12 −

RL9
RL10
RL11
RL12

RELAY OUTPUT CONTACTS

CASE EARTH

MODULE TERMINAL BLOCKS VIEWED FROM REAR (WITH INTEGRAL CASE EARTH STRAP)
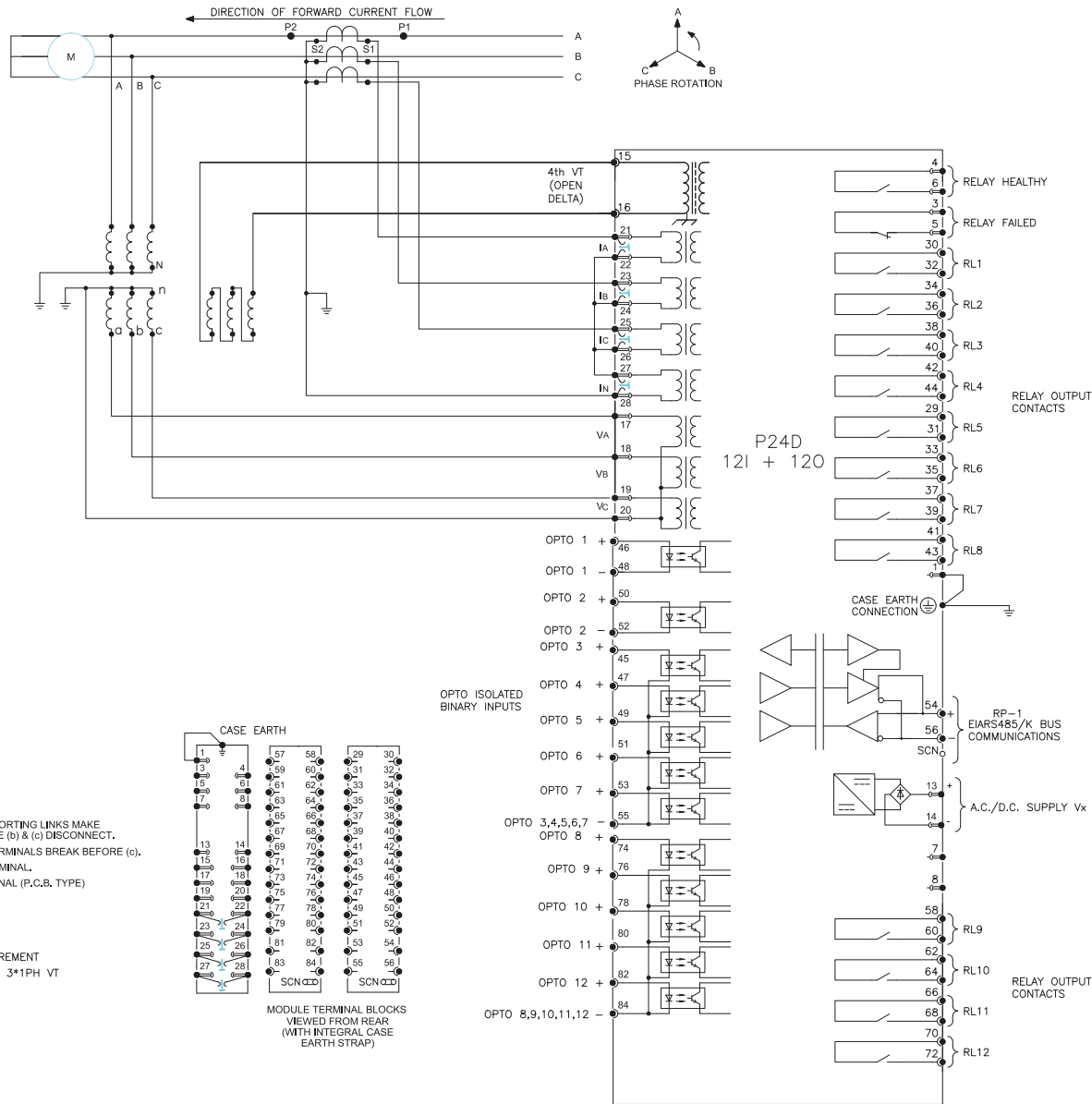
SCN   SCN

NOTES:
1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.
3. EARTH CONNECTIONS ARE TYPICAL ONLY.
4. RESIDUAL VOLTAGE MEASUREMENT REQUIRE A 5 LIMB VT OR 3*1PH VT

Date:	12/10/2017	Name:	V.SIVASAMBO	Drg Title:	MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & E/F (12 I/P & 12 O/P)	Next Stage: -	Drg No:	10P24D18-1	ECN No:	Revision:	Iteration:
Date:	12/10/2017	Chkd:	S WOOTTON						CID005225	B	2
Sub-contractor reference: -				CAD DATA 1:1 DIMENSIONS: mm	Linear Tol mm: -		PLM No:	A20028609	Sht: 1	Status:	
Finish: -				DO NOT SCALE	Angular Tol deg: -	GE Grid Solutions			Next Sht: 2	IN WORK	

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

4th VT (OPEN DELTA)

P24D
12I + 12O
+ ETHERNET

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

OPTO ISOLATED BINARY INPUTS

CASE EARTH

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE EARTH STRAP)

RP-1
EIARS485/K BUS
COMMUNICATIONS

RL9
RL10
RL11
RL12

RELAY OUTPUT CONTACTS

RJ45
10 BASE-T/
100 BASE-TX

TX+
TX-
RX+
RX-

LC
10 BASE-FL
OR
100 BASE-FX

A.C./D.C. SUPPLY Vx
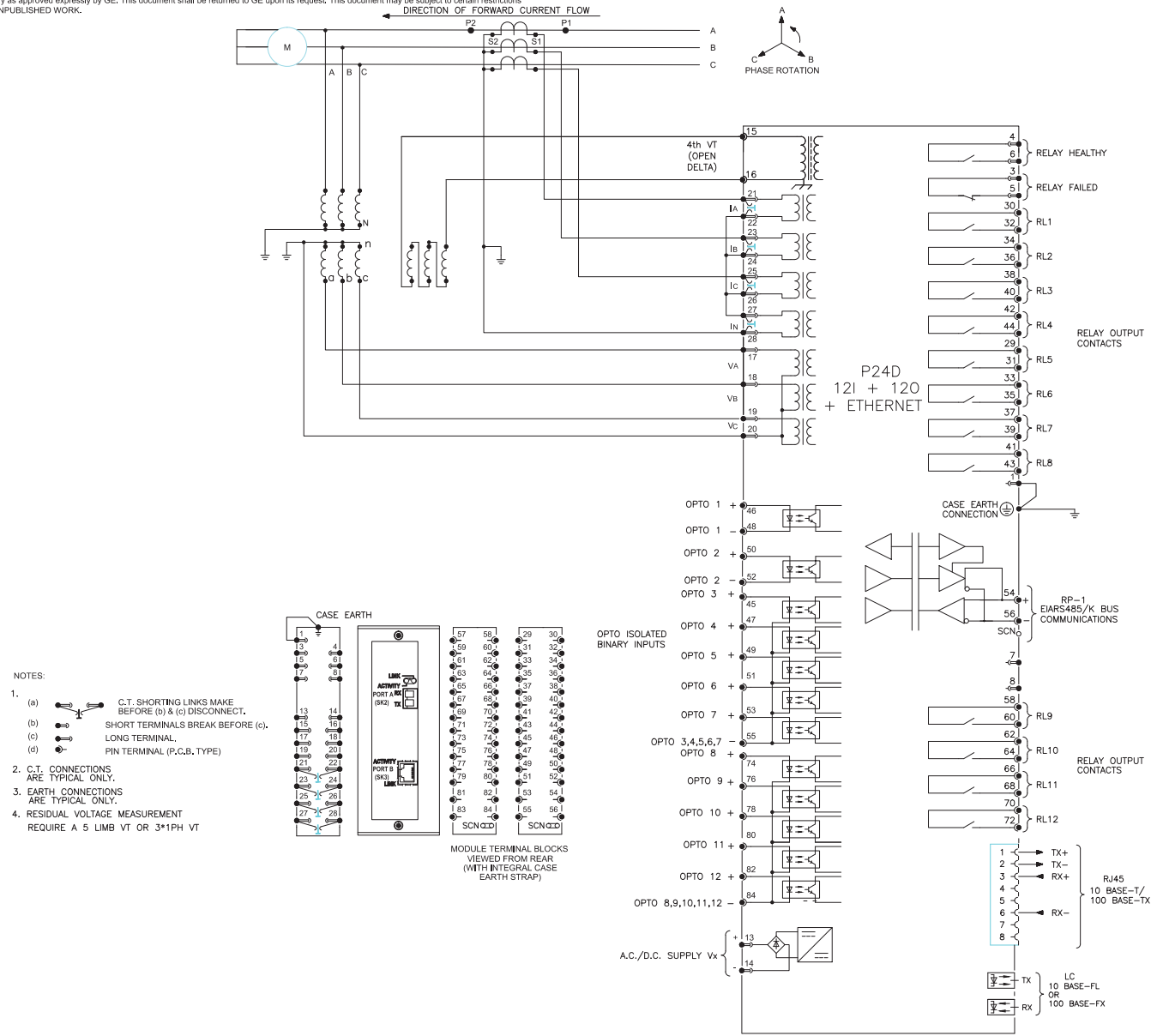
NOTES:
1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.
3. EARTH CONNECTIONS ARE TYPICAL ONLY.
4. RESIDUAL VOLTAGE MEASUREMENT REQUIRE A 5 LIMB VT OR 3*1PH VT

| Date: | 12/10/2017 | Name: | V.SIVASAMBO | Drg Title: | MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & E/F (12 I/P & 12 O/P) WITH ETHERNET | Next Stage: - | Drg No: | 10P24D18-2 | ECN No: CID005225 | Revision: B | Iteration: 2 |
| Date: | 12/10/2017 | Chkd: | S WOOTTON | | | | | | | | |

Sub-contractor reference: -

Finish: -

CAD DATA 1:1 DIMENSIONS: mm
DO NOT SCALE

Linear Tol mm: -
Angular Tol deg: -

GE Grid Solutions

PLM No: A20028616

Sht: 2
Next Sht: 3

Status: IN WORK

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

4th VT (OPEN DELTA)

P24D
12I + 12O
+ ETHERNET

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

OPTO 1 +
OPTO 1 −
OPTO 2 +
OPTO 2 −
OPTO 3 +
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 3,4,5,6,7
OPTO 8 +
OPTO 9 +
OPTO 10 +
OPTO 11 +
OPTO 12 +
OPTO 8,9,10,11,12 −

OPTO ISOLATED BINARY INPUTS

RP−1
EIARS485/K BUS
COMMUNICATIONS
SCN

RL9
RL10
RL11
RL12

RELAY OUTPUT CONTACTS

CASE EARTH

ACTIVITY PORT A (SK2) LINK

ACTIVITY PORT B (SK3) LINK

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE EARTH STRAP)

SK2
TX+
TX−
RX+
RX−

RJ45
10 BASE−T/
100 BASE−TX

SK3
TX+
TX−
RX+
RX−

RJ45
10 BASE−T/
100 BASE−TX

A.C./D.C. SUPPLY Vx

NOTES:
1.
(a)   C.T. SHORTING LINKS MAKE
        BEFORE (b) & (c) DISCONNECT.
(b)   SHORT TERMINALS BREAK BEFORE (c).
(c)   LONG TERMINAL.
(d)   PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS
   ARE TYPICAL ONLY.

3. EARTH CONNECTIONS
   ARE TYPICAL ONLY.

4. RESIDUAL VOLTAGE MEASUREMENT
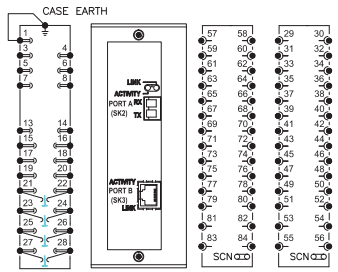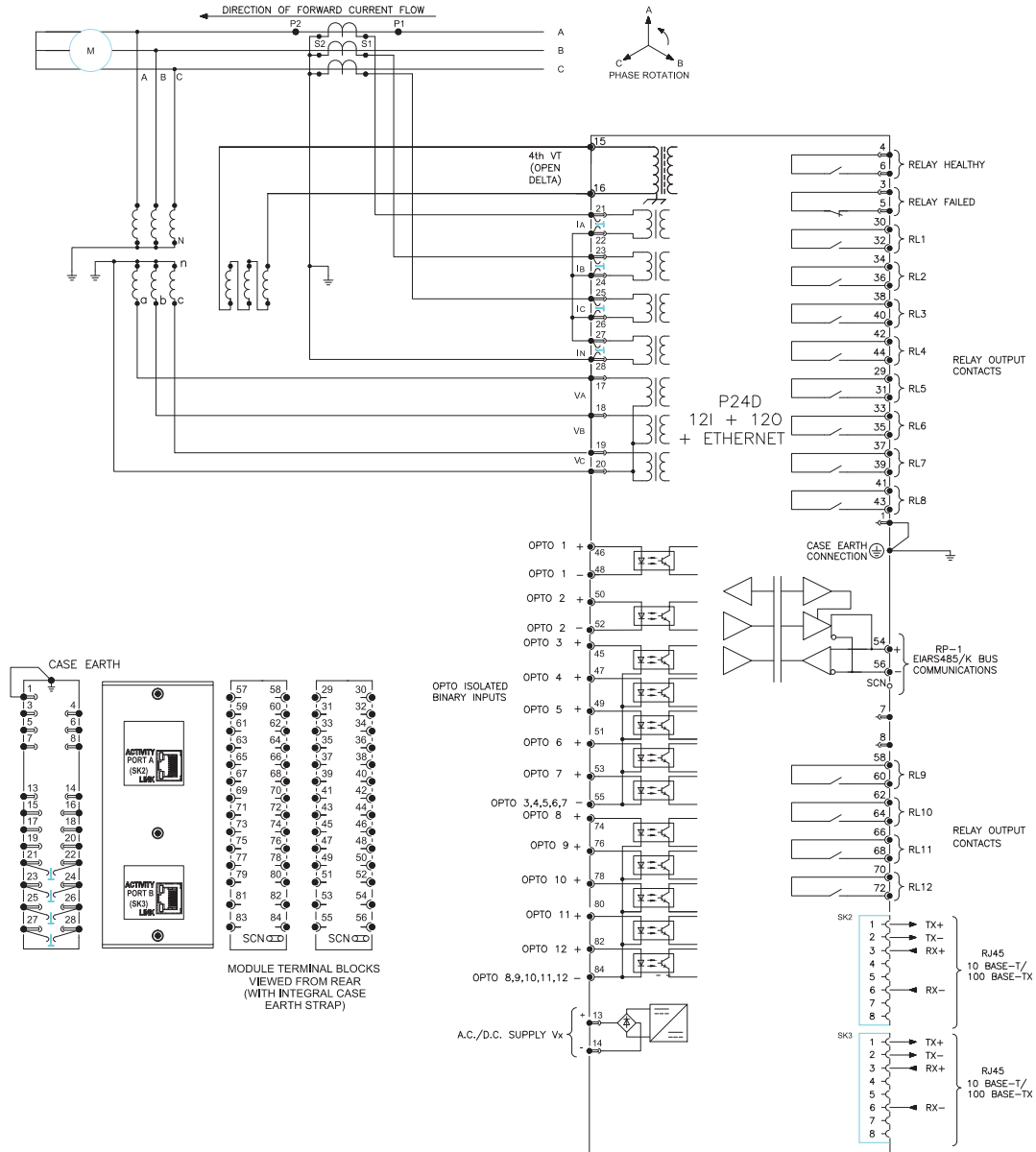   REQUIRE A 5 LIMB VT OR 3*1PH VT

Date: 12/10/2017	Name: V.SIVASAMBO	Drg Title: MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & E/F (12 I/P & 12 O/P) WITH DUAL COPPER ETHERNET	Next Stage: -	Drg No: 10P24D18-3	ECN No: CID005225	Revision: B	Iteration: 2
Date: 12/10/2017	Chkd: S WOOTTON						
Sub-contractor reference: -		CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: - / Angular Tol deg: -	Grid Solutions	PLM No: A20028619	Sht: 3	Status: IN WORK
Finish: -						Next Sht: 4	

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

4th VT (OPEN DELTA)

P24D
12I + 12O
+ ETHERNET

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

OPTO 1 +
OPTO 1 −
OPTO 2 +
OPTO 2 −
OPTO 3 +
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 3,4,5,6,7
OPTO 8 +
OPTO 9 +
OPTO 10 +
OPTO 11 +
OPTO 12 +
OPTO 8,9,10,11,12 −

OPTO ISOLATED BINARY INPUTS

RP−1
EIARS485/K BUS COMMUNICATIONS

RL9
RL10
RL11
RL12

RELAY OUTPUT CONTACTS

SK2 TX LC 10 BASE−FL OR 100 BASE−FX
     RX

SK3 TX LC 10 BASE−FL OR 100 BASE−FX
     RX

A.C./D.C. SUPPLY Vx

CASE EARTH

PORT A (SK2)
RX TX
ACTIVITY LINK

PORT B (SK3)
RX TX
ACTIVITY LINK

MODULE TERMINAL BLOCKS VIEWED FROM REAR (WITH INTEGRAL CASE EARTH STRAP)

NOTES:

1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.

3. EARTH CONNECTIONS ARE TYPICAL ONLY.

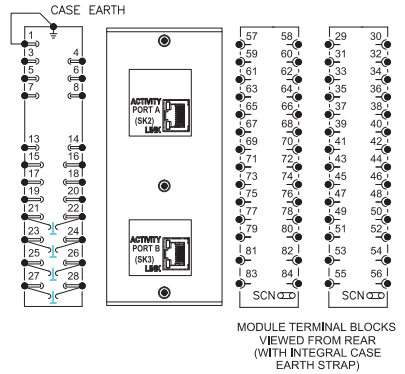4. RESIDUAL VOLTAGE MEASUREMENT REQUIRE A 5 LIMB VT OR 3*1PH VT

| Date: 12/10/2017 | Name: V.SIVASAMBO | Drg Title: MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & E/F (12 I/P & 12 O/P) WITH DUAL FIBRE ETHERNET | Next Stage: - | Drg No: 10P24D18-4 | ECN No: CID005225 | Revision: B | Iteration: 2 |
| Date: 12/10/2017 | Chkd: S WOOTTON | | | | | | |

Sub-contractor reference: -

Finish: -

CAD DATA 1:1 DIMENSIONS: mm
DO NOT SCALE

Linear Tol mm: -
Angular Tol deg: -

GE Grid Solutions

PLM No: A20028621

Sht: 4
Next Sht: -

Status: IN WORK

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

4th VT (OPEN DELTA)

P24D 12I + 12O

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

OPTO ISOLATED BINARY INPUTS

OPTO 1 +
OPTO 1 −
OPTO 2 +
OPTO 2 −
OPTO 3 +
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 3,4,5,6,7 −
OPTO 8 +
OPTO 9 +
OPTO 10 +
OPTO 11 +
OPTO 12 +
OPTO 8,9,10,11,12 −

RP−1 EIARS485/K BUS COMMUNICATIONS

A.C./D.C. SUPPLY Vx

RL9
RL10
RL11
RL12

RELAY OUTPUT CONTACTS

CASE EARTH

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE
EARTH STRAP)

NOTES:

1.
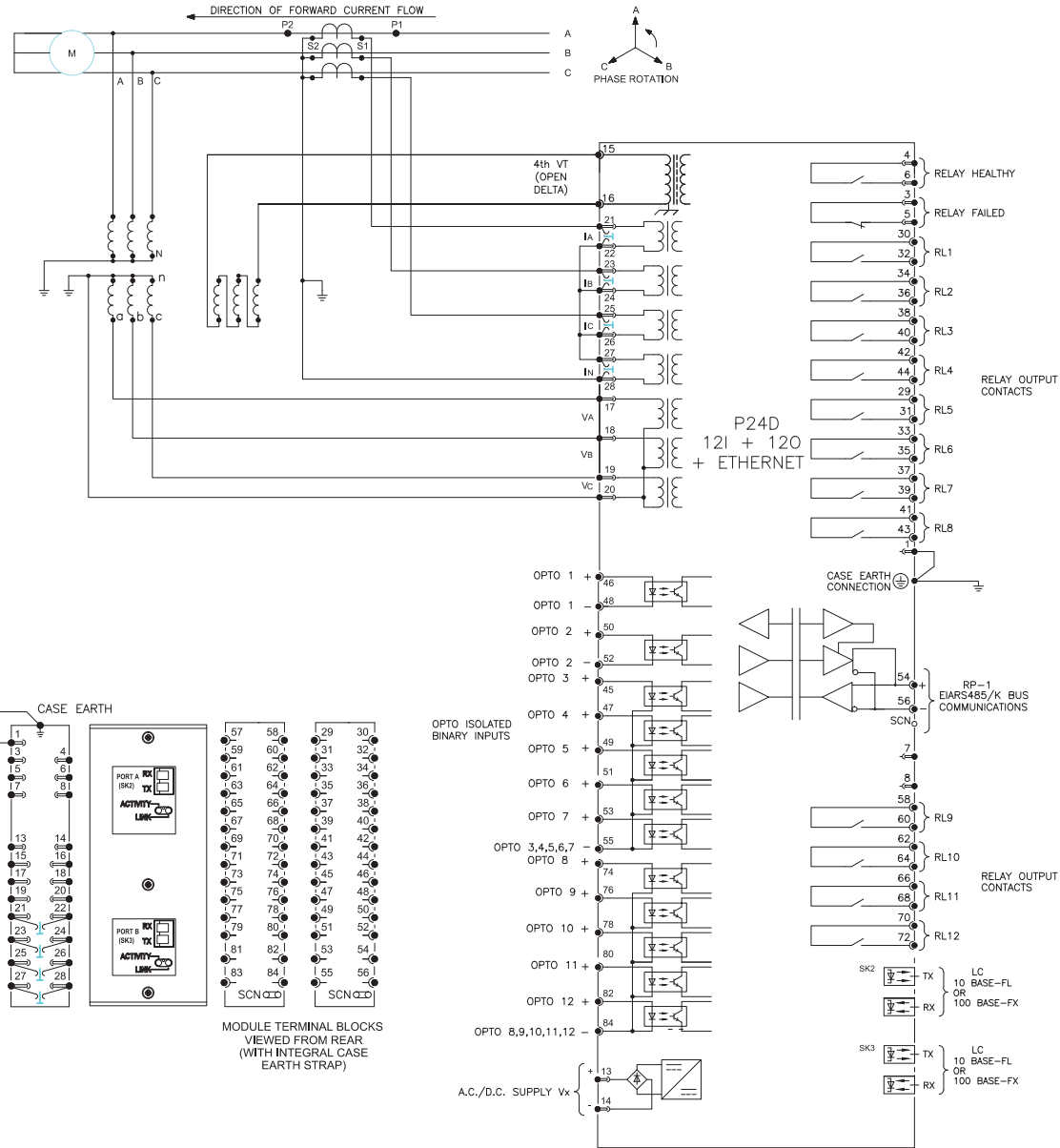(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.

3. CT/VT EARTH CONNECTIONS ARE TYPICAL ONLY.

4. RESIDUAL VOLTAGE MEASUREMENT REQUIRE A 5 LIMB VT OR 3*1PH VT

| Date: 12/10/2017 | Name: V.SIVASAMBO | Drg Title: MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & SEF (12 I/P & 12 O/P) | Next Stage: - | Drg No: 10P24D19-1 | ECN No: CID005225 | Revision: B | Iteration: 2 |
| Date: 12/10/2017 | Chkd: S WOOTTON | | | | | | |

| Sub-contractor reference: - | CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE | Linear Tol mm: - / Angular Tol deg: - | GE Grid Solutions | PLM No: A20028624 | Sht: 1 | Status: IN WORK |
| Finish: - | | | | | Next Sht: 2 | |

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

4th VT
(OPEN DELTA)

IA
IB
IC
IN SENSITIVE
VA
VB
VC

P24D
12I + 12O
+ ETHERNET

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

OPTO 1 +
OPTO 1 −
OPTO 2 +
OPTO 2 −
OPTO 3 +
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 3,4,5,6,7
OPTO 8 +
OPTO 9 +
OPTO 10 +
OPTO 11 +
OPTO 12 +
OPTO 8,9,10,11,12

OPTO ISOLATED BINARY INPUTS

RP−1
EIARS485/K BUS
COMMUNICATIONS
SCN

RL9
RL10
RL11
RL12

RELAY OUTPUT CONTACTS

A.C./D.C. SUPPLY Vx

TX+
TX−
RX+
RX−

RJ45
10 BASE−T/
100 BASE−TX

TX
RX
LC
10 BASE−FL
OR
100 BASE−FX

CASE EARTH

LINK
ACTIVITY
PORT A RX
(SK2) TX

ACTIVITY
PORT B
(SK3) LINK

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE EARTH STRAP)

SCN
SCN
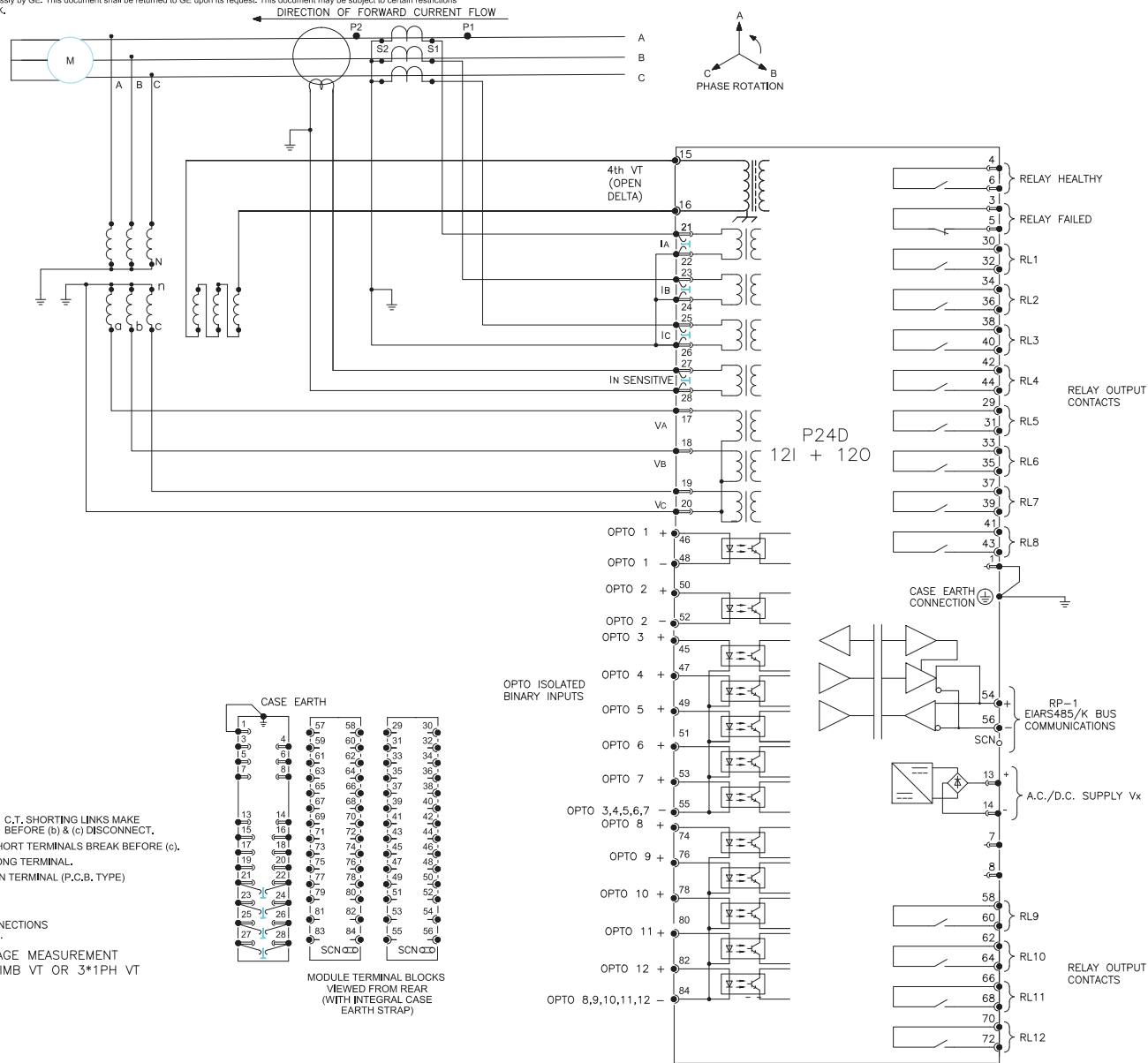
NOTES:

1.
(a)   C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b)   SHORT TERMINALS BREAK BEFORE (c).
(c)   LONG TERMINAL.
(d)   PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.
3. CT/VT EARTH CONNECTIONS ARE TYPICAL ONLY.
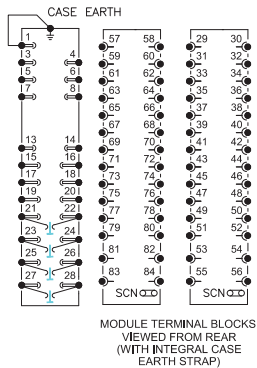4. RESIDUAL VOLTAGE MEASUREMENT REQUIRE A 5 LIMB VT OR 3*1PH VT

Date: 12/10/2017	Name: V.SIVASAMBO	Drg Title: MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & SEF (12 I/P & 12 O/P) WITH ETHERNET	Next Stage: -	Drg No: 10P24D19-2	ECN No: CID005225	Revision: B	Iteration: 2
Date: 12/10/2017	Chkd: S WOOTTON						
Sub-contractor reference: -		CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: - / Angular Tol deg: -	Grid Solutions	PLM No: A20028626	Sht: 2	Status: IN WORK
Finish: -						Next Sht: 3	

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

4th VT
(OPEN DELTA)

P24D
12I + 12O
+ ETHERNET

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

OPTO ISOLATED BINARY INPUTS

OPTO 1 +
OPTO 1 -
OPTO 2 +
OPTO 2 -
OPTO 3 +
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 3,4,5,6,7 -
OPTO 8 +
OPTO 9 +
OPTO 10 +
OPTO 11 +
OPTO 12 +
OPTO 8,9,10,11,12 -

RP-1
EIARS485/K BUS
COMMUNICATIONS
SCN

RL9
RL10
RL11
RL12

RELAY OUTPUT CONTACTS

CASE EARTH

ACTIVITY PORT A (SK2) LINK

ACTIVITY PORT B (SK3) LINK

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE EARTH STRAP)
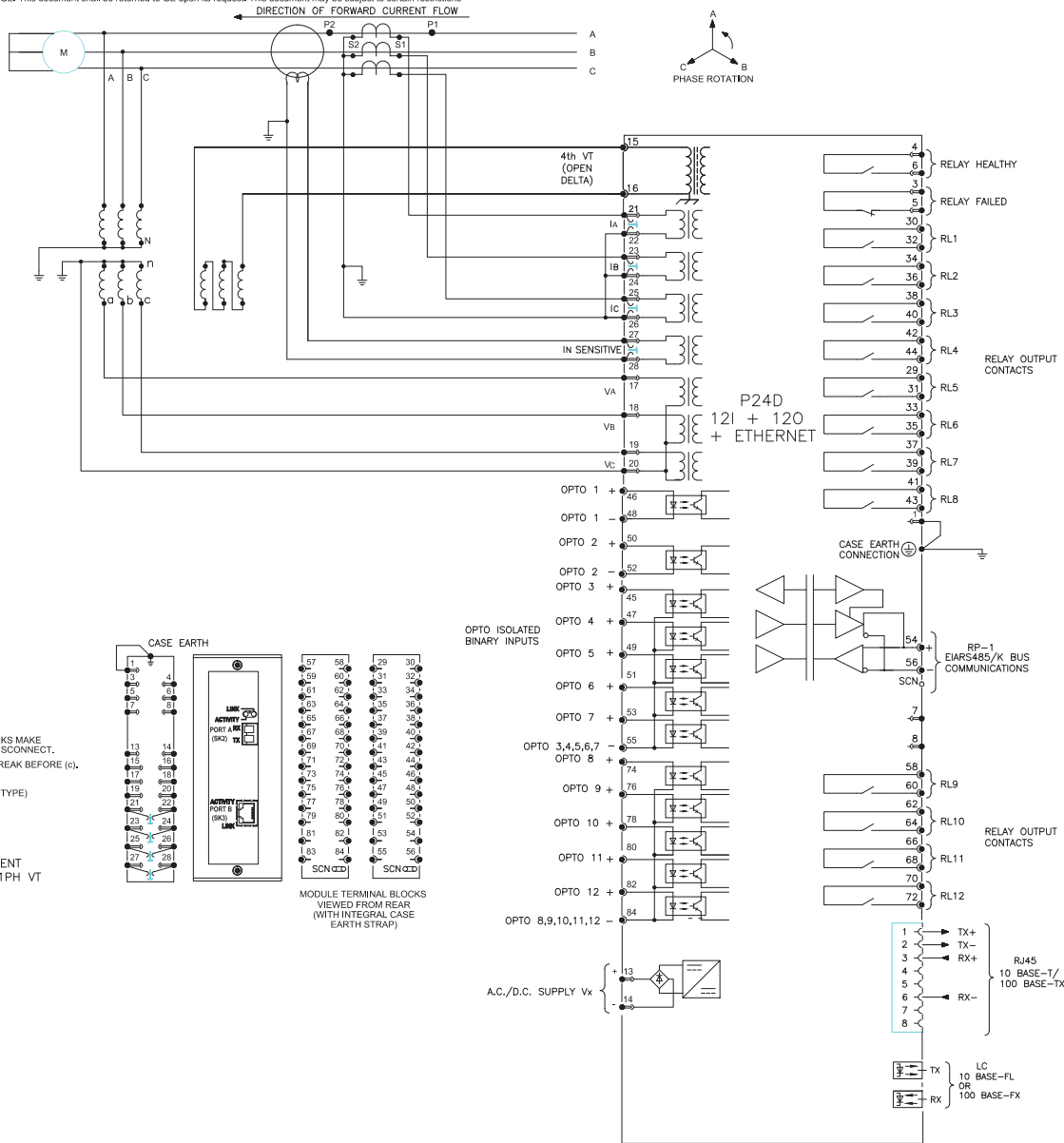
A.C./D.C. SUPPLY Vx

NOTES:

1.
   (a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
   (b) SHORT TERMINALS BREAK BEFORE (c).
   (c) LONG TERMINAL.
   (d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.

3. CT/VT EARTH CONNECTIONS ARE TYPICAL ONLY.

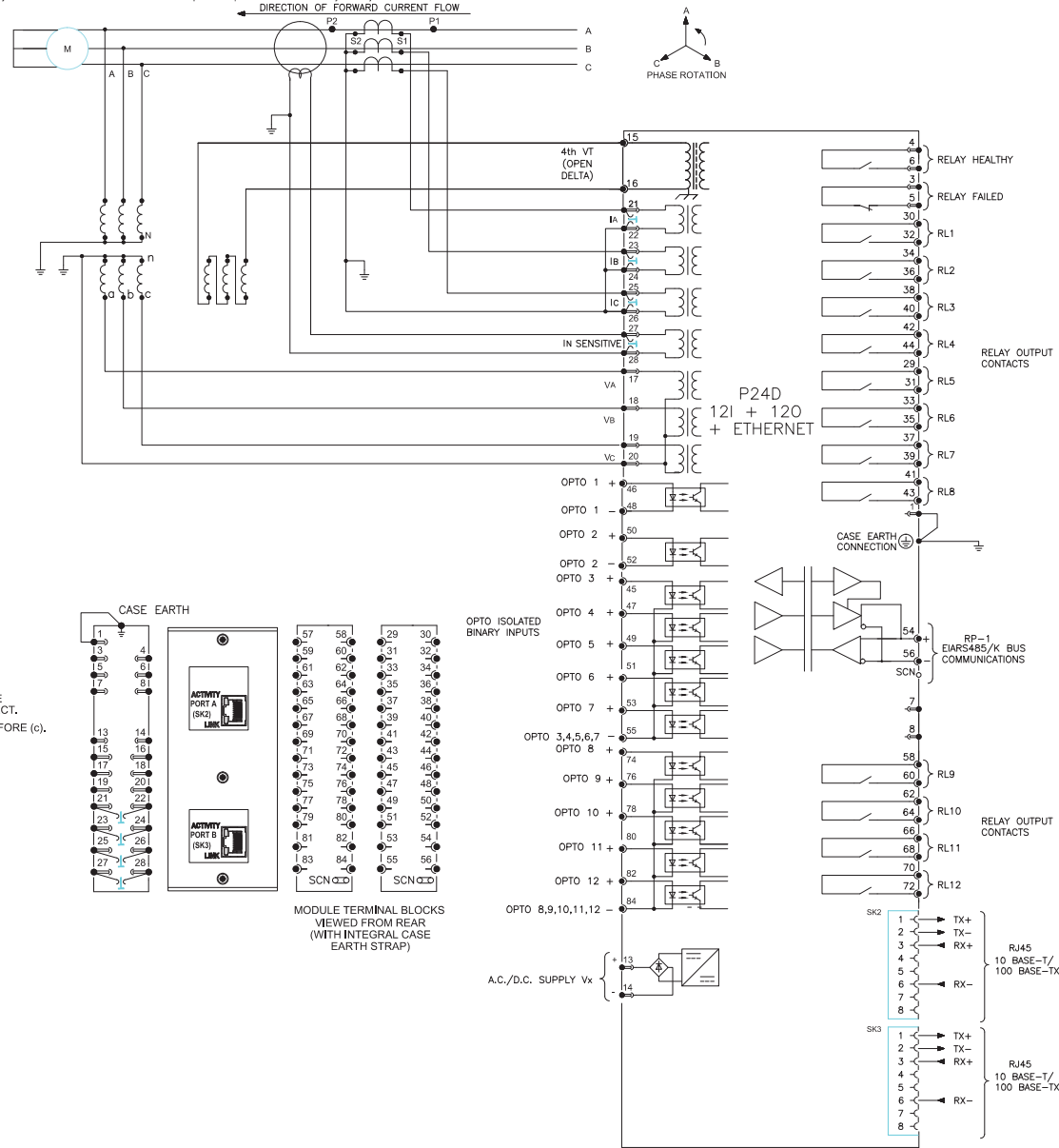4. RESIDUAL VOLTAGE MEASUREMENT REQUIRE A 5 LIMB VT OR 3*1PH VT

SK2
1 TX+
2 TX-
3 RX+
4
5
6 RX-
7
8
RJ45
10 BASE-T/
100 BASE-TX

SK3
1 TX+
2 TX-
3 RX+
4
5
6 RX-
7
8
RJ45
10 BASE-T/
100 BASE-TX

| Date: | 13/10/2017 | Name: | V.SIVASAMBO | Drg Title: | MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & SEF (12 I/P & 12 O/P) WITH DUAL COPPER ETHERNET | Next Stage: | | Drg No: | 10P24D19-3 | ECN No: | CID005225 | Revision: B | Iteration: 2 |
| Date: | 13/10/2017 | Chkd: | S WOOTTON | | | | | | | | | |

Sub-contractor reference: -

Finish: -

CAD DATA 1:1 DIMENSIONS: mm
DO NOT SCALE

Linear Tol mm: -
Angular Tol deg: -

Grid Solutions

PLM No: A20028632

Sht: 3
Next Sht: 4

Status: IN WORK

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

4th VT
(OPEN DELTA)

IA
IB
IC
IN SENSITIVE
VA
VB
VC

P24D
12I + 12O
+ ETHERNET

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

OPTO 1 +
OPTO 1 −
OPTO 2 +
OPTO 2 −
OPTO 3 +
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 3,4,5,6,7 −
OPTO 8 +
OPTO 9 +
OPTO 10 +
OPTO 11 +
OPTO 12 +
OPTO 8,9,10,11,12 −

OPTO ISOLATED BINARY INPUTS

RP−1
EIARS485/K BUS COMMUNICATIONS
SCN

RL9
RL10
RL11
RL12

RELAY OUTPUT CONTACTS

CASE EARTH

PORT A RX
(SK2) TX
ACTIVITY
LINK

PORT B RX
(SK3) TX
ACTIVITY
LINK

SCN   SCN

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE
EARTH STRAP)

A.C./D.C. SUPPLY Vx

SK2 TX
LC
10 BASE−FL
OR
100 BASE−FX
RX

SK3 TX
LC
10 BASE−FL
OR
100 BASE−FX
RX

NOTES:
1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.
3. CT/VT EARTH CONNECTIONS ARE TYPICAL ONLY.
4. RESIDUAL VOLTAGE MEASUREMENT REQUIRE A 5 LIMB VT OR 3*1PH VT

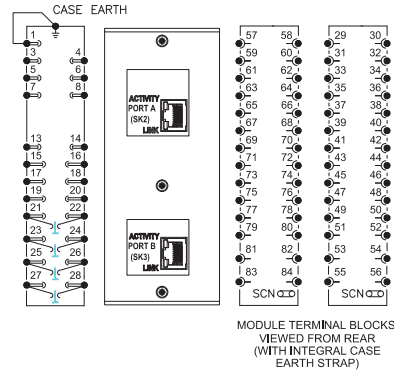| Date: 13/10/2017 | Name: V.SIVASAMBO | Drg Title: MOTOR PROTECTION WITH VOLTAGE & PHASE CURRENT INPUTS & SEF (12 I/P & 12 O/P) WITH DUAL FIBRE ETHERNET | Next Stage: | Drg No: 10P24D19-4 | ECN No: CID005225 | Revision: B | Iteration: 2 |
Date: 13/10/2017	Chkd: S WOOTTON						
Sub-contractor reference: -		CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: - Angular Tol deg: -	Grid Solutions	PLM No: A20028634	Sht: 4 Next Sht: -	Status: IN WORK
Finish: -							

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

P24N
8I + 80

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT
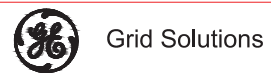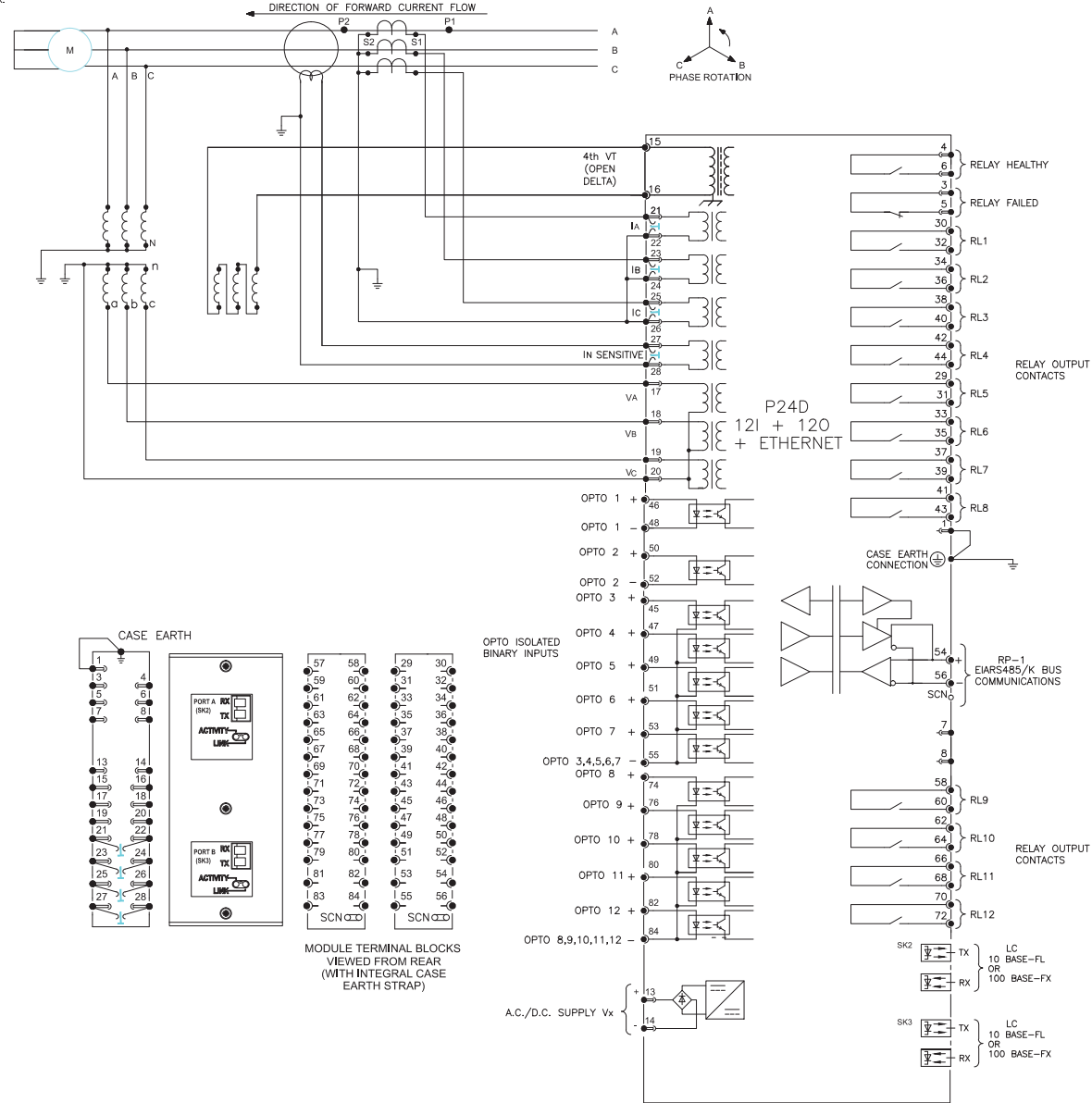CONTACTS

CASE EARTH
CONNECTION

CASE EARTH

NOTES:

1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.
3. EARTH CONNECTIONS ARE TYPICAL ONLY.

OPTO 1+
OPTO 2+
OPTO 3+
OPTO 1,2,3 –
OPTO 4+
OPTO 5+
OPTO 6+
OPTO 7+
OPTO 8+
OPTO 4,5,6,7,8 –

OPTO ISOLATED
BINARY INPUTS

EIARS485/K BUS
COMMUNICATIONS

A.C./D.C. SUPPLY Vx

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE
EARTH STRAP)

Date:	13/10/2017	Name:	V.SIVASAMBO	Drg Title:	MOTOR PROTECTION WITH PHASE CURRENT INPUTS & E/F (8 I/P & 8 O/P)	Next Stage:		Drg No:	10P24N01-1	ECN No:	CID005225	Revision:	B	Iteration:	2
Date:	13/10/2017	Chkd:	S WOOTTON												
Sub-contractor reference: -				CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE		Linear Tol mm: - Angular Tol deg: -		Grid Solutions		PLM No:	A20028636	Sht: 1		Status: IN WORK	
Finish: -											Next Sht: -			

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

A
C   B

P2   P1
M   S2   S1

A
B
C

21 IA 22
23 IB 24
25 IC 26
27 IN SENSITIVE 28

P24N
8I + 80

4 } RELAY HEALTHY
6
3 } RELAY FAILED
5
30 } RL1
32
34 } RL2
36
38 } RL3
40
42 } RL4
44
29 } RL5
31
33 } RL6
35
37 } RL7
39
41 } RL8
43
1

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

OPTO 1+   46
OPTO 2+   48
OPTO 3+   50
OPTO 1,2,3− 52
OPTO 4+   45
OPTO 5+   47
OPTO 6+   49
OPTO 7+   51
OPTO 8+   53
OPTO 4,5,6,7,8− 55

OPTO ISOLATED BINARY INPUTS

54 +
56 −   EIARS485/K BUS COMMUNICATIONS
SCN

13 +
14 −   A.C./D.C. SUPPLY Vx

7
8

CASE EARTH

1   4
3   6
5   29 30
7   31 32
9   33 34
10   35 36
13   37 38
14   39 40
     41 42
17   43 44
18   45 46
19   47 48
20   49 50
21   51 52
22   53 54
23   55 56
24
25
26 SCN
27
28

MODULE TERMINAL BLOCKS VIEWED FROM REAR
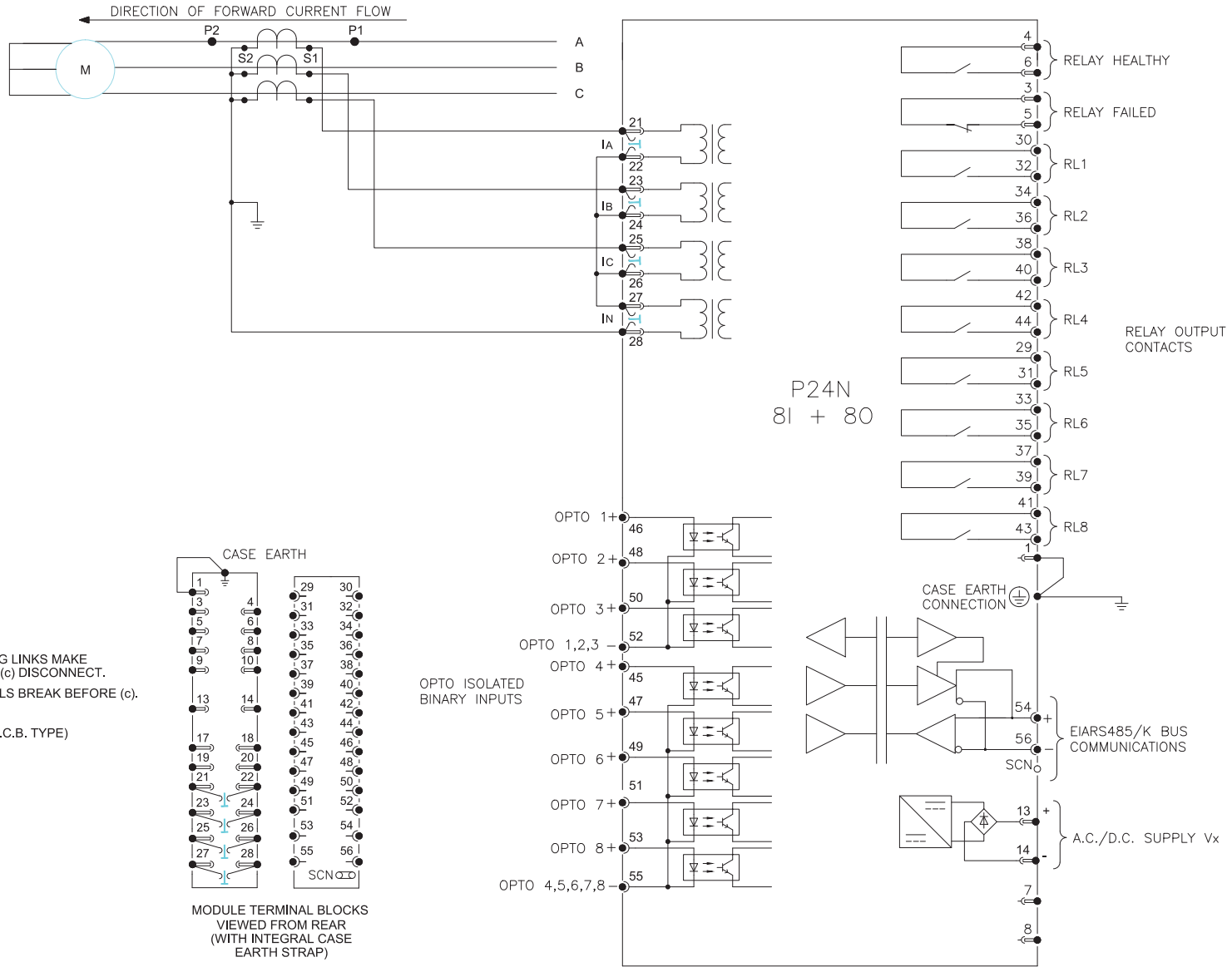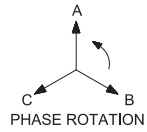(WITH INTEGRAL CASE EARTH STRAP)

NOTES:

1.
(a)   C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b)   SHORT TERMINALS BREAK BEFORE (c).
(c)   LONG TERMINAL.
(d)   PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.

3. CT/VT EARTH CONNECTIONS ARE TYPICAL ONLY.

Date: 13/10/2017	Name: V.SIVASAMBO	Drg Title: MOTOR PROTECTION WITH PHASE CURRENT INPUTS & SEF (8 I/P & 8 O/P)	Next Stage: -	Drg No: 10P24N02-1	ECN No: CID005225	Revision: B	Iteration: 2
Date: 13/10/2017	Chkd: S WOOTTON						
Sub-contractor reference: -		CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: - Angular Tol deg: -	GE Grid Solutions	PLM No: A20028638	Sht: 1	Status: IN WORK
Finish: -					Next Sht: -		

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

P24N
8I + 8O
+ Ethernet

RELAY HEALTHY
RELAY FAILED

RL1
RL2
RL3
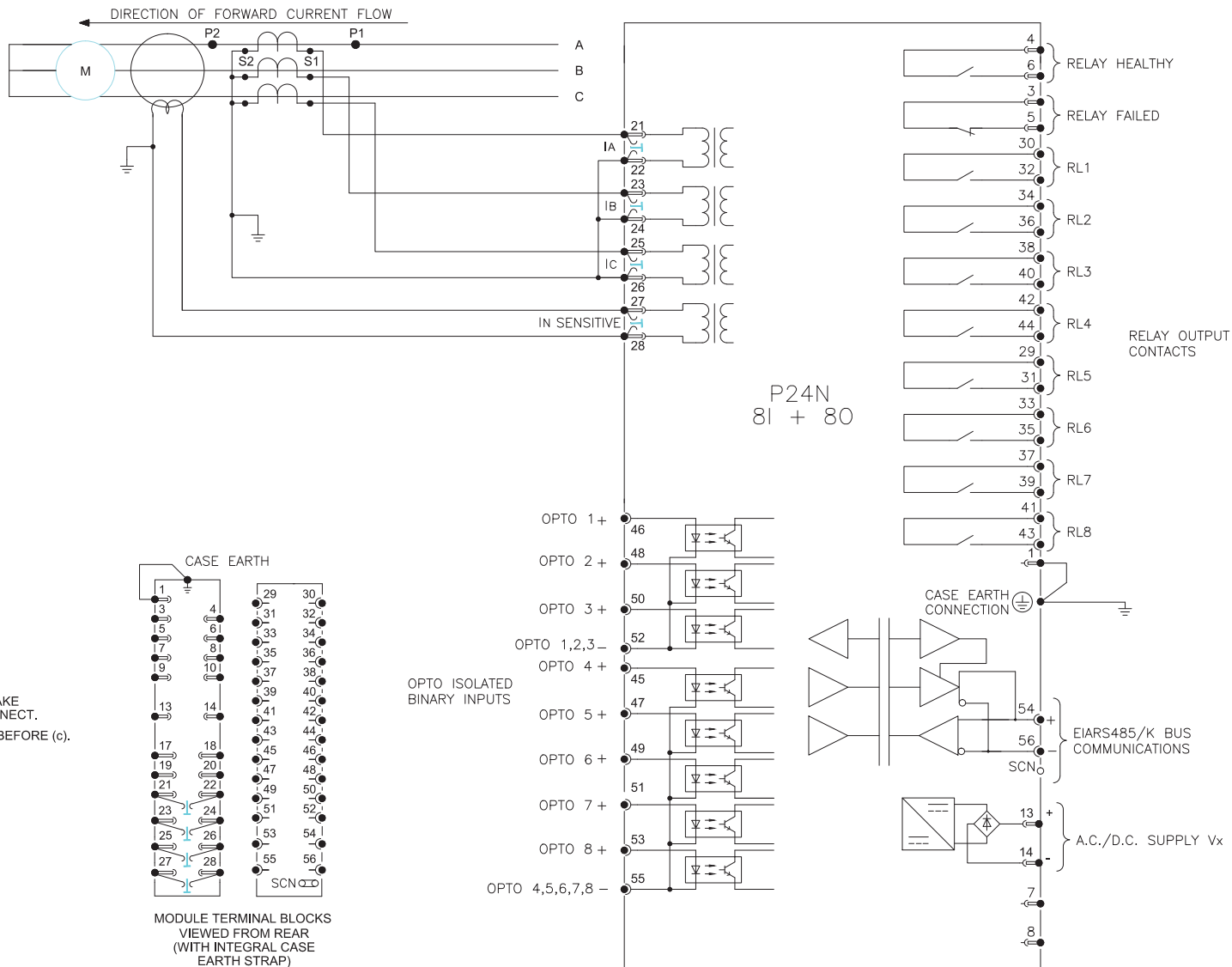RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

NOTES:

1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.

3. CT/VT EARTH CONNECTIONS ARE TYPICAL ONLY.

OPTO 1 +   46
OPTO 2 +   48
OPTO 3 +   50
OPTO 1,2,3   52
OPTO 4 +   45
OPTO 5 +   47
OPTO 6 +   49
OPTO 7 +   51
OPTO 8 +   53
OPTO 4,5,6,7,8   55

OPTO ISOLATED BINARY INPUTS

EIARS485/K BUS COMMUNICATIONS

CASE EARTH

LINK
ACTIVITY
PORT A RX
(SK2) TX

ACTIVITY
PORT B
(SK3) LINK

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE
EARTH STRAP)

A.C./D.C. SUPPLY Vx

TX+
TX−
RX+
RX−

RJ45
10 BASE−T/
100 BASE−TX

TX
RX

LC
10 BASE−FL
OR
100 BASE−FX

| Date: | 13/10/2017 | Name: | V.SIVASAMBO | Drg Title: | MOTOR PROTECTION WITH PHASE CURRENT INPUTS & E/F (8 I/P & 8 O/P) WITH ETHERNET | Next Stage: | - | Drg No: | 10P24N03-1 | ECN No: | CID005225 | Revision: | B | Iteration: | 2 |
| Date: | 13/10/2017 | Chkd: | S WOOTTON | | | | | | | | | | | | |

| Sub-contractor reference: | - | CAD DATA 1:1 DIMENSIONS: mm | Linear Tol mm: | - | | Grid Solutions | PLM No: | A20028640 | Sht: | 1 | Status: | IN WORK |
| Finish: | - | DO NOT SCALE | Angular Tol deg: | - | | | | | Next Sht: | 2 | | |

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

P24N
8I + 8O
+ Ethernet

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION
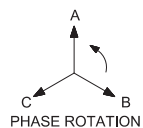
NOTES:

1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.

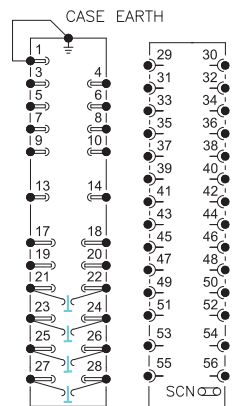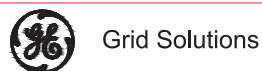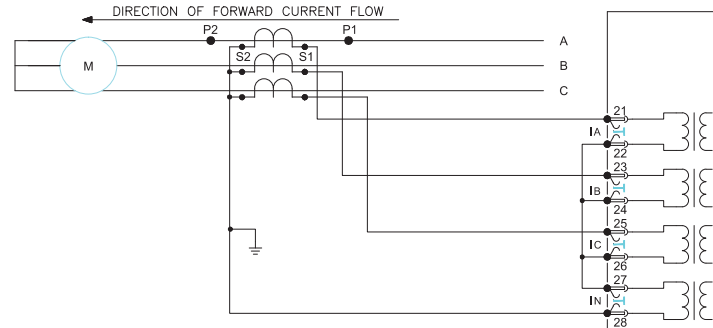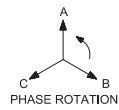3. CT/VT EARTH CONNECTIONS ARE TYPICAL ONLY.

OPTO ISOLATED BINARY INPUTS

OPTO 1 +   46
OPTO 2 +   48
OPTO 3 +   50
OPTO 1,2,3 - 52
OPTO 4 +   45
OPTO 5 +   47
OPTO 6 +   49
OPTO 7 +   51
OPTO 8 +   53
OPTO 4,5,6,7,8 55

EIARS485/K BUS COMMUNICATIONS
SCN

A.C./D.C. SUPPLY Vx

CASE EARTH

ACTIVITY PORT A (SK2) LINK

ACTIVITY PORT B (SK3) LINK

MODULE TERMINAL BLOCKS VIEWED FROM REAR (WITH INTEGRAL CASE EARTH STRAP)

SCN

SK2
1 TX+
2 TX-
3 RX+
4
5
6 RX-
7
8

RJ45 10 BASE-T/ 100 BASE-TX

SK3
1 TX+
2 TX-
3 RX+
4
5
6 RX-
7
8

RJ45 10 BASE-T/ 100 BASE-TX

Date:	13/10/2017	Name:	V.SIVASAMBO	Drg Title:	MOTOR PROTECTION WITH PHASE CURRENT INPUTS & E/F (8 I/P & 8 O/P) WITH DUAL COPPER ETHERNET	Next Stage: -	Drg No:	10P24N03-2	ECN No: CID005225	Revision: B	Iteration: 2
Date:	13/10/2017	Chkd:	S WOOTTON								
Sub-contractor reference: -				CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: - Angular Tol deg: -	Grid Solutions	PLM No:	A20028642	Sht: 2 Next Sht: 3	Status: IN WORK	
Finish: -											

PHASE ROTATION

DIRECTION OF FORWARD CURRENT FLOW

M

P2 · S2 S1 · P1

A
B
C

IA 21 / 22
IB 23 / 24
IC 25 / 26
IN 27 / 28

P24N
8I + 8O
+ Ethernet

RELAY HEALTHY 4 / 6
RELAY FAILED 3 / 5
RL1 30 / 32
RL2 34 / 36
RL3 38 / 40
RL4 42 / 44
RL5 29 / 31
RL6 33 / 35
RL7 37 / 39
RL8 41 / 43

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

NOTES:

1.
(a)   C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b)   SHORT TERMINALS BREAK BEFORE (c).
(c)   LONG TERMINAL.
(d)   PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.

3. CT/VT EARTH CONNECTIONS ARE TYPICAL ONLY.

OPTO ISOLATED BINARY INPUTS

OPTO 1 + 46
OPTO 2 + 48
OPTO 3 + 50
OPTO 1,2,3 − 52
OPTO 4 + 45
OPTO 5 + 47
OPTO 6 + 49
OPTO 7 + 51
OPTO 8 + 53
OPTO 4,5,6,7,8 − 55

EIARS485/K BUS COMMUNICATIONS
54 +
56 −
SCN

7
8

A.C./D.C. SUPPLY Vx
+ 13
− 14

CASE EARTH

PORT A (SK2) RX TX ACTIVITY LINK

PORT B (SK3) RX TX ACTIVITY LINK

1 2 / 3 4 / 5 6 / 7 8 / 9 10 / 13 14 / 17 18 / 19 20 / 21 22 / 23 24 / 25 26 / 27 28

29 30 / 31 32 / 33 34 / 35 36 / 37 38 / 39 40 / 41 42 / 43 44 / 45 46 / 47 48 / 49 50 / 51 52 / 53 54 / 55 56

SCN

MODULE TERMINAL BLOCKS VIEWED FROM REAR (WITH INTEGRAL CASE EARTH STRAP)

SK2 TX RX LC 10 BASE−FL OR 100 BASE−FX
SK3 TX RX LC 10 BASE−FL OR 100 BASE−FX

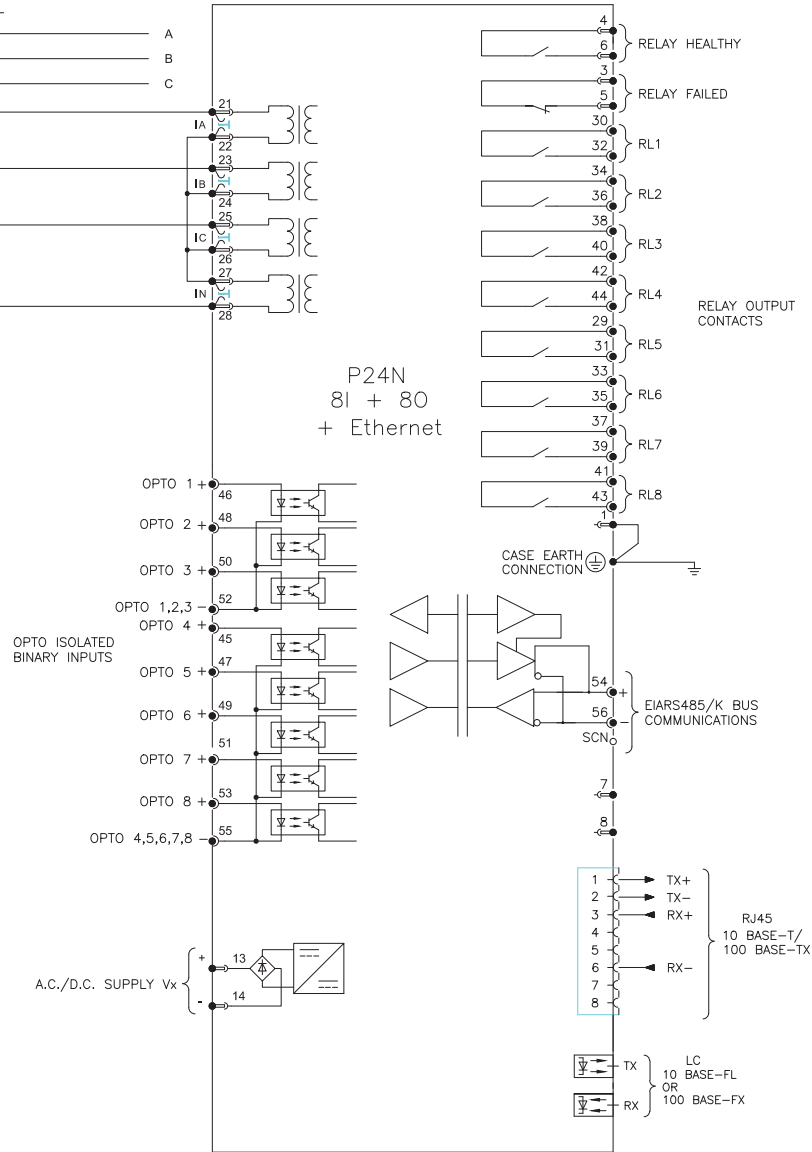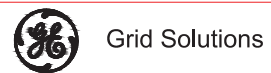| Date: 13/10/2017 | Name: V.SIVASAMBO | Drg Title: MOTOR PROTECTION WITH PHASE CURRENT INPUTS & E/F (8 I/P & 8 O/P) WITH DUAL FIBRE ETHERNET | Next Stage: - | Drg No: 10P24N03-3 | ECN No: CID005225 | Revision: B | Iteration: 2 |
Date: 13/10/2017	Chkd: S WOOTTON						
Sub-contractor reference: -		CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: - / Angular Tol deg: -	GE Grid Solutions	PLM No: A20028644	Sht: 3	Status: IN WORK
Finish: -						Next Sht: -	

A
C   B
PHASE ROTATION

DIRECTION OF FORWARD CURRENT FLOW

M   P2   P1   A
S2   S1   B
C

P24N
8I + 8O
+ Ethernet

IA   21
22
IB   23
24
IC   25
26
27
IN SENSITIVE   28

4
6   RELAY HEALTHY
3
5   RELAY FAILED
30
32   RL1
34
36   RL2
38
40   RL3
42
44   RL4   RELAY OUTPUT
CONTACTS
29
31   RL5
33
35   RL6
37
39   RL7
41
43   RL8

CASE EARTH
CONNECTION

NOTES:
1.
(a)   C.T. SHORTING LINKS MAKE
BEFORE (b) & (c) DISCONNECT.
(b)   SHORT TERMINALS BREAK BEFORE (c).
(c)   LONG TERMINAL.
(d)   PIN TERMINAL (P.C.B. TYPE)

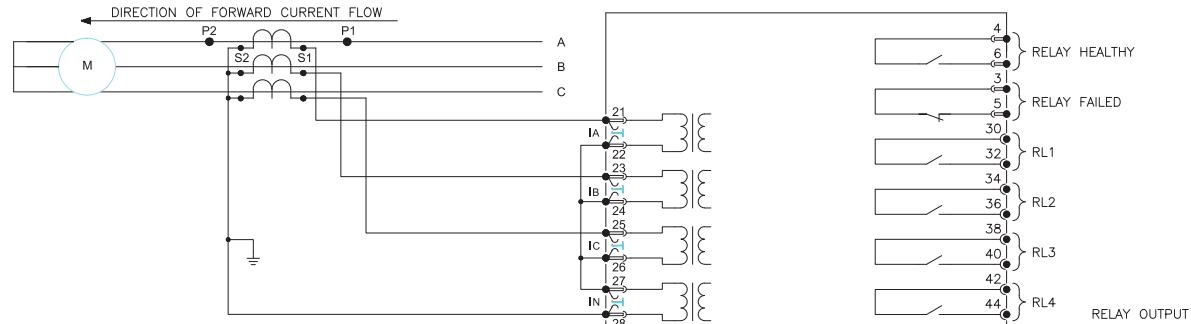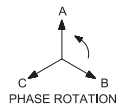2. C.T. CONNECTIONS ARE TYPICAL ONLY.
3. EARTH CONNECTIONS ARE TYPICAL ONLY.

OPTO 1+   46
OPTO 2+   48
OPTO 3+   50
OPTO 1,2,3 −   52
OPTO 4+   45
OPTO 5+   47
OPTO 6+   49
OPTO 7+   51
OPTO 8+   53
OPTO 4,5,6,7,8   55

OPTO ISOLATED
BINARY INPUTS

54
56   EIARS485/K BUS
COMMUNICATIONS
SCN

7
8

CASE EARTH

1
3   4
5   6
7   8
9   10
13   14
17   18
19   20
21   22
23   24
25   26
27   28

LINK
ACTIVITY
PORT A RX
(SK2)   TX

ACTIVITY
PORT B
(SK3)   LINK

29   30
31   32
33   34
35   36
37   38
39   40
41   42
43   44
45   46
47   48
49   50
51   52
53   54
55   56
SCN

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE
EARTH STRAP)

A.C./D.C. SUPPLY Vx   +   13
−   14

1   TX+
2   TX−
3   RX+
4
5
6   RX−
7
8

RJ45
10 BASE−T/
100 BASE−TX

TX   LC
10 BASE−FL
OR
RX   100 BASE−FX

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

P24N
8I + 8O
+ Ethernet

OPTIONAL FEATURE
SEE NOTE 4

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT
CONTACTS

CASE EARTH
CONNECTION
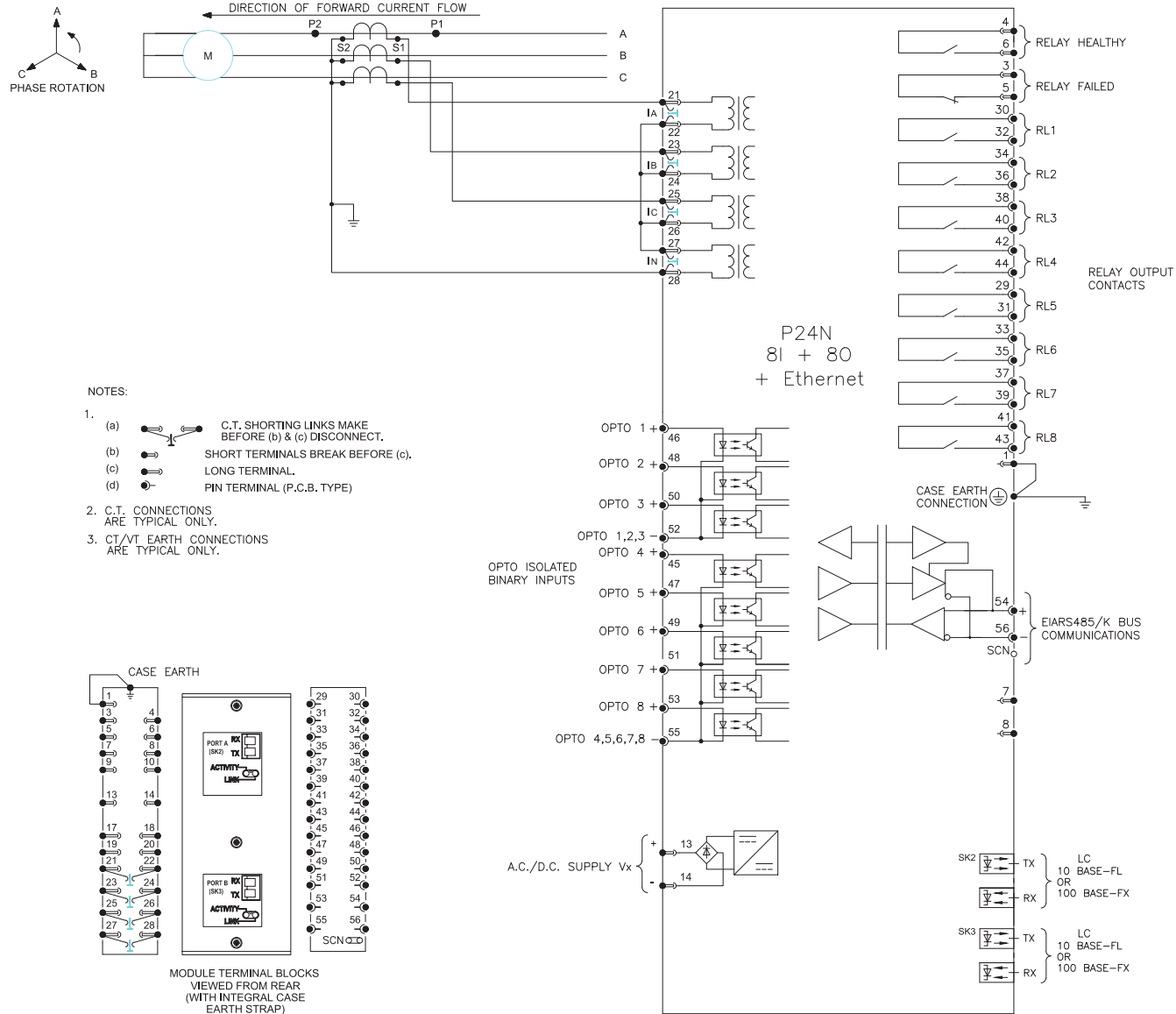
IA
IB
IC
IN SENSITIVE

NOTES:
1.
(a)   C.T. SHORTING LINKS MAKE
       BEFORE (b) & (c) DISCONNECT.
(b)   SHORT TERMINALS BREAK BEFORE (c).
(c)   LONG TERMINAL.
(d)   PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS
   ARE TYPICAL ONLY.
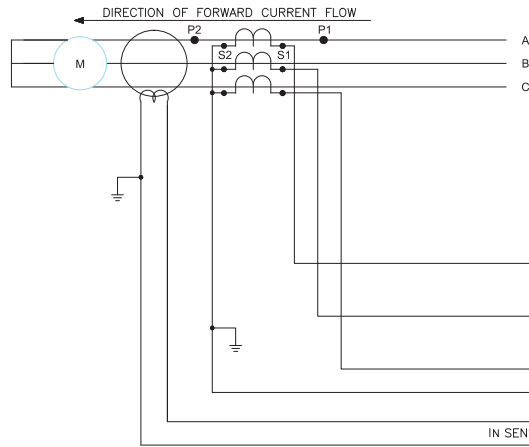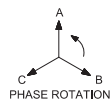
3. CT/VT EARTH CONNECTIONS
   ARE TYPICAL ONLY.

4. TERMINALS 9 & 10: OPTIONAL SHORTING LINK (ORDERING OPTION). ONLY
   AVAILABLE FOR THE 30TE MODEL VARIANTS.
   WHEN THESE TERMINALS ARE USED FOR CAPACITOR CONE APPLICATIONS
   PLEASE REFER TO ALSTOM GRID APPLICATION GUIDE AG013 FOR SAFETY
   PROCEDURE.

OPTO 1+
OPTO 2+
OPTO 3+
OPTO 1,2,3 −
OPTO 4+
OPTO 5+
OPTO 6+
OPTO 7+
OPTO 8+
OPTO 4,5,6,7,8 −

OPTO ISOLATED
BINARY INPUTS

EIARS485/K BUS
COMMUNICATIONS
SCN

CASE EARTH

ACTIVITY
PORT A
(SK2)
LINK

ACTIVITY
PORT B
(SK3)
LINK

SCN

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE
EARTH STRAP)

A.C./D.C. SUPPLY Vx

SK2
TX+
TX−
RX+
RX−
RJ45
10 BASE−T/
100 BASE−TX

SK3
TX+
TX−
RX+
RX−
RJ45
10 BASE−T/
100 BASE−TX

Date:	16/10/2017	Name:	V.SIVASAMBO	Drg Title:	MOTOR PROTECTION WITH PHASE CURRENT INPUTS & SEF (8 I/P 8 O/P) WITH DUAL COPPER ETHERNET	Next Stage:	-	Drg No:	10P24N04-2	ECN No:	CID005225	Revision: B	Iteration: 2
Date:	16/10/2017	Chkd:	S WOOTTON										
Sub-contractor reference:	-			CAD DATA 1:1 DIMENSIONS: mm	Linear Tol mm: -			PLM No:	A20028649	Sht: 2		Status:	IN WORK
Finish:	-			DO NOT SCALE	Angular Tol deg: -		GE Grid Solutions			Next Sht: 3			

DIRECTION OF FORWARD CURRENT FLOW

A
C   B
PHASE ROTATION

P2   P1
S2   S1
A
B
C

M

9
OPTIONAL FEATURE
SEE NOTE 4
10

21
IA
22
23
IB
24
25
IC
26
27
IN SENSITIVE
28

P24N
8I + 8O
+ Ethernet

4
6   RELAY HEALTHY
3
5   RELAY FAILED
30
32   RL1
34
36   RL2
38
40   RL3
42
44   RL4
29
31   RL5
33
35   RL6
37
39   RL7
41
43   RL8
1

RELAY OUTPUT
CONTACTS

CASE EARTH
CONNECTION

NOTES:
1.
(a)   C.T. SHORTING LINKS MAKE
         BEFORE (b) & (c) DISCONNECT.
(b)   SHORT TERMINALS BREAK BEFORE (c).
(c)   LONG TERMINAL.
(d)   PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS
   ARE TYPICAL ONLY.

3. CT/VT EARTH CONNECTIONS
   ARE TYPICAL ONLY.

4. TERMINALS 9 & 10: OPTIONAL SHORTING LINK (ORDERING OPTION).
ONLY AVAILABLE FOR THE 30TE MODEL VARIANTS.
WHEN THESE TERMINALS ARE USED FOR CAPACITOR CONE APPLICATIONS
PLEASE REFER TO ALSTOM GRID APPLICATION GUIDE AG013 FOR SAFETY
PROCEDURE.

OPTO 1+   46
OPTO 2+   48
OPTO 3+   50
OPTO 1,2,3 - 52
OPTO 4+   45
OPTO 5+   47
OPTO 6+   49
OPTO 7+   51
OPTO 8+   53
OPTO 4,5,6,7,8 - 55

OPTO ISOLATED
BINARY INPUTS

54
56   EIARS485/K BUS
         COMMUNICATIONS
SCN

7
8

CASE EARTH

PORT A
(SK2)   RX
         TX
ACTIVITY
LINK

PORT B
(SK3)   RX
         TX
ACTIVITY
LINK

SCN

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE
EARTH STRAP)

A.C./D.C. SUPPLY Vx
+ 13
- 14

SK2   TX   LC
      RX   10 BASE-FL
             OR
             100 BASE-FX

SK3   TX   LC
      RX   10 BASE-FL
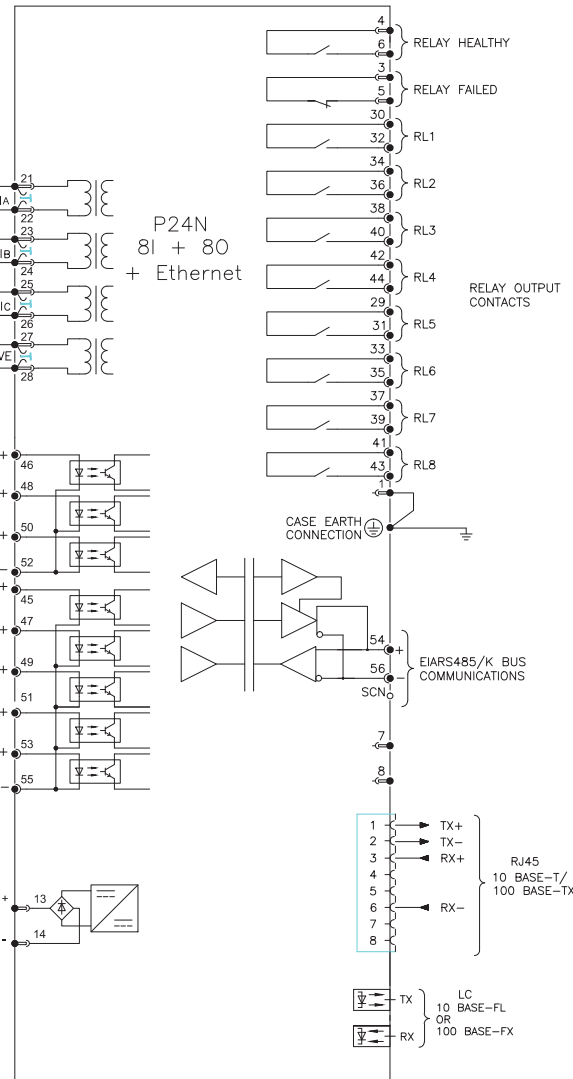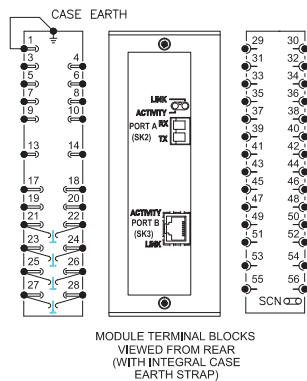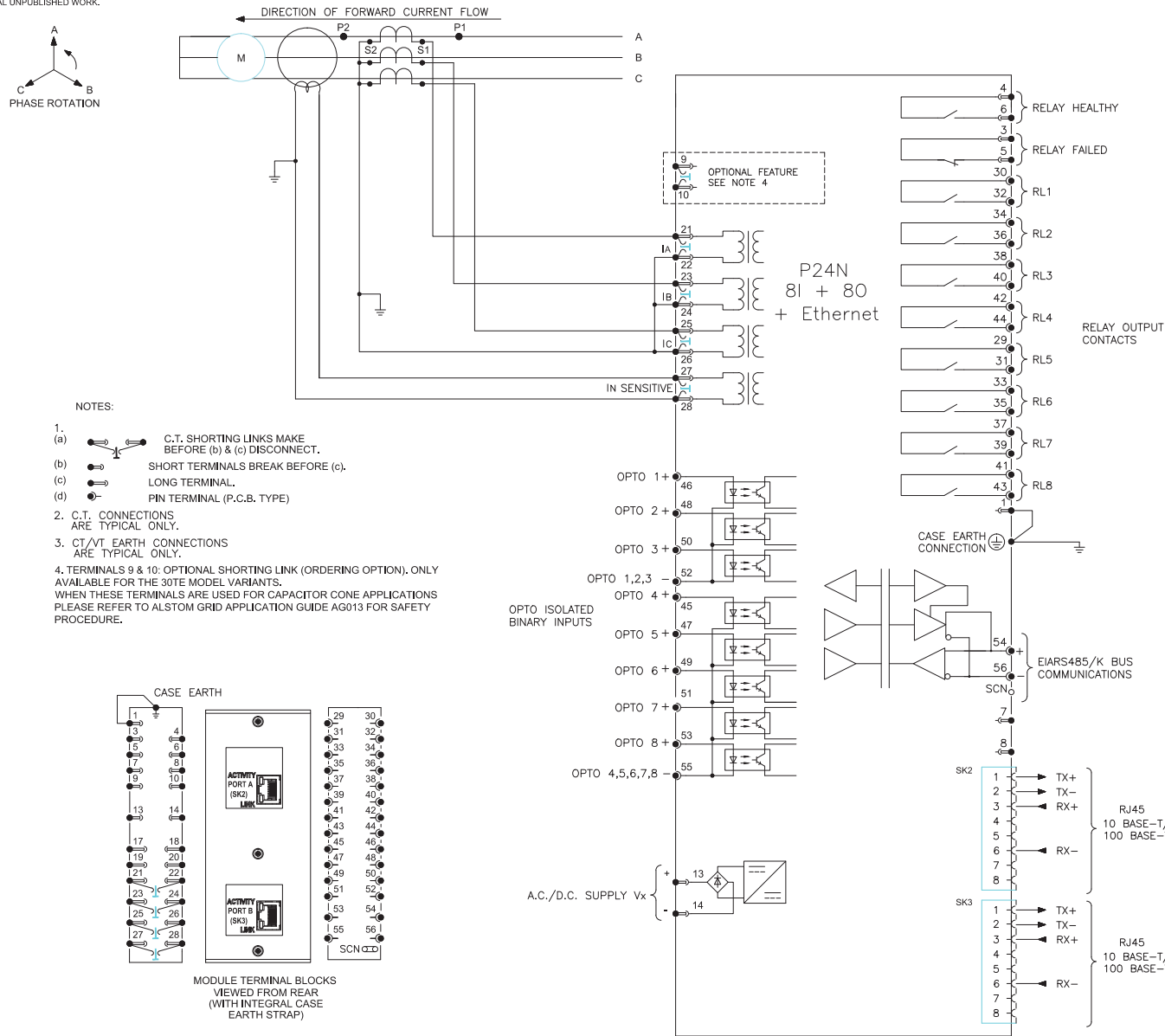   OR
             100 BASE-FX

Date: 16/10/2017	Name: V.SIVASAMBO	Drg Title: MOTOR PROTECTION WITH PHASE CURRENT INPUTS & SEF (8 I/P 8 O/P) WITH DUAL FIBRE ETHERNET	Next Stage: -	Drg No: 10P24N04-3	ECN No: CID005225	Revision: B	Iteration: 2
Date: 16/10/2017	Chkd: S WOOTTON						
Sub-contractor reference: -		CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: -	GE Grid Solutions	PLM No: A20028651	Sht: 3	Status: IN WORK
Finish: -			Angular Tol deg: -			Next Sht: -	

PHASE ROTATION

DIRECTION OF FORWARD CURRENT FLOW

P24N
11I + 12O
+ 2 RS485

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

OPTO ISOLATED BINARY INPUTS

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 −
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8 −
OPTO 9 +
OPTO 10 +
OPTO 11 +
OPTO 9,10,11 −

RP−1
EIARS485/K BUS COMMUNICATIONS

A.C./D.C. SUPPLY Vx

RL9
RL10
RL11
RL12

RELAY OUTPUT CONTACTS

RP−2
EIARS485/K BUS COMMUNICATIONS

NOTES:
1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.
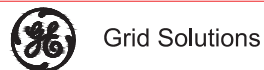3. EARTH CONNECTIONS ARE TYPICAL ONLY.

CASE EARTH

MODULE TERMINAL BLOCKS VIEWED FROM REAR (WITH INTEGRAL CASE EARTH STRAP)

Date:	16/10/2017	Name:	V.SIVASAMBO	Drg Title:	MOTOR PROTECTION WITH PHASE CURRENT INPUTS & E/F (11 I/P & 12 O/P) WITH 2 RS485	Next Stage:	-	Drg No:	10P24N05-1	ECN No: CID005225	Revision: B	Iteration: 2
Date:	16/10/2017	Chkd:	S WOOTTON									
Sub-contractor reference:	-			CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE		Linear Tol mm: -		Grid Solutions	PLM No: A20028653	Sht: 1	Status: IN WORK	
Finish:	-					Angular Tol deg: -				Next Sht: -		

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

P24N
11I + 12O
+ 2 RS485
+ ETHERNET

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RELAY OUTPUT CONTACTS
RL5
RL6
RL7
RL8

CASE EARTH CONNECTION

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 −
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8
OPTO 9 +
OPTO 10 +
OPTO 11 +
OPTO 9,10,11 −

OPTO ISOLATED BINARY INPUTS

A.C./D.C. SUPPLY Vx

RP−1
EIARS485/K BUS COMMUNICATIONS
SCN

RL9
RL10
RELAY OUTPUT CONTACTS
RL11
RL12

RP−2
EIARS485/K BUS COMMUNICATIONS
SCN

TX+
TX−
RX+
RX−
RJ45
10 BASE−T/
100 BASE−TX

TX
RX
LC
10 BASE−FL
OR
100 BASE−FX

NOTES:
1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.

3. EARTH CONNECTIONS ARE TYPICAL ONLY.

CASE EARTH

LINK
ACTIVITY
PORT A
(SK2)
RX
TX

ACTIVITY
PORT B
(SK3)
LINK

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE
EARTH STRAP)

| Date: | 16/10/2017 | Name: | V.SIVASAMBO | Drg Title: | MOTOR PROTECTION WITH PHASE CURRENT INPUTS & E/F (11 I/P & 12 O/P) WITH 2 RS485 & ETHERNET | Next Stage: | | Drg No: | 10P24N05-2 | ECN No: CID005225 | Revision: B | Iteration: 2 |
| Date: | 16/10/2017 | Chkd: | S WOOTTON | | | | | | | | | |

| Sub-contractor reference: - | CAD DATA 1:1 DIMENSIONS: mm | Linear Tol mm: - | | Grid Solutions | PLM No: A20028655 | Sht: 2 | Status: |
| Finish: - | DO NOT SCALE | Angular Tol deg: - | | | | Next Sht: 3 | IN WORK |

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

P24N
11I + 12O
+ 2 RS485
+ ETHERNET

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

NOTES:
1.
(a)   C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b)   SHORT TERMINALS BREAK BEFORE (c).
(c)   LONG TERMINAL.
(d)   PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.
3. EARTH CONNECTIONS ARE TYPICAL ONLY.

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 −
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8 −
OPTO 9 +
OPTO 10 +
OPTO 11 +
OPTO 9,10,11 −

OPTO ISOLATED BINARY INPUTS

RP−1 EIARS485/K BUS COMMUNICATIONS

RL9
RL10
RL11
RL12

RELAY OUTPUT CONTACTS

A.C./D.C. SUPPLY Vx

RP−2 EIARS485/K BUS COMMUNICATIONS

CASE EARTH

ACTIVITY PORT A (SK2) LINK

ACTIVITY PORT B (SK3) LINK

MODULE TERMINAL BLOCKS VIEWED FROM REAR (WITH INTEGRAL CASE EARTH STRAP)

SK2
1 TX+
2 TX−
3 RX+
4
5
6 RX−
7
8
RJ45 10 BASE−T/ 100 BASE−TX

SK3
1 TX+
2 TX−
3 RX+
4
5
6 RX−
7
8
RJ45 10 BASE−T/ 100 BASE−TX

| Date: | 16/10/2017 | Name: | V.SIVASAMBO | Drg Title: | MOTOR PROTECTION WITH PHASE CURRENT INPUTS & E/F (11 I/P & 12 O/P) WITH 2 RS485 & DUAL COPPER ETHERNET | Next Stage: - | Drg No: | 10P24N05-3 | ECN No: CID005225 | Revision: B | Iteration: 2 |
| Date: | 16/10/2017 | Chkd: | S WOOTTON | | | | | | | | |

Sub-contractor reference: -

Finish: -

CAD DATA 1:1 DIMENSIONS: mm
DO NOT SCALE

Linear Tol mm: -
Angular Tol deg: -

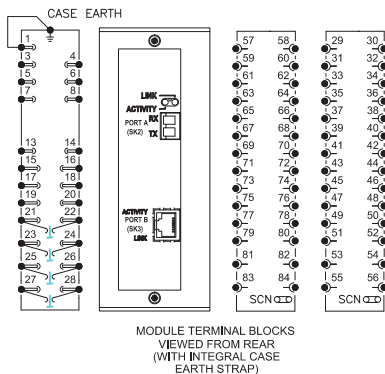Grid Solutions

PLM No: A20028657

Sht: 3
Next Sht: 4

Status: IN WORK

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

M

P2 S2 S1 P1

A
B
C

IA 21 / 22
IB 23 / 24
IC 25 / 26
IN 27 / 28

P24N
11I + 12O
+ 2 RS485
+ ETHERNET

RELAY HEALTHY 4 / 6
RELAY FAILED 3 / 5

RL1 30 / 32
RL2 34 / 36
RL3 38 / 40
RL4 42 / 44
RL5 29 / 31
RL6 33 / 35
RL7 37 / 39
RL8 41 / 43

RELAY OUTPUT CONTACTS

OPTO 1 + 46
OPTO 2 + 48
OPTO 3 + 50
OPTO 1,2,3 52
OPTO 4 + 45
OPTO 5 + 47
OPTO 6 + 49
OPTO 7 51
OPTO 8 53
OPTO 4,5,6,7,8 55
OPTO 9 74
OPTO 10 + 76
OPTO 11 + 78
OPTO 9,10,11 – 80

OPTO ISOLATED BINARY INPUTS

CASE EARTH CONNECTION

RP–1 EIARS485/K BUS COMMUNICATIONS 54 + / 56 SCN

7
8

RL9 58 / 60
RL10 62 / 64
RL11 66 / 68
RL12 70 / 72

RELAY OUTPUT CONTACTS

A.C./D.C. SUPPLY Vx 13 + / 14

RP–2 EIARS485/K BUS COMMUNICATIONS 82 + / 84 SCN

SK2 TX / RX LC 10 BASE–FL OR 100 BASE–FX
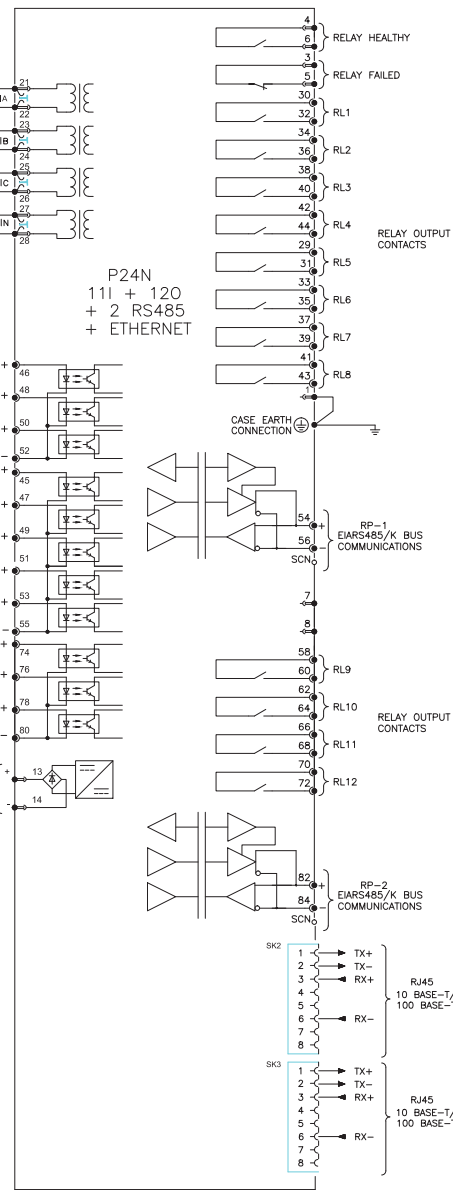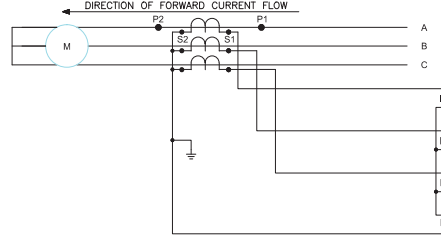
SK3 TX / RX LC 10 BASE–FL OR 100 BASE–FX

NOTES:

1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.
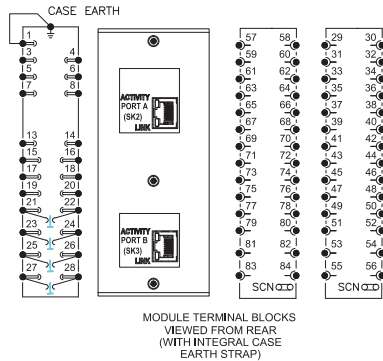
3. EARTH CONNECTIONS ARE TYPICAL ONLY.

CASE EARTH

PORT A RX TX (SK2)
ACTIVITY
LINK

PORT B RX TX (SK3)
ACTIVITY
LINK

1 / 3 / 5 / 7
4 / 8
13 / 14
15 / 16
17 / 18
19 / 20
21 / 22
23 / 24
25 / 26
27 / 28

57 / 58
59 / 60
61 / 62
63 / 64
65 / 66
67 / 68
69 / 70
71 / 72
73 / 74
75 / 76
77 / 78
79 / 80
81 / 82
83 / 84
SCN

29 / 30
31 / 32
33 / 34
35 / 36
37 / 38
39 / 40
41 / 42
43 / 44
45 / 46
47 / 48
49 / 50
51 / 52
53 / 54
55 / 56
SCN

MODULE TERMINAL BLOCKS VIEWED FROM REAR (WITH INTEGRAL CASE EARTH STRAP)

Date:	16/10/2017	Name:	V.SIVASAMBO	Drg Title:	MOTOR PROTECTION WITH PHASE CURRENT INPUTS & E/F (11 I/P & 12 O/P) WITH 2 RS485 & DUAL FIBRE ETHERNET	Next Stage:	-	Drg No:	10P24N05-4	ECN No:	CID005225	Revision:	B	Iteration:	2
Date:	16/10/2017	Chkd:	S WOOTTON												
Sub-contractor reference:	-			CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE		Linear Tol mm:	-		Grid Solutions	PLM No:	A20028659	Sht:	4	Status:	IN WORK
Finish:	-					Angular Tol deg:	-			Next Sht:	-			

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

P24N
11I + 12O
+ 2 RS485

RELAY HEALTHY

RELAY FAILED

RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 −
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8 −
OPTO 9 +
OPTO 10 +
OPTO 11 +
OPTO 9,10,11 −

OPTO ISOLATED BINARY INPUTS

RP−1
EIARS485/K BUS COMMUNICATIONS

SCN

A.C./D.C. SUPPLY Vx

RL9
RL10
RL11
RL12

RELAY OUTPUT CONTACTS

RP−2
EIARS485/K BUS COMMUNICATIONS

SCN

NOTES:

1.
(a)   C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b)   SHORT TERMINALS BREAK BEFORE (c).
(c)   LONG TERMINAL.
(d)   PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.

3. CT/VT EARTH CONNECTIONS ARE TYPICAL ONLY.

CASE EARTH

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE
EARTH STRAP)

Date:	16/10/2017	Name:	V.SIVASAMBO	Drg Title:	MOTOR PROTECTION WITH PHASE CURRENT INPUTS & SEF (11 I/P & 12 O/P) WITH 2 RS485	Next Stage:		Drg No:	10P24N06-1	ECN No:	CID005225	Revision:	B	Iteration:	2
Date:	16/10/2017	Chkd:	S WOOTTON												
Sub-contractor reference: -				CAD DATA 1:1 DIMENSIONS: mm		Linear Tol mm: -		PLM No:	A20028661	Sht: 1		Status:	IN WORK		
Finish: -				DO NOT SCALE		Angular Tol deg: -				Next Sht: -					

Grid Solutions

PHASE ROTATION

DIRECTION OF FORWARD CURRENT FLOW

P24N
11I + 12O
+ 2 RS485
+ ETHERNET

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION
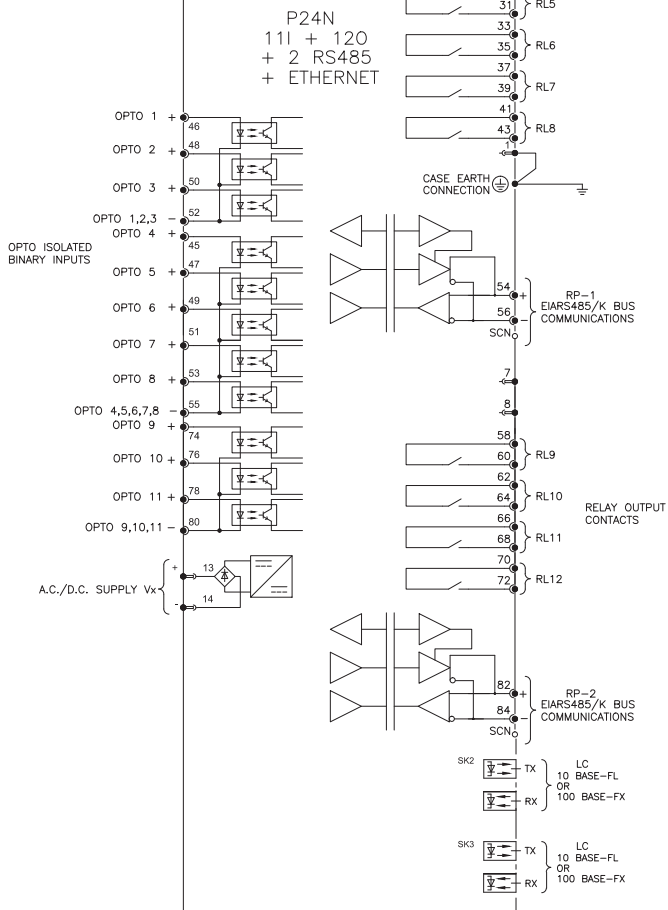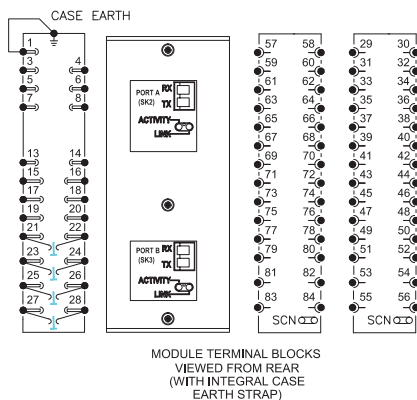
NOTES:

1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.

3. CT/VT EARTH CONNECTIONS ARE TYPICAL ONLY.

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 −
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8 −
OPTO 9 +
OPTO 9 −
OPTO 10 +
OPTO 10 −
OPTO 11 +
OPTO 11 −

OPTO ISOLATED BINARY INPUTS

RP−1 EIARS485/K BUS COMMUNICATIONS
SCN

RP−2 EIARS485/K BUS COMMUNICATIONS
SCN

RL9
RL10
RL11
RL12

RELAY OUTPUT CONTACTS

A.C./D.C. SUPPLY Vx

CASE EARTH

LINK
ACTIVITY
PORT A RX (SK2)
TX

ACTIVITY
PORT B (SK3)
LINK

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE
EARTH STRAP)

TX+
TX−
RX+
RX−

RJ45
10 BASE−T/
100 BASE−TX

TX
RX

LC
10 BASE−FL
OR
100 BASE−FX

Date: 16/10/2017	Name: V.SIVASAMBO	Drg Title: MOTOR PROTECTION WITH PHASE CURRENT INPUTS & SEF (11 I/P & 12 O/P) WITH 2 RS485 & ETHERNET	Next Stage: -	Drg No: 10P24N06-2	ECN No: CID005225	Revision: B	Iteration: 2
Date: 16/10/2017	Chkd: S WOOTTON						
Sub-contractor reference: -		CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: -	Grid Solutions	PLM No: A20028663	Sht: 2	Status: IN WORK
Finish: -			Angular Tol deg: -			Next Sht: 3	

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

P24N
11I + 12O
+ 2 RS485
+ ETHERNET

RELAY HEALTHY
RELAY FAILED
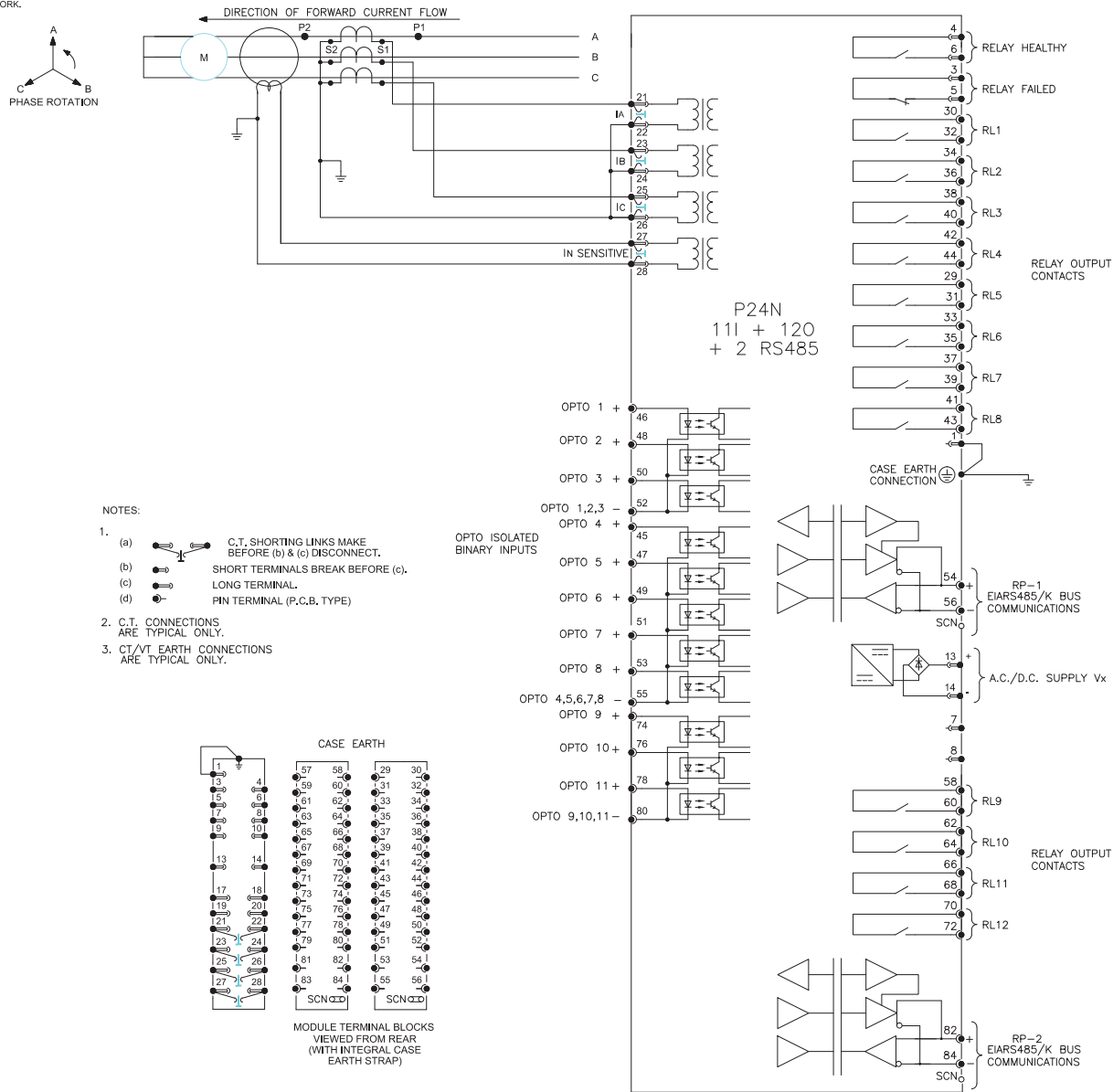RL1
RL2
RL3
RL4   RELAY OUTPUT CONTACTS
RL5
RL6
RL7
RL8

NOTES:

1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.
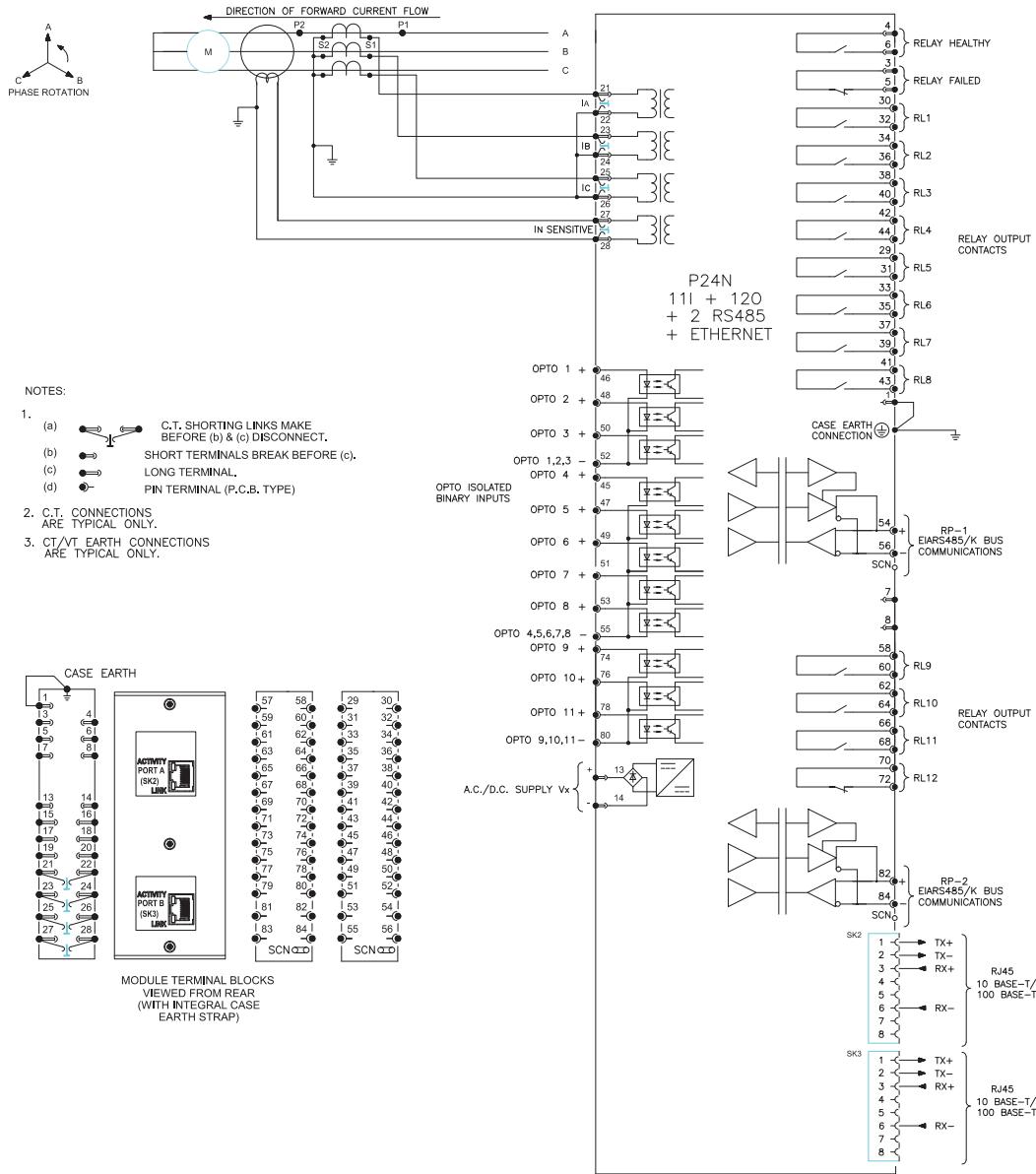
3. CT/VT EARTH CONNECTIONS ARE TYPICAL ONLY.

OPTO ISOLATED BINARY INPUTS

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 −
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8 −
OPTO 9 +
OPTO 10 +
OPTO 11 +
OPTO 9,10,11 −

A.C./D.C. SUPPLY Vx

CASE EARTH CONNECTION

RP−1 EIARS485/K BUS COMMUNICATIONS
SCN

RL9
RL10   RELAY OUTPUT CONTACTS
RL11
RL12

RP−2 EIARS485/K BUS COMMUNICATIONS
SCN

CASE EARTH

ACTIVITY PORT A (SK2) LINK

ACTIVITY PORT B (SK3) LINK

MODULE TERMINAL BLOCKS VIEWED FROM REAR (WITH INTEGRAL CASE EARTH STRAP)

SCN   SCN

SK2
1 TX+
2 TX−
3 RX+
4
5
6 RX−
7
8
RJ45 10 BASE−T/ 100 BASE−TX
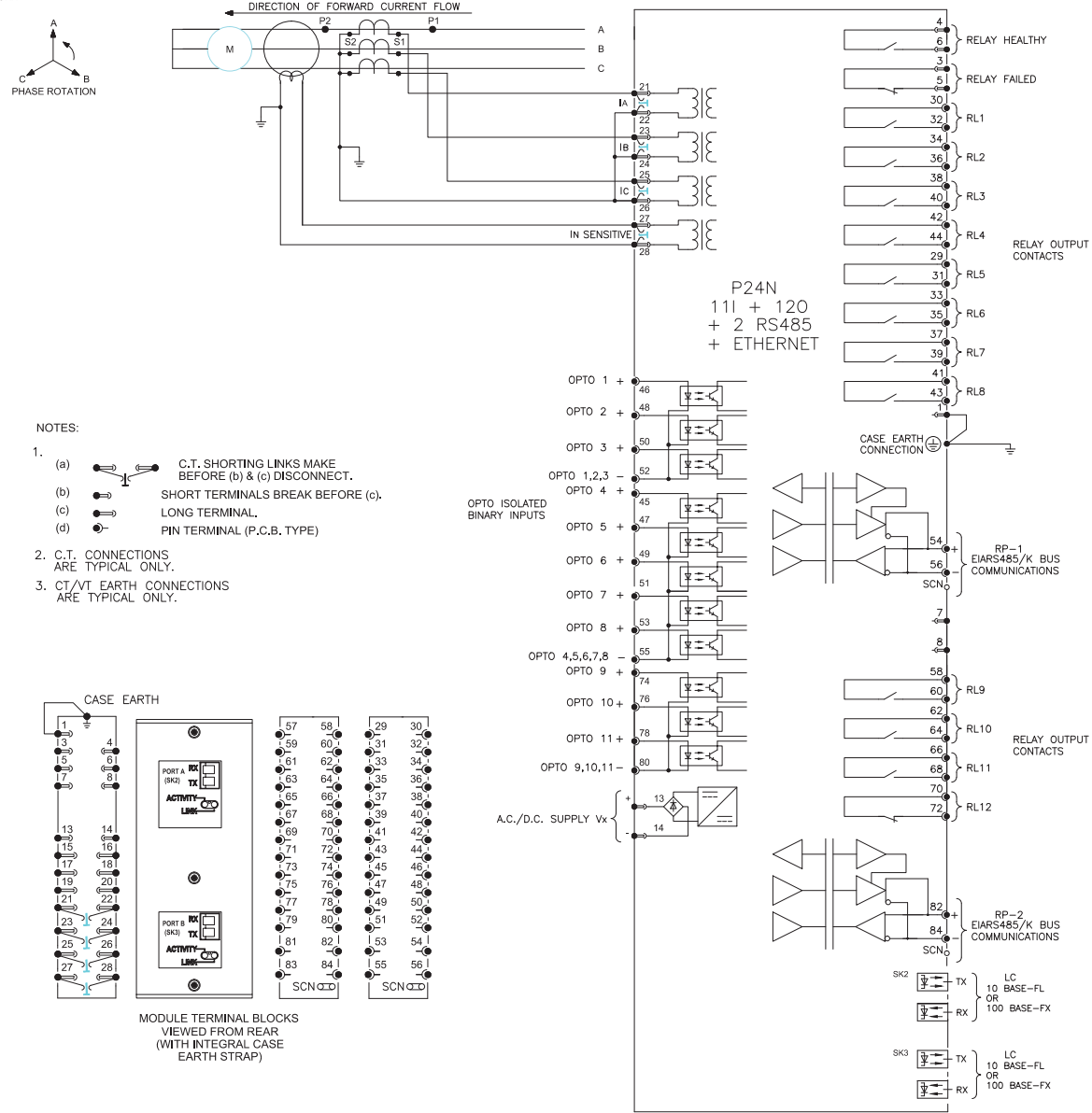
SK3
1 TX+
2 TX−
3 RX+
4
5
6 RX−
7
8
RJ45 10 BASE−T/ 100 BASE−TX

Date: 16/10/2017	Name: V.SIVASAMBO	Drg Title: MOTOR PROTECTION WITH PHASE CURRENT INPUTS & SEF (11 I/P & 12 O/P) WITH 2 RS485 & DUAL COPPER ETHERNET	Next Stage: -	Drg No: 10P24N06-3	ECN No: CID005225	Revision: B	Iteration: 2
Date: 16/10/2017	Chkd: S WOOTTON						
Sub-contractor reference: -		CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: - / Angular Tol deg: -	Grid Solutions	PLM No: A20028665	Sht: 3	Status: IN WORK
Finish: -						Next Sht: 4	

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

P24N
11I + 12O
+ 2 RS485
+ ETHERNET

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 −
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8 −
OPTO 9 +
OPTO 10 +
OPTO 11 +
OPTO 9,10,11 −

OPTO ISOLATED BINARY INPUTS

RP−1 EIARS485/K BUS COMMUNICATIONS
SCN

RL9
RL10
RL11
RL12

RELAY OUTPUT CONTACTS

A.C./D.C. SUPPLY Vx

RP−2 EIARS485/K BUS COMMUNICATIONS
SCN

SK2   TX   LC 10 BASE−FL OR 100 BASE−FX   RX
SK3   TX   LC 10 BASE−FL OR 100 BASE−FX   RX

NOTES:

1.
(a)   C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b)   SHORT TERMINALS BREAK BEFORE (c).
(c)   LONG TERMINAL.
(d)   PIN TERMINAL (P.C.B. TYPE).

2. C.T. CONNECTIONS ARE TYPICAL ONLY.

3. CT/VT EARTH CONNECTIONS ARE TYPICAL ONLY.

CASE EARTH

PORT A (SK2)   RX   TX
ACTIVITY LINK

PORT B (SK3)   RX   TX
ACTIVITY LINK

SCN
SCN

MODULE TERMINAL BLOCKS VIEWED FROM REAR (WITH INTEGRAL CASE EARTH STRAP)

Date:	16/10/2017	Name:	V.SIVASAMBO	Drg Title:	MOTOR PROTECTION WITH PHASE CURRENT INPUTS & SEF (11 I/P & 12 O/P) WITH 2 RS485 & DUAL FIBRE ETHERNET	Next Stage:	-	Drg No:	10P24N06-4	ECN No: CID005225	Revision: B	Iteration: 2
Date:	16/10/2017	Chkd:	S WOOTTON									
Sub-contractor reference: -				CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: - Angular Tol deg: -		GE Grid Solutions	PLM No: A20028667		Sht: 4	Status: IN WORK	
Finish: -									Next Sht: -		

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

A B C

P2 P1
S2 S1

M

A
B
C

IA 21 / 22
IB 23 / 24
IC 25 / 26
IN 27 / 28

P24N
11I + 12O
TCS

RELAY HEALTHY 4 / 6
RELAY FAILED 3 / 5
RL1 30 / 32
RL2 34 / 36
RL3 38 / 40
RL4 42 / 44
RL5 29 / 31
RL6 33 / 35
RL7 37 / 39
RL8 41 / 43

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

NOTES:
1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.
3. EARTH CONNECTIONS ARE TYPICAL ONLY.

OPTO ISOLATED BINARY INPUTS

OPTO 1 + 46
OPTO 2 + 48
OPTO 3 + 50
OPTO 1,2,3 – 52
OPTO 4 + 45
OPTO 5 + 47
OPTO 6 + 49
OPTO 7 + 51
OPTO 8 + 53
OPTO 4,5,6,7,8 – 55

OPTO 9 + 74 / – 76
OPTO 10 + 78 / – 80
OPTO 11 + 82 / – 84

RP−1
EIARS485/K BUS COMMUNICATIONS
54 / 56
SCN

A.C./D.C. SUPPLY Vx
13 +
14 –

7
8

RL9 58 / 60
RL10 62 / 64
RL11 66 / 68
RL12 70 / 72

RELAY OUTPUT CONTACTS

CASE EARTH

MODULE TERMINAL BLOCKS VIEWED FROM REAR (WITH INTEGRAL CASE EARTH STRAP)

SCN SCN

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

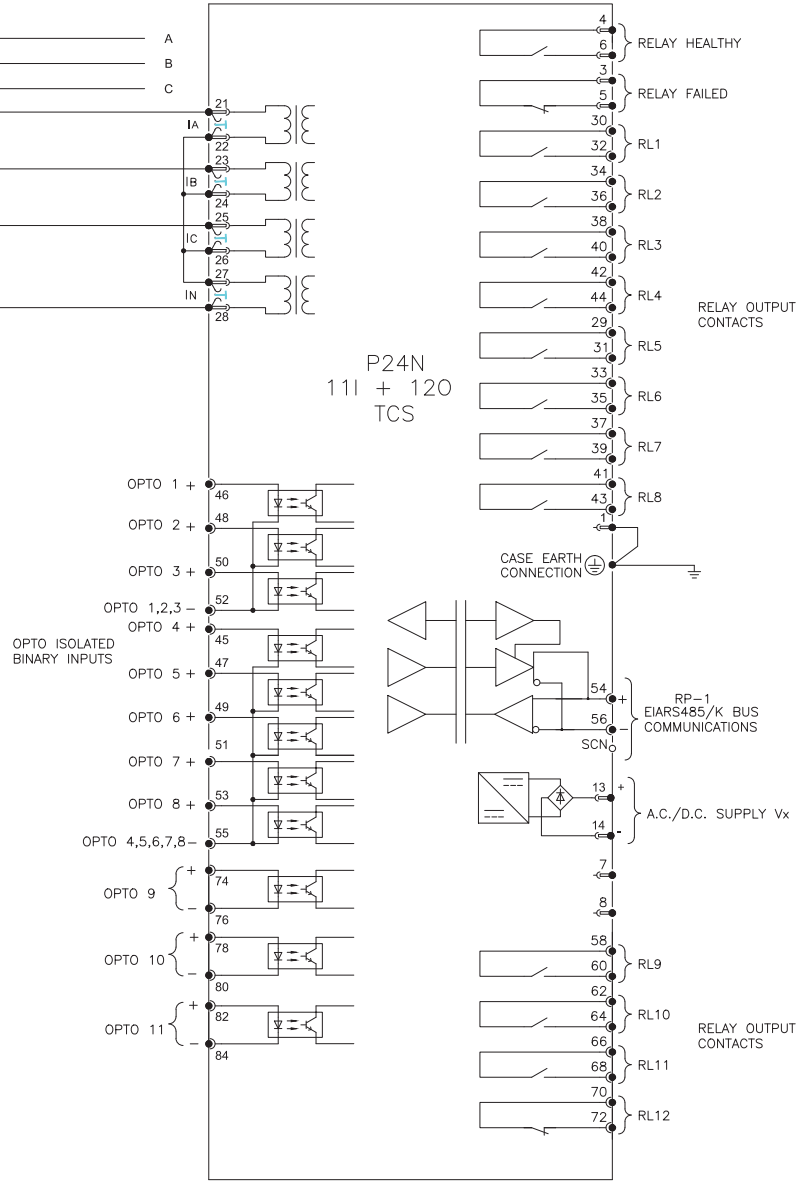NOTES:

1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.

3. EARTH CONNECTIONS ARE TYPICAL ONLY.

CASE EARTH

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE
EARTH STRAP)

P24N
11I + 12O
TCS+ETHERNET

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8
RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 –
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8 –
OPTO ISOLATED BINARY INPUTS

OPTO 9
OPTO 10
OPTO 11

A.C./D.C. SUPPLY Vx

RP–1
EIARS485/K BUS
COMMUNICATIONS

RL9
RL10
RL11
RL12
RELAY OUTPUT CONTACTS

TX+
TX–
RX+
RX–
RJ45
10 BASE–T/
100 BASE–TX

TX
RX
LC
10 BASE–FL
OR
100 BASE–FX

Date:	16/10/2017	Name:	V.SIVASAMBO	Drg Title:	MOTOR PROTECTION WITH PHASE CURRENT INPUTS & E/F (11 I/P & 12 O/P) WITH TCS & ETHERNET	Next Stage:		Drg No:	10P24N07-2	ECN No: CID005225	Revision: B	Iteration: 2
Date:	16/10/2017	Chkd:	S WOOTTON									
Sub-contractor reference: -				CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: - / Angular Tol deg: -		Grid Solutions	PLM No:	A20028671	Sht: 2 / Next Sht: 3	Status: IN WORK	
Finish: -												

PHASE ROTATION

DIRECTION OF FORWARD CURRENT FLOW

P24N
11I + 12O
TCS+ETHERNET

RELAY HEALTHY
RELAY FAILED

RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

NOTES:

1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.

3. EARTH CONNECTIONS ARE TYPICAL ONLY.

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 −
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8 −

OPTO ISOLATED BINARY INPUTS

OPTO 9
OPTO 10
OPTO 11

A.C./D.C. SUPPLY Vx

CASE EARTH CONNECTION

CASE EARTH

ACTIVITY PORT A (SK2) LINK

ACTIVITY PORT B (SK3) LINK

MODULE TERMINAL BLOCKS VIEWED FROM REAR (WITH INTEGRAL CASE EARTH STRAP)

SCN
SCN

RP−1 EIARS485/K BUS COMMUNICATIONS
SCN

RL9
RL10
RL11
RL12

RELAY OUTPUT CONTACTS

SK2
1 TX+
2 TX−
3 RX+
4
5
6 RX−
7
8
RJ45 10 BASE−T/ 100 BASE−TX
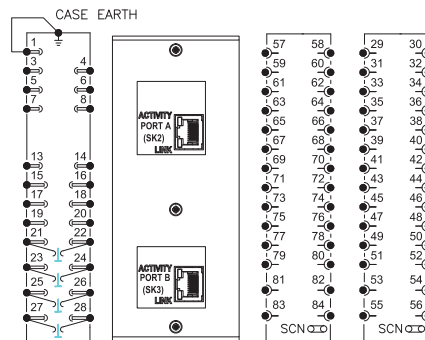
SK3
1 TX+
2 TX−
3 RX+
4
5
6 RX−
7
8
RJ45 10 BASE−T/ 100 BASE−TX

Date:	16/10/2017	Name:	V.SIVASAMBO	Drg Title:	MOTOR PROTECTION WITH PHASE CURRENT INPUTS & E/F (11 I/P & 12 O/P) WITH TCS & DUAL COPPER ETHERNET	Next Stage:	-	Drg No:	10P24N07-3	ECN No:	CID005225	Revision:	B	Iteration:	2
Date:	16/10/2017	Chkd:	S WOOTTON												
Sub-contractor reference:	-			CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE		Linear Tol mm:	-			PLM No:	A20028673	Sht:	3	Status:	IN WORK
Finish:	-					Angular Tol deg:	-		Grid Solutions			Next Sht:	4		

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

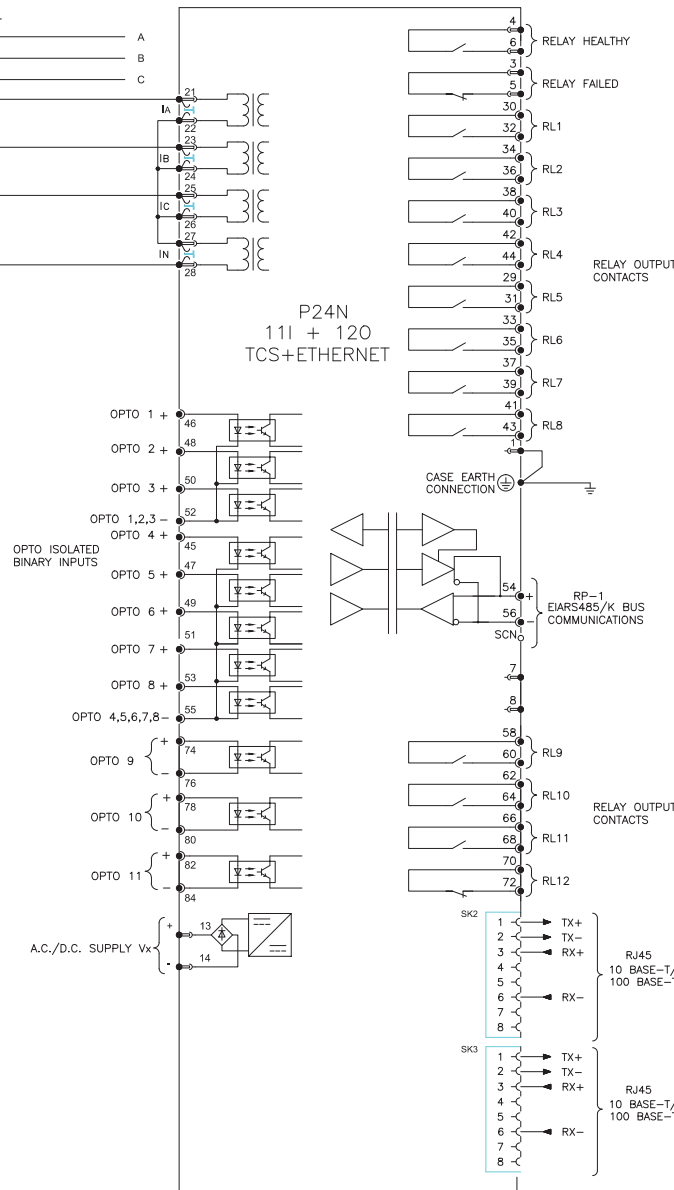NOTES:

1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.

3. EARTH CONNECTIONS ARE TYPICAL ONLY.

P24N
11I + 12O
TCS+ETHERNET

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4   RELAY OUTPUT CONTACTS
RL5
RL6
RL7
RL8

CASE EARTH CONNECTION

RP-1
EIARS485/K BUS
COMMUNICATIONS

OPTO ISOLATED BINARY INPUTS

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 −
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8 −
OPTO 9
OPTO 10
OPTO 11

CASE EARTH

PORT A RX (SK2) TX
ACTIVITY LINK

PORT B RX (SK3) TX
ACTIVITY LINK

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE
EARTH STRAP)

RL9
RL10   RELAY OUTPUT CONTACTS
RL11
RL12

A.C./D.C. SUPPLY Vx

SK2   TX   LC 10 BASE−FL OR 100 BASE−FX
      RX

SK3   TX   LC 10 BASE−FL OR 100 BASE−FX
      RX

| Date: | 17/10/2017 | Name: | V.SIVASAMBO | Drg Title: | MOTOR PROTECTION WITH PHASE CURRENT INPUTS & E/F (11 I/P & 12 O/P) WITH TCS & DUAL FIBRE ETHERNET | Next Stage: | | Drg No: | 10P24N07-4 | ECN No: | CID005225 | Revision: | B | Iteration: | 2 |
| Date: | 17/10/2017 | Chkd: | S WOOTTON | | | | | | | | | | | | |

| Sub-contractor reference: - | CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE | Linear Tol mm: - | | Grid Solutions | PLM No: A20028688 | Sht: 4 | Status: |
| Finish: - | | Angular Tol deg: - | | | | Next Sht: - | IN WORK |

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RELAY OUTPUT CONTACTS
RL5
RL6
RL7
RL8

P24N
11I + 12O
TCS

NOTES:

1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.
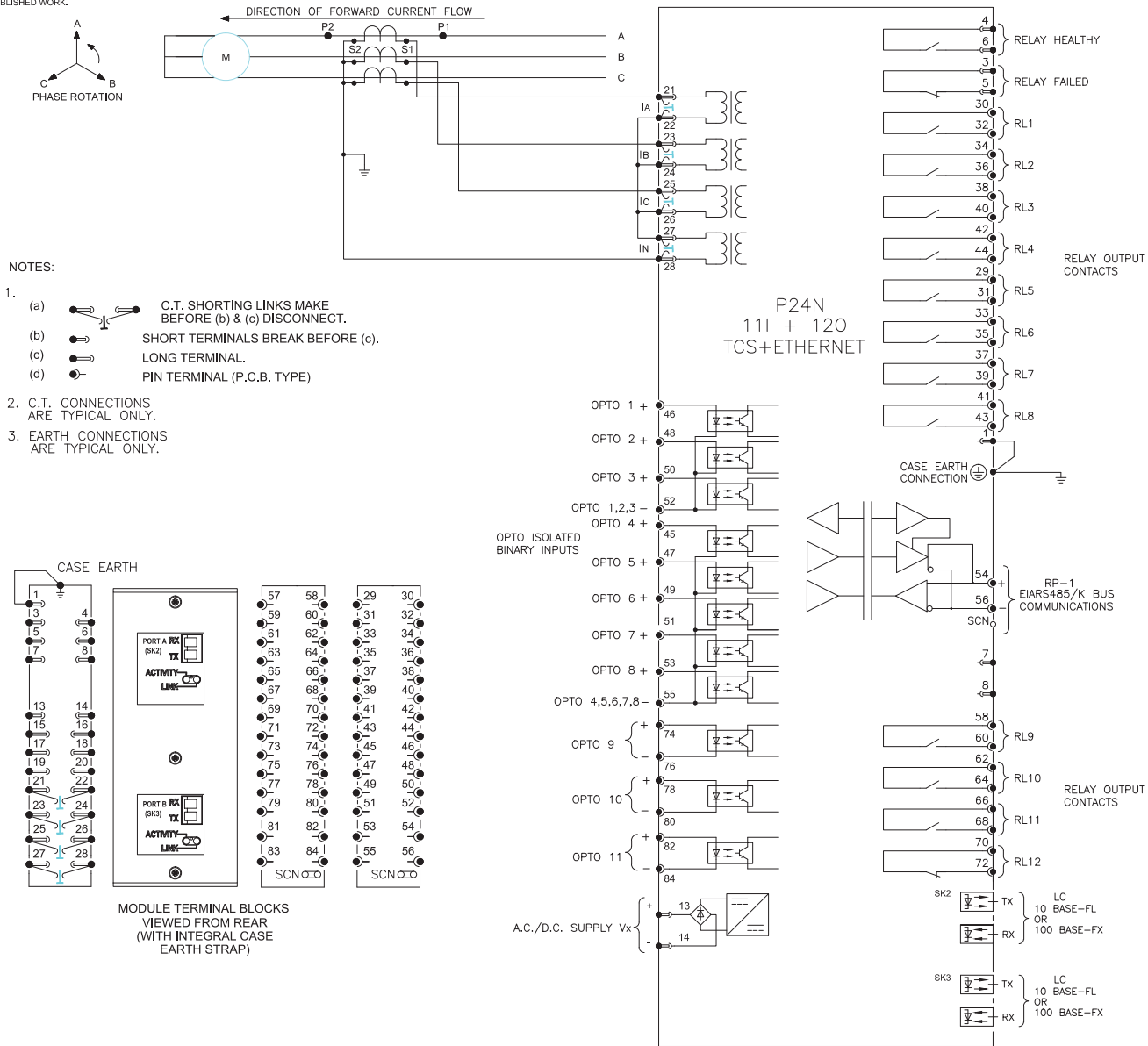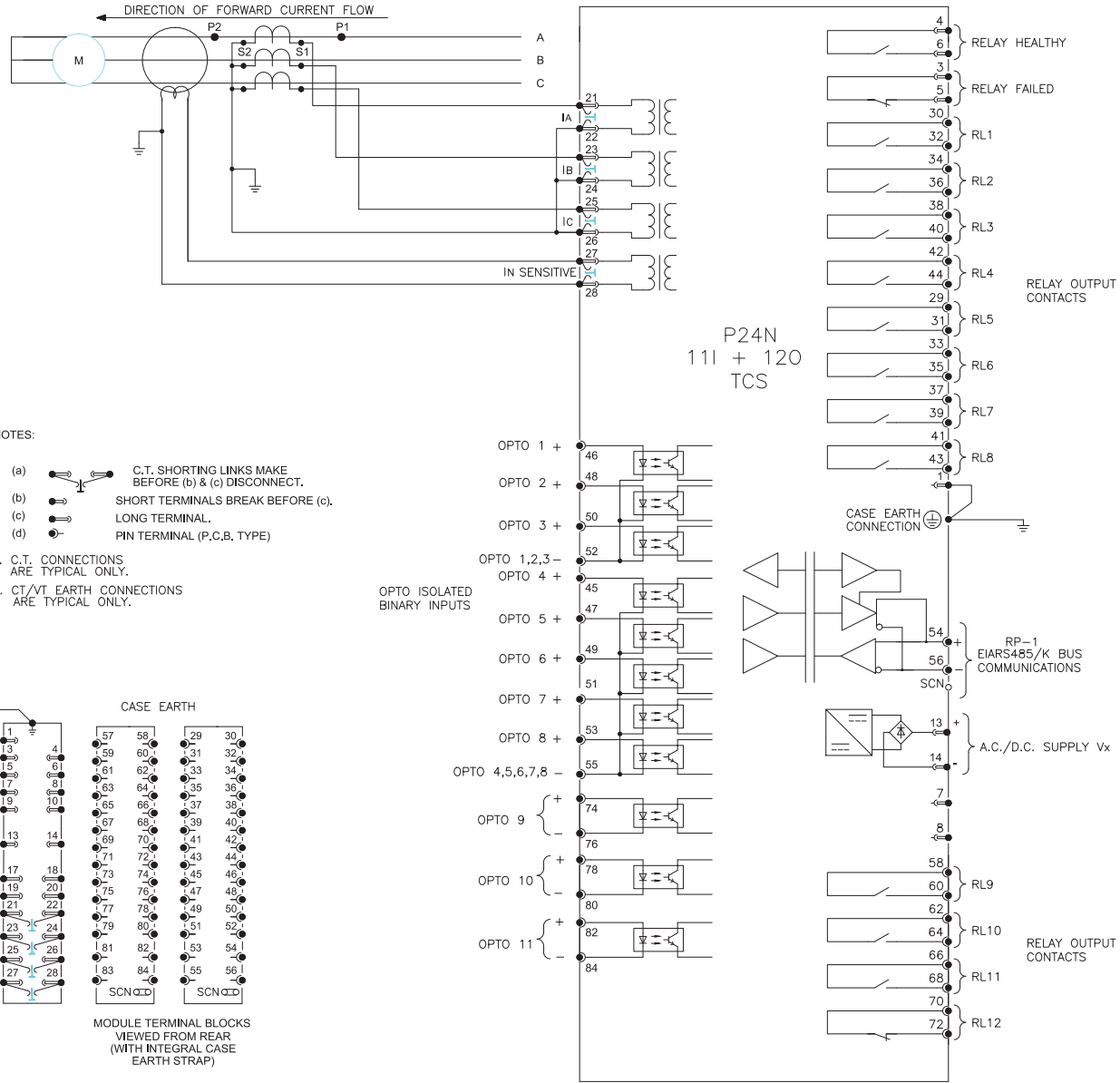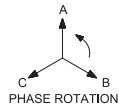
3. CT/VT EARTH CONNECTIONS ARE TYPICAL ONLY.

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 –
OPTO 4 +
OPTO ISOLATED BINARY INPUTS
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8 –
OPTO 9
OPTO 10
OPTO 11

CASE EARTH CONNECTION

RP–1
EIARS485/K BUS COMMUNICATIONS
SCN

A.C./D.C. SUPPLY Vx

RL9
RL10
RELAY OUTPUT CONTACTS
RL11
RL12

CASE EARTH

MODULE TERMINAL BLOCKS VIEWED FROM REAR (WITH INTEGRAL CASE EARTH STRAP)

SCN   SCN

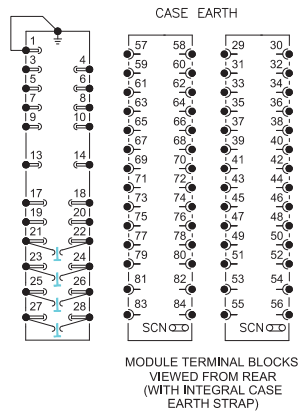| Date: | 17/10/2017 | Name: | V.SIVASAMBO | Drg Title: | MOTOR PROTECTION WITH PHASE CURRENT INPUTS & SEF (11 I/P & 12 O/P) WITH TCS | Next Stage: | - | Drg No: | 10P24N08-1 | ECN No: CID005225 | Revision: B | Iteration: 2 |
Date:	17/10/2017	Chkd:	S WOOTTON									
Sub-contractor reference:	-			CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: - Angular Tol deg: -		Grid Solutions	PLM No:	A20028690	Sht: 1	Status: IN WORK	
Finish:	-							Next Sht: -			

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

P24N
11I + 12O
TCS + ETHERNET

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

NOTES:

1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.
3. CT/VT EARTH CONNECTIONS ARE TYPICAL ONLY.

OPTO ISOLATED BINARY INPUTS

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 −
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8 −
OPTO 9
OPTO 10
OPTO 11

RP−1
EIARS485/K BUS COMMUNICATIONS

RL9
RL10
RL11
RL12

RELAY OUTPUT CONTACTS

CASE EARTH

MODULE TERMINAL BLOCKS VIEWED FROM REAR (WITH INTEGRAL CASE EARTH STRAP)

LINK
ACTIVITY
PORT A (SK2) RX TX
ACTIVITY
PORT B (SK3) LINK

A.C./D.C. SUPPLY Vx

RJ45
10 BASE−T/
100 BASE−TX

TX+
TX−
RX+
RX−

LC
10 BASE−FL
OR
100 BASE−FX
TX
RX

| Date: | 17/10/2017 | Name: | V.SIVASAMBO | Drg Title: | MOTOR PROTECTION WITH PHASE CURRENT INPUTS & SEF (11 I/P & 12 O/P) WITH TCS & ETHERNET | Next Stage: - | Drg No: 10P24N08-2 | ECN No: CID005225 | Revision: B | Iteration: 2 |
| Date: | 17/10/2017 | Chkd: | S WOOTTON | | | | | | | |

| Sub-contractor reference: - | CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE | Linear Tol mm: - Angular Tol deg: - | GE Grid Solutions | PLM No: A20028692 | Sht: 2 | Status: IN WORK |
| Finish: - | | | | | Next Sht: 3 | |

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

NOTES:

1.
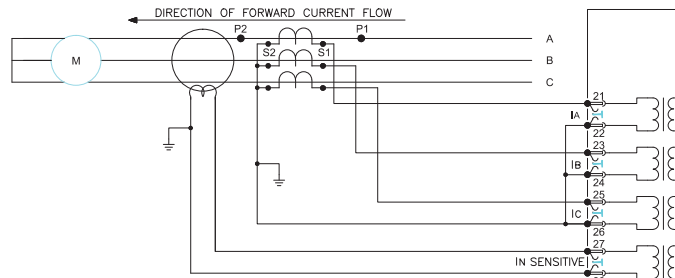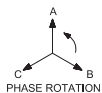(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.

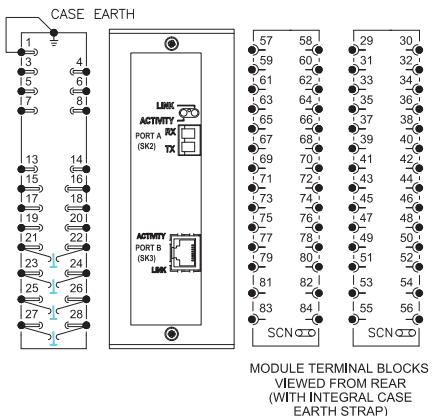3. CT/VT EARTH CONNECTIONS ARE TYPICAL ONLY.

P24N
11I + 12O
TCS + ETHERNET

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8
RELAY OUTPUT CONTACTS

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 –
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8 –
OPTO 9
OPTO 10
OPTO 11

OPTO ISOLATED BINARY INPUTS

CASE EARTH CONNECTION

RP–1
EIARS485/K BUS COMMUNICATIONS
SCN

RL9
RL10
RL11
RL12
RELAY OUTPUT CONTACTS

A.C./D.C. SUPPLY Vx

CASE EARTH

ACTIVITY PORT A (SK2) LINK
ACTIVITY PORT B (SK3) LINK

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE EARTH STRAP)

SCN   SCN

SK2
1 TX+
2 TX–
3 RX+
4
5
6 RX–
7
8
RJ45
10 BASE–T/
100 BASE–TX

SK3
1 TX+
2 TX–
3 RX+
4
5
6 RX–
7
8
RJ45
10 BASE–T/
100 BASE–TX

| Date: | 17/10/2017 | Name: | V.SIVASAMBO | Drg Title: | MOTOR PROTECTION WITH PHASE CURRENT INPUTS & SEF (11 I/P & 12 O/P) WITH TCS & DUAL COPPER ETHERNET | Next Stage: - | Drg No: | 10P24N08-3 | ECN No: CID005225 | Revision: B | Iteration: 2 |
| Date: | 17/10/2017 | Chkd: | S WOOTTON | | | | | | | | |

| Sub-contractor reference: - | CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE | Linear Tol mm: - | GE Grid Solutions | PLM No: A20028694 | Sht: 3 | Status: |
| Finish: - | | Angular Tol deg: - | | | Next Sht: 4 | IN WORK |

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

P24N
11I + 12O
TCS + ETHERNET

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8
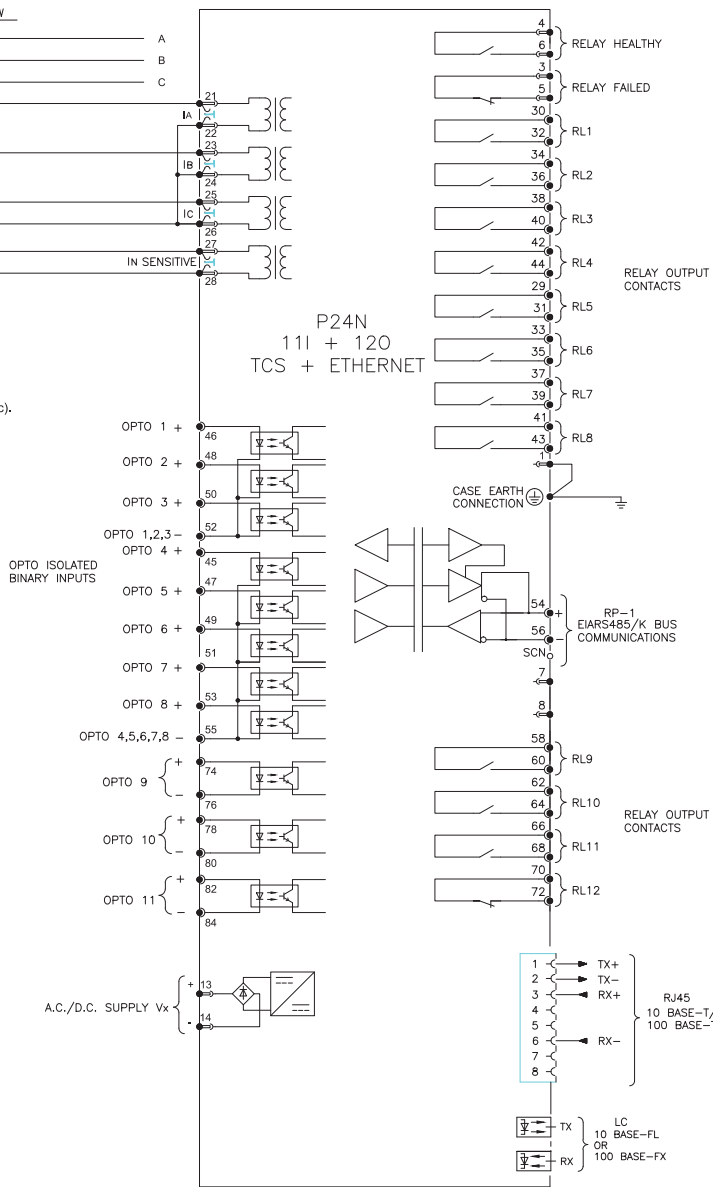RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

NOTES:

1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.
3. CT/VT EARTH CONNECTIONS ARE TYPICAL ONLY.

OPTO 1 +   46
OPTO 2 +   48
OPTO 3 +   50
OPTO 1,2,3 −   52
OPTO 4 +   45
OPTO 5 +   47
OPTO 6 +   49
OPTO 7 +   51
OPTO 8 +   53
OPTO 4,5,6,7,8 −   55

OPTO ISOLATED BINARY INPUTS

OPTO 9   + 74 / − 76
OPTO 10 + 78 / − 80
OPTO 11 + 82 / − 84

A.C./D.C. SUPPLY Vx   + 13 / − 14

RP−1
EIARS485/K BUS COMMUNICATIONS
SCN

RL9
RL10
RL11
RL12
RELAY OUTPUT CONTACTS

SK2   TX / RX   LC 10 BASE−FL OR 100 BASE−FX
SK3   TX / RX   LC 10 BASE−FL OR 100 BASE−FX

CASE EARTH

PORT A (SK2) RX TX
ACTIVITY LINK

PORT B (SK3) RX TX
ACTIVITY LINK

MODULE TERMINAL BLOCKS VIEWED FROM REAR (WITH INTEGRAL CASE EARTH STRAP)

SCN   SCN

| Date: | 17/10/2017 | Name: | V.SIVASAMBO | Drg Title: | MOTOR PROTECTION WITH PHASE CURRENT INPUTS & SEF (11 I/P & 12 O/P) WITH TCS & DUAL FIBRE ETHERNET | Next Stage: | - | Drg No: | 10P24N08-4 | ECN No: CID005225 | Revision: B | Iteration: 2 |
| Date: | 17/10/2017 | Chkd: | S WOOTTON | | | | | | | | | |

Sub-contractor reference: -
Finish: -

CAD DATA 1:1 DIMENSIONS: mm
DO NOT SCALE

Linear Tol mm: -
Angular Tol deg: -

GE Grid Solutions

PLM No: A20028696

Sht: 4
Next Sht: -

Status: IN WORK

DIRECTION OF FORWARD CURRENT FLOW
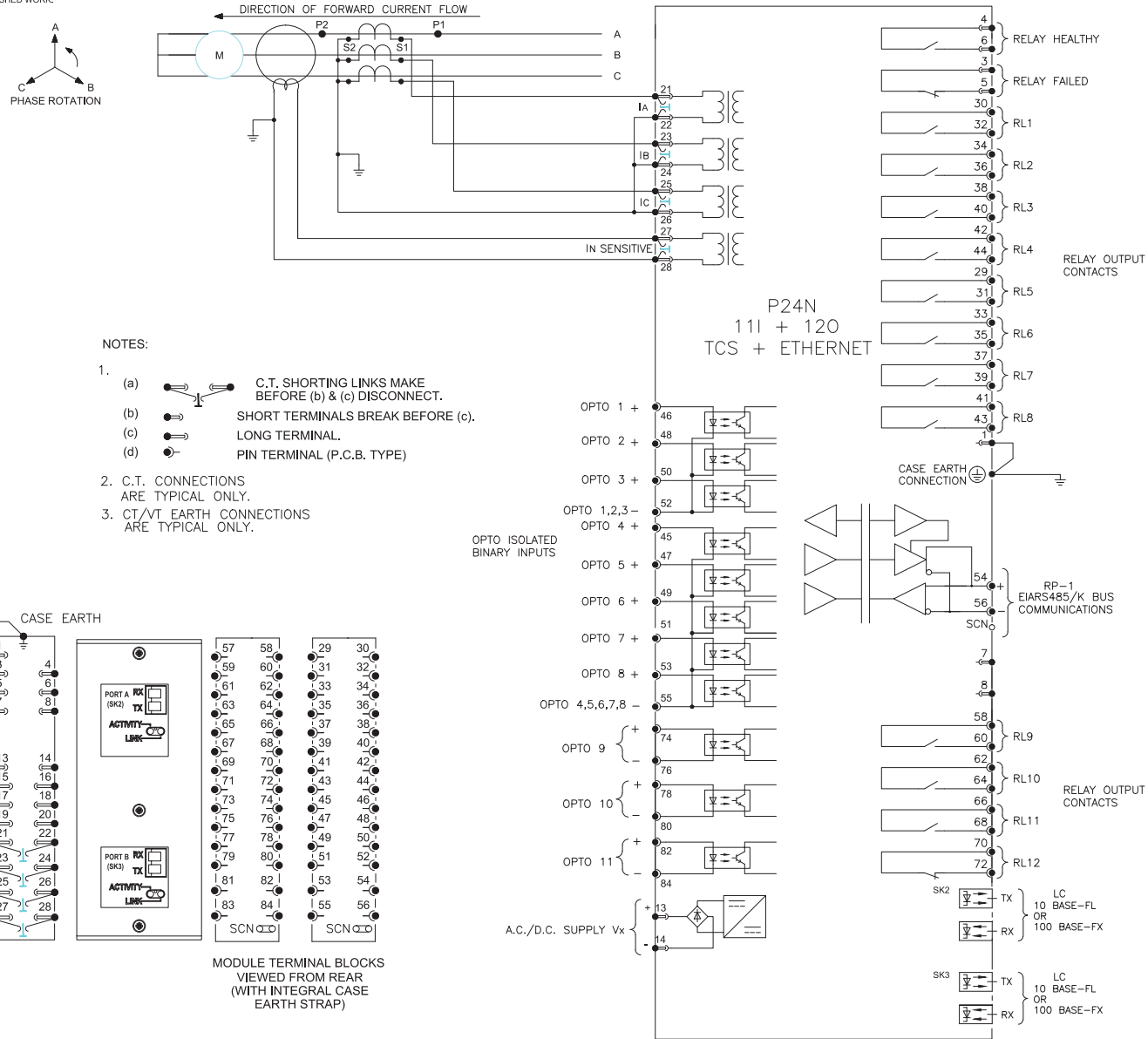
PHASE ROTATION

P24N
13I + 12O

NOTES:

1.
(a)   C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b)   SHORT TERMINALS BREAK BEFORE (c).
(c)   LONG TERMINAL.
(d)   PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.

3. EARTH CONNECTIONS ARE TYPICAL ONLY.

OPTO ISOLATED BINARY INPUTS

CASE EARTH

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE
EARTH STRAP)

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

RP-1
EIARS485/K BUS
COMMUNICATIONS

A.C./D.C. SUPPLY Vx

RL9
RL10
RL11
RL12

RELAY OUTPUT CONTACTS

Date:	17/10/2017	Name:	V.SIVASAMBO	Drg Title:	MOTOR PROTECTION WITH PHASE CURRENT INPUTS & E/F (13 I/P & 12 O/P)	Next Stage:	-	Drg No:	10P24N09-1	ECN No:	CID005225	Revision:	B	Iteration:	2
Date:	17/10/2017	Chkd:	S WOOTTON												
Sub-contractor reference:	-			CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE			Linear Tol mm: - Angular Tol deg: -	GE Grid Solutions	PLM No:	A20028698	Sht: 1		Status: IN WORK			
Finish:	-										Next Sht: -				

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

P24N
13I + 12O
+ ETHERNET

NOTES:

1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.

3. EARTH CONNECTIONS ARE TYPICAL ONLY.

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8
RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 –
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8
OPTO 9 +
OPTO 10 +
OPTO 11 +
OPTO 12 +
OPTO 13 +
OPTO 9,10,11,12,13

OPTO ISOLATED BINARY INPUTS

RP-1 EIARS485/K BUS COMMUNICATIONS

RL9
RL10
RL11
RL12
RELAY OUTPUT CONTACTS

CASE EARTH

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE EARTH STRAP)

LINK
ACTIVITY
PORT A (SK2)
RX
TX

ACTIVITY
PORT B (SK3)
LINK

SCN
SCN

A.C./D.C. SUPPLY Vx

TX+
TX–
RX+
RX–
RJ45
10 BASE-T/
100 BASE-TX

TX
RX
LC
10 BASE-FL
OR
100 BASE-FX

Date: 17/10/2017	Name: V.SIVASAMBO	Drg Title: MOTOR PROTECTION WITH PHASE CURRENT INPUTS & E/F (13 I/P & 12 O/P) & ETHERNET	Next Stage: -	Drg No: 10P24N09-2	ECN No: CID005225	Revision: B	Iteration: 2
Date: 17/10/2017	Chkd: S WOOTTON						
Sub-contractor reference: -		CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: - / Angular Tol deg: -	Grid Solutions	PLM No: A20028701	Sht: 2	Status: IN WORK
Finish: -						Next Sht: 3	

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

P24N
13I + 12O
+ ETHERNET

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

NOTES:

1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.

3. EARTH CONNECTIONS ARE TYPICAL ONLY.

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 −
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8 −
OPTO 9 +
OPTO 10 +
OPTO 11 +
OPTO 12 +
OPTO 13 +
OPTO 9,10,11,12,13 −

OPTO ISOLATED BINARY INPUTS

CASE EARTH CONNECTION

RP−1
EIARS485/K BUS
COMMUNICATIONS
SCN

CASE EARTH

ACTIVITY
PORT A
(SK2)
LINK

ACTIVITY
PORT B
(SK3)
LINK

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE EARTH STRAP)

SCN   SCN

RL9
RL10
RL11
RL12

RELAY OUTPUT CONTACTS

A.C./D.C. SUPPLY Vx

SK2
1 TX+
2 TX−
3 RX+
4
5
6 RX−
7
8

RJ45
10 BASE−T/
100 BASE−TX

SK3
1 TX+
2 TX−
3 RX+
4
5
6 RX−
7
8

RJ45
10 BASE−T/
100 BASE−TX

Date:	17/10/2017	Name:	V.SIVASAMBO	Drg Title:	MOTOR PROTECTION WITH PHASE CURRENT INPUTS & E/F (13 I/P & 12 O/P) & DUAL COPPER ETHERNET	Next Stage:	-	Drg No:	10P24N09-3	ECN No: CID005225	Revision: B	Iteration: 2
Date:	17/10/2017	Chkd:	S WOOTTON									

Sub-contractor reference: -	CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: -	Angular Tol deg: -	Grid Solutions	PLM No: A20028703	Sht: 3	Status: IN WORK
Finish: -						Next Sht: 4	

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

P24N
13I + 12O
+ ETHERNET

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
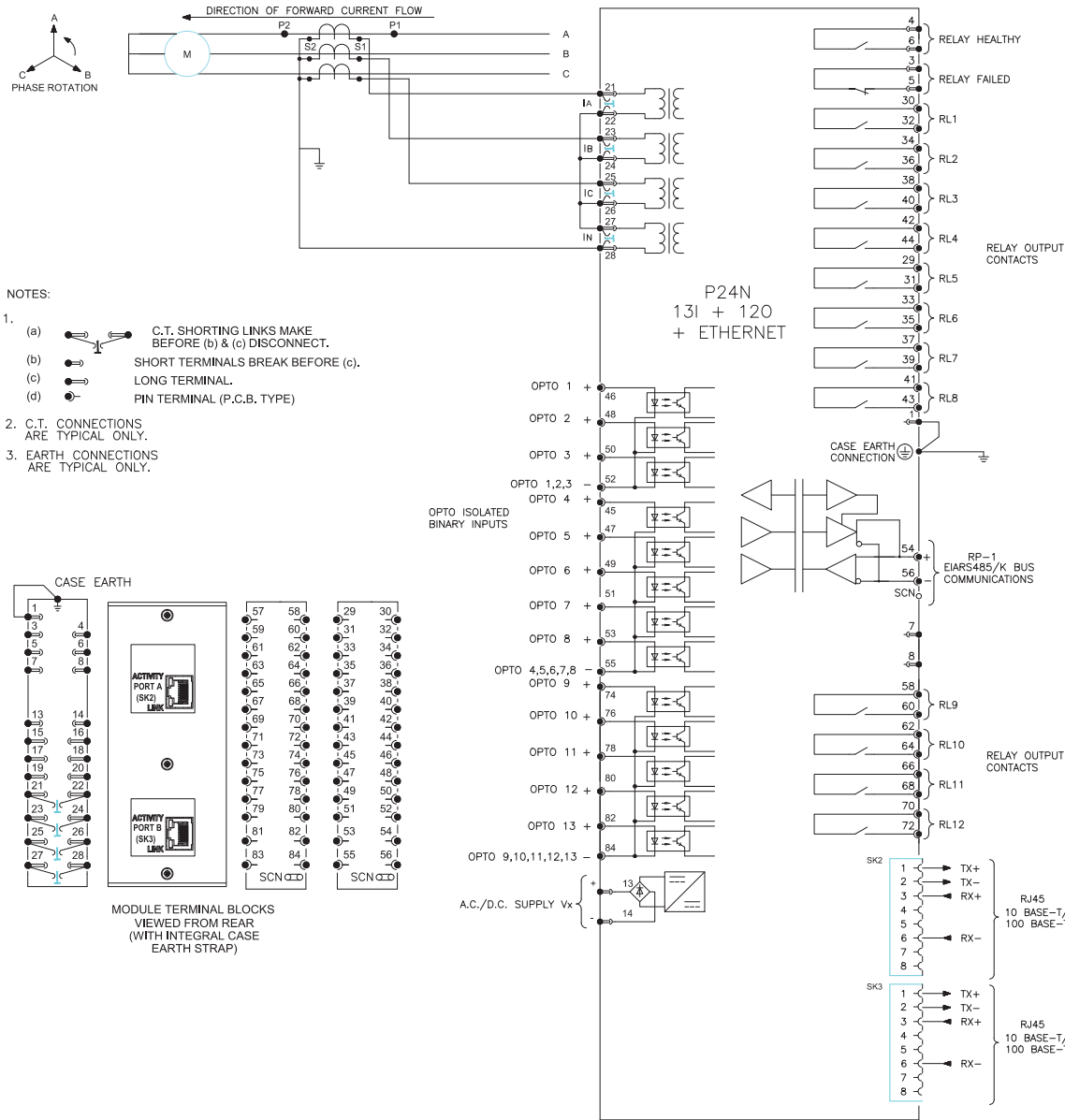RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

NOTES:

1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

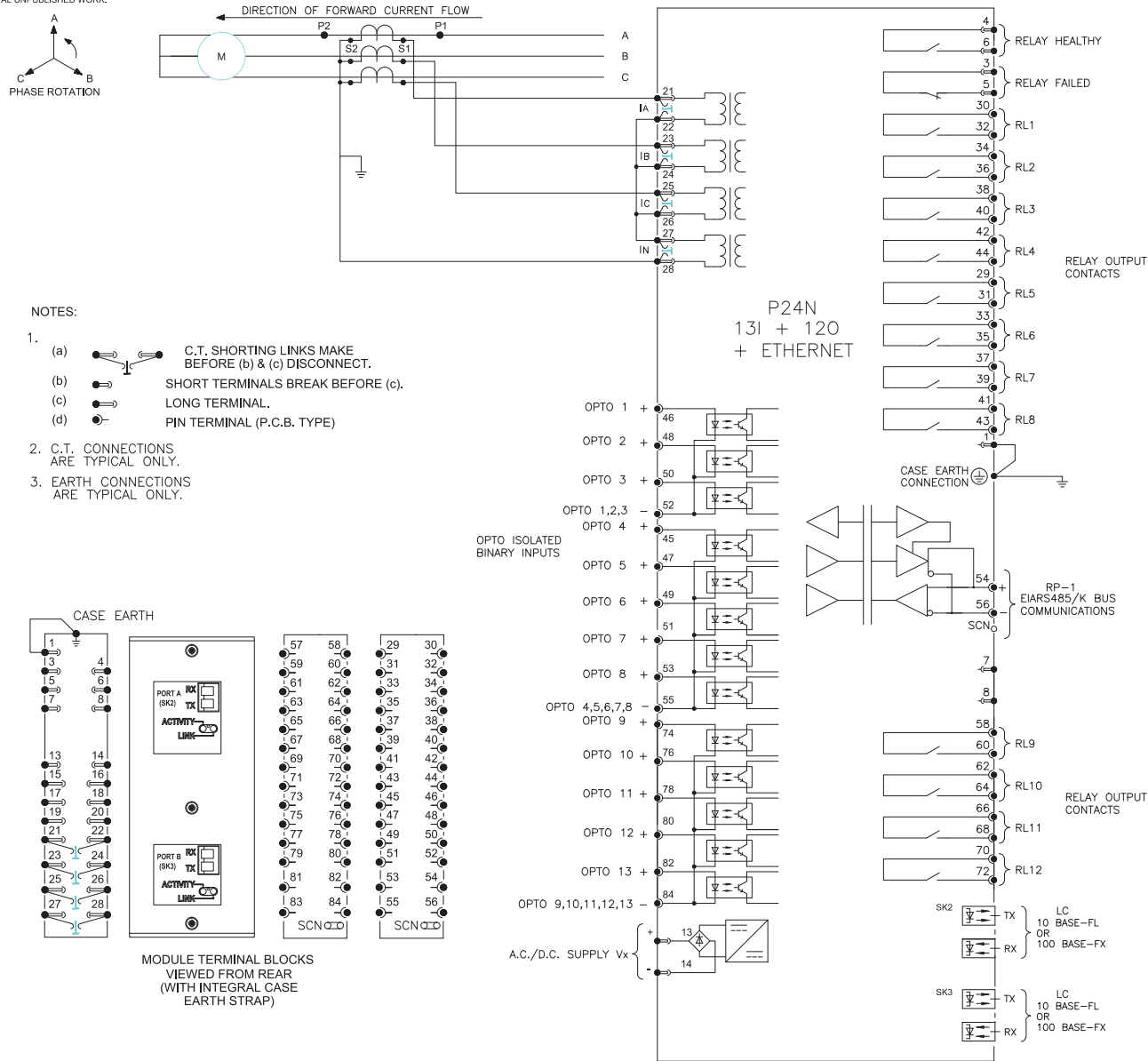2. C.T. CONNECTIONS ARE TYPICAL ONLY.

3. EARTH CONNECTIONS ARE TYPICAL ONLY.

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 −
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8 −
OPTO 9 +
OPTO 10 +
OPTO 11 +
OPTO 12 +
OPTO 13 +
OPTO 9,10,11,12,13 −

OPTO ISOLATED BINARY INPUTS

RP−1
EIARS485/K BUS COMMUNICATIONS
SCN

RL9
RL10
RL11
RL12

RELAY OUTPUT CONTACTS

A.C./D.C. SUPPLY Vx

SK2
TX
RX
LC
10 BASE−FL
OR
100 BASE−FX

SK3
TX
RX
LC
10 BASE−FL
OR
100 BASE−FX

CASE EARTH

PORT A (SK2)
RX
TX
ACTIVITY
LINK

PORT B (SK3)
RX
TX
ACTIVITY
LINK

SCN
SCN

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE
EARTH STRAP)

Date: 23/10/2017	Name: V.SIVASAMBO	Drg Title: MOTOR PROTECTION WITH PHASE CURRENT INPUTS & E/F (13 I/P & 12 O/P) & DUAL FIBRE ETHERNET	Next Stage: -	Drg No: 10P24N09-4	ECN No: CID005225	Revision: B	Iteration: 2
Date: 23/10/2017	Chkd: S WOOTTON						
Sub-contractor reference: -		CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: - Angular Tol deg: -	GE Grid Solutions	PLM No: A20028768	Sht: 4	Status: IN WORK
Finish: -					Next Sht: -		

DIRECTION OF FORWARD CURRENT FLOW

A
B
C
PHASE ROTATION

P2   P1
S2   S1
M

A
B
C

IA   21
      22
IB   23
      24
IC   25
      26
IN SENSITIVE   27
                28

P24N
13I + 12O

RELAY HEALTHY   4 / 6
RELAY FAILED   3 / 5
RL1   30 / 32
RL2   34 / 36
RL3   38 / 40
RL4   42 / 44
RL5   29 / 31
RL6   33 / 35
RL7   37 / 39
RL8   41 / 43

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

NOTES:
1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.

3. CT/VT EARTH CONNECTIONS ARE TYPICAL ONLY.

OPTO ISOLATED BINARY INPUTS

OPTO 1 +   46
OPTO 2 +   48
OPTO 3 +   50
OPTO 1,2,3 −   52
OPTO 4 +   45
OPTO 5 +   47
OPTO 6 +   49
OPTO 7 +   51
OPTO 8 +   53
OPTO 4,5,6,7,8 −   55
OPTO 9 +   74
OPTO 10 +   76
OPTO 11 +   78
OPTO 12 +   80
OPTO 13 +   82
OPTO 9,10,11,12,13 −   84

RP−1
EIARS485/K BUS COMMUNICATIONS
54 +
56 −
SCN

A.C./D.C. SUPPLY Vx
13 +
14 −
7
8

RL9   58 / 60
RL10   62 / 64
RL11   66 / 68
RL12   70 / 72

RELAY OUTPUT CONTACTS

CASE EARTH

1
3   4
5   6
7   8
9   10
13   14
17   18
19   20
21   22
23   24
25   26
27   28

57   58
59   60
61   62
63   64
65   66
67   68
69   70
71   72
73   74
75   76
77   78
79   80
81   82
83   84
SCN

29   30
31   32
33   34
35   36
37   38
39   40
41   42
43   44
45   46
47   48
49   50
51   52
53   54
55   56
SCN

MODULE TERMINAL BLOCKS VIEWED FROM REAR (WITH INTEGRAL CASE EARTH STRAP)

Date: 23/10/2017   Name: V.SIVASAMBO
Date: 23/10/2017   Chkd: S WOOTTON
Drg Title: MOTOR PROTECTION WITH PHASE CURRENT INPUTS & SEF (13 I/P & 12 O/P)
Next Stage: -
Drg No: 10P24N10-1
ECN No: CID005225
Revision: B
Iteration: 2

Sub-contractor reference: -
Finish: -
CAD DATA 1:1 DIMENSIONS: mm
DO NOT SCALE
Linear Tol mm: -
Angular Tol deg: -
Grid Solutions
PLM No: A20028770
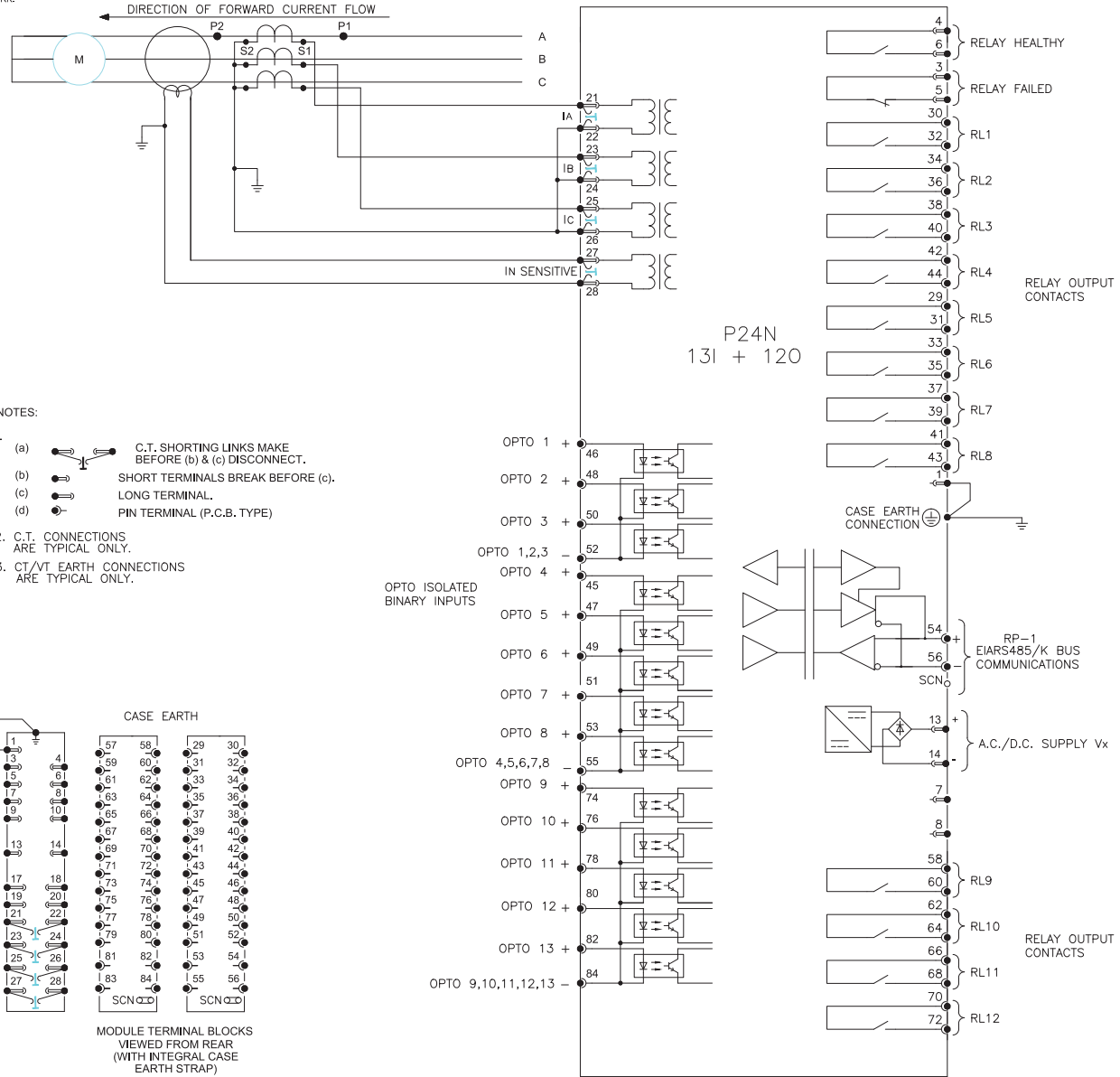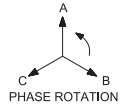Sht: 1
Next Sht: -
Status: IN WORK

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

P24N
13I + 12O
+ ETHERNET

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
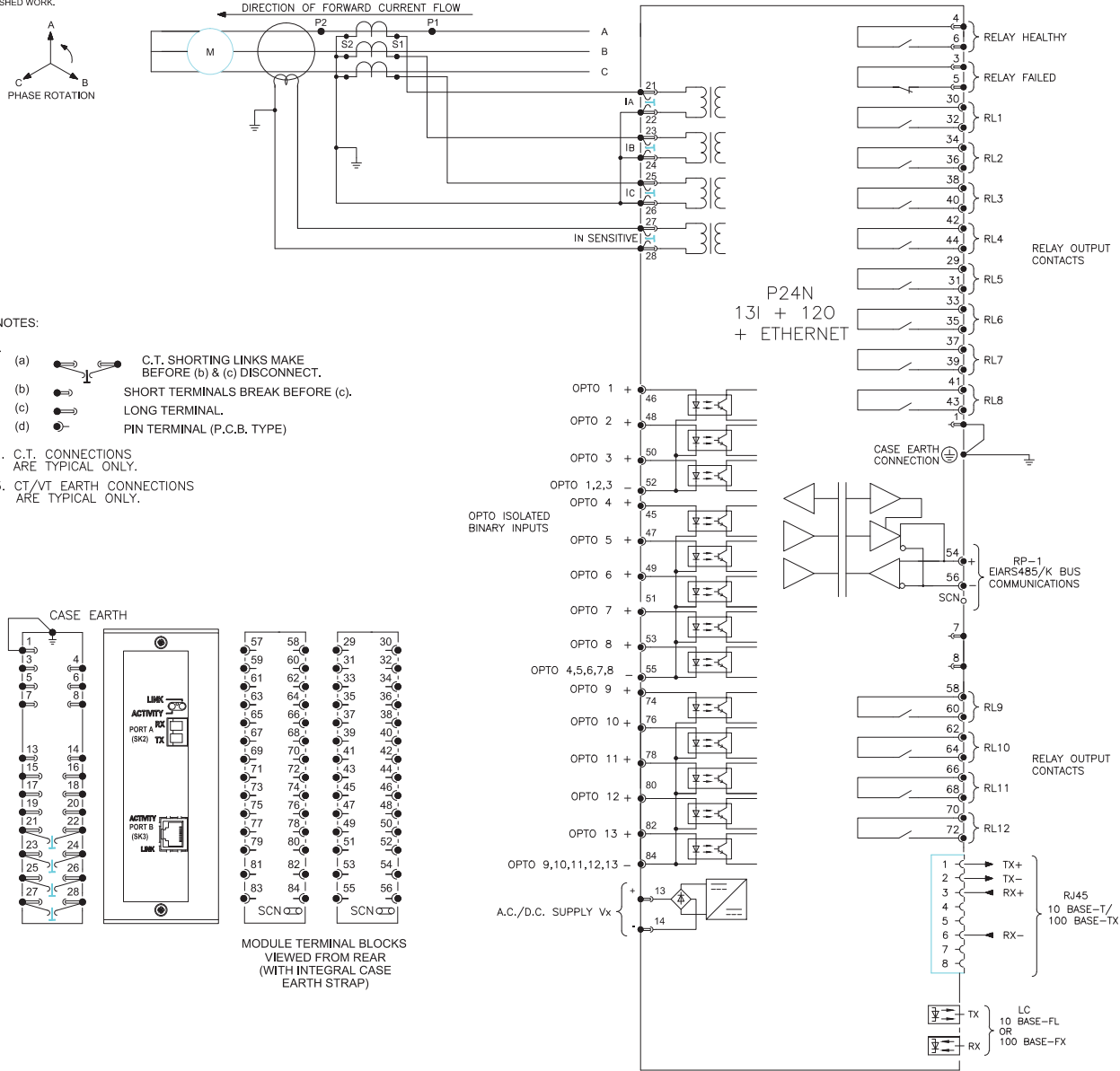RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

NOTES:

1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.
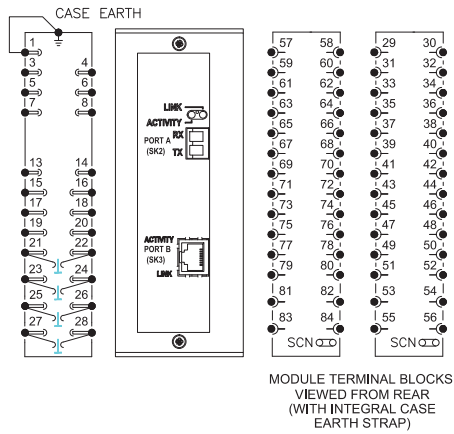
3. CT/VT EARTH CONNECTIONS ARE TYPICAL ONLY.

OPTO ISOLATED BINARY INPUTS

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 –
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8
OPTO 9 +
OPTO 10 +
OPTO 11 +
OPTO 12 +
OPTO 13 +
OPTO 9,10,11,12,13 –

A.C./D.C. SUPPLY Vx

RP-1
EIARS485/K BUS
COMMUNICATIONS

RL9
RL10
RL11
RL12

RELAY OUTPUT CONTACTS

CASE EARTH

LINK
ACTIVITY
PORT A RX
(SK2) TX

ACTIVITY
PORT B
(SK3)
LINK

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE
EARTH STRAP)

SCN

TX+
TX–
RX+
RX–

RJ45
10 BASE-T/
100 BASE-TX

TX
RX

LC
10 BASE-FL
OR
100 BASE-FX

| Date: | 23/10/2017 | Name: | V.SIVASAMBO | Drg Title: | MOTOR PROTECTION WITH PHASE CURRENT INPUTS & SEF (13 I/P & 12 O/P) & ETHERNET | Next Stage: | - | Drg No: | 10P24N10-2 | ECN No: CID005225 | Revision: B | Iteration: 2 |
| Date: | 23/10/2017 | Chkd: | S WOOTTON | | | | | | | | | |

| Sub-contractor reference: - | CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE | Linear Tol mm: - | Angular Tol deg: - | Grid Solutions | PLM No: A20028772 | Sht: 2 | Status: IN WORK |
| Finish: - | | | | | | Next Sht: 3 | |

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

P24N
13I + 12O
+ ETHERNET

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

RP-1
EIARS485/K BUS COMMUNICATIONS

RL9
RL10
RL11
RL12

RELAY OUTPUT CONTACTS

NOTES:

1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.

3. CT/VT EARTH CONNECTIONS ARE TYPICAL ONLY.

OPTO ISOLATED BINARY INPUTS

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 −
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8 −
OPTO 9 +
OPTO 10 +
OPTO 11 +
OPTO 12 +
OPTO 13 +
OPTO 9,10,11,12,13 −

A.C./D.C. SUPPLY Vx

CASE EARTH

ACTIVITY PORT A (SK2) LINK

ACTIVITY PORT B (SK3) LINK

MODULE TERMINAL BLOCKS VIEWED FROM REAR (WITH INTEGRAL CASE EARTH STRAP)

SK2
1 TX+
2 TX−
3 RX+
4
5
6 RX−
7
8
RJ45 10 BASE-T/ 100 BASE-TX

SK3
1 TX+
2 TX−
3 RX+
4
5
6 RX−
7
8
RJ45 10 BASE-T/ 100 BASE-TX

| Date: | 23/10/2017 | Name: | V.SIVASAMBO | Drg Title: | MOTOR PROTECTION WITH PHASE CURRENT INPUTS & SEF (13 I/P & 12 O/P) & DUAL COPPER ETHERNET | Next Stage: | - | Drg No: | 10P24N10-3 | ECN No: | CID005225 | Revision: | B | Iteration: | 2 |
| Date: | 23/10/2017 | Chkd: | S WOOTTON | | | | | | | | | | | | |

Sub-contractor reference: -

Finish: -

CAD DATA 1:1 DIMENSIONS: mm
DO NOT SCALE

Linear Tol mm: -
Angular Tol deg: -

Grid Solutions

PLM No: A20028774

Sht: 3
Next Sht: 4

Status: IN WORK

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

P24N
13I + 12O
+ ETHERNET

A
B
C

P2   P1
S2   S1
M

IA   21 / 22
IB   23 / 24
IC   25 / 26
IN SENSITIVE   27 / 28

RELAY HEALTHY   4 / 6
RELAY FAILED   3 / 5
RL1   30 / 32
RL2   34 / 36
RL3   38 / 40
RL4   42 / 44
RL5   29 / 31
RL6   33 / 35
RL7   37 / 39
RL8   41 / 43

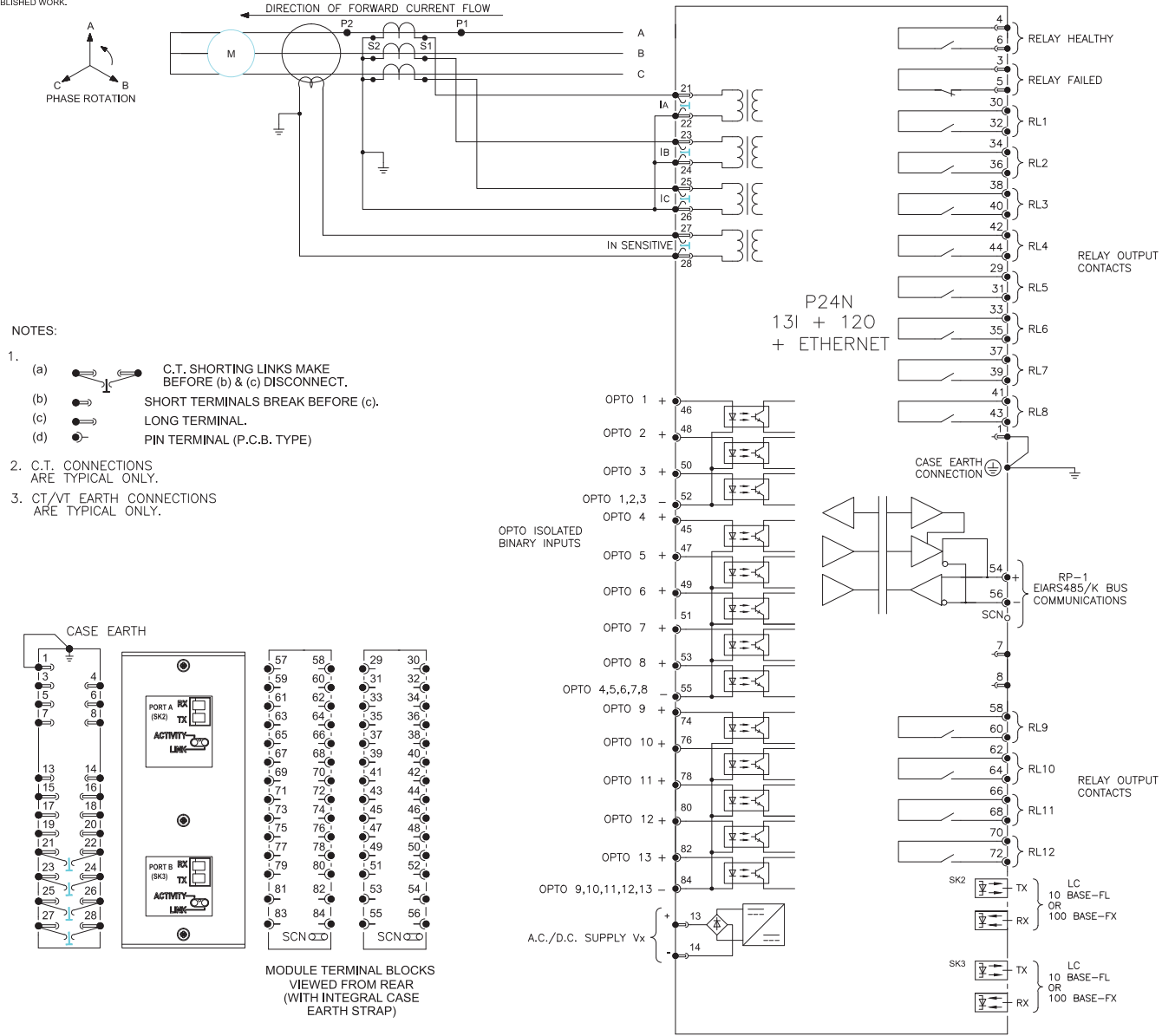RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION   1

NOTES:

1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE).

2. C.T. CONNECTIONS ARE TYPICAL ONLY.

3. CT/VT EARTH CONNECTIONS ARE TYPICAL ONLY.

OPTO 1 +   46
OPTO 2 +   48
OPTO 3 +   50
OPTO 1,2,3 −   52
OPTO 4 +   45
OPTO 5 +   47
OPTO 6 +   49
OPTO 7 +   51
OPTO 8 +   53
OPTO 4,5,6,7,8 −   55
OPTO 9 +   74
OPTO 10 +   76
OPTO 11 +   78
OPTO 12 +   80
OPTO 13 +   82
OPTO 9,10,11,12,13 −   84

OPTO ISOLATED BINARY INPUTS

RP−1 EIARS485/K BUS COMMUNICATIONS
54 +
56 −
SCN

RL9   58 / 60
RL10   62 / 64
RL11   66 / 68
RL12   70 / 72

RELAY OUTPUT CONTACTS

A.C./D.C. SUPPLY Vx   + 13 / − 14

SK2   TX / RX   LC 10 BASE−FL OR 100 BASE−FX

SK3   TX / RX   LC 10 BASE−FL OR 100 BASE−FX

CASE EARTH

1 / 3 / 5 / 7
4 / 6 / 8
PORT A (SK2)   RX / TX   ACTIVITY / LINK
13 / 15 / 17 / 19 / 21 / 23 / 25 / 27
14 / 16 / 18 / 20 / 22 / 24 / 26 / 28
PORT B (SK3)   RX / TX   ACTIVITY / LINK

57 / 59 / 61 / 63 / 65 / 67 / 69 / 71 / 73 / 75 / 77 / 79 / 81 / 83
58 / 60 / 62 / 64 / 66 / 68 / 70 / 72 / 74 / 76 / 78 / 80 / 82 / 84
SCN

29 / 31 / 33 / 35 / 37 / 39 / 41 / 43 / 45 / 47 / 49 / 51 / 53 / 55
30 / 32 / 34 / 36 / 38 / 40 / 42 / 44 / 46 / 48 / 50 / 52 / 54 / 56
SCN

MODULE TERMINAL BLOCKS VIEWED FROM REAR (WITH INTEGRAL CASE EARTH STRAP)

Date: 23/10/2017	Name: V.SIVASAMBO	Drg Title: MOTOR PROTECTION WITH PHASE CURRENT INPUTS & SEF (13 I/P & 12 O/P) & DUAL FIBRE ETHERNET	Next Stage: -	Drg No: 10P24N10-4	ECN No: CID005225	Revision: B	Iteration: 2
Date: 23/10/2017	Chkd: S WOOTTON						
Sub-contractor reference: -		CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: - Angular Tol deg: -	PLM No: A20028776	Sht: 4	Status: IN WORK	
Finish: -					Next Sht: -		

GE Grid Solutions

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

P2   P1

M

S2   S1

A
B
C

SEE NOTES 2 & 3

21
I A
22
23
I B
24
25
I C
26
27
I N
28

RELAY HEALTHY
4
6

RELAY FAILED
3
5

RL1
30
32

RL2
34
36

RL3
38
40

RL4
42
44

RELAY OUTPUT CONTACTS

P24N
3I + 40

NOTES:

1.
(a)   C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b)   SHORT TERMINALS BREAK BEFORE (c).
(c)   LONG TERMINAL.
(d)   PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.
3. EARTH CONNECTIONS ARE TYPICAL ONLY.

OPTO 1+   46
OPTO 2+   48
OPTO 3+   50
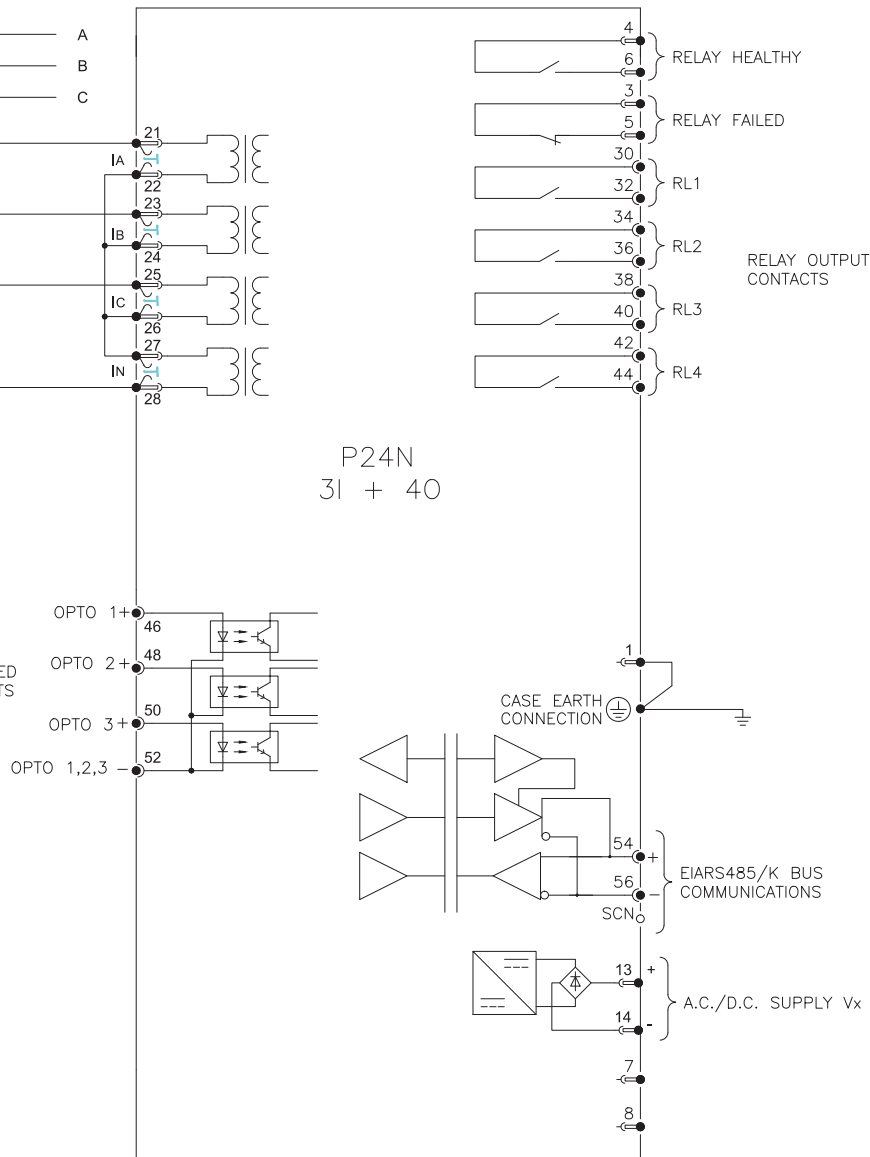OPTO 1,2,3 -   52

OPTO ISOLATED BINARY INPUTS

CASE EARTH CONNECTION
1

CASE EARTH

29   30
31   32
33   34
35   36
37   38
39   40
41   42
43   44
45   46
47   48
49   50
51   52
53   54
55   56

1
3   4
5   6
7   8
9   10
13   14
17   18
19   20
21   22
23   24
25   26
27   28

SCN

MODULE TERMINAL BLOCKS VIEWED FROM REAR (WITH INTEGRAL CASE EARTH STRAP)

EIARS485/K BUS COMMUNICATIONS
54   +
56
SCN

A.C./D.C. SUPPLY Vx
13   +
14   -

7
8

Date: 13/11/2017	Name: V.SIVASAMBO	Drg Title: MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND EARTH FAULT (3 I/P & 4 O/P)	Next Stage: -	Drg No: 10P24N12-1	ECN No: CID005225	Revision: B	Iteration: 2
Date: 13/11/2017	Chkd: S WOOTTON						
Sub-contractor reference: -		CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: - Angular Tol deg: -	GE Grid Solutions	PLM No: A20028950	Sht: 1	Status: IN WORK
Finish: -						Next Sht: -	

PHASE ROTATION

DIRECTION OF FORWARD CURRENT FLOW

P2   P1
A
B
C

S2   S1

M

SEE NOTES 2 & 3

IA   21
     22
IB   23
     24
IC   25
     26
IN   27
     28

P24N
6I + 80
TCS

4
6   RELAY HEALTHY
3
5   RELAY FAILED
30
32   RL1
34
36   RL2
38
40   RL3
42
44   RL4
58
60   RL5
62
64   RL6
66
68   RL7
70
72   RL8

RELAY OUTPUT
CONTACTS

NOTES:

1.
(a)   C.T. SHORTING LINKS MAKE
      BEFORE (b) & (c) DISCONNECT.
(b)   SHORT TERMINALS BREAK BEFORE (c).
(c)   LONG TERMINAL.
(d)   PIN TERMINAL (P.C.B. TYPE)

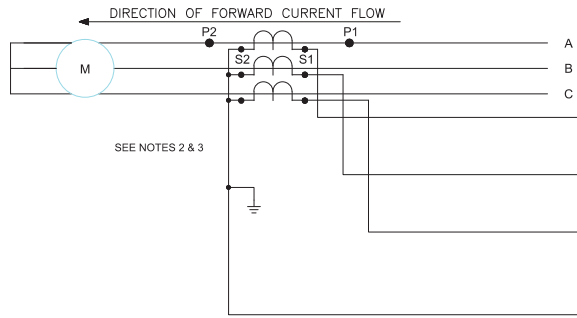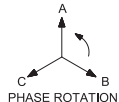2. C.T. CONNECTIONS ARE TYPICAL ONLY.
3. EARTH CONNECTIONS ARE TYPICAL ONLY.

OPTO 1 +   46
OPTO 2 +   48
OPTO 3 +   50
OPTO 1,2,3 −   52

OPTO ISOLATED
BINARY INPUTS

OPTO 4   + 74
           76
OPTO 5   + 78
         − 80
OPTO 6   + 82
           84

1
CASE EARTH
CONNECTION

54 +
56 −   RP−1
SCN   EIARS485/K BUS
         COMMUNICATIONS

13 +
14 −   A.C./D.C. SUPPLY Vx
7
8

CASE EARTH

1
3   4
5   6
7   8
9   10

13   14

17   18
19   20
21   22

23   24
25   26
27   28

57   58
59   60
61   62
63   64
65   66
67   68
69   70
71   72
73   74
75   76
77   78
79   80
81   82
83   84

SCN

29   30
31   32
33   34
35   36
37   38
39   40
41   42
43   44
45   46
47   48
49   50
51   52
53   54
55   56

SCN

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
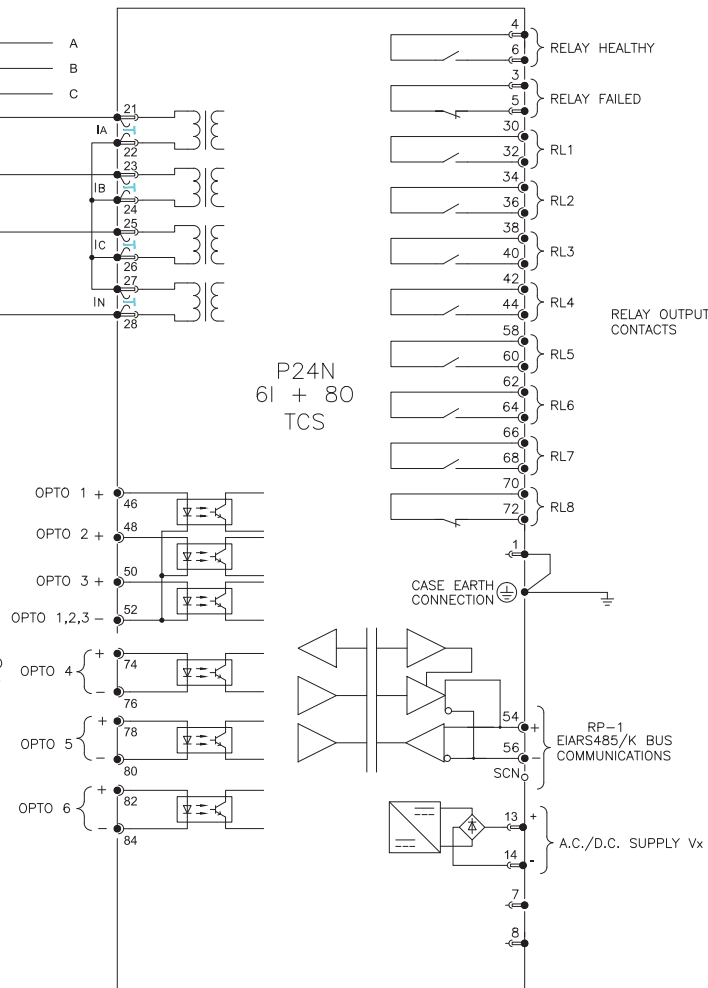(WITH INTEGRAL CASE
EARTH STRAP)

Date:	13/11/2017	Name:	V.SIVASAMBO	Drg Title:	MOTOR PROTECTION WITH PHASE CURRENT INPUTS & EARTH FAULT (6 I/P & 8 O/P) WITH TCS	Next Stage:	-	Drg No:	10P24N13-1	ECN No: CID005225	Revision: B	Iteration: 4

| Date: | 13/11/2017 | Chkd: | S WOOTTON |

| Sub-contractor reference: | - | CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE | Linear Tol mm: - Angular Tol deg: - | Grid Solutions | PLM No: A20028778 | Sht: 1 | Status: IN WORK |
| Finish: | - | | | | | Next Sht: - | |

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

P24N
10I + 12O
+ 2 RS485

RELAY HEALTHY
RELAY FAILED

RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 -

OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8 -

OPTO ISOLATED BINARY INPUTS

RP-1
EIARS485/K BUS COMMUNICATIONS

A.C./D.C. SUPPLY Vx

OPTO 9 +
OPTO 9 -
OPTO 10 +
OPTO 10 -

RL9
RL10
RL11
RL12

RELAY OUTPUT CONTACTS

RP-2
EIARS485/K BUS COMMUNICATIONS

NOTES:
1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.
3. EARTH CONNECTIONS ARE TYPICAL ONLY.

CASE EARTH

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE
EARTH STRAP)

Date: 23/10/2017	Name: V.SIVASAMBO	Drg Title: MOTOR PROTECTION WITH PHASE CURRENT INPUTS & EARTH FAULT (6 I/P & 8 O/P) WITH TCS	Next Stage: -	Drg No: 10P24N14-1	ECN No: CID005225	Revision: B	Iteration: 2
Date: 23/10/2017	Chkd: S WOOTTON						
Sub-contractor reference: -		CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: - / Angular Tol deg: -	Grid Solutions	PLM No: A20028780	Sht: 1	Status: IN WORK
Finish: -					Next Sht: 2		

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

P24N
10I + 12O
+ 2 RS485
+ ETHERNET

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8
RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION
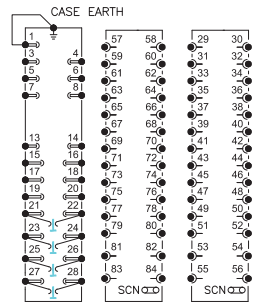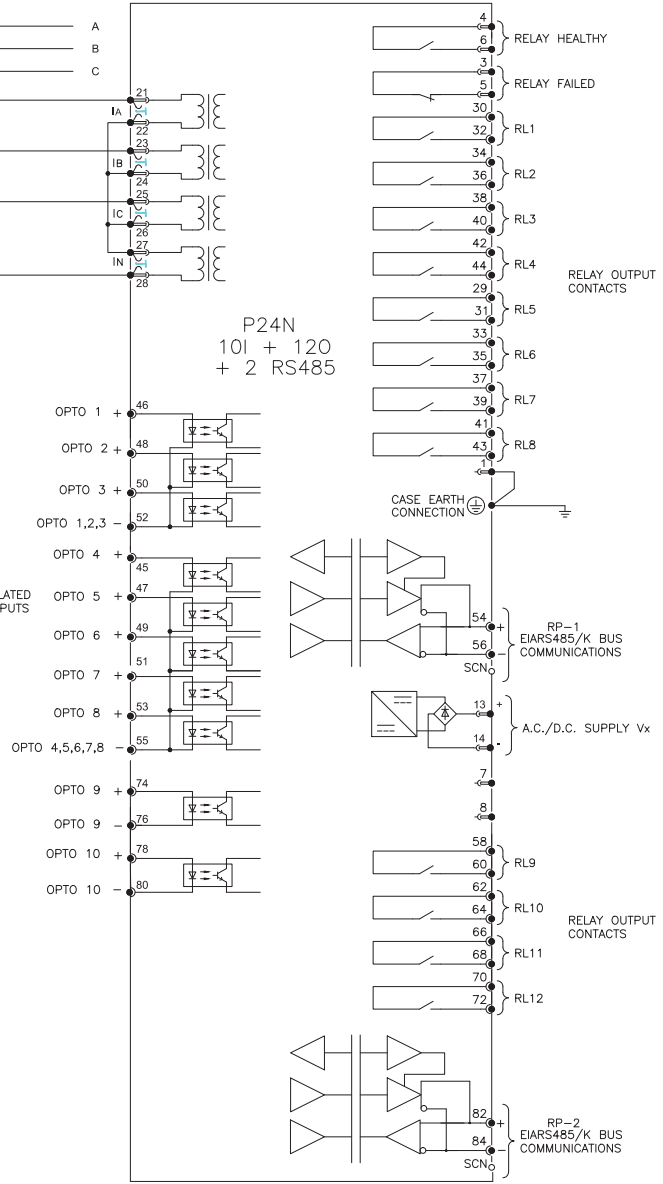
NOTES:

1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.
3. EARTH CONNECTIONS ARE TYPICAL ONLY.

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 -
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8 -
OPTO 9 +
OPTO 9 -
OPTO 10 +
OPTO 10 -

OPTO ISOLATED BINARY INPUTS

CASE EARTH

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE EARTH STRAP)

RP-1
EIARS485/K BUS
COMMUNICATIONS

RL9
RL10
RL11
RL12
RELAY OUTPUT CONTACTS

A.C./D.C. SUPPLY Vx

RP-2
EIARS485/K BUS
COMMUNICATIONS

TX+
TX-
RX+
RX-
RJ45
10 BASE-T/
100 BASE-TX

TX
RX
LC
10 BASE-FL
OR
100 BASE-FX

Date: 07/11/2017	Name: V.SIVASAMBO	Drg Title: MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND E/F (10 I/P & 12 O/P) WITH 2 RS485 & ETHERNET	Next Stage: -	Drg No: 10P24N14 -2	ECN No: CID005225	Revision: B	Iteration: 1
Date: 07/11/2017	Chkd: S WOOTTON						
Sub-contractor reference: -		CAD DATA 1:1 DIMENSIONS: mm	Linear Tol mm: -	PLM No: A20029148	Sht: 2	Status: IN WORK	
Finish: -		DO NOT SCALE	Angular Tol deg: -		Next Sht: 3		

Grid Solutions

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

P24N
10I + 12O
+ 2 RS485
+ ETHERNET

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

RP-1
EIARS485/K BUS
COMMUNICATIONS

RP-2
EIARS485/K BUS
COMMUNICATIONS

RL9
RL10
RL11
RL12

RELAY OUTPUT CONTACTS

OPTO ISOLATED BINARY INPUTS

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 −
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8 −
OPTO 9 +
OPTO 9 +
OPTO 10 +
OPTO 10 +

A.C./D.C. SUPPLY Vx

SK2
TX+
TX−
RX+
RX−
RJ45
10 BASE−T/
100 BASE−TX

SK3
TX+
TX−
RX+
RX−
RJ45
10 BASE−T/
100 BASE−TX

NOTES:

1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.
3. EARTH CONNECTIONS ARE TYPICAL ONLY.

CASE EARTH

ACTIVITY
PORT A
(SK2)

ACTIVITY
PORT B
(SK3)

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE
EARTH STRAP)

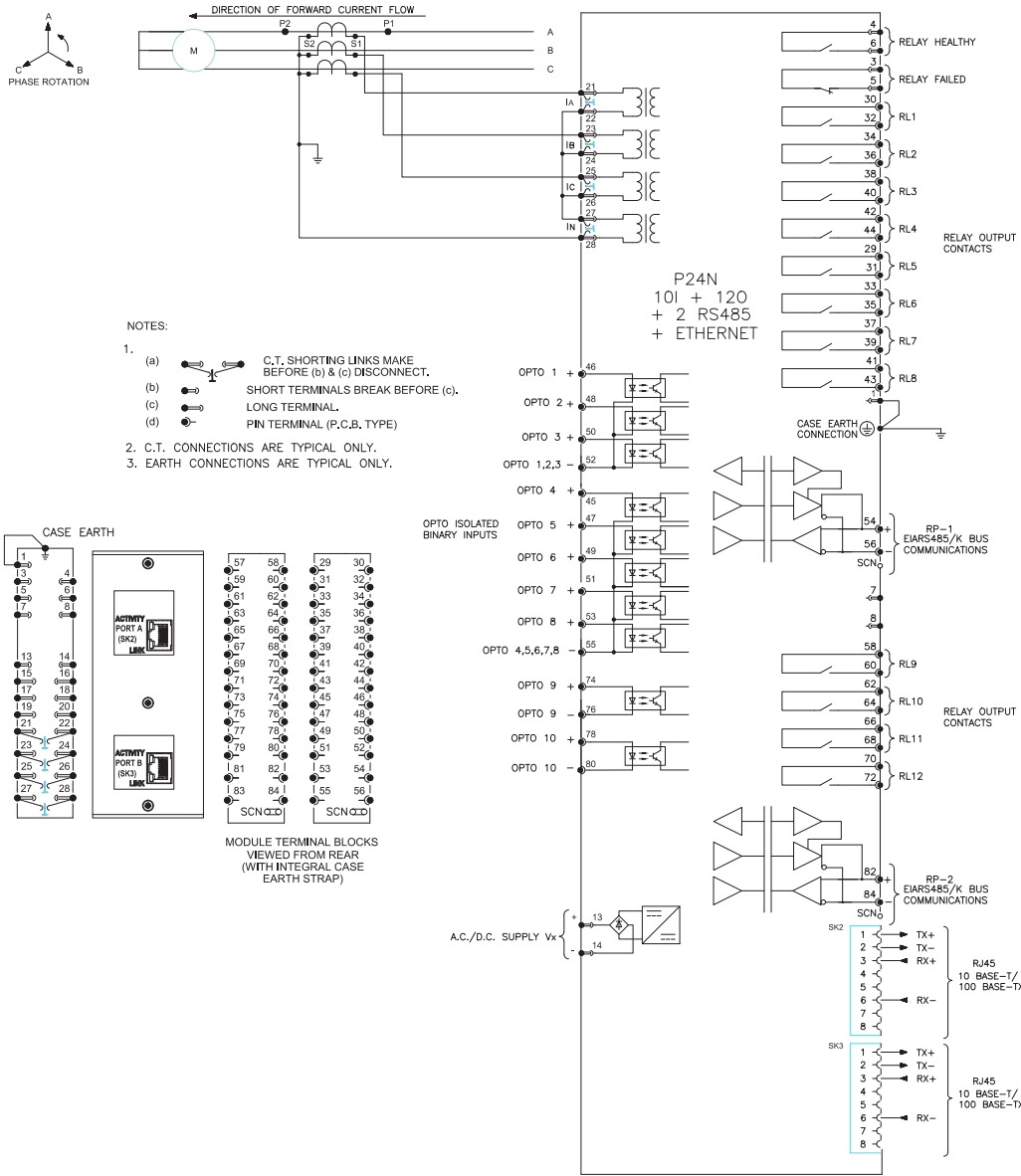| Date:	07/11/2017	Name:	V.SIVASAMBO	Drg Title:	MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND E/F (10 I/P & 12 O/P) WITH 2 RS485 & DUAL COPPER ETHERNET	Next Stage: -	Drg No:	10P24N14 -3	ECN No:	Revision:	Iteration:
Date:	07/11/2017	Chkd:	S WOOTTON						CID005225	B	1
Sub-contractor reference: -				CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: - Angular Tol deg: -	Grid Solutions	PLM No:	A20029152	Sht: 3	Status: IN WORK	
Finish: -									Next Sht: 4		

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

P24N
10I + 12O
+ 2 RS485
+ ETHERNET

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

NOTES:

1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.
3. EARTH CONNECTIONS ARE TYPICAL ONLY.

OPTO ISOLATED BINARY INPUTS

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 −
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8 −
OPTO 9 +
OPTO 9 −
OPTO 10 +
OPTO 10 −

RP−1
EIARS485/K BUS COMMUNICATIONS
SCN

CASE EARTH

PORT A RX TX (SK2)
ACTIVITY LINK

PORT B RX TX (SK3)
ACTIVITY LINK

MODULE TERMINAL BLOCKS VIEWED FROM REAR (WITH INTEGRAL CASE EARTH STRAP)

SCN
SCN

A.C./D.C. SUPPLY Vx

RL9
RL10
RL11
RL12

RELAY OUTPUT CONTACTS

RP−2
EIARS485/K BUS COMMUNICATIONS
SCN

SK2 TX
RX
LC
10 BASE−FL
OR
100 BASE−FX

SK3 TX
RX
LC
10 BASE−FL
OR
100 BASE−FX

Date:	07/11/2017	Name:	V.SIVASAMBO	Drg Title:	MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND E/F (10 I/P & 12 O/P) WITH 2 RS485 & DUAL FIBRE ETHERNET	Next Stage: -	Drg No:	10P24N14 -4	ECN No: CID005225	Revision: B	Iteration: 1
Date:	07/11/2017	Chkd:	S WOOTTON								
Sub-contractor reference: -				CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: - Angular Tol deg: -		PLM No:	A20029154	Sht: 4	Status: IN WORK	
Finish: -						Grid Solutions			Next Sht: -		

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

P24N
10I + 12O
+ 2 RS485

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT
CONTACTS

CASE EARTH
CONNECTION

OPTO 1 +   46
OPTO 2 +   48
OPTO 3 +   50
OPTO 1,2,3 −   52

OPTO ISOLATED
BINARY INPUTS

OPTO 4   45
OPTO 5   47
OPTO 6   49
OPTO 7 +   51
OPTO 8 +   53
OPTO 4,5,6,7,8   55
OPTO 9   74
OPTO 9   76
OPTO 10 +   78
OPTO 10 −   80

RP−1
EIARS485/K BUS
COMMUNICATIONS
SCN

A.C./D.C. SUPPLY Vx

RL9
RL10
RL11
RL12

RELAY OUTPUT
CONTACTS

RP−2
EIARS485/K BUS
COMMUNICATIONS
SCN

NOTES:
1.
(a)   C.T. SHORTING LINKS MAKE
       BEFORE (b) & (c) DISCONNECT.
(b)   SHORT TERMINALS BREAK BEFORE (c).
(c)   LONG TERMINAL.
(d)   PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.
3. EARTH CONNECTIONS ARE TYPICAL ONLY.

CASE EARTH

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE
EARTH STRAP)

Date:	07/11/2017	Name:	V.SIVASAMBO	Drg Title:	MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND SEF (10 I/P & 12 O/P) WITH 2 RS485	Next Stage:	-	Drg No:	10P24N15-1	ECN No: CID005225	Revision: B	Iteration: 1
Date:	07/11/2017	Chkd:	S WOOTTON									

Sub-contractor reference: -
Finish: -

CAD DATA 1:1 DIMENSIONS: mm
DO NOT SCALE

Linear Tol mm: -
Angular Tol deg: -

Grid Solutions

PLM No: A20029157

Sht: 1
Next Sht: 2

Status: IN WORK

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

M

P24N
10I + 12O
+ 2 RS485
+ ETHERNET

IA 21
22
IB 23
24
IC 25
26
27
IN SENSITIVE 28

RELAY HEALTHY 4 / 6
RELAY FAILED 3 / 5
RL1 30 / 32
RL2 34 / 36
RL3 38 / 40
RL4 42 / 44
RL5 29 / 31
RL6 33 / 35
RL7 37 / 39
RL8 41 / 43

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

OPTO 1 + 46
OPTO 2 + 48
OPTO 3 + 50
OPTO 1,2,3 − 52

OPTO ISOLATED BINARY INPUTS

OPTO 4 + 45
OPTO 5 + 47
OPTO 6 + 49
OPTO 7 + 51
OPTO 8 + 53
OPTO 4,5,6,7,8 − 55
OPTO 9 + 74
OPTO 9 − 76
OPTO 10 + 78
OPTO 10 − 80

RP−1
EIARS485/K BUS COMMUNICATIONS
54 / 56
SCN

RL9 58 / 60
RL10 62 / 64
RL11 66 / 68
RL12 70 / 72

RELAY OUTPUT CONTACTS

7 / 8

A.C./D.C. SUPPLY Vx 13 / 14

RP−2
EIARS485/K BUS COMMUNICATIONS
82 / 84
SCN

1 TX+
2 TX−
3 RX+
4
5 RX−
6
7
8

RJ45
10 BASE−T/
100 BASE−TX

TX LC
10 BASE−FL
OR
RX 100 BASE−FX

NOTES:
1.
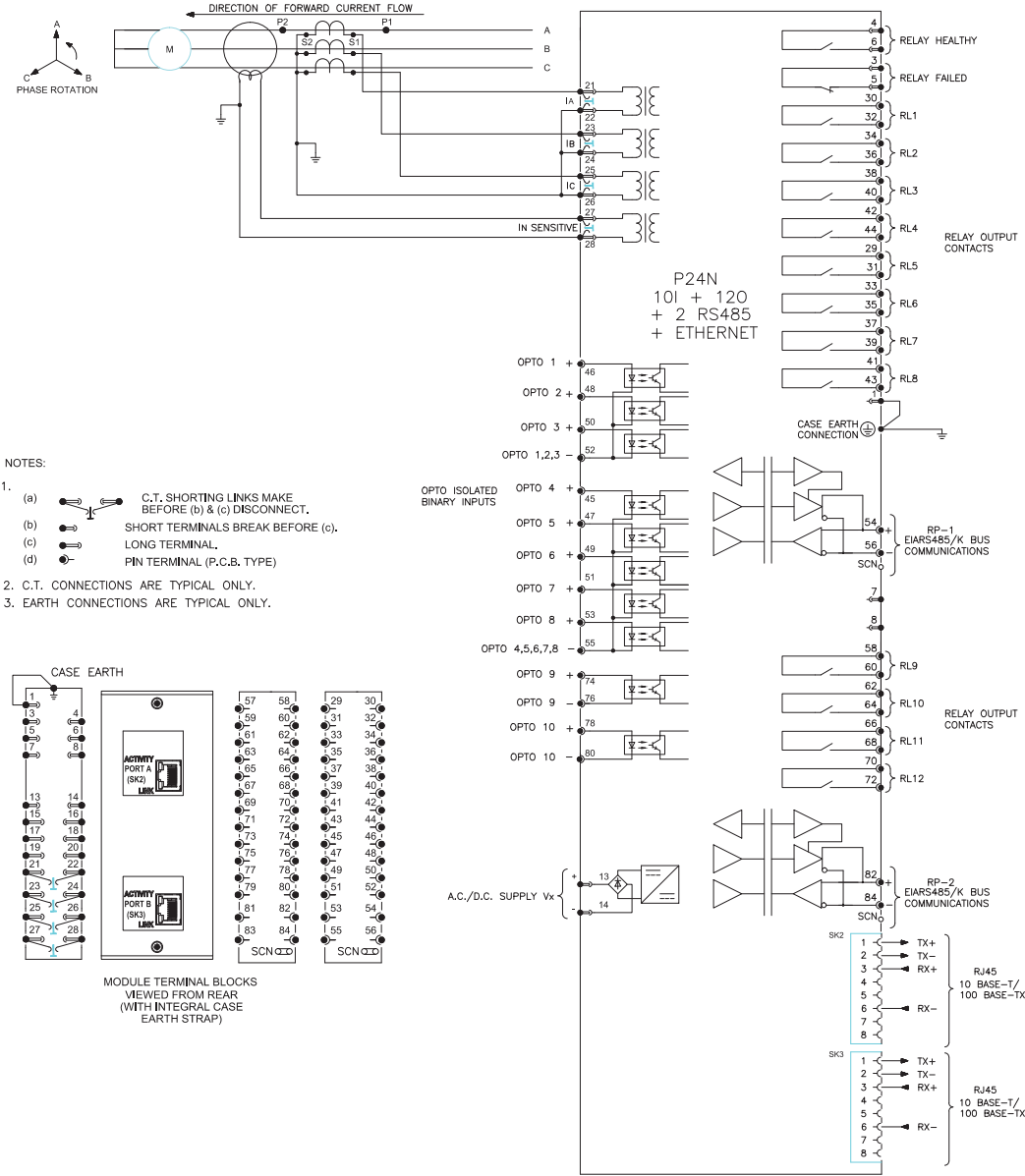(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.
3. EARTH CONNECTIONS ARE TYPICAL ONLY.

CASE EARTH

LINK
ACTIVITY
PORT A
(SK2) TX
RX

ACTIVITY
PORT B
(SK3)
LINK

SCN SCN

MODULE TERMINAL BLOCKS
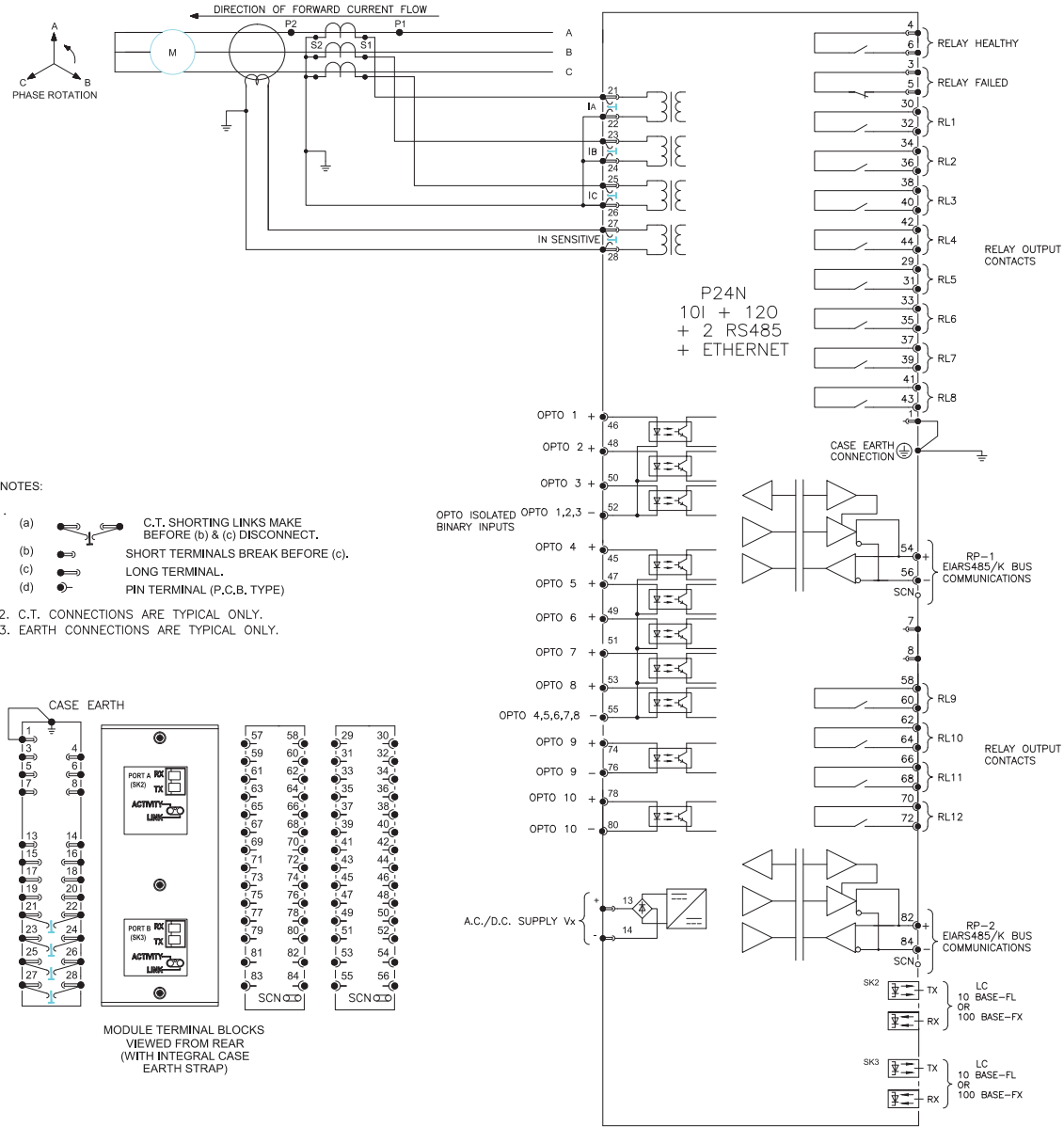VIEWED FROM REAR
(WITH INTEGRAL CASE
EARTH STRAP)

Date: 07/11/2017	Name: V.SIVASAMBO	Drg Title: MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND SEF (10 I/P & 12 O/P) WITH 2 RS485 & ETHERNET	Next Stage: -	Drg No: 10P24N15-2	ECN No: CID005225	Revision: B	Iteration: 1
Date: 07/11/2017	Chkd: S WOOTTON						
Sub-contractor reference: -		CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: -	Grid Solutions	PLM No: A20029159	Sht: 2	Status: IN WORK
Finish: -			Angular Tol deg: -			Next Sht: 3	

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

P24N
10I + 12O
+ 2 RS485
+ ETHERNET

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RELAY OUTPUT CONTACTS
RL5
RL6
RL7
RL8

CASE EARTH CONNECTION

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO 1,2,3 −
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8 −
OPTO 9 +
OPTO 9 −
OPTO 10 +
OPTO 10 −

OPTO ISOLATED BINARY INPUTS

RP-1 EIARS485/K BUS COMMUNICATIONS

RL9
RL10
RELAY OUTPUT CONTACTS
RL11
RL12

A.C./D.C. SUPPLY Vx

RP-2 EIARS485/K BUS COMMUNICATIONS

SK2
RJ45 10 BASE-T/ 100 BASE-TX
TX+
TX−
RX+
RX−

SK3
RJ45 10 BASE-T/ 100 BASE-TX
TX+
TX−
RX+
RX−

NOTES:
1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.
3. EARTH CONNECTIONS ARE TYPICAL ONLY.

CASE EARTH

ACTIVITY PORT A (SK2)

ACTIVITY PORT B (SK3)

MODULE TERMINAL BLOCKS VIEWED FROM REAR (WITH INTEGRAL CASE EARTH STRAP)

Date:	07/11/2017	Name:	V.SIVASAMBO	Drg Title:	MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND SEF (10 I/P & 12 O/P) WITH 2 RS485 & DUAL COPPER ETHERNET	Next Stage: -		Drg No: 10P24N15-3	ECN No: CID005225	Revision: B	Iteration: 1
Date:	07/11/2017	Chkd:	S WOOTTON								
Sub-contractor reference: -				CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE		Linear Tol mm: - Angular Tol deg: -	Grid Solutions	PLM No: A20029161	Sht: 3	Status: IN WORK	
Finish: -								Next Sht: 4		

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

P24N
10I + 12O
+ 2 RS485
+ ETHERNET

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

OPTO 1 +
OPTO 2 +
OPTO 3 +
OPTO ISOLATED OPTO 1,2,3 –
BINARY INPUTS

OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 8 +
OPTO 4,5,6,7,8 –

OPTO 9 +
OPTO 9 –
OPTO 10 +
OPTO 10 –

RP–1
EIARS485/K BUS
COMMUNICATIONS
SCN

RL9
RL10
RL11
RL12

RELAY OUTPUT CONTACTS

RP–2
EIARS485/K BUS
COMMUNICATIONS
SCN

A.C./D.C. SUPPLY Vx

SK2   TX
LC
10 BASE–FL
OR
100 BASE–FX
RX

SK3   TX
LC
10 BASE–FL
OR
100 BASE–FX
RX

NOTES:
1.
(a)   C.T. SHORTING LINKS MAKE
       BEFORE (b) & (c) DISCONNECT.
(b)   SHORT TERMINALS BREAK BEFORE (c).
(c)   LONG TERMINAL.
(d)   PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.
3. EARTH CONNECTIONS ARE TYPICAL ONLY.

CASE EARTH

PORT A RX
(SK2) TX
ACTIVITY
LINK

PORT B RX
(SK3) TX
ACTIVITY
LINK

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE
EARTH STRAP)

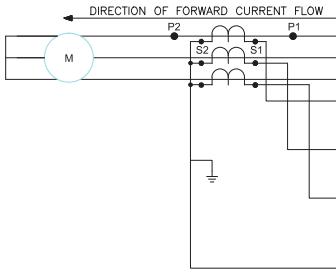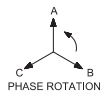| Date: 07/11/2017 | Name: V.SIVASAMBO | Drg Title: | Next Stage: - | Drg No: 10P24N15-4 | ECN No: CID005225 | Revision: B | Iteration: 1 |
Date: 07/11/2017	Chkd: S WOOTTON	MOTOR PROTECTION WITH PHASE CURRENT INPUTS AND SEF (10 I/P & 12 O/P) WITH 2 RS485 & DUAL FIBRE ETHERNET					
Sub-contractor reference: -		CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: -	Grid Solutions	PLM No: A20029163	Sht: 4	Status: IN WORK
Finish: -			Angular Tol deg: -			Next Sht: -	

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

RELAY HEALTHY

RELAY FAILED

RL1

RL2

RL3

RL4

RL5

RL6

RL7

RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

P24N
12I + 12O

NOTES:

1.
(a)   C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b)   SHORT TERMINALS BREAK BEFORE (c).
(c)   LONG TERMINAL.
(d)   PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.

3. EARTH CONNECTIONS ARE TYPICAL ONLY.

OPTO ISOLATED BINARY INPUTS

OPTO 1 +   46
OPTO 1 −   48
OPTO 2 +   50
OPTO 2 −   52
OPTO 3 +   45
OPTO 4 +   47
OPTO 5 +   49
OPTO 6 +   51
OPTO 7 +   53
OPTO 3,4,5,6,7   55
OPTO 8 +   74
OPTO 9 +   76
OPTO 10 +   78
OPTO 11 +   80
OPTO 12 +   82
OPTO 8,9,10,11,12   84

A.C./D.C. SUPPLY Vx   13   14

RP-1
EIARS485/K BUS COMMUNICATIONS

54
56
SCN

RL9
RL10
RL11
RL12

RELAY OUTPUT CONTACTS

CASE EARTH

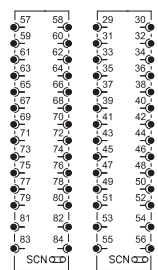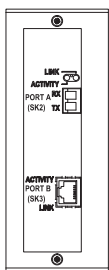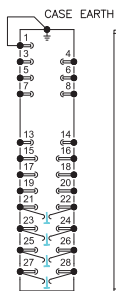MODULE TERMINAL BLOCKS VIEWED FROM REAR (WITH INTEGRAL CASE EARTH STRAP)

Date:	23/10/2017	Name:	V.SIVASAMBO	Drg Title:	MOTOR PROTECTION WITH PHASE CURRENT INPUTS & E/F (10 I/P & 12 O/P) WITH 2 RS485	Next Stage:		Drg No:	10P24N16-1	ECN No:	CID005225	Revision: B	Iteration: 2
Date:	23/10/2017	Chkd:	S WOOTTON										
Sub-contractor reference: -				CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE		Linear Tol mm: -		PLM No:	A20028783	Sht: 1		Status: IN WORK
Finish: -						Angular Tol deg: -				Next Sht: 2		

Grid Solutions

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

P24N
12I + 12O
+ ETHERNET

RELAY HEALTHY
RELAY FAILED
RL1
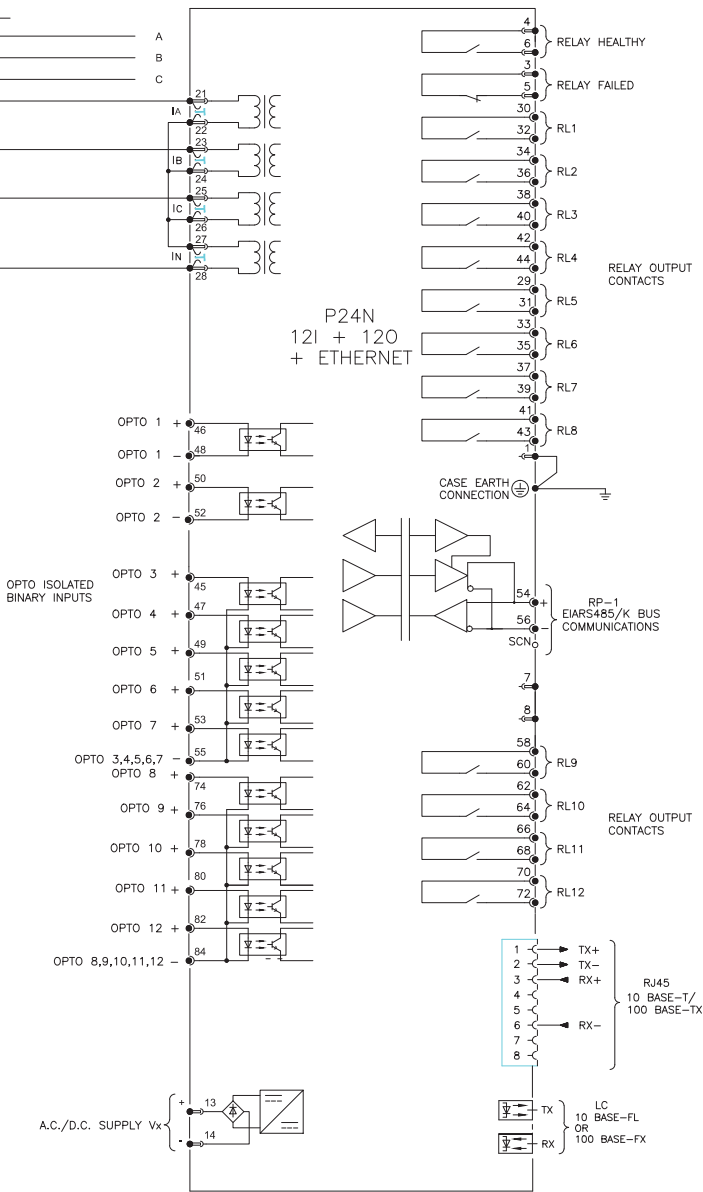RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

NOTES:
1.
(a)   C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b)   SHORT TERMINALS BREAK BEFORE (c).
(c)   LONG TERMINAL.
(d)   PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.

3. EARTH CONNECTIONS ARE TYPICAL ONLY.

OPTO 1 +   46
OPTO 1 -   48
OPTO 2 +   50
OPTO 2 -   52

CASE EARTH CONNECTION

OPTO ISOLATED BINARY INPUTS

OPTO 3 +   45
OPTO 4 +   47
OPTO 5 +   49
OPTO 6 +   51
OPTO 7 +   53

OPTO 3,4,5,6,7 -   55

RP-1
EIARS485/K BUS COMMUNICATIONS
54 +
56 -
SCN

CASE EARTH

LINK
ACTIVITY
PORT A RX
(SK2) TX

ACTIVITY
PORT B
(SK3) LINK

OPTO 8 +   74
OPTO 9 +   76
OPTO 10 +   78
OPTO 11 +   80
OPTO 12 +   82

OPTO 8,9,10,11,12 -   84

RL9
RL10
RL11
RL12

RELAY OUTPUT CONTACTS

MODULE TERMINAL BLOCKS VIEWED FROM REAR (WITH INTEGRAL CASE EARTH STRAP)

RJ45
10 BASE-T/
100 BASE-TX

1   TX+
2   TX-
3   RX+
4
5
6   RX-
7
8

A.C./D.C. SUPPLY Vx   13   14

LC
10 BASE-FL
OR
100 BASE-FX

TX
RX

PHASE ROTATION

DIRECTION OF FORWARD CURRENT FLOW

A
B
C

P2   P1
S2   S1

IA 21
    22
IB 23
    24
IC 25
    26
IN 27
    28

P24N
12I + 12O
+ ETHERNET

RELAY HEALTHY   4 / 6
RELAY FAILED   3 / 5

RL1   30 / 32
RL2   34 / 36
RL3   38 / 40
RL4   42 / 44
RL5   29 / 31
RL6   33 / 35
RL7   37 / 39
RL8   41 / 43

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

NOTES:
1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

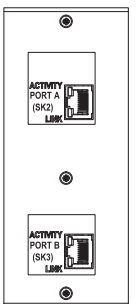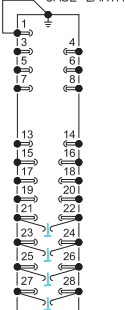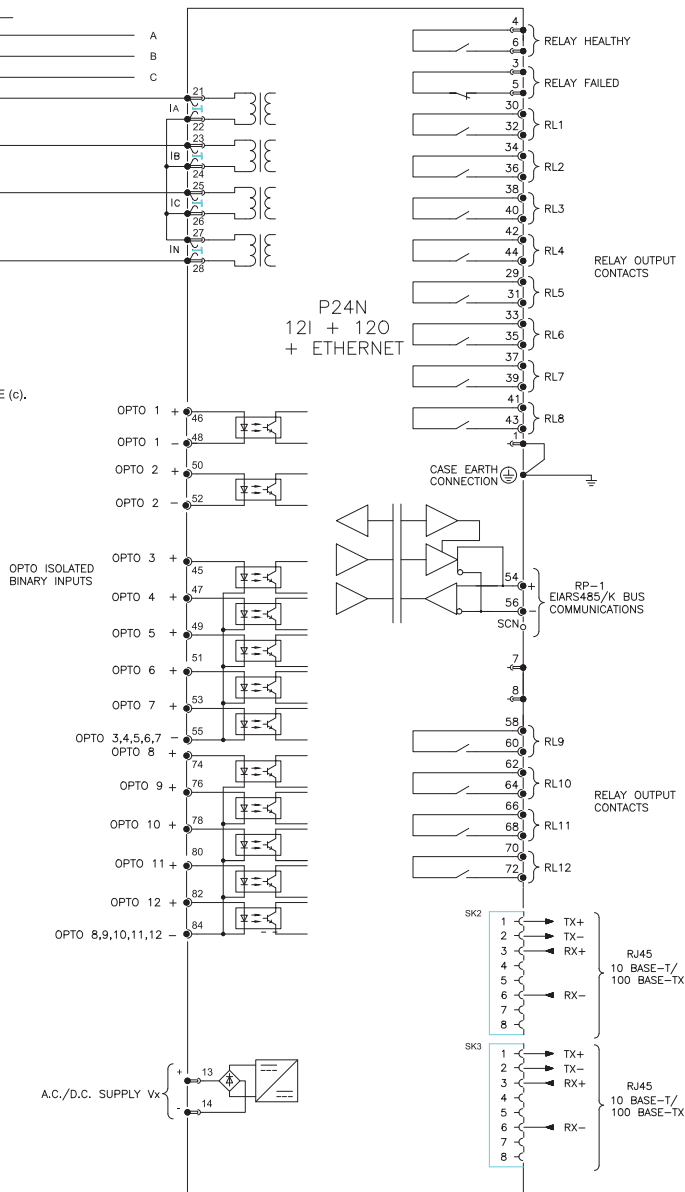2. C.T. CONNECTIONS ARE TYPICAL ONLY.

3. EARTH CONNECTIONS ARE TYPICAL ONLY.

OPTO 1 +   46
OPTO 1 −   48
OPTO 2 +   50
OPTO 2 −   52

OPTO ISOLATED BINARY INPUTS

OPTO 3 +   45
OPTO 4 +   47
OPTO 5 +   49
OPTO 6 +   51
OPTO 7 +   53
OPTO 3,4,5,6,7 −   55
OPTO 8 +   74
OPTO 9 +   76
OPTO 10 +   78
OPTO 11 +   80
OPTO 12 +   82
OPTO 8,9,10,11,12 −   84

54 / 56   RP−1 EIARS485/K BUS COMMUNICATIONS
SCN

7 / 8

RL9   58 / 60
RL10   62 / 64
RL11   66 / 68
RL12   70 / 72

RELAY OUTPUT CONTACTS

CASE EARTH

1   3   4
5   6
7   8
13   14
15   16
17   18
19   20
21   22
23   24
25   26
27   28

ACTIVITY PORT A (SK2) LINK

ACTIVITY PORT B (SK3) LINK

57 58   29 30
59 60   31 32
61 62   33 34
63 64   35 36
65 66   37 38
67 68   39 40
69 70   41 42
71 72   43 44
73 74   45 46
75 76   47 48
77 78   49 50
79 80   51 52
81 82   53 54
83 84   55 56
SCN   SCN

MODULE TERMINAL BLOCKS VIEWED FROM REAR (WITH INTEGRAL CASE EARTH STRAP)

SK2
1   TX+
2   TX−
3   RX+
4
5
6   RX−
7
8
RJ45 10 BASE−T/ 100 BASE−TX

SK3
1   TX+
2   TX−
3   RX+
4
5
6   RX−
7
8
RJ45 10 BASE−T/ 100 BASE−TX

A.C./D.C. SUPPLY Vx   +13 / −14

Date: 23/10/2017	Name: V.SIVASAMBO	Drg Title: MOTOR PROTECTION WITH PHASE CURRENT INPUTS & E/F (10 I/P & 12 O/P) WITH 2 RS485 & DUAL COPPER ETHERNET	Next Stage: -	Drg No: 10P24N16-3	ECN No: CID005225	Revision: B	Iteration: 2
Date: 23/10/2017	Chkd: S WOOTTON						
Sub-contractor reference: -		CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: - / Angular Tol deg: -	Grid Solutions	PLM No: A20028787	Sht: 3 / Next Sht: 4	Status: IN WORK
Finish: -							

PHASE ROTATION

DIRECTION OF FORWARD CURRENT FLOW

P24N
12I + 12O
+ ETHERNET

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

NOTES:

1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.
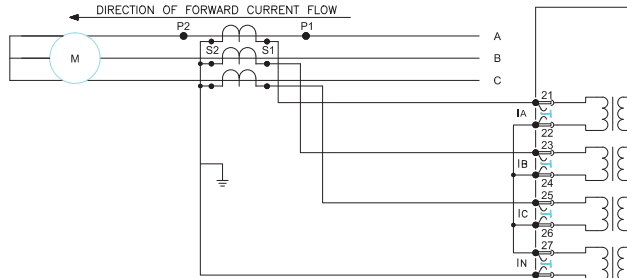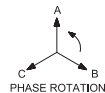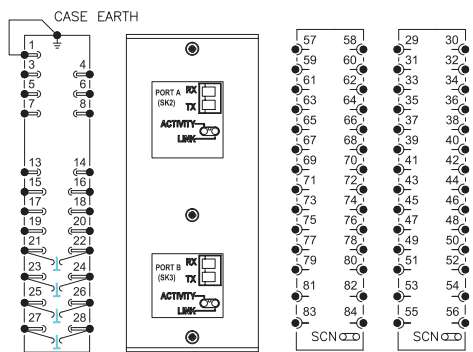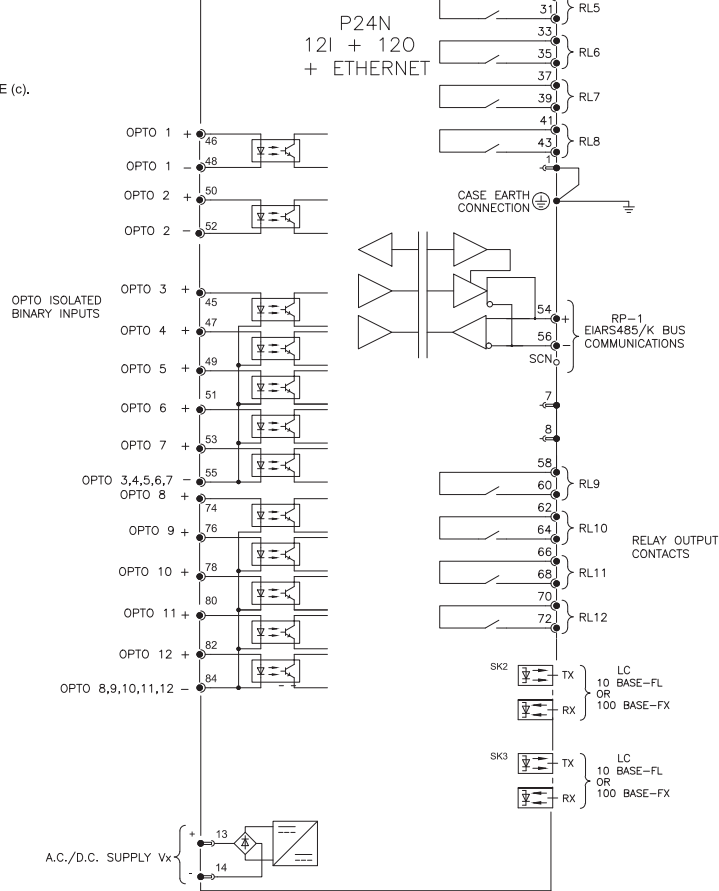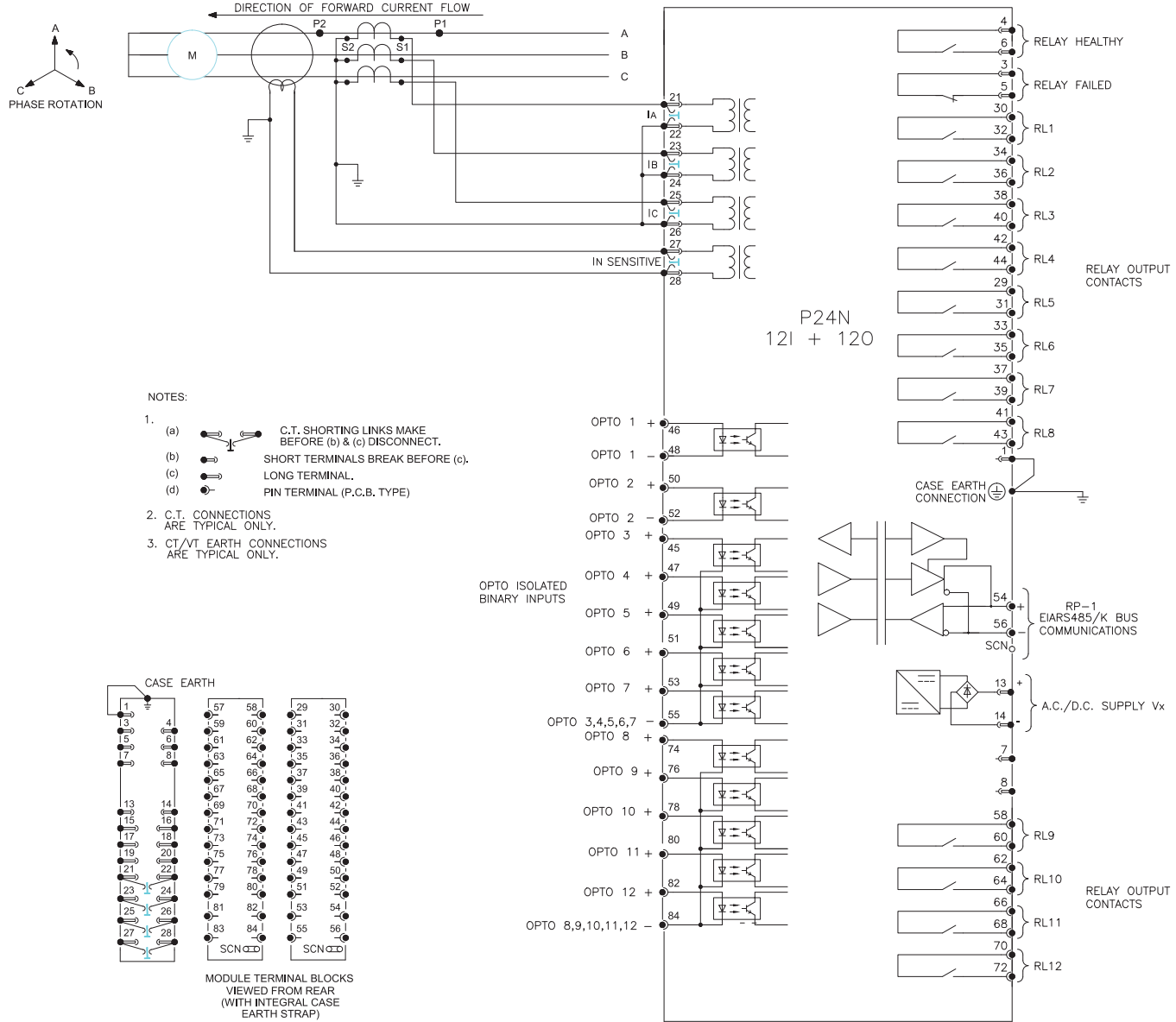
3. EARTH CONNECTIONS ARE TYPICAL ONLY.

OPTO 1 +   46
OPTO 1 −   48
OPTO 2 +   50
OPTO 2 −   52

OPTO ISOLATED BINARY INPUTS

OPTO 3 +   45
OPTO 4 +   47
OPTO 5 +   49
OPTO 6 +   51
OPTO 7 +   53
OPTO 3,4,5,6,7   55
OPTO 8 +   74
OPTO 9 +   76
OPTO 10 +   78
OPTO 11 +   80
OPTO 12 +   82
OPTO 8,9,10,11,12 −   84

RP−1 EIARS485/K BUS COMMUNICATIONS

RL9
RL10
RL11
RL12

RELAY OUTPUT CONTACTS

SK2 TX
LC
10 BASE−FL
OR
100 BASE−FX
RX

SK3 TX
LC
10 BASE−FL
OR
100 BASE−FX
RX

CASE EARTH

PORT A RX
(SK2) TX
ACTIVITY
LINK

PORT B RX
(SK3) TX
ACTIVITY
LINK

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE
EARTH STRAP)

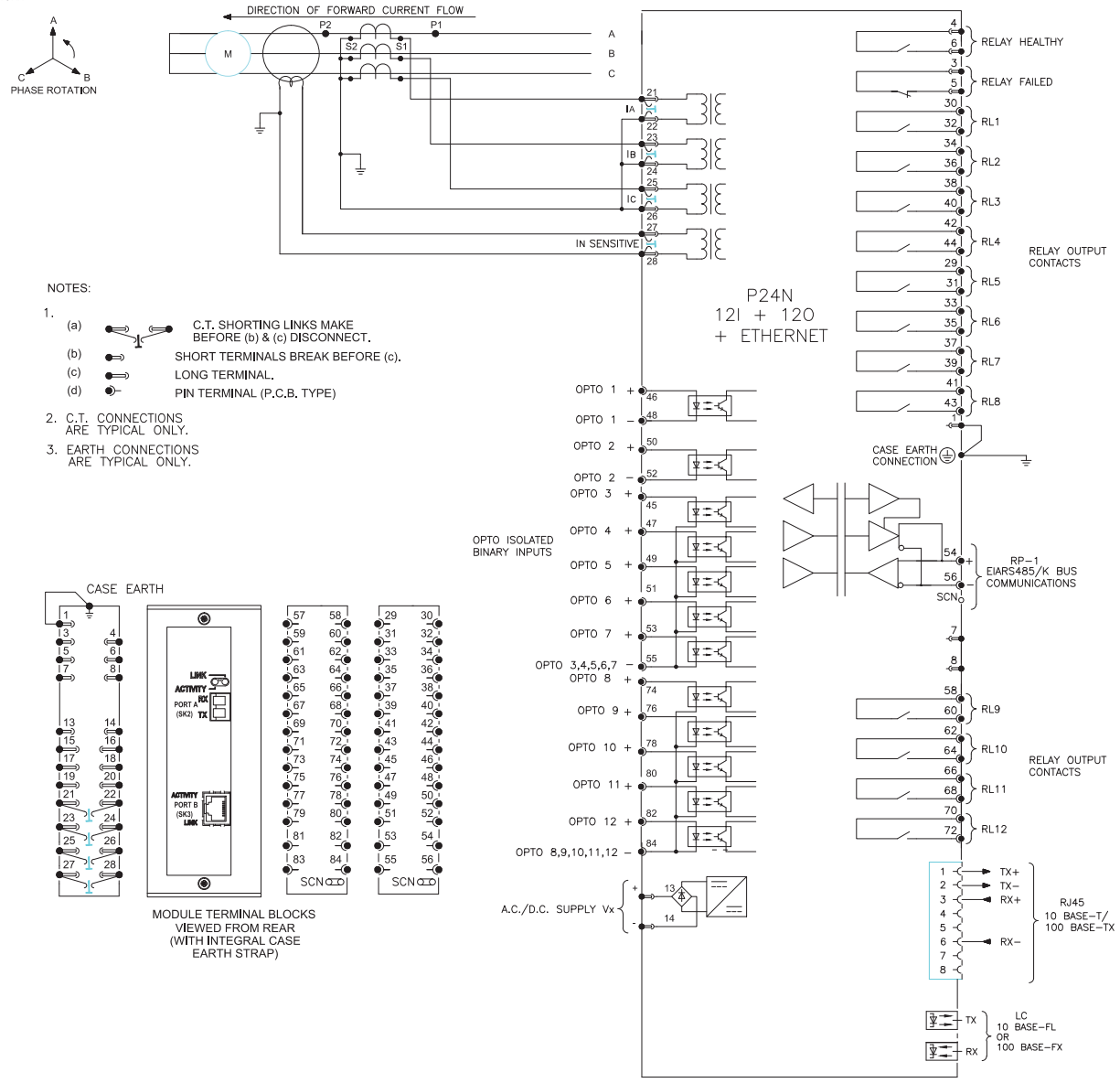A.C./D.C. SUPPLY Vx   13   14

| Date: | 23/10/2017 | Name: | V.SIVASAMBO | Drg Title: | MOTOR PROTECTION WITH PHASE CURRENT INPUTS & E/F (10 I/P & 12 O/P) WITH 2 RS485 & DUAL FIBRE ETHERNET | Next Stage: - | Drg No: 10P24N16-4 | ECN No: CID005225 | Revision: B | Iteration: 2 |
| Date: | 23/10/2017 | Chkd: | S WOOTTON | | | | | | | |

| Sub-contractor reference: - | CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE | Linear Tol mm: - | Grid Solutions | PLM No: A20028789 | Sht: 4 | Status: IN WORK |
| Finish: - | | Angular Tol deg: - | | | Next Sht: - | |

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

P24N
12I + 12O

RELAY HEALTHY

RELAY FAILED

RL1

RL2

RL3

RL4

RL5

RL6

RL7

RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

RP-1
EIARS485/K BUS COMMUNICATIONS
SCN

A.C./D.C. SUPPLY Vx

RL9

RL10

RL11

RL12

RELAY OUTPUT CONTACTS

NOTES:

1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.

3. CT/VT EARTH CONNECTIONS ARE TYPICAL ONLY.

OPTO ISOLATED BINARY INPUTS

OPTO 1 +
OPTO 1 −
OPTO 2 +
OPTO 2 −
OPTO 3 +
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 3,4,5,6,7 −
OPTO 8 +
OPTO 9 +
OPTO 10 +
OPTO 11 +
OPTO 12 +
OPTO 8,9,10,11,12 −

CASE EARTH

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE EARTH STRAP)
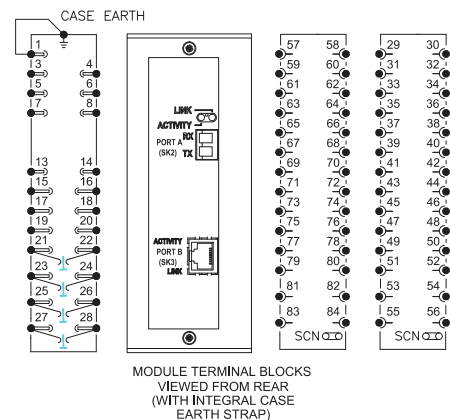
IA
IB
IC
IN SENSITIVE

Date:	24/10/2017	Name:	V.SIVASAMBO	Drg Title:	MOTOR PROTECTION WITH PHASE CURRENT INPUTS & SEF (10 I/P & 12 O/P) WITH 2 RS485	Next Stage: -	Drg No:	10P24N17-1	ECN No: CID005225	Revision: B	Iteration: 2
Date:	24/10/2017	Chkd:	S WOOTTON								

Sub-contractor reference: -	CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: - Angular Tol deg: -	Grid Solutions	PLM No:	A20028791	Sht: 1	Status: IN WORK
Finish: -						Next Sht: 2	

DIRECTION OF FORWARD CURRENT FLOW
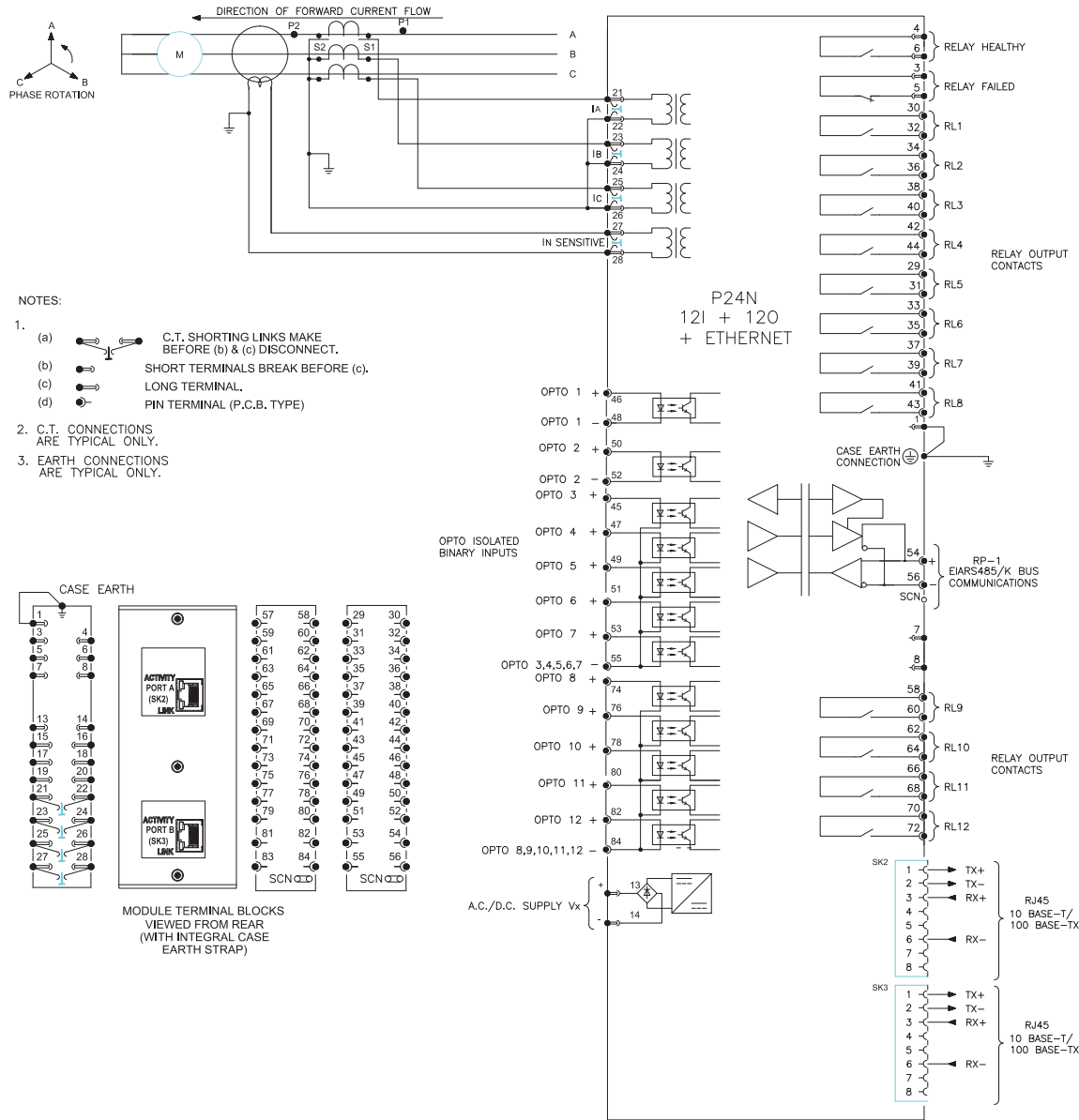
PHASE ROTATION

P24N
12I + 12O
+ ETHERNET

NOTES:

1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.

3. EARTH CONNECTIONS ARE TYPICAL ONLY.

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

OPTO ISOLATED BINARY INPUTS

RP−1 EIARS485/K BUS COMMUNICATIONS

CASE EARTH

MODULE TERMINAL BLOCKS VIEWED FROM REAR (WITH INTEGRAL CASE EARTH STRAP)

RL9
RL10
RL11
RL12

RELAY OUTPUT CONTACTS

A.C./D.C. SUPPLY Vx

RJ45
10 BASE−T/
100 BASE−TX

TX+
TX−
RX+
RX−
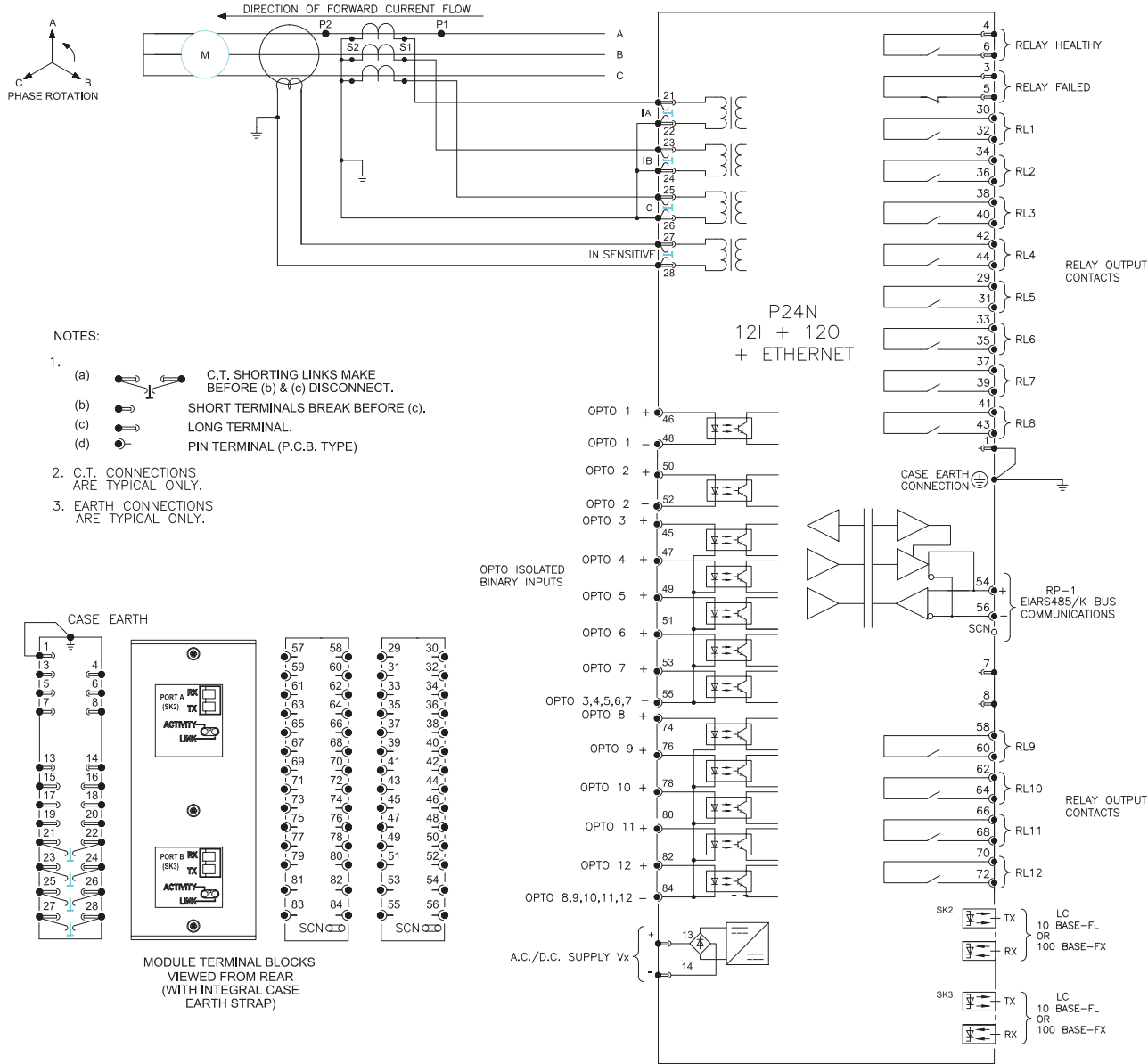
LC
10 BASE−FL
OR
100 BASE−FX

Date: 23/10/2017	Name: V.SIVASAMBO	Drg Title: MOTOR PROTECTION WITH PHASE CURRENT INPUTS & SEF (10 I/P & 12 O/P) WITH 2 RS485 & ETHERNET	Next Stage: -	Drg No: 10P24N17-2	ECN No: CID005225	Revision: B	Iteration: 2
Date: 23/10/2017	Chkd: S WOOTTON						
Sub-contractor reference: -		CAD DATA 1:1 DIMENSIONS: mm DO NOT SCALE	Linear Tol mm: - Angular Tol deg: -	GE Grid Solutions	PLM No: A20028793	Sht: 2	Status: IN WORK
Finish: -						Next Sht: 3	

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

M

P2 S2 S1 P1

A
B
C

IA — 21 / 22
IB — 23 / 24
IC — 25 / 26
IN SENSITIVE — 27 / 28

P24N
12I + 12O
+ ETHERNET

RELAY HEALTHY — 4 / 6
RELAY FAILED — 3 / 5
RL1 — 30 / 32
RL2 — 34 / 36
RL3 — 38 / 40
RL4 — 42 / 44
RL5 — 29 / 31
RL6 — 33 / 35
RL7 — 37 / 39
RL8 — 41 / 43

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION — 1

NOTES:

1.
(a) C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b) SHORT TERMINALS BREAK BEFORE (c).
(c) LONG TERMINAL.
(d) PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.

3. EARTH CONNECTIONS ARE TYPICAL ONLY.

OPTO ISOLATED BINARY INPUTS

OPTO 1 + — 46
OPTO 1 − — 48
OPTO 2 + — 50
OPTO 2 − — 52
OPTO 3 + — 45
OPTO 4 + — 47
OPTO 5 + — 49
OPTO 6 + — 51
OPTO 7 + — 53
OPTO 3,4,5,6,7 − — 55
OPTO 8 + — 74
OPTO 9 + — 76
OPTO 10 + — 78
OPTO 11 + — 80
OPTO 12 + — 82
OPTO 8,9,10,11,12 − — 84

RP−1
EIARS485/K BUS COMMUNICATIONS — 54 / 56
SCN
7 / 8

RL9 — 58 / 60
RL10 — 62 / 64
RL11 — 66 / 68
RL12 — 70 / 72

RELAY OUTPUT CONTACTS

A.C./D.C. SUPPLY Vx — 13 / 14

CASE EARTH

ACTIVITY PORT A (SK2) LINK
ACTIVITY PORT B (SK3) LINK

MODULE TERMINAL BLOCKS VIEWED FROM REAR (WITH INTEGRAL CASE EARTH STRAP)

SCN
SCN

SK2
1 — TX+
2 — TX−
3 — RX+
4
5
6 — RX−
7
8
RJ45 10 BASE−T/ 100 BASE−TX

SK3
1 — TX+
2 — TX−
3 — RX+
4
5
6 — RX−
7
8
RJ45 10 BASE−T/ 100 BASE−TX

| Date: | 24/10/2017 | Name: | V.SIVASAMBO | Drg Title: | MOTOR PROTECTION WITH PHASE CURRENT INPUTS & SEF (10 I/P & 12 O/P) WITH 2 RS485 & DUAL COPPER ETHERNET | Next Stage: | - | Drg No: | 10P24N17-3 | ECN No: CID005225 | Revision: B | Iteration: 2 |
| Date: | 24/10/2017 | Chkd: | S WOOTTON | | | | | | | | |

Sub-contractor reference: -
Finish: -

CAD DATA 1:1 DIMENSIONS: mm
DO NOT SCALE

Linear Tol mm: -
Angular Tol deg: -

GE Grid Solutions

PLM No: A20028795

Sht: 3
Next Sht: 4

Status: IN WORK

DIRECTION OF FORWARD CURRENT FLOW

PHASE ROTATION

P24N
12I + 12O
+ ETHERNET

RELAY HEALTHY
RELAY FAILED
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8

RELAY OUTPUT CONTACTS

CASE EARTH CONNECTION

NOTES:

1.
(a)   C.T. SHORTING LINKS MAKE BEFORE (b) & (c) DISCONNECT.
(b)   SHORT TERMINALS BREAK BEFORE (c).
(c)   LONG TERMINAL.
(d)   PIN TERMINAL (P.C.B. TYPE)

2. C.T. CONNECTIONS ARE TYPICAL ONLY.

3. EARTH CONNECTIONS ARE TYPICAL ONLY.

OPTO ISOLATED BINARY INPUTS

OPTO 1 +
OPTO 1 -
OPTO 2 +
OPTO 2 -
OPTO 3 +
OPTO 4 +
OPTO 5 +
OPTO 6 +
OPTO 7 +
OPTO 3,4,5,6,7
OPTO 8 +
OPTO 9 +
OPTO 10 +
OPTO 11 +
OPTO 12 +
OPTO 8,9,10,11,12 -

RP-1
EIARS485/K BUS COMMUNICATIONS
SCN

CASE EARTH

PORT A (SK2)
RX TX
ACTIVITY
LINK

PORT B (SK3)
RX TX
ACTIVITY
LINK

MODULE TERMINAL BLOCKS
VIEWED FROM REAR
(WITH INTEGRAL CASE EARTH STRAP)

SCN   SCN

RL9
RL10
RL11
RL12

RELAY OUTPUT CONTACTS

A.C./D.C. SUPPLY Vx

SK2   TX   LC 10 BASE-FL OR 100 BASE-FX
RX

SK3   TX   LC 10 BASE-FL OR 100 BASE-FX
RX

Date: 24/10/2017	Name: V.SIVASAMBO	Drg Title: MOTOR PROTECTION WITH PHASE CURRENT INPUTS & SEF (10 I/P & 12 O/P) WITH 2 RS485 & DUAL FIBRE ETHERNET	Next Stage: -	Drg No: 10P24N17-4	ECN No: CID005225	Revision: B	Iteration: 2
Date: 24/10/2017	Chkd: S WOOTTON						

Imagination at work

Grid Solutions
St Leonards Building
Redhill Business Park
Stafford, ST16 1WT, UK
+44 (0) 1785 250 070
contact.centre@ge.com

P24xM-TM-EN-2.1