MiCOM P40 Agile

P241, P242, P243

Technical Manual
Rotating Machine Protection Relay

Hardware version: J and K
Software version: 70
Publication reference: P24x/EN M/J82

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SAFETY SECTION

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1. 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.

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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.

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

Risk of electric shock

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

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

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4.   INSTALLING, 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

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

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

	Always use the equipment as specified. Failure to do so will jeopardise the protection provided by the equipment.

	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.

	Isolate the equipment before working on the terminal strips.

	Use a suitable protective barrier for areas with restricted space, where there is a risk of electric shock due to exposed terminals.

	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.

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

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Testing may leave capacitors charged to dangerous voltage levels. Discharge capacitors by reducing test voltages to zero before disconnecting test leads.

Operate the equipment within the specified electrical and environmental limits.

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

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.

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).

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

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).

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.

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.

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

4.5 Equipment Connections

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

⚠ 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.

⚠ Always use insulated crimp terminations for voltage and current connections.

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

⚠ 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

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

⚠ Do not remove the PCT.

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

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

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> 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.

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

> 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

> Check voltage rating/polarity (rating label/equipment documentation).

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

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

> Check integrity of the PCT connection.

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

4.8 Peripheral Circuitry

> 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.

> *For most GE 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.*

> 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.

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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.

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.

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

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.

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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.

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5.   DECOMMISSIONING AND DISPOSAL

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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.

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.

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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.

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INTRODUCTION

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FIGURES

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1 MICOM DOCUMENTATION STRUCTURE

The technical manual provides a functional and technical description of the MiCOM protection relay as well as a comprehensive set of instructions for using the device.

The chapter contents are summarized below:

P24x/EN IT   Introduction
A guide to the MiCOM range of relays and the documentation structure. Also a general functional overview of the relay and brief application summary is given.

P24x/EN TD   Technical Data
Technical data including setting ranges, accuracy limits, recommended operating conditions, ratings and performance data. Compliance with norms and international standards is quoted where appropriate.

P24x/EN GS   Getting Started
A guide to the different user interfaces of the protection relay describing how to start using it. This chapter provides detailed information regarding the communication interfaces of the relay.

P24x/EN ST   Settings
List of all relay settings, including ranges, step sizes and defaults, together with a brief explanation of each setting.

P24x/EN OP   Operation
A comprehensive and detailed functional description of all protection and non-protection functions.

P24x/EN AP   Application Notes
This chapter includes a description of common power system applications of the relay, calculation of suitable settings, some typical worked examples, and how to apply the settings to the relay.

P24x/EN PL   Programmable Logic
Overview of the programmable scheme logic and a description of each logical node.

P24x/EN MR   Measurements and Recording
Detailed description of the relays recording and measurements functions including the configuration of the event and disturbance recorder and measurement functions.

P24x/EN FD   Firmware Design
Overview of the operation of the relay's hardware and software. This chapter includes information on the self-checking features and diagnostics of the relay.

P24x/EN CM   Commissioning
Instructions on how to commission the relay, comprising checks on the calibration and functionality of the relay.

P24x/EN MT   Maintenance
A general maintenance policy for the relay is outlined.

P24x/EN TS   Troubleshooting
Advice on how to recognize failure modes and the recommended course of action. Includes guidance on who in GE to contact for advice.

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P24x/EN SC   SCADA Communications

This chapter provides an overview regarding the SCADA communication interfaces of the relay. Detailed protocol mappings, semantics, profiles and interoperability tables are not provided within this manual. Separate documents are available per protocol, available for download from our website.

P24x/EN SG   Symbols and Glossary

List of common technical abbreviations found within the product documentation.

P24x/EN IN   Installation

Recommendations on unpacking, handling, inspection and storage of the relay. A guide to the mechanical and electrical installation of the relay is provided, incorporating earthing recommendations.

P24x/EN VH   Firmware and Service Manual Version History

History of all hardware and software releases for the product.

Appendix A   Ordering Options

A snapshot of the CORTEC is supplied as a static table in the Appendices of this document.

Appendix B   Wiring Diagrams

All external wiring connections to the relay are included.

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2 INTRODUCTION TO MICOM

MiCOM is a comprehensive solution capable of meeting all electricity supply requirements. It comprises a range of components, systems and services from General Electric.

Central to the MiCOM concept is flexibility.

MiCOM provides the ability to define an application solution and, through extensive communication capabilities, integrate it with your power supply control system.

The components within MiCOM are:

- P range protection relays;
- C range control products;
- M range measurement products for accurate metering and monitoring;
- S range versatile PC support and substation control packages.

MiCOM products include extensive facilities for recording information on the state and behavior of the power system using disturbance and fault records. They can also provide measurements of the system at regular intervals to a control center enabling remote monitoring and control to take place.

For up-to-date information on any MiCOM product, visit our website.

2.1 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 Data chapter.

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3   PRODUCT SCOPE

The MiCOM P241/2/3 universal motor protection relays have been developed and designed for the protection of medium sized to large rotating machines, both synchronous and Induction.

The P243 can offer motor differential protection, providing the neutral star point of the machine is accessible, in addition to the features of the P241/2.

The P242/3 also includes 10 function keys for integral scheme or operator control functionality and tri-color (red/yellow/green) LEDs.

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.

3.2   Legacy Front Panel Compatibility

Two front panel options are available with this software version. They are as follows:

- Black and silver front panel, USB type B, internal supercapacitor
- White front panel, lithium battery backup, front panel serial and parallel port options

All available mounting options are listed in the Cortec, which can be found in the Ordering Options Appendix.

Functional parity between the white and the black/silver front panel IEDs is maintained using an internal supercapacitor, which replaces the lithium battery, and a front panel USB type B port for communications.

> **Note:**   To maintain software compatibility, IEDs will refer to the 'Battery' when a supercapacitor is fitted, as this provides backup battery functionality in the black and silver front panel versions.

3.3   Functional Overview

The P241/2/3 universal motor protection relays contain a wide variety of protection functions. The protection features are summarized below:

PROTECTION FUNCTIONS OVERVIEW		P24x
87	Three-phase machine differential protection is provided to detect stator phase faults. The differential protection can be selected as percentage biased or high impedance.	3
50/51	Four non-directional overcurrent protection stages are provided for protection against three-phase and phase-earth short circuit faults. Stage 1 and 2 may be set Inverse Definite Minimum Time (IDMT) or Definite Time (DT); stages 3 and 4 may be set DT only.	1/2/3
50N/51N	Two stages of earth fault protection are provided for stator earth faults. Each stage can be set to either non-directional or directional forward. Stage 1 can be set Inverse Definite Minimum Time (IDMT) or Definite Time (DT). Stage 2 can be set Definite Time (DT) only. The earth fault current can be detected using internally derived current from the 3 phases.	1/2/3

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PROTECTION FUNCTIONS OVERVIEW		P24x
50N/51N/67N	Two stages of sensitive earth fault protection are provided. Each stage can be set to either non-directional or directional forward. Stage 1 can be set Inverse Definite Minimum Time (IDMT) or Definite Time (DT). `Stage 2 can be set to Definite Time (DT) only. The earth fault current is detected by using current measured from a sensitive current input,	1/2/3
32N/64N	The sensitive earth fault element can also be configured as a wattmetric element suitable for Petersen Coil earthed systems. This form of protection uses the same sensitive earth fault directional characteristic but with a current, voltage and residual power threshold.	1/2/3
32R	One stage of reverse power protection is provided, which measures active power to detect power flow from the motor to the system when the busbar is lost.	1/2/3
37	Two stages of under power are used to detect a loss of load due to a shaft failure or a pump running unprimed. This feature is disabled during starting	1/2/3
40	A two stage offset mho definite time impedance element is provided to detect failure of the machine excitation. A power factor alarm element is also available to offer more sensitive protection.	1/2/3
49	Thermal overload protection based on I1 and I2 is provided to protect the stator/rotor against overloading due to balanced and unbalanced currents. Both alarm and trip stages are provided.	1/2/3
46	Two negative phase sequence overcurrent elements are provided to detect a phase failure or unbalanced load. Stage 1 can be set Definite Time (DT) only and Stage 2 can be set Inverse Definite Minimum Time (IDMT) only.	1/2/3
55	Two stages (lag and Lead) of power factor protection are provided for out-of-step protection on synchronous machines. Both stages can be set to Definite Time (DT) only. Requires breaker status (52a) to operate.	1/2/3
59N	Residual overvoltage protection is available for stator earth fault protection where there is an isolated or high impedance earth. The residual voltage can be measured from a residual voltage input or can be calculated from the three phase to neutral voltage measurements. Two independent stages of protection are provided for each measured neutral voltage input and also for the calculated value, Stage 1 can be selected as either Inverse Definite Minimum Time (IDMT) or Definite Time (DT). Stage 2 can be selected as Definite Time (DT) only	1/2/3
27	A 2 stage undervoltage protection element, phase to neutral or phase to phase measuring is provided. Stage 1 may be selected as either IDMT or DT and stage 2 is DT only.	1/2/3
59	A 2 stage overvoltage protection element, phase to neutral or phase to phase measuring is provided. Both stages can be selected as DT only.	1/2/3
47/27	One stage of three phase voltage check element is provided. It monitors the input voltage magnitude and phase sequence to ensure they are correct before allowing the machine to start. Input voltage rotation is checked by monitoring positive sequence voltage > Negative sequence voltage.	1/2/3
47	Two definite time stages of negative sequence overvoltage are provided.	1/2/3
81U	2 stages of definite time underfrequency protection are provided to protect machines against loss of supply. This feature is disabled during starting.	1/2/3
48/51LR	A starting current detector and a starting time delay protects the motor from excessively long starts. This protection function is activated either by the 52a contact, the starting current or both the 52a contact and the starting current.	1/2/3
14	Where the motor stall withstand time may be shorter than the starting time, a digital input is provided to accommodate a speed switch to distinguish between start and stall.	1/2/3
50S	A stall during running is given by a current exceeding the programmed current threshold following a successful start.	1/2/3

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PROTECTION FUNCTIONS OVERVIEW		P24x
66	For the number of starts limitation protection a separate count of "hot" and "cold" starts is maintained by the relay using the data held in the motor thermal replica. Starting is blocked if the permitted number of starts is exceeded by the use of a time between starts timer.	1/2/3
27 (remanent)	Used to detect when the rotor has completely stopped, in order to allow re-starting of the motor. Operation can be triggered by either a remanant voltage threshold or by a time delay.	1/2/3
RTD	10 RTDs (PT100/Ni100/Ni120) are provided to monitor the temperature accurately in the windings and bearings of the machine. Each RTD has an instantaneous alarm and definite time trip stage.	Option 1/2/3
50BF	A 2 stage circuit breaker failure function is provided.	1/2/3
47	Both input voltage phase rotation and magnitude are monitored to ensure they are correct before allowing the machine to start.	1/2/3
VTS	Voltage transformer supervision is provided (1, 2 & 3 phase fuse failure detection) to prevent mal-operation of voltage dependent protection elements upon loss of a VT input signal.	1/2/3
CTS	Current transformer supervision is provided to prevent mal-operation of current dependent protection elements upon loss of a CT input signal. CTS is provided for both sets of 3 phase CTs in the P243 relay.	1/2/3
CLIO	4 analog (or current loop) inputs are provided for transducers (vibration, tachometers etc.). Each input has a definite time trip and alarm stage. Each input can be independently selected as 0-1/0-10/0-20/4-20 mA. 4 analogue (or current loop) outputs are provided for the analogue measurements in the relay. Each output can be independently selected as 0-1/0-10/0-20/4-20 mA.	Option 1/2/3
	A facility is provided using an offline graphical programmable curve tool. This enables the user to configure a customized multiples of a current setting versus operating time curve and an associated reset curve. Two pairs of configurable operate-reset curves are made available to the user, one pair for thermal and one pair for overcurrent or sensitive/derived earth fault protection. The curves can be defined as a number of curve points or a user defined formula. The curves can then be downloaded to the relay and can also be extracted from the relay. The user programmable curves are available for Thermal, first and second stage overcurrent, first stage sensitive earth fault and first stage derived earth fault protection functions. To find out how to use the tool, see the *Px4x/EN UPCT/B11* document.	1/2/3
	A phase rotation facility (ABC/ACB) is provided to maintain correct operation of all the protection functions even when the motor is running in a reverse direction. This is achieved through user configurable settings available to two setting groups.	1/2/3
	Reacceleration, Low Voltage Ride Through and Auto Re-start functions are provided following a voltage reduction in the system.	1/2/3
	Programmable function keys	10 (P242/3)
	Programmable LEDs (tri-color P242/3, red P241)	18 (P242/3) 8 (P241)
	Digital inputs (order option)	8 to 16
	Output relays (order option)	7 to 16
	Front communication port (EIA(RS)232)	1/2/3
	NERC Compliant cyber-security	
	Rear IEC 61850 Ethernet communication port.	Option 1/2/3
	Redundant IEC 61850 Ethernet communication port.	Option 1/2/3
	Time synchronization port (IRIG-B)	Option 1/2/3

The P24x supports the following relay management functions in addition to the functions shown above.

- Measurement of all instantaneous & integrated values
- Circuit breaker, status & condition monitoring
- Trip circuit and coil supervision (using PSL)
- 2 Alternative setting groups
- Control inputs
- Programmable Scheme Logic
- Programmable allocation of digital inputs and outputs
- Sequence of event recording
- Comprehensive disturbance recording (waveform capture)
- Fault recording
- Fully customizable menu texts
- Multi-level password protection
- Power-up diagnostics and continuous self-monitoring of relay
- Commissioning test facilities
- Real time clock/time synchronization - time synchronization possible from IRIG-B input, opto input or communications
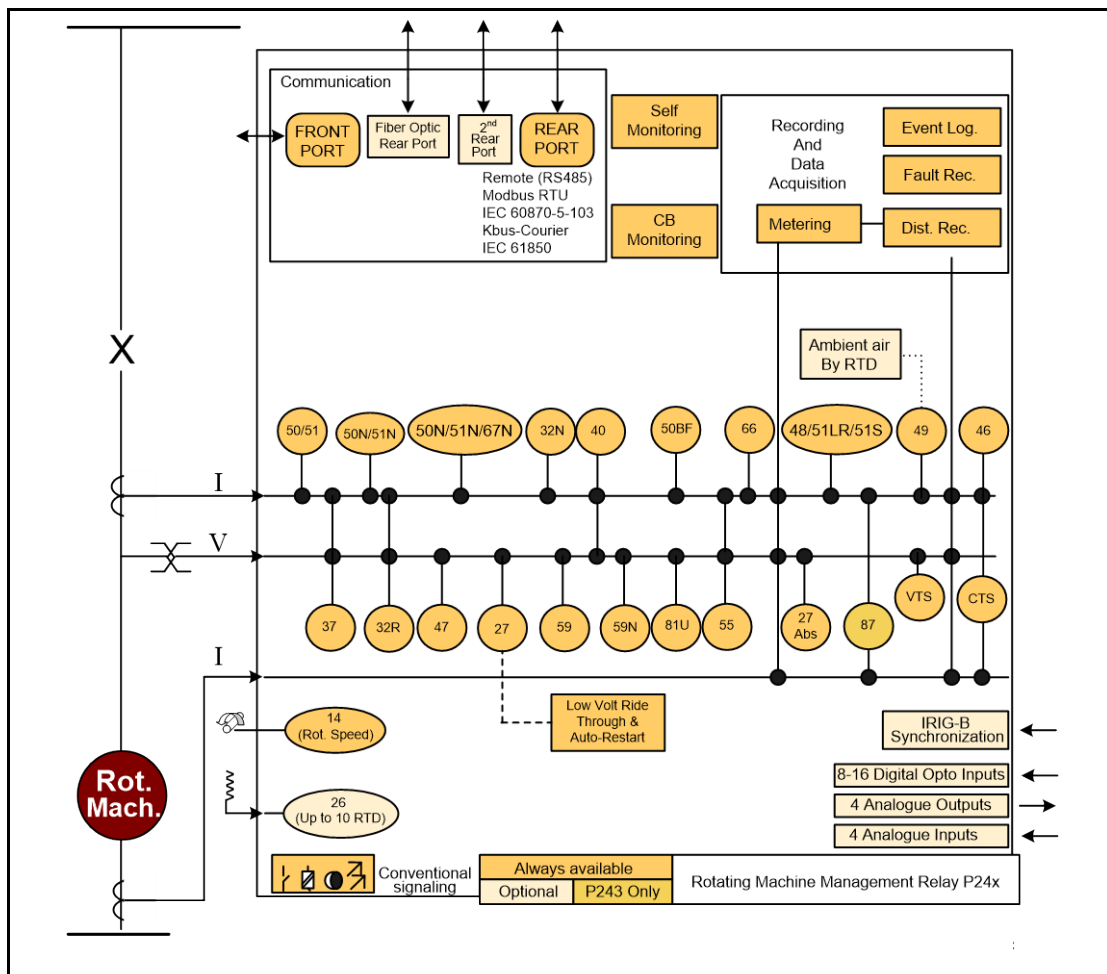
3.4 Application Overview

Figure 1: Functional diagram

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TD

TECHNICAL DATA

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Technical data

Mechanical Specifications

Design

Modular MiCOM Px40 platform relay, P241 in 40TE case, P242 in 60TE case, P243 in 80TE case.
Mounting is front of panel flush mounting or 19" rack mounted (ordering options).

Enclosure Protection

Per IEC 60529:1989/A2:2013
IP 52 Protection (front panel) against dust and dripping water,
IP 50 Protection for rear and sides of the case, against dust,
IP 10 Protection Product safety protection for the rear due to live connections on the terminal block.

Weight

P241 (40TE): 7.3kg
P242 (60TE): 9.2kg (with RTD, CLIO cards)
P243 (80TE): 11.5kg (with RTD, CLIO cards)

Terminals

AC Current and Voltage Measuring Inputs

Located on heavy duty (black) terminal block:
Threaded M4 terminals, for ring lug connection.
CT inputs have integral safety shorting, upon removal of the terminal block.

General Input/Output Terminals

For power supply, opto inputs, output contacts and RP1 rear communications.
Located on general purpose (grey) blocks:
Threaded M4 terminals, for ring lug connection.

Case Protective Earth Connection

Two rear stud connections, threaded M4.
Must be earthed (grounded) for safety, minimum earth wire size 2.5 mm^2.

Front USB Port*

EIA(RS)232 DCE, USB type B
Courier protocol for interface to MiCOM S1 Agile software.
Isolation to ELV (extra low voltage) level.
Maximum cable length 5 m.
*Only available on the Black/silver front panel.

Front Port Serial PC Interface

EIA(RS)232 DCE, 9 pin D-type female connector Socket SK1.
Courier protocol for interface to MiCOM S1 Agile software.
Isolation to ELV (extra low voltage) level.
Maximum cable length 15 m.
*Only available on the white front panel.

Front Download/Monitor Port*

EIA(RS)232, 25 pin D-type female connector Socket SK2.
For firmware and menu text downloads.
Isolation to ELV level.
*Only available on the white front panel.

Rear IRIG-B interface modulated or un-modulated

BNC plug
Isolation to SELV level.
50 ohm coaxial cable.

Optional rear redundant Ethernet connection for IEC 61850 (2 Fibre Optic or 2 RJ45 ports)

100 base FX interface

Interface in accordance with IEEE802.3 and IEC 61850
Wavelength: 1300 nm
Fiber: multi-mode 50/125 μm or 62.5/125 μm
Connector style: BFOC 2.5 -(ST®)
Transmitter optical characteristics 100 base FX interface

Parameter	Sym	Min	Typ	Max	Unit
Output Optical Power BOL 62.5/125 μm, NA = 0.275 Fiber EOL	PO	-19 -20	-16.8	-14	dBm avg.
Output Optical Power BOL 50/125 μm, NA = 0.20 Fiber 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 ("0")			-45	dBm avg.

BOL - Beginning of life
EOL - End of life

Receiver optical characteristics 100 base FX interface

Parameter	Sym	Min	Typ	Max	Unit
Input Optical	PIN Min.		-33.5	-31	dBm avg.

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Power Minimum at Window Edge	(W)			
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.

TD

Fiber defect connector (watchdog relay) – redundant Ethernet board

Connector (3 terminals):   2 NC contacts
Rated voltage: 250 V
Continuous current: 5 A
Short-duration current: 30 A for 3 s
Breaking capacity:
  DC: 50 W resistive
  DC: 25 W inductive (L/R = 40 ms)
  AC: 1500 VA resistive (cos ϕ = unity)
  AC: 1500 VA inductive (cos ϕ = 0.5)
Subject to maxima of 5 A and 250 V

10BaseT/100BaseTX Communications

The same as optional rear Ethernet connection for IEC 61850

Ratings

AC measuring inputs

Nominal frequency: 50 and 60 Hz (settable)
Operating range: 45 to 65 Hz

AC current

Nominal current (In): 1 and 5 A dual rated.
(1 A and 5 A inputs use different transformer tap connections, check correct terminals are wired).
Nominal burden
< 0.04 VA at In, <40 mΩ (0-30 In) In = 1 A
< 0.01 VA at In, <8 mΩ (0-30 In)   In = 5 A

Thermal withstand:
  continuous 4 In
  for 10 s: 30 In
  for 1 s; 100 In
Standard: linear to 64 In (non-offset AC current).
Sensitive: linear to 2 In (non-offset AC current).

AC voltage

Nominal voltage (Vn): 100 to 120 V phase-phase
Nominal burden per phase: < 0.02 VA rms at 110/$\sqrt{3}$ V

Thermal withstand:
  continuous 2 Vn
  for 10 s: 2.6 Vn
Linear to 200 V.

Power supply

Auxiliary voltage (Vx)

Three ordering options:
(i)   Vx: 24 to 48 Vdc
(ii) Vx: 48 to 110 Vdc, and 40 to 100 Vac (rms)
(iii) Vx: 110 to 250 Vdc, and 100 to 240 Vac (rms)

Operating range

(i)   19 to 65 V (dc only for this variant)
(ii)   37 to 150 V (dc), 32 to 110 V (ac)
(iii)   87 to 300 V (dc), 80 to 265 V (ac).
With a tolerable ac ripple of up to 12% for a dc supply, per IEC 60255-11: 1979.

Nominal burden

Quiescent burden: 11 W or 22 VA. (Extra 1.25 W or 2.5 VA when fitted with second rear communications board).
Additions for energized binary inputs/outputs:
Per opto input:
  0.09 W or 0.18 VA (24 to 54 V),
  0.12 W or 0.24 VA (110/125 V),
  0.19 W or 0.38 VA (220/250 V).
Per energized output relay: 0.13 W or 0.26 VA

Power-up time

Time to power up < 11 s.

Power supply interruption

3 power supply options:
(i) Vx: 24 to 48 V dc
(ii) Vx: 48 to 110 V dc, 40 to 100 V ac (rms)
(iii) (i) Vx: 110 to 250 V dc, 100 to 240 V ac (rms)
Per IEC 60255-11: 2008
The relay will withstand a 100% interruption in the DC supply without de-energizing as follows:
(i) Vx: 24 to 48 V dc
Quescent / half load
20 ms at 24 V
50 ms at 36 V
100 ms at 48 V
maximum loading:
20 ms at 24 V
50 ms at 36V
100 ms at 48 V
(ii) Vx: 48 to 110 V dc
Quescent / half load
20 ms at 36 V
50 ms at 60 V
100 ms at 72 V
200 ms at 110 V
maximum loading:
20 ms at 36 V
50 ms at 60 V

100 ms at 85 V
200 ms at 110 V
(iii) (i) Vx: 110 to 250 V dc
Quescent / half load
50 ms at 110 V
100 ms at 160 V
200 ms at 210 V
maximum loading:
20 ms at 85 V
50 ms at 98V
100 ms at 135 V
200 ms at 174 V
Per IEC 60255-11: 2008:
The relay will withstand an interruption in the
  AC supply without de-energizing as follows:
(ii) Vx = 40 to 100 V ac
Quescent / half load
50 ms at 27 V for 100% voltage dip
maximum loading:
10 ms at 27 V for 100% voltage dip
(iii) Vx = 100 to 240 V ac
Quescent / half load
50 ms at 80 V for 100% voltage dip
maximum loading:
50 ms at 80 V for 100% voltage dip
Maximum loading = all digital inputs/outputs
  energized
Quescent or 1/2 loading = 1/2 of all digital
  inputs/outputs energized

Battery backup*

Front panel mounted
Type ½ AA, 3.6 V Lithium Thionyl Chloride
Battery (SAFT advanced battery reference
  LS14250)
Battery life (assuming relay energized for 90%
  time) >10 years
*Only available on the white front panel

Supercapacitor*

Discharge time >14 days
*Only available on the black/silver front panel.

Digital ("Opto") inputs

Universal opto inputs with programmable
voltage thresholds (24/27, 30/34, 48/54,
110/125, 220/250 V). May be energized from
the 48 V field voltage, or the external battery
supply.
Rated nominal voltage: 24 to 250 Vdc
Operating range: 19 to 265 Vdc
Withstand: 300 Vdc, 300 Vrms.
Peak current of opto input when energized is
  3.5 mA (0-300 V)
Nominal pick-up and reset thresholds:
Nominal battery 24/27: 60 - 80% DO/PU
  (logic 0) <16.2   (logic 1) >19.2
Nominal battery 24/27: 50 - 70% DO/PU
  (logic 0) <12.0   (logic 1) >16.8
Nominal battery 30/34: 60 - 80% DO/PU
  (logic 0) <20.4   (logic 1) >24.0

Nominal battery 30/34: 50 - 70% DO/PU
  (logic 0) <15.0   (logic 1) >21.0
Nominal battery 48/54: 60 - 80% DO/PU
  (logic 0) <32.4   (logic 1) >38.4
Nominal battery 48/54: 50 - 70% DO/PU
  (logic 0) <24.0   (logic 1) >33.6
Nominal battery 110/125: 60 - 80% DO/PU
  (logic 0) <75.0   (logic 1) >88.0
Nominal battery 110/125: 50 - 70% DO/PU
  (logic 0) <55.0   (logic 1) >77.0
Nominal battery 220/250: 60 - 80% DO/PU
  (logic 0) <150.0   (logic 1) >176.0
Nominal battery 220/250: 50 - 70% DO/PU
  (logic 0) <110   (logic 1) >154
Recognition time:
  <2 ms with long filter removed,
  <12 ms with half cycle ac immunity filter on

Output contacts

Standard contacts

General purpose relay outputs for signaling,
tripping and alarming:
Continuous Carry Ratings (Not Switched):
Maximum continuous current: 10 A (UL: 8 A)
Short duration withstand carry: 30 A for 3 s
                                 250 A for 30 ms
Rated voltage: 300 V

Make & Break Capacity:
  DC: 50 W resistive
  DC: 62.5 W inductive (L/R = 50 ms)
  AC: 2500 VA resistive (cos ϕ = unity)
  AC: 2500 VA inductive (cos ϕ = 0.7)
Make, Carry:
  30 A for 3 secs, dc resistive, 10,000
  operations (subject to the above limits of
  make / break capacity and rated voltage)
Make, Carry & Break:
  30 A for 200 ms, ac resistive, 2,000
  operations (subject to a maximum load of
  7500 W)
  4 A for 1.5 secs, dc resistive, 10,000
  operations (subject to the above limits of
  make / break capacity & rated voltage)

  0.5 A for 1 sec, dc inductive, 10,000
  operations (subject to the above limits of
  make / break capacity & rated voltage)

  10 A for 1.5 secs, ac resistive / inductive,
  10,000 operations (subject to the above
  limits of make / break capacity & rated
  voltage)

Durability:
  Loaded contact: 10 000 operations
                         minimum,
  Unloaded contact: 100 000 operations
                         minimum.

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Operate Time
  Less than 5 ms
Reset Time
  Less than 5 ms

Watchdog contacts
Non-programmable contacts for relay
healthy/relay fail indication:
Breaking capacity:
  DC: 30 W resistive
  DC: 15 W inductive (L/R = 40 ms)
  AC: 375 VA inductive (cos ϕ = 0.7)

IRIG-B 12X Interface (modulated)
External clock synchronization per IRIG
standard 200-98, format B12x
Input impedance 6 kΩ at 1000 Hz
Modulation ratio: 3:1 to 6:1
Input signal, peak-peak: 200 mV to 20 V

IRIG-B 00X Interface (Un-modulated)
External clock synchronization per IRIG
standard 200-98, format B00X.
Input signal TTL level
Input impedance at dc 10 kΩ

Environmental conditions

Ambient temperature range
Per IEC 60255-6: 1988:
Operating temperature range:
  -25°C to +55°C (or -13°F to +131°F)
Storage and transit:
  -25°C to +70°C (or -13°F to +158°F)

Per IEC 60068-2-1: 2007
-25°C storage (96 hours)
-40°C operation (96 hours)

Per IEC 60068-2-2: 2007
+85°C storage (96 hours)
+85°C operation (96 hours)

Ambient humidity range
Per IEC 60068-2-78: 2013:
  56 days at 93% relative humidity and +40 °C
Per IEC 60068-2-30: 2005:
  Damp heat cyclic, six (12 + 12) hour cycles,
  93% RH, +25 to +55°C

Corrosive environments
Per IEC 60068-2-60: 1995, Part 2, Test Ke,
Method (class) 3
  Industrial corrosive environment/poor
environmental control, mixed gas flow test.
  21 days at 75% relative humidity and +30ºC
  exposure to elevated concentrations of H_2S,
NO_2, Cl_2 and SO_2.

Type tests

Insulation
Per IEC 60255-27: 2013:
Insulation resistance > 100 MΩ at 500 Vdc
(Using only electronic/brushless insulation
tester).

Creepage distances and clearances
IEC 60255-27: 2013
Pollution degree 3,
Overvoltage category III,
Impulse test voltage 5 kV.

High voltage (dielectric) withstand
(i) Per IEC 60255-27: 2013, 2 kV rms
  AC, 1 minute:
Between all independent circuits.
Between independent circuits and protective
(earth) conductor terminal.
  1 kV rms AC for 1 minute, across open
  watchdog contacts.
  1 kV rms AC for 1 minute, across open
  contacts of changeover output relays.
  1 kV rms AC for 1 minute for all D-type
  EIA(RS)232/EIA(RS)485 ports between the
  communications port terminals and protective
  (earth) conductor terminal.
(ii) Per ANSI/IEEE C37.90-2005
  (reaffirmed 1994):
  1.5 kV rms AC for 1 minute, across open
  contacts of normally open output relays.
  1 kV rms AC for 1 minute, across open
  watchdog contacts.
  1 kV rms AC for 1 minute, across open
  contacts of changeover output relays.

Impulse voltage withstand test
Per IEC 60255-27: 2013:
Front time: 1.2 µs, Time to half-value: 50 µs,
Peak value: 5 kV, 0.5J
Between all independent circuits.
Between all independent circuits and
protective (earth) conductor terminal.
Between the terminals of independent circuits.
EIA(RS)232 & EIA(RS)485 ports and normally
open contacts of output relays excepted.

Electromagnetic compatibility (EMC)

1 MHz burst high frequency disturbance
test
Per IEC 60255-22-1: 2008, Class III,
Common-mode test voltage: 2.5 kV,
Differential test voltage: 1.0 kV,
Test duration: 2 s, Source impedance: 200 Ω
(EIA(RS)232 ports excepted).

Damped oscillatory test
Per EN61000-4-18: 2007 + A1: 2010: Level 3
100 kHz and 1 MHz
Common mode test voltage: 2.5 kV
Power Supply, Relay contacts, CT, VT, Opto
Input, Communications, IRIG-B
Differential mode test voltage: 1 kV
Power Supply, Relay contacts, CT, VT, Opto
  Input
3 MHz, 10 MHz and 30 MHz
Common mode test voltage: 4 kV
Power Supply, Relay contacts, CT, VT, Opto
Input, Communications, IRIG-B

Immunity to electrostatic discharge
Per IEC 60255-26:2013, Class 4,
  15 kV discharge in air to user interface,
  display, communication port and exposed
  metalwork.
8 kV point contact discharge to any part of the
front of the product.

**Electrical fast transient or burst
requirements**
Per IEC 60255-26:2013, IEC 61000-4-4:2012.
Test severity Class III and IV:
Amplitude: 2 kV, burst frequency 5 kHz
(Class III),
Amplitude: 4 kV, burst frequency 2.5 kHz
(Class IV).
  Applied directly to auxiliary supply, and
  applied to all other inputs. (EIA(RS)232 ports
  excepted).
Amplitude: 4 kV, burst frequency 5 kHz
(Class IV) applied directly to auxiliary.

Surge withstand capability
Per IEEE/ANSI C37.90.1: 2002:
  4 kV fast transient and 2.5 kV oscillatory
  applied directly across each output contact,
  optically isolated input, and power supply
  circuit.
4 kV fast transient and 2.5 kV oscillatory
  applied common mode to communications,
  IRIG-B.

Surge immunity test
(EIA(RS)232 ports excepted).
Per IEC 60255-26:2013, IEC 61000-4-
5:2014+AMD1:2017,
Time to half-value: 1.2 / 50 μs,
  Amplitude: 4 kV between all groups and
  protective (earth) conductor terminal,
  Amplitude: 2 kV between terminals of each
  group.

Conducted/radiated immunity
For RTDs used for tripping applications the
conducted and radiated immunity performance
is guaranteed only when using totally shielded
RTD cables (twisted leads).

**Immunity to radiated electromagnetic
energy**
Per IEC 60255-26:2013, IEC 61000-4-3:2006
+ A2:2010
Test field strength, frequency band 80 to 1000
MHz:
  10 V/m,
  Test using AM: 1 kHz / 80%,
  Spot tests at 80, 160, 450, 900 MHz
Per IEEE/ANSI C37.90.2: 2004:
80 MHz to 1000 MHz, 1 kHz 80% am and am
pulsed modulated.
Field strength of 35 V/m.

**Radiated immunity from digital
communications**
Per IEC 61000-4-3:2006 + A2:2010:
Test field strength, frequency band 800 to 960
MHz, and 1.4 to 2.0 GHz:
  30 V/m,
  Test using AM: 1 kHz/80%.

**Radiated immunity from digital radio
telephones**
Per IEC 60255-26:2013, IEC 61000-4-3:2006
+ A2:2010
10 V/m, 900 MHz and 1.89 GHz.

**Immunity to conducted disturbances
induced by radio frequency fields**
Per IEC 61000-4-6: 1996, Level 3,
Disturbing test voltage: 10 V.

Magnetic field immunity
Per IEC 61000-4-8:2009, Level 5,
  100 A/m applied continuously,
  1000 A/m applied for 3s.
Per IEC 61000-4-9:2016, Level 5,
  1000 A/m applied in all planes.
Per IEC 61000-4-10:2016, Level 5,
  100 A/m applied in all planes at
  100 kHz/1 MHz with a burst duration of 2 s.

Conducted emissions
Per IEC 60255-26:2013, EN55022: 2010
  0.15 - 0.5 MHz, 79 dBμV (quasi peak)
66 dBμV (average)
  0.5 – 30 MHz, 73 dBμV (quasi peak)
60 dBμV (average).

Radiated emissions
Per IEC 60255-26:2013
  30 – 230 MHz, 40 dBμV/m at 10 m
  measurement distance
  230 – 1 GHz, 47 dBμV/m at 10 m
  measurement distance.

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EU directives

EMC compliance
Per 2014/30/EU:
Compliance to the European Commission Directive on EMC is claimed via the Technical Construction File route. Product Specific Standards were used to establish conformity:
IEC 60255-26:2013

Product safety
Per 2014/35/EU
Compliance to the European Commission Low Voltage Directive. (LVD) is demonstrated using a Technical File.
A product specific standard was used to establish conformity.
IEC 60255-27:2005

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R&TTE compliance
Radio and Telecommunications Terminal Equipment (R & TTE) directive 99/5/EC. Compliance demonstrated by compliance to both the EMC directive and Low voltage directive, down to zero volts.
Applicable to rear communications ports.

Mechanical robustness

Vibration test
Per EN 60255-21-1:1998
  Response Class 2
  Endurance Class 2

Shock and bump
Per EN 60255-21-2:1988
  Shock response Class 2
  Shock withstand Class 1
  Bump Class 1

Seismic test
Per EN 60255-21-3: 1993
  Class 2

Transit Packaging Performance
Product testing to simulate protection offered by primary packaging carton, to ISTA 1C specification

Vibration and Drop Release Tests:

Vibration tests in 3 orientations, vibratory

movement 7 Hz, amplitude 5.3 mm, acceleration 1.05g
Drop tests - 10 drops from 61 cm height on multiple carton faces, edges and corners

P24x third party compliances
Underwriters laboratory (UL)

File Number: E202519
Original Issue Date: 21-04-2005
(Complies with Canadian and US requirements).

Energy Networks Association (ENA)

Certificate Number: 104 Issue 2
Assessment Date: 16-04-2004

Protection functions

Thermal overload

Accuracy

Setting accuracy: ±5%
Reset: 97% of thermal setting ±5%
Thermal alarm Pick-up:
Calculated trip time ±5% or 40 ms whichever is
  greater
Thermal overload Pick-up:
Calculated trip time ±5% or 40 ms whichever is
  greater
Cooling time accuracy: ±5% of theoretical
Repeatability: <2.5%

4-Stage non-directional short-circuit protection

Accuracy

Pick-up: Setting ±5%
Drop-off: 0.95 x Setting ±5%
Minimum trip level (IDMT): 1.05 x Setting ±5%
IDMT characteristic shape: ±5% or 40 ms
  whichever is greater*
IEEE reset: ±5% or 50 ms whichever is greater
DT operation: ±2% or 50 ms whichever is
  greater
DT Reset: ±5%
Characteristic UK: IEC 6025-3…1998
Characteristic US: IEEE
  C37.112…1996
* Under reference conditions

Sensitive directional earth fault

SEF Accuracy

Pick-up: Setting ±5%
Drop-off: 0.95 x Setting ±5%
IDMT trip level elements: 1.05 x Setting ±5%
IDMT characteristic shape: ±5% or 40 ms
  whichever is greater
IEEE reset: ±5% or 40 ms whichever is greater
DT operation: ±2% or 40 ms whichever is
  greater
DT reset: ±5%
Repeatability: <2.5%

Wattmetric SEF accuracy

P = 0W Pick-up: PO> ±5%
P > 0W Pick-up: P> ±5%
P = 0W Drop-off: (0.95 x ISEF>) ±5%
P > 0W Drop-off: 0.9 x P> ±5%
Boundary accuracy: ±5% with 1° hysteresis
Repeatability: <2.5%

Polarizing quantities accuracy

Operating boundary Pick-up: ±2° of RCA ±90°
Hysteresis: <3°
ISEF>Vnpol Pick-up: Setting ±10%
ISEF>Vnpol Drop-off: 0.9 x Setting or 0.7 V
  (whichever is greater) ±10%

2-Stage negative phase sequence overcurrent

Accuracy

I2>Pick-up: Setting ±5%
I2> Drop-off: 0.95 x Setting ±5%
Vpol Pick-up: Setting ±5%
Vpol Drop-off: 0.95 x Setting ±5%
DT operation: ±2% or 40 ms whichever is
  greater
IDMT operation: ±5% or 40 ms whichever is
  greater

3 Phase voltage check

Accuracy

Pick-up: Setting ±5%
Drop-off: 0.95 x Setting ±5%
Repeatability (operating threshold): <1%
Repeatability (operating times): <10 ms

2-Stage directional/non-directional derived earth fault

Accuracy

Pick-up: Setting ±5%
Drop-off: 0.95 x Setting ±5%
IDMT trip level elements: 1.05 x Setting ±5%
IDMT characteristic shape: ±5% or 40 ms
  whichever is greater
IEEE reset: ±5% or 40 ms whichever is greater
DT operation: ±2% or 40 ms whichever is
  greater
DT reset: ±5%
Repeatability: 2.5%

Zero polarizing

Operating pick-up: ±2%o of RCA ±90%
Hysteresis: <3°
VN > Pick-up: Setting ±10%
VN > Drop-off: 0.9 x Setting ±10%

Negative polarizing

Operating Pick-up: ±2%o of RCA ±90%
Hysteresis: <3°
VN 2 > Pick-up: Setting ±10%
VN 2 > Drop-off: 0.9 x Setting ±10%
I2 > Pick up: Setting ±10%
I2 > Drop-off: 0.9 x Setting ±10%

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Stall protection
Pick-up: Setting ±5%

Timer accuracy
Timers: ±2% or 40 ms whichever is greater
Reset time: <30 ms

Motor differential protection

Accuracy
Pick-up: Formula ±5%
Drop-off: 95% of setting ±5%
Operating time: <30 ms for currents
  applied at 4x pickup level or greater
Repeatability: <7.5%
Disengagement time: <40 ms

Neutral displacement/residual overvoltage

Accuracy
DT/IDMT Pick-up: Setting ±5%
Drop-off: 0.95 x Setting ±5%
IDMT characteristic shape: ±5% or 40 ms
  whichever is greater
DT operation: ±2% 40 ms whichever is
  greater
Instantaneous operation <55 ms
Reset: <35 ms
Repeatability: <1%

Loss of load

Accuracy
Pick-up: Setting ±5% or 2 W
Drop-off:
  0.95 of setting ±5%
Angle variation Pick-up:
  Expected pick-up angle ±2 degree
Angle variation Drop-off:
  Expected drop-off angle ±2.5 degree
Operating time: ±2% or 40 ms whichever is
  greater
Repeatability: <5%
Disengagement time: <50 ms
tRESET: ±5%
Instantaneous operating time: <50 ms

Out of step
Pick-up: Setting ±5%
DT operation: ±2% or 40 ms whichever is
  greater

Reverse power

Accuracy
Pick-up: Setting ±5% or 2 W
Drop-off:
  0.95 of setting ±5%
Angle variation Pick-up:
  Expected pick-up angle ±2 degree
Angle variation Drop-off:
  Expected drop-off angle ±2.5 degree
Operating time: ±2% or 40 ms whichever is
  greater
Repeatability: <5%
Disengagement time: <50 ms
tRESET: ±5%
Instantaneous operating time: <50 ms

Anti-backspin
Pick-up: Setting ±5%
DT operation: ±2% or 40 ms whichever is
  greater
Repeatability: <1%

Field failure

Accuracy
Mho characteristic Pick-up:
  Characteristic shape ±5%
Linear characteristic Pick-up:
  Characteristic shape ±10%
Mho characteristic Drop-off:
  105% of setting ±5%
Linear characteristic Drop-off:
  105% of setting ±10%
Operating time: ±2% or 60 ms whichever is
  greater
Repeatability: <1%
Disengagement time: <50 ms

Voltage protection

Undervoltage

Accuracy
DT Pick-up: Setting ±5%
IDMT Pick-up: (0.95 x Setting) ±5%
Drop-off: 1.05 x Setting ±5%
IDMT characteristic shape: ±5% or 40 ms
  whichever is greater
DT operation: ±2% or 40 ms whichever is
  greater
Reset: <75 ms
Repeatability: <1%

Overvoltage

Accuracy

DT Pick-up: Setting ±5%
IDMT Pick-up: Setting ±5%
Drop-off: 0.95 x Setting ±5%
IDMT characteristic shape: ±5% or 40 ms
  whichever is greater
DT operation: ±2% or 40 ms whichever is
  greater
Reset: <75 ms
Repeatability: <1%

2-Stage negative phase sequence overvoltage

Accuracy

Pick-up: Setting +-5%
Drop-off: 0.95 x Setting +-5%
Repeatability (operating threshold): <1%
DT operation: +-2% or 40 ms whichever is
  greater
Reset: <75 ms
Repeatability: <1%

Underfrequency

Accuracy

Pick-up: Setting ±0.01 Hz
Drop-off: (Setting +0.025 Hz) ±0.01 Hz
DT operation: ±2% or 40 ms whichever is
  greater*
  * The operating will also include a time for
  the relay to frequency track 20 Hz/ second).

Resistive temperature detectors

Accuracy

Pick-up: Setting ±1°C
Drop-off: 0.95 x Setting (min -2º)
Operating time: ±2% or <1.1 s

CB fail

Timer accuracy

Timers: ±2% or 40 ms whichever is greater
Reset time: <30 ms

Undercurrent accuracy

Pick-up: ±10% or 25 mA whichever is greater
Operating time: < 12 ms (Typical <10 ms)
Reset: < 15 ms (Typical < 10 ms)

CB state monitoring control and condition monitoring

Accuracy

Timers: ±2% or 20 ms whichever is greater
Broken current accuracy: ±5%

Programmable scheme logic

Accuracy

Output conditioner timer: Setting ±2% or 50 ms
  whichever is greater
Dwell conditioner timer: Setting ±2% or 50 ms
  whichever is greater
Pulse conditioner timer: Setting ±2% or 50 ms
  whichever is greater

Measurements and recording facilities

Measurements

Accuracy

Current: 0.05…3 In: ±1% of reading
Voltage: 0.05…2 Vn: ±5% of reading
Power (W): 0.2…2 Vn, 0.05…3 In: ±5% of
  reading at unity power factor
Reactive Power (VArs): 0.2…2 Vn, 0.05…3 In:
  ±5% of reading at zero power factor
Apparent Power (VA): 0.2…2 Vn, 0.05…3 In:
  ±5% of reading
Energy (Wh): 0.2…2 Vn, 0.2…3 In: ±5% of
  reading at zero power factor
Energy (Varh): 0.2…2 Vn, 0.2…3 In: ±5% of
  reading at zero power factor
Phase accuracy: 0°…360: ±5%
Frequency: 45…65 Hz: ±0.025 Hz

IRIG-B and real time clock

Performance

Year 2000: Compliant
Real time accuracy: < ±1 second / day

Features

Real time 24 hour clock settable in hours,
  minutes and seconds
Calendar settable from January 1994 to
  December 2092
Clock and calendar maintained via battery
  after loss of auxiliary supply
Internal clock synchronization using IRIG-B
Interface for IRIG-B signal is BNC

TD

Current loop input and outputs

Accuracy

Current loop input accuracy: ±1% of full scale

CLI drop-off threshold: 0.95 x setting ±5% of full scale

CLI sampling interval: 50 ms

CLI instantaneous operating time: < 250 ms

CLI DT operating time: ±2% setting or 200 ms whichever is the greater

CLO conversion interval: 50 ms

CLO latency: < 0.27 s depending on CLO output parameter's internal refresh rate - (0.2 s)

Current loop output accuracy: ±0.5% of full scale

Repeatability: <5%

CLI - Current Loop Input (Analog Input)

CLO - Current Loop Output (Analog Output)

Other specifications

CLI load resistance 0-1 mA: < 4 kΩ

CLI load resistance 0-1 mA/0-20 mA/4 20 mA: <300 Ω

Isolation between common input channels: zero

Isolation between input channels and case earth/other circuits: 2 kV rms for 1 minute

CLO compliance voltage 0-1 mA/0 10 mA: 10 V

CLO compliance voltage 0-20 mA/4 20 mA: 8.8 V

Isolation between common output channels: zero

Isolation between output channels and case earth/other circuits: 2 kV rms for 1 minute

Disturbance records

Accuracy

Magnitude and relative phases: ±5% of applied quantities

Duration: ±2%

Trigger Position: ±2% (minimum 100ms) Record length: 19 records each 10.5 s duration with 8 analog channels and 32 digital channels.

Event, fault & maintenance records

Maximum 512 events in a cyclic memory

Maximum 5 fault records

Maximum 5 maintenance records

Accuracy

Event time stamp resolution: 1 ms

TD

Settings, measurements and records list

Settings list

Global settings (system data)
Language: English/French/German/Spanish
Frequency: 50/60 Hz

Circuit breaker control (CB control)
CB Control by:
  Disabled
  Local
  Remote
  Local + Remote
  Opto
  Opto + Local
  Opto + Remote
  Opto + Rem + Local

Close Pulse Time:	0.1…5 sec
Trip Pulse Time:	0.1…5 sec
Man Close Delay:	0.0…60 sec

Date and time
Battery Alarm: Disabled/Enabled

Configuration
Setting Group:
  Select via Menu
  Select via Optos

Active Settings:	Group 1/2
Setting Group 1:	Disabled/Enabled
Setting Group 2:	Disabled/Enabled
Thermal Overload:	Disabled/Enabled
Short Circuit:	Disabled/Enabled
Sensitive E/F:	Disabled/Enabled
Neg. Seq. O/C:	Disabled/Enabled
3PH Volt Check:	Disabled/Enabled
Derived E/F:	Disabled/Enabled
Neg. Seq. O/V	Disabled/Enabled
Stall Detection:	Disabled/Enabled
Differential:	Disabled/Enabled
Residual O/V NVD:	Disabled/Enabled
Limit Nb Starts:	Disabled/Enabled
Loss of Load:	Disabled/Enabled
Out of Step:	Disabled/Enabled
Reverse Power:	Disabled/Enabled
Anti-Backspin:	Disabled/Enabled
Field Failure:	Disabled/Enabled
Volt Protection:	Disabled/Enabled
Under Frequency:	Disabled/Enabled
RTD Inputs:	Disabled/Enabled
CB Fail:	Disabled/Enabled
Supervision	Disabled/Enabled

System Config:	Invisible/Visible
Input Labels:	Invisible/Visible
Output Labels:	Invisible/Visible
RTD Labels:	Invisible/Visible
CT & VT Ratios:	Invisible/Visible
Record Control:	Invisible/Visible
Disturb Recorder:	Invisible/Visible
Measure't Setup:	Invisible/Visible
Comms Settings:	Invisible/Visible
Commission Tests:	Invisible/Visible
Setting Values:	Primary/Secondary
Control Inputs:	Invisible/Visible
CLIO Inputs:	Disabled/Enabled
CLIO Outputs:	Disabled/Enabled
CLIO Labels:	Disabled/Enabled
Ctrl I/P Config:	Invisible/Visible
Ctrl I/P Labels:	Invisible/Visible
Direct Access:	Disabled/Enabled
Function Keys:	Invisible/Visible
LCD Contrast:	0…31

CT and VT ratios
Main VT Primary:	100...1000000 V
Main VT Sec'y:	80...140 V
Phase CT Primary:	1A…30 kA
Phase CT Sec'y:	1A/5 A
SEF CT Primary:	1A…30 kA
SEF CT Sec'y:	1A/5 A

VT Connecting Mode:
  3 VT
  2 VT + Residual
2 VT + Vremanent
(Vremanent phase-phase)

NVD VT Primary	100...1000000V
NVD VT Secondary	80...140 V

Sequence of event recorder (record control)
Alarm Event:	No/Yes
Relay O/P Event:	No/Yes
Opto Input Event:	No/Yes
General Event:	No/Yes
Fault Rec Event:	No/Yes
Maint Rec Event:	No/Yes
Protection Event:	No/Yes
DDB 31 - 0:	(up to):
DDB 1022 - 992:	

  Binary function link strings, selecting which DDB signals will be stored as events, and which will be filtered out.

Oscillography (disturbance recorder)
Duration:	0.10…10.50 s
Trigger Position:	0.0…100.0%
Trigger Mode:	Single/Extended
Analog Channel 1:	(up to):
Analog Channel 8	(depending on model):

  Disturbance channels selected from:
VA/VB/VC/IA/IB/IC/IA-2/IB-2/IC-2/IN/VAB/VCB/VN/VRM (*depending on model*)

TD

Digital Input 1:   (up to):
Digital Input 32:
Selected binary channel assignment from any DDB status point within the relay (opto input, output contact, alarms, starts, trips, controls, logic…).
Input 1 Trigger: No Trigger/Trigger Edge -/+ (Low to High)/Trigger Edge +/- (High to Low)
   (up to):
Input 32 Trigger: No Trigger/Trigger Edge -/+ / Trigger Edge +/-

Measured operating data (measure't setup)

Default Display:
  3Ph + N Current
  3Ph Voltage
  Power
  Date and Time
  Description
  Plant Reference
  Frequency
  Thermal State

Local Values:	Primary/Secondary
Remote Values:	Primary/Secondary
Measurement Ref:	VA/VB/VC/IA/IB/IC
Demand Interval:	1…99 mins
Alarm Fix Demand:	Invisible/Visible
3 Phase Watt Thresh:	1 In……120 In W
3 Phase Var Thresh:	1 In……120 In VAr
Alarm Energies:	Invisible/Visible
W Fwd Thresh:	1 In……1000 In Wh
W Rev Thresh:	1 In……1000 In Wh
Var Fwd Thresh:	1 In……1000 In VArh
Var Rev Thresh:	1 In……1000 In VArh
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

Optional Ethernet or Redundant Ethernet port

NIC Protocol: data
NIC MAC Address: data
NIC Tunl Timeout: 1…30 mins
NIC Link Report:Alarm, Event, None
NIC Link Timeout:0.1…60 s

Commission tests

Monitor Bit 1:
  (up to):
Monitor Bit 8:
  Binary function link strings, selecting which DDB signals have their status visible in the Commissioning menu, for test purposes
Test Mode:
  Disabled
  Test Mode
  Blocked Contacts
Test Pattern:

Configuration of which output contacts are to be energized when the contact test is applied.

Circuit breaker condition monitoring (CB monitor setup)

Broken I^:	1.0…2.0
I^ Maintenance:	Alarm Disabled/Enabled
I^ Maintenance:	1…25000
No. CB Ops Maint:	Alarm Disabled/Enabled
No. CB Ops Maint:	1…10000
CB Time Maint: Alarm Disabled/Enabled	
CB Time Maint: 0.005…0.500 s	

Opto coupled binary inputs (opto config)

Global Nominal V:
  24 - 27 V
  30 - 34 V
  48 - 54 V
  110 - 125 V
  220 - 250 V
Custom
Opto Input 1:
  (up to):
Opto Input #. (# = max. opto no. fitted):
  Custom options allow independent thresholds to be set per opto, from the same range as above.
Opto Filter Control:
  Binary function link string, selecting which optos will have an extra 1/2 cycle noise filter, and which will not.
Characteristics:
  Standard 60% - 80%
  50% - 70%
Time stamping accuracy: ±1 msec

Control inputs into PSL (ctrl. I/P config.)

Hotkey Enabled:
  Binary function link string, selecting which of the control inputs will be driven from Hotkeys.

Control Input 1:	Latched/Pulsed
(up to):	
Control Input 32:	Latched/Pulsed

Ctrl Command 1:
  (up to):
Ctrl Command 32:
  ON/OFF
  SET/RESET
  IN/OUT
  ENABLED/DISABLED

Function keys

Fn. Key Status 1:
  (up to):
Fn. Key Status 10
  Disable
  Lock
  Unlock/Enable

Fn. Key 1 Mode: Toggled/Normal
  (up to):
Fn. Key 10 Mode: Toggled/Normal
Fn. Key 1 Label:
  (up to):
Fn. Key 10 Label:
User defined text string to describe the function of the particular function key

IED configurator

Switch Conf.Bank: No Action/Switch Banks

IEC 61850 GOOSE

GoEna: Disabled/Enabled
Test Mode: Disabled/Pass Through/Forced
VOP Test Pattern: 0x00000000...
0xFFFFFFFF
Ignore Test Flag: No/Yes

TD

Control input user labels
(ctrl. I/P labels)

Control Input 1:
  (up to):
Control Input 32:
  User defined text string to describe the function of the particular control input

Settings in multiple groups

Note: *All settings here onwards apply for setting groups # = 1 to 2.*

Protection functions

System config.
Phase Sequence: Standard ABC/Reverse ACB

Thermal
Ith Current Set:	0.2 In…1.5 In
K Coefficient:	0…10
Thermal Const T1:	1min…180min
Thermal Const T2:	1min…360min
Thermal Const Tr:	1min…999min
Thermal Trip:	Disabled/Enabled
Thermal Alarm:	Disabled/Enabled
Alarm Threshold:	0.2%…100%
Thermal Lockout:	Disabled/Enabled
Lockout Thresh:	0.2…100%
Inh Trip Dur St:	Disabled/Enabled

Maximum user curve time delay setting
$1 \times e^{30}$

4-stage non-directional short circuit protection
Phase O/C: Sub Heading
I>1 Function:
  Disabled
  DT
  IEC S Inverse
  IEC V Inverse
  IEC E Inverse
  UK LT Inverse
  UK Rectifier
  RI
  IEEE M Inverse
  IEEE V Inverse
  IEEE E Inverse
  US Inverse
  US ST Inverse

I>1 Current Set:	0.2…15 In
I>1 Time Delay:	0.040…100.00 s
I>1 TMS:	0.025…1.200
I>1 Time Dial:	0.01…100.00
I>1 K (RI):	0.10…10.00
I>1 Reset Char:	DT/Inverse
I>1 tRESET:	0.00…100.00 s
I>2 as I>1	
I>3 Status:	Disabled/Enabled
I>3 Current Set:	0.20…15.00 In
I>3 Time Delay:	0.040…100.00 s
I>4 as I>3	

Maximum user curve time delay setting
$1 \times e^{308}$

IDMT curves

Inverse time (IDMT) characteristic

IDMT characteristics are selectable from a choice of four IEC/UK and five IEEE/US curves as shown in the table below.

The IEC/UK IDMT curves conform to the following formula:

$$t = T \times \left(\frac{K}{(I/I_S)^{\alpha} - 1} + L \right)$$

The IEEE/US IDMT curves conform to the following formula:

$$t = TD / 7 x \left(\frac{K}{I / Is^a - 1} + L \right)$$

Where:

t	=	Operation time
K	=	Constant
I	=	Measured current
IS	=	Current threshold setting
α	=	Constant
L	=	ANSI/IEEE constant (zero for IEC/UK curves)
T	=	Time multiplier setting for IEC/UK curves
TD	=	Time dial setting for IEEE/US curves

IDMT characteristics

IDMT curve	Stand.	K	α	L
Standard inverse	IEC	0.14	0.02	0
Very inverse	IEC	13.5	1	0
Extremely inverse	IEC	80	2	0
Long time inverse	UK	120	1	0
Moderately inverse	IEEE	0.0515	0.02	0.114
Very inverse	IEEE	19.61	2	0.491
Extremely inverse	IEEE	28.2	2	0.1217
Inverse	US-C08	5.95	2	0.18
Short time inverse	US-C02	0.16758	0.02	0.11858

The IEC extremely inverse curve becomes definite time at currents greater than 20 x setting. The IEC standard, very and long time inverse curves become definite time at currents greater than 30 x setting. The rectifier curve becomes definite time at currents greater than 8xsttings.

The definite time part of the IEC inverse time characteristics at currents greater than 20x and 30x setting are only relevant for currents in the operating range of the relay. The operating range of the P241/2/3 current inputs

is 0 – 64 In for the standard current inputs and is 0 – 2 In for the sensitive current input.

The RI curve (electromechanical) has been included in the first and second stage characteristic setting options for Phase Overcurrent and Earth Fault protections. The curve is represented by the following equation:

$$t = K \times \left(\frac{1}{0.339 - \left(0.236/M \right)} \right) \text{ in seconds}$$

With K adjustable from 0.1 to 10 in steps of 0.05

$$M \quad = \quad I/Is$$

For all IEC/UK curves, the reset characteristic is definite time only.

For all IEEE/US curves, the reset characteristic can be selected as either inverse curve or definite time.

The inverse reset characteristics are dependent upon the selected IEEE/US IDMT curve as shown in the table below.

All inverse reset curves conform to the following formula:

$$tRESET = \frac{TD \times S}{(1 - M^2)} \text{ in seconds}$$

Where:

TD = Time dial setting for IEEE curves
S = Constant
M = I/Is

Curve description	Standard	S
Moderately inverse	IEEE	4.85
Very inverse	IEEE	21.6
Extremely inverse	IEEE	29.1
Inverse	US	5.95
Short time inverse	US	2.261

Amercian Curves

Curve 5	IEEE moderately inverse
Curve 6	IEEE very inverse
Curve 7	IEEE extremely inverse
Curve 8	US inverse
Curve 9	US short time inverse

P2137ENa

IEC Curves

Curve 1	Standard inverse
Curve 2	Very inverse
Curve 3	Extremely inverse
Curve 4	UK long time inverse

P2136ENa

TD
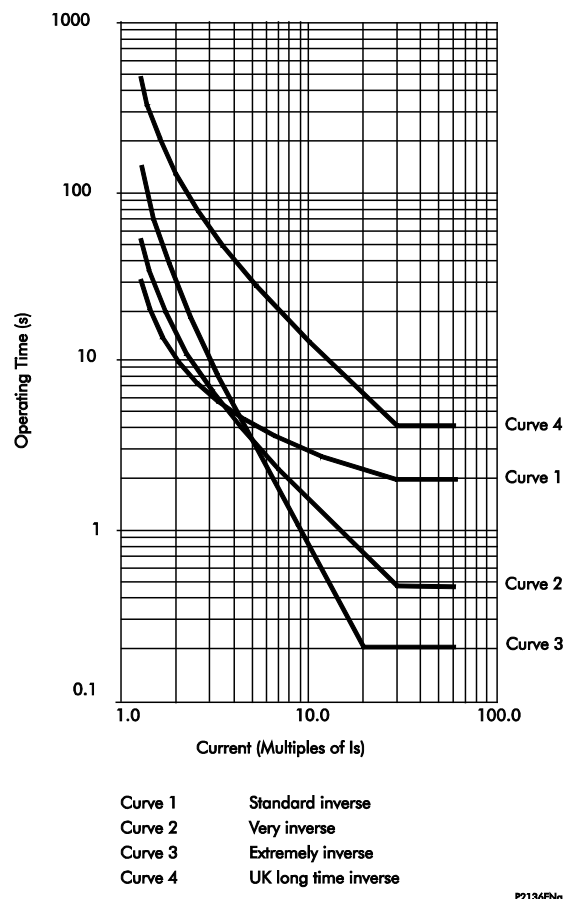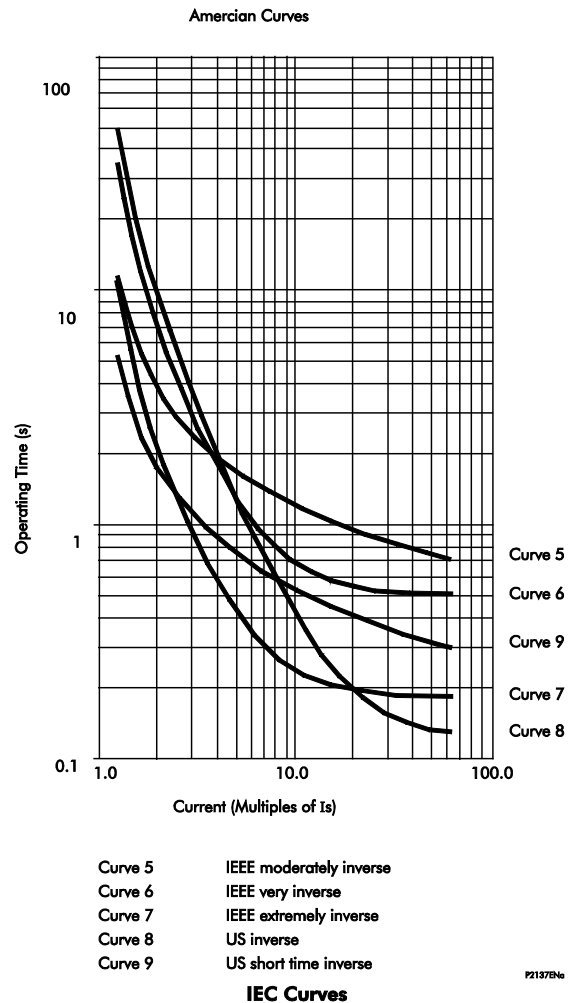
Earth fault
ISEF>1 Function:
  Disabled
  DT
  IEC S Inverse
  IEC V Inverse
  IEC E Inverse
  UK LT Inverse
  UK Rectifier
  IEEE M Inverse
  IEEE V Inverse
  IEEE E Inverse
  US Inverse
  US ST Inverse
ISEF>1 Direction:
  Non-Directional
  Directional Fwd

ISEF>1 Current:	0.005 In…1 In
ISEF>1 T Delay:	0.04…200.0 s
ISEF>1 TMS:	0.025…1.2
ISEF>1 Time Dial:	0.5…15
ISEF>1 Reset Chr:	DT/Inverse
ISEF>1 tReset:	0…100 s
ISEF>2 Function:	Disabled/Enabled

ISEF>2 Direction:
  Non-Directional
  Directional Fwd

ISEF>2 Current Set:	0.005In…1In
ISEF>2 T Delay:	0.04…200 s
ISEF> Char Angle:	-180°…+180°
ISEF> VN Pol Set:	0.5…25 V

(Earth Fault Wattmetric)

PO> Function:	Disabled/Enabled
PO> Current Set:	0.005 In…1 In
PO> Voltage Set:	0.5…80 V
PO> Coeff K Set:	1…10
PO> Char Angle:	-180°…+180°
PO> Time Delay:	0.04…100 s

Negative sequence overcurrent

I2>1 Status:	Disabled/DT
I2>1 Current Set:	0.05…4 In
I2>1 Time Delay:	0.04…200 s
I2>2 Status:	Disabled/IMDT
I2>2 Current Set:	0.05…4 In
I2>2 TMS:	0.07…2

3 phase voltage check

Start Low V Set:	0.1 Vn…1.0 Vn

Earth fault derived
IN>1 Function:
  Disabled
  DT
  IEC S Inverse
  IEC V Inverse
  IEC E Inverse
  UK LT Inverse
  UK Rectifier
  IEEE M Inverse
  IEEE V Inverse

  IEEE E Inverse
  US Inverse
  US ST Inverse
IN>1 Direction:
  Non-Directional
  Directional Fwd

IN>1 Current Set:	0.08In…32 In
IN>1 T Delay:	0.04…100 s
IN>1 TMS:	0.025…1.2
IN>1 Time Dial:	0.5…15
IN>1 Reset Chr:	DT/Inverse
IN>1 tReset:	0…100 s
IN>2 Function:	Disabled/DT

IN>2 Direction:
  Non-Directional
  Directional Fwd

IN>2 Current:	0.08 In…32 In
IN>2 T Delay:	0.04…100 s
IN> Char Angle:	-180°…+180°

IN> Type Pol Type:
  Zero Sequence
  Neg Sequence

IN> VN Pol Set:	0.5…25 V
IN> V2pol Set:	0.5…25 V
IN2> I2pol Set:	0.002 In…0.8 In

Maximum user curve time delay setting
  $1 \times e^{308}$

Stall detection
Prolonged Start:
  Disabled/Enabled
Start Criteria:
  52 a
  I
  52 a + I

Starting Current:	1*In…5*In

Prol Start time:
  1…200 s
Stall Rotor Strt:
  Disabled/Enabled
Stall Detection:
  Disabled/Enabled

Stall Setting:	1*In…5*In
Stall Time:	0.1…60 s

Reacceleration:
  Disabled/Enabled
Reacc Low Voltage Setting:
  50…120 V
LV Ride Thru:
  Disabled/Enabled
Reac. High V Setting:
  50…120 V
Reac. Time:
  0.1…60 s
Auto Re-Start:
  Disabled/Enabled
Reac. Long Time:
  0…60 s
Reac. Shed Time:
  0…5940 s

Motor differential protection
Diff Function:
  Disabled
  Percentage Bias
  High Impedance
Diff Is1:   0.05…0.50 In
Diff k1:   0…20%
Diff Is2:   1…5.0 In
Diff k2:   20…150.00%

Residual O/V NVD
VN>1 Function:
  Disabled
  DT
  IDMT
VN>1 Voltage Set: 0.5….80 V
VN>1 Time Delay: 0.04…100 s
VN>1 TMS: 0.05…100
VN>2 Status: Disabled/DT
VN>2 Voltage Set: 0.5…80 V
VN>2 Time Delay: 0.04…100 s

Limit Nb starts
Hot Start status:
  Disabled/Enabled
Hot start Nb: 1…5
Cold Start Stat:
  Disabled/Enabled
Cold start Nb: 1…5
Supervising Time: 10…120 min
T Betw St Status:
  Disabled/Enabled
Time betw start: 1…120 min
Inhib Start Ttime: 1…120 min

Loss of load
P<1 Status: Disabled/DT
P<1 Power Set: 1*In …120*In W
P<1 Time Delay: 0.04…100s
P<2 Status: Disabled/DT
P<2 Power Set: 1*In …120*In W
P<2 Time Delay: 0.04…100 s
P< Drop-off Time   0.05…300 s

Out of step (power factor)
PF< Status Lead: Disabled/DT
Power Fact lead: 0.1…0.9
PF< Lead TD: 0.05…100 s
PF< Status Llag: Disabled/DT
Power Fact Lag: 0.1…0.9
PF< Lag TD: 0.05…100 s
PF< Drop-off time: 0.05…300 s

Reverse power
Rev P< Power Set: 1*In…120*In W
Rev P< Time Delay: 0.04…100 s
Rev P< Drop-of Ti: 0.05…300 s

Anti-backspin
VRem Anti-backs: 1…120 V
Anti-backs Delay: 1…7200 s

Field failure
FFail Alm Status: Disabled/Enabled
FFail Alm Angle: 15°…75°
FFail Alm Delay: 0.00…100.0 s
FFail 1 Status: Disabled/Enabled
FFail 1 -Xa1:   0…40.0/InΩ
FFail 1 Xb1:   25…325.0/InΩ
FFail 1 Time Delay: 0…100 s
FFail 1 DO Timer: 0…100 s
FFail 2 as FFail1

Volt protection

Undervoltage
V<1 Measurment Mode:
  Phase-Phase/Any Phase
V<1 Function:
  Disabled
  DT
  IDMT
V<1 Voltage Set: 15…120 V
V<1 Time Delay: 0.04… 600 s
V<1 TMS: 0.5…100
V<1 PoleDead Inh   Enabled/Disabled
V<1 tReset   0… 600 s
V<2 Status: Disabled/DT
V<2 Voltage Set: 15…120V
V<2 Time Delay: 0.04… 600 s
Inhib During St: Disabled/DT
V<2 PoleDead Inh   Enabled/Disabled
V<2 tReset   0… 600 s

Overvoltage
V>1 Measurment Mode:
  Phase-Phase/Any Phase
V>1 Status: Disabled/DT
V>1 Voltage Set: 50…200 V
V>1 time Delay: 0.04… 600 s
V>2 Status: Disabled/DT
V>2 Voltage Set: 50…200 V
V>2 Time Delay: 0.04… 600 s

NPS Overvoltage
V2>1 Status: Enabled/Disabled
V2>1 Voltage Set: 1 to 110 V
V2>1 Time Delay: 0.04 to 100 s
V2>2 Status: Enabled/Disabled
V2>2 Voltage Set: 1 to 110 V
V2>2 Time Delay: 0.04 to 100 s

Underfrequency
F<1 Status: Disabled/DT
F<1 Setting: 45…65 Hz
F<1 Time Delay: 0.1…100 s
F<2 Status: Disabled/DT
F<2 Setting: 45…65 Hz
F<2 Time Delay: 0.1…100 s

TD

TD

RTD protection

Select RTD:
  Bit 0 - Select RTD 1
  Bit 1 - Select RTD 2
  Bit 2 - Select RTD 3
  Bit 3 - Select RTD 4
  Bit 4 - Select RTD 5
  Bit 5 - Select RTD 6
  Bit 6 - Select RTD 7
  Bit 7 - Select RTD 8
  Bit 8 - Select RTD 9
  Bit 9 - Select RTD 10
Binary function link string, selecting which RTDs (1 - 10) are enabled.
RTD 1 Alarm Set: 0°C…200°C
RTD 1 Alarm Dly: 0s…100s
RTD 1 Trip Set: 0°C…200°C
RTD 1 Trip Dly: 0s…100s
RTD2/3/4/5/6/7/8/9/10 as RTD1
Ext. Temp. Influence: Disabled/DT
Ext. Temp. RTD: 1…10
Ext. RTD Back-up: 1…10
Type RTD:
  PT100
  Ni100
  Ni120
RTD Unit:
  Degree Celsius
  Fahrenheit

CB fail

CB Fail 1 Status: Disabled/Enabled
CB Fail 1 Timer: 0.00…10.00 s
CB Fail 2 Status: Disabled/Enabled
CB Fail 2 Timer: 0.00…10.00 s
CBF Non I Reset: I< Only, CB Open & I<, Prot
  Reset & I<
CBF Ext Reset: I< Only, CB Open & I <, Prot
  Reset & I<
I< Current Set: 0.02…3.200 In

Supervisory functions

Voltage transformer supervision (fuse failure)

Accuracy

Fast block operation: <25 ms
Fast block reset: <30 ms
Time delay: Setting ±2% or 20 ms whichever is
  greater

Current transformer supervision

Accuracy

IN > Pick-up: Setting ±5%
VN < Pick-up: Setting ±5%
IN > Drop-off: 0.9 x Setting ±5%
VN < Drop-off: (1.05 x Setting) ±5% or 1 V
  whichever is greater
CTS block operation: < 1 cycle

CTS reset: < 35 ms

Input labels

Opto Input 1…16: Opto 1…Opto 16

User defined text string to describe the function of the particular opto input.

Output labels

Relay 1…16: Relay 1…Relay 16

User defined text string to describe the function of the particular relay output contact.

RTD labels

RTD 1-10: RTD1…RTD10

User defined text string to describe the function of the particular RTD.

CLIO labels

CLIO Input 1…16:
  Analog Input 1…Analog Input 16

User defined text string to describe the function of the particular analog input.

Analogue Input (current loop input)

CLIO Inputs
Range 1:
  Disabled
  0 - 1 mA
  0 - 10 mA
  0 - 20 mA
  4 - 20 mA
Unit 1: Unit Range
  None -32.5 k...50 k
  A   0...100 k
  V   0...20 k
  Hz   0...100
  W   -1.41 G...1.41 G
  Var   -1.41 G...1.41 G
  VA   0...1.41 G
  °C   -40...400
  F   -40...752
  %   0...150
  s   0...300
Minimum 1:   As above for unit range
Maximum 1:   As above for unit range
Function 1:   Disabled/Enabled
Alarm Set 1:   As above for unit range
Alarm Delay 1: 0…300 s
Trip Set 1:   As above for unit range
Trip Delay 1:   0…300 s
Drop-off Time: 0.1…300
CLI2/3/4 as CLI1

Analogue output (current loop output)

CLIO Outputs
Range 1:

0 - 1 mA
0 - 10 mA
0 - 20 mA
4 - 20 mA
ANALOG OUTPUT 1: As shown below*
Minimum 1: Range, step size and unit
  corresponds to the selected parameter
Maximum 1: Same as Minimum 1
ANALOG OUTPUT2/3/4 as ANALOG
OUTPUT1
ANALOG Output Parameters
Current Magnitude:
  IA Magnitude
  IB Magnitude
  IC Magnitude
  IN Measured Mag
  0.00…100 kA
Phase Currents:
  IA RMS
  IB RMS
  IC RMS
  In RMS
  0.00…100 kA
P-N Voltage Magnitude:
  VAN Magnitude
  VBN Magnitude
  VCN Magnitude
  0.0…20 kV
RMS Phase P-N Voltages:
  VAN RMS
  VBN RMS
  VCN RMS
  0.0…20 kV
P-P Voltage Magnitude:
  VAB Magnitude
  VBC Magnitude
  VCA Magnitude
  0.0…20 kV
RMS Phase P-P Voltages:
  VAB RMS
  VBC RMS
  VCA RMS
  0.0…20 kV
Frequency: 0.00…100.0 Hz
3 Phase Watts: 30MW… 30MW
3 Phase Vars: 30MVar… 30 MVar
3 Phase VA: 30MVA… 30 MVA
3Ph Power Factor: -1…1
RTD 1-10: -40°C…400.0°C
Number of Hottest RTD: 1..10
Thermal State: 0-150
Time to Thermal Trip: 0…300 s
Time to Next Start: 0…300 s

Plant supervision

CB state monitoring control and condition monitoring

Accuracy
Timers: ±2% or 20 ms whichever is greater
Broken current accuracy: ±5%

Programmable scheme logic

Accuracy
Output conditioner timer: Setting ±2% or 50 ms
  whichever is greater
Dwell conditioner timer: Setting ±2% or 50 ms
  whichever is greater
Pulse conditioner timer: Setting ±2% or 50 ms
  whichever is greater

IEC 61850 Ethernet data

100 Base FX Interface

Transmitter optical characteristics
(TA = 0°C to 70°C, VCC = 4.75 V to 5.25 V)

Parameter	Sym	Min.	Typ.	Max.	Unit
Output Optical Power BOL 62.5/125 µm, NA = 0.275 Fiber EOL	PO	-19 -20	-16.8	-14	dBm avg.
Output Optical Power BOL 50/125 µm, NA = 0.20 Fiber 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 ("0")			-45	dBm avg.

BOL - Beginning of life
EOL - End of life
Receiver optical characteristics
(TA = 0°C to 70°C, VCC = 4.75 V to 5.25 V)

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.

Note: *The 10BaseFL connection will no longer be supported as IEC 61850 does not specify this interface*

TD

TD

Measurements list

Measurements 1
Iφ Magnitude
Iφ Phase Angle
  Per phase (φ = A, B, C) current
  measurements
IN Derived Mag
IN Derived Angle
ISEF Magnitude
ISEF Angle
I1 magnitude
I2 magnitude
I0 Magnitude
Iφ RMS
  Per phase (φ = A, B, C) RMS current
  measurements
Vφ-φ Magnitude
Vφ-φ Phase Angle
Vφ Magnitude
Vφ Phase Angle
  All phase-phase and phase-neutral voltages
  (φ = A, B, C, N).
Vr Antibacks Mag
V1 Magnitude
V2 Magnitude
Vφ RMS
Vφ-φ RMS
  All phase-phase and phase-neutral voltages
(φ = A, B, C, AB, BC, CA).
Frequency
Ratio I2/I1
IA2 Magnitude
IA2 Angle
IB2 Magnitude
IB2 Angle
IC2 Magnitude
IC2 Angle
IA Differential
IB Differential
IC Differential
IA Bias
IB Bias
IC Bias

Measurements 2
3 Phase Watts
3 Phase VArs
3 Phase VA
Zero Seq Power
3Ph Power Factor
3Ph WHours Fwd
3Ph WHours Rev
3Ph VArHours Fwd
3Ph VArHours Rev
Reset Energies: No/Yes
3Ph W Fix Demand
3Ph VArs Fix Dem
3Ph W Peak Dem
3Ph VAr Peak Dem
Reset Demand: No/Yes
3Ph I Maximum

3Ph V Maximum
Reset Maximum I/V: No/Yes

Measurements 3 (model specific)
Thermal Load
Thermal State
Time to Th Trip
Reset Th State: No/Yes
RTD#1 Temperature……
……...to RTD#10 Temperature
Nb of Hot St Allow
Nb of Cold St Allow
Time to Next St
Emergency Rest: No/Yes
Last Start Time
Last St Current
Nb of Starts
Reset Nb of St: No/Yes
Nb Emergency Rst
Reset Nb Em Rst: No/Yes
Nb of Reaccelerat
Reset Nb of Reacc: No/Yes
Motor Run Time
Reset Motor Run T: No/Yes
RTD open Cct
RTD Short Cct
RTD Data Error
Reset RTD Flags: No/Yes
Nb Hottest RTD
Hottest RTD Temp
Reset Max RTD Temp: No/Yes
Analog Input 1
Analog Input 2
Analog Input 3
Analog Input 4

Measurements 4 (model specific)
Nb Control trips
Nb Thermal Trip
Nb Trip I> 1
Nb Trip I> 2
Nb Trip I> 3
Nb Trip I> 4
Nb Trip V2>1
Nb Trip V2>2
Nb Trip Vdip
Nb Trip ISEF>1
Nb Trip ISEF>2
Nb Trip IN>1
Nb Trip IN>2
Nb Trip I2>1
Nb Trip I2> 2
Nb Trip P0>
Nb Trip V<1
Nb Trip V<2
Nb Trip F<1
Nb Trip F<2
Nb F.Fail1 Trip
Nb F.Fail2 Trip
Nb Trip P<1
Nb Trip P<2
Nb Trip PF< Lead

Nb Trip PF< Lag
Nb Trip Rev P
Nb Trip V> 1
Nb Trip V> 2
Nb Trip VN>1
Nb Trip VN>2
Nb Prolong St
Nb Lock Rot-sta
Nb Lock-Rot-run
Nb Trip RTD#1…Nb Trip RTD#10
Nb Trip Diff
Nb A Input 1Trip
Nb A Input 2Trip
Nb A Input 3Trip
Nb A Input 4Trip
Nb FFail1 Trip
Nb FFail2 Trip
Nb Trip I>3
Nb Trip I>4
Reset Trip Stat: No/Yes

TD

CB condition
CB Operations
Total Iφ Broken
   Cumulative breaker interruption duty on a
   per phase basis (φ = A, B, C).
CB Operate Time
Reset CB Data: No/Yes

TD

GETTING STARTED

GS

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1 GETTING STARTED

1.1 Front Panel

Depending on the exact model and chosen options, the product will be housed in either a 40TE, 60TE or 80TE case. The front panels of the products based on 40TE and 80TE cases have a lot of commonality and differ only in the number of hotkeys and user-programmable LEDs.

Figure 1: Front panel (40TE)

Figure 2: Front panel (60TE)

GS

The front panel consists of:

- Top and bottom compartments with hinged cover
- LCD display
- Keypad
- USB Type B port inside the bottom compartment*
- 9 pin D-type serial port*
- 25 pin D-type parallel port*
- Fixed function LEDs
- Function keys and LEDs (60TE and 80TE models)
- Programmable LEDs

  Note: *Legacy/white front panel options are fitted with serial and parallel ports, black and silver front panel options are fitted with USB type B ports. For details, refer to the Ordering Options Appendix.

1.1.1 Front Panel Compartments

The top compartment contains labels for the:

- Serial number
- Current and voltage ratings.

The bottom compartment contains:

- A compartment for a 1/2 AA size backup battery (used to back up the real time clock and event, fault, and disturbance records)[1]
- A 9-pin female D-type front port for an EIA(RS)232 serial connection to a PC[1]
- A 25-pin female D-type parallel port for monitoring internal signals and downloading software and language text[1]
- USB Type B port[2]

  Note: [1]Only available on the white front panel options.

  [2]Only available on the black and silver front panel options.

  See Mounting Options in the Ordering Options Appendix.

1.1.2 HMI Panel

The keypad provides full access to the device functionality using a range of menu options. The information is displayed on the LCD. The LCD is a high resolution monochrome display with 16 characters by 3 lines and controllable back light.
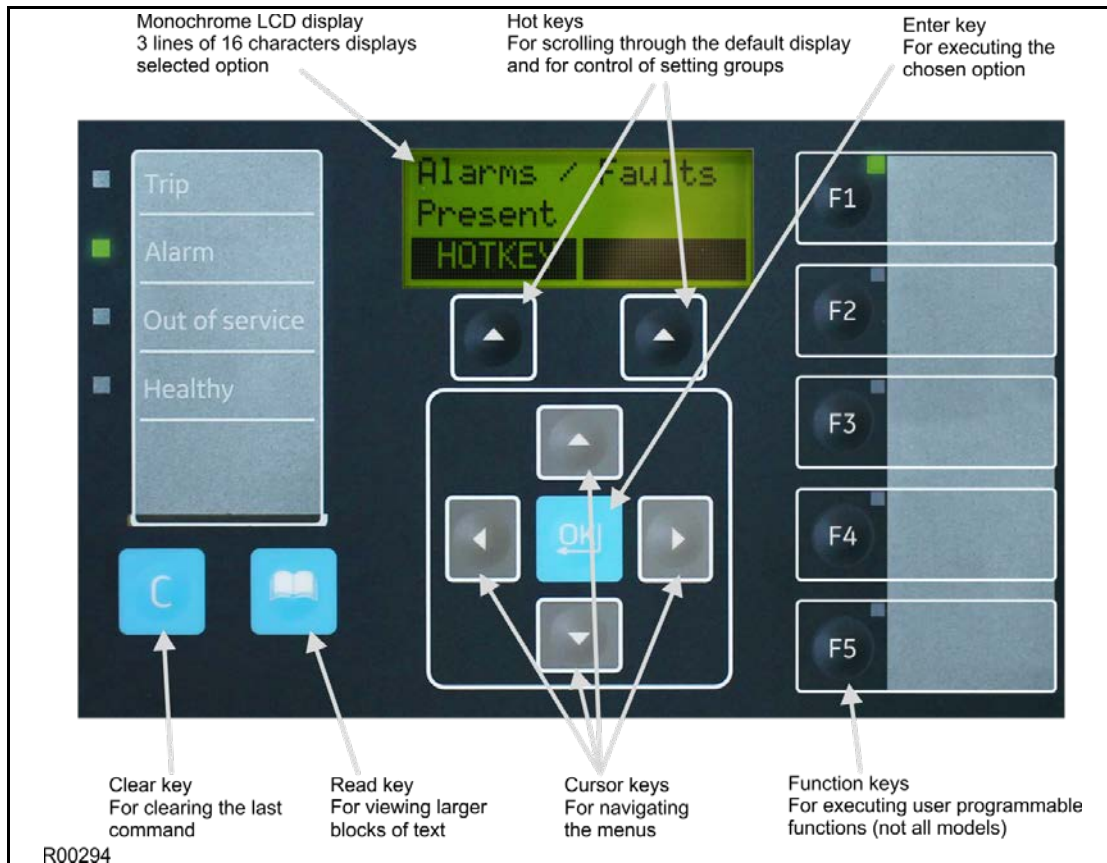
Figure 3: HMI panel (60TE)

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

1.1.3   USB Port

The USB port is situated inside the bottom compartment, 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.

⚠ **When not in use, always close the cover of the USB port to prevent
contaminationl.**

1.1.4   Front Serial Port (SK1)

The front serial port is a 9-pin female D-type connector, providing RS232 serial data
communication. It is situated under the bottom hinged cover, and is used to communicate

with a locally connected PC. It is used to transfer settings data between the PC and the relay.

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.

This port can be considered as a DCE (Data Communication Equipment) port, so you can connect this port device to a PC with an EIA(RS)232 serial cable up to 15 m in length.

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

GS

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

1.1.5 Front Serial Port (SK1) Connections

The port pin-out follows the standard for Data Communication Equipment (DCE) device with the following pin connections on a 9-pin connector.

Pin number	Description
2	Tx Transmit data
3	Rx Receive data
5	0 V Zero volts common

You must use the correct serial cable, or the communication will not work. A straight-through serial cable is required, connecting pin 2 to pin 2, pin 3 to pin 3, and pin 5 to pin 5.

Once the physical connection from the unit to the PC is made, the PC's communication settings must be set to match those of the realy. The following table shows the unit's communication settings for the front port.

Protocol	Courier
Baud rate	19,200 bits/s
Courier address	1
Message format	11 bit - 1 start bit, 8 data bits, 1 parity bit (even parity), 1 stop bit

1.1.6 Front Parallel Port (SK2)

The front parallel port uses a 25 pin D-type connector. It is used for commissioning, downloading firmware updates and menu text editing.

1.1.7 Fixed Function LEDs

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

- Trip (Red) switches ON when the relay 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 relay 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 relay's protection is unavailable.

- Healthy (Green) is ON when the relay 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.

1.1.8   Function Keys

The function keys are associated with programmable LEDs for local control.

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.

1.1.9   Programmable LEDs

The device has a number of programmable LEDs, which can be associated with PSL-generated signals. The programmable LEDs for most models are tri-colour and can be set to RED, YELLOW or GREEN. However the programmable LEDs for some models are single-colour (red) only. The single-colour LEDs can be recognised by virtue of the fact they are large and slightly oval, whereas the tri-colour LEDs are small and round.

GS

2   REAR PANEL

All current and voltage signals, digital logic input signals and output contacts are connected at the rear of the relay. Also connected at the rear is the twisted pair wiring for the rear EIA(RS)485 communication port, the IRIG-B time synchronizing input and the optical fiber rear communication port which are both optional.

GS
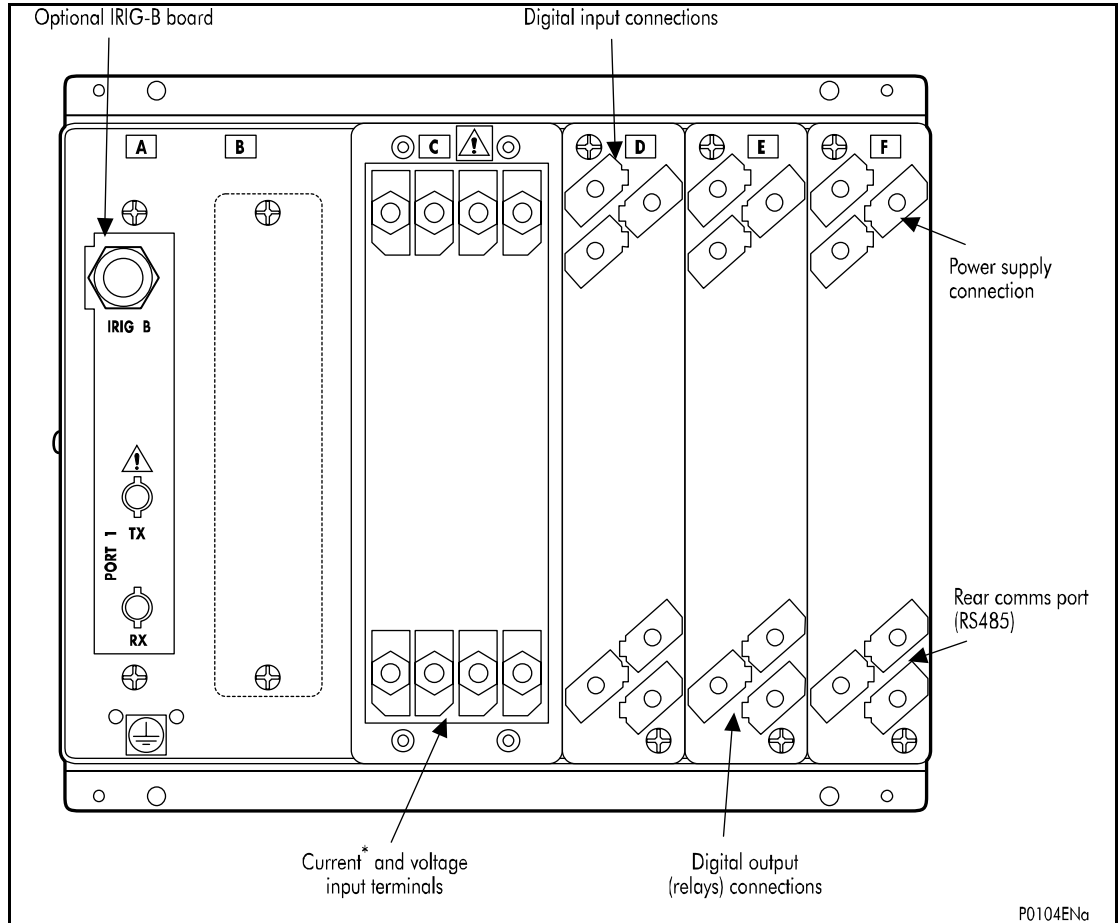
Figure 4: Relay rear view

Refer to Appendix B to see the full wiring diagrams list.

3   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 relays is called MiCOM S1 Agile. It is a collection of software tools, which is used for setting up and managing the relays.

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 GE 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 GE 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.

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3.1   The User Programmable Curve Tool (UPCT)

The User Programmable Curve Tool (UPCT) allows you to create user-defined curves and to download and upload these curves to and from the relay. You can use this tool to create programmable operate and reset curves. You can also create and visualize curves either by entering formulae or data points.
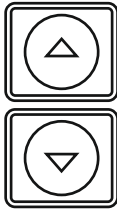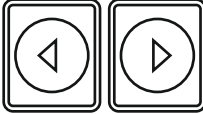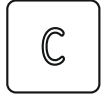
The UPCT is supported from software version 57 onwards. More information on UPCT can be found in the P40-M&CR-SAS-UG-EN-n user guide

4   USING THE HMI PANEL

Using the HMI, you can:

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

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

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

4.1   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.

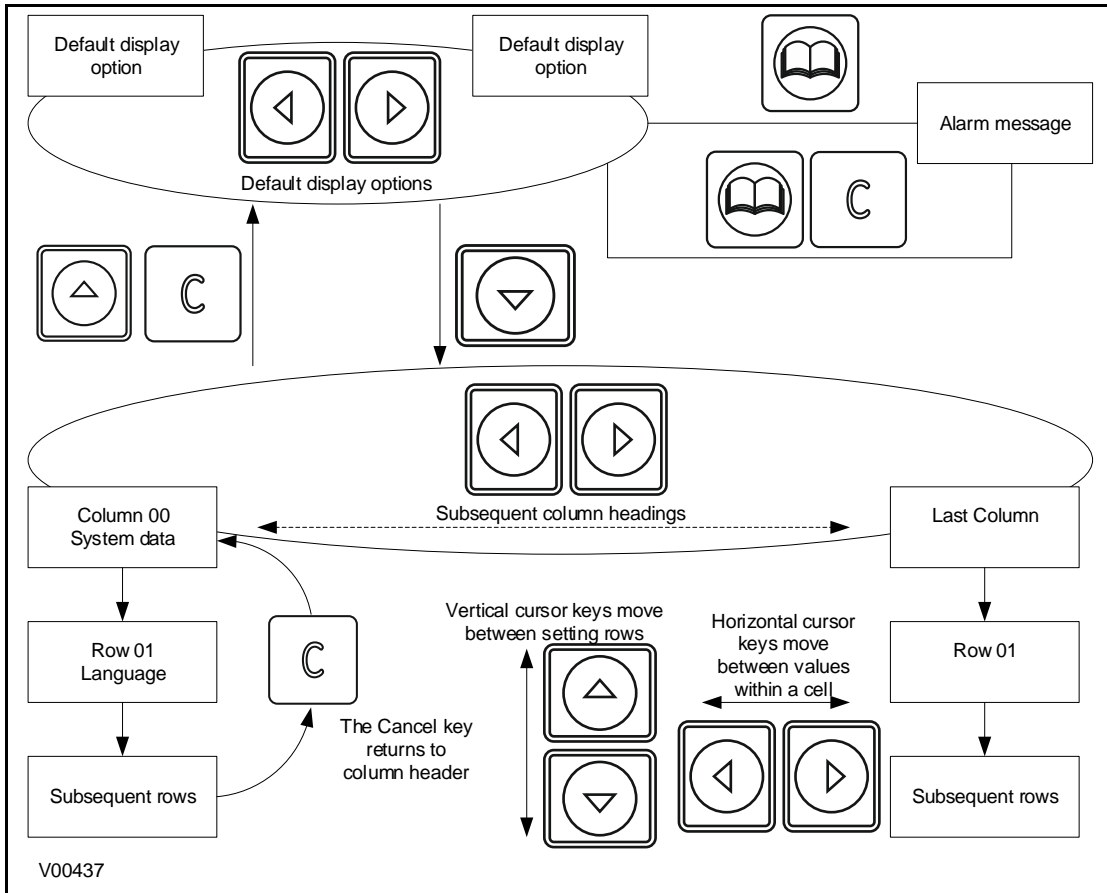The figure below shows how to navigate the menu items in the form of a menu navigation map.

Figure 5: Menu navigation

4.2   Getting Started

When you first start the relay, 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
```

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.

GS

4.3   Default Display

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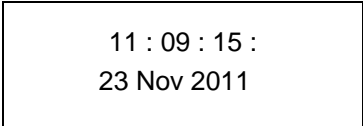
NERC Compliant banner

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.

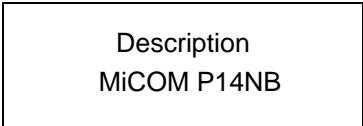> ACCESS ONLY FOR
> AUTHORISED USERS

Date and time
For example:

> 11 : 09 : 15 :
> 23 Nov 2011

Description (user-defined)
For example:

> Description
> MiCOM P14NB

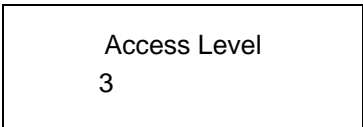**Plant reference (user-defined)**
For example:

> Plant Reference
> MiCOM

Access Level
For example:

> Access Level
> 3

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

4.4 Default Display Navigation

The following diagram is an example of the default display navigation. In this example, we have used a cybersecure 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.

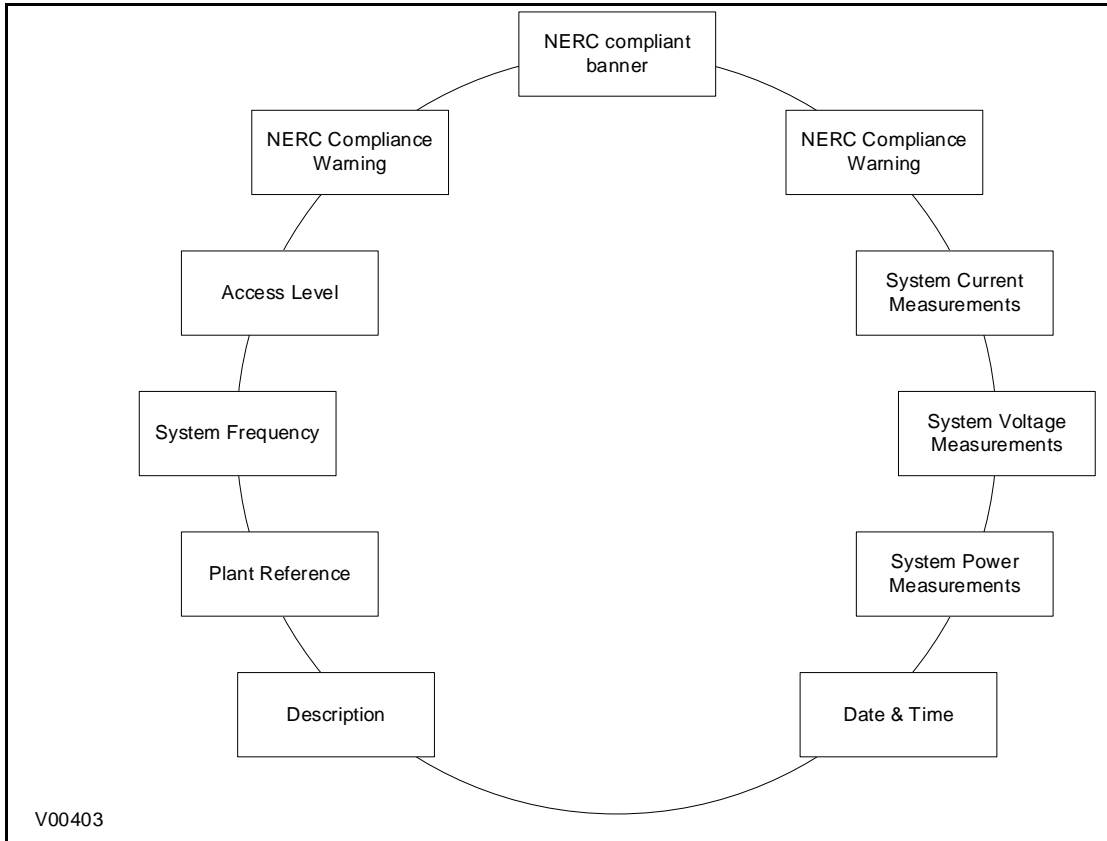Use the horizontal cursor keys to step through from one display to the next.

Figure 6: 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 relay 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.

4.5 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
**** Level 1
```

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

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

3. Press the **Enter key** to confirm the password. If you enter an incorrect password, an invalid password message is displayed then the display reverts to **Enter password**. Upon entering a valid password a message appears indicating that the password is correct and if so what level of access has been unlocked. If this level is sufficient to edit the selected setting, the display returns to the setting page to allow the edit to continue. If the correct level of password has not been entered, the password prompt page appears again.

4. To escape from this prompt press the Clear key. Alternatively, enter the password using System data > Password. If the keypad is inactive for 15 minutes, the password protection of the front panel user interface reverts to the default access level.

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

4.6 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.

4.7 Menu Structure

Settings, commands, records and measurements are stored inside the unit in non-volatile memory in a local database. When using the Human Machine Interface (HMI) it is convenient to visualize 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 more convenient to specify all the settings in a single column, detailing the complete Courier address for each setting. The above table may therefore be represented as follows:

Setting	Column	Row	Description
SYSTEM DATA	**00**	**00**	**First Column definition**
Language (Row 01)	00	01	First setting within first column
Password (Row 02)	00	02	Second setting within first column
Sys Fn Links Row 03)	00	03	Third setting within first column
…	…	…	
VIEW RECORDS	**01**	**00**	**Second Column definition**
Select Event [0...n]	01	01	First setting within second column
Menu Cell Ref	01	02	Second setting within second column
Time & Date	01	03	Third setting within second column
…	…	…	
MEASUREMENTS 1	**02**	**00**	**Third Column definition**
IA Magnitude	02	01	First setting within third column
IA Phase Angle	02	02	Second setting within third column
IB Magnitude	02	03	Third setting within third column
…	…	…	

The first three column headers are common throughout the entire Px40 series. 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 Px40 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 documentation and not make any assumptions

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4.8 Changing the Settings

1. Starting at the default display, press the **down** cursor key to show the first column heading.
2. Use the horizontal cursor keys to select the required column heading.
3. Use the vertical cursor keys to view the setting data in the column.
4. To return to the column header, either press the **up** cursor key for a second or so, or press the **Cancel** key once. It is only possible to move across columns at the column heading level.

GS

5. To return to the default display, press the **up** cursor key or the **Cancel** key from any of the column headings. If you use the auto-repeat function of the up cursor key, you cannot go straight to the default display from one of the column cells because the auto-repeat stops at the column heading.

6. To change the value of a setting, go to the relevant cell in the menu, then press the **Enter** key to change the cell value. A flashing cursor on the LCD shows that the value can be changed. You may be prompted for a password first.

7. To change the setting value, press the **up** and **down** cursor keys. If the setting to be changed is a binary value or a text string, select the required bit or character to be changed using the left and right cursor keys.

8. Press the **Enter** key to confirm the new setting value or the **Clear** key to discard it. The new setting is automatically discarded if it is not confirmed within 15 seconds.

9. For protection group settings and disturbance recorder settings, the changes must be confirmed before they are used. When all required changes have been entered, return to the column heading level and press the **down** cursor key. Before returning to the default display, the following prompt appears.

```
Update settings?
Enter or clear
```

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

Notes   For the protection group and disturbance recorder settings, If the menu time-out occurs before the setting changes have been confirmed, the setting values are also discarded. Control and support settings, however, are updated immediately after they are entered, without the **Update settings?** Prompt.

4.9   Direct Access (the Hotkey Menu)

For settings and commands that need to be executed quickly or on a regular basis, the relay 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**.

4.9.1   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, press the key directly below the HOTKEY text on the LCD.

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

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.

4.9.2   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          │
│                          │
└─────────────────────────┘
```

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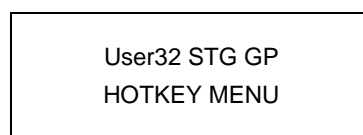
Press the **right** cursor key twice to get to the first control input, or the **left** cursor key to get to the last control input.

```
┌─────────────────────────┐
│      STP GP User02       │
│      Control Input 1     │
│                          │
└─────────────────────────┘
```
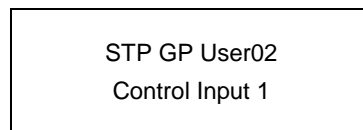
Now you can execute the chosen function (Set/Reset in this case).

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

Note: With the exception of pulsed operation, the status of the control inputs is stored in the battery/supercapacitor* backed memory. If the auxiliary supply is interrupted, the status of all the inputs is recorded. When the auxiliary power supply is restored, the control inputs are reinstated to their status before the supply failed. If the battery is missing or discharged, the control inputs set to logic 0 once the auxiliary supply is restored.

Note: *Battery fitted to white front panel versions, supercapacitor fitted to black and silver front panel versions. For details, refer to the Ordering Options Appendix.

4.9.3   Circuit Breaker Control

The CB control functionality varies from one Px40 relay to another. CB control using the hotkey menu is not included in the P241/2/3.
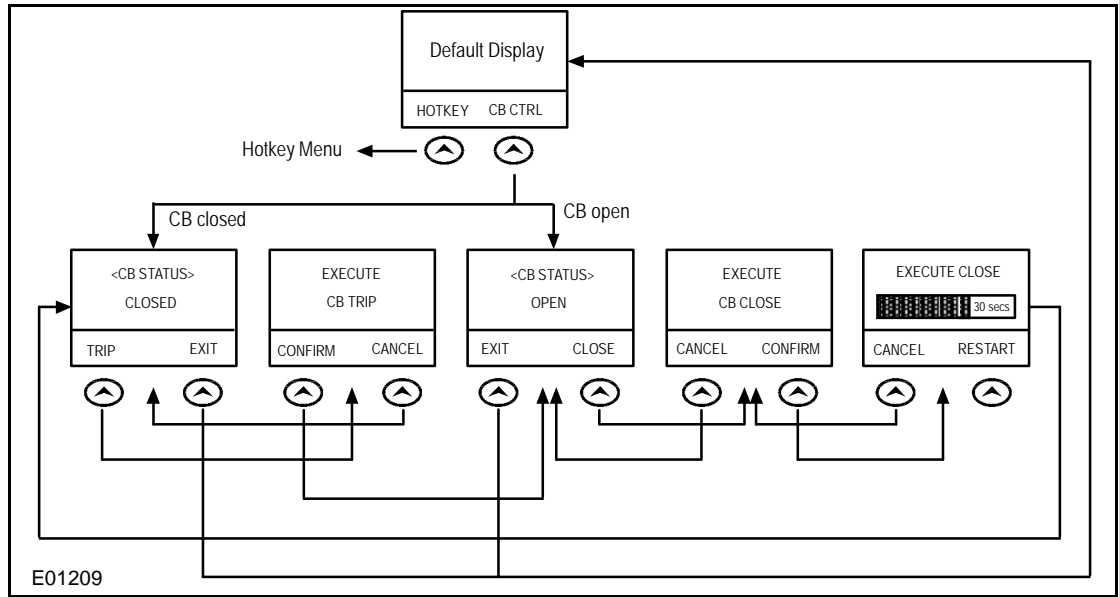
Figure 7: Hotkey menu navigation

4.10   Function Keys (P242/3)

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.
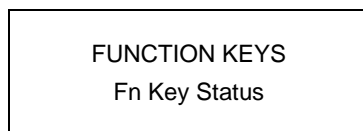
The next cell down (**Fn Key 1**) allows you to activate or disable the first function key (1). The **Lock** setting allows a function key to be locked. This allows function keys that are set to Toggled mode and their DDB signal active 'high', to be locked in their active state, preventing any further 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.
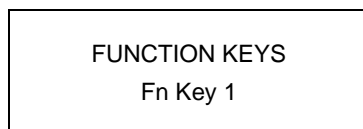
The next cell down (**Fn Key 1 Mode**) allows you to set the function key to **Normal** or **Toggled**. In the Toggle mode the function key DDB signal output stays in the set state until a reset command is given, by activating the function key on the next key press. In the Normal mode, the function key 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        │
│                             │
└─────────────────────────────┘
```

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       │
│                             │
└─────────────────────────────┘
```

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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 relay 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.

5 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.

5.1 Using an SNTP Signal

When using SNTP to maintain the clock, the relay must first be connected to the SNTP server, which should be energized and functioning.

1. Ensure that the relay is receiving valid time synchronisation messages by checking that the **SNTP Status** cell reads **Server 1 OK** or **Server 2 OK**.
2. Check that the **Act. Time Source** cell reads **SNTP**.
3. Once the relay is using SNTP as the active time source, adjust the time offset of the universal coordinated time on the SNTP Server equipment, so that local time is displayed.
4. Check that the time, date and month are correct in the **Date/Time** cell.

5.2 Using an IRIG-B Signal

When using IRIG-B to maintain the clock, the relay must first be connected to the timing source equipment (usually a P594/RT430), which should be energized and functioning.

The relay uses IRIG B as the primary source. However, if IRIG B is not available it will automatically switch to the secondary source (SNTP). If both options are not available it will be a free running clock.

1. Ensure the relay is receiving the IRIG-B signal by checking that **IRIG-B Status** cell reads **Active**
2. Check that the **Act. Time Source cell** reads **IRIG-B**. This indicates that the relay is using IRIG-B as the source for its time.
3. Once the relay is using IRIG-B as the active time source, adjust the time offset of the universal 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 this also needs to be set manually in this cell.
5. If the auxiliary supply fails, the time and date are maintained by the auxiliary battery. Therefore, when the auxiliary supply is restored, you should not have to set the time and date again. To test this, remove the IRIG-B signal, and then remove the auxiliary supply. Leave the device de-energized for approximately 30 seconds. On re-energization, the time should be correct.
6. Reconnect the IRIG-B signal.

5.3 Without a Timing Source Signal

If the time and date is not being maintained by an IRIG-B, PTP or SNTP signal, in the **DATE AND TIME** column, ensure that both the **Primary Source** and **Secondary Source** are set to **NONE**.

1. Check that **Act. Time Source** cell reads **Free Running**.
2. Set the date and time to the correct local time and date using the Date/Time cell or the serial protocol.
3. If the auxiliary supply fails, the time and date are maintained by the auxiliary battery. Therefore, when the auxiliary supply is restored, you should not have to set the time and date again. To test this, remove the auxiliary supply. Leave the device de-energized for approximately 30 seconds. On re-energization, the time should be correct.

5.4 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.

5.5 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

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6   PHASE ROTATION

The product provides a facility to maintain correct operation of all the protection functions even when the system is running in a reverse phase sequence. This is achieved by the Phase Sequence setting in the **SYSTEM CONFIG** column, and is available for the two setting groups.

You can configure the **Phase Sequence** setting to **Standard ABC** or **Reverse ABC**. This setting does not perform any internal phase swapping of the analog channels.

The Phase Sequence setting affects the sequence component calculation as follows (In this example, the positive and negative sequence currents are shown. The same principle applies to voltages):

Standard ABC

$$I_1 = 1/3(I_A + aI_B + a^2I_C)$$

$$I_2 = 1/3(I_A + a^2I_B + aI_C)$$

Reverse ABC

$$I_1 = 1/3(I_A + a^2I_B + aI_C)$$

$$I_2 = 1/3(I_A + aI_B + a^2I_C)$$

where a is the operator $1\angle 120°$

The phase Sequence setting also affects the directional overcurrent protection as follows:

Standard ABC
- Phase A: Use I_A and V_{BC}
- Phase B: Use I_B and V_{CA}
- Phase C: Use I_C and V_{AB}

Reverse ABC
- Phase A: Use I_A and $-V_{BC}$
- Phase B: Use I_B and $-V_{CA}$
- Phase C: Use I_C and $-V_{AB}$

6.1   CT and VT Reversal

The product also provides VT and CT reversal settings (in the **SYSTEM CONFIG** column), which can be used in applications where some or all of the voltage or current inputs are temporarily reversed, for example in pump storage applications. These settings affect the order of the analog channels in the device and are set to emulate the order of the channels on the power system. So assuming the settings emulate the change in phase configuration on the power system, all the protection functions will naturally operate as per a standard phase rotation system. The phase sequence calculations and the protection functions all remain unchanged.

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7   CHANGING SETTING GROUPS

You can select the setting group using opto inputs, a menu selection, and for some models the hotkey menu or function keys. You can choose which method by 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**, activating DDB # 107 (Setting group) can switch the relay to setting group 2.

Each setting group has its own PSL. Once a PSL has been designed it can be sent to any one of 2 setting groups in the device When downloading a PSL to the device, enter the setting group to which it will be sent. The same applies when extracting a PSL from the device.

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SETTINGS

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CONTENTS

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1 SETTINGS

The P241/2/3 must be configured to the system and application using appropriate settings. In this chapter the settings are described in the sequence: protection settings, control and configuration settings and the disturbance recorder settings. The relay is supplied with a factory-set configuration of default settings.

1.1 Relay Settings Configuration

The relay is a multi-function device that supports numerous different protection, control and communication features. To simplify the setting of the unit, there is a C**onfiguration** settings column, which can be used to enable or disable many of the unit's functions. The settings associated with any disabled function do not appear in the menu. To disable a function, change the relevant cell in the **Configuration** column from **Enabled** to **Disabled**.

The **Configuration** column controls which of the two protection settings groups is selected as active through the **Active settings** cell. A protection setting group can also be disabled in the configuration column, provided it is not the present active group. Similarly, a disabled setting group cannot be set as the active group.

It is possible to copy the contents of one of the setting groups to that of another group. To do this, set the **Copy from** cell to the protection setting group to be copied, then set the **Copy to** cell to the protection group where the copy is to be placed. The copied settings are initially placed in a temporary scratchpad and are only used after they have been confirmed.

To restore the default values to the settings in any protection settings group, set the **restore defaults** cell to the relevant group number. It is possible to set the **restore defaults** cell to **all settings** to restore the default values to all of the relay's settings, not just the protection groups' settings. The default settings are initially placed in the scratchpad and are only used by the relay after they have been confirmed.

Note: If you restore defaults to all settings, it includes the rear communication port settings. If the new (default) settings do not match those of the master station, rear port communication may be disrupted

Menu text	Default setting	Available settings
Restore Defaults	No Operation	No Operation All Settings Setting Group 1 Setting Group 2
Setting to restore a setting group to factory default settings.		
Setting Group	Select via Menu	Select via Menu Select via Optos
Allows setting group changes to be initiated via opto inputs via Setting Group DDB signal in the programmable scheme logic or via the Menu settings.		
Active Settings	Group 1	Group 1, Group 2
Selects the active setting group.		
Save Changes	No Operation	No Operation, Save, Abort
Saves all relay settings.		
Copy from	Group 1	Group 1, 2
Allows displayed settings to be copied from a selected setting group.		
System Config	Visible	Invisible or Visible
Sets the System Config menu visible further on in the relay settings menu.		
Copy to	No Operation	No Operation Group 1, 2
Allows displayed settings to be copied to a selected setting group. (ready to paste).		
Setting Group 1	Enabled	Enabled or Disabled
To enable or disable Group 1 settings. If the setting group is disabled from the configuration, then all associated settings and signals are hidden, with the exception of this setting. (paste).		
Setting Group 2 (as above)	Disabled	Enabled or Disabled

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Menu text	Default setting	Available settings
Thermal Overload	Enabled	Enabled or Disabled
Enables (activates) or disables (turns off) the Thermal Overload protection function. ANSI 49.		
Short Circuit	Enabled	Enabled or Disabled
Enables (activates) or disables (turns off) the Short Circuit Protection function. ANSI 50/51.		
Sensitive E/F	Enabled	Enabled or Disabled
Enables (activates) or disables (turns off) the Sensitive Earth Fault protection function and Wattmetric earth fault element. ANSI 50N/51N/67N/32N/64N.		
Neg. Seq. O/C	Enabled	Enabled or Disabled
Enables (activates) or disables (turns off) the Negative Sequence Overcurrent protection function. ANSI 46.		
3PH Volt Check	Disabled	Enabled or Disabled
Enables (activates) or disables (turns off) the Reverse phase sequence (V2>V1) and undervoltage detection function. ANSI 47.		
Derived E/F	Disabled	Enabled or Disabled
Enables (activates) or disables (turns off) the Derived Earth Fault Protection function. ANSI 50N/51N.		
Neg. Seq. O/V	Disabled	Enabled or Disabled
Enables (activates) or disables (turns off) the Negative Sequence Overvoltage Protection function. ANSI 47.		
Stall Detection	Enabled	Enabled or Disabled
Enables (activates) or disables (turns off) the Stalling Protection function. ANSI 50S.		
Differential	Disabled	Enabled or Disabled
Enables (activates) or disables (turns off) the Motor Differential protection function. ANSI 87.		
Residual O/V NVD	Disabled	Enabled or Disabled
Enables (activates) or disables (turns off) the Residual Overvoltage (Neutral Voltage Displacement) Protection function. ANSI 59N.		
Limit Nb Starts	Enabled	Enabled or Disabled
Enables (activates) or disables (turns off) the Limit Number of Starts Protection function. ANSI 48/51LR/66		
Loss of Load	Disabled	Enabled or Disabled
Enables (activates) or disables (turns off) the Loss of Load Protection function. ANSI 37		
Out of Step	Disabled	Enabled or Disabled
Enables (activates) or disables (turns off) the Out of Step (Underpower Factor) Protection function. ANSI 55.		
Reverse Power	Disabled	Enabled or Disabled
Enables (activates) or disables (turns off) the Reverse Power Protection function. ANSI 32R.		
Anti-Backspin	Disabled	Enabled or Disabled
Enables (activates) or disables (turns off) the Anti-Backspin Protection function. ANSI 27 (Remanent voltage).		
Field Failure	Disabled	Enabled Disabled
Enables (activates) or disables (turns off) the Field Failure protection function ANSI 40		

Menu text	Default setting	Available settings
Volt Protection	Enabled	Enabled or Disabled
Enables (activates) or disables (turns off) the Volt Protection (Under/Overvoltage) function. ANSI 27/59.		
Under Frequency	Disabled	Enabled or Disabled
Enables (activates) or disables (turns off) the Under Frequency protection function. ANSI 81U		
RTD Inputs	Disabled	Enabled or Disabled
Enables (activates) or disables (turns off) the RTD (Resistance Temperature Device) Inputs.		
CB Fail	Disabled	Enabled or Disabled
Enables (activates) or disables (turns off) the Circuit Breaker Fail Protection function. ANSI 50BF.		
Input Labels	Visible	Invisible or Visible
Sets the Input Labels menu visible in the relay settings menu.		
Output Labels	Visible	Invisible or Visible
Sets the Output Labels menu visible in the relay settings menu.		
RTD Labels	Visible	Invisible or Visible
Sets the RTD Labels menu visible in the relay settings menu.		
CT & VT Ratios	Visible	Invisible or Visible
Sets the Current & Voltage Transformer Ratios menu visible in the relay settings menu.		
Record Control	Visible	Invisible or Visible
Sets the Record Control menu visible in the relay settings menu.		
Disturb. Recorder	Visible	Invisible or Visible
Sets the Disturbance Recorder menu visible in the relay settings menu.		
Measure't. Set-up	Visible	Invisible or Visible
Sets the Measurement Setup menu visible in the relay settings menu.		
Comms. Settings	Visible	Invisible or Visible
Sets the Communications Settings menu visible in the relay settings menu. These are the settings associated with the first and second rear communications ports.		
Commission Tests	Visible	Invisible or Visible
Sets the Commissioning Tests menu visible in the relay settings menu.		
Setting Values	Primary	Primary or Secondary
This affects all protection settings that are dependent on CT and VT ratio's.		
Control Inputs	Visible	Invisible or Visible
Sets the Control Inputs menu visible in the relay setting menu.		
CLIO Inputs	Enabled	Enabled or Disabled
Enables (activates) or disables (turns off) the CLIO (Current Loop Input Output) Inputs function.		
CLIO Outputs	Enabled	Enabled or Disabled
Enables (activates) or disables (turns off) the CLIO (Current Loop Input Output) Outputs function.		
CLIO Labels		
Enables (activates) or disables (turns off) the CLIO (Current Loop Input Output) Labels.		
Ctrl I/P Config.	Invisible	Invisible or Visible
Sets the Control Input Configuration menu visible in the relay setting menu.		
Ctrl I/P Labels	Invisible	Invisible or Visible
Sets the Control Input Labels menu visible in the relay setting menu.		
Direct Access	Disabled	Enabled/Disabled/Hotkey
Defines what controls are available via the direct access keys - Enabled (Hotkey and CB Control functions) / Hotkey Only (Control Inputs and Setting group selection) / CB Cntrl Only (CB open/close).		

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Menu text	Default setting	Available settings
Function Key	Visible	Invisible or Visible
Sets the Function Key menu visible in the relay setting menu.		
LCD Contrast	11	0…31
Sets the LCD contrast. To confirm acceptance of the contrast setting the relay prompts the user to press the right and left arrow keys together instead of the enter key as an added precaution to someone accidentally selecting a contrast which leaves the display black or blank. **Note:** The LCD contrast can be set using the front port communications port with the S1 setting software if the contrast is set incorrectly such that the display is black or blank.		

Table 1: General configuration settings

1.2   Protection Settings

The protection settings include all the following items that become active once enabled in the configuration column of the relay menu database:

- Protection element settings.
- Scheme logic settings.

There are two groups of protection settings, with each group containing the same setting cells. One group of protection settings is selected as the active group, and is used by the protection elements. The settings for group 1 only are shown below. The settings are discussed in the same order in which they are displayed in the menu.

1.2.1   System Config

A facility is provided in the P241/2/3 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 two setting groups.

Menu text	Default setting	Setting range		Step size
		Min	**Max**	
GROUP 1: SYSTEM CONFIG				
Phase Sequence	Standard ABC	Standard ABC, Reverse ACB		N/A
The Phase Sequence setting applies to a power system that has a permanent phase sequence of either ABC or ACB.				

Table 2: System configuration settings

1.2.2   Thermal Overload Protection

The thermal overload function within the P241/2/3 relay uses a multiple time constant thermal replica. This replica takes into account the overheating generated by the negative phase sequence current in the motor.

Menu text	Default setting	Setting range		Step size
		Min	**Max**	
GROUP 1: THERMAL OVERLOAD				
Ith Current Set	1 In	0.2 In	1.5 In	0.01 In
Thermal overload current setting.				
K Coefficient	3	0	10	1
Negative sequence current heating factor.				
Thermal Const T1	20 min	1 min	180 min	1 min
Overload time constant.				
Thermal Const T2	20 min	1 min	360 min	1 min
Start-up time constant.				

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Menu text	Default setting	Setting range		Step size
		Min	**Max**	
GROUP 1: THERMAL OVERLOAD				
Cooling Const Tr	20 min	1 min	999 min	1 min
Cooling time constant.				
Thermal Trip	Enabled	Enabled/Disabled		
Enables or disables tripping of the relay if the thermal setting is exceeded.				
Thermal Alarm	Enabled	Enabled/Disabled		
Enables or disables the setting of an alarm threshold for the thermal state.				
Alarm Threshold	90%	0.2%	100%	0.01%
Thermal alarm threshold (in percentage).				
Thermal Lockout	Enabled	Enabled/Disabled		
Enables or disables the lockout of a restart if the thermal state exceeds a threshold.				
Lockout Thresh	20%	0.2%	100%	0.01%
Thermal state setting for the thermal lockout protection (in percentage).				
Inh Trip Dur St	Disabled	Enabled, Disabled		
Inhibits a trip during the start sequence of the motor until Thermal State < Lockout Threshold.				
Thermal Overload	Thermal Model	Thermal Model, User Curve		
Choice of default Thermal Model or a user pre-programmed operate thermal curve which has been downloaded to the relay using the programmable curve tool. There are 4 Curve Characteristics that can be sent to the relay from the Programmable Curve Tool - Curve 1, Curve 2, Curve 3 and Curve 4. Curve 3 is defined as the thermal operate curve.				
Reset	Thermal Model	Thermal Model, User Curve		
Choice of default Thermal Model or a user pre-programmed reset thermal curve which has been downloaded to the relay using the programmable curve tool. There are 4 Curve Characteristics that can be sent to the relay from the Programmable Curve Tool - Curve 1, Curve 2, Curve 3 and Curve 4. Curve 4 is defined as the thermal reset curve.				

Table 3: Thermal over load protection settings

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1.2.3   Short Circuit Protection

The short circuit protection included in the P241/2/3 relay provides four stage non-directional three-phase overcurrent protection with independent time delay characteristics. All overcurrent settings apply to all three phases but are independent for each of the four stages.

The first two stages of overcurrent protection have time-delayed characteristics which are selectable between inverse definite minimum time (IDMT), definite time (DT) and User Curve. The third and fourth stages have definite time characteristics only.

Menu text	Default setting	Setting range		Step size
		Min.	Max.	
GROUP 1				
SHORT CIRCUIT				
I>1 Function	IEC S Inverse	Disabled, DT, IEC S Inverse, IEC V Inverse, IEC E Inverse, UK LT Inverse, UK Rectifier, RI, IEEE M Inverse, IEEE V Inverse, IEEE E Inverse, US Inverse, US ST Inverse, User Curve.		
Tripping characteristic for the first stage overcurrent protection. There are 4 User Curve Characteristics that can be sent to the relay from the Programmable Curve Tool - Curve 1, Curve 2, Curve 3 and Curve 4. Curve 1 is defined as the Short Circuit or Sensitive E/F or Derived Earth Fault operate curve. Curve 2 is defined as the Short Circuit or Sensitive E/F or Derived Earth Fault reset curve. When the User Curve1 is chosen as operate curve, its corresponding reset curve is automatically chosen as the one assigned in the User Programmable Curve Tool.				
I>1 Current Set	7.5 In	0.08 In	15 In	0.1 In
Pick-up setting for first stage overcurrent protection.				
I>1 Time Delay	0.1	0.04	100	0.01
Operating time-delay setting for the definite time setting if selected for first stage element.				
I>1 TMS	1	0.025	1.2	0.025
Time multiplier setting to adjust the operating time of the IEC IDMT characteristic.				
I>1 Time Dial	7	0.01	100	0.01
Time multiplier setting to adjust the operating time of the IEEE/US IDMT and User curves.				
I>1 K (RI)	1	0.1	10	0.05
Time multiplier setting to adjust the operating time for the RI curve.				
I>1 Reset Char	DT	DT or Inverse, User Curve		N/A
Type of reset/release characteristic of the IEEE/US curves. There are 4 User Curve Characteristics that can be sent to the relay from the Programmable Curve Tool - Curve 1, Curve 2, Curve 3 and Curve 4. Curve 2 is defined as the Short Circuit or Sensitive E/F or Derived Earth Fault reset curve. When the User Curve1 is chosen as operate curve, its corresponding reset curve is automatically chosen as the one assigned in the User Programmable Curve Tool.				
I>1 tRESET	0	0 s	100 s	0.01 s
Reset/release time setting for definite time reset characteristic.				
I>2 Cells as for I>1 above				
Setting the same as for the first stage overcurrent protection.				
I>3 Function	Disabled	Disabled or Enabled		N/A
Enable or disables the third stage overcurrent protection.				
I>3 Current Set	15 In	0.08 In	15 In	0.1 In
Pick-up setting for third stage overcurrent protection.				
I>3 Time Delay	0.04	0.04 s	100 s	0.01 s
Operating time-delay setting for third stage overcurrent protection.				
I>4 Cells as for I>3 Above				
Settings the same as the third stage overcurrrent protection.				

Table 4: Short circuit protection settings

1.2.4   Sensitive Earth Fault Protection

The Sensitive Earth Fault protection included in the P241/2/3 relay two stages of directional/non-directional, sensitive earth fault protection. The SEF element can also be configured as a wattmetric earth fault element.

Menu text	Default setting	Setting range		Step size
		Min	**Max**	
Group 1:				
SENSITIVE E/F				
ISEF>1 Function	IEC Standard Inverse	Disabled, DT, IEC S Inverse, IEC V Inverse, IEC E Inverse, UK LT Inverse, IEEE M Inverse, IEEE V Inverse, IEEE E Inverse, US Inverse, US ST Inverse, User Curve.		
Selection of the first stage sensitive earth fault element. There are 4 User Curve Characteristics that can be sent to the relay from the Programmable Curve Tool - Curve 1, Curve 2, Curve 3 and Curve 4. Curve 1 is defined as the Short Circuit or Sensitive E/F or Derived Earth Fault operate curve. Curve 2 is defined as the Short Circuit or Sensitive E/F or Derived Earth Fault reset curve. When the User Curve1 is chosen as operate curve, its corresponding reset curve is automatically chosen as the one assigned in the User Programmable Curve Tool.				
ISEF>1 Direction	Non-Directional	Non-directional Fwd	Directional	
Selection of the directional first stage sensitive earth fault element.				
ISEF>1 Current	0.2 In	0.005 In	1 In	0.001 In
Current setting for the first stage sensitive earth fault element.				
ISEF>1 T Delay	1 sec	0.04 sec	200 sec	0.01sec
Definite Time setting for first stage sensitive earth fault element if ISEF>1 Function is selected as DT.				
ISEF>1 TMS	1	0.025	1.2	0.025
Time Multiplier setting for first stage sensitive earth fault element if ISEF>1 Function has an Inverse Definite Minimum Time (IDMT) setting.				
ISEF>1 Time Dial	7	0.5	15	0.1
Time Dial setting for first stage sensitive earth fault element if ISEF>1 Function is set as a US inverse time curve.				
ISEF>1 Reset Chr	DT	DT, Inverse, User Curve		
Time reset characteristic for first stage sensitive earth fault element if ISEF>1 Function is set as a US Inverse time curve. There are 4 User Curve Characteristics that can be sent to the relay from the Programmable Curve Tool - Curve 1, Curve 2, Curve 3 and Curve 4. Curve 2 is defined as the Short Circuit or Sensitive E/F or Derived Earth Fault reset curve. When the User Curve1 is chosen as operate curve, its corresponding reset curve is automatically chosen as the one assigned in the User Programmable Curve Tool.				
ISEF>1 tReset	0 sec	0 sec	100 sec	0.01 sec
Reset time setting for first stage sensitive earth fault element if ISEF>1 Function is set as Inverse Definite Minimum Time (IDMT).				
ISEF>2 Function	Disabled	Disabled, DT		
Enables or disables the second stage sensitive overcurrent element.				
ISEF>2 Direction	Non-directional	Non-directional Fwd	Directional	
Selection of the directional second stage sensitive earth fault element.				
ISEF>2 Current	0.2 In	0.005 In	1 In	0.001 In
Current setting for the second stage sensitive earth fault element.				
ISEF> 2 T Delay	1 sec	0.04 sec	200 sec	0.01 sec
Definite Time (DT) setting for the second stage sensitive earth fault element.				
ISEF> Directional	Menu Sub-heading			
ISEF> Char Angle	-45°	-180°	+180°	1°
Characteristic angle for the sensitive earth fault directional element.				
ISEF> VN Pol Set	5 V	0.5 V	25 V	0.5 V
Minimum voltage reference setting for the sensitive earth fault directional element.				
Wattmetric SEF	Menu Sub-heading			
PO> Function	Disabled	Disabled, Enabled		
Enables or Disables the Wattmetric sensitive directional earth fault element.				

ST

Menu text	Default setting	Setting range		Step size
		Min	**Max**	
Group 1: SENSITIVE E/F				
PO> Current Set	0.2 In	0.005 In	1 In	0.001 In
Current setting for the Wattmetric sensitive directional earth fault element.				
PO Voltage Set	5 V	0.5 V	80 V	0.5 V
Voltage setting for the Wattmetric sensitive directional earth fault element.				
PO> Coeff K Set	1	1	10	1
Power Threshold setting for the Wattmetric sensitive directional earth fault element.				
PO> Char Angle	0°	-180°	+180°	1°
Characteristic angle setting for the Wattmetric sensitive directional earth fault element.				
PO> Time Delay	0.2 sec	0.04 sec	100 sec	0.01 sec
Time Delay setting for the Wattmetric sensitive directional earth fault element.				
ISEF> VTS Blocking	3	0	3	1
Setting that determines whether VT supervision logic signals blocks the sensitive earth fault stage. When the relevant bit is set to 1, operation of VTS will block the stage if directionalized, when set to 0 the function will be settled to Non-directional.				

Table 5: Sensitive earth fault protection settings

1.2.5   Negative Sequence Overcurrent

The Negative sequence overcurrent protection included in the P241/2/3 relay provides 2 stages of NPS. The first stage can be selected as Definite Time (DT) only and the second stage can be selected as Inverse Definite Minimum Time (IDMT) only.

Menu text	Default setting	Setting range		Step size
		Min	**Max**	
Group 1: NEG SEQ O/C				
I2>1 Status	DT	Disabled, DT		
Enables or Disables the first stage negative sequence overcurrent (NPS) element.				
I2>1 Current Set	0.3 In	0.05 In	4 In	0.025 In
Current setting for the first stage negative sequence overcurrent (NPS) element.				
I2>1 Time Delay	0.2 sec	0.04 sec	200 sec	0.01 sec
Definite Time (DT) setting for the first stage negative sequence overcurrent (NPS) element.				
I2>2 Status	Disabled	Disabled, IDMT		
Enables or Disables the second stage negative sequence overcurrent (NPS) element.				
I2>2 Current Set	0.5 In	0.05 In	4 In	0.05 In
Current setting for the second stage negative sequence overcurrent (NPS) element.				
I2>2 TMS	1	0.7	2	0.025
Time Multiplier Setting (TMS) for the second stage negative sequence overcurrent (NPS) element.				

Table 6: Negative sequence overcurrent protection settings

1.2.6   Three Phase Voltage Check

The three phase voltage check function included in the P241/2/3 relay provides a single low voltage threshold setting, which ensures both correct phase rotation (V1 > V2) and sufficient supply voltage prior to permitting motor starting.

ST

Menu text	Default setting	Setting range		Step size
		Min.	**Max.**	
GROUP 1: 3PH VOLT CHECK				
Start Low V Set	100 V	10 V	120 V	1 V
Phase-Neutral Low Voltage threshold setting.				
V< Measur't Mode	Phase-Neutral	Phase-Neutral/Phase-Phase		
Phase-Neutral Low Voltage threshold setting.				

Table 7: Three phase voltage check setting

1.2.7 Derived Earth Fault

The Derived Earth Fault function within the P241/2/3 relay provides 2 stages of derived directional earth fault protection. Stage 1 can be set Definite Time (DT) or Inverse Definite Minimum Time (IDMT) or User Curve and stage 2 can be set Definite Time (DT) only.

ST

Menu text	Default setting	Setting range		Step size
		Min.	**Max.**	
GROUP 1: DERIVED EARTH FAULT				
IN>1 Function	IEC S Inverse	Disabled, DT, IEC S Inverse, IEC V Inverse, IEC E Inverse, UK LT Inverse, IEEE M Inverse, IEEE V Inverse, IEEE E Inverse, US Inverse, US ST Inverse, User Curve.		
Selection of the first stage derived earth fault element. There are 4 User Curve Characteristics that can be sent to the relay - Curve 1, Curve 2, Curve 3 and Curve 4. Curve 1 is defined as the Short Circuit or Sensitive E/F or Derived Earth Fault operate curve. Curve 2 is defined as the Short Circuit or Sensitive E/F or Derived Earth Fault reset curve. When the User Curve1 is chosen as operate curve, its corresponding reset curve is automatically chosen as the one assigned in the User Programmable Curve Tool.				
IN>1 Direction	Non-Directional	Non-directional Directional Fwd		
Selection of the directional first stage derived earth fault element.				
IN>1 Current	0.2 In	0.08 In	32 In	0.01 In
Current setting for the first stage derived earth fault element.				
IN>1 T Delay	1	0.04 sec	100 sec	0.1 sec
Definite Time setting for first stage derived earth fault element if IN>1 Function is selected as DT.				
IN>1 TMS	1	0.025	1.2	0.025
Time Multiplier setting for first stage sensitive earth fault element if IN>1 Function has an Inverse Definite Minimum Time (IDMT) setting.				
IN>1 Time Dial	7	0.5	15	0.1
Time Dial setting for first stage derived earth fault element if IN>1 Function is set as a US inverse time curve.				
IN>1 Reset Chr	DT	DT, Inverse, User Curve		
Time reset characteristic for first stage derived earth fault element if IN>1 Function is set as a US Inverse time curve. There are 4 User Curve Characteristics that can be sent to the relay from the Programmable Curve Tool - Curve 1, Curve 2, Curve 3 and Curve 4. Curve 2 is defined as the Short Circuit or Sensitive E/F or Derived Earth Fault reset curve. When the User Curve1 is chosen as operate curve, its corresponding reset curve is automatically chosen as the one assigned in the User Programmable Curve Tool.				
IN>1 tReset	0	0 sec	100 sec	0.01 sec
Reset time setting for first stage derived earth fault element if IN>1 Function is set as Inverse Definite Minimum Time (IDMT).				
IN>2 Function	Disabled	Disabled, DT		
Enables or Disables the second stage derived earth fault element.				

Menu text	Default setting	Setting range		Step size
		Min.	Max.	
IN>2 Direction	Non-Directional	Non-directional Directional Fwd		
Selection of the directional second stage derived earth fault element.				
IN>2 Current	0.2 In	0.08 In	32 In	0.01 In
Current setting for the second stage derived earth fault element.				
IN>2 T Delay	1	0.04	100 sec	0.01 sec
Definite Time (DT) setting for the second stage derived earth fault element.				
IN> Directional	Menu Sub-heading			
IN> Char Angle	-45°	-180°	+180°	1°
Characteristic angle for the derived earth fault directional element.				
IN> Pol Type	Zero Sequence	Zero sequence, Neg sequence		
Selection of polarization type depending on VT connection used.				
IN> VN Pol Set	5 V	0.5 V	25 V	0.5 V
Minimum voltage reference setting for the derived earth fault directional element.				
IN> V2pol Set	5 V	0.5 V	25 V	0.5 V
Minimum Negative sequence Voltage reference setting for the derived earth fault directional element.				
IN2> I2pol Set	0.08 In	0.002 In	0.8 In	0.001 In
Minimum Negative sequence current reference setting for the derived earth fault directional element.				
IN> VTS Blocking	3	0	3	1
Setting that determines whether VT supervision logic signals blocks the derived earth fault stage. When the relevant bit is set to 1, operation of VTS will block the stage if directionalized, when set to 0 the function will be settled to Non-directional.				

Table 8: Derived earth fault protection settings

1.2.8   Negative Sequence Overvoltage

The Negative sequence overvoltage function within the P241/2/3 relay provides 2 stages of negative sequence overvoltage protection. Each stage can be selected as Definite Time (DT).

Menu text	Default setting	Setting range		Step size
		Min.	Max.	
GROUP 1: NEG SEQ O/V				
V2>1 Status	DT	Disabled, DT		
Enables or Disables the first stage negative sequence overvoltage element.				
V2>1 Volt Set	5 V	1 V	110 V	100 mV
Voltage setting for the first stage negative sequence overvoltage element.				
V2>1 Time Delay	5 sec	0.04 sec	100 sec	0.01 sec
Definite Time (DT) setting for the first stage negative sequence overvoltage element.				
V2>2 Status	DT	Disabled, DT		
Enables or Disables the second stage negative sequence overvoltage element.				
V2>2 Volt Set	5 V	1 V	110 V	100 mV
Voltage setting for the second stage negative sequence overvoltage element.				
V2>2 Time Delay	5 sec	0.04 sec	100 sec	0.01 sec
Definite Time (DT) setting for the second stage negative sequence overvoltage element.				

Table 9: Negative sequence overvoltage protection settings

1.2.9   Stall Detection

The Stall detection in the P241/2/3 relay is available for protection of the motor during the starting sequence.

Menu text	Default setting	Setting range		Step size
		Min	Max	
GROUP 1: STALL DETECTION				
Prolonged Start	Enabled	Disabled, Enabled		
Enables or disables the detection of a prolonged start.				
Start Criteria	52a	52a I 52a + I		
Selects the detection method of a motor start. Options are change of state of Circuit Breaker (52a), exceeding the starting current threshold or both.				
Starting Current	3 In	1 In	5 In	0.5 In
Starting current setting. A normal start will be detected if the current falls below this threshold within the prolonged start time setting. Setting in multiples of nominal current setting.				
Prol Start time	5 sec	1 sec	200 sec	1 sec
Starting supervision time. The motor current has to fall below the starting current threshold within this time for a normal start to be detected.				
Stall Rotor-Strt	Disabled	Disabled, Enabled		
Enables or disables the locked rotor during starting element. Used in conjunction with the speed switch input if the starting time is greater than the safe stall time.				
Stall Detection	Enabled	Disabled, Enabled		
Enables or disables the stall detection element.				
Stall Setting	2 In	1 In	3 In	0.5 In
Stall current setting.				
Stall Time	2 sec	0.1 sec	60 sec	0.1 sec
Stall Time Delay setting.				
Reacceleration	Disabled	Disabled, Enabled		
Enables or disables the reacceleration of the motor following a reduction in system voltage.				
Reacc Low V Set	100 V	50 V	120 V	1 V
Undervoltage setting for the reacceleration element.				
LV Ride Thru	Disabled	Disabled, Enabled		
Enables or disables the ride through of the motor following a reduction in system voltage.				
Reacc High V Set	100 V	50 V	120 V	1 V
Over voltage setting for ride through of the motor following a temporary dip in system voltage.				
Reacc Time	6 sec	40 ms	60 sec	10 ms
Low voltage ride through delay time setting during which conditional ride through is authorized.				
Auto Re-Start	Disabled	Disabled, Enabled		
Enables or disables automatic re-start of the motor after a trip due to failed ride through attempt.				
Reacc Long Time	20 sec	0 sec	60 sec	100 ms
Delay time for automatic re-start of the motor during which conditional re-start is authorized.				
Reacc Shed Time	0 sec	0 sec	5940 sec	100 ms
Delay time for sequencing automatic re-start of the motor.				

Table 10: Stall protection settings

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1.2.10   Motor Differential Protection (P243 only)

The differential protection included in the P243 relay may be configured to operate as either a high impedance or biased differential element.

Menu text	Default setting	Setting range		Step size
		Min.	**Max.**	
GROUP 1: DIFFERENTIAL				
Diff Function	Percentage Bias	Disabled Percentage Bias High Impedance		
Setting to select the function of the differential protection element.				
Diff Is1	0.1 In	0.05 In	0.5 In	0.01 In
Minimum differential operating current of the low impedance biased characteristic. Also, the pick-up setting of the high impedance differential protection.				
Diff K1	0%	0 %	20%	5%
Slope angle setting for the first slope of the low impedance biased characteristic.				
Diff Is2	1.2 In	1 In	5 In	0.1 In
The bias current operating threshold for the second slope, low impedance characteristic.				
Diff K2	150%	20%	150%	10%
Slope angle setting for the second slope of the low impedance biased characteristic.				

Table 11: Differential protection settings

1.2.11   Residual Overvoltage (Neutral Voltage Displacement)

The neutral voltage displacement (NVD) element within the P241/2/3 relay is of two-stage design, each stage having separate voltage and time delay settings. Stage 1 may be set to operate on either an IDMT or DT characteristic, while stage 2 may be set to DT only.

Menu text	Default setting	Setting range		Step size
		Min.	**Max.**	
GROUP 1: RESIDUAL O/V NVD				
VN>1 Function	Disabled	Disabled DT IDMT		
Selection of the first stage residual overvoltage (NVD) element.				
VN>1 Voltage Set	5 V	0.5 V	80 V	0.5 V
Voltage setting for the first stage residual overvoltage (NVD) element.				
VN>1 Time Delay	5 sec	0.04 sec	100 sec	0.01 sec
Definite Time (DT) setting for the first stage residual overvoltage (NVD) element if VN>1 Function is set as DT.				
VN>1 TMS	1	0.05	100	0.05
Time Multiplier setting for the first stage residual overvoltage (NVD) element if VN>1 Function is set as IDMT.				
VN>2 Status	Disabled	Disabled, DT		
Enables or disables the second stage residual overvoltage (NVD).				
VN>2 Voltage Set	10 V	0.5 V	80 V	0.5 V
Voltage setting for the second stage residual overvoltage (NVD) element.				
VN>2 Time Delay	10 sec	0.04 sec	100 sec	0.01 sec
Definite Time (DT) setting for the second stage residual overvoltage (NVD) element.				

Table 12: Residual overvoltage protection settings

ST

1.2.12 Limit Number of Starts Protection

The start protection within the P241/2/3 relay supervises the maximum allowable number of starts, hot or cold, that the motor is permitted for. The relay distinguishes between a hot start or a cold start by using the data held in the motor thermal replica. Starting is blocked if the permitted number of starts is exceeded by the use of a time between starts timer.

Menu text	Default setting	Setting range		Step size
		Min.	**Max.**	
GROUP 1: LIMIT NB STARTS				
Hot Start status	Disabled	Disabled, Enabled		
Enables or disables the setting of a maximum number of hot starts before a relay issues an alarm.				
Hot start Nb	1	1	5	1
Maximum number of hot starts allowed before starting of the motor is inhibited.				
Cold Start Stat	Disabled	Disabled, Enabled		
Enables or disables the setting of a maximum number of cold starts before a relay issues an alarm.				
Cold start Nb	1	1	5	1
Maximum number of cold starts allowed before starting of the motor is inhibited.				
Supervising Time	10 min	10 min	120 min	1 min
Supervising period for the number of hot and cold starts.				
T Betw St Status	Disabled	Disabled, Enabled		
Enables or disables the setting of a minimum time between motor starts.				
Time betw start	2 min	1 min	120 min	1 min
Minimum time period setting allowable between each motor start.				
Inhib Start Time	10 min	1 min	120 min	1 min
Inhibition time setting. If the maximum number of starts (hot or cold) is reached, this time delay will start and inhibit a new start before it ends.				

Table 13: Limit number of start protection settings

1.2.13 Loss of Load (Under Power)

The Loss of Load protection within the P241/2/3 relay uses 2 underpower elements to detect a loss of load due to a shaft failure or a pump running unprimed. Both stages are selectable to Definite Time (DT). This feature is only enabled when the circuit breaker is closed, therefore it requires a 52a CB auxiliary contact mapped to an opto input to monitor the breaker status.

Menu text	Default setting	Setting range		Step size
		Min	**Max**	
GROUP1: LOSS OF LOAD				
P<1 Status	DT	Disabled, DT		
Enables or disables the first stage underpower element.				
P<1 Power Set	1 In W	1 In W	120 In W	1 In W
First stage underpower threshold.				
P<1 Time Delay	0.2 sec	0.04 sec	100 sec	0.01 sec
Definite Time (DT) setting for first stage underpower element.				
P<2 Status	Disabled	Disabled, DT		
Enables or disables the second stage underpower element.				
P<2 Power Set	1 In W	1 In W	120 In W	1 In W
Second stage undrepower threshold.				
P<2 Time Delay	0.2 sec	0.04 sec	100 sec	0.01 sec
Definite Time (DT) setting for second stage underpower element.				

ST

Menu text	Default setting	Setting range		Step size
		Min	**Max**	
GROUP1: LOSS OF LOAD				
P<Drop-off Time	5 sec	0.05 sec	300 sec	0.05 sec
Time delay on drop-off to ensure inhibition during motor starting.				

Table 14: Loss of load protection settings

1.2.14   Out of Step Protection (Under Power Factor)

The P241/2/3 relays provide power factor protection on synchronous machines by monitoring the 3 phase power factor. Both Lead and Lag elements are settable to Definite Time (DT). This feature is only enabled when the circuit breaker is closed, therefore it requires a 52 a CB auxiliary contact mapped to an opto input to monitor the breaker status.

Menu text	Default setting	Setting range		Step size
		Min.	**Max.**	
GROUP 1: OUT OF STEP				
PF< Status Lead	DT	Disabled, DT		
Enables or disables the lead level element of the under power factor protection.				
Power Fact Lead	0.9	0.1	0.9	0.1
Power Factor setting for the lead level element.				
PF< Lead TD	0.05 sec	0.05 sec	100 sec	0.01 sec
Time delay setting associated with the lead level element of the under power factor protection.				
PF< Status Lag	Disabled	Disabled, DT		
Enables or disables the lag level element of the under power factor protection.				
Power Fact Lag	0.9	0.1	0.9	0.1
Power Factor setting for the lag level element.				
PF< Lag TD	0.05 sec	0.05 sec	100 sec	0.01 sec
Time delay setting associated with the lag level element of the under power factor protection.				
PF< Drop-of Time	7 sec	0.05 sec	300 sec	0.05 sec
Time delay on drop-off.				

Table 15: Out of step protection settings

1.2.15   Reverse Power

The P241/2/3 relays provides reverse power protection which is used to detect the reverse flow of power due to a synchronous motor feeding a fault. This feature is only enabled when the circuit breaker is closed, therefore it requires a 52 a CB auxiliary contact mapped to an opto input to monitor the breaker status.

Menu text	Default setting	Setting range		Step size
		Min.	**Max.**	
GROUP 1: REVERSE POWER				
Rev P< Power Set	1 In W	1 In W	120 In W	1 In W
Setting for the reverse power stage.				
Rev P< Time Delay	0.2 sec	0.04 sec	100 sec	0.01 sec
Time delay associated with the reverse power stage.				
Rev P< Drop-of Ti	5 sec	0.05 sec	300 sec	0.05 sec
Time delay on drop-off to ensure inhibition during motor starting.				

Table 16: Reverse power protection settings

1.2.16 Anti-Backspin Protection

The P241/2/3 relays provide anti-backspin protection.

Menu text	Default setting	Setting range		Step size
		Min.	Max.	
GROUP 1: ANTI-BACKSPIN				
VRem Antibacks	10 Vn	1 Vn	120 Vn	1 Vn
Setting of the remanent phase-phase voltage element.				
Antibacks Delay	3000 secs	1 secs	7200 secs	1 secs
Time delay setting associated with the remanent voltage anti-backspin protection.				

Table 17: Anti-Backspin protection settings

1.2.17 Field Failure Protection

The field failure protection included in the P241/2/3 relay provides two impedance based stages of protection and a leading power factor alarm element.

ST

Menu text	Default setting	Setting range		Step size
		Min	Max	
GROUP1: FIELD FAILURE				
FFail Alm Status	Disabled	Disabled, Enabled		
Enables or disables the Field Failure Alarm function.				
FFail Alm Angle	-15°	-75°	75°	1°
Pick-up setting for field failure alarm angle (leading power factor angle).				
FFail Alm Delay	5 sec	0 sec	100 sec	0.1 sec
Operating time-delay setting of the field failure alarm.				
FFail1 Status	Enabled	Disabled, Enabled		
Enables or disables the first stage field failure protection function.				
FFail1 Xa1	-20 /In Ω	-40/In Ω	365/In Ω	0.5/In Ω
Negative reactance offset setting of first stage field failure impedance protection.				
FFail1 Xb1	220/In Ω	25/In Ω	325/In Ω	1/In Ω
Diameter setting of circular impedance characteristic of first stage field failure protection.				
FFail1 TimeDelay	5 sec	0 sec	100 sec	0.1 sec
Operating time-delay setting of the field failure first stage protection.				
FFail1 DO Timer	0 s	0 s	10 s	0.1 s
Drop-off time-delay setting of the first stage field failure protection.				
FFail2 Status	Enabled	Disabled, Enabled		
Enables or disables the second stage field failure protection function.				
FFail2 Xa2	-20/In Ω	-40/In Ω	365/In Ω	0.5/In Ω
Negative reactance offset setting of second stage field failure impedance protection.				
FFail2 Xb2	110/In Ω	25/In Ω	325/In Ω	1/In Ω
Diameter setting of circular impedance characteristic of second stage field failure protection.				
FFail2 TimeDelay	0 s	0 s	100 s	0.1 s
Operating time-delay setting of the field failure second stage protection.				
FFail2 DO Timer	0 s	0 s	10 s	0.1 s
Drop-off time-delay setting of the second stage field failure protection.				

Table 18: Field failure protection settings

1.2.18   Voltage Protection

The undervoltage and overvoltage protection included within the P241/2/3 relay both consist of two independent stages. The Undervoltage protection stage 1 can be set to Inverse Definite Minimum Time (IDMT) and the second stage can be set to Definite Time (DT).   This feature is only enabled when the circuit breaker is closed, therefore it requires a 52a CB auxiliary contact mapped to an opto input to monitor the breaker status.

The overvoltage protection stage 1 and stage 2 can be set to Definite Time (DT) only.

Menu text	Default setting	Setting range		Step size
		Min.	**Max.**	
GROUP 1: VOLT PROTECTION				
UNDERVOLTAGE	Menu Sub-heading			
V< Measur't Mode	Phase-Phase	Phase-Neutral, Phase-Phase		
Sets the measured input voltage used for the undervoltage elements.				
V< Operate Mode	Any Phase	Any Phase, Three Phase		
Determines whether any phase or all three phases must satisfy the undervoltage criteria before a decision is made.				
V<1 Function	Disabled	Disabled DT IDMT		
Selection of first stage undervoltage element.				
V<1 Voltage Set	93 V	15 V	120 V	1 V
Setting of the first stage undervoltage element.				
V<1 Time Delay	0.5 sec	0.04 sec	7200 sec	0.01 sec
Definite Time (DT) setting for the first stage undervoltage element if V<1 Function is set as DT.				
V<1 TMS	1	0.5	100	0.01
Time Multiplier Setting of first stage undervoltage element if V<1 Function is set as IDMT.				
V<1 PoleDead Inh	Enabled	Disabled, Enabled		
This setting enables or disables the Pole Dead inhibit logic.				
V<1 tReset	0	0 sec	600	0.01
This setting determines the Reset time for IEC reset characteristic				
V<2 Status	Disabled	Disabled/DT		
Selection of second stage undervoltage element.				
V<2 Voltage Set	60 V	15 V	120 V	1 V
Setting of the second stage undervoltage element.				
V<2 Time Delay	0.25 sec	0.04 sec	100 sec	0.01 sec
Definite Time (DT) setting for the first stage undervoltage element if V<1 Function is set as DT.				
Inhib During St	Disabled	Disabled, Enabled		
Setting to enable or disable the inhibit of undervoltage elements during motor starting.				
V<2 PoleDead Inh	Enabled	Disabled, Enabled		
This setting enables or disables the Pole Dead inhibit logic.				
V<2 tReset	0	0 sec	600	0.01
This setting determines the Reset time for IEC reset characteristic				
GROUP 1: VOLT PROTECTION				
OVERVOLTAGE	Menu Sub-Heading			
V> Measur't Mode	Phase-Phase	Phase-Neutral, Phase-Phase		
Sets the measured input voltage used for the overvoltage elements.				
V> Operate Mode	Any Phase	Any Phase, Three Phase		
Determines whether any phase or all three phases must satisfy the overvoltage criteria before a decision is made.				

ST

Menu text	Default setting	Setting range		Step size
		Min.	**Max.**	
GROUP 1: VOLT PROTECTION				
V>1 Status	Disabled	Disabled, DT		
Enable or disables the first stage overvoltage element.				
V>1 Voltage Set	165 V	50 V	200 V	1 V
Setting of the first stage overvoltage element.				
V>1 Time Delay	10 sec	0.04 sec	7200 sec	0.01 sec
Definite Time (DT) setting for the first stage overvoltage element.				
V>2 Status	DT	Disabled, DT		
Enable or disables the second stage overvoltage element.				
V>2 Voltage Set	140 V	50 V	200 V	1 V
Setting of the second stage overvoltage element.				
V>2 Time Delay	5 sec	0.04	7200 sec	0.01 sec
Definite Time (DT) setting for the second stage overvoltage element.				

Table 19: Under/Overvoltage protection settings

ST

1.2.19 Underfrequency Protection

The P241/2/3 relay includes 2 stages of underfrequency protection to protect synchronous machine against loss of AC supply. Each stage can be selected as Definite Time (DT). This feature is only enabled when the circuit breaker is closed, therefore it requires a 52a CB auxiliary contact mapped to an opto input to monitor the breaker status.

Menu text	Default setting	Setting range		Step size
		Min.	Max.	
GROUP 1: UNDERFREQUENCY				
F<1 Status	Disabled	Disabled, DT		
Enables or disables the first stage underfrequency element.				
F<1 Setting	49 Hz	45 Hz	65 Hz	0.01 Hz
Pick-up setting for the first stage underfrequency element.				
F<1 Time Delay	0.1 sec	0.1 sec	100 sec	0.01 sec
Operating time-delay setting for the definite time first stage underfrequency element.				
F<2 Status	Disabled	Disabled, DT		
Enables or disables the second stage underfrequency element.				
F<2 Setting	48 Hz	45 Hz	65 Hz	0.01 Hz
Pick-up setting for the second stage underfrequency element.				
F<2 Time Delay	0.1 sec	0.1 sec	100 sec	0.01 sec
Operating time-delay setting for the definite time second stage underfrequency element.				

Table 20: Underfrequency protection settings

1.2.20 Resistor Temperature Device (RTD)

The P241/2/3 relays provide temperature protection from 10 PT100/Ni100/Ni120 resistor temperature devices (RTD). Each RTD has a definite time trip and alarm stage.

ST

Menu text	Default setting	Setting range		Step size
		Min.	Max.	
GROUP 1: RTD PROTECTION				
Select RTD	0000000000	Bit 0 - Select RTD 1 Bit 1 - Select RTD 2 Bit 2 - Select RTD 3 Bit 3 - Select RTD 4 Bit 4 - Select RTD 5 Bit 5 - Select RTD 6 Bit 6 - Select RTD 7 Bit 7 - Select RTD 8 Bit 8 - Select RTD 9 Bit 9 - Select RTD 10		N/A
10 bit setting to enable or disable the 10 RTDs. For each bit 1 = Enabled, 0 = Disabled.				
RTD 1 Alarm Set	80°C	0°C	400°C	1°C
Temperature setting for the RTD 1 alarm element.				
RTD 1 Alarm Dly	0 s	0	100 s	1 s
Operating time delay setting for the RTD 1 alarm element.				
RTD 1 Trip Set	100°C	0°C	400°C	1°C
Temperature setting for the RTD 1 trip element.				
RTD 1 Trip Dly	0 s	0	100 s	1 s
Operating time delay setting for the RTD 1 alarm element.				
RTD 2-10 Alarm and Trip Settings are the same as RTD1.				
Ext Temp Influen	Disabled	Disabled, DT		
Enables or disables the adaptation of the thermal replica according to the external ambient temperature measurement.				
Ext Temp RTD	1	1	10	1
RTD which will be used to adapt the thermal replica for the external ambient temperature.				
Ext RTD Back-up	2	1	10	1
Back-up RTD which will be used to adapt the thermal replica for the external ambient temperature.				
RTD Type	PT100	PT100, Ni100, Ni120		
Type of RTD.				
RTD Unit	Degree Celsius	Degree Celsius, Fahrenheit		
Unit of RTD temperature measurement.				

Table 21: RTD protection settings

1.2.21　　Circuit Breaker Fail

This function consists of a two-stage circuit breaker fail function that can be initiated by:

- Current based protection elements
- Non current based protection elements
- External protection elements

For current-based protection, the reset condition is based on undercurrent operation to determine that the CB has opened. For the non-current based protection, the reset criteria may be selected by means of a setting for determining a CB Failure condition.

It is common practice to use low set undercurrent elements in protection relays to indicate that circuit breaker poles have interrupted the fault or load current, as required.

Menu text	Default setting	Setting range		Step size
		Min.	**Max.**	
GROUP 1: CB FAIL				
BREAKER FAIL	Sub-heading			
CB Fail 1 Status	Enabled	Enabled or Disabled		
Enables or disables the first stage of the circuit breaker function.				
CB Fail 1 Timer	0.2 s	0 s	10 s	0.01 s
Circuit breaker fail timer setting for stage 1 for which the initiating condition must be valid.				
CB Fail 2 Status	Disabled	Enabled or Disabled		
Enables or disables the second stage of the circuit breaker function.				
CB Fail 2 Timer	0.4 s	0 s	10 s	0.01 s
Circuit breaker fail timer setting for stage 2 for which the initiating condition must be valid.				
CBF Non I Reset	CB Open & I<	I< Only, CB Open & I<, Prot. Reset & I<		
Setting which determines the elements that will reset the circuit breaker fail time for non current based protection functions (e.g. voltage, frequency) initiating circuit breaker fail conditions.				
CBF Ext Reset	CB Open & I<	I< Only, CB Open & I<, Prot. Reset & I<		
Setting which determines the elements that will reset the circuit breaker fail time for external protection functions initiating circuit breaker fail conditions.				
UNDERCURRENT	Sub-heading			
I< Current Set	0.1 In	0.02 In	3.2 In	0.0 1In
Circuit breaker fail phase fault undercurrent setting. This undercurrent element is used to reset the CB failure function initiated from the internal or external protection (Any Trip and Ext Trip signals).				

Table 22: CBF protection settings

1.2.22   Supervision (VTS and CTS)

The VTS feature in the relay operates on detection of negative phase sequence (NPS) voltage without the presence of negative phase sequence current. This gives operation for the loss of one or two-phase voltages. Stability of the VTS function is assured during system fault conditions, by the presence of NPS current. The use of negative sequence quantities ensures correct operation even where three-limb or V connected VT's are used.

Under the loss of all three-phase voltages to the relay, there will be no negative phase sequence quantities present to operate the VTS function. However, under such circumstances, a collapse of the three-phase voltages will occur. If this is detected without a corresponding change in any of the phase current signals (which would be indicative of a fault), then a VTS condition will be raised. In practice, the relay detects the presence of superimposed current signals, which are changes in the current applied to the relay.

If a VT were inadvertently left isolated prior to line energization, incorrect operation of voltage dependent elements could result. The previous VTS element detected three-phase VT failure by absence of all three-phase voltages with no corresponding change in current. On line energization there will, however, be a change in current (as a result of load or line charging current for example). An alternative method of detecting three-phase VT failure is therefore required on line energization.

The absence of measured voltage on all three-phases on line energization can be as a result of 2 conditions. The first is a three-phase VT failure and the second is a close up three-phase fault. The first condition would require blocking of the voltage dependent function and the second would require tripping. To differentiate between these 2 conditions an overcurrent level detector (VTS I> Inhibit) is used which will prevent a VTS block from being issued if it operates. This element should be set in excess of any non-fault based currents on line energization (load, line charging current, transformer inrush current if applicable) but below the level of current produced by a close up three-phase fault. If the line is now closed where a three-phase VT failure is present the overcurrent detector will not operate and a VTS block will be applied. Closing onto a three-phase fault will result in operation of the overcurrent detector and prevent a VTS block being applied.

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The CT supervision feature operates on detection of derived zero sequence current, in the absence of corresponding derived zero sequence voltage that would normally accompany it.

The CT supervision can be set to operate from the residual voltage measured at the VNEUTRAL input (VN1 input for P241/2/3) or the residual voltage derived from the three phase-neutral voltage inputs as selected by the 'CTS Vn Input' setting.

There are two stages of CT supervision CTS-1 and CTS-2. CTS-1 supervises the CT inputs to IA, IB, IC which are used by the biased differential protection and all the power, impedance and overcurrent based protection functions. CTS-2 supervises the CT inputs to IA-2, IB-2, IC-2 which are used by the biased or high impedance differential or interturn protection in the P243. The CTS-2 independent enabled/disabled setting is to prevent CTS-2 from giving unnecessary alarms when the Generator Differential is disabled. For interturn faults, some utilities may isolate the faulted winding section and return the generator to service, therefore producing unbalanced phase currents. Under these circumstances the CTS-2 may also need to be disabled or de-sensitized to prevent a false alarm and a false block.

Menu text	Default setting	Setting range		Step size
		Min.	Max.	
SUPERVISION				
GROUP 1				
VT SUPERVISION	Sub-heading			
VTS I2> Inhibit	0.05 In	0.05 In	0.5 In	0.0 1In
This NPS overcurrent setting is used to inhibit the voltage transformer supervision in the event of a fault occurring on the system with negative sequence current above this setting.				
VTS Time Delay	5 s	1 s	10 s	0.1 s
Operating time-delay setting of the VTS element on detection of a voltage supervision condition.				
Detect 3 P	Disabled	Enabled or Disabled		N/A
This overcurrent setting is used to inhibit the voltage transformer supervision in the event of a loss of all 3 phase voltages caused by a close up 3 phase fault occurring on the system following closure of the CB to energize the line.				
Threshold 3P	30 V	10 V	70 V	1 V
3 phase under voltage level setting. This setting is used to indicate a close up 3 phase fault or a 3 phase VT failure condition.				
Delta I >	0.1 In	0.1 In	5 In	0.01 In
Delta (superimposed) phase current setting. This setting is used to distinguish between a close up 3 phase fault and a 3 phase VT failure condition under load conditions. For a close up 3 phase fault there will be a loss of 3 phase voltage but there will be a delta change in the measured current. For a 3 phase VT failure where there will a loss of 3 phase voltage but no delta change in the measured current.				
VTS I> Inhibit	10 In	0.1 In	32 In	0.1 In
This overcurrent setting is used to inhibit the voltage transformer supervision in the event of a loss of all 3 phase voltages caused by a close up 3 phase fault occurring on the system following closure of the CB to energize the line.				
CT SUPERVISION	Sub-heading			
CTS1 Status	Disabled	Enabled or Disabled		N/A
Enables or disables the current transformer supervision 1 element.				
CTS1 VN< Inhibit	0.05 Vn	0.01 Vn	0.2 Vn	0.01 Vn
Residual/neutral voltage setting to inhibit the CTS1 element.				
CTS1 IN> Set	0.2 In	0.08 x In	4 x In	0.01 x In
Residual/neutral current setting for a valid current transformer supervision condition for CTS1.				
CTS1 Time Delay	5 s	0 s	10 s	1 s
Operating time-delay setting of CTS1.				

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Menu text	Default setting	Setting range		Step size
		Min.	**Max.**	
CTS2 settings are the same as CTS1				
To be used only for P243 differential protection scheme.				

Table 23: VTS and CTS protection settings

1.2.23   Current Loop Inputs And Outputs (CLIO)

Four analog or current loop (analog) inputs are provided for transducers with ranges of
0 - 1 mA, 0 - 10 mA, 0 - 20 mA or 4 - 20 mA. The analog inputs can be used for various
transducers such as vibration monitors, tachometers and pressure transducers. Associated
with each input there are two protection stages, one for alarm and one for trip. Each stage
can be individually enabled or disabled and each stage has a definite time delay setting.
The Alarm and Trip stages operate when the input value rises above the Alarm/Trip
threshold.

Four current loop (analog) outputs are provided with ranges of 0 - 1 mA, 0 - 10 mA,
0 - 20 mA or 4 - 20 mA which can alleviate the need for separate transducers. These may
be used to feed standard moving coil ammeters for analog indication of certain measured
quantities or into a SCADA using an existing analog RTU.

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Menu text	Default setting	Setting range		Step size
		Min.	Max.	
GROUP 1: CLIO INPUTS				
Range 1	Disabled	Disabled, 0 - 1 mA, 0 - 10 mA, 0 - 20 mA, 4 - 20 mA		
Enables or disables the current loop (transducer) input 1 element.				
Unit 1	None	None, A, V, Hz, W, Var, VA, °C, F, %, s		
Current loop 1 input unit type.				
Minimum 1	0	A list of parameters are shown in the table below.		
Current loop input 1 minimum setting. Defines the lower range of the physical or electrical quantity measured by the transducer.				
Maximum 1	0	A list of parameters are shown in the table below.		
Current loop input 1 maximum setting. Defines the upper range of the physical or electrical quantity measured by the transducer.				
Function 1	Disabled	Disabled, Enabled		
Enables or disables the current loop (transducer) input 1 alarm and trip stages.				
Alarm Set 1	0	A list of parameters are shown in the table below.		
Pick-up setting for the current loop input 1 alarm element.				
Alarm Delay 1	0	0	300 s	1 s
Operating time-delay setting of current loop input 1 alarm element.				
Trip Set 1	0	A list of parameters are shown in the table below.		
Pick-up setting for the current loop input 1 trip element.				
Trip Delay 1	0	0	300 s	1 s
Operating mode of the current loop input 1 trip element.				
CLI2/3/4 settings are the same as CLI1				
Drop-of Time	5 sec	0.1 sec	300 sec	0.1 sec
Drop-off time delay of the current loop inputs 1/2/3/4.				
GROUP 1: CLIO OUTPUTS				
Range 1	Disabled	Disabled, 0 - 1 mA, 0 - 10 mA, 0 - 20 mA, 4 - 20 mA		
Current loop 1 output type.				

Menu text	Default setting	Setting range		Step size
		Min.	Max.	
ANALOG OUTPUT 1	IA Magnitude	A list of parameters are shown in the table below		
This setting defines the measured quantity assigned to current loop output 1.				
Minimum 1	0	Range, step size and unit corresponds to the selected parameter in the table below		
Current loop output 1 minimum setting. Defines the lower range of the measurement.				
Maximum 1	100 A	Range, step size and unit corresponds to the selected parameter in the table below		
Current loop output 1 maximum setting. Defines the upper range of the measurement.				
Analog Output 2/3/4 settings are the same as Analog Output 1 except Analog Output 2/3/4 measurements are VA Magnitude, Frequency and RTD1 Temperature.				

Table 24: Current loop inputs and outputs settings

Analog (Current loop) input units and setting ranges are shown below

Analog input unit	Setting range		Step size
	Min.	Max.	
A	0	100 k	1
V	0	20 k	1
Hz	0	100	1
W	-1.41 G	1.41 G	1
VAr	-1.41 G	1.41 G	1
VA	0	1.41 G	1
°C	-40	400	1
F	-40	752	1
%	0	150	0.1
s	0	300	0.1
None	-32.5 k	50 k	0.1

Table 25: Current loop inputs units and setting ranges

The CLIO output conversion task runs every 50 ms and the refresh interval for the output measurements is nominally 200 ms.

Current loop output parameters are shown in the following table:

Current loop output parameter	Abbreviation	Units	Range	Step	Default min.	Default max.
Current Magnitude	IA Magnitude IB Magnitude IC Magnitude IN Magnitude	A	0 to 100 k	1	0	100
RMS Phase Currents	IA RMS IB RMS IC RMS IN RMS	A	0 to 100 k	1	0	100
P-N voltage Magnitude	VAN Magnitude VBN Magnitude VCN Magnitude VN Magnitude	V	0 to 20 k	1	0	100
RMS Phase-N Voltages	VAN RMS VBN RMS VCN RMS	V	0 to 20 k	1	0	100

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Current loop output parameter	Abbreviation	Units	Range	Step	Default min.	Default max.
P-P Voltage Magnitude	VAB Magnitude VBC Magnitude VCA Magnitude	V	0 to 20 k	1	0	100
RMS Phase-Phase Voltages	VAB RMS Magnitude VBC RMS Magnitude VCA RMS Magnitude	V	0 to 20 k	1	0	100
Frequency	Frequency	Hz	0 to 100	1	0	100
3 Ph Active Power	Three-Phase Watts	W	-30M to 30 M	1	0	100
3 Ph Reactive Power	Three-Phase Vars	Var	- 30M to 30 M	1	0	100
3 Ph Apparent Power	Three-Phase VA	VA	- 30M to 30 M	1	0	100
3 Ph Power Factor	3Ph Power Factor	-	-1 to 1	0.01	0	1
RTD Temperatures	RTD 1 RTD 2 RTD 3 RTD 4 RTD 5 RTD 6 RTD 7 RTD 8 RTD 9 RTD 10	°C	-40°C to 400°C	1°C	0°C	100°C
Nb of hottest RTD	Nb Hottest RTD		1-10	1	1	10
Thermal State	Thermal State	%	0-150	0.1	0	100
Time to Thermal Trip	Time to Thermal Trip	Sec	0-300	0.1	0	100
Time to next start	Time to Next Start	Sec	0-300	0.1	0	100

Table 26: Current loop outputs units and setting range

Note 1: The current loop (Analog) outputs are refreshed every 200 ms.

Note 2: The polarity of Watts, Vars and power factor is affected by the Measurements Mode setting.

Note 3: These settings are for nominal 1 A and 100/120 V versions only. For other nominal versions they need to be multiplied accordingly.

Note 4: All current loop (Analog) output measurements are in primary values.

1.2.24 Input Labels

Menu text	Default setting	Setting range	Step size
GROUP 1: INPUT LABELS			
Opto Input 1	Opto 1	16 Character Text	
Text label to describe each individual opto input. This text will be displayed in the programmable scheme logic and event record description of the opto input.			
Opto Input 2 to 16	Opto 2 to 16	16 Character Text	
Text label to describe each individual opto input. This text will be displayed in the programmable scheme logic and event record description of the opto input.			

Table 27: Input labels settings

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1.2.25   Output Labels

Menu text	Default setting	Setting range	Step size
GROUP 1:			
OUTPUT LABELS			
Relay 1	Relay 1	16 Character Text	
Text label to describe each individual relay output contact. This text will be displayed in the programmable scheme logic and event record description of the relay output contact.			
Relay 2 to 16	Relay 2 to Relay 16	16 Character Text	
Text label to describe each individual relay output contact. This text will be displayed in the programmable scheme logic and event record description of the relay output contact.			

Table 28: Output labels settings

1.2.26   RTD Labels

Menu text	Default setting	Setting range	Step size
GROUP 1:			
RTD LABELS			
RTD 1	RTD 1	16 Character Text	
Text label to describe each individual RTD. This text will be displayed in the Measurements 3 menu and fault records for the description of the RTDs.			
RTD 2 to 10	RTD 2 to RTD 10	16 Character Text	
Text label to describe each individual RTD. This text will be displayed in the Measurements 3 menu and fault records for the description of the RTDs.			

Table 29: RTD labels settings

1.2.27   Analog Input labels

Menu text	Default setting	Setting range	Step size
GROUP 1:			
CLIO LABELS			
CLIO Input 1	Analog Input 1	16 Character Text	
Text label to describe each individual current loop/analogue input. This text will be displayed in the Measurements 3 menu and fault records for the description of the current loop/analogue inputs.			
CLIO Input 2 to 4	Analog Input 2 to 4	16 Character Text	
Text label to describe each individual current loop/analogue input. This text will be displayed in the Measurements 3 menu and fault records for the description of the current loop/analogue inputs.			

Table 30: Current loop analog input label settings

1.3   Control and Support Settings

The control and support settings are part of the main menu and are used to configure the relays global configuration. It includes submenu settings as below which are discussed in more detail below:

- Relay function configuration settings
- Open/close circuit breaker
- CT & VT ratio settings
- Reset LEDs
- Active protection setting group
- Password & language settings
- Circuit breaker control & monitoring settings
- Communications settings
- Measurement settings
- Event & fault record settings

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- User interface settings
- Commissioning settings

1.3.1   System Data

This menu provides information for the device and general status of the relay.

Menu text	Default setting	Setting range		Step size
		Min.	**Max.**	
SYSTEM DATA				
Language	English	English, Francais, Deutsch, Espanol, Chinese & Russian		N/A
The default language used by the device. Selectable as English, French, German, Spanish.				
Password	****			
Device password for level 1 or 2. If password level 1 is input then the access level is set as 1 and if password level 2 is input then the access level is set as 2.				
Description	MiCOM			
16 character relay description. Can be edited.				
Plant Reference	MiCOM			
Plant description. Can be edited.				
Model Number	P241??????0600J P242??????0600K P243??????0600K			
Relay model number.				
Serial Number	149188B			
Relay serial number.				
Frequency	50 Hz	50 Hz	60 Hz	10 Hz
Relay set frequency. Settable as 50 or 60 Hz.				
Comms. Level				
Displays the conformance of the relay to the Courier Level 2 comms.				
Relay Address				
Sets the first rear port relay address.				
Plant Status	0000000000000000			
Displays the circuit breaker plant status for up to 8 circuit breakers. The P24x relay supports only a single circuit breaker configuration.				
Control Status	0000000000000000			
Not used.				
Active Group	1			
Displays the active settings group.				
CB Trip/Close	No Operation	No Operation, Trip, Close		
Manually trips/closes the relay.				
Software Ref. 1				
Displays the relay software version including protocol and relay model. Software Ref.				
Opto I/P Status	0000000000000000			
This menu cell displays the status of the relay's opto-isolated inputs as a binary string, a **1** indicating an energized opto-isolated input and a **0** a de-energized one.				
Relay O/P Status	0000001000000000			
This menu cell displays the status of the relay's output contacts as a binary string, a **1** indicating an operated state and **0** a non-operated state.				
Alarm Status 1	00000000000000000000000000000000			
This menu cell displays the status of the first 32 alarms as a binary string, a **1** indicating an ON state and **0** an OFF state. Includes fixed and user settable alarms. See Data Type G96 in the Relay Menu Database for more details.				

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Menu text	Default setting	Setting range		Step size
		Min.	Max.	
Alarm Status 2	00000000000000000000000000000000			
This menu cell displays the status of the second 32 alarms as a binary string, a **1** indicating an ON state and **0** an OFF state. See Data Type G111 in the Relay Menu Database for more details.				
Alarm Status 3	00000000000000000000000000000000			
This menu cell displays the status of the third 32 alarms as a binary string, a **1** indicating an ON state and **0** an OFF state. Assigned specifically for platform alarms. See Data Type G303 in the Relay Menu Database for more details.				
Access Level	2			
Access Level. Read only. The table below describes the password control.				

Set the "Password Control" cell to	The "Access Level" cell displays	Operations		Type of Password required
0	0	**Read** access to all settings, alarms, event records and fault records		None
		Execute Control Commands, e.g. circuit breaker open/close. Reset of fault and alarm conditions. Reset LEDs. Clearing of event and fault records.		Level 1 Password
		Edit all other settings		Level 2 Password
1	1	**Read** access to all settings, alarms, event records and fault records		None
		Execute Control Commands, e.g. circuit breaker open/close. Reset of fault and alarm conditions. Reset LEDs. Clearing of event and fault records.		None
		Edit all other settings		Level 2 Password
2 (Default)	2(Default)	**Read** access to all settings, alarms, event records and fault records		None
		Execute Control Commands, e.g. circuit breaker open/close. Reset of fault and alarm conditions. Reset LEDs. Clearing of event and fault records.		None
		Edit all other settings		**None**

Menu text	Default setting	Min.	Max.	Step size
Password Control	2	0	2	1
Sets the menu access level for the relay. This setting can only be changed when level 2 access is enabled.				
Password Level 1	****			
Password level 1 setting (4 characters).				
Password Level 2	****			
Password level 2 setting (4 characters).				

Table 31: System data

1.3.2   View Records

This menu provides information on fault and maintenance records. The relay will record the last 5 fault records and the last 10 maintenance records.

Menu text	Default setting	Setting range		Step size
		Min.	Max.	
VIEW RECORDS				
Select Event	0	0	249	
Setting range from 0 to 249. This selects the required event record from the possible 250 that may be stored. A value of 0 corresponds to the latest event and so on.				
Event Type	(From record)	Latched alarm active, Latched alarm inactive, Self reset alarm active, Self reset alarm inactive, Relay contact event, Opto-isolated input event, Protection event, General event, Fault record event, Maintenance record event		
Indicates the type of event.				
Time and Date	Data			
Time & Date Stamp for the event given by the internal Real Time Clock.				
Event text	Data.			
Up to 32 Character description of the Event. See event sheet in the Measurements and Recording chapter, *P24x/EN/MR* for details.				
Event Value	Data.			
32 bit binary string indicating ON or OFF (1 or 0) status of relay contact or opto input or alarm or protection event depending on event type. Unsigned integer is used for maintenance records. See event sheet in the Measurements and Recording chapter, *P24x/EN/MR* for details.				
Select Fault	0	0	4	1
Setting range from 0 to 4. This selects the required fault record from the possible 5 that may be stored. A value of 0 corresponds to the latest fault and so on.				
Start elements	00000000000000000000000000000000			
32 bit binary string gives the status of the first 32 start signals. See Data Type G84 in the Relay Menu Database for more details.				
Trip elements 1	00000000000000000000000000000000			
32 bit binary string gives status of first 32 trip signals. See Data Type G85 in the Relay Menu Database for more details.				
Trip elements 2	00000000000000000000000000000000			
32 bit binary string gives status of second 32 trip signals. See Data Type G86 in the Relay Menu Database for more details.				
Faulted Phase	00000000			
Displays the faulted phase as a binary string, bits 0 – 8 = Start A/B/C/N Trip A/B/C/N.				
Fault Alarms	00000000000000000000000000000000			
This menu cell displays the status of the 32 fault alarms as a binary string, a **1** indicating an ON state and **0** an OFF state. See Data Type G87 in the Relay Menu Database for more details.				
Active Group				
Active setting group 1-2.				
Fault Time	Data.			
Fault Time and Date				
System Frequency	Data			
System frequency.				
The following cells provide measurement information of the fault : IA, IB, IC, VAB, VBC, VCA, VAN, IN Derived, IN, Thermal State, I2, 3Ph Power Factor, IN>PO, VN, 3-Phase Active Power, RTD 1-10 Temperature, IA2, IB2, IC2, IA/IB/IC Differential, IA/IB/IC Bias, Analog Input 1-4.				
Select Report	0	0	4	1
Setting range from 0 to 4. This selects the required maintenance report from the possible 5 that may be stored. A value of 0 corresponds to the latest report and so on.				
Report Text	Data.			
Up to 32 Character description of the occurrence. See the Measurements and Recording chapter, *P24x/EN/MR* for more details.				
Maintenance Type	Data.			

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Menu text	Default setting	Setting range		Step size
		Min.	**Max.**	
Maintenance record fault type. This will be a number defining the fault type.				
Maintenance Data	Data.			
Error code associated with the failure found by the self monitoring. The Maint Type and Data cells are numbers representative of the occurrence. They form a specific error code which should be quoted in any related correspondence to Report Data.				
Reset Indication	No	No/Yes		N/A
Resets latched IEDs and latched relay contacts provided the relevant protection element has reset.				

Table 32: View records settings

1.3.3   Measurements 1

This menu provides measurement information.

Menu text	Default setting	Setting range		Step size
		Min.	**Max.**	
MEASUREMENTS 1				
IA Magnitude	Data.			
IA Phase Angle	Data.			
IB Magnitude	Data.			
IB Phase Angle	Data			
IC Magnitude	Data.			
IC Phase Angle	Data.			
IN Derived Mag	Data.			
IN Derived Angle	Data.			
I SEF Magnitude	Data.			
I SEF Angle	Data.			
I1 Magnitude	Data. Positive sequence current.			
I2 Magnitude	Data. Negative sequence current.			
I0 Magnitude	Data. Zero sequence current.			
IA RMS	Data.			
IB RMS	Data.			
IC RMS	Data.			
IN RMS	Data			
VAB Magnitude	Data.			
VAB Phase Angle	Data.			
VBC Magnitude	Data.			
VBC Phase Angle	Data.			
VCA Magnitude	Data.			
VCA Phase Angle	Data.			
VAN Magnitude	Data. If Anti-backspin function is disabled			
VAN Phase Angle	Data. If Anti-backspin function is disabled			
VBN Magnitude	Data. If Anti-backspin function is disabled			
VBN Phase Angle	Data. If Anti-backspin function is disabled			
VCN Magnitude	Data. If Anti-backspin function is disabled			
VCN Phase Angle	Data. If Anti-backspin function is disabled			
VN Magnitude	Data. If Anti-backspin function is disabled			
VN Phase Angle	Data. If Anti-backspin function is disabled			
Vr Antibacks Mag	Data. If Anti-backspin function is enabled			
V1 Magnitude	Data. Positive sequence voltage.			

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Menu text	Default setting	Setting range		Step size
		Min.	Max.	
V2 Magnitude	Data. Negative sequence voltage.			
VA RMS Magnitude	Data. If Anti-backspin function is disabled			
VB RMS Magnitude	Data. If Anti-backspin function is disabled			
VC RMS Magnitude	Data. If Anti-backspin function is disabled			
VAB RMS Magnitude	Data. If Anti-backspin function is disabled			
VBC RMS Magnitude	Data.			
VCA RMS Magnitude	Data.			
Frequency	Data.			
Ratio I2/I1	Data			
IA2 Magnitude	Data.			
IA2 Phase Angle	Data			
IB2 Magnitude	Data.			
IB2 Phase Angle	Data.			
IC2 Magnitude	Data.			
IC2 Phase Angle	Data			
IA Differential	Data.			
IB Differential	Data			
IC Differential	Data.			
IA Bias	Data.			
IB Bias	Data.			
IC Bias	Data.			

Table 33: Measurement 1 menu

1.3.4   Measurements 2

This menu provides measurement information.

Menu text	Default setting	Setting range		Step size
		Min.	Max.	
MEASUREMENTS 2				
3 Phase Watts	Data.			
3 Phase VARs	Data.			
3 Phase VA	Data.			
Zero Seq power	Data.			
3Ph Power Factor	Data.			
3Ph WHours Fwd	Data.			
3Ph WHours Rev	Data.			
3Ph VArHours Fwd	Data.			
3Ph VArHours Rev	Data.			
Resest Energies	No	Yes/No		
3Ph W Fix Demand	Data.			
3Ph VAr Fix Demand	Data.			
3Ph W Peak Dem	Data.			
3Ph VAr Peak Dem	Data.			
Reset Demand	No	No, Yes		
Reset demand measurements command. Can be used to reset the fixed and peak demand value measurements to 0.				
3 Ph I Maximum	Data			

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Menu text	Default setting	Setting range		Step size
		Min.	**Max.**	
3Ph V Maximum	Data			
Reset Max I/V	No	No, Yes		

Table 34: Measurement 2 menu

1.3.5 Measurements 3 (Product Specific Measurements)

This menu provides measurement information.

Menu text	Default setting	Setting range		Step size
		Min.	**Max.**	
MEASUREMENTS 3				
Thermal Load	Data: - If Thermal Function is enabled			
Load as a ratio of full load (I_{eq}/I_{th}) where I_{eq} is the equivalent thermal load and I_{th} is the thermal setting.				
Thermal State	Data: - If Thermal Function is enabled			
Time to Th Trip	Data: - If Thermal Function is enabled			
Reset Th State	No	No/Yes		N/A
RTD#1 Temperature	Data: - If RTD#1 is enabled			
RTD#2-#10 Temperature	Data: - If RTD#2- #10 is enabled			
Nb Hot St. Allow	Data			
Nb Cold St Allow	Data			
Time to Next St	Data			
Emergency Rest	Data			
Last Start Time	Data: - If Function Prolonged Starts is enabled			
Last St Current	Data: - If Function Prolonged Starts is enabled			
Nb of starts	Data: - If Function Prolonged Starts is enabled			
Reset Nb of St	No	No/Yes		N/A
Nb Emergency Rst	Data: - If Function Prolonged Starts is enabled			
Reset Nb Em Rst	No	No/Yes		N/A
Nb Reaccelarat	Data: - If Function Reacceleration is enabled			
Reset Nb Reacc	No	No/Yes		N/A
Reset number of reacceleration command. Resets state to 0				
Motor Run Time	Data.			
This menu cell displays the accumulated motor run time. Motor run time is initiated each time the switching device is closed and remains closed. The run time unit is automatically adjusted (mhours, hours, Khours). Maximum value is 2^{127} hours.				
Reset Motor Run T	No	No/Yes		N/A
Reset number of motor running hours recorded command. Resets state to 0.				
RTD Open Cct	0000000000			
This menu cell displays the status of the ten RTDs as a binary string, 0 = No Open Circuit, 1 = Open Circuit. The Open Cct alarms are latched.				
RTD Short Cct	0000000000			
This menu cell displays the status of the ten RTDs as a binary string, 0 = No Short Circuit, 1 = Short Circuit. The Short Cct alarms are latched.				
RTD Data Error	0000000000			
This menu cell displays the status of the ten RTDs as a binary string, 0 = No Data Error, 1 = Data Error. The Data Error alarms are latched.				
Reset RTD flags	No	No, Yes		N/A
Reset RTD alarms command. Resets latched RTD Open Cct, Short Cct, Data Error alarms.				

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Menu text	Default setting	Setting range		Step size
		Min.	**Max.**	
Nb Hottest RTD	Data.			
Hottest RTD Temp	Data.			
Reset Max RTD Temp	No	No, Yes		N/A
Reset hottest RTD measurement command. Resets thermal state to 0.				
Analog Input 1	Data. Analog (Current loop/transducer) input 1.			
Analog Input 2	Data. Analog (Current loop/transducer) input 2.			
Analog Input 3	Data. Analog (Current loop/transducer) input 3.			
Analog Input 4	Data. Analog (Current loop/transducer) input 4.			

Table 35: Measurement 3 menu

1.3.6   Measurements 4 (Product Specific Measurements)

This menu provides measurement information.

Menu text	Default setting	Setting range		Step size
		Min.	**Max.**	
MEASUREMENTS 4				
Nb Control Trips	Data: - If CB control is enabled.			
Nb Thermal Trip	Data. - If Thermal Function is enabled			
Nb Trip I> 1	Data: - If Short Circuit Protection is Enabled			
Nb Trip I> 2	Data: - If Short Circuit Protection is Enabled			
Nb Trip ISEF>1	Data: - If Earth Fault Protection is Enabled			
Nb Trip ISEF>2	Data: - If Earth Fault Protection is Enabled			
Nb Trip IN>1	Data: - If Derived Earth Fault Protection is Enabled			
Nb Trip IN>2	Data: - If Derived Earth Fault Protection is Enabled			
Nb Trip I2>1	Data: - If NPS protection is enabled			
Nb Trip I2>2	Data: - If NPS protection is enabled			
Nb Trip PO>	Data: - If Derived Earth Fault Wattmetric Protection is Enabled			
Nb Trip V<1	Data: - If Undervoltage Protection is enabled			
Nb Trip V<2	Data: - If Undervoltage Protection is enabled			
Nb Trip F<1	Data: - If underfrequency Protection is enabled			
Nb Trip F<2	Data: - If Underfrequency Protection is enabled			
Nb Trip P<1	Data: - If Loss of Load Protection is enabled			
Nb Trip P<2	Data: - If Loss of Load Protection is enabled			
Nb Trip PF< Lead	Data			
Nb Trip PF< Lag	Data			
Nb Trip Rev P	Data: - If Reverse Power Protection is enabled			
Nb Trip V>1	Data: - If overvoltage Protection is enabled			
Nb Trip V>2	Data: - If overvoltage protection is enabled			
Nb Trip NVD VN>1	Data: - If NVD Protection is enabled			
Nb Trip NVD VN>2	Data: - If NVD Protection is enabled			
Nb Prolong St	Data: - If Prolonged Start Status enabled			
Nb Lock Rot-sta	Data: - If Locked Rotor Start<Stall and prolonged start status enabled			
Nb Lock Rot-run	Data			
Nb Trip RTD#1	Data: - If RTD#1 is enabled			
Nb Trip RTD#2-10	Data: - If RTD#2 - #10 is enabled			
Nb Trip Diff	Data: - If Differential Protection is enabled			
Nb A Input 1 Trip	Data: - If analogue input 1 enabled			

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Menu text	Default setting	Setting range		Step size
		Min.	Max.	
Nb A Input 2 Trip	Data: - If analogue input 2 enabled			
Nb A Input 3 Trip	Data: - If analogue input 3 enabled			
Nb A Input 4 Trip	Data: - If analogue input 4 enabled			
Nb FFail1 Trip	Data If Field Failure 1 function enabled			
Nb FFail2 Trip	Data If Field Failure 2 function enabled			
Nb Trip I> 3	Data if I>3 enabled			
Nb Trip I> 4	Data if I>4 enabled			
Nb Trip V2>1	Data: If Negative Sequence O/V function enabled			
Nb Trip V2>2	Data: If Negative Sequence O/V function enabled			
Nb Trip Vdip	Data: If LV Ride Thru function enabled			
Reset Trip Stat	No	No, Yes		
Reset Trip counter statistics command. Resets all counters to 0				

Table 36: Measurement 4 menu

1.3.7 Circuit Breaker Condition

The P241/2/3 relays include measurements to monitor the CB condition.

Menu text	Default setting	Setting range		Step size
		Min.	Max.	
CB CONDITION				
CB Operations	Data. Number of CB trip operations.			
Total IA Broken	Data. Accumulated broken current for A phase protection trip.			
Total IB Broken	Data. Accumulated broken current for B phase protection trip.			
Total IC Broken	Data. Accumulated broken current for C phase protection trip.			
CB Operate Time	Data. CB operating time = time from protection trip to undercurrent elements indicating the CB is open.			
Reset CB Data	No	No, Yes		N/A
Reset CB Data command. Resets CB Operations and Total IA/IB/IC broken current counters to 0.				

Table 37: Circuit breaker condition menu

1.3.8 Circuit Breaker Control

The P241/2/3 relays include settings to reset CB condition monitoring lockout alarms and set the type of CB auxiliary contacts that will be used to indicate the CB position.

Menu text	Default setting	Setting range		Step size
		Min.	Max.	
CB CONTROL				
CB Control by	Disabled	Disabled, Local, Remote, Local+Remote, Opto, Opto+Local, Opto+Remote, Opto+Local+Remote		
Selects which method the CB can be controlled by.				
Close Pulse Time	0.5 sec	0.1 sec	5 sec	0.1 sec
Defines the duration of the close pulse.				
Trip Pulse Time	0.5 sec	0.1 sec	5 sec	0.1 sec
Defines the duration of the trip pulse.				
Man Close Delay	1 s	0 sec	60 sec	1 sec
This defines the delay time before the close pulse is executed.				

Table 38: Circuit breaker control settings

1.3.9 Date and Time

Displays the date and time as well as the battery* condition.

Menu text	Default setting	Setting range		Step size
		Min.	Max.	
DATE AND TIME				
Date/Time	Data			
Displays the relay's current date and time.				
IRIG-B Status	Data	Card not fitted/Card failed/ Signal healthy/No signal		N/A
Displays the status of IRIG-B.				
Battery Status	Dead or Healthy			
Displays whether the battery is healthy or not.				
Battery Alarm	Enabled	Disabled or Enabled		N/A
Enables or disables battery alarm. The battery alarm needs to be disabled when a battery is removed or not used.				

Table 39: Date and time menu

> **Note:** * Option dependent on model/version--see the mounting options in the Cortec for details.

1.3.10 CT and VT Ratios

Menu text	Default setting	Setting range		Step size
		Min.	Max.	
CT AND VT RATIOS				
Main VT Primary	110.0 V	100	1000 kV	1
Main voltage transformer input, primary voltage setting.				
Main VT Sec'y	110.0 V	80	140	1
Main transformer input, secondary voltage setting.				
Phase CT Primary	1.000 A	1	30 k	1
Phase current transformer input, primary current rating setting.				
Phase CT Sec'y	1.000 A	1	5	4
Phase current transformer input, secondary current rating setting.				
SEF CT Primary	1.000 A	1	30 k	1
Sensitive current transformer input, primary current rating setting.				
SEF CT Secondary	1.000 A	1	5	4
Sensitive current transformer input, secondary current rating setting.				
VT Connecting Mode	3 VT	3 VT 2 VT + Residual 2 VT + Vremanent		
VT connection setting cell				
NVD VT Primary	110 V	100 V	1000 kV	1 V
NVD voltage transformer input, primary voltage setting				
NVD VT Secondary	110 V	80 V	140 V	1 V
NVD voltage transformer input, secondary voltage setting				

Table 40: CT and VT ratio settings

1.3.11 Record Control

It is possible to disable the reporting of events from all interfaces that support setting changes. The settings that control the reporting of various types of events are in the Record Control column. The effect of setting each to disabled is as follows:

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Menu text	Default setting	Available settings
RECORD CONTROL		
Clear Events	No	No or Yes
Selecting Yes will cause the existing event log to be cleared and an event will be generated indicating that the events have been erased.		
Clear Faults	No	No or Yes
Selecting Yes will cause the existing fault records to be erased from the relay.		
Clear Test Log	No	No or Yes
Selecting Yes will cause the existing maintenance records to be erased from the relay.		
Alarm Event	No	No/Yes
Disabling this setting means that no event will be generated for all alarms.		
RelayO/P Event	No	No/Yes
Disabling this setting means that no event will be generated for any change in relay output contact state.		
Opto Input Event	No	No/Yes
Disabling this setting means that no event will be generated for any change in logic input state.		
General Event	No	No/Yes
Disabling this setting means that no General Events will be generated.		
Fault Rec Event	No	No/Yes
Disabling this setting means that no event will be generated for any fault that produces a fault record.		
Maint. Rec Event	No	No/Yes
Disabling this setting means that no event will be generated for any maintenance records.		
Protection Event	No	No/Yes
Disabling this setting means that no event will be generated for any operation of the protection elements.		
DDB 31 - 0	11111111111111111111111111111111	
32 bit setting to enable or disable the event recording for DDBs 0-31. For each bit 1 = event recording Enabled, 0 = event recording Disabled.		
DDB 1022 - 992	11111111111111111111111111111111	
32 bit setting to enable or disable the event recording for DDBs 1022 – 992. For each bit 1 = event recording Enabled, 0 = event recording Disabled. There are similar cells showing 32 bit binary strings for all DDBs from 0 – 1022. The first and last 32 bit binary strings only are shown here.		
Clear Dist Recs	No	No/Yes
Clears all stored disturbance records from the relay.		

Table 41: Record control menu

1.3.12 Disturbance Recorder Settings

The disturbance recorder settings include the record duration and trigger position, selection of analog and digital signals to record, and the signal sources that trigger the recording.

Menu text	Default setting	Setting range		Step size
		Min.	Max.	
DISTURB RECORDER				
Duration	1.5 s	0.1 s	10.5 s	0.01 s
Overall recording time setting.				
Trigger Position	30%	0	100%	0.1%
Trigger point setting 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 1s post fault recording times.				

Menu text	Default setting	Setting range		Step size
		Min.	**Max.**	
Trigger Mode	Single	Single or Extended		
If set to single mode, if a further trigger occurs whilst a recording is taking place, the recorder will ignore the trigger. However, if this has been set to "Extended", the post trigger timer will be reset to zero, thereby extending the recording time.				
Analog. Channel 1	VAN	VA, VB, VC, IA, IB, IC, IN, IA-2, IB-2, IC-2, VAB, VBC, VN, VRM		
Selects any available analog input to be assigned to this channel.				
Analog. Channel 2	VBN	As above		
Analog. Channel 3	VCN	As above		
Analog. Channel 4	IA	As above		
Analog. Channel 5	IB	As above		
Analog. Channel 6	IC	As above		
Analog. Channel 7	IN	As above		
Analog. Channel 8	IN	As above		
Digital Input 1 to 32	Relays 1 to 12 and Opto's 1 to 12	Any of 16 O/P Contacts or Any of 16 Opto Inputs or Internal Digital Signals		
The digital channels may be mapped to any of the opto isolated inputs or output contacts, in addition to a number of internal relay digital signals, such as protection starts, LEDs etc.				
Input 1 to 32 Trigger	No Trigger except Dedicated Trip Relay O/P's which are set to Trigger Edge -/+	No Trigger, Trigger Edge -/+, Trigger Edge +/-		
Any of the digital channels may be selected to trigger the disturbance recorder on either a low to high (-/+) or a high to low (+/-) transition.				

Table 42: Disturbance record settings

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1.3.13   Measurement Setup

Menu text	Default settings	Available settings	
MEASURE'T SETUP			
Default Display	Description	3Ph + N Current/3Ph Voltage/Power/Date and Time/Description/Plant Reference/Frequency/Thermal State	
This setting can be used to select the default display from a range of options.			
Note:	It is also possible to view the other default displays whilst at the default level using the ◊ □and ◊ keys. However once the 15 minute timeout elapses the default display will revert to that selected by this setting.		
Local Values	Primary	Primary/Secondary	
This setting controls whether measured values using the front panel user interface and the front courier port are displayed as primary or secondary quantities.			
Remote Values	Primary	Primary/Secondary	
This setting controls whether measured values using the rear communication port are displayed as primary or secondary quantities.			
Measurement Ref.	VA	VA/VB/VC/IA/IB/IC	
Using this setting the phase reference for all angular measurements by the relay can be selected.			
Demand Interval	30 minutes	1 to 99 minutes step 1 minute	
This setting defines the length of the fixed demand window.			
Alarm Fix Dem	Invisible	Invisible/Visible	
Sets the Alarm Fix Demand Status menu visible in the relay settings.			
3Ph W Thresh	50 In Wh	1 In Wh	120 In Wh
3 phase watt alarm setting.			

Menu text	Default settings	Available settings	
MEASURE'T SETUP			
3Ph VAr Thresh	50 In VArh	1 In VArh	120 In VArh
3 phase VArs alarm setting.			
Alarm Energies	Invisible	Invisible/Visible	
Sets the Alarm Energies Status menu visible in the relay settings.			
W Fwd Thresh	50 In Wh	1 In Wh	1000 In Wh
3 phase Watt Hour Forward alarm setting.			
W Rev Thresh	50 In Wh	1 In Wh	1000 In Wh
3 phase Watt Hour Reverse alarm setting.			
VAr Fwd Thresh	50 In VArh	1 In VArh	1000 In VArh
3 phase VAr Hour Forward alarm setting.			
VAr Rev Thresh	50 In VArh	1 In VArh	1000 In VArh
3 phase VAr Hour Reverse alarm setting.			
Motor Hour Run > 1	Disabled	Disabled/Enabled	
Enables or disables the first stage Hour Run Meter element.			
Motor Hour Run > 1	500 hours	1 Hour	9999 Hours
Hour Run Meter stage 1 setting.			
Motor Hour Run > 2	Disabled	Disabled/Enabled	
Enables or disables the second stage Hour Run Meter element.			
Motor Hour Run > 2	500 Hours	1 Hour	9999 Hours
Hour Run Meter stage 2 setting.			
Remote 2 Values	Primary	Primary/Secondary	
This setting controls whether measured values using the second rear communication port are displayed as primary or secondary quantities.			

Table 43: Measurement setup settings

1.3.14   Communications

The communications settings apply to the rear communications ports only and will depend
on the particular protocol being used. Further details are given in the SCADA
Communications chapter (*P24x/EN/SC*).

1.3.14.1 Communications Settings for Courier Protocol

Menu text	Default setting	Setting range		Step size
		Min.	**Max.**	
COMMUNICATIONS				
RP1 Protocol	Courier			
Indicates the communications protocol that will be used on the rear communications port.				
RP1 Address	255	0	255	1
This cell sets the unique address for the relay such that only one relay is accessed by master station software.				
RP1 Inactivity Timer	10 min	1 min	30 min	1 min
This cell controls how long the relay will wait without receiving any messages on the rear port before it reverts to its default state, including resetting any password access that was enabled.				
RP1 Physical Link	RS485	RS485 or Fiber Optic		
This cell defines whether an electrical EIA(RS)485, fiber optic or KBus connection is being used for communication between the master station and relay. If 'Fiber Optic' is selected, the optional fiber optic communications board will be required.				
RP1 Card Status	KBus OK, EIA485 OK, Fiber Optic OK			
First rear communication port 1 status				

Menu text	Default setting	Setting range		Step size
		Min.	**Max.**	
RP1 Port Config.	Kbus	Kbus, EAI(RS)485		
This cell defines whether an electrical KBus or EIA(RS)485 is being used for communication between the master station and relay.				
RP1 Comms Mode	IEC 60870 FT1.2	IEC 60870 FT1.2, 10Bit		
The choice is either IEC 60870 FT1.2 for normal operation with 11-bit modems, or 10-bit no parity.				
RP1 Baud Rate	19200 bits/s	9600 bits/s, 19200 bits/s or 38400 bits/s		
This cell controls the communication speed between relay and master station. It is important that both relay and master station are set at the same speed setting.				

Table 44: Communication settings for courier protocol

1.3.14.2 Communications Settings for MODBUS Protocol

Menu text	Default setting	Setting range		Step size
		Min.	**Max.**	
COMMUNICATIONS				
RP1 Protocol	MODBUS			
Indicates the communications protocol that will be used on the rear communications port.				
RP1 Address	1	1	247	1
This cell sets the unique address for the relay such that only one relay is accessed by master station software.				
RP1 Inactiv Timer	10 mins.	1 min.	30 mins.	1 min.
This cell controls how long the relay will wait without receiving any messages on the rear port before it reverts to its default state, including resetting any password access that was enabled.				
RP1 Baud Rate	19200 bits/s	9600 bits/s, 19200 bits/s or 38400 bits/s		
This cell controls the communication speed between relay and master station. It is important that both relay and master station are set at the same speed setting.				
RP1 Parity	None	Odd, Even or None		
This cell controls the parity format used in the data frames. It is important that both relay and master station are set with the same parity setting.				
RP1 Physical Link	RS485	RS485 or Fiber Optic		
This cell defines whether an electrical EIA(RS) 485 or fiber optic connection is being used for communication between the master station and relay. If **Fiber Optic** is selected, the optional fiber optic communications board will be required.				
MODBUS IEC Time	Standard IEC	Standard IEC or Reverse		
When **Standard IEC** 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.				

Table 45: Communication settings for MODBUS protocol

1.3.14.3 Communications Settings for IEC 60870-5-103 Protocol

Menu text	Default setting	Setting range		Step size
		Min.	**Max.**	
COMMUNICATIONS				
RP1 Protocol	IEC 60870-5-103			
Indicates the communications protocol that will be used on the rear communications port.				
RP1 Address	1	0	254	1
This cell sets the unique address for the relay such that only one relay is accessed by master station software.				
RP1 Inactiv Timer	15 mins.	1 min.	30 mins.	1 min.
This cell controls how long the relay will wait without receiving any messages on the rear port before it reverts to its default state, including resetting any password access that was enabled.				

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Menu text	Default setting	Setting range		Step size
		Min.	**Max.**	
RP1 Baud Rate	19200 bits/s	9600 bits/s or 19200 bits/s		
This cell controls the communication speed between relay and master station. It is important that both relay and master station are set at the same speed setting.				
RP1 Measure't Period	15 s	1 s	60 s	1 s
This cell controls the time interval that the relay will use between sending measurement data to the master station.				
RP1 Physical Link	RS485	RS485 or Fiber Optic		
This cell defines whether an electrical EIA(RS) 485 or fiber optic connection is being used for communication between the master station and relay. If **Fiber Optic** is selected, the optional fiber optic communications board will be required.				
RP1 CS103 Blocking	Disabled	Disabled, Monitor Blocking or Command Blocking		
There are three settings associated with this cell:				
Disabled - No blocking selected. Monitor Blocking - When the monitor blocking DDB Signal is active high, either by energizing an opto input or control input, reading of the status information and disturbance records is not permitted. When in this mode the relay returns a "termination of general interrogation" message to the master station. Command Blocking - When the command blocking DDB signal is active high, either by energizing 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 relay returns a **negative acknowledgement of command** message to the master station.				

Table 46: Communication settings for IEC-103 protocol

1.3.14.4 Communications Settings for Ethernet Port – IEC 61850

Menu text	Default setting	Setting range		Step size
		Min.	**Max.**	
NIC Protocol	IEC 61850			
Indicates that IEC 61850 will be used on the rear Ethernet port.				
NIC MAC Address	Ethernet MAC Address			
Indicates the MAC address of the rear Ethernet port.				
NIC Tunl Timeout	5 mins	1 min	30 mins	1 min
Duration of time waited before an inactive tunnel to MiCOM S1 Studio is reset.				
NIC Link Report	Alarm	Alarm, Event, None		
Configures how a failed/unfitted network link (copper or fiber) is reported:				
Alarm - An alarm is raised for a failed link Event - An event is logged for a failed link None - Nothing reported for a failed link				

Table 47: Communication settings for IEC-61850 protocol

1.3.14.5 IED Configurator (for IEC 61850 Configuration)

The contents of the **IED CONFIGURATOR** column are mostly data cells, displayed for information but not editable. To edit the configuration, it is necessary to use the IED Configurator tool within MiCOM S1 Agile.

Menu text	Default setting	Setting range		Step size
		Min.	Max.	
IED CONFIGURATOR				
Switch Conf.Bank	No Action	No Action, Switch Banks		
Setting which allows the user to switch between the current configuration, held in the Active Memory Bank (and partly displayed below), to the configuration sent to and held in the Inactive Memory Bank.				
Restore MCL	No Action	No Action, Restore		
Setting which allows the user to restore MCL or no action.				
Active Conf.Name	Data			
The name of the configuration in the Active Memory Bank, usually taken from the SCL file.				
Active Conf.Rev	Data			
Configuration revision number of the Active Memory Bank, used for version management.				
Inact.Conf.Name	Data			
The name of the configuration in the Inactive Memory Bank, usually taken from the SCL file.				
Inact.Conf.Rev	Data			
Configuration revision number of the Inactive Memory Bank, used for version management.				
IP PARAMETERS				
IP Address	Data			
Displays the unique network IP address that identifies the relay.				
Subnet Mask	Data			
Displays the sub-network that the relay is connected to.				
Gateway	Data			
Displays the IP address of the gateway (proxy) that the relay is connected to.				
SNTP PARAMETERS				
SNTP Server 1	Data			
Displays the IP address of the primary SNTP server.				
SNTP Server 2	Data			
Displays the IP address of the secondary SNTP server.				
IEC 61850 SCL.				
IED Name	Data			
8 character IED name, which is the unique name on the IEC 61850 network for the IED, usually taken from the SCL file.				
IEC 61850 GOOSE				
GoEna	0x00000000	0x00000000	0x11111111	1
Setting to enable GOOSE publisher settings.				
Test Mode	0x00000000	0x00000000	0x11111111	1
The Test Mode cell allows the test pattern to be sent in the GOOSE message, for example for testing or commissioning.				
Ignore Test Flag	No	No, Yes		
When set to **Yes**, the test flag in the subscribed GOOSE message is ignored and the data treated as normal.				

Table 48: IEC-61850 IED configurator

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1.3.14.6 Rear Port 2 Connection Settings

The settings shown are those configurable for the second rear port which is only available with the courier protocol.

Menu text	Default setting	Setting range		Step size
		Min.	Max.	
COMMUNICATIONS				
RP2 Protocol	Courier			
Indicates the communications protocol that will be used on the second rear communications port.				
RP2 Card Status	Unsupported, Card Not fitted, EIA232 OK, EIA485 OK, K-BUS OK			
Second rear communication port 2 status.				
RP2 Port Config.	EIA232	EIA232, EIA485 or KBus		
This cell defines whether an electrical EIA(RS)232, EIA(RS)485 or KBus is being used for communication.				
RP2 Comms. Mode	IEC 60870 FT1.2 Frame	IEC 60870 FT1.2 Frame or 10-Bit No Parity		
The choice is either IEC 60870 FT1.2 for normal operation with 11-bit modems, or 10-bit no parity.				
RP2 Address	255	0	255	1
This cell sets the unique address for the relay such that only one relay is accessed by master station software.				
RP2 Inactiv Timer	15 mins.	1 min.	30 mins.	1 min.
This cell controls how long the relay will wait without receiving any messages on the rear port before it reverts to its default state, including resetting any password access that was enabled.				
RP2 Baud Rate	19200 bits/s	9600 bits/s, 19200 bits/s or 38400 bits/s		
This cell controls the communication speed between relay and master station. It is important that both relay and master station are set at the same speed setting.				

Table 49: Rear port connection settings

1.3.15 Commissioning Tests

There are menu cells which allow the status of the opto-isolated inputs, output relay contacts, internal digital data bus (DDB) signals and user-programmable LEDs to be monitored. Additionally there are cells to test the operation of the output contacts and user-programmable LEDs.

Menu text	Default setting	Available settings
COMMISSION TESTS		
Opto I/P Status	0000000000000000	
This menu cell displays the status of the relay's opto-isolated inputs as a binary string, a **1** indicating an energized opto-isolated input and a **0** a de-energized one.		
Relay O/P Status	0000000000000000000000000000000	
This menu cell displays the status of the relay's output contacts as a binary string, a **1** indicating an operated state and **0** a non-operated state.		
When the **Test Mode** cell is set to **Enabled** the **Relay O/P Status** cell does not show the current status of the output relays and so can not be used to confirm operation of the output relays. Therefore it will be necessary to monitor the state of each contact in turn.		
Test Port Status	00000000	
This menu cell displays the status of the eight digital data bus (DDB) signals that have been allocated in the **Monitor Bit** cells.		
Monitor Bit 1	LED 1	0 to 1022
The eight **Monitor Bit** cells allow the user to select the status of which digital data bus signals can be observed in the **Test Port Status** cell or using the monitor/download port.		
Monitor Bit 8	LED 8	0 to 1022
The eight **Monitor Bit** cells allow the user to select the status of which digital data bus signals can be observed in the **Test Port Status** cell or via the monitor/download port.		

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Menu text	Default setting	Available settings
IED Test Mode	Disabled	Disabled, Test Mode, Contacts Blocked
The Test Mode menu cell is used to allow secondary injection testing to be performed on the relay without operation of the trip contacts. It also enables a facility to directly test the output contacts by applying menu controlled test signals. To select test mode the Test Mode menu cell should be set to **Test Mode**, which takes the relay out of service and blocks the maintenance, counters. It also causes an alarm condition to be recorded and the yellow **Out of Service LED** to illuminate and an alarm message **Prot'n. Disabled** is given. This also freezes any information stored in the CB Condition column and in IEC 60870-5-103 builds changes the Cause of Transmission, COT, to Test Mode. To enable testing of output contacts the Test Mode cell should be set to Contacts Blocked. This blocks the protection from operating the contacts and enables the test pattern and contact test functions which can be used to manually operate the output contacts. Once testing is complete the cell must be set back to **Disabled** to restore the relay back to service.		
Test Pattern	00000000000000000000000000000000	0 = Not Operated 1 = Operated
This cell is used to select the output relay contacts that will be tested when the **Contact Test** cell is set to **Apply Test**.		
Contact Test	No Operation	No Operation, Apply Test, Remove Test
When the **Apply Test** command in this cell is issued the contacts set for operation (set to **1**) in the Test **Pattern cell** change state. After 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 issuing the **Remove Test** command. The command text on the LCD will again revert to **No Operation** after the **Remove Test** command has been issued.		
Note: When the **Test Mode** cell is set to **Enabled** the **Relay O/P Status** cell does not show the current status of the output relays and so can not be used to confirm operation of the output relays. Therefore it will be necessary to monitor the state of each contact in turn.		
Test LEDs	No Operation	No Operation Apply Test
When the **Apply Test** command in this cell is issued the 8 (P241) or 18 (P242/3) user-programmable LEDs will illuminate for approximately 2 seconds before they extinguish and the command text on the LCD reverts to **No Operation**.		
Red LED Status	000000000000000000	
This cell is an 18 bit binary string that indicates which of the user-programmable LEDs on the relay are illuminated with the Red LED input active when accessing the relay from a remote location, a **1** indicating a particular LED is lit and a **0** not lit. If both the Green and Red LED status bits for an LED are on then this indicates the LED is yellow. This is only applicable to the P242/3 which has programmable tri-color LEDs – red/yellow/green.		
Green LED Status	000000000000000000	
This cell is an 18 bit binary string that indicates which of the user-programmable LEDs on the relay are illuminated with the Green LED input active when accessing the relay from a remote location, a **1** indicating a particular LED is lit and a **0** not lit. If both the Green and Red LED status bits for an LED are on then this indicates the led is yellow. This is only applicable to the P242/3 which has programmable tri-color LEDs – red/yellow/green.		
IED Mod/Beh		ON, ON/blocked, Test, Test/blocked, Off
Indicates the current Mod/Beh status of whole IED.		
Subscriber Sim	Disabled	Disabled, Enabled
Used to enable/disable the 'subscriber simulation' feature, for Sampled Values and GOOSE subscriptions.		
DDB 31 - 0	00000000000000000000001000000000	
Displays the status of DDB signals 0-31.		
DDB 1022 - 922	00000000000000000000000000000000	
Displays the status of DDB signals 1022 - 922. There are similar cells showing 32 bit binary strings for all DDBs from 0 - 1022. The first and last 32 bit words only are shown here.		

Table 50: Commissioning tests menu cells

ST

ST

1.3.16   Circuit Breaker Condition Monitor Setup

The Circuit Breaker condition monitoring includes features to monitor the CB condition such as the current broken, number of CB operations, number of CB operations in a set time and CB operating time. Alarms or a circuit breaker lockout can be raised for different threshold values.

Menu text	Default setting	Setting range		Step size
		Min.	Max.	
CB MONITOR SETUP				
Broken I^	2	1	2	0.1
This sets the factor to be used for the cumulative I^ counter calculation that monitors the cumulative severity of the duty placed on the interrupter. This factor is set according to the type of Circuit Breaker used.				
I^ Maintenance	Alarm Disabled	Alarm Disabled, Alarm Enabled		
Enables or disables the cumulative I^ maintenance alarm element.				
I^ Maintenance	1000 In^	1 In^	25000 In^	1 In^
Threshold setting for the cumulative I^ maintenance counter. This alarm indicates when preventative maintenance is due.				
No CB Ops Maint	Alarm Disabled	Alarm Disabled, Alarm Enabled		
Number of circuit breaker operations setting for the maintenance alarm.				
No CB Ops Maint	10	1	10000	1
Threshold setting for number of circuit breaker operations for the maintenance alarm. This alarm indicates when preventative maintenance is due.				
CB Time Maint	Alarm Disabled	Alarm Disabled, Alarm Enabled		
Enables or disables the circuit breaker operating time maintenance alarm.				
No CB Ops Maint	0.1 s	0.005 s	0.5 s	0.001 s
Circuit breaker operating time threshold setting. This alarm is set in relation to the specified interrupting time of the circuit breaker.				

Table 51: Circuit breaker condition monitoring menu

1.3.17   Opto Configuration

Menu text	Default setting	Setting range		Step size
		Min.	Max.	
OPTO CONFIG.				
Global Nominal V	24 - 27	24 - 27, 30 - 34, 48 - 54, 110 - 125, 220 - 250, Custom		
Sets the nominal battery voltage for all opto inputs by selecting one of the five standard ratings in the Global Nominal V settings. If Custom is selected then each opto input can individually be set to a nominal voltage value.				
Opto Input 1	24 - 27	24 - 27, 30 - 34, 48 - 54, 110 - 125, 220 - 250		
Each opto input can individually be set to a nominal voltage value if custom is selected for the global setting.				
Opto Input 2 - 16	24 - 27	24 - 27, 30 - 34, 48 - 54, 110 - 125, 220 - 250		
Each opto input can individually be set to a nominal voltage value if custom is selected for the global setting.				
Opto Filter Cntl.	1111111111111111	0 = Disable Filtering 1 = Enable filtering		
A binary string is used to represent the opto inputs available. A **1** or **0** is used to enable or disable for each input a pre-set filter of ½ cycle that renders the input immune to induced ac noise on the wiring.				

Menu text	Default setting	Setting range		Step size
		Min.	**Max.**	
Characteristics	Standard 60% - 80%	Standard 60% - 80%, 50% - 70%		
Selects the pick-up and drop-off characteristics of the optos. Selecting the standard setting means they nominally provide a Logic 1 or On value for Voltages ≥80% of the set lower nominal voltage and a Logic 0 or Off value for the voltages ≤60% of the set higher nominal voltage.				

Table 52: Opto inputs configuration settings

1.3.18   Control Inputs

The control inputs function as software switches that can be set or reset either locally or remotely. These inputs can be used to trigger any function that they are connected to as part of the PSL.

Menu text	Default setting	Setting range	Step size
CONTROL INPUTS.			
Ctrl Status	11111111111111111111111111111111		
This menu cell displays the status of the relay's control inputs as a binary string, a '1' indicating an ON control input and a '0' an OFF one.			
Control Input 1	No Operation	No Operation, Set, Reset	
Command to Set or Reset Control Input 1.			
Control Input 2 to 32	No Operation	No Operation, Set, Reset	
Commands to Set or Reset Control Inputs 2 to 32.			

Table 53: Control inputs settings

1.3.19   Control Input Configuration

The control inputs function as software switches that can be set or reset either locally or remotely. These inputs can be used to trigger any function that they are connected to as part of the PSL.

Menu text	Default setting	Setting range	Step size
CTRL I/P CONFIG.			
Hotkey Enabled	11111111111111111111111111111111		
Setting to allow the control inputs to be individually assigned to the **Hotkey** menu by setting **1** in the appropriate bit in the **Hotkey Enabled** cell. The hotkey menu allows the control inputs to be set, reset or pulsed without the need to enter the **CONTROL INPUTS** column.			
Control Input 1	Latched	Latched, Pulsed	
Configures the control inputs as either **latched** or **pulsed**. A latched control input will remain in the set state until a reset command is given, either by the menu or the serial communications. A pulsed control input, however, will remain energized for 10 ms after the set command is given and will then reset automatically (i.e. no reset command required).			
Ctrl Command 1	Set/Reset	Set/Reset, In/Out, Enabled/Disabled, On/Off	
Allows the SET / RESET text, displayed in the hotkey menu, to be changed to something more suitable for the application of an individual control input, such as **ON / OFF, IN / OUT** etc.			
Control Input 2 to 32	Latched	Latched, Pulsed	
Configures the control inputs as either latched or pulsed.			
Ctrl Command 2 to 32	Set/Reset	Set/Reset, In/Out, Enabled/Disabled, On/Off	
Allows the SET / RESET text, displayed in the hotkey menu, to be changed to something more suitable for the application of an individual control input, such as ON / OFF, IN / OUT etc.			

Table 54: Control inputs configuration settings

ST

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1.3.20   Function Keys

Menu text	Default setting	Setting range		Step size
		Min.	**Max.**	
FUNCTION KEYS				
Fn. Key Status	0000000000			
Displays the status of each function key.				
Fn. Key 1	Unlocked	Disabled, Locked, Unlocked (Enabled)		
Setting to activate the function key. The **Locked** setting allows a function key output that is set to toggle mode to be locked in its current active state.				
Fn. Key 1 Mode	Toggled	Toggled, Normal		
Sets the function key in toggled or normal mode. In **Toggled** mode, the first keypress will latch the function key DDB output signal ON and the next keypress will reset the function key DDB output to OFF. This feature can be used to enable/disable relay functions. In the **Normal** mode the function key DDB signal output will remain ON/ **high** as long as the key is pressed.				
Fn. Key 1 Label	Function Key 1			
Allows the text of the function key to be changed to something more suitable for the application.				
Fn. Key 2 to 10 Status	Unlocked	Disabled, Locked, Unlocked (Enabled)		
Setting to activate the function key. The **Locked** setting allows a function key output that is set to toggle mode to be locked in its current active position.				
Fn. Key 2 to 10 Mode	Toggled	Toggled, Normal		
Sets the function key in toggled or normal mode. In **Toggled** mode, the first keypress will latch the function key DDB output signal ON and the next keypress will reset the function key DDB output to OFF. This feature can be used to enable/disable relay functions. In the Normal mode the function key DDB signal output will remain ON/ **high** as long as the key is pressed.				
Fn. Key 2 to 10 Label	Function Key 2 to 10			
Allows the text of the function key to be changed to something more suitable for the application.				

Table 55: Function keys configuration settings

1.3.21   Control Input Labels

Menu text	Default setting	Setting range	Step size
CTRL I/P LABELS			
Control Input 1	Control Input 1	16 Character Text	
Text label to describe each individual control input. This text will be displayed when a control input is accessed by the hotkey menu and it is displayed in the programmable scheme logic description of the control input.			
Control Input 2 to 32	Control Input 2 to 32	16 Character Text	
Text label to describe each individual control input. This text will be displayed when a control input is accessed by the hotkey menu and it is displayed in the programmable scheme logic description of the control input.			

Table 56: Control input label settings

1.3.22   PSL DATA Column

Menu text	Default setting	Setting range	Step size
PSL DATA			
Grp 1 PSL Ref	Model Number	32 Character Text	
When downloading a PSL to the relay, the user will be prompted to enter which groups the PSL is for and a reference ID. The first 32 characters of the reference ID will be displayed in this cell. The left and right keys can be used to scroll through 32 characters as only 16 can be displayed at any one time.			
18 Nov 2002 08:59:32.047	Data.		
This cell displays the date and time when the PSL was down loaded to the relay.			

Menu text	Default setting	Setting range	Step size
Grp 1 PSL ID – 2062813232	Data.		
This is a unique number for the PSL that has been entered. Any change in the PSL will result in a different number being			
Grp 2 PSL Ref	Model Number	32 Character Text	
When downloading a PSL to the relay, the user will be prompted to enter which groups the PSL is for and a reference ID. The first 32 characters of the reference ID will be displayed in this cell. The left and right keys can be used to scroll through 32 characters as only 16 can be displayed at any one time.			
18 Nov 2002 08:59:32.047	Data.		
This cell displays the date and time when the PSL was down loaded to the relay.			
Grp 2 PSL ID – 2062813232	Data.		
This is a unique number for the PSL that has been entered. Any change in the PSL will result in a different number being			

Table 57: PSL data menu

ST

ST

OP

OPERATION

OP

CONTENTS

OP

OP

FIGURES

OP

TABLES

OP

1 OPERATION OF INDIVIDUAL PROTECTION FUNCTIONS

The following sections detail the individual protection functions.

1.1 Motor Starting and Running (Stall Protection) (48/51LR/50S/14)

Stall protection description

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

1.1.1 Prolonged Start

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

Single criteria: A change in the interrupting device position is either detected using open to close detection of a circuit breaker or a detection of a starting current. While using only I criteria, the starting current of motor needs to be higher than the start current threshold. The start criteria can be set to 52a or I in the **STALL DETECTION** menu settings for single criteria method

Extended criteria: A change in the interrupting device position is detected along with the detection of a starting current **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 starting current threshold before the expiry of normal starting time a trip is initialized.

The following diagram shows detection of a successful start with the use of the extended criteria.
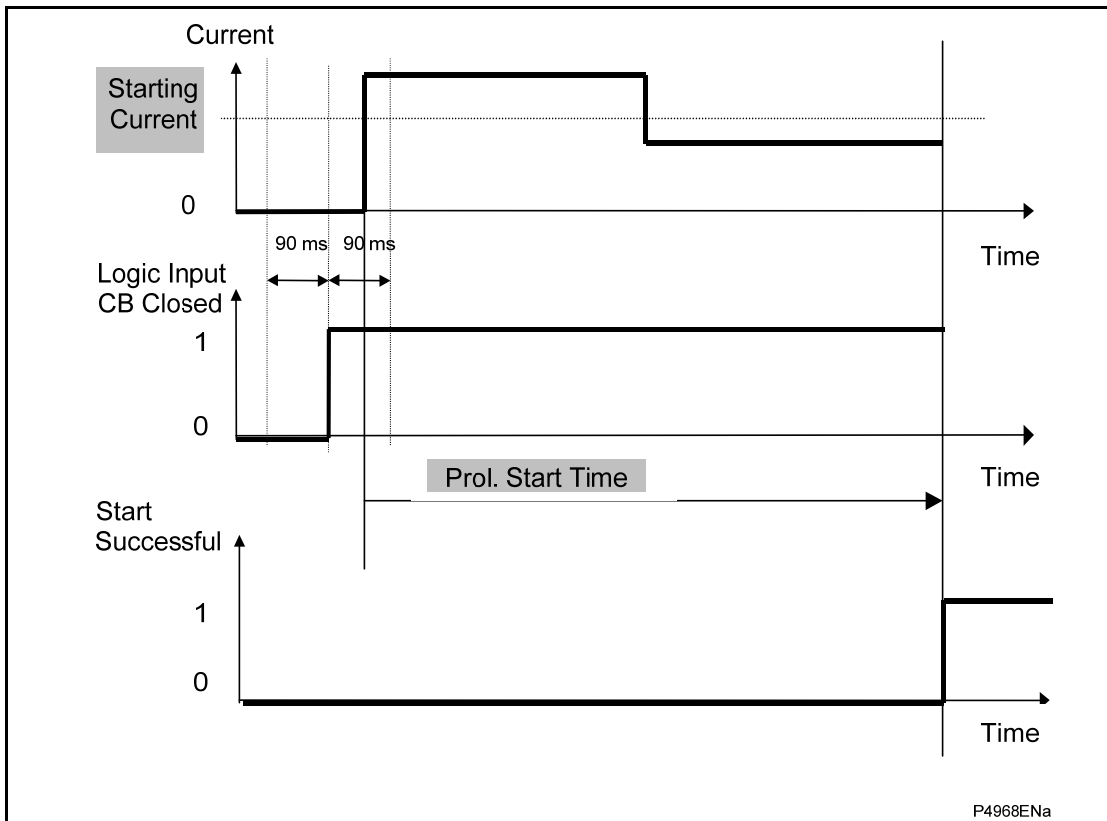
Figure 1: Start successful

An alarm **Prolonged Start: DDB 299** is generated if the current fails to fall below the starting current threshold before the end of the starting timer.

1.1.2 Locked Rotor During Starting – (Stall Time < Start Time)

For certain 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 P24x relay overcomes it by using a contact from a speed sensing device wired into a specified opto input (Speed Input: DDB 104). Change in 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: DDB 302). While using speed switch input, the **Stall Rot-Strt** setting is required to be enabled.

> **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.

Figure 2 shows the principle of this function:
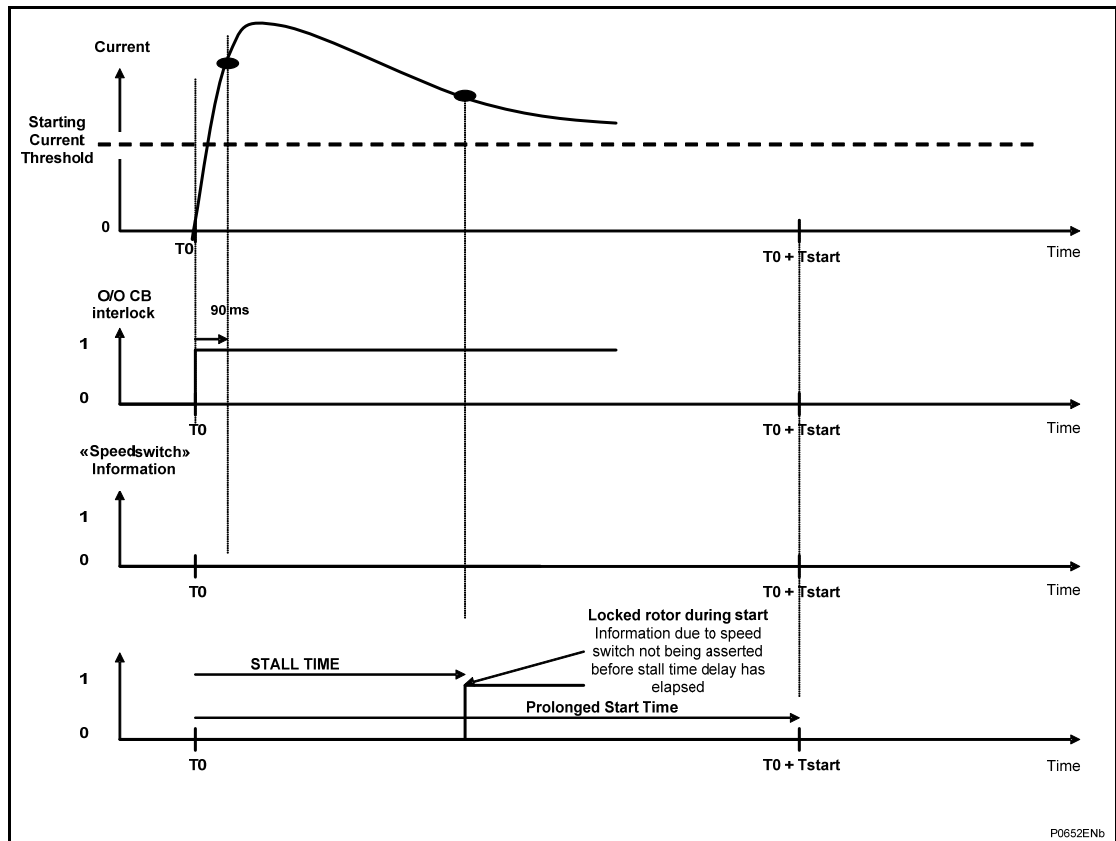
Figure 2: Locked rotor detection

For this case, 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 does NOT generate a tripping order.

1.1.3 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 closed condition** (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: DDB 301).

1.1.4 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**.

1.1.5 Reacceleration after a Reduction in System Voltage

If there is a low voltage condition on the system for more than 100 ms and, once the voltage has recovered, the current drawn by motors can exceed the stalling current threshold within 5 seconds (**Reac in Progress**: DDB 300), the stall protection is disabled during this scenario to allow for reacceleration. A settable undervoltage threshold **Reac Low V Set** makes it possible to detect a voltage drop.
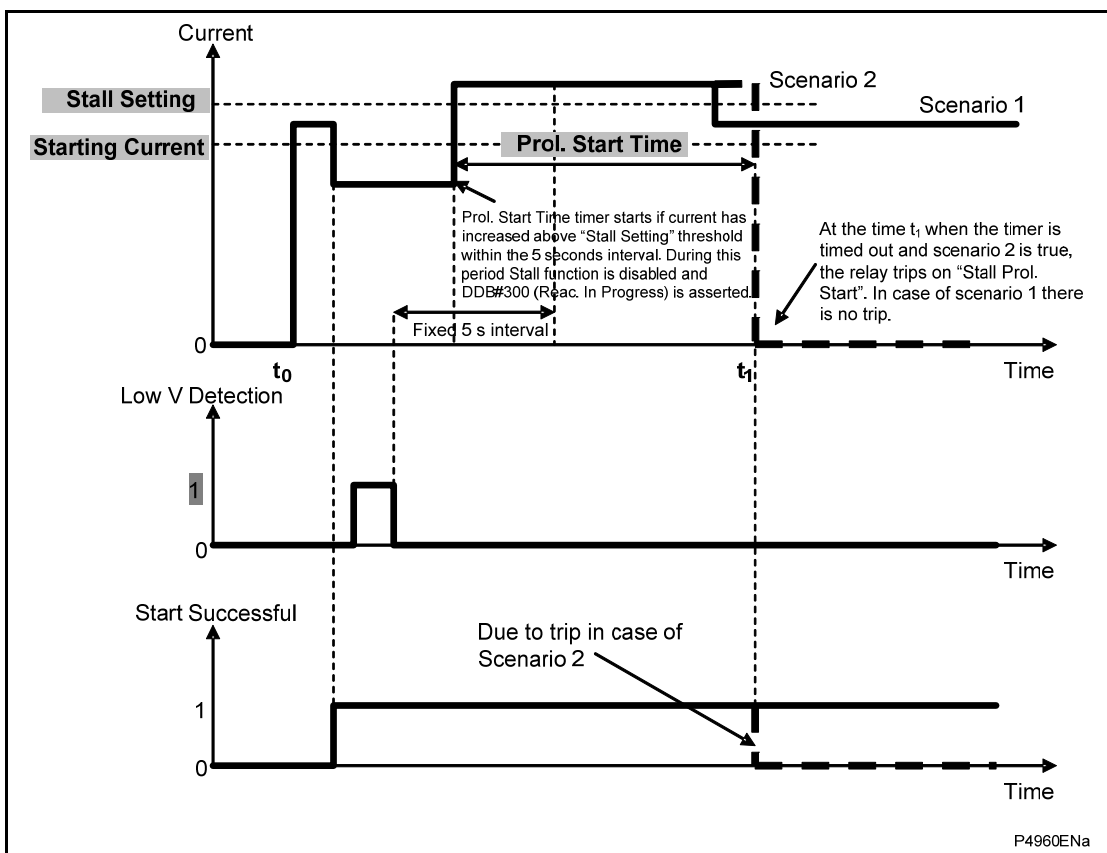
Figure 3: Reacceleration detection

Highlighted in Figure 3 are the last 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.

If the current exceeds the **stall setting** threshold after the 5 s window used for reacceleration criteria and remains above the stall setting before expiry of stall time, the stall the **Stall Rotor Run** issues the tripping command.

This function is disabled during the starting period. This period begins when DDB start in progress #297 is asserted and ends when DDB start successful #298 is asserted.

1.1.6 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. **Reac Time** is the time delay corresponds to the maximum duration of voltage sag for which the motor reacceleration is authorized.

OP

On detection of a voltage drop, the relay initiates a time-delay Reac Time. The diagrams below show the relay behaviour under different conditions:
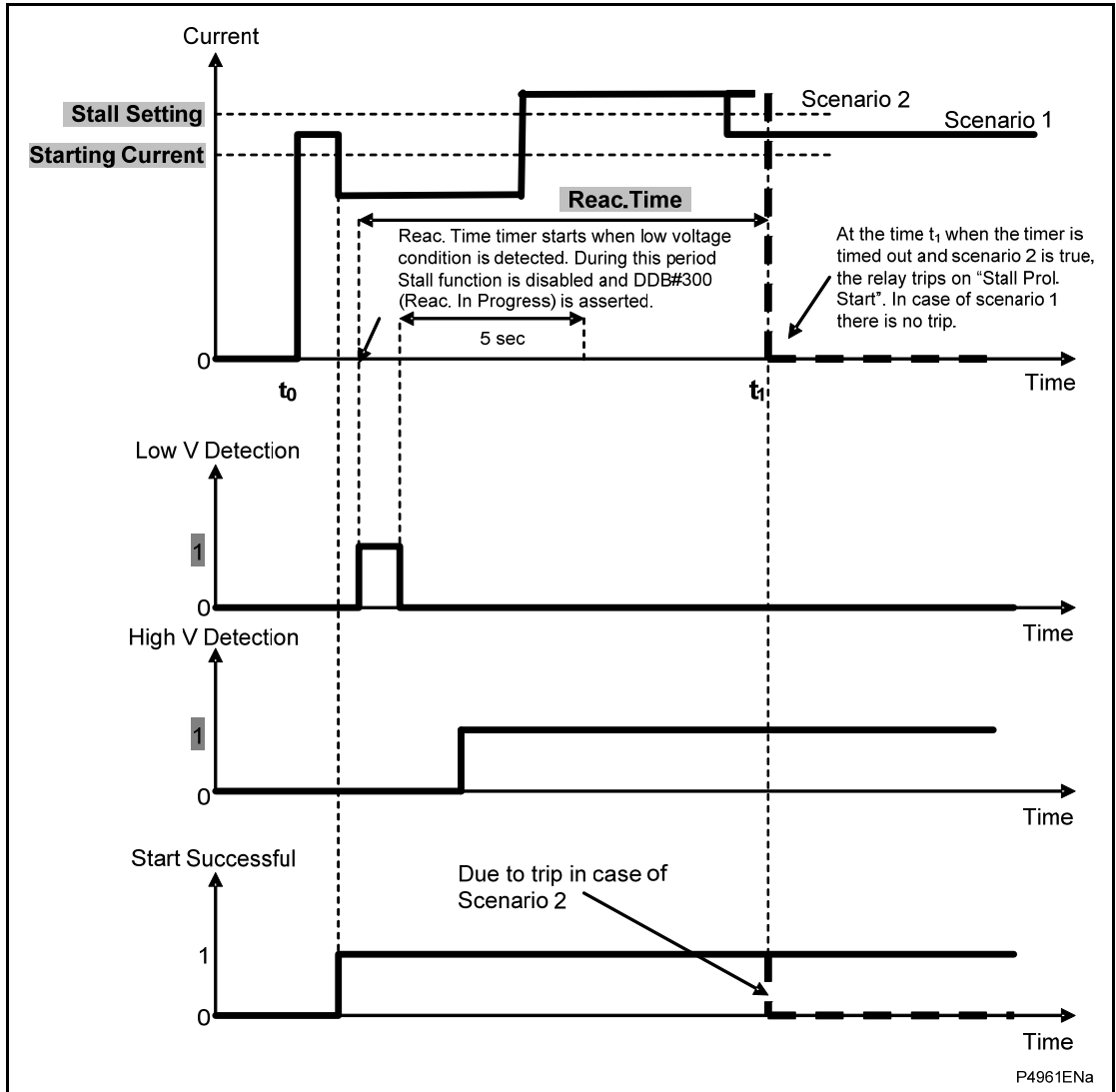
Figure 4: Adjustable reacceleration authorization - Voltage restored within the set time.

Current

Stall Setting

Starting Current

Scenario 2

Scenario 1

Reac. Time

Reac. Time timer starts when low voltage condition is detected. During this period Stall function is disabled and DDB#300 (Reac. In Progress) is asserted.

At the time t_1 when the timer is timed out and the voltage has not been restored, the relay trips on "Vdip DDB#402".

0

t_0

t_1

Time

Low V Detection

1

0

Time

High V Detection

1

0

Time

Start Successful

1

0

Time

P4962ENa
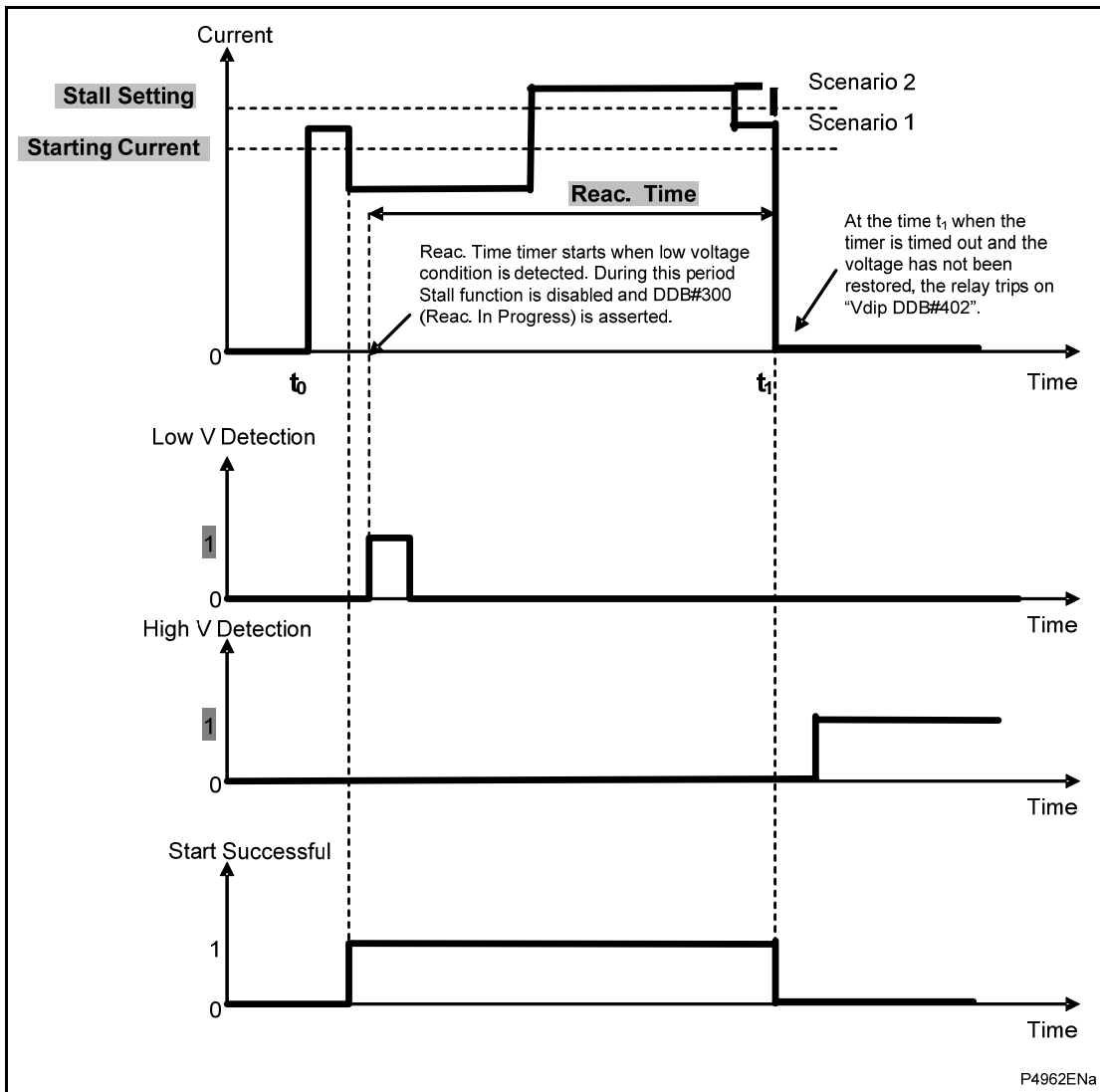
Figure 5: Adjustable reacceleration authorization - Voltage restored after the set time

1.1.7   Auto Re-start Authorization: Re-start/Load 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. **Reac Long Time** threshold setting can be used when it is appropriate to restart the motor without any staged startup sequence. **Reac Shed Time** threshold setting can be used to cover cases when restoration is from backup power, and 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:
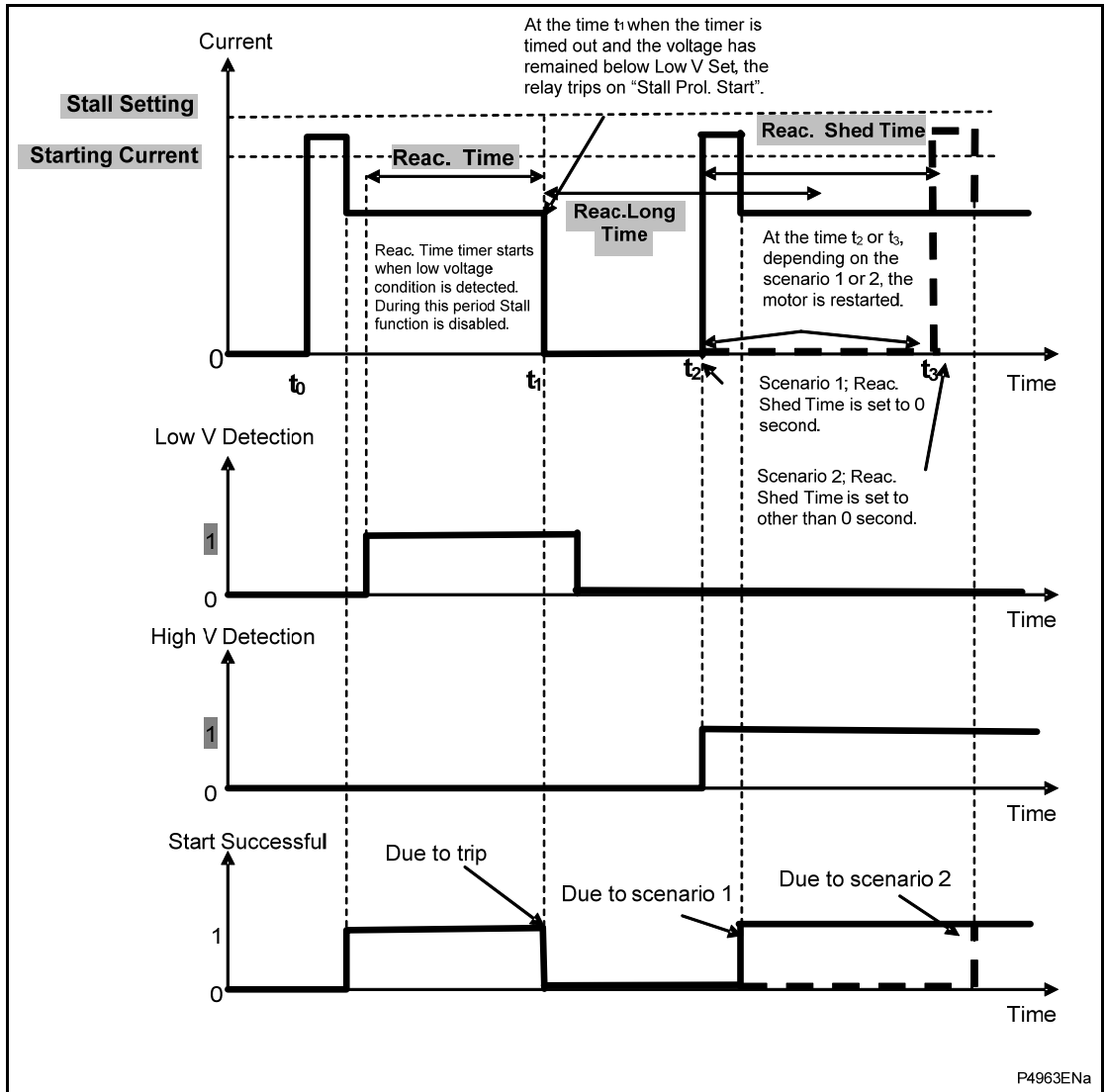
Figure 6: Automatic restart authorized- voltage restored within the set time

VT monitors the busbar voltage for automatic restart function to operate correctly. When restart is authorized, DDBs "Auto Re-Start #404" and "Auto Re-Start OK #403" are asserted.
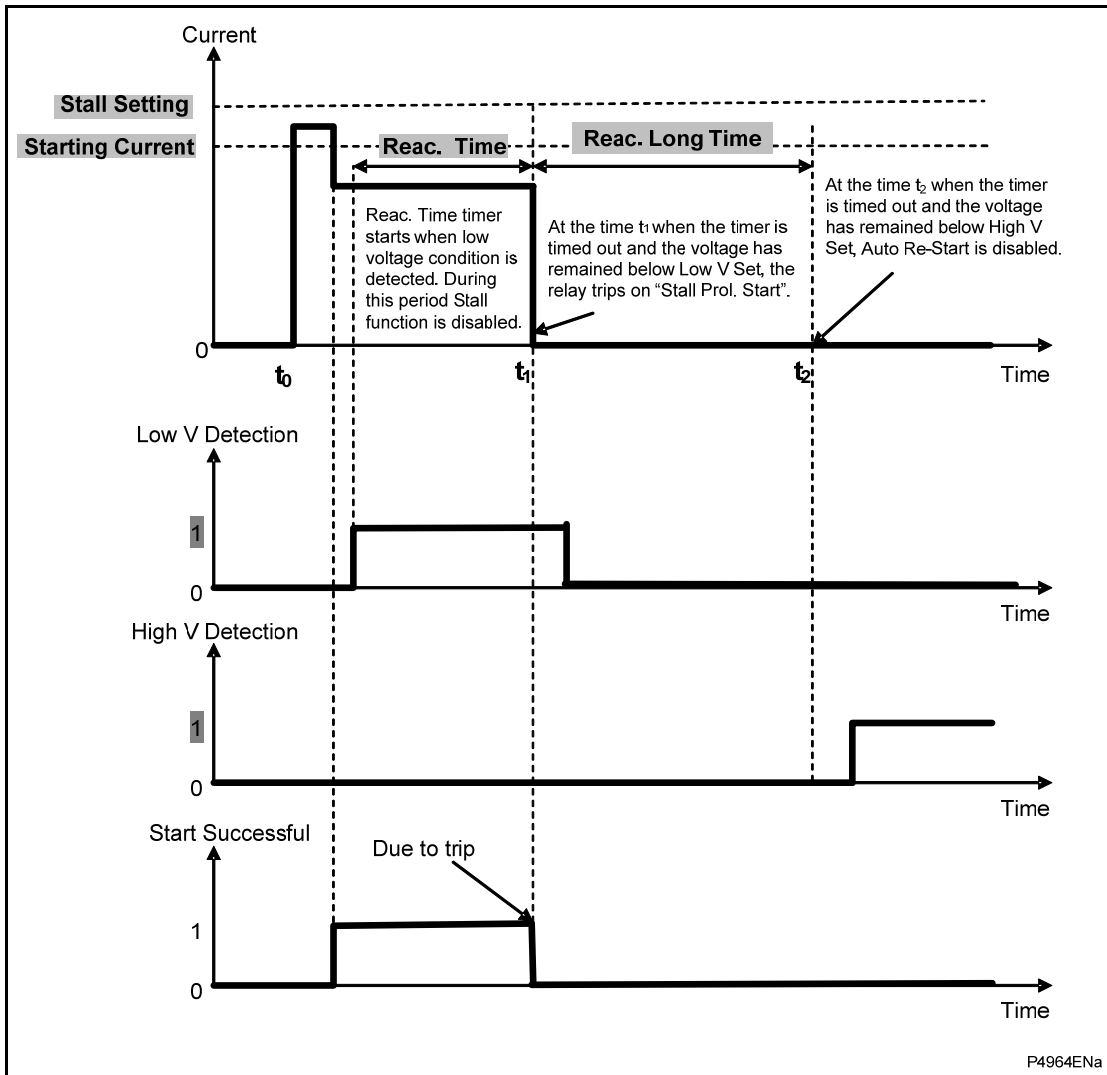
Figure 7: Automatic restart failed- voltage restored after the set time.

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), DDB "Auto Re-Start KO #405 becomes asserted. For default LED and Output Relay management refer to default PSL.

1.2   Number of Starts Limitation (66)

1.2.1   Starts Inhibition

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 allowable 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 based on starting criteria (CB status/Current/Both) 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 Ith. Therefore the number of hot starts and cold starts protections should be disabled because they could give an unexpected result.

First diagram:

The maximum number of starts within the **Supervising Time** has been reached so 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, with the default settings and a tn of 8 mins for example, the inhibition time before a new start is 52 mins.
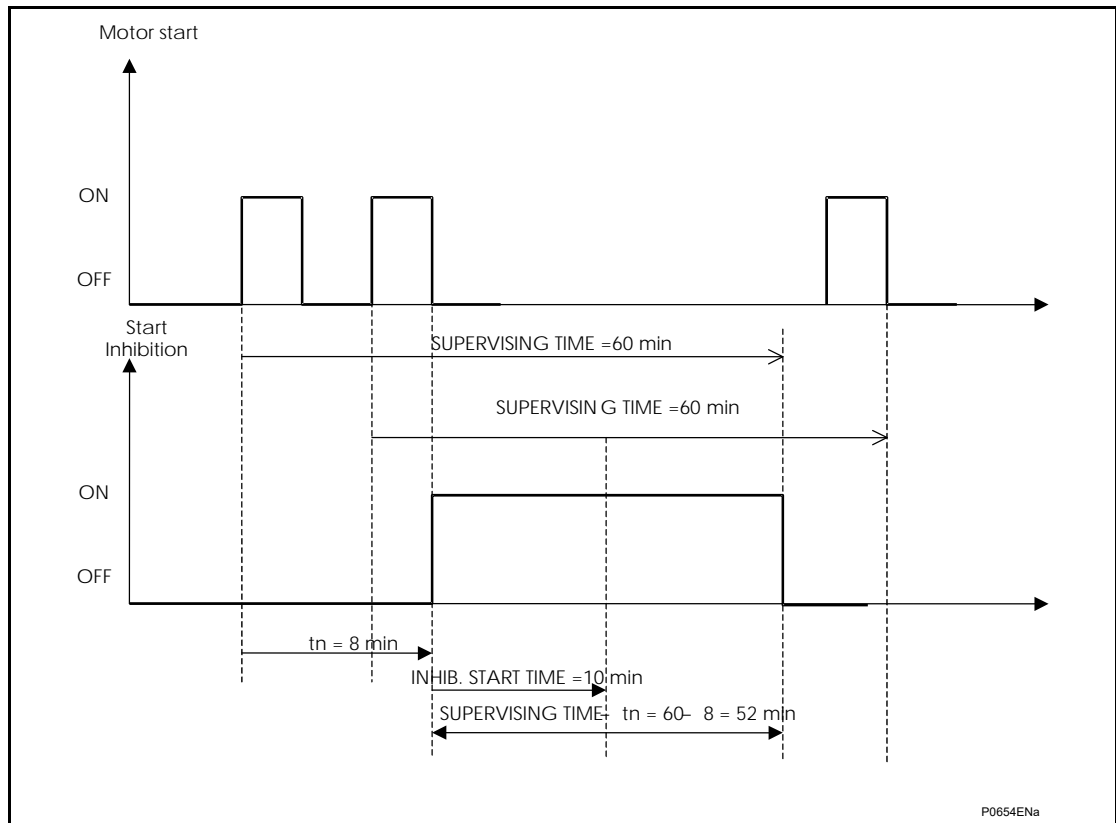
Figure 8: Start inhibition example 1

Second diagram:

The maximum number of starts within the **Supervising Time** has been reached so 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, with the default settings and a **tn** of 55 mins for example, the inhibition time before a new start is 10 mins.

P0655ENa
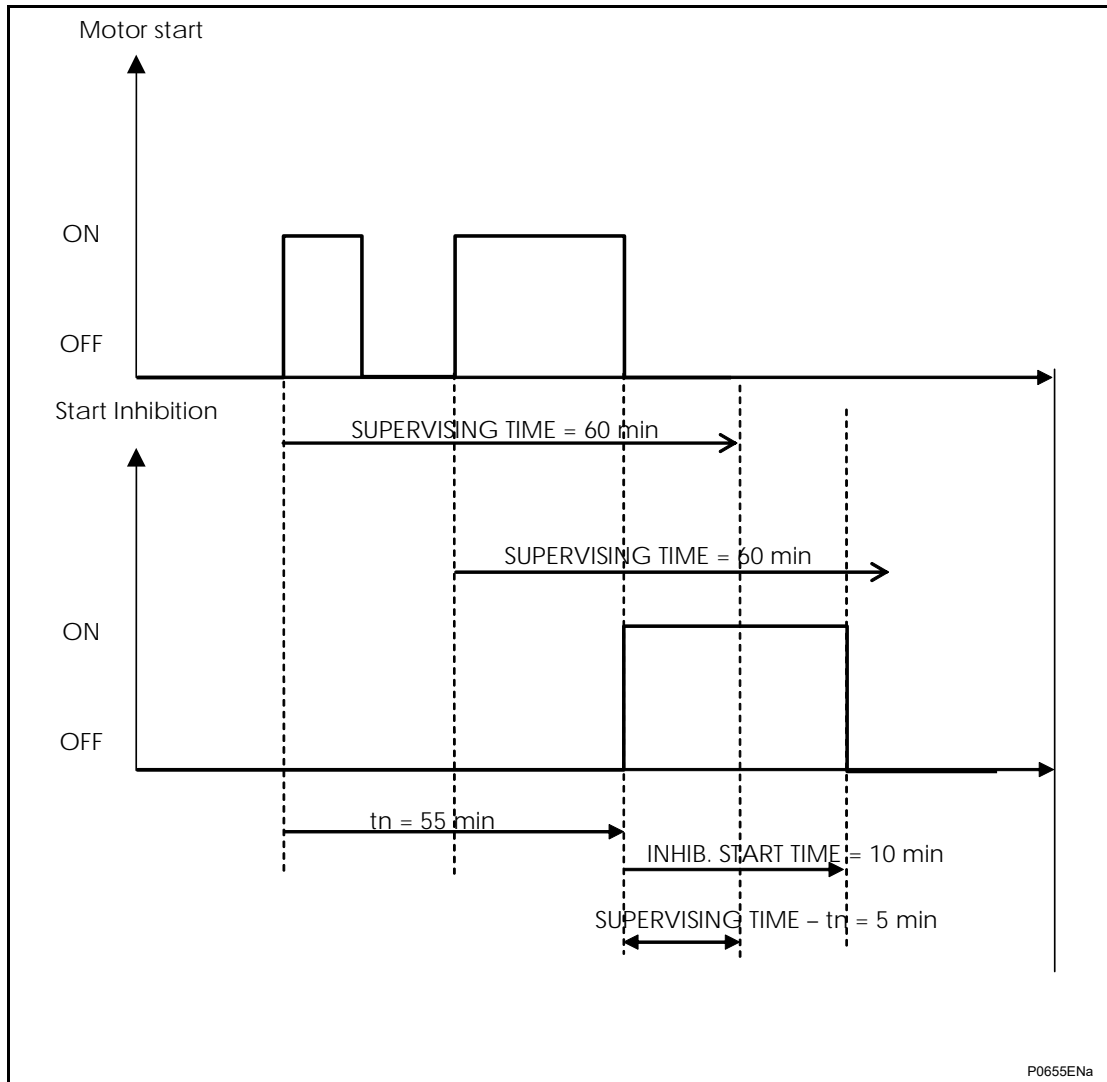
Figure 9: Start inhibition example 2

The **Start Lockout** information (Hot Start Nb: DDB 181, Cold Start Nb: DDB 182) 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.

1.2.2   Time Between Starts

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

The **Start Lockout** information (Time Betwe Start: DDB180) is present until the end of the greater time delay between the **Inhib.Start Time** and the **Time Between Start**.
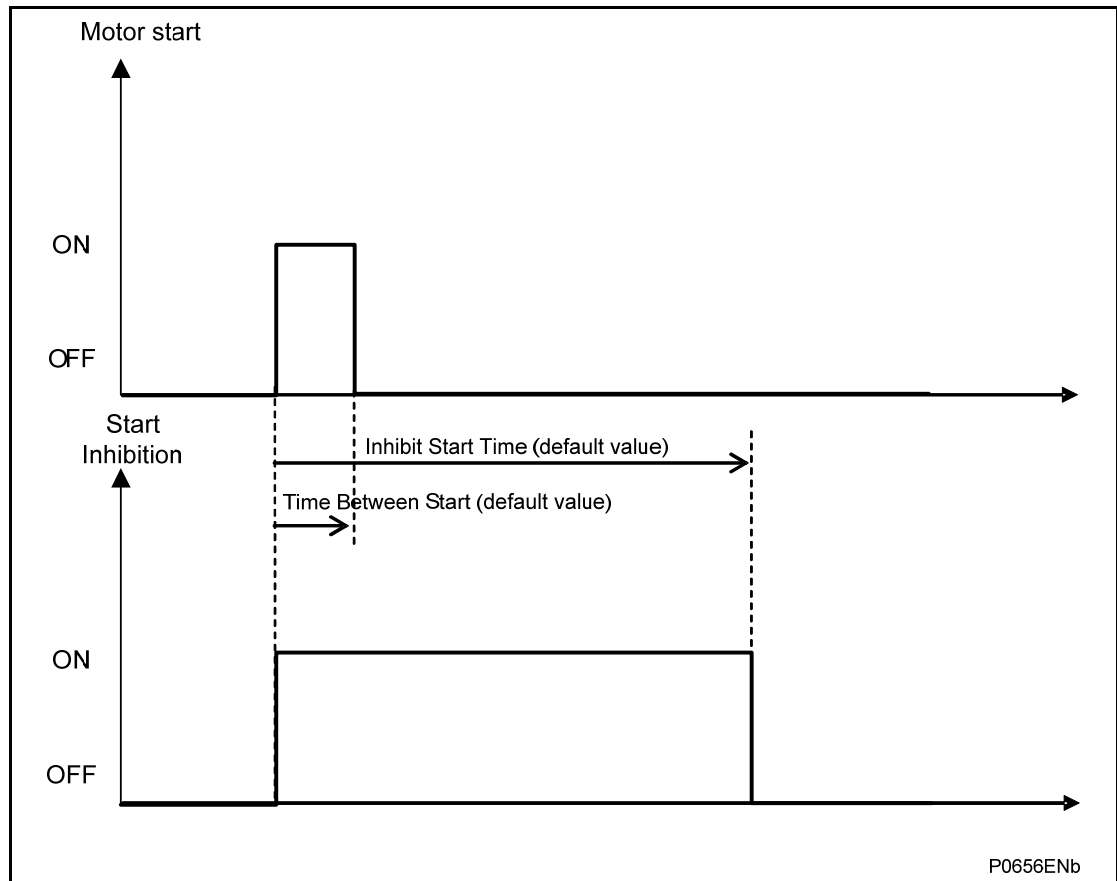
Figure 10: Time between starts

1.3   Anti-Backspin Protection (27 Remanent)

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 this function depends on the parameter **VT connecting mode**. If this is set to **2 VT + Vremanent**, the function uses an undervoltage with the connected Phase-Phase remanent voltage. If not the function uses only a time delay.

As soon as the CB is opened, the delay setting **Anti-backs Delay** is started and the DDB signal **Antibkspin Alarm: DDB233** goes high.

Notes: When the 2 VT + Vremanent input is used, it must be connected to V_3 input on the relay using a third VT. Also the first VT must be connected to V_1 (V_{ab}) and the second VT connected to V_2 (V_{bc}) inputs on the relay. See the connection diagram in the Installation chapter, *P24x/EN IN*.

Connection of remanent voltage to input V_3 on the relay disables measurement of V_a, V_b, V_c, and V_0. Therefore all power and energy calculations (W, VA, VAr, Wh) are inhibited. Also the following quantities become invisible in the relevant measurement column:

- Peak and RMS quantities of phase to neutral voltages of all three phases

- V0

- Watts, VA, VAr and Wh

All of the following protection functions which require measured quantities of phase to neutral or V_0 become disabled or invisible:

- 'Out of step'

- 'Field failure'

- 'Residual O/V'

- 'Reverse power'

- 'Loss of Load'

- '3 Phase Voltage Check'

- Directional elements of 'Derived Earth Fault' and 'Sensitive Earth Fault'

- Also the disturbance recorder can not be configured for any of the phase-to-neutral voltages.

1.3.1 2 VT + Vremanent

Connected:

During the **Anti-backs Delay** time the remanent phase-phase voltage must decrease below the **VRem Anti-backs** setting. As soon as this voltage is under the threshold, the DDB signal **Antibkspin Alarm: DDB 233** is reset (along with the time delay) and a new start is authorized. If the threshold is not reached and the time delay expires, the signal **Antibkspin Alarm** is reset and a new start is authorized (see Figure 11).

Not connected:

When the 2 VT + Vremanent VT is not used, the anti-backspin protection function uses a time delay only **Anti-backs Delay**. While the timer is operating, a new start is not authorized. A new start is authorized only when the timer has timed out.
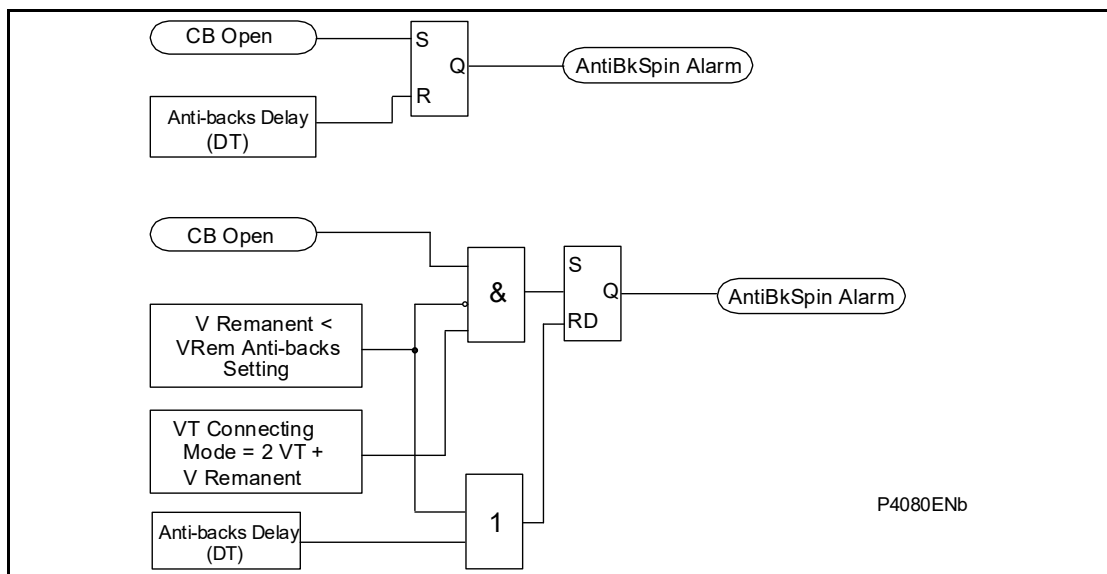
Figure 11: Anti-Backspin logic diagram

1.4 Thermal Overload (49)

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.

1.4.1 Thermal Replica

Both the positive or RMS and negative sequence currents are analysed, to monitor the thermal state accounting for any phase unbalance present. This thermal model takes into account the overheating, generated by the negative phase sequence current in the rotor.

The equivalent motor heating current is calculated by:

$$I_{eq} = \sqrt{(I_1^2 + K I_2^2)}$$

Note: This equation is used in software version A4.x(09) and before

or

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

Note: This equation is used in software version B1.0(20) or later

Where:

I_1 = Positive sequence current

I_{rms} : root mean square current

I_2 : negative sequence current

K is a constant proportional to the thermal capacity of the motor

The equivalent motor heating current is calculated every 20 ms. The maximum value recorded is then used by the thermal algorithm.

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

Ith 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).

1.4.2.1   Compensation for Ambient Temperature by RTD

To compensate for the ambient temperature variation, the thermal setting is corrected depending on the ambient temperature. The new value of the thermal capacity used becomes:

$$K' = I_{eq} / (coef * I_{th})$$

Where the correction coefficient is calculated depending on the ambient temperature as shown below:

Coef = 1   for T < 40° C

Coef = 1.4 - (0.01T)   for 40° C ≤ T ≤ 65° C

Coef = 0.75   for T > 65° C
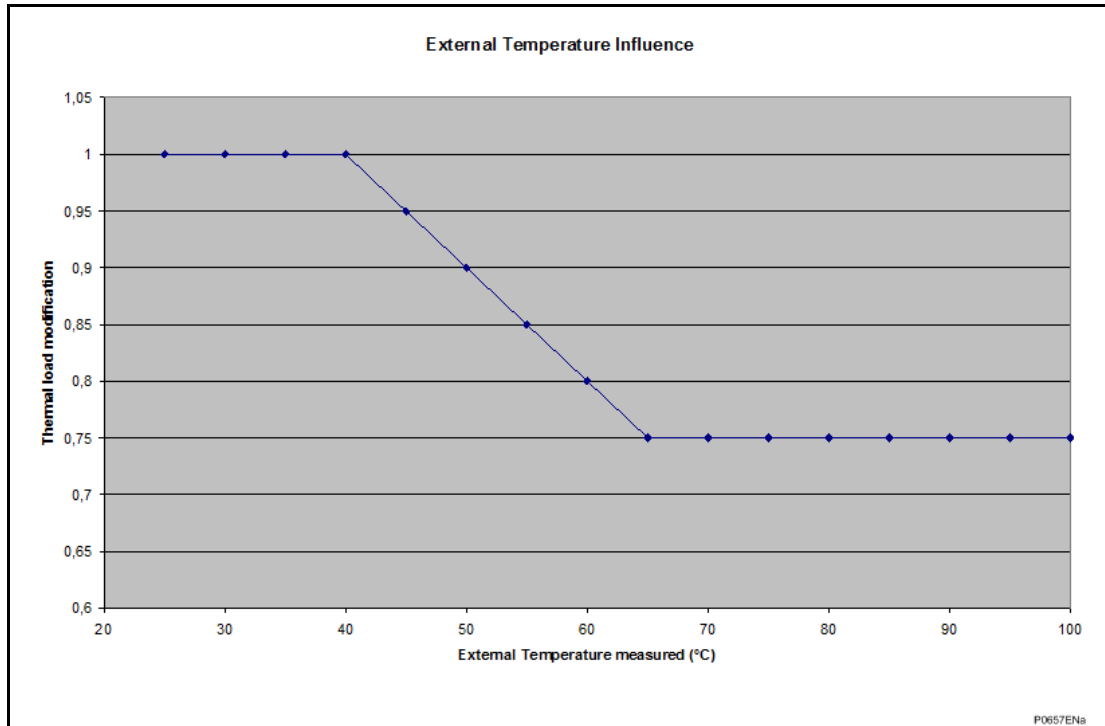
Figure 12: Ambient temperature compensation

This compensation factor is taken into account when any one of the ten possible RTDs are selected to measure the external or ambient temperature (see menu **RTD PROTECTION**).

The P24x relay can accommodate ten PT100, Ni100 or Ni120 RTDs. These RTDs are used to monitor the temperature of the stator windings, bearings and ambient temperature. Each RTD software element has two time delayed outputs; one for alarm and one for trip.

RTDs are fragile and susceptible to over voltage, therefore they are usually used in pairs: one main and one back-up. Open circuit and short circuit detection of the RTDs is also provided.

Only one external RTD influences the thermal curve. The second RTD is for back-up.

1.4.2.2   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 (Reset Thermal: DDB109), 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 (DDB 236). A further DDB signal **Thermal Alarm** is generated from the thermal alarm stage (DDB 178). The state of the DDB signal can be programmed to be viewed in the **Monitor Bit** x cells of the **COMMISSION TESTS** column in the relay.

Figure 13: Thermal overload protection logic diagram

1.4.2.3   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: DDB 179) 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:

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

Where:

T_r = cooling time constant,

θ_1 = initial thermal state,

θ_2 = final thermal state = 97% of thermal lockout threshold.
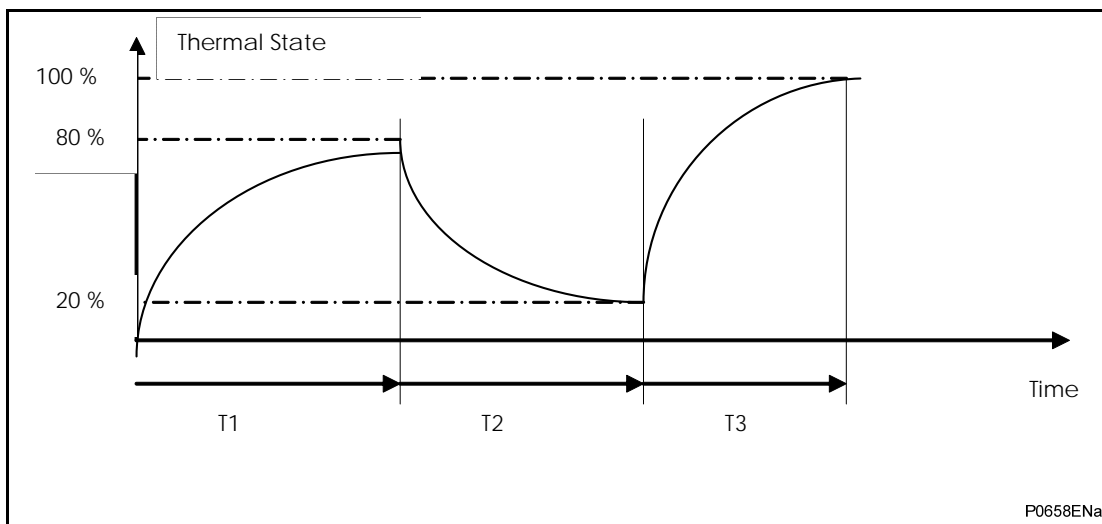
Figure 14: Cooling time constant

1.4.2.4   Emergency Restart

In an emergency, it may be necessary to restart a hot motor. An emergency restart can be enabled through an opto input (Emergency Rest: DDB108), using the user interface or the remote communications. This feature removes all start inhibits (Thermal lockout, No of Hot starts, No of cold starts, and the Time between starts).

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

In an emergency restart, the thermal curve during start-up is inhibited, even if this function is not used during a start-up in normal operation.

1.4.2.5   User Programmable Curve for Thermal Over Load Protection

For information on how to program a customized thermal over load curve and send and extract curves to and from the relay, refer to the document *Px4x/EN UPCT/B11*.

> **Note 1:**   If a user programmable curve is enabled in the Thermal Overload protection, the thermal state remains at 0% for as long as Ieq is less than Ith. Therefore the number of hot starts and cold starts should not be used.

> **Note 2:**   If Data Points rather than a Formula are used to configure a customized curve, data entered in the Time column can be in scientific format and the maximum time allowed by the tool is 1E+308.

1.5   Motor Differential Protection (87)

Circulating current differential protection operates on the principle that current entering and leaving a protection zone is equal. Any difference between these currents indicates a fault in the zone. If CTs are connected as shown in Figure 15, current flowing through the protection zone causes current to circulate around the secondary wiring. If the CTs are of the same ratio and have identical magnetizing characteristics, they produce identical secondary currents so zero current flows through the relay.

If there is a fault in the protection zone, there is a difference between the output from each CT. This difference flows through the relay causing it to operate.

P2157ENa
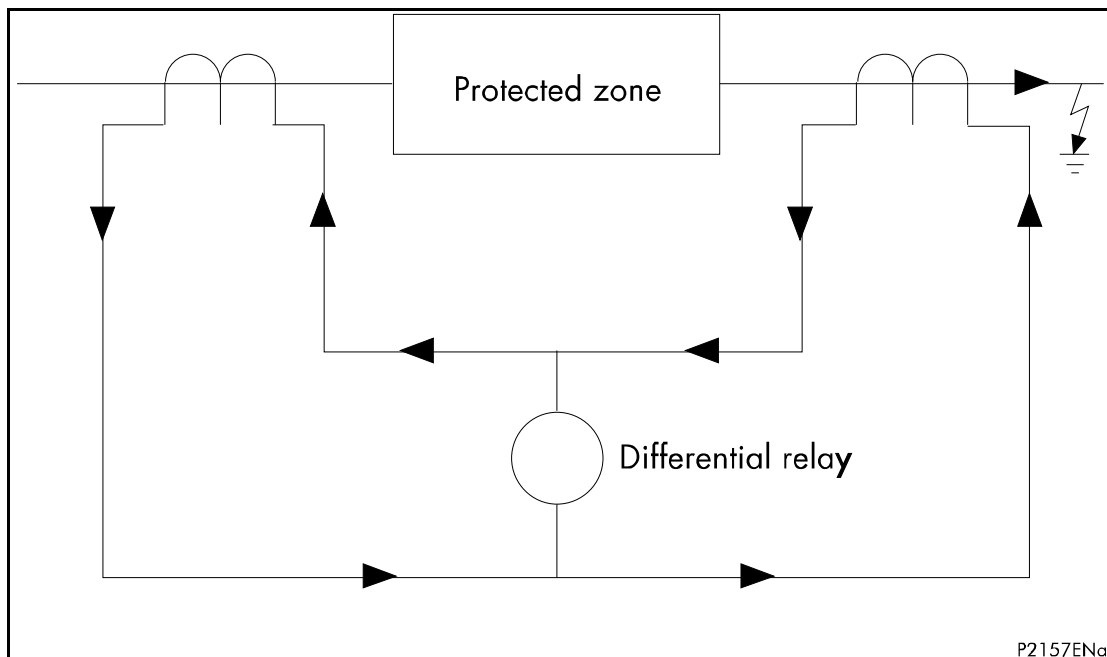
Figure 15:   Principle of circulating current differential protection

Heavy through current arising from an external fault condition can cause one CT to saturate more than the other. This results in a difference between the secondary current produced by each CT. It is essential to stabilize the protection for these conditions. Two methods are commonly used. The biasing technique is where the relay setting is raised as through current increases. The high impedance technique, where the relay impedance under maximum through fault conditions is high, so the current in the differential element is insufficient to operate the relay.

The motor differential protection function available in the P243 relay can be used in either biased differential or high impedance differential mode. Both modes of operation are equally valid although users may prefer one over the other. The operating principle of each is described in the following sections.

A DDB (Digital Data Bus) signal indicates the tripping of each phase of differential protection (Diff Trip A/B/C: DDB 315, DDB 316, DDB 317).

OP

Also there is a three phase trip DDB signal (Trip Diff: DDB 318). These signals are 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 the **Monitor Bit x** cells of the **COMMISSION TESTS** column in the relay.

The motor differential protection operation is shown in the following diagram:
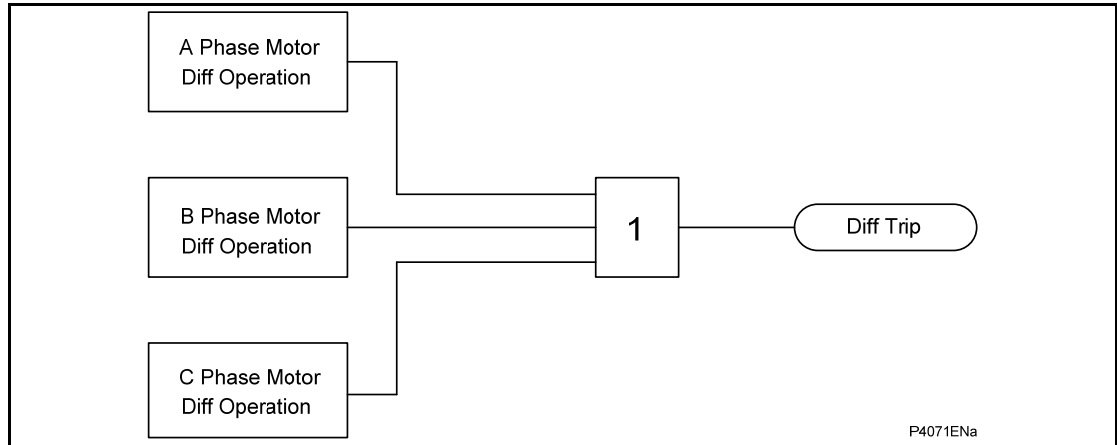
Figure 16: Motor differential logic diagram

1.5.1   Biased Differential Protection

In a biased differential relay, the through current is used to increase the setting of the differential element. For heavy through faults, it is unlikely that the CT output at each zone end is identical. This is due to the effects of CT saturation. In this case a differential current can be produced. However, the biasing increases the relay setting so that the differential spill current is insufficient to operate the relay.

A dual slope percentage bias characteristic is used in the P24x. The lower slope provides sensitivity for internal faults. The higher slope provides stability under through fault conditions. During these there may be transient differential currents due to saturation effect of the motor CTs.

The through current is calculated as the average of the scalar sum of the current entering and leaving the protection zone. This calculated through-current is then used to apply a percentage bias to increase the differential setting. The percentage bias can be varied to give the operating characteristic shown in Figure 17.
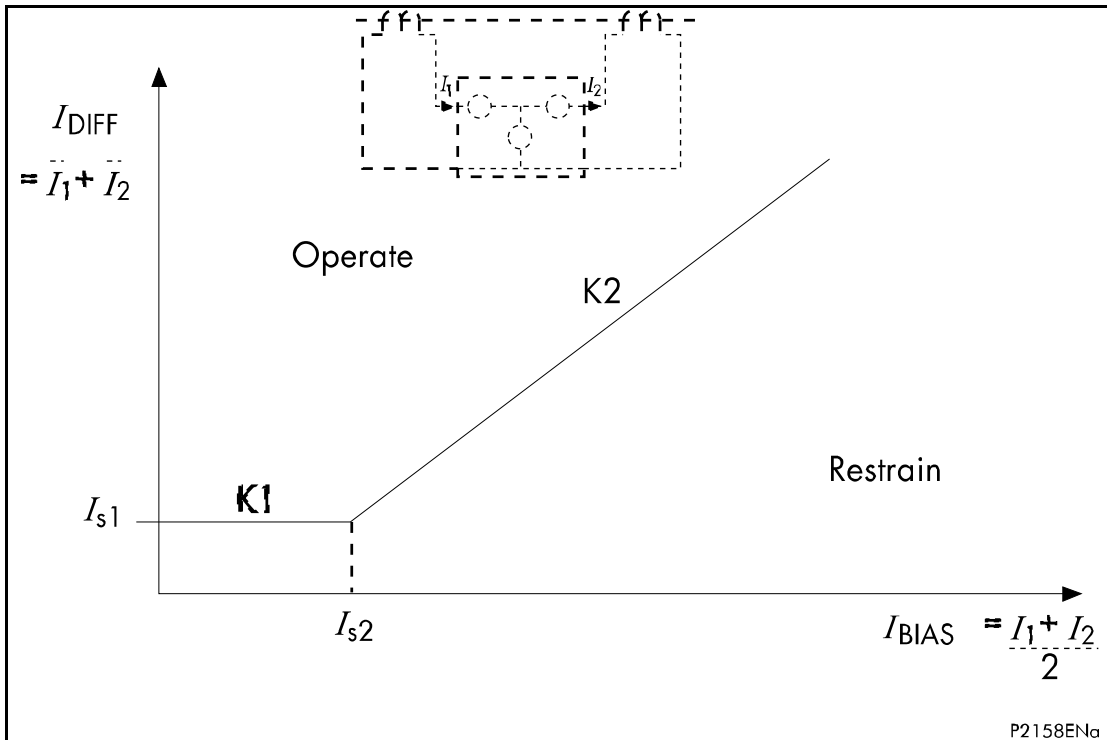
Figure 17: Biased differential protection operating characteristic

The P243 relay has two bias settings. The initial bias slope, **Diff k1**, is applied for through currents up to **Diff Is2**. The second bias slope, **Diff k2**, is applied for through currents above the **Diff Is2** setting.

The Biased differential protection function uses the two sets of three-phase current measurement inputs (IA, IB, IC, IA2, IB2, IC2), connected to measure the phase current at the neutral end and terminals of the machine, as shown in Figure 17. The bias and differential currents are calculated by the relay software. They provide a phase segregated differential protection function and may be viewed in the **MEASUREMENTS 1** column in the relay menu.

1.5.2 Differential and Bias Current Calculation

The calculation is performed on a per phase basis. The differential current is the vector sum of the phase currents measured at either end of the generator. The mean bias current (Ibias) is the scalar mean of the magnitude of these currents, that is,

$$I_{a-diff} = \left| \overline{I_{a-1}} + \overline{I_{a-2}} \right|$$

$$I_{b-diff} = \left| \overline{I_{b-1}} + \overline{I_{b-2}} \right|$$

$$I_{c-diff} = \left| \overline{I_{c-1}} + \overline{I_{c-2}} \right|$$

$$I_{a-bias} = \frac{\left|\overline{I_{a-1}}\right| + \left|\overline{I_{a-2}}\right|}{2}$$

$$I_{b-bias} = \frac{\left|\overline{I_{b-1}}\right| + \left|\overline{I_{b-2}}\right|}{2}$$

$$I_{c-bias} = \frac{\left|\overline{I_{c-1}}\right| + \left|\overline{I_{c-2}}\right|}{2}$$

To provide further stability for external faults, a number of additional measures are taken on the bias calculations:

1.5.2.1   Delayed Bias

The bias quantity used is the maximum of the bias quantities calculated in the last cycle. This maintains the bias level, providing stability while an external fault is cleared. This feature is implemented on a per phase basis. The algorithm is expressed as follows; the function is executed 4 times per cycle:

Ia-bias(n) = Maximum [Ia-bias(n), Ia-bias(n-1), ..., Ia-bias(n - 3)]

Ib-bias(n) = Maximum [Ib-bias(n), Ib-bias(n-1),........, Ib-bias(n - 3)]

Ic-bias(n) = Maximum [Ic-bias(n), Ic-bias(n-1), ..., Ic-bias(n - 3)]

1.5.2.2   Transient Bias

If there is a sudden increase in the mean-bias measurement, an additional bias quantity is introduced into the bias calculation on a per phase basis. This bias quantity decays exponentially afterwards. The transient bias is reset to zero once the relay has tripped or if the mean bias quantity is below the Is1 setting. The transient bias is used to make the protection stable for external faults. It also allows for the time delay in CT saturation caused by small external fault currents and high X/R ratios. For single-end or double-end fed faults, the differential current is dominant and the transient bias has no effect.

The transient bias is removed after the relay has tripped to avoid the possibility of chattering. It is also removed when Ibias is less than Is1 to avoid the possibility of residual values due to the numerical effects.

1.5.2.3   Maximum Bias

The bias quantity used per phase for the percentage bias characteristic is the maximum bias current calculated from all three phases,

I-bias-max = Maximum [Ia-bias, Ib-bias, Ic-bias]

1.5.2.4   Tripping Criteria

The tripping criteria per phase are formulated as follows. The differential threshold changes according to the value of I-bias-max, as in the percentage bias characteristic.

Note: The transient bias is on a per phase basis and is not be affected by the K1 or K2 setting.

For I-bias-max <= Is2

Idiff > K1*I-bias-max + Transient_bias + Is1

For I-bias-max > Is2

Idiff > K2*I-bias-max + Transient Bias - Is2*(K2-K1) + Is1

A count strategy is used so the protection operates slower near the boundary of operation. This approach is used to stabilize the relay under some marginal transient conditions.

Figure 18: Relay connections for biased differential protection

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1.5.3 High Impedance Differential Protection

The high impedance principle is best explained by considering a differential scheme where one CT is saturated for an external fault, as shown in Figure 19.

Figure 19: **Principle of high impedance differential protection**

Voltage across relay circuit

$$V_s = K I_f (R_{CT} + 2R_L) \text{ - where } K = 1.5$$

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

$$R_{ST} = \frac{V_s}{I_s} - R_R$$

I_F = Maximum secondary through fault current

Where R_R = Relay burden

R_{CT} = Current transformer secondary winding resistance

R_L = Resistance of a single lead from the relay to the current transformer

P0115ENd

Figure 19: Principle of high impedance differential protection

If the relay circuit is considered to be very high impedance, the secondary current produced by the healthy CT flows through the saturated CT. If the magnetizing impedance of the saturated CT is considered to be negligible, the maximum voltage across the relay circuit is equal to the secondary fault current multiplied by the connected impedance, (R_{L3} + R_{L4} + R_{CT2}).

The relay can be made stable for this maximum applied voltage by increasing the overall impedance of the relay circuit, so the resulting current through the relay is less than its current setting. As the impedance of the relay input alone is relatively low, a series connected external resistor is required. The value of this resistor, R_{ST}, is calculated by the formula shown in Figure 19. An additional non-linear resistor (Metrosil) may be required to limit the peak secondary circuit voltage during internal fault conditions.

To ensure that the protection operates quickly during an internal fault, the CTs used to operate the protection must have a knee point voltage of at least 2 Vs.

The high impedance differential protection function uses the IA2, IB2, IC2 current inputs connected to measure the differential current in each phase, as shown in Figure 20.

R_{ST} ≅ Stabilising resistor
NLR ≅ Non-linear resistance (Metrosil)

MiCOM P243

I_{A2}
I_{B2}
I_{C2}

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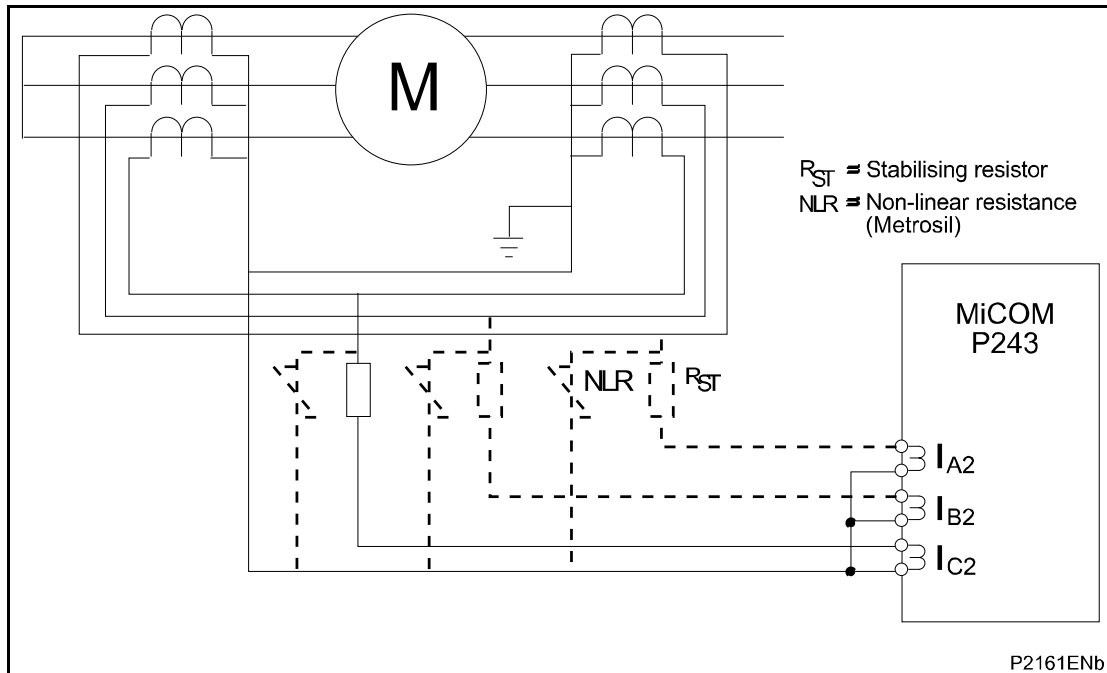
Figure 20: Relay connections for high impedance differential protection

1.5.4   Self Balance Winding Differential

An alternative is to use self balance type differential protection arrangement, as shown in Figure 21, using the IA2, IB2, IC2 set of CTs

For this configuration, the relay must be set to **High Impedance** using the cell **Diff Function** in the **Differential** protection menu

Spill current can be kept to a minimum if the conductors are placed reasonably concentrically in the window of the core balance current transformers. With this low spill current and a reasonable independence of CT ratio to full load, a lower fault setting could be achieved compared to conventional high impedance circulating current differential schemes.

Disadvantages

1. Both ends of each phase winding need to pass through the CT. Therefore extra cabling is needed on the neutral end.

2. To avoid long cabling, the position of CTs is restricted to the proximity of the machine output terminals. In this case the cable between the machine output terminals and controlling switchgear might not be included in the differential zone.

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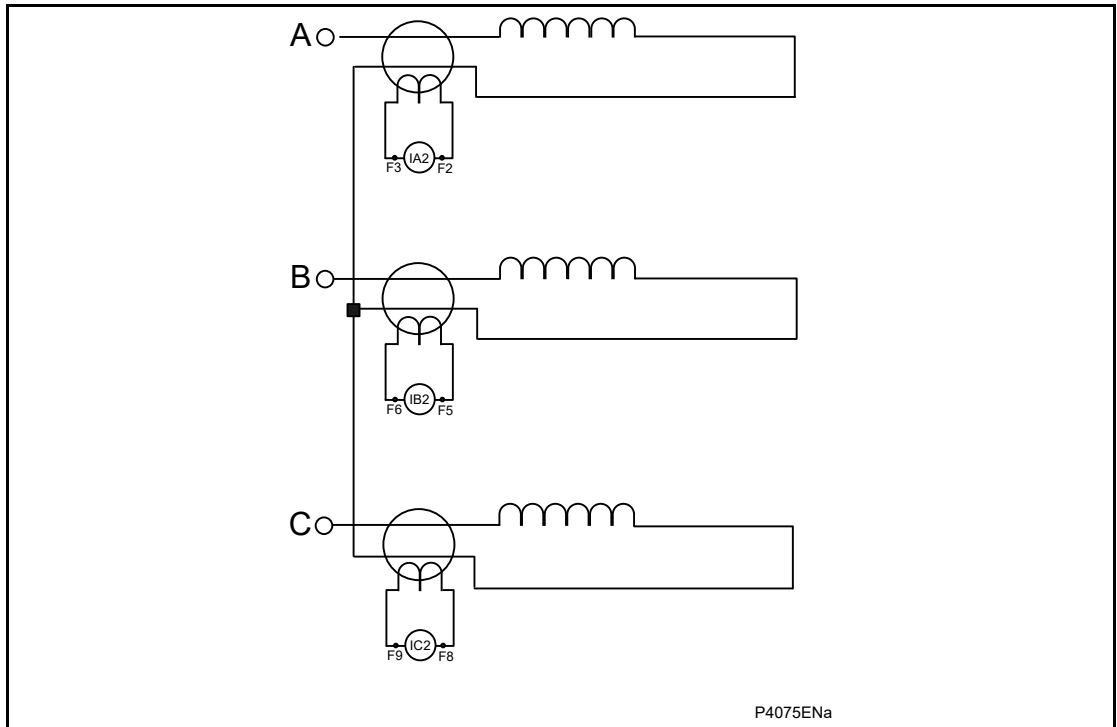
Figure 21: Self-balance winding differential protection

1.6   Short Circuit Protection (50/51)

The overcurrent protection included in the P24x relays provides four-stage non-directional three-phase overcurrent protection with independent time delay characteristics. All overcurrent settings apply to all three phases but are independent for each of the four stages.

The first two stages of overcurrent protection have time-delayed characteristics. These are selectable between inverse definite minimum time (IDMT) and definite time (DT). The third and fourth stages have definite time characteristics only.

If a definite time setting of less than 100 ms is set, to avoid tripping during start-up due to asymmetric CT saturation, the definite time element has a minimum operating time of 100 ms for currents in the range of 1 x I> to 1.13 x I> as shown in Figure 19.
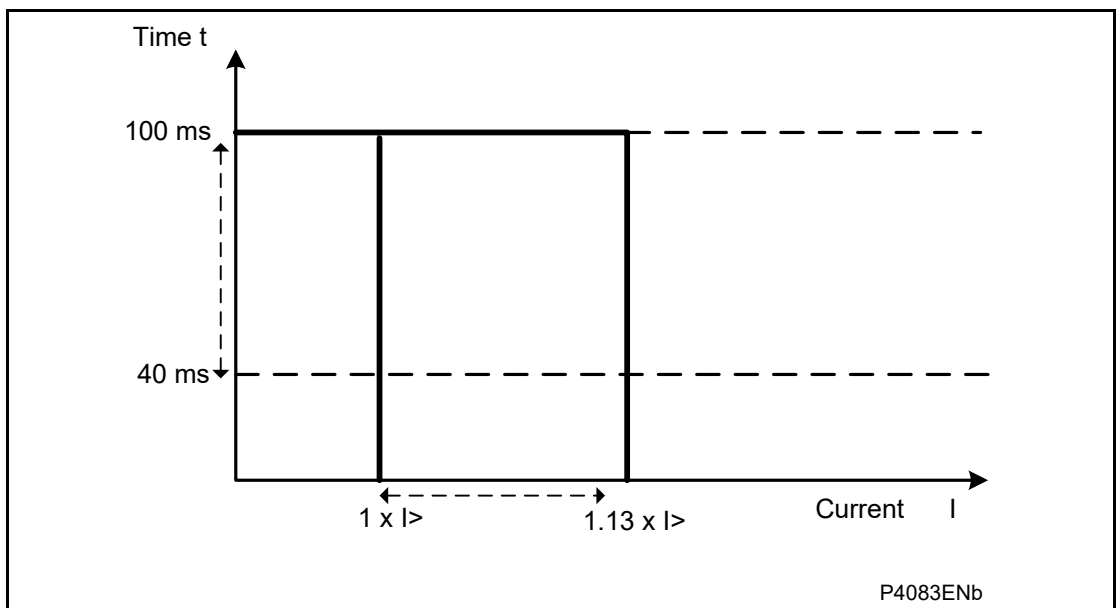
P4083ENb

Figure 22: Definite time overcurrent element

Various methods can be used to achieve correct relay co-ordination on a system: by time alone, current alone or a combination of both time and current. Grading by current is only possible where there is an appreciable difference in fault level between the two relay locations. 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 coordinating overcurrent relays is the IDMT type.

These inverse time delayed characteristics comply with the following formula:

IEC curves   IEEE curves   User Curves

$$t = Tx\left(\frac{\beta}{\left(M^{\alpha}-1\right)}+L\right)+C \quad \text{or} \quad t = TD/7x\left(\frac{\beta}{\left(M^{\alpha}-1\right)}+L\right) \quad t = \left(TD/7\right)xt_{ucrv}$$

Where:

t   =   Operation time

β   =   Constant

M   =   I/Is

K   =   Constant

I   =   Measured current

Is   =   Current threshold setting

α   =   Constant

L   =   ANSI/IEEE constant (zero for IEC curves)

T   =   Time multiplier setting for IEC curves

TD   =   Time dial setting for IEEE and user programmable curves

t_{ucrv} =   User curve operating time

Curve description	Standard	β constant	α constant	L constant
Standard Inverse	IEC	0.14	0.02	0
Very Inverse	IEC	13.5	1	0
Extremely Inverse	IEC	80	2	0
Long Time Inverse	UK	120	1	0
Rectifier	UK	45900	5.6	0
Moderately Inverse	IEEE	0.0515	0.02	0.114
Very Inverse	IEEE	19.61	2	0.491
Extremely Inverse	IEEE	28.2	2	0.1217
Inverse	US	5.95	2	0.18
Short Time Inverse	US	0.16758	0.02	0.11858

Table 1: Standard IDMT curves and their corresponding coeficients

The IEEE, US curves and User 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 employed for the IEEE/US/User curves. The menu is arranged so that if an IEC/UK curve is selected, the I> Time Dial cell is not visible and vice versa for the TMS setting.

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Note: The IEC/UK inverse characteristics can be used with a definite time reset characteristic. However, the IEEE/US/User curves may have an inverse or definite time reset characteristic. The following equation can be used to calculate the inverse reset time for IEEE/US/User curves:

$$tRESET = \frac{TD/7 \times S}{\left(1 - M^2\right)} \text{ in seconds}$$

Where:

TD   =   Time dial setting for IEEE and user programmable curves

S   =   Constant

M   =   I/Is

Curve description	Standard	S constant
Moderately Inverse	IEEE	4.85
Very Inverse	IEEE	21.6
Extremely Inverse	IEEE	29.1
Inverse	US	5.95
Short Time Inverse	US	2.261

Table 2: IEEE and US reset curve "S" coefficient values

And for user programmable curves $tRESET = t = TD \times t_{ucrv}$

1.6.1 RI Curve

The RI curve (electromechanical) has been included in the first and second stage characteristic setting options for phase overcurrent and earth protections. The curve is represented by the following equation.

$$t = K \times \left(\frac{1}{0.339 - \left(0.236/M\right)} \right) \text{ in seconds}$$

With K adjustable from 0.1 to 10 in steps of 0.05

M   =   I / Is

1.6.2 Timer Hold Facility

The first two stages of overcurrent protection in the P24x relay are provided with a timer hold facility, which may either be set to zero or to a definite time value

Note: If an IEEE/US operate curve is selected, the reset characteristic may be set to either definite or inverse time in cell **I>1 Reset Char**; otherwise this setting cell is not visible in the menu.

Setting the timer to zero causes the overcurrent timer for that stage to reset instantaneously once the current falls below 95% of the current setting. Setting of the hold timer to a value other than zero delays the resetting of the protection element timers for this period. This may be useful in certain applications, for example when grading with upstream electromechanical overcurrent relays which have inherent reset time delays.

Another situation where the timer hold facility can be used to reduce fault clearance times is for intermittent faults. For example in plastic insulated cable, the fault energy can melt and reseal the cable insulation, 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 of the overcurrent relay is instantaneous, the relay is repeatedly reset and not able to trip until the fault becomes permanent. Using the Timer Hold facility, the relay integrates the fault current pulses, reducing fault clearance time.

Settings **I>1 tRESET** and **I>2 tRESET** are the timer hold facility for the first and second overcurrent stages.

> **Note:** This cell is not visible for the IEEE/US curves if an inverse time reset characteristic has been selected, as the reset time is then determined by the programmed time dial setting.

The functional logic diagram for non-directional overcurrent is shown in Figure 23. The overcurrent block is a level detector that detects if the current magnitude is above the threshold. It provides a start and also initiates the IDMT/DT characteristic depending on the setting.
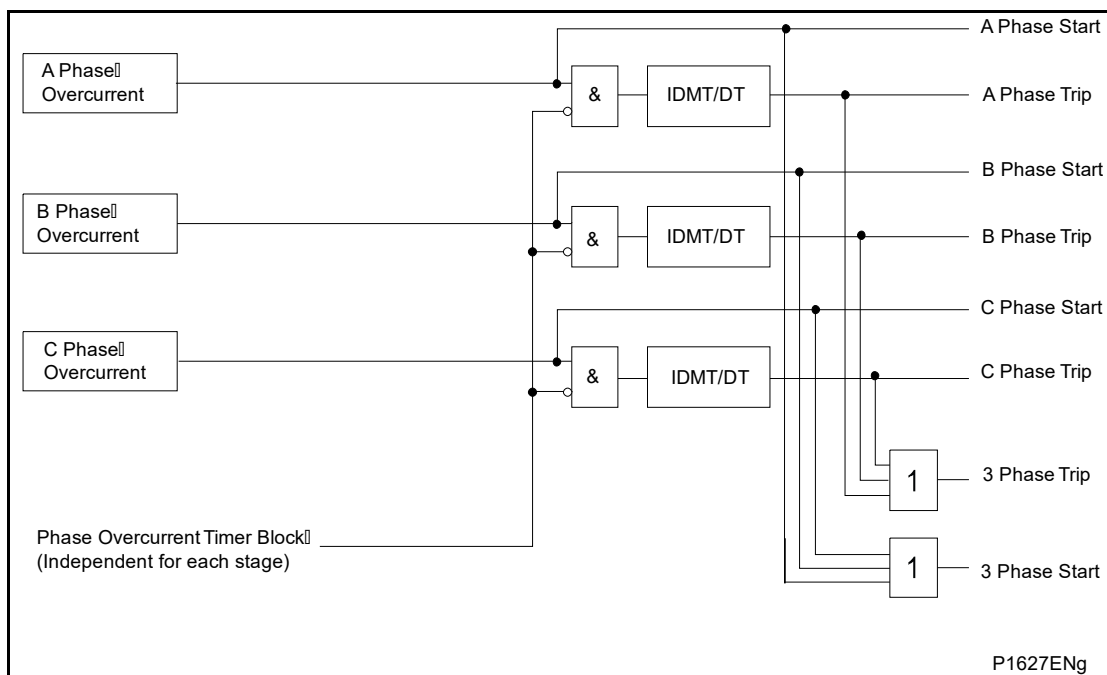
Figure 23: Non-directional overcurrent logic diagram

There is a timer block input for each stage which resets the overcurrent timers of all three phases if energized, taking account of the reset time delay if selected for the **I>1** and **I>2** stages.

> **Note:** The short circuit element acts even if the current input signals are saturated

A DDB (Digital Data Bus) signal is available to indicate the start and trip of each phase of the short circuit protection stages (Start I>1/2/3/4 A,B,C: DDB 242,243,244/DDB 253,254,255/DDB 343,344,345/DDB 354,355,356 Trip I>1/2/3/4 A,B,C: DDB 245,246,247/ DDB 256,257,258/DDB 346,347,348/DDB 357,358,359). In addition a three phase start and trip DDB signal is provided (Start I>1/2/3/4: DDB 241/252/342/353 Trip I>1/2/3/4: DDB237/ 248/338/349). Also DDBs are provided to block or to inhibit overcurrent function (Timer Block I>1/2/3/4: DDB 133/135/137/139 Inhibit I>1/2/3/4: DDB 134/136/138/140). These signals are used to operate the output relays, trigger the disturbance recorder and either block the associated timer or inhibit the overcurrent function as programmed into the programmable Scheme Logic (PSL). The state of the DDB signals can also be programmed to be viewed in the **Monitor Bit x** cells of the **COMMISSION TESTS** column in the relay.

1.6.3 User Programmable Overcurrent Protection

The overcurrent curve facility for the first and second stages of short circuit protection is user programmable. For information on how to program a customized overcurrent curve and send and extract curves to and from the relay, see document *P40-M&CR-SAS-UG-EN-n*.

1.7 Negative Sequence Overcurrent Protection (NPS) (46)

The P24x relays provide two independent stages of negative phase sequence overcurrent protection. Stage 1 has a current pick up setting **I2>1 Current Set**, and is time delayed in operation by the adjustable timer **I2>1 Time Delay**. Stage 2 has a current pick up setting **I2>2 Current Set** and is time delayed in operation by a Time Multiplier Setting **I2>2 TMS**.

The second stage element monitors the negative phase sequence current and trip according to an inverse characteristic as follows:

$$T = TMS \times (1.2/(I_2/I_{\mathsf{n}\, s})) \qquad \text{for } I_2/ I_s \leq 2$$

$$T = TMS*0.6 \qquad \text{for } I_2/\text{-}I_S > 2$$

A DDB (Digital Data Bus) signal indicates the trip of the negative phase sequence overcurrent protection stages (Trip I2>1/2: DDB274, 275). These signals are 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 the **Monitor Bit x** cells of the **COMMISSION TESTS** column in the relay.
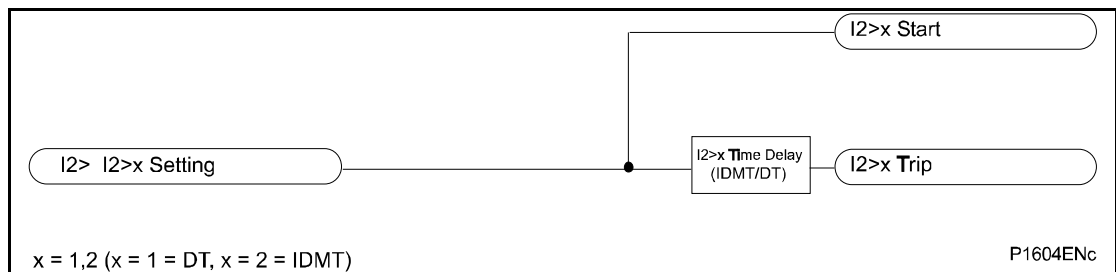
Figure 24: Negative sequence overcurrent logic diagram

1.8 Voltage Elements (27/59/59N)

1.8.1 Undervoltage Protection (27)

Both the under and overvoltage protection functions are in the **Volt Protection** menu. The undervoltage protection in the P24x relays has of two independent stages.

Stage 1 can be selected as IDMT, DT or Disabled, in the **V<1 Function** cell. Stage 2 is DT only and is enabled or disabled in the **V<2 Status** cell.

The IDMT characteristic available on the first stage is defined by the following formula:

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

Where:

K   =   Time multiplier setting

t   =   Operating time in seconds

M   =   Measured voltage/relay setting voltage (V< Voltage Set)

> **Note:** The Measured quantity of the undervoltage function can be chosen as either **Phase-Neutral** or Phase-Phase using the relay menu **V< 1/2 Measur't Mode**. The operation of the undervoltage function can be chosen as either **Three Phase** or **Any Phase** using the relay menu **V< 1/2 Operate Mode**.

Two stages provide both alarm and trip stages, where required. Alternatively, different time settings may be required depending on the severity of the voltage dip. For example, motor loads can withstand a small voltage depression for longer than if a major voltage excursion occured.

> **Note:** The Undervoltage protection is blocked if the Circuit breaker is open. Therefore the 52a breaker status (CB Closed 3ph - DDB 105) must be mapped in the PSL for the Undervoltage protection to operate. Also In the case of VT failure, the undervoltage function is deactivated.

The undervoltage fault protection starts are mapped internally to the ANY START DDB signal – DDB 369.

A DDB (Digital Data Bus) signal is available to indicate the trip of each of the undervoltage protection stages (Trip V<1/2 AB/BC/CA: DDB 276-278, 284-286 Trip V<1/2 A/B/C: DDB 383-385, 389-391). There is a three-phase trip DDB signal (Trip V<1/2: DDB 279, 287). Also there are DDBs to block or to inhibit undervoltage function (Timer Block V<1/2: DDB 129/131 Inhibit V<1/2: DDB 130/132). These signals are used to operate the output relays, trigger the disturbance recorder and either block the associated timer or inhibit the undervoltage function as programmed into the programmable Scheme Logic (PSL). The state of the DDB signals can also be programmed to be viewed in the **Monitor Bit x** cells of the **COMMISSION TESTS** column in the relay.
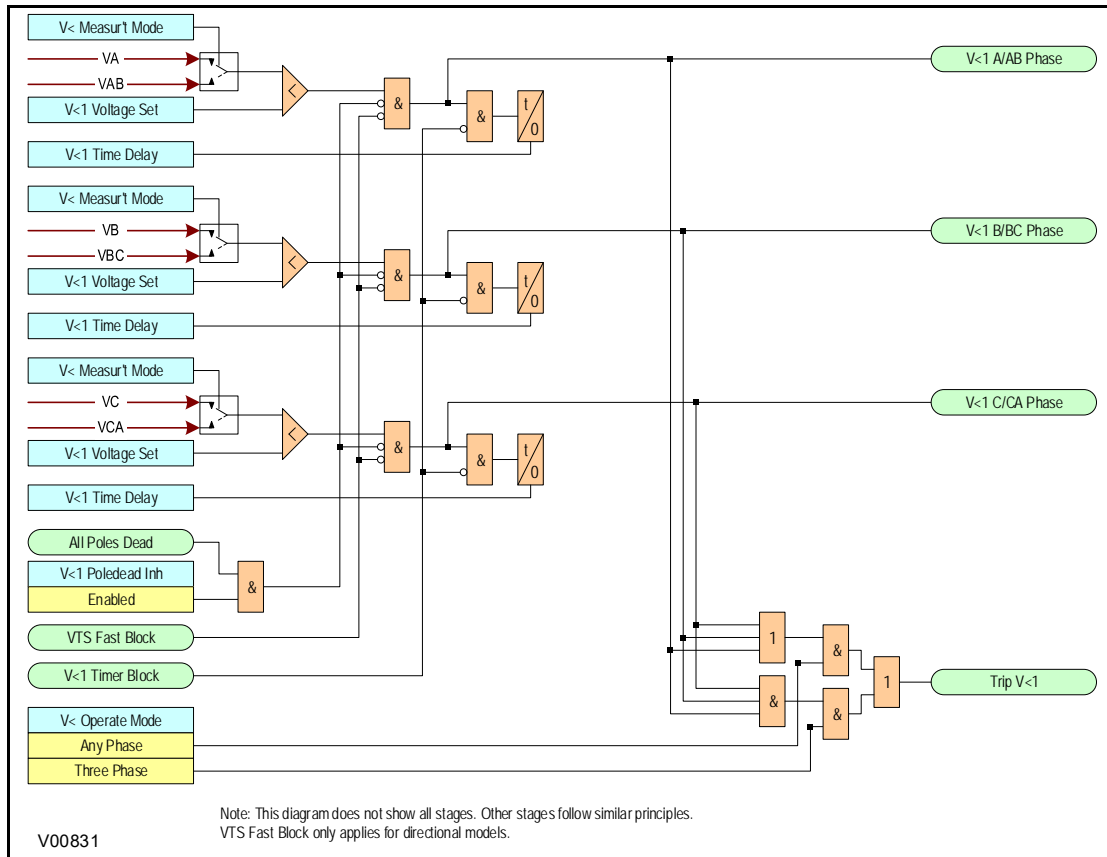
Figure 25: Undervoltage - single and three phase tripping mode (single stage)

1.8.2   Overvoltage Protection (59)

The overvoltage protection in the P24x relays has two independent stages.

Stage 1 and 2 can be selected as DT or Disabled in the **V>1/2 Status** cell.

> **Note:**   The measured quantity of the overvoltage function can be chosen as either **Phase-Neutral** or **Phase-Phase** via the relay menu **V< 1/2 Measur't Mode**. The operation of the overvoltage function can be chosen as either **Three Phase** or **Any Phase** via the relay menu **V< 1/2 Operate Mode.**

The overvoltage fault protection starts are mapped internally to the **ANY START** DDB signal – DDB 369.

A DDB (Digital Data Bus) signal indicates the trip of each of the overvoltage protection stages (Trip V>1/2 AB/BC/CA: DDB 280-282, 288-290 Trip V<1/2 A/B/C: DDB 386-388, 392-394). There is a three-phase trip DDB signal (Trip V>1/2: DDB 283, 291). These signals are 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 the **Monitor Bit x** cells of the **COMMISSION TESTS** column in the relay.
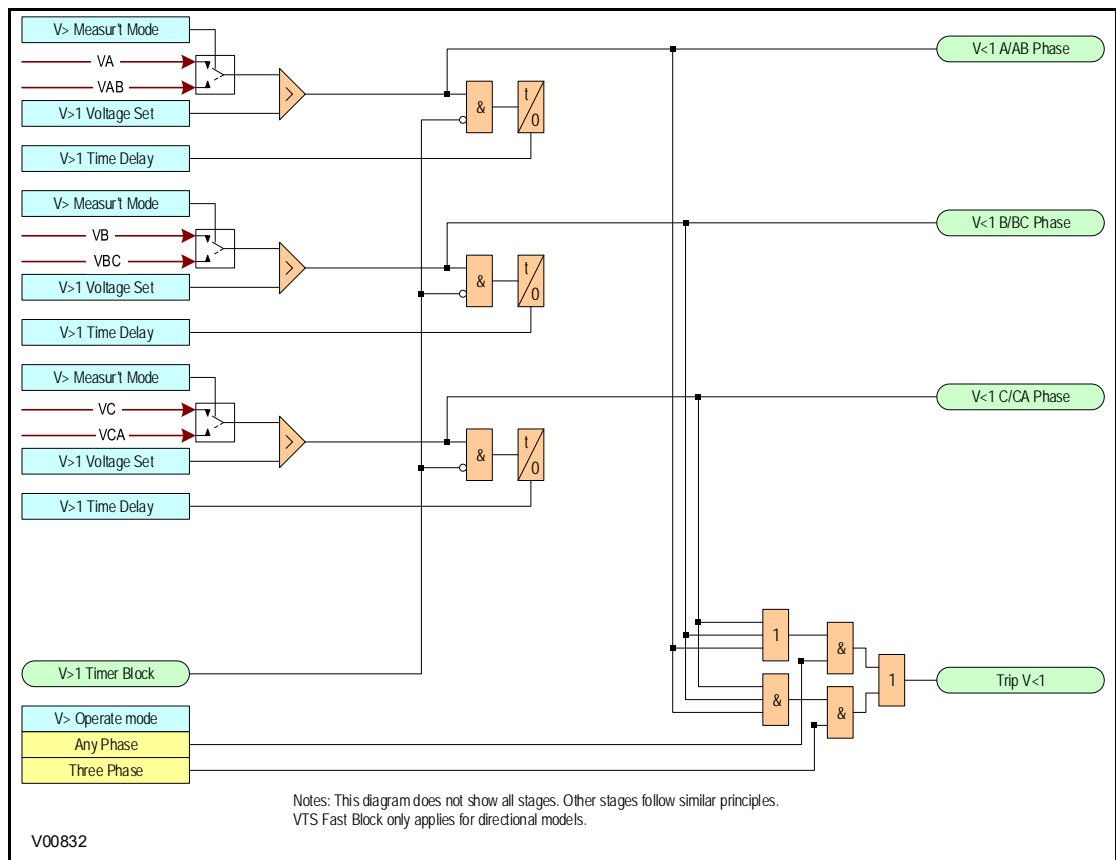

Figure 26: Overvoltage - single and three phase tripping mode (single stage)

1.8.3   Negative Sequence Overvoltage (47)

Negative sequence overvoltage protection functions can be found in the relay menu **NEG SEQ O/V**. Two definite time stages of negative sequence overvoltage are available in the P241, P242 and P243. The negative sequence overvoltage elements can be selected as DT or Disabled in the **V2>status** cell. In the case of VT failure, the V2> function is deactivated.

The negative sequence overvoltage fault protection starts are mapped internally to the ANY START DDB signal – DDB 369.

A DDB (Digital Data Bus) signal indicates the start and the trip of each of the negative sequence overvoltage protection stages (Start V2>1/2 DDB 395, 397 Trip V2>1/2 DDB 396, 398). Also DDBs are provided to block or to inhibit negative sequence overvoltage function (Timer Block V<1/2: DDB 125/127 Inhibit V<1/2: DDB 126/128). These signals are 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 the **Monitor Bit x** cells of the **COMMISSION TESTS** column in the relay.

1.8.4   3 Phase Voltage Checking (47/27)

The input voltage rotation and magnitude are monitored to determine both correct phase rotation and sufficient supply voltage, before allowing the motor to start.

For a good starting condition, the positive sequence voltage (V1) should be greater than the negative sequence voltage (V2). Also the phase voltages VA and VB and VC should be greater than the user settable threshold (V s).

The result of this function may be used into the programmable scheme logic to inhibit the start of the motor if the voltage is not sufficient (3Ph Volt Alarm: DDB177).

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

1.8.5   Residual Overvoltage / NVD Protection (59N)

The neutral voltage displacement protection function of the P24x relays consist of two stages of measured (VN>1, VN>2) neutral overvoltage protection. Stage one can be set as Definite Time (DT) or Inverse Definite Minimum Time (IDMT).

The operation of this function depends on the parameter **VT connecting mode**: If this is set to **2 VT + Residual**, the function uses the residual voltage measured from the connected residual voltage input.

Note: If VT connecting mode is selected as 3VT, then derived neutral voltage protection is available and if it is selected as 2VT+Residual then measured neutral voltage protection is available.
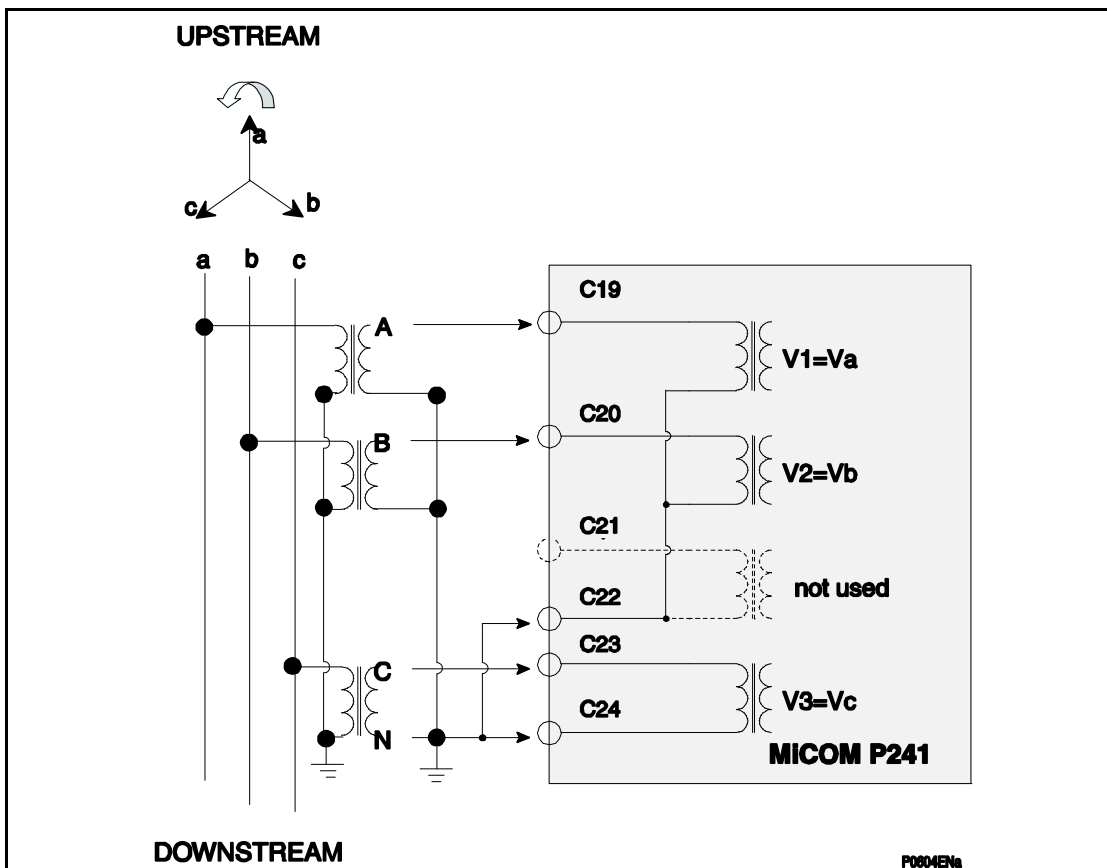
Figure 27: 3 VTS configuration

OP
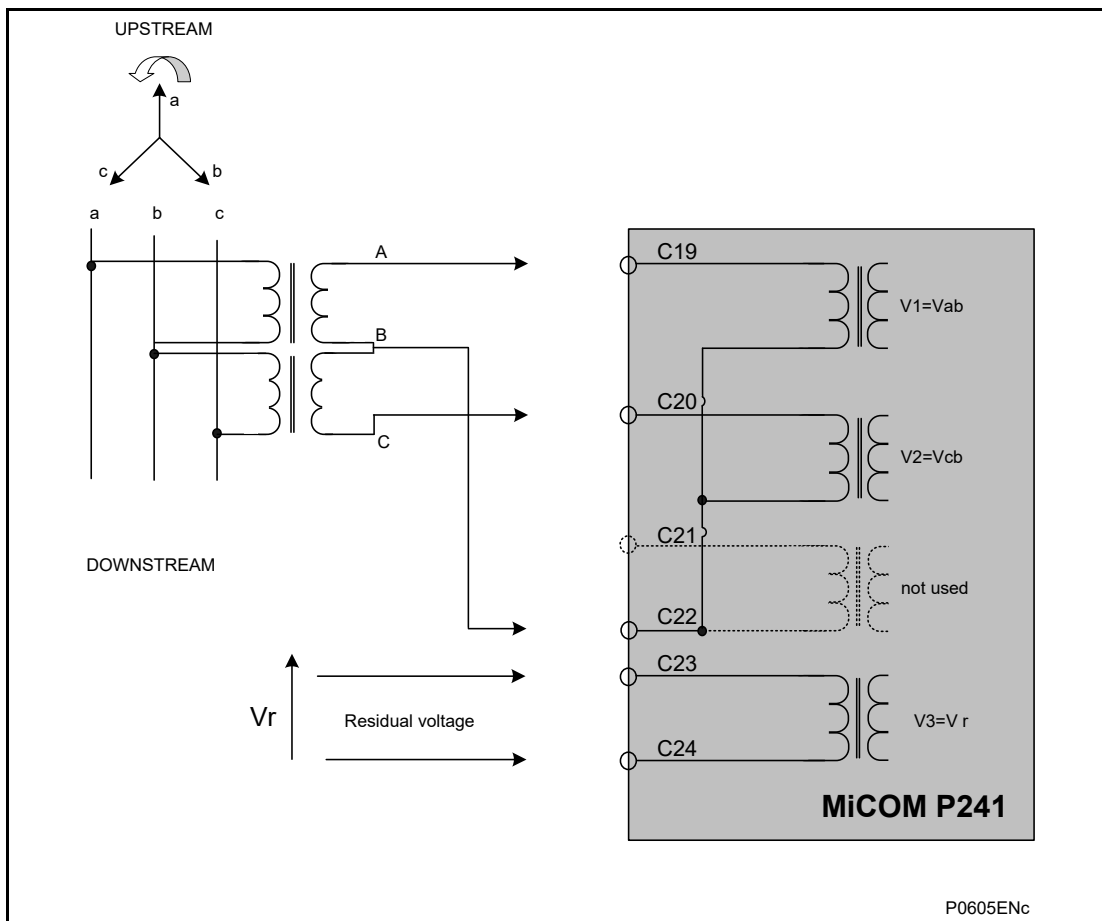
Figure 28: Alternative relay connections for residual overvoltage/NVD protection
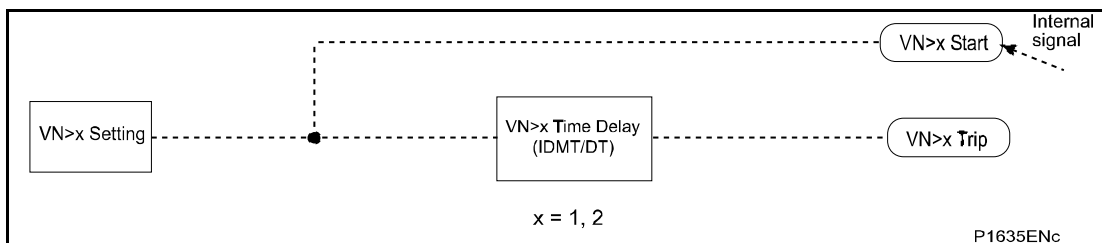
Figure 29: Residual overvoltage logic (single stage)

The residual overvoltage fault protection starts are mapped internally to the ANY START DDB signal – DDB 369.

A DDB (Digital Data Bus) signal is available to indicate the trip of each of the neutral voltage protection stages (Trip NVD VN>1/2: DDB 292, 293). These signals are 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 the **Monitor Bit x** cells of the **COMMISSION TESTS** column in the relay.

The IDMT characteristic available on the first stage is defined by the following formula:

$$t = K / (M – 1)$$

Where:

K   =   Time Multiplier Setting (**VN>1 TMS**)

t   =   Operating Time in Seconds

M   =   Measured Residual Voltage/Relay Setting Voltage (**VN>1 Voltage Set**)

1.8.6   Underfrequency Protection (81U)

The P24x relays include 2 stages of underfrequency. Stage 1 and 2 may be selected as DT or Disabled, in the **F<1/2 Status** cell.

The logic diagram for the underfrequency logic is as shown in Figure 30. Only a single stage is shown. The other stage is identical in functionality.

If the frequency is below the setting and the breaker is closed (52A input high), the DT timer is started.

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 get the information CB closed / CB open.

If the frequency cannot be determined (Frequency Not Found), the function is also blocked. A DDB (Digital Data Bus) signal indicates the trip of each of the underfrequency protection stages (Trip F<1/2: DDB 259, 260). These signals are 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 the **Monitor Bit x** cells of the **COMMISSION TESTS** column in the relay.
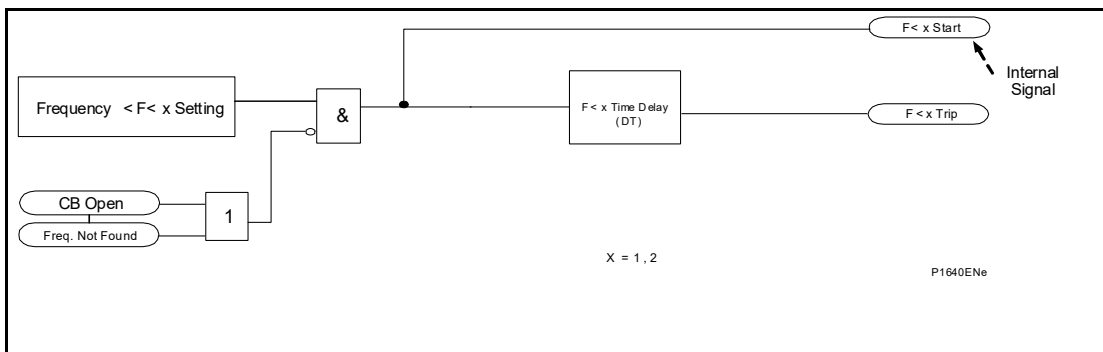
Figure 30: Underfrequency logic

1.8.7   Field Failure Protection Function (40)

The field failure protection of the P24x consists of two elements, an impedance element with two time delayed stages and a power factor alarm element, shown in Figure 31. The Field Failure protection impedance elements have an adjustable delay on reset (delayed drop off) timer. The elements operate from phase A current and phase A voltage signals measured by the Ia and Va inputs on the relay. The minimum phase current and voltage required for P241/2/3 field failure protection to work is 20 mA and 1 V (In = 1 A, Vn = 100/120 V) and 100 mA and 1 V (In = 5 A, Vn = 100/120 V).
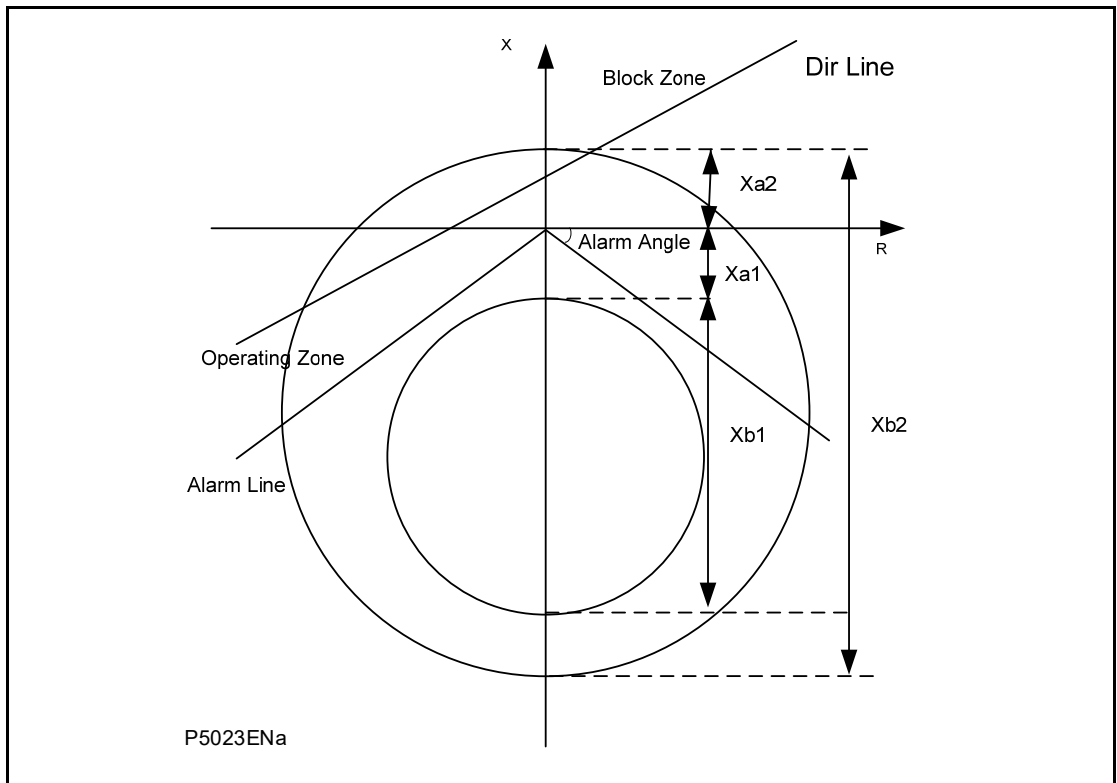
Figure 31: Field failure protection characteristics

DDB signals FFail Start 1/2: DDB 334, DDB 335, Field Fail1/2 Trip: DDB 336, DDB 337 indicate the start and tripping of each stage. A further DDB **Field Fail Alarm** signal is generated from the field failure alarm stage (DDB 234). The state of the DDB signals can be programmed to be viewed in **COMMISSION TESTS > Monitor Bit x**.

The field failure protection starts are mapped internally to the ANY START DDB signal – DDB 369.

The field failure protection is provided with a FFail Block signal (DDB 117) which may be used in the Programmable Scheme Logic to block the Field Failure protection.
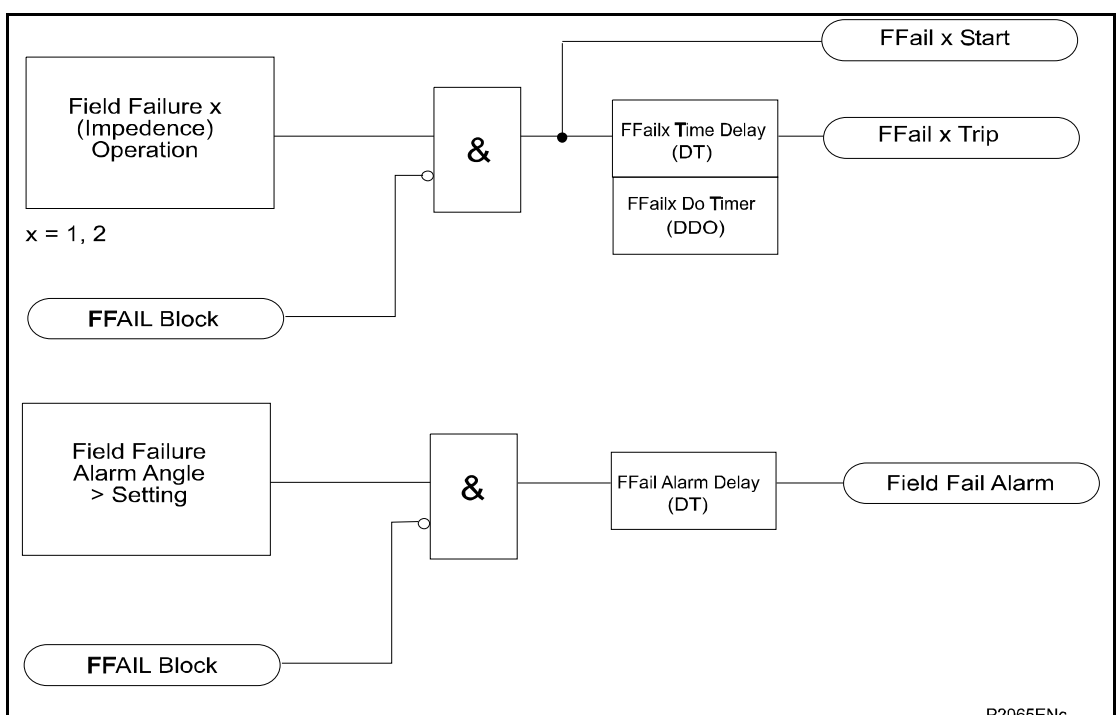
Figure 32: Field failure logic diagram

1.9 Power Elements (32R/37/55)

The standard power protection elements of the P24x relay calculate the three-phase active power based on the following formula using the current measured at the Ia, Ib, Ic inputs of the relay.

$$P = Va\ Ia\ \cos\phi_a + Vb\ Ib\ \cos\phi_b + Vc\ Ic\ \cos\phi_c$$

1.9.1 Reverse Power (32R)

When a power supply failure occurs on the feeder, synchronous motors become generators due to the inertia of their load and induction motors become induction 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 P24x 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: DDB 273 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.

OP
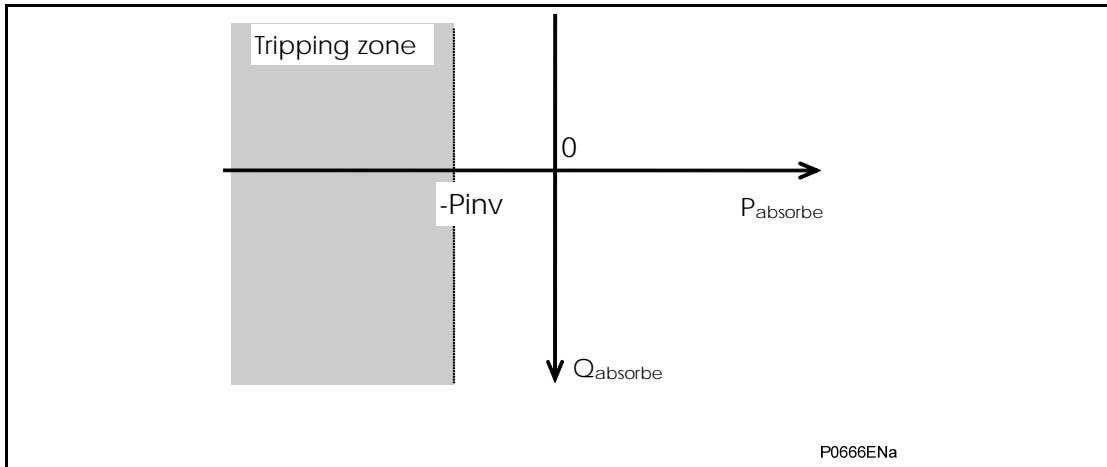
Figure 33: Reverse power protection
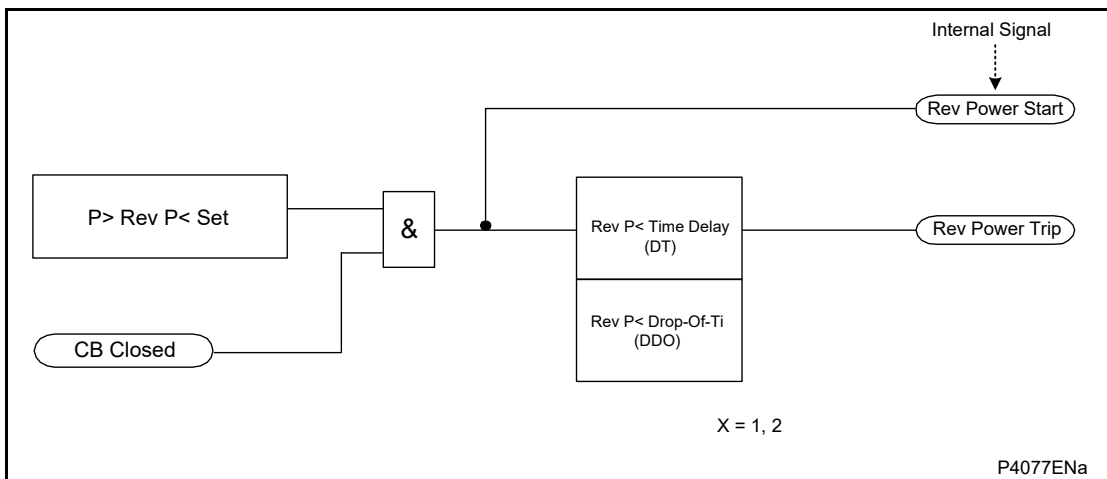
Figure 34: Reverse power logic diagram

1.9.2   Out of Step Protection (Under Power Factor) (55)

1.9.2.1   Principle
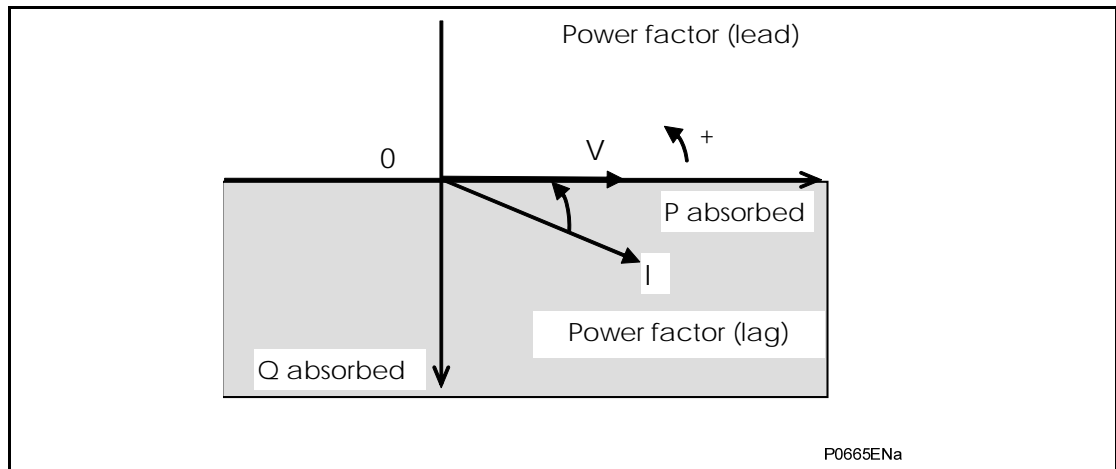
Figure 35: Out of step protection
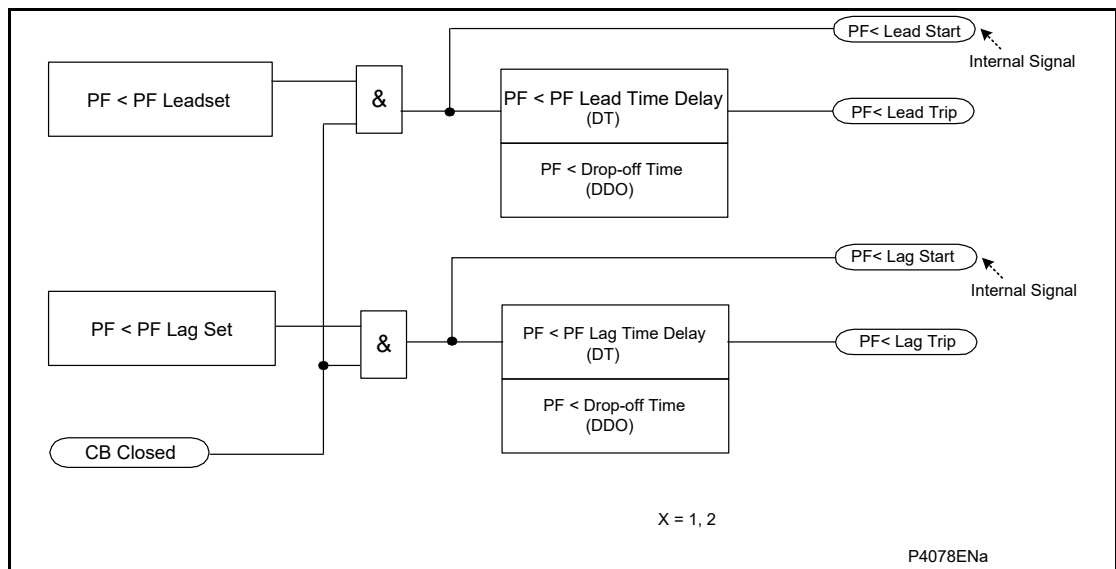
Figure 36: Out of step logic diagram

1.9.2.2   Feature Description

Power factor protection is provided for out-of-step protection of synchronous machines. The 3ph power factor is taken into account and this element is inhibited for 5 seconds to avoid tripping during the motor start.

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.

Trip PF<Lead/Lag: DDB 271, 272 indicates the trip of each of the out of step protection stages. These signals are 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**.

1.9.3   Loss of Load (Under Power) (37)

A trip is initiated if the minimum 3 phase active power is less than the programmed threshold for a settable time delay. Since rated power cannot be reached during starting, this feature can be disabled using a delay on drop off time during the motor start time.

A low forward power condition can only be established when the circuit breaker is closed and the active power calculated is above zero.

> **Note:** As the absolute power is used for this function, it can also be used to protect against the reverse power of some synchronous motors.

Trip P<1/2: DDB 269, 270 indicates the trip of each of the underpower protection stages. These signals are 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.
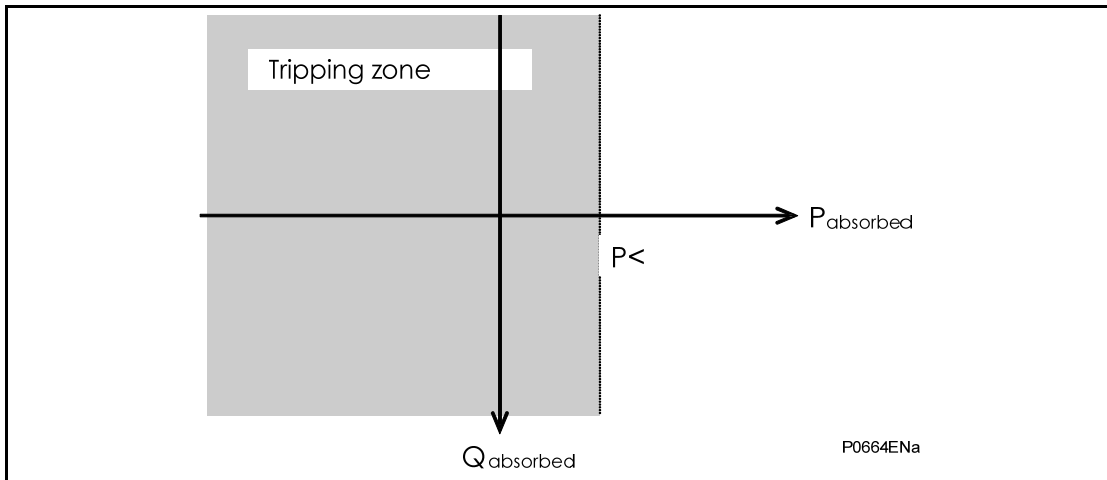
Figure 37: Loss of load (underpower) protection

Tripping conditions:

CB Closed,

P active < **P<1 Power Set' or 'P<2 Power Set**

> **Note:** If the active power is negative, this function may generate a trip.
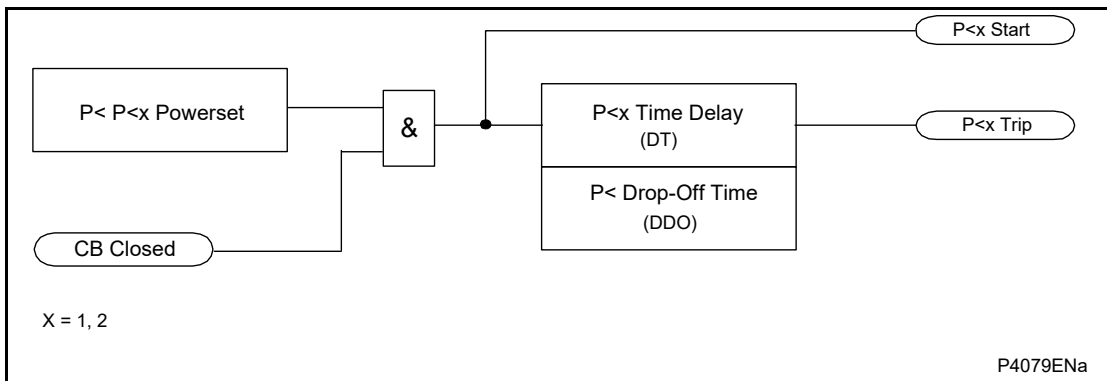
Figure 38: Loss of load logic diagram

1.10 Sensitive Earth Fault Protection Function (50N/51N/67N/32N/64N)

The P24x has two stages of sensitive earth fault protection. The first stage can be set as Inverse Definite Minimum Time (IDMT) and the second stage as Definite Time (DT) only. When directional earth fault protection is required, derive the operating current from either a core balanced CT or the residual connection of three-phase CTs at the terminals of the machine. The direction of the earth fault current for this element is determined with reference to the polarizing signal, the residual voltage. The polarizing signal is taken from the residual overvoltage/NVD protection input.

The element cannot operate unless the voltage exceeds the polarizing voltage threshold. This helps to restrain the element during phase/phase faults when transient CT saturation produces spill current in the residual connection of the phase CTs. No residual voltage is present during such non-earth fault conditions so the DEF element cannot operate. The element is therefore enabled only during genuine earth fault conditions when significant residual voltage is present. See Figure 39.
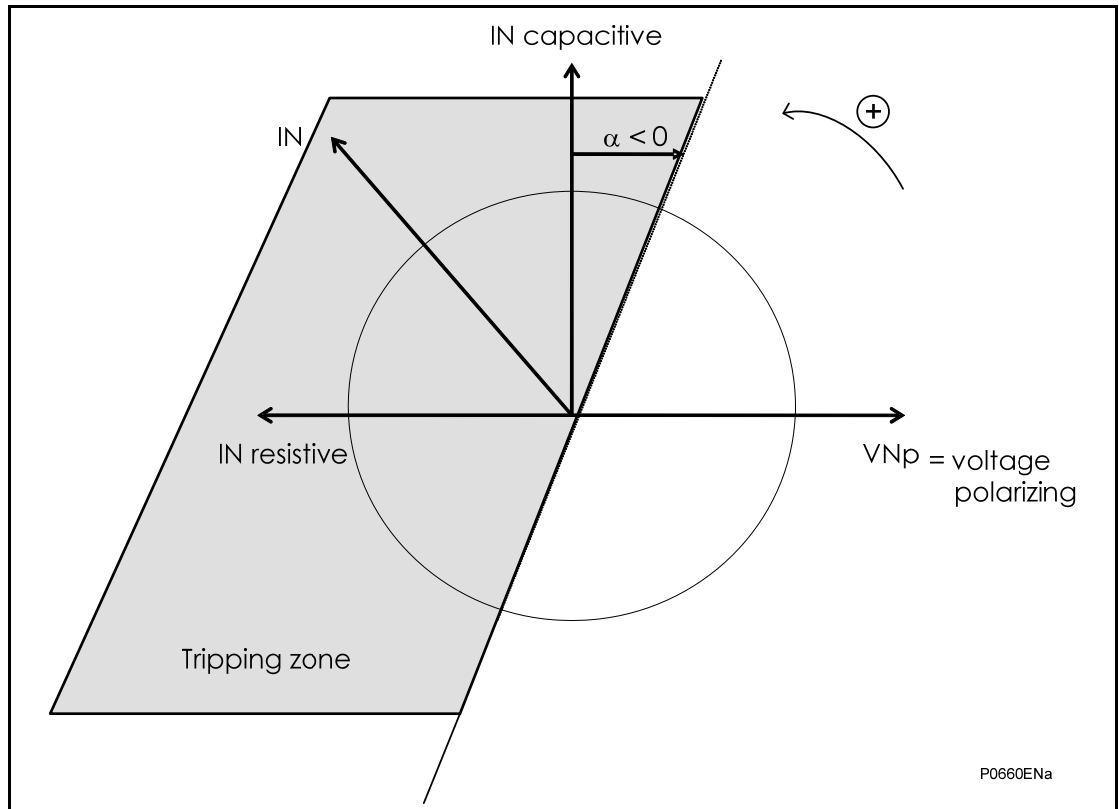
Figure 39: Directional sensitive earth fault characteristic

P0661ENa
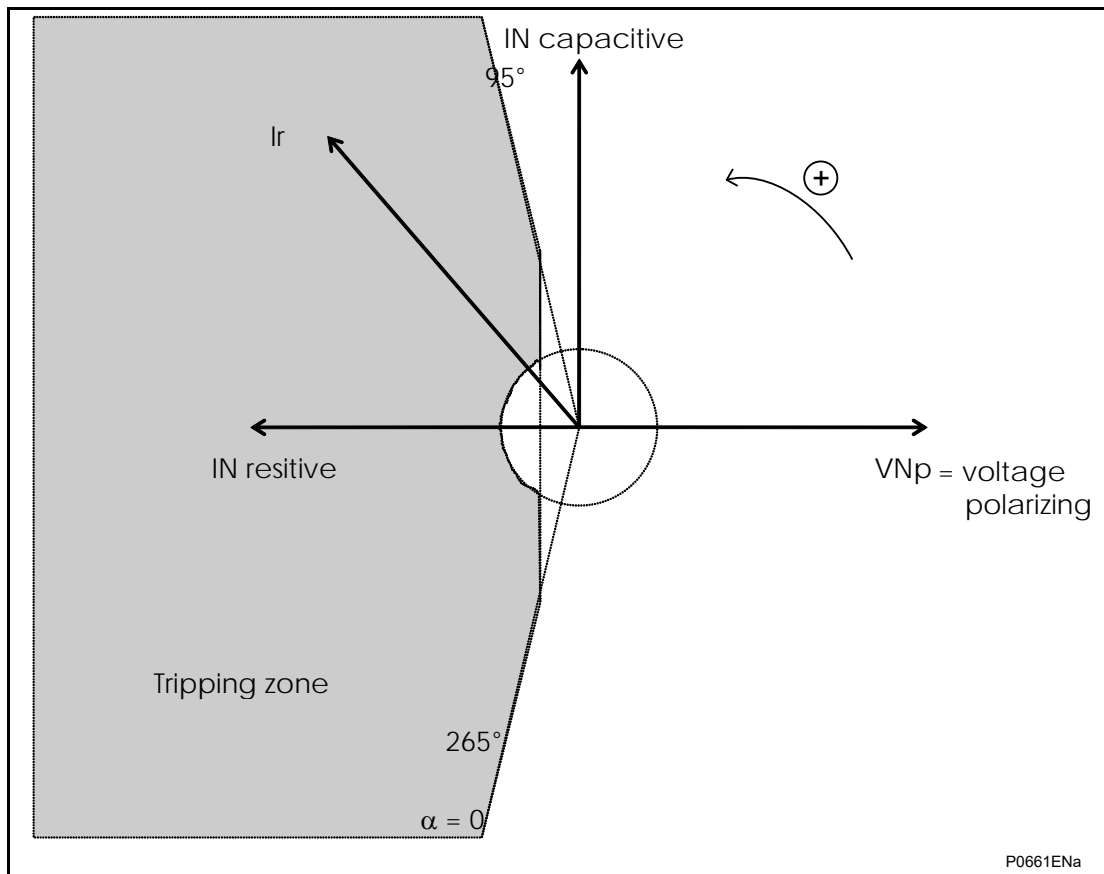
Figure 40: Wattmetric directional characteristic

The Wattmetric active power is given by the following formula:

$$PO = \frac{1}{3} \times V_n \times I_n \times Cos(\phi 0 - \alpha)$$

With: $\phi 0$ = phase shift between (In) and (-Vn)

α = Characteristic Angle

The tripping conditions are:

In = Residual current > **PO> Current Set**

Vn = residual voltage > **PO> Voltage Set**

$\phi 0$ = Arg(In) – Arg(Vn) ε [95° + α, 265° + α] where α = **PO> Char Angle**

$$PO = \frac{1}{3} \times V_n \times I_n \times Cos(\phi 0 - \alpha)$$ > K x (PO> Current Set)x(PO> Voltage Set)

Start ISEF>1/2: DDB 262, 264, Start PO>: DDB295, Trip ISEF>1/2: DDB261, 263 and Trip PO>: DDB294 indicate the start and trip of each of the sensitive earth fault and wattmetric earth fault protection stages. These signals are 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**.

OP
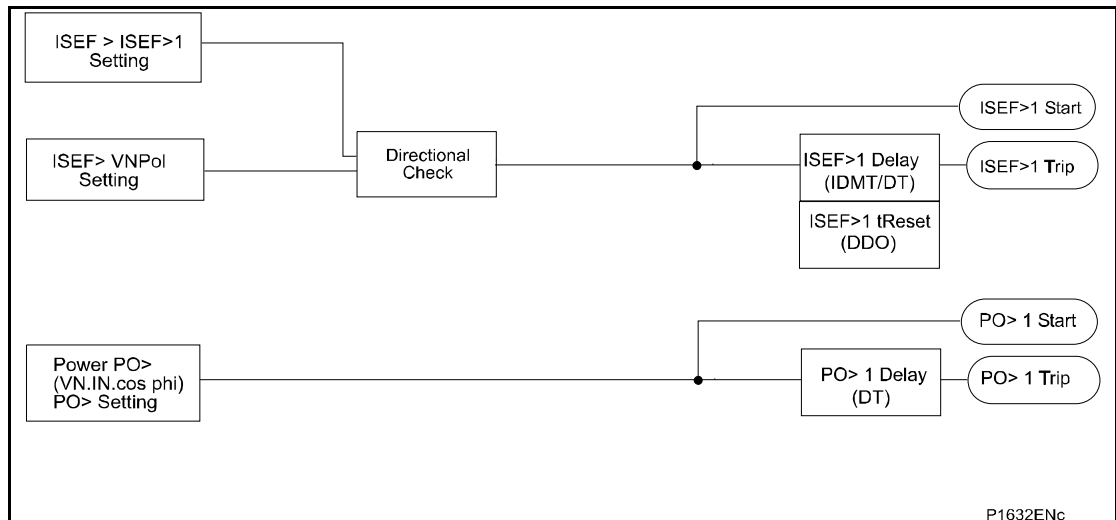
Figure 41: Directional SEF with VN polarization and wattmetric SEF

The standard directional sensitive earth fault element uses the following directional check criteria.

Directional forward

$$-90° < (\text{angle}(I_N) - \text{angle}(V_N + 180°) - RCA) < 90°$$

OP

1.10.1 User Programmable Sensitive Earth Fault Protection

There is a user programmable sensitive earth fault curve facility for the first stage of sensitive earth fault protection. For information on how to program a customized sensitive earth fault curve and send and extract curves to and from the relay see the P40-M&CR-SAS-UG-EN-n user guide.

1.10.2 Derived Earth Fault Protection Function (50N/51N)

The derived earth fault protection can be either non-directional or directional. To cover all types of applications schemes, the criteria used for the directional boundary can be determined in the following ways.

3 VTs connection scheme. This uses the same criteria as for sensitive earth fault protection (zero-sequence voltage polarization), with the same tripping conditions,

2 VTs connection scheme. In this case the criteria can be the angle between the negative phase sequence current and the negative phase sequence voltage.

The tripping conditions are indicated below:

I2 =	negative phase sequence current > **IN> I2pol Set**
V2 =	negative phase sequence voltage > **IN> V2pol Set**
$\phi0$ =	$\text{Arg}(I2) - \text{Arg}(V2) \in [95+\alpha, 265° + \alpha]$ where α = **IN> Char Angle**

Start IN>1/2: DDB 266, 268 and Trip IN>1/2: DDB 265, 267 indicate the start and trip of each of the derived earth fault protection stages. These signals are 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**.
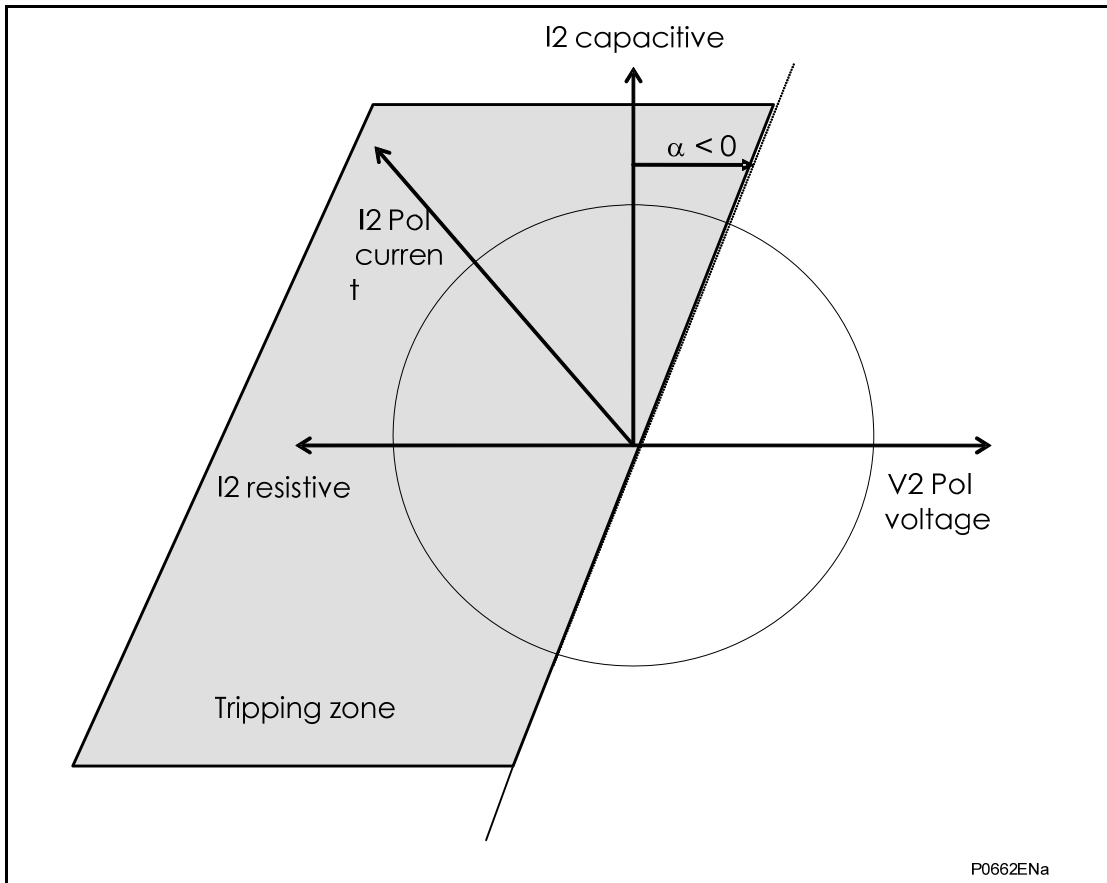
Figure 42: Derived earth fault characteristic
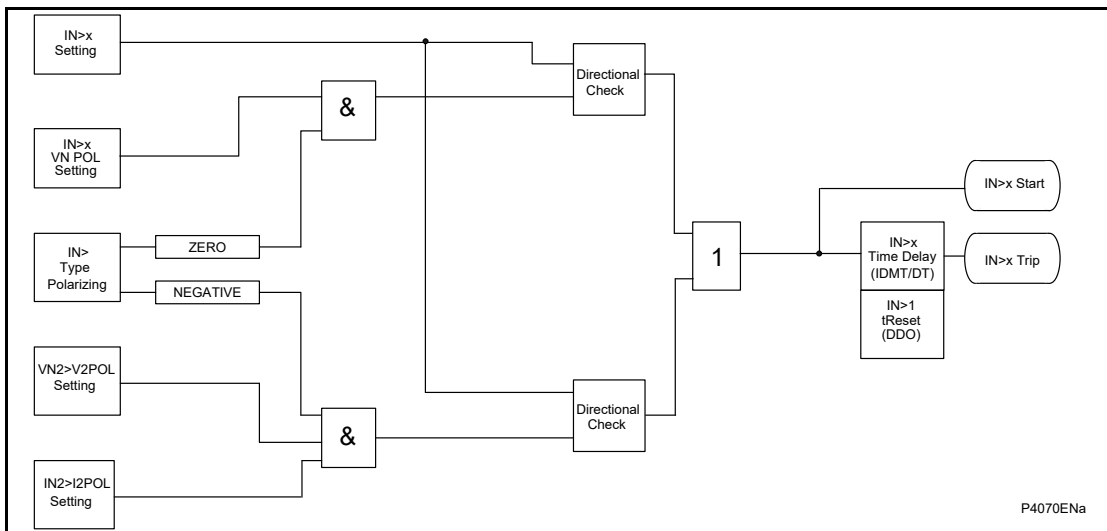
Figure 43: Derived directional earth fault logic diagram
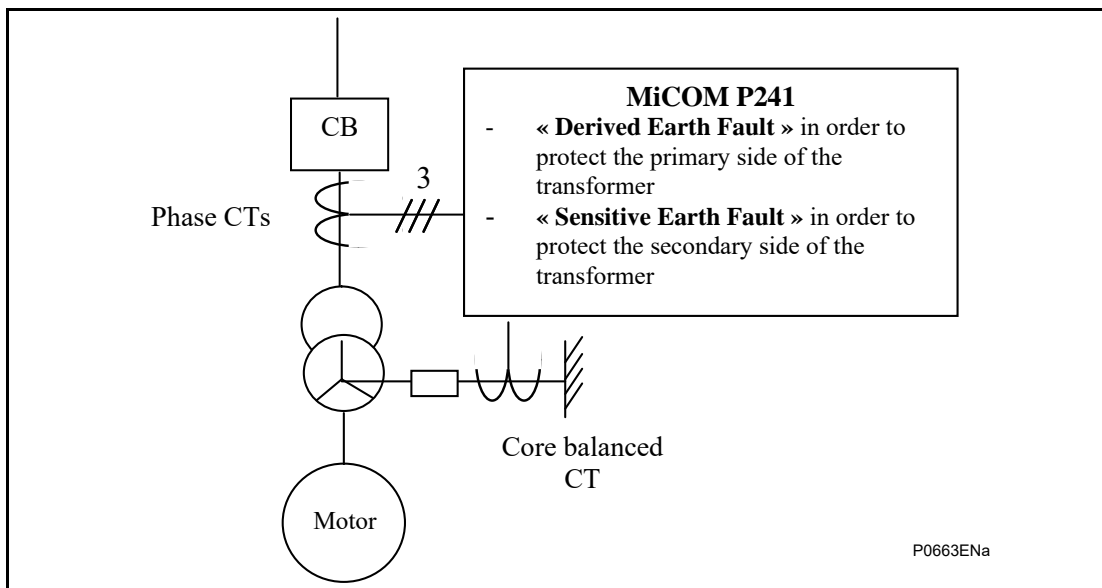
Figure 44: Typical derived earth fault application

1.10.3   User Programmable Derived Earth Fault Protection

There is a user programmable derived earth fault curve facility for the first stage of derived earth fault protection. For information on how to program a customized derived earth fault curve and send and extract curves to and from the relay see the P40-M&CR-SAS-UG-EN-n user guide.

1.10.4   Resistive Temperature Device (RTD) Thermal Protection

To protect against any general or localized overheating, the P241/2/3 relay has the ability to accept inputs from up to 10 - 3 wire Type A PT100, Ni100 or Ni120 resistive temperature sensing devices (RTD). These are connected as shown in Figure 45 below.
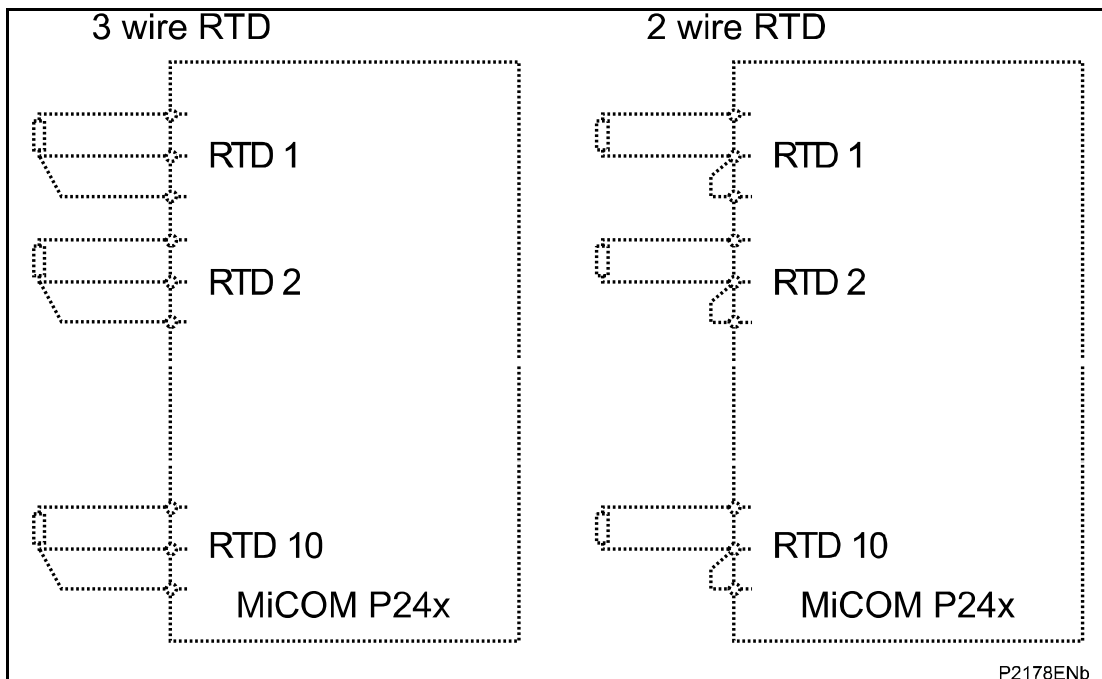
Figure 45: Connection for RTD thermal probes

These probes can be strategically placed in areas of the machine that are susceptible to overheating or heat damage.

The probes can also be used to measure the external ambient temperature. The ambient temperature can be used to adapt the thermal overload protection operating time. A main

and back-up RTD can be selected in the settings for the external ambient temperature. The units of temperature measurement Celsius or Fahrenheit can also be selected.

- Typically a PT100/Ni100/Ni120 RTD probe can measure temperature within the range –0° to +400°C. The resistance of these devices changes with temperature, at 0°C a PT100 has a resistance of 100 Ω.

Should the measured resistance of an RTD be outside of the permitted range, an RTD failure alarm is raised, indicating an open or short circuit RTD input. These conditions are signalled by the DDB signals **RTD Open Cct**, **RTD Short Cct** and **RTD Data Error**. These DDB statuses are also shown in the **MEASUREMENTS 3** column.

DDB signals are also available to indicate the alarm and trip of the each and any RTD. You can set the monitor bit cells in the **COMMISSION TESTS** column to view the statuses of these signals.

See the Installation chapter (*P24x/EN IN*), for recommendations on RTD connections and cables.
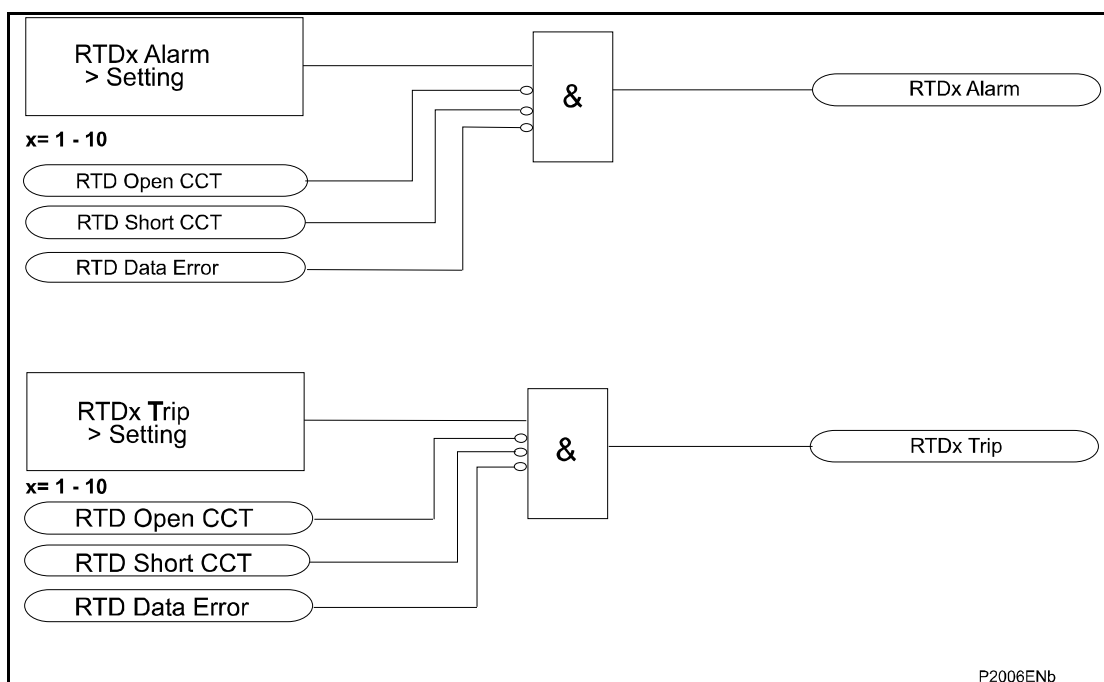
Figure 46: RTD logic diagram

1.10.4.1 Principle of the RTD Connection

An RTD connection is used to compensate the influence of resistors r1 and r2.
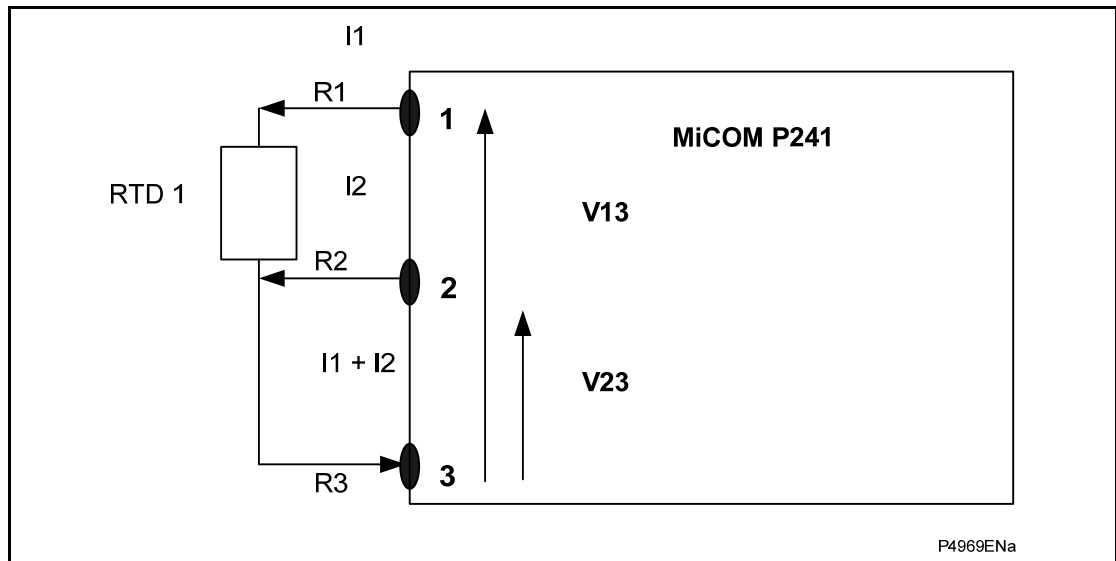
Figure 47: RTD connection

The MICOM P241 injects a constant current from connections 1 and 2, therefore i1 = i2

$$V13 = r1 * I1 + R_{rtd} * I1 + r3 * (I1 + I2),$$

$$V23 = r2 * I2 + r3 * (I1 + I2),$$

$$V13 - V23 = r1 * I1 + Rrtd * I1 + r3 * I1 + r3 * I2 - r2 * I2 - r3 * I1 - r3 * i2$$

Assuming the three cables have the same length and are of the same material, resisitors r1, r2 and r3 are the same.

$$V13 - V23 = R_{rtd} * I1 = \text{Voltage at the RTD terminals.}$$

1.11   Circuit Breaker Failure Protection (50BF)

1.11.1   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 resets when the circuit breaker opens to isolate the fault. If breaker opening is not detected, **CB Fail 1 Timer** times out and closes an output contact assigned to breaker fail (Trip CBF1: DDB 319, using PSL). This contact is used to backtrip upstream switchgear, generally tripping all infeeds connected to the same busbar section.

- A retripping scheme, plus delayed backtripping. **CB Fail 1 Timer** is used to route a trip to a second trip circuit of the same circuit breaker. This requires duplicated circuit breaker trip coils and is known as retripping. If retripping fails to open the circuit breaker, there is an additional time delay and a backtrip can be issued. The backtrip uses **CB Fail 2 Timer**, which is also started at the instant of the initial protection element trip (Trip CBF2: DDB 320).

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.

The CBF can be reset from a breaker open indication or from a protection reset. In these cases resetting is only allowed provided the undercurrent elements have also 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

Initiation (menu selectable)	CB fail timer reset mechanism
Non-current based protection (e.g. 27/59N/81U/32R..)	Three options are available: ● All I< elements operate ● Protection element reset AND all I< elements operate ● CB open AND all I< operate
External protection	Three options are available: ● All I< elements operate ● Protection element reset AND all I< elements operate ● CB open AND all I< operate

Table 3: CBF resetting options
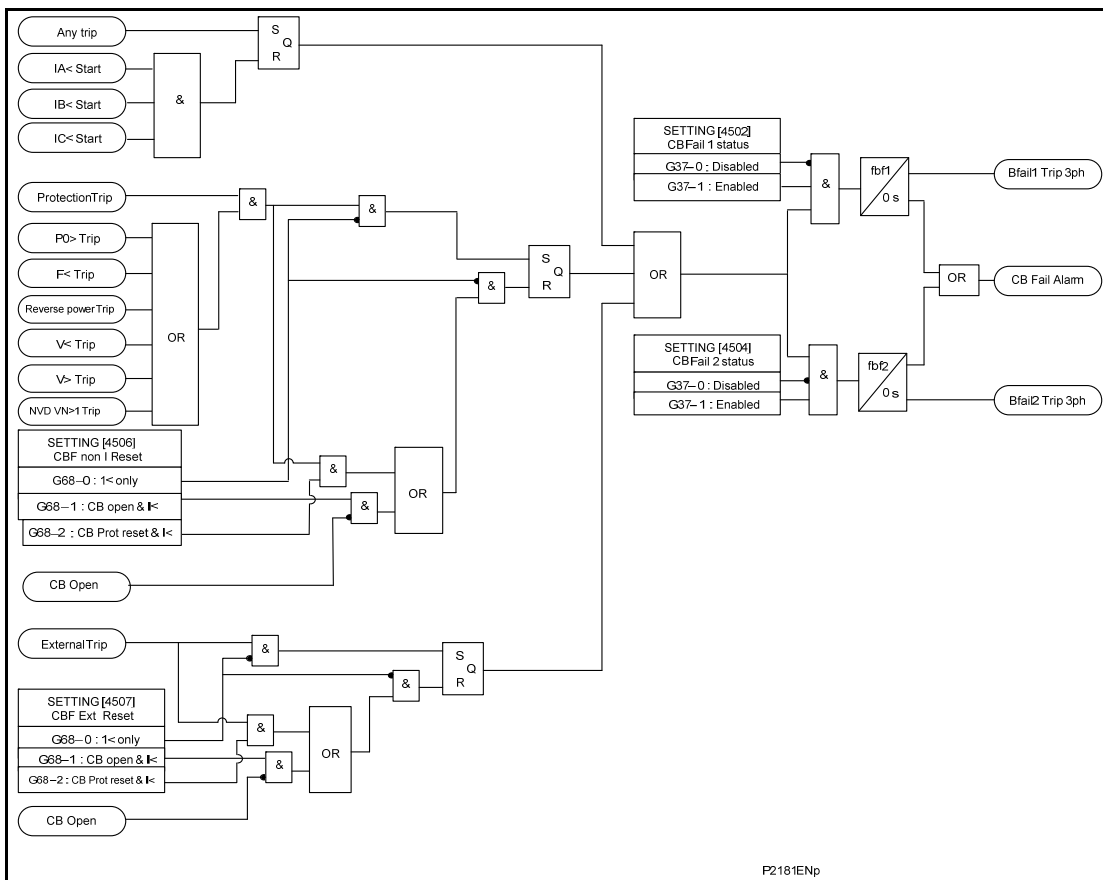
Figure 48: CB fail logic

1.11.2   Current Loop Input Implementation

There are four analog (or current loop) inputs for transducers with ranges of 0 - 1 mA, 0 – 10 mA, 0 - 20 mA or 4 - 20 mA. The analog inputs can be used for various transducers such as vibration monitors, tachometers and pressure transducers. Associated with each current loop input are units (A, V, Hz, W, Var, VA, °C, F, %, s). There are also two protection stages, one for alarm and one for trip. Each current loop input can be individually enabled or disabled and each input has a definite time delay alarm and trip stage. There is also a delay on drop off time which applies to all inputs.

The Alarm and Trip stages operate when the input current is above the input value. The sample interval is nominally 50 ms per input.

The relationship between the transducer measuring range and the current input range is linear. The maximum and minimum settings correspond to the limits of the current input range. This relationship is shown below. The diagram also shows the relationship between the measured current and the analog to digital conversion (ADC) count. The hardware

design allows for over-ranging, with the maximum ADC count (4095 for a 12-bit ADC) corresponding to 1.0836 mA for the 0 - 1 mA range, and 22.7556 mA for the 0 - 10 mA, 0 - 20 mA and 4 - 20 mA ranges. The device will therefore continue to measure and display values beyond the maximum setting, within its numbering capability.
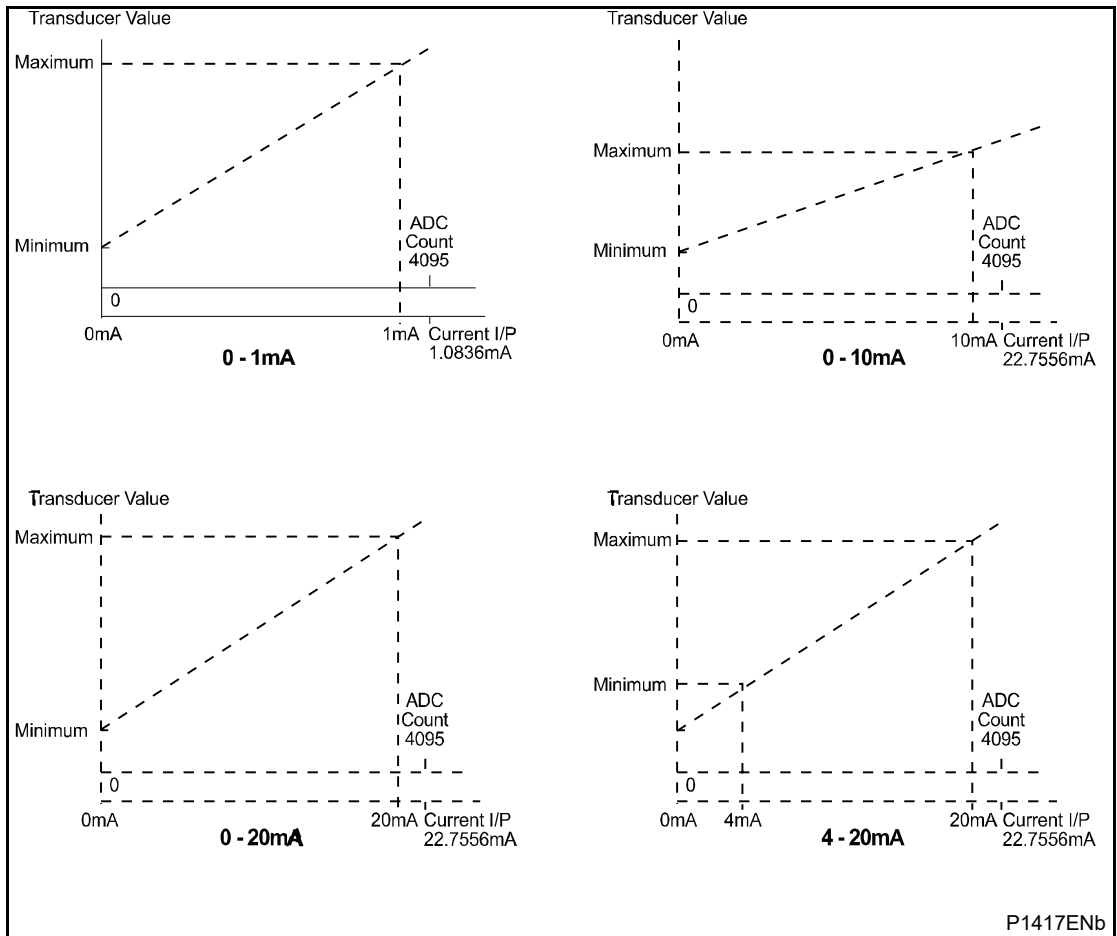
Figure 49: Relationship between the transducer measuring quantity and the current input range

> **Note:**   If the maximum is set less than the minimum, the slopes of the graphs will be negative. This is because the mathematical relationship remains the same irrespective of how maximum and minimum are set. For example, for 0 - 1 mA range, maximum always corresponds to 1 mA and minimum corresponds to 0 mA.

Analog Inp1/2/3/4 Alarm (DDB 211-214) and Trip Analog Inp1/2/3/4 (DDB 321-324) indicate operation of the alarm and trip stages of the each current loop inputs.

The **Monitor Bit** cells of the **COMMISSIONTESTS** column can be configured to show the state of the DDB signals.

The current loop input starts are mapped internally to the Any Start DDB signal (DDB 369).
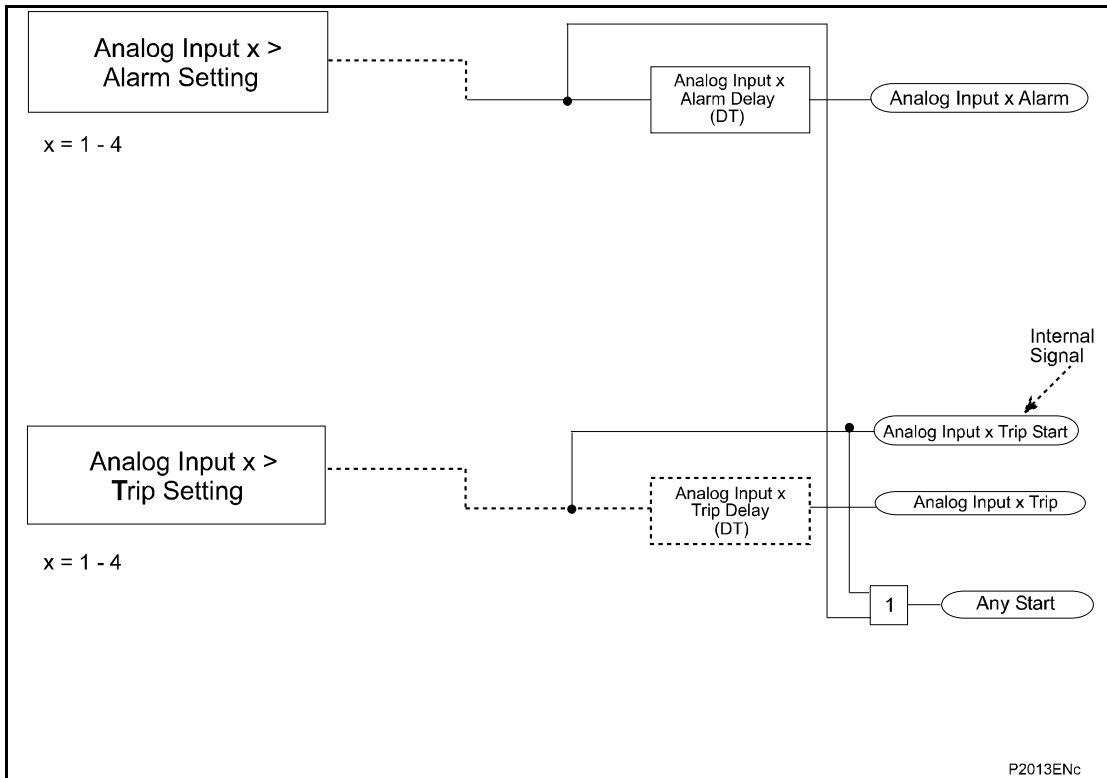
Figure 50: Analog (current loop) input logic diagram

1.11.3 Current Loop Output Implementation

Four analog current outputs are provided with ranges of 0 - 1 mA, 0 - 10 mA, 0 - 20 mA or 4 - 20 mA, which can alleviate the need for separate transducers. These may be used to feed moving coil ammeters for measuring analog quantities, or to feed into a SCADA using an existing analog remote terminal unit (RTU).

The current loop input conversion task runs every 50 ms and the refresh interval for the output measurements is nominally 200 ms.

You can set the measuring range for each analog output. The range limits are defined by the **Maximum** and **Minimum** settings. This allows you to zoom in and monitor a restricted range of the measurements with the desired resolution. For voltage, current and power quantities, these settings are set in primary quantities.

The output current of each analog output is linearly scaled to its range limits, as defined by the Maximum and Minimum settings, as shown below:
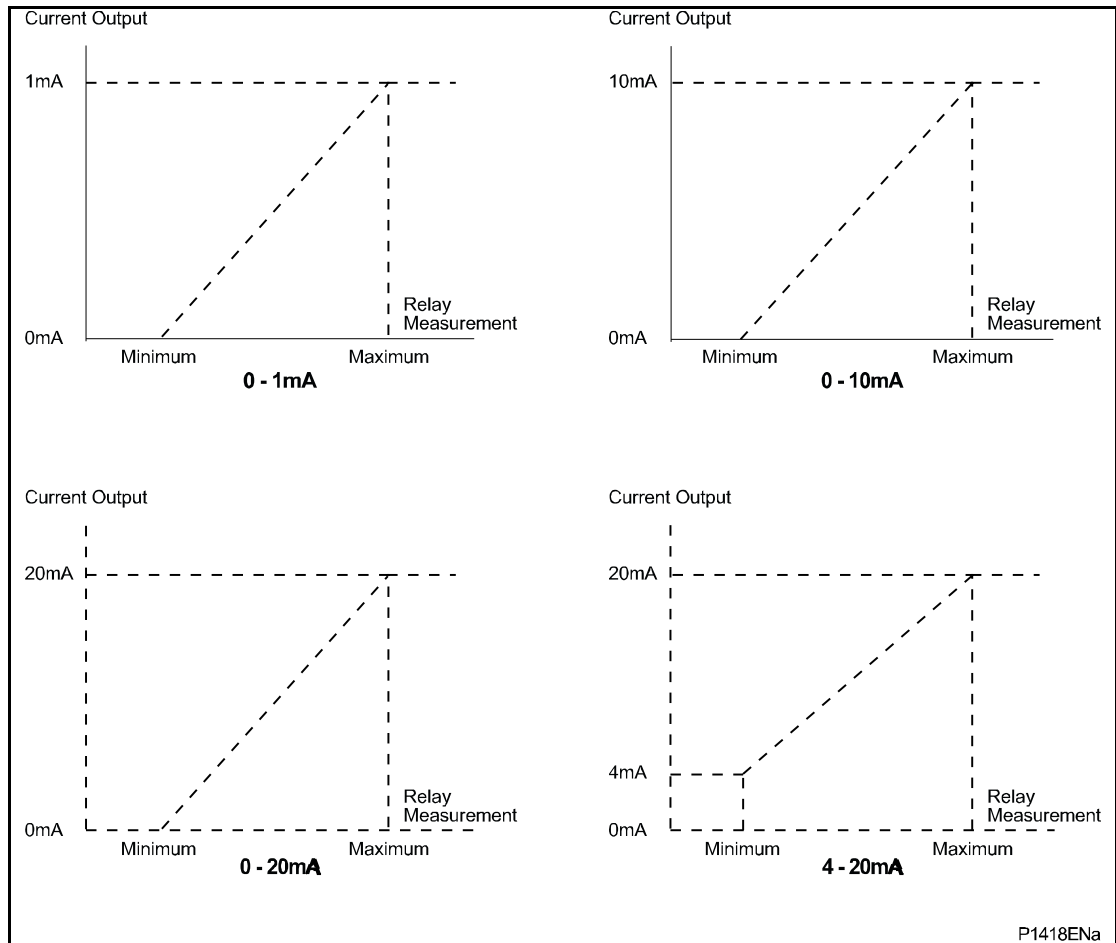
Figure 51: Relationship between the current output and the relay measurement

> **Note:**   If the Maximum is set less than the Minimum, the slopes of the graphs will
> be negative. This is because the mathematical relationship remains the
> same irrespective of how Maximum and Minimum are set. For example, for
> 0 - 1 mA range, Maximum always corresponds to 1 mA and Minimum
> corresponds to 0 mA.

The transducers inside the device are of the current output type. This means that the correct value of output is always maintained over the load range specified. The range of load resistance varies a great deal, depending on the design and the value of output current. Transducers with a full-scale output of 10 mA will normally feed any load up to a value of 1000 ohms (compliance voltage 10V). This equates to an approximate cable length of 15 km.

We recommend using a screened cable, earthed at one end. This helps reduce interference on the output current signal. The table below shows typical cable impedances per kilometer for common cables. The compliance voltage dictates the maximum load that a transducer output can feed. Therefore, the 20 mA output will be restricted to a maximum load of 500 ohms.

Cable	1/0.6 mm	1/0.85 mm	1/1.38 mm
CSA (mm^2)	0.28	0.57	1.50
R (Ω/km)	65.52	32.65	12.38

Table 4: Impedance per kilometre values of typical cables

You can connect the receiving equipment at any point in the output loop and install additional equipment later.

You do not need to adjust the transducer output, providing the compliance voltage is not exceeded.

Where you use the output current range for control purposes, you may wish to fit appropriately rated diodes, or Zener diodes, across the terminals of each of the units in the series loop. This will guard against the possibility of their internal circuitry becoming open circuit. In this way, a faulty unit in the loop does not cause all the indications to disappear, because the constant current nature of the transducer output simply raises the voltage and continues to force the correct output signal around the loop.

Current loop output parameter	Abbreviation	Units	Range	Step	Default min.	Default max.
Current Magnitude	IA Magnitude IB Magnitude IC Magnitude IN Magnitude	A	0 to 100 k	1	0	100
RMS Phase Currents	IA RMS IB RMS IC RMS IN RMS	A	0 to 100 k	1	0	100
P-N voltage Magnitude	VAN Magnitude VBN Magnitude VCN Magnitude VN Magnitude	V	0 to 20 k	1	0	100
P-N voltage RMS	VAN RMS VBN RMS VCN RMS VN RMS	V	0 to 20 k	1	0	100
P-P voltage Magnitude	VAB Magnitude VBC Magnitude VCA Magnitude	V	0 to 20 k	1	0	100
RMS Phase-Phase Voltages	VAB RMS Magnitude VBC RMS Magnitude VCA RMS Magnitude	V	0 to 20 k	1	0	100
Frequency	Frequency	Hz	0 to 100	1	0	100
3 Ph Active Power	Three-Phase Watts	W	-10 M to 30 M	1	0	100
3 Ph Reactive Power	Three-Phase Vars	Var	-10 M to 30 M	1	0	100
3 Ph Apparent Power	Three-Phase VA	VA	-10 M to 30 M	1	0	100
3 Ph Power Factor	3Ph Power Factor		-1 to 1	0.01	0	1
RTD Temperatures	RTD 1 RTD 2 RTD 3 RTD 4 RTD 5 RTD 6 RTD 7 RTD 8 RTD 9 RTD 10	°C	-40 to 400	1	0	100.0
Number of hottest RTD	Nb Hottest RTD		1-10	1	0	10
Thermal State	Thermal State	%	0 to 150	0.1	0	100

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Current loop output parameter	Abbreviation	Units	Range	Step	Default min.	Default max.
Time to Thermal Trip	Time to Thermal Trip	Sec	0-300	0.1	0	100
Time to Next Start	Time to Next Start	Sec	0-300	0.1	0	100

Table 5: Current loop output parameters

Note 1:   The current loop (analog) outputs are refreshed every 200 ms.

Note 2:   The polarity of Watts, Vars and power factor is affected by the Measurements Mode setting.

Note 3:   These settings are for nominal 1 A and 100/120 V versions only. For other nominal versions they need to be multiplied accordingly.

Note 4:   All current loop (analog) output measurements are in primary values.

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2   OPERATION OF NON PROTECTION FUNCTIONS

2.1   Voltage Transformer Supervision

The voltage transformer supervision (VTS) feature is used to detect failure of the AC voltage inputs to the relay. This may be caused by voltage transformer faults, overloading, or faults on the interconnecting wiring to relays, which usually results in one or more voltage transformer fuses blowing.

If there is a failure of the AC voltage input, the device 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 on line energization

2.1.1   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.

Negative sequence VTS element:

The negative sequence thresholds used by the element are $V2 = 10$ V and $I2 = 0.05$ to 0.5 In settable (defaulted to 0.05 In).

2.1.2   Loss of all Three-Phase Voltages Under Load Conditions

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.

Use **Threshold 3P** to set the phase voltage level detector from 10 V to 70 V (default 30 V).

Use **Delta I>** to set the sensitivity of the superimposed current elements from 0.1 In to 5 In (default 0.1 In).

2.1.3   Absence of Three-Phase Voltages On Line Energization

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 an overcurrent level detector (**VTS I> Inhibit and VTS I2 & I0 > 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 energization (load, line charging current, transformer inrush current if applicable), but below the level of current produced by a close up three-phase fault.

If the line is then closed where a three-phase VT failure is present, the overcurrent detector will not operate and a VTS block is applied. Closing onto a three-phase fault results in operation of the overcurrent detector and prevents a VTS block being applied.
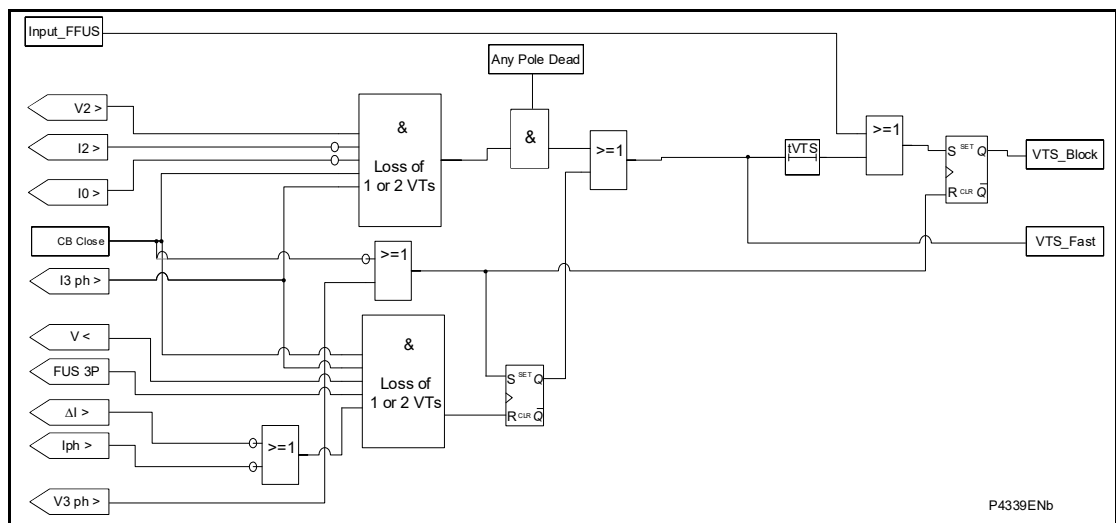
Figure 52: VT supervision logic diagram

VTS Fast is given by the following equation.

(V2> And /I2> And /I0 And CB_Close And I3ph>) Or (FUS3P And V< And CB_Close And I3ph> And (/ΔI> Or /Iph>)

The following dedicated level detectors are required to drive the VTS logic.

- I3Ph> This level detector operates in less than 20 ms and the setting should be greater than the load current. This setting is specified as the VTS current threshold. These level detectors pick-up at 100% of the setting and drop-off at 95% of the setting.

- I2> This level detector operates on negative sequence current and has a user setting. This level detector picks-up at 100% of the setting and drops-off at 95% of the setting.

- ΔI> This level detector operates on superimposed phase currents and is settable.

- V3Ph> This level detector operates on phase voltages and is settable.

- V2> This level detector operates on negative sequence voltage. It has a fixed setting of 10 V with pick-up at 100% of the setting and drop-off at 95% of the setting.

2.1.3.1   Inputs

Signal name	Description
I3Ph>	Phase current levels (Fourier magnitudes)
I2>	I2 level (Fourier magnitude).
ΔI	Phase current samples (current and one cycle previous)

Signal name	Description
V3Ph>	Phase voltage signals (Fourier magnitudes)
V2>	Negative sequence voltage (Fourier magnitude)
Input FFUs	To remotely initiate the VTS blocking using an opto
FUS3P	Detect 3P setting which allows the fuse failure 3 poles detection

Table 6: VTS inputs level detector settings outputs

Signal name	Description
VTS Fast	Internal fuse failure
VTS Block	Alarm indication, internal fuse failure confirmed at the end of VTS timer

Table 7: VTS outputs

2.1.4   Operation

The relay may respond as follows to an operation of any VTS element:

- Forced blocking of voltage dependent protection elements (DDB 364 VT Supervision, Fast Block and DDB 363 VT, confirmed block)

- VTS provides alarm indication (DDB 363 VT, confirmed block). The confirmed fuse failure VTS_Block blocks the following protection functions:

  - Undervoltage
  - Positive sequence undervoltage
  - Loss of load
  - Reverse power
  - Residual Overvoltage
  - Wattmetric SEF
  - Reacceleration (if enabled)
  - Overcurrent DEF (if directional is used)
  - Overcurrent SEF (if directional is used)

Functions which use the directional element are blocked if set as directional:

- IN> VTS Blocking = xx for each stage. When the relevant bit is set to 1, operation of VTS blocks the stage if directionalised. When set to 0 the function is set to Non-directional.

- ISEF> VTS Blocking = xx for each stage. When the relevant bit is set to 1, operation of VTS blocks the stage if directionalised. When set to 0 the function is set to Non-directional.

The internal fuse failure VTS_Fast blocks the same functions but if a fault is detected before the confirmation timer is issued, the functions are unblocked. The fault can be detected by the criteria Iph>, I2>, I0> and ΔI>.

The VTS I> Inhibit element is used to override a VTS block if a fault occurs on the system which could trigger the VTS logic. Once the VTS block has been established, subsequent system faults should not override the block. The VTS block is therefore latched after a user settable time delay VTS Time Delay. Once the signal has latched, it is reset automatically by CB Open or by the three-phase voltages returning above the phase detector level settings.

A VTS indication is given after the VTS Time Delay has expired.

If a miniature circuit breaker (MCB) is used to protect the voltage transformer ac output circuits, use MCB auxiliary contacts to indicate a three-phase output disconnection. The VTS logic can operate correctly without this input. However, this facility provides compatibility with current practices of various utilities. Energizing an opto-isolated input assigned to DDB 362 MCB/VTS on the relay provides the necessary block.

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The blocking of the VTS logic for a number of different fault conditions is considered below.

    1. Phase-phase fault

The I2> element detects phase-phase faults when the CB is closed and blocks the VTS logic.

    2. Three phase faults

The delta current level detectors detect the change in current for a close up 3 phase fault when the CB is closed and block the VTS.

The IPh> level detector detects a 3 phase fault when closing the CB onto a fault and blocks the VTS logic.

2.2   Current Transformer Supervision

The CT supervision feature operates when it detects derived residual current, without the corresponding derived or measured residual voltage that would normally accompany it.

The CT supervision can be set to operate from the residual voltage measured at the VNEUTRAL input (VN1 input for P241/2/3) or the residual voltage derived from the three-phase neutral voltage inputs as selected by the **CTS Vn Input** setting.

The voltage transformer connection used must be able to refer residual voltages from the primary to the secondary side. Therefore, this element should only be enabled where the three-phase VT is of five limb construction, or comprises three single-phase units, and has the primary star point earthed. A derived residual voltage or a measured residual voltage is available.

There are two stages of CT supervision CTS-1 and CTS-2. The derived neutral current is calculated vectorially from IA, IB, IC for CTS-1 and IA-2, IB-2, IC-2 for CTS-2. The neutral voltage is measured or derived, and is settable by the user.

CTS-1 supervises the CT inputs to IA, IB, IC which are used by the biased differential protection and all the power, impedance and overcurrent based protection functions. CTS-2 supervises the CT inputs to IA-2, IB-2, IC-2 which are used by the biased differential protection in the P243. The CTS-2 independent enabled/disabled setting prevents CTS-2 from giving unnecessary alarms when the Motor Differential is disabled.

When the element operates, a time-delayed alarm appears on the LCD and event record. Also DDB 229 (**CT-1 Fail Alarm**) and DDB 230 (**CT-2 Fail Alarm**), with an instantaneous block DDB 360 (**CTS-1 Block**) and DDB 361 (**CTS-2 Block**) to inhibit protection elements. Protection elements operating from derived quantities, (Negative Phase Sequence (NPS) Overcurrent, NPS Thermal, Thermal Overload protection) are always blocked when the CTS-1 supervision element operates. Other protection functions can be blocked by customizing the PSL and integrating DDB 360 (**CTS-1 Block**) and DDB 361 (**CTS-2 Block**) with the protection function logic.
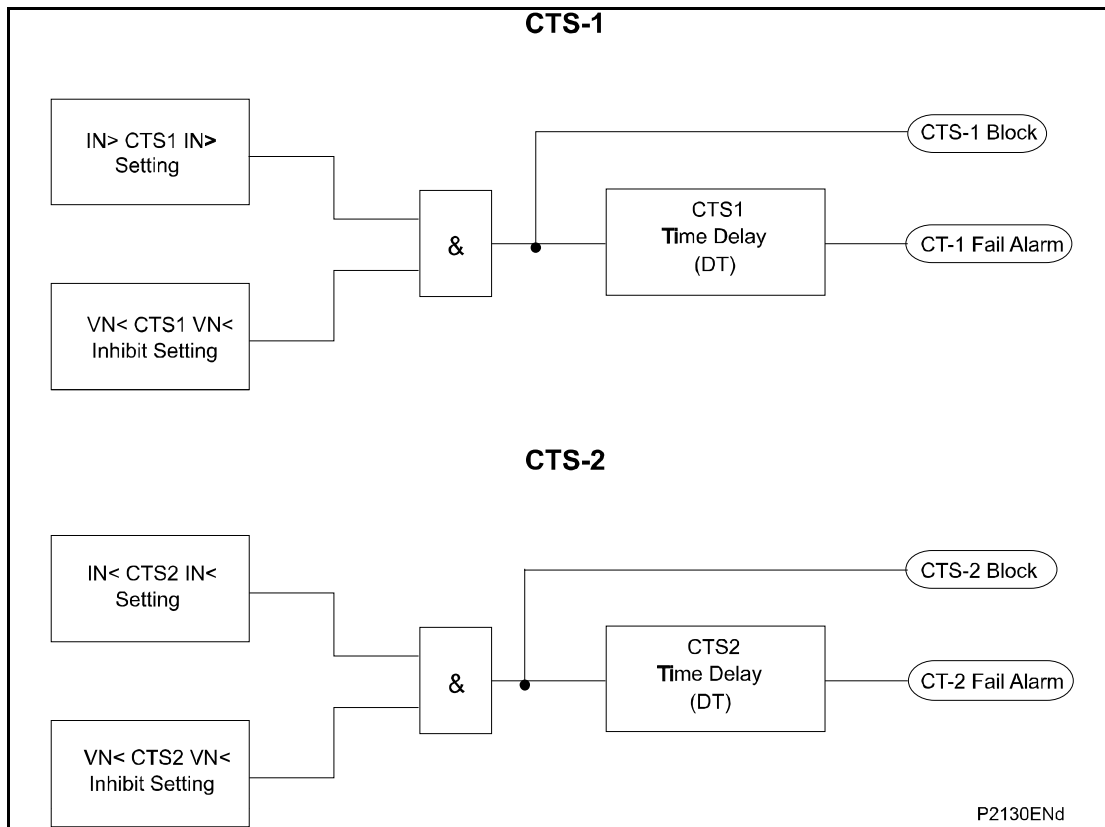
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Figure 53: CT supervision diagram

2.3 Circuit Breaker State Monitoring

MiCOM relays can be set to monitor normally open (52a) and normally closed (52b) auxiliary contacts of the circuit breaker. Under healthy conditions, these contacts are in opposite states. If both sets of contacts are open it indicates one of the following conditions.

- Auxiliary contacts/wiring defective

- Circuit Breaker (CB) is defective

- CB is in isolated position

If both sets of contacts are, only one of the following two conditions applies.

- 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 delay. An output contact can be assigned to this function using the PSL. The time delay is set to avoid unwanted operation during normal switching.

If only 52A is used, the relay assumes a 52B signal from the absence of the 52A signal. Circuit breaker status information is available in this case but no discrepancy alarm is available. This is also true if only a 52B is used. If both 52A and 52B are used, status information is available and a discrepancy alarm can be produced (CB Status Alarm, DDB 185) according to the following table. 52A and 52B inputs are assigned to relay opto-isolated inputs using the PSL (CB Aux 3ph 52A: DDB 105, CB Aux 3ph 52A: DDB 106). The CB State Monitoring logic is shown in Figure 54.

Auxiliary contact position		CB state detected	Action
52A	52B		
Open	Closed	Breaker Open	Circuit breaker healthy
Closed	Open	Breaker Closed	Circuit breaker healthy

Auxiliary contact position		CB state detected	Action
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

Table 8: Possible states of CB auxiliary contacts and the CTS element corresponding actions

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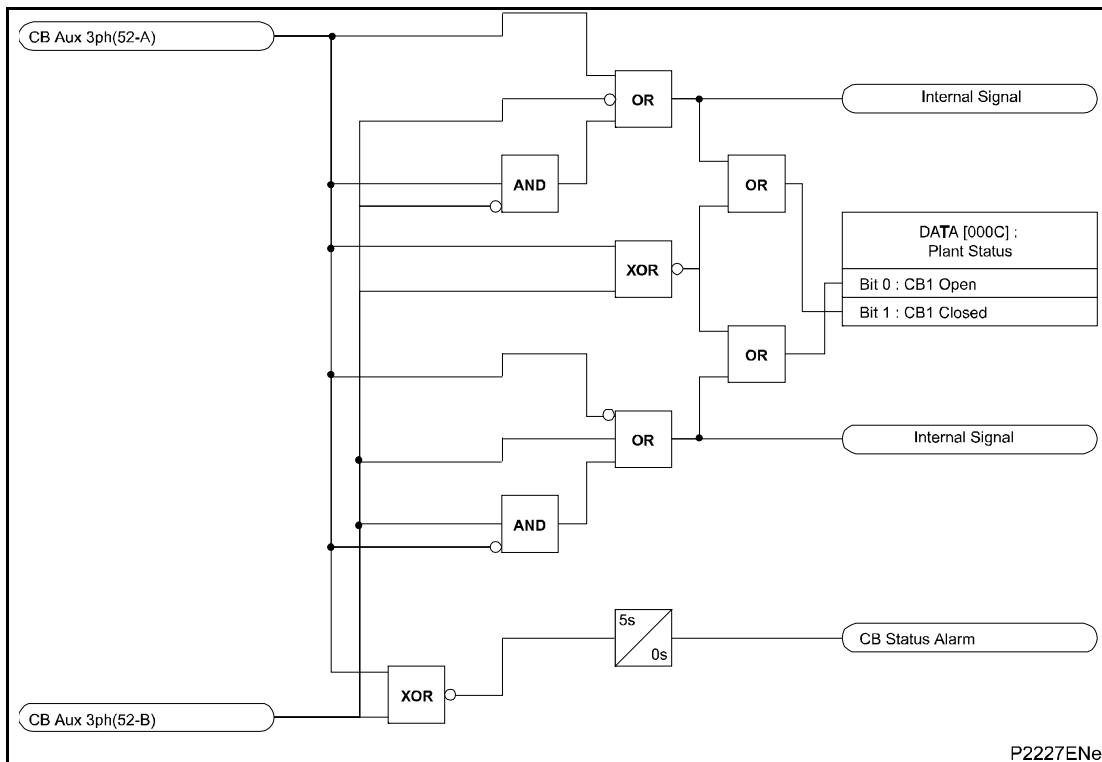
Figure 54: CB state monitoring

2.4   Circuit Breaker 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.

2.4.1   Features

For each circuit breaker trip operation the relay records statistics as shown in the following table taken from the relay menu. The menu cells shown are counter values only. The Min./Max. values show the range of the counter values. These cells can not be set.

Menu text	Default setting	Setting range		Step size
		Min.	**Max.**	
CB Operations	0	0	10000	1
Displays the total number of trips issued by the relay.				
Total IA Broken	0	0	25000 In^	1
Displays the total accumulated fault current interrupted by the relay for the A phase.				
Total IB Broken	0	0	25000 In^	1

Menu text	Default setting	Setting range		Step size
		Min.	Max.	
Displays the total accumulated fault current interrupted by the relay for the A phase.				
Total IC Broken	0	0	25000 In^	1 In^
Displays the total accumulated fault current interrupted by the relay for the A phase.				
CB Operate Time	0	0	0.5 s	0.001
Displays the calculated CB operating time. CB operating time = time from protection trip to undercurrent elements indicating the CB is open.				
Reset All Values	No		Yes, No	
Reset CB Data command. Resets CB Operations and Total IA/IB/IC broken current counters to 0.				

Table 9: Circuit breaker condition monitoring features

These counters may be reset to zero, for example, following maintenance inspection and overhaul.

The circuit breaker condition monitoring counters are updated every time the relay issues a trip command. If the breaker is tripped by an external protection device it is also possible to update the CB condition monitoring. This is done by allocating one of the relay's opto-isolated inputs using the programmable scheme logic to accept a trigger from an external device. The signal mapped to the opto is **External Trip**, DDB 115.

Measurement 3 > Motor Run Time shows the motor accumulated run time. This is initiated each time the switching device is closed and remains closed.

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2.5   Circuit Breaker Control

The relay includes the following options to control a single circuit breaker:

- Local tripping and closing, using the relay menu.

- Local tripping and closing, using relay opto-isolated inputs. (DDD111:Close, DDB112: Trip)

- Remote tripping and closing, using the relay communications.

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.

OP
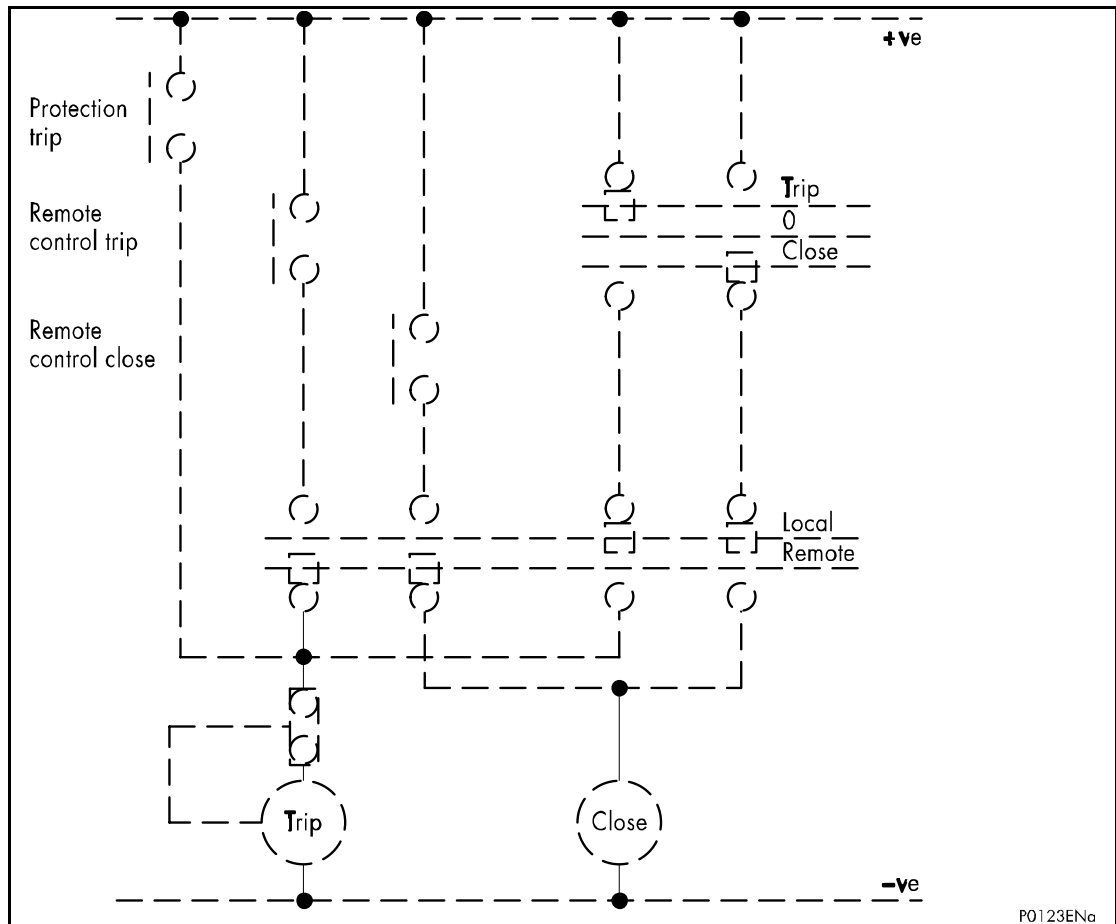
Figure 55: Remote control of circuit breaker

A manual trip is allowed if the circuit breaker is initially closed. Likewise, a close command can only be issued if the CB is initially open. To confirm these states it is necessary to use the breaker 52A contact.

For local control, the **CB control by** cell should be set accordingly.

The output contact can be set to operate following a time delay defined by the setting **Man Close Delay**. One reason for this delay is to give personnel time to safely move away from the circuit breaker following a CB close command.

The length of the trip or close control pulse can be set using 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.

> **Note:**   The manual close commands are found in the **SYSTEM DATA** column and the hotkey menu.

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.

If the CB fails to respond to the control command (indicated by no change in the state of CB Status inputs) a **CB Failed to Trip** or **CB Failed to Close** alarm is generated after the relevant trip or close pulses have expired. These alarms can be viewed on the relay LCD display, remotely using the relay communications, or can be assigned to operate output contacts for annunciation using the PSL.

2.6   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 chapter.

2.7 Reset of Programmable LEDs and Output Contacts

The programmable LEDs and output contacts can be set to be latched in the programmable scheme logic. If there is a fault record, clearing the fault record by pressing the **clear** key once the fault record has been read clears any latched LEDs and output contacts. If there is no fault record, as long as the initiating signal to the LED or output contact is reset, the LEDs and contacts can be reset by one of the following methods.

- Using the **View Records - Reset Indications** menu command cell.

- Using DDB 113 **Reset Latches** which can be mapped to an Opto Input or a Control Input for example.

2.8 Any Trip

The **Any Trip** DDB (DDB 371) is a combination of all the individual trip signals. This DDB has been made independent from relay 3 in the version C2.0 software and later. In the previous versions of software the **Any Trip** signal was the operation of Relay 3. In the version C2.0 software and later DDB371 is the **Any Trip** signal and any output contact used for tripping can be connected to the **Any Trip** DDB leaving Relay 3 to be freely assigned for any function. The **Any Trip** signal affects the following functions:

- Operates the Trip LED

- Triggers CB condition maintenance counters

- Used to measure the CB operating time

- Triggers the circuit breaker failure logic

- Used in the Fault recorder logic

In the default PSL, Relay 3 is still mapped to the **Any Trip** DDB and **Trip LED** DDB as well as the **Fault REC TRIG** DDB signals as shown in the PSL diagram below.
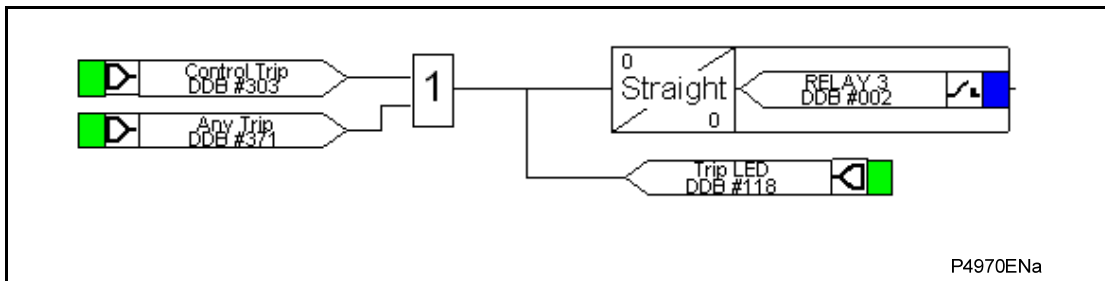
Figure 56: Default PSL showing Any Trip mapping

The new **Trip LED** DDB (DDB118) allows (in PSL) switching on Trip LED for a particular trip signal concerned. An example is shown below.
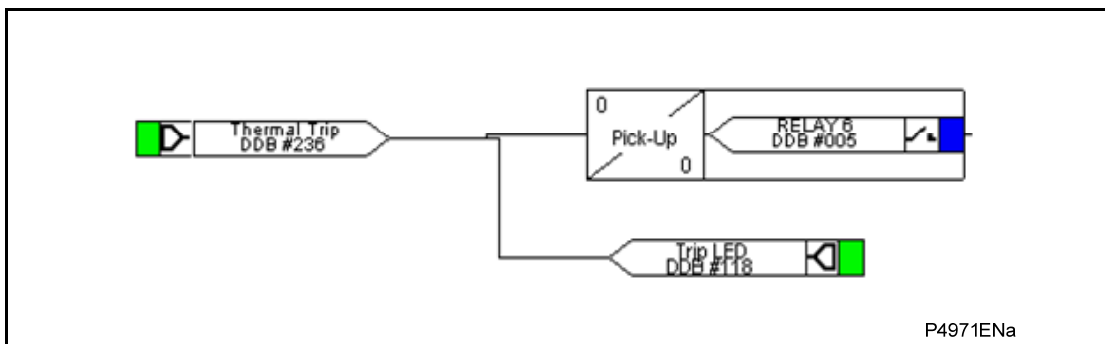
Figure 57: Example of using Trip LED

In the scheme shown above the trip relay is relay 6. Only the thermal trip provokes a Trip, and the Trip LED is switched on only with the thermal Trip.

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1   INTRODUCTION

1.1   Protection of Asynchronous and Synchronous Motors

Both asynchronous (induction) and synchronous motors perform a vital role in many industrial processes throughout the world, a vast majority of which would be unable to function without such a device. Loss of a motor through damage incurs much more than a possible electrical rewind but also a stop in an electrical process, resulting in expensive plant down time. This problem may be exacerbated by the damaged machine being positioned in an inaccessible position, such as an awkward corner of a factory or by a spare not being readily available. Therefore, prior warning of a problem is vitally important to reduce the impact on a process resulting from a faulted motor.

Comprehensive protection relays, such as the P24x, can be used to protect a motor from catastrophic failure, or possibly give the operator prior warning of a problem, which can reduce plant down time. Any protective device, though reliable in operation under abnormal conditions, must not affect the continuous operation of the motor under normal operating conditions.

Unfortunately, motor characteristics vary greatly depending on their precise application. Each application requires careful consideration regarding the specification and setting of the motor protection. For example, starting and stalling currents and times must be known when applying overload protection, and furthermore the thermal withstand of the machine under balanced and unbalanced loading must be defined.

The conditions which motor protection detects can be divided into two broad categories; imposed external conditions and internal faults. Imposed external conditions include unbalanced supply voltages, undervoltages, single phasing and reverse phase sequence starting and in synchronous machines only, loss of synchronism. Internal faults include bearing failures, internal shunt faults (commonly earth faults), and overloads.

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2   APPLICATION OF INDIVIDUAL PROTECTION FUNCTIONS

The following sections detail the individual protection functions in addition to where and how they may be applied.

2.1   Motor Differential Protection (P243 only) (87)

Failure of stator windings or connection insulation can result in severe damage to the windings and the stator core. The extent of the damage depends on the fault current level and the duration of the fault. Protection should be applied to limit the damage and repair costs.

The MiCOM P243 provides motor differential protection. This form of unit protection allows discriminative detection of winding faults. It has no intentional time delay where a significant fault current arises. Arrange the protection zone, defined by the location of the CTs, to overlap protection for other items of plant, such as a busbar or transformer.

Heavy through current arising from an external fault condition can cause one CT to saturate more than the other. This results in a difference between the secondary current produced by each CT. It is essential to stabilize the protection for these conditions. Three methods are commonly used:

- A biasing technique, where the relay setting is raised as through-current increases.

- A high impedance technique, where the relay impedance is such that under maximum through-fault conditions, the current in the differential element is insufficient for the relay to operate.

- A self balance type differential protection arrangement.

> **Note:** If the conductors are placed reasonably concentric within the window of the core balance current transformers, spill current can be kept to a minimum. With this low spill current and a reasonably independence of CT ratio to full load a lower fault setting could be achieved than conventional high impedance circulating current differential schemes.

The motor differential protection function available in the P24x relay can be used in either biased differential or high impedance differential mode.

> **Note:** The high impedance mode can be used to achieve a self balance scheme. Both modes of operation are equally valid; users may have a preference for one over the other. The operating principle of each is described in the Operation chapter, *P24x/EN OP*.

2.1.1   Biased Differential Protection Setting Guidelines

To select biased differential protection, set the **Diff Function** cell to **Percentage Bias**.

Set the differential current setting **Diff Is1** to a low setting to protect as much of the machine winding as possible. A setting of 5% of rated current of the machine is generally considered to be adequate. Set **Diff Is2**, the threshold above which the second bias setting is applied, to 120% of the machine rated current.

Set the initial bias slope setting, **Diff k1** to 0% to provide optimum sensitivity for internal faults. Set the second bias slope, **Diff k2** to 150% to provide adequate stability for external faults.

These settings can be increased where low accuracy class CTs are used to supply the protection.

2.1.2   High Impedance Differential Protection Setting Guidelines

Set the **Diff Function** cell to **High Impedance** to select high impedance differential protection.

Set the differential current setting **Diff Is1** to a low setting to protect as much of the machine winding as possible. A setting of 5% of rated current of the machine is adequate. This setting 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.

The primary operating current (Iop) is a function of the current transformer ratio, the relay operating current (**Diff Is1**), the number of current transformers in parallel with a relay element (n) and the magnetizing current of each current transformer (Ie) at the stability voltage (Vs). This relationship can be expressed in three ways:

To determine the maximum current transformer magnetizing current to achieve a specific primary operating current with a particular relay operating current.

$$I_e < \frac{1}{n} \times \left(\frac{I_{OP}}{CT.Ratio} - Mot.Diff.REF > I_S 1 \right)$$

To determine the maximum relay current setting to achieve a specific primary operating current with a given current transformer magnetizing current.

$$Mot.Diff.I_S 1 < \left(\frac{I_{OP}}{CT.Ratio} - nI_e \right)$$

To express the protection primary operating current for a particular relay operating current and with a particular level of magnetizing current.

$$I_{OP} = (CT.Ratio) \times (Mot.Diff.I_S 1 + nI_e)$$

To achieve the required primary operating current with the current transformers that are used, a current setting (Diff Is1) must be selected for the high impedance element, as detailed in expression (ii) above. The setting of the stabilizing resistor (RST) must be calculated in the following manner, where the setting is a function of the required stability voltage setting (Vs) and the relay current setting (Diff Is1).

$$R_{ST} = \frac{V_S}{Mot.Diff.I_S 1} .... = ... \frac{1.5 \times I_F \times (R_{CT} + 2RL)}{Mot.Diff.I_S 1}$$

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

2.1.3   Use of METROSIL Non-Linear Resistors

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

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

Metrosils are used to limit the peak voltage developed by the current transformers under internal fault conditions, to a value below the insulation level of the current transformers, relay and interconnecting leads, which are normally able to withstand 3000 V peak.

The following formulae should be used to estimate the peak transient voltage that can be produced for an internal fault.

$$Vp = 2\sqrt{2V_k (V_f - V_k)}$$

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

Where:

V_p = Peak voltage developed by the CT under internal fault conditions.

V_k = Current transformer knee-point voltage.

V_f = Maximum voltage that would be produced if CT saturation did not occur.

I'_f = Maximum internal secondary fault current.

R_{CT} = Current transformer secondary winding resistance.

R_L = Maximum lead burden from current transformer to relay.

R_{ST} = Relay stabilizing resistor.

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

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

$$V = CI^{0.25}$$

Where:

- V = Instantaneous voltage applied to the Metrosil
- C = Constant of the non-linear resistor ("Metrosil").
- I = Instantaneous current through the non-linear resistor ("Metrosil").

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

$$I(rms) = 0.52 \left(\frac{Vs\ (rms) \times \sqrt{2}}{C} \right)^4$$

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.

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

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

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Relay voltage setting	Nominal characteristic		Recommended metrosil type	
	C	β	Single pole relay	Triple pole relay
Up to 125 V RMS	450	0.25	600 A/S1/S256	600 A/S3/1/S802
125 to 300 V RMS	900	0.25	600 A/S1/S1088	600 A/S3/1/S1195

Table 1: Recommended characteristics and types of Metrosil units to be used with 1 Amp CTs

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

Metrosil Units 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 shown in the following table:

Secondary internal fault current	Recommended METROSIL type			
	Relay voltage setting			
Amps RMS	Up to 200 V RMS	250 V RMS	275 V RMS	300 V RMS
50 A	600 A/S1/S1213 C = 540/640 35 mA RMS	600 A/S1/S1214 C = 670/800 40 mA RMS	600 A/S1/S1214 C = 670/800 50 mA RMS	600 A/S1/S1223 C = 740/870* 50 mA RMS
100 A	600 A/S2/P/S1217 C = 470/540 70 mA RMS	600 A/S2/P/S1215 C = 570/670 75 mA RMS	600 A/S2/P/S1215 C = 570/670 100 mA RMS	600 A/S2/P/S1196 C = 620/740 100 mA RMS *
150 A	600 A/S3/P/S1219 C = 430/500 100 mA RMS	600 A/S3/P/S1220 C = 520/620 100 mA RMS	600 A/S3/P/S1221 C= 570/670** 100 mA RMS	600 A/S3/P/S1222 C = 620/740*** 100 mA RMS

Table 2: Recommended characteristics and types of Metrosil units to be used with 5 Amp CTs

> **Note:**   *2400 V peak   **2200 V peak   ***2600 V peak

In some situations single disc assemblies are acceptable, contact GE for detailed applications.

> **Note:**   The Metrosil units recommended for use with 5 Amp CTs can also be applied for use with triple pole relays and consist of three single pole units mounted on the same central stud but electrically insulated for each other. To order these units please specify "Triple Pole Metrosil Type", followed by the single pole type reference.

2.1.4   Self Balance Winding Differential Setting Guidelines

For this configuration, the relay must be set to **High Impedance** using the cell **Diff Function** in the **Differential** protection menu. Set the differential current setting **Diff Is1** to a low setting to protect as much of the machine winding as possible. A setting of 5% of rated current of the machine is generally considered adequate.

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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.

Disadvantages:

1. The necessity of passing both ends of each phase winding through the CT and so the need for extra cabling on the neutral end.
2. To avoid long cabling, position of CTs are restricted to the proximity of the machine output terminals in which case the cable between the machine output terminals and controlling switchgear might not be included within the differential zone.

2.2 Thermal Overload Protection (49)

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

2.2.1 Introduction

Overloads can result in stator temperature rises which exceed the thermal limit of the winding insulation. Empirical results 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 may not damage the machine. However, sustained overloads of a few per cent may 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. It is not therefore 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, it can be shown 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. A more accurate representation of the thermal state of the motor can be obtained through the use of temperature monitoring devices (RTDs) which target these specific areas.

2.2.2 Thermal Replica

The P24x 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 positive or 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 therefore 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 expressions;

$$I_{eq} = \sqrt{(I1^2 + KI_2^2)}$$

> **Note:** This equation is used in software version A4.x (09) and before

$$I_{eq} = \sqrt{(I_{RMS}^2 + KI_2^2)}$$

> **Note:** This equation is used in software version B1.0 (20) and later

Where;

I_{RMS} = Root Mean Square current

I_1 = Positive sequence current

I_2 = Negative sequence current

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

As previously described, the temperature of a motor rises exponentially with increasing current. Similarly, when current decreases, the temperature also decreases in a similar manner. Therefore, to achieve close sustained overload protection, the P24x 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 2Ith.

- 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 $\%\theta = (I_{eq}/I_{th})^2 \times 100$.

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

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

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

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".

2.2.3   Thermal Overload Setting Guidelines

2.2.3.1   Thermal setting I_{th}

The **I_{th} 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 may be run at some 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 may 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 P24x 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
Starting	D.O.L

Table 3: Specific motor parameters used to show how to determine the P24x settings

For this application we have assumed the machine is a CMR motor and therefore the Ith setting is calculated as follows;

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

Where:

I_{CMR} = Continuous Motor Rating

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

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

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2.2.3.2   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**

2.2.3.3   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 as possible 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, since 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 may not be available. However, a graphical representation of these values may be given. In such applications, a stator heating time constant must be chosen, such 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 particular application the stator thermal time constants of the motor are known, therefore 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 Figure 1.

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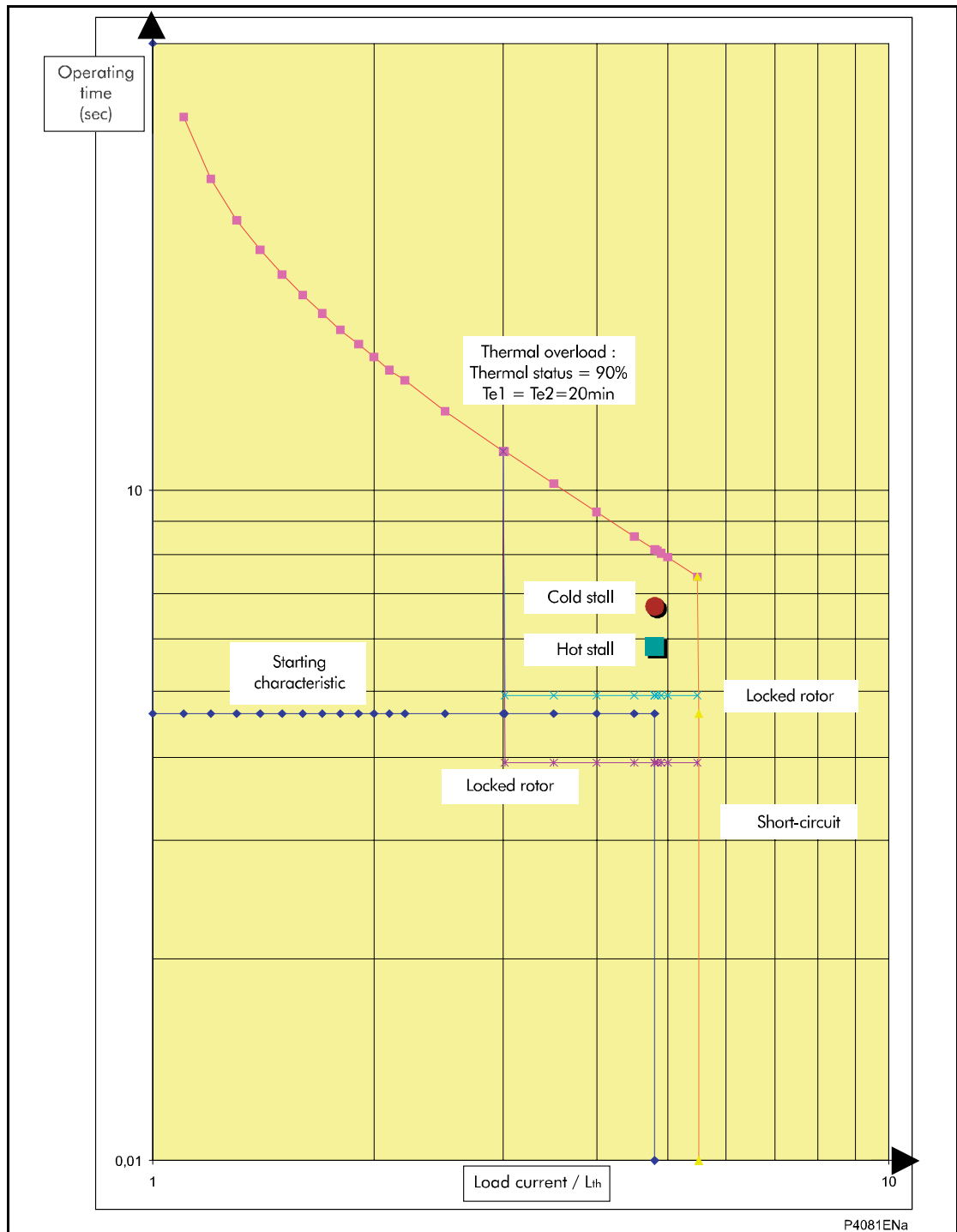
Figure 1: Example of settings

2.2.4   Thermal State Modification

If a CMR induction motor is fully loaded, this is equivalent to a temperature of 100%, as far
as the thermal replica is concerned. The motor protection relay is therefore 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 Figure 2.
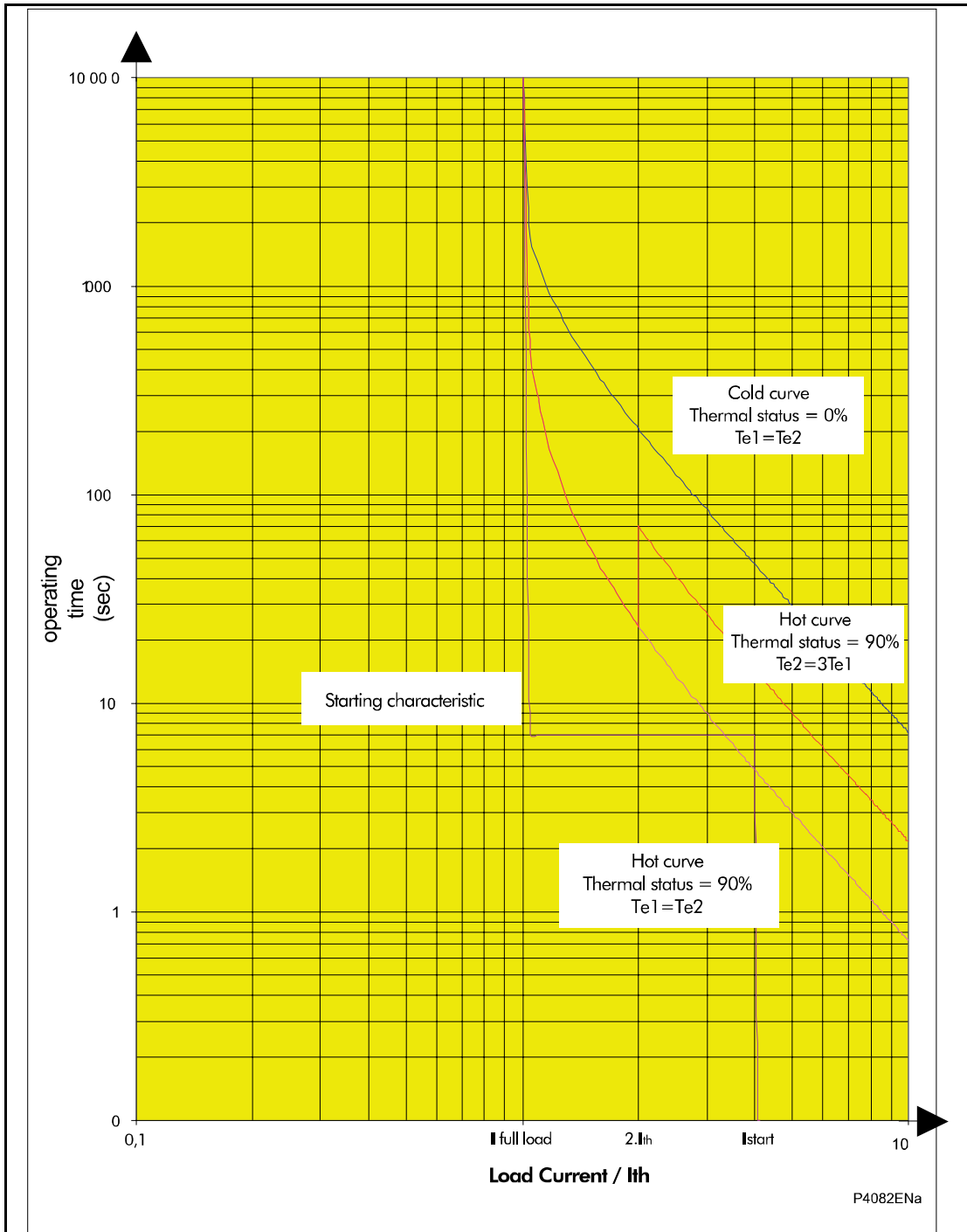
Figure 2: Thermal curve modification

In the past, motor manufacturers and end users have been aware of the limitation of the stator thermal model and the possible solution has been to oversize the machine, which is expensive.

The P24x relay incorporates a feature whereby the thermal curve can be modified to overcome this problem. Previously, the relay has 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, it may be necessary to set T2 to a higher value than T1 to avoid the starting characteristic. This is shown in Figure 2.

2.2.5   Thermal Probe Influence

Motors are designed to operate within a specific ambient temperature. If the machine is operated in a higher ambient temperature than specified, the windings may overheat resulting in insulation deterioration, even if it is operating within rated load. Therefore, if the machine is operated in an environment where the ambient temperature may fluctuate, it is important to compensate the thermal overload curve to maintain close thermal overload protection. Strategically placed temperature sensors can be used to provide information on ambient conditions, which in turn can then be used to influence the thermal replica. Motors which are particularly at risk are those operated in direct sunlight, boiler houses, tropical environments and motors which are reliant on forced cooling.

The power delivered by a motor varies with the ambient temperature, the following table shows variations in power delivered as the temperature changes for a typical motor.

Ambient Temperature °C	40	45	50	55	60
Power delivered as a % of nominal power	100	95	90	85	80

Table 4: Reduction of per unit power delivered by motors relative to the ambient temperature

As the nominal power varies linearly with nominal current, with a constant voltage, the above table is applicable to nominal current.

The thermal setting is also directly proportional to nominal current. So to compensate for the ambient temperature variation, the thermal setting is corrected dependent on the ambient temperature for the following conditions:

- During the calculation of thermal state
- During the detection of thermal alarm
- During the detection of thermal overload
- During the detection of thermal lockout

A correction coefficient is calculated depending on the temperature as shown in the table below and is multiplied to the thermal thresholds:

Ambient Temperature °C	40	45	50	55	60	65
Multiplication Coefficient	1	0.95	0.90	0.85	0.80	0.75

Table 5: Correction coefficients used by the relay to offset the thermal replica at different ambient temperatures

The P24x accepts inputs from up to 10 RTDs (resistance temperature detectors). Two of these RTDs (one main and one back-up), can be used to measure the external/ambient temperature and influences the thermal curve.

2.2.6   Specific Applications

2.2.6.1   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.

2.2.6.2   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 usually 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.

2.2.6.3   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. A typical setting would be 90%

2.2.6.4   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. It is typically set to the minimum value of 20%Ith.

2.3   Resistive Temperature Detectors

Prolonged overloading of motors or generators can cause their windings to overheat, resulting in premature ageing of the insulation, or in extreme cases, insulation failure. Worn or unlubricated bearings can also generate localized heating within the bearing housing. To protect against any general or localized overheating, the P24x relays have the ability to accept inputs from resistive temperature sensing devices (RTDs). Such probes are strategically placed in areas of the machine which are susceptible to overheating, or heat damage.

2.3.1   RTD Thermal Protection Features

Typically an RTD probe can measure temperature within the range -40 to +400°C. The temperature at each probe location can be determined by the relay, and is available for:

- Temperature monitoring, displayed locally, or remotely via the relay communications
- Alarming, should a temperature threshold be exceeded for longer than a set time delay
- Tripping, should a temperature threshold be exceeded for longer than a set time delay
- Should the measured resistance be outside of the permitted range, an RTD failure alarm is raised, indicating an open or short circuit RTD input

> **Note:**   Direct temperature measurement can provide more reliable thermal protection than devices which use a thermal replica energized from phase current. The latter is susceptible to inaccuracies in time constants used by the replica model, and also inaccuracies due to the variation in ambient temperature.

2.3.2   RTD Thermal Protection Settings

Typical operating temperatures for protected plant are given. Actual figures must be obtained from the equipment manufacturers:

Parameter	Typical service temperature at full load	Short term overloading
Bearing temperature of motors or generators	Possibly 60 – 80°C, depending on the type of bearing.	+60 - +80°C
Top oil temperature of transformers	80°C (50 – 60°C above ambient).	A temperature gradient from winding temperature is usually assumed, such that top oil RTDs can provide winding protection.
Winding hot spot temperature	98°C for normal ageing of insulation.	Cyclic overloading might give +140°C during emergencies.

Table 6: Typical operating temperatures of a healthy plan

The P24x relay has an alarm threshold setting, with a time delay for each RTD input. Each input also has a trip element, with a temperature threshold and a time delay. The time delays may be set to 0 s if instantaneous protection is required.

Temperature settings can be set in degrees Celsius or Fahrenheit within the range 0-400°C.

2.4 Short Circuit Protection (50/51)

Faults between phases seldom occur because of the relatively large 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; such as terminal flashovers.

The short circuit protection included within the P24x 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> as shown in Figure 6.

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 function to block the short circuit protection function under normal conditions and unblock 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:
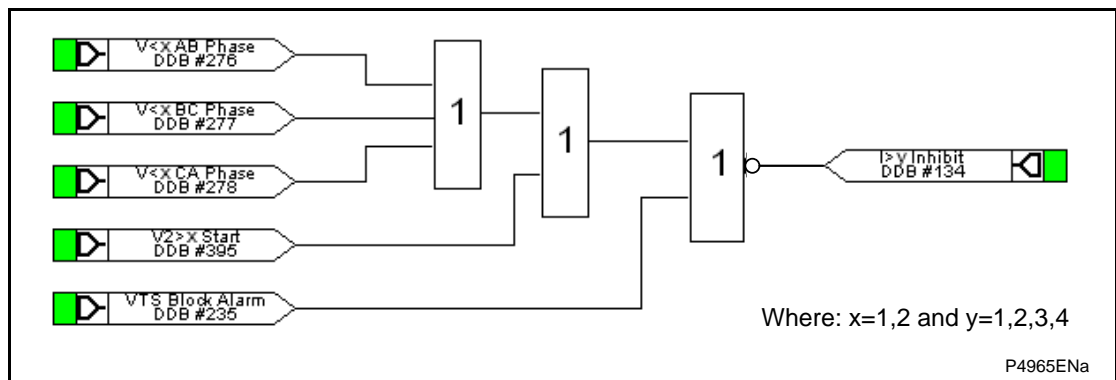
Figure 3: OR logic
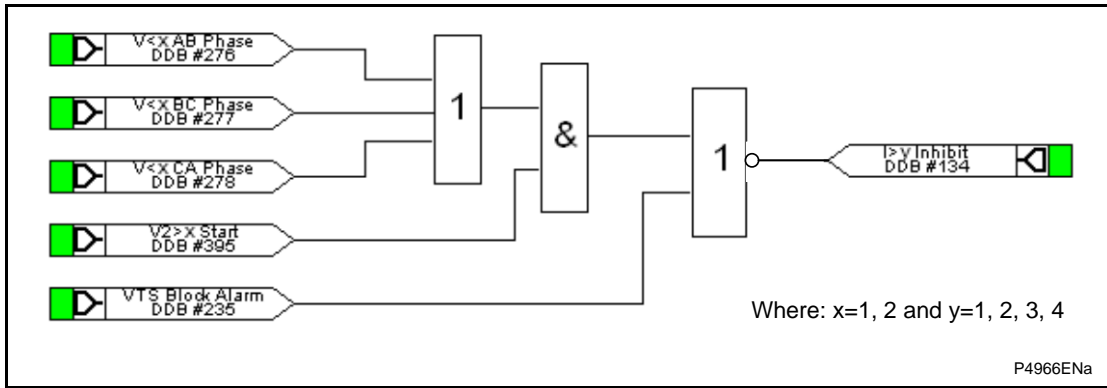
Figure 4: AND logic

In case of VT failure, V< and V2> functions are disabled automatically. Therefore, associated start elements remain in the reset condition but VTS Block Alarm is asserted and in turn I> function is unblocked. As V< and V2> are only used to block I> from tripping during start and should not generate a trip, it is required to inhibit these elements and this can be done in the PSL. See Figure 5 as an example.
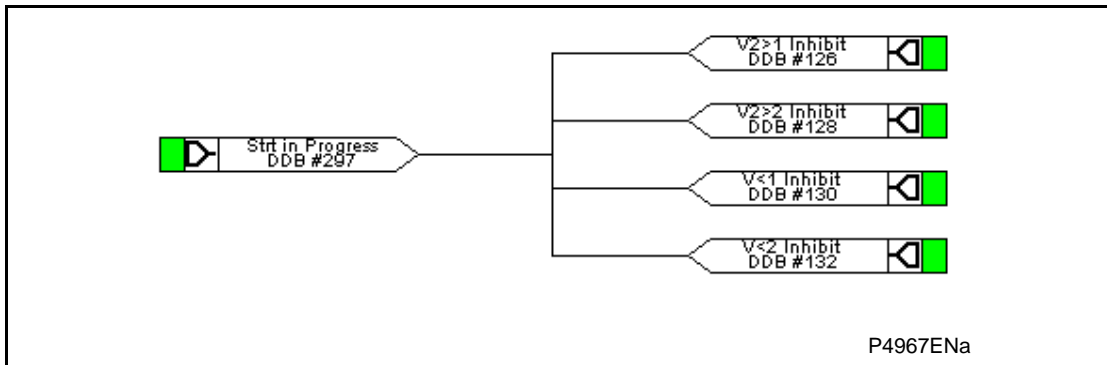
Figure 5: Inhibition of V< and V2> during start

The definite time characteristic is shown below in Figure 6.
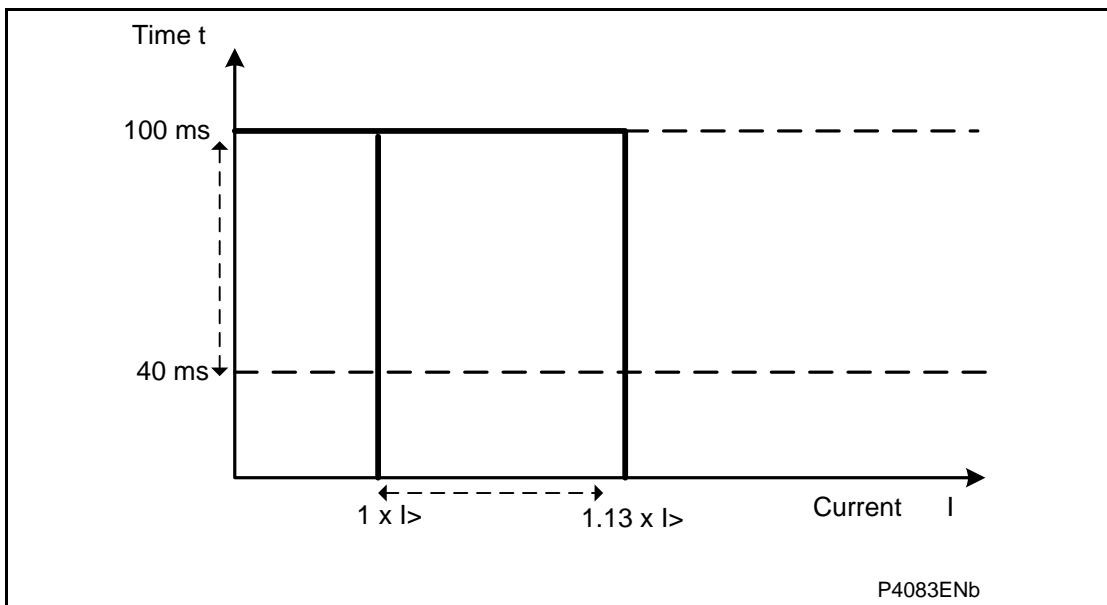
Figure 6: Definite time overcurrent element

2.4.1   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 very much system dependent, but may typically 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 is to prevent the contactor attempting to interrupt current in excess of its breaking capacity.

2.4.2   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

These settings are shown in Figure 6.

2.5   Earth Fault Protection (50N/51N/67N/32N/64N)

One of the most common faults on a motor is a stator winding fault. This is usually the result of prolonged or cyclic overheating, which causes the insulation to deteriorate. Since the windings are surrounded by an earthed metal case, stator faults usually manifest themselves as earth faults. The type of earth fault protection and CT arrangement adopted depends on the amount of earth fault current available during a fault. The magnitude of current is dependent on the system earthing arrangements.

The P24x earth fault element is equipped with two independent stages, which are selectable as either forward, reverse or non-directional. The first stage may be selected as either IDMT or DT and the second stage is DT only.

The inverse time delayed characteristics listed above, comply with the following formula:

$$t = T \times \left\{ \left[K / ((I/Is)^{\alpha} (- 1)) \right] + L \right\}$$

Where;

t   = operation time

K   = constant

I   = measured current

Is   = current threshold setting

α = constant

L   = ANSI/IEEE constant (zero for IEC curves)

T   = Time multiplier Setting or Time Dial Setting

Curve description	Standard	K constant	α constant	L constant
Standard Inverse	IEC	0.14	0.02	0
Very Inverse	IEC	13.5	1	0
Extremely Inverse	IEC	80	2	0
Long Time Inverse	UK	120	1	0
Moderately Inverse	IEEE	0.0515	0.02	0.114
Very Inverse	IEEE	19.61	2	0.491
Extremely Inverse	IEEE	28.2	2	0.1217
Inverse	US-C08	5.95	2	0.18
Short Time Inverse	US-C02	0.02394	0.02	0.01694

Table 7: Standard IDMT curve constant values

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Note: 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 employed for the IEEE/US curves. Both the TMS and Time Dial settings act as multipliers on the basic operating time.

Note: All the curves are shown in the Technical Data chapter, *P24X/EN TD*.

The element operates from residual current obtained from either the residual connection of the three phase CTs, or from an independent core balance CT. The core-balance CT is normally of the ring type, through the centre of which is passed the three phase cable to the motor. The advantage in using this CT arrangement lies in the fact that only one CT core is used, in place of the conventional three phase CTs whose three secondary windings are residually connected. In this way the CT magnetizing current at relay operation is reduced by approximately three-to-one; an important consideration in the detection of low level earthfaults, where low effective settings are required. Furthermore, the primary current rating does not need to be related to motor full load current as no secondary current flows under normal balanced conditions. This allows the CT ratio to be chosen such as to optimize the effective primary pick-up current.

Core-balance transformers are normally mounted over a cable at a point close to the cable gland. Physically split cores, that is 'slip-over' types, are normally available for applications in which the cable is already in position, as on existing installations. Figure 7 shows the correct method of earthing the cable sheath when using a core balance CT.

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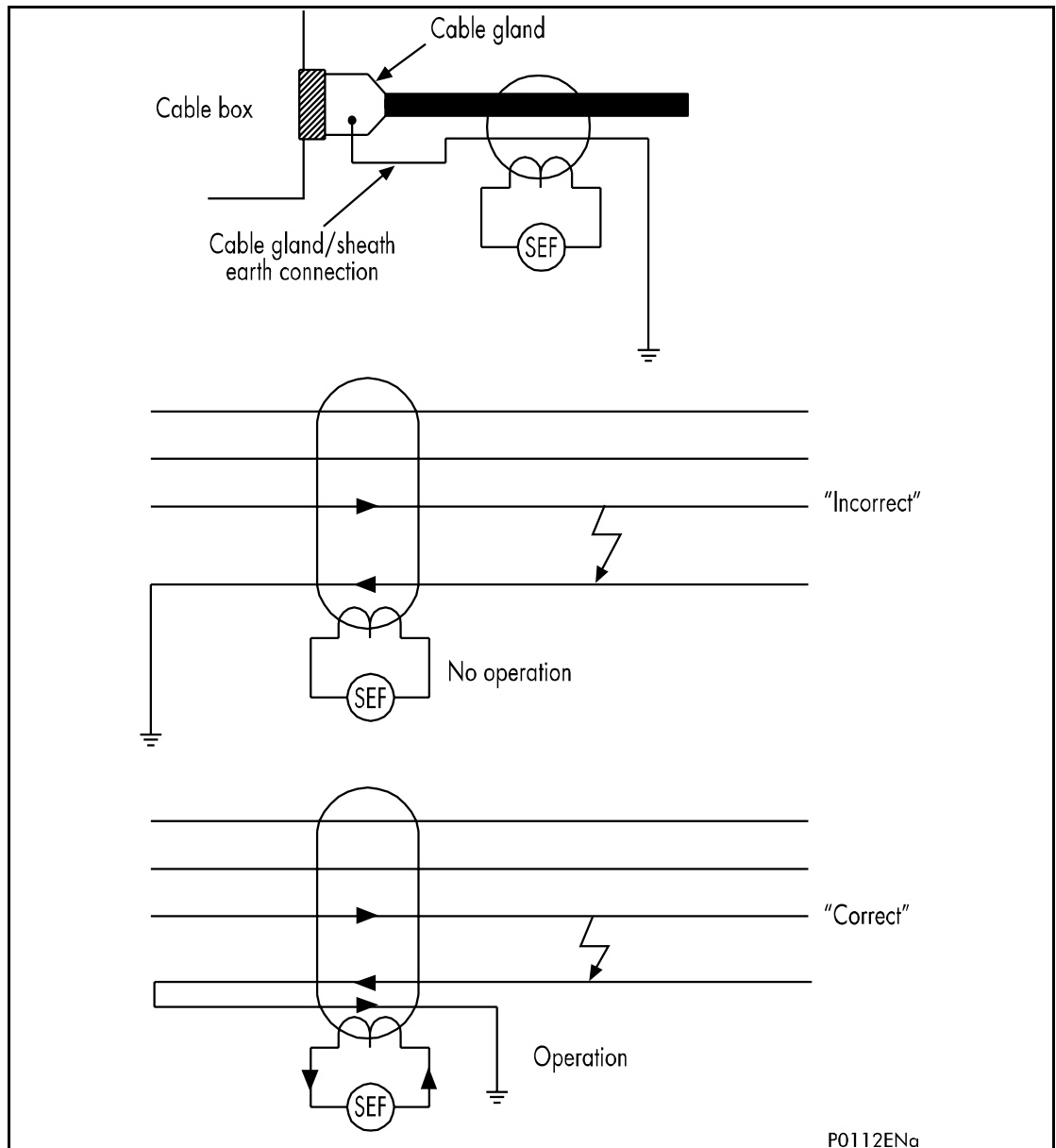
Figure 7: Core balanced CT with cable

Where directional earth fault protection is required, the element should be polarized from residual voltage (-3Vo). This is derived from either the three phase VT inputs to the relay or the residual voltage input. The **VT Connect Mode**, **3VT, 2VT+VResidual, 2VT+Vremanent** can be selected in the **CT and VT Ratios** menu.

Different VT ratio settings for the three modes of connection are available.

2.5.1   Solidly Earthed System Principle

On solidly earthed systems, for earth fault settings >20% of the motor continuous rated current, it is acceptable to use the conventional residual CT connection for the detection of earth faults. Below 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

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 may be gained by the use of insulated systems. However, it is still vital that detection of the fault is achieved. This is obviously not possible by means of standard current operated earth fault protection. One possibility for fault detection is by means of a residual overvoltage device. This functionality is included within the P24x relay and is detailed in section 2.6. However, fully discriminative earth fault protection on this type of system may 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. It is therefore essential that a core balance CT is used for this application.
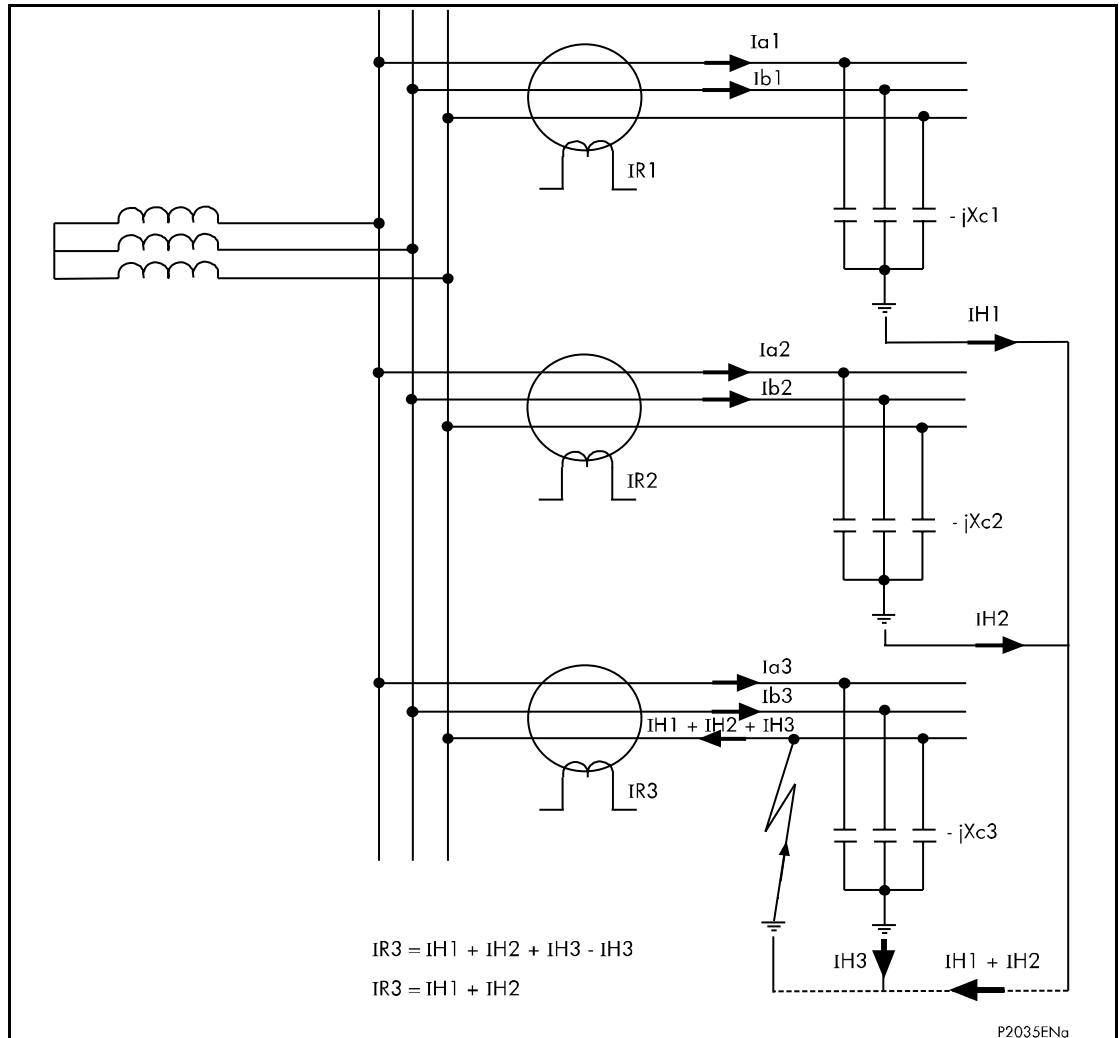
Figure 9: Current distribution in an insulated system with C phase fault

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.
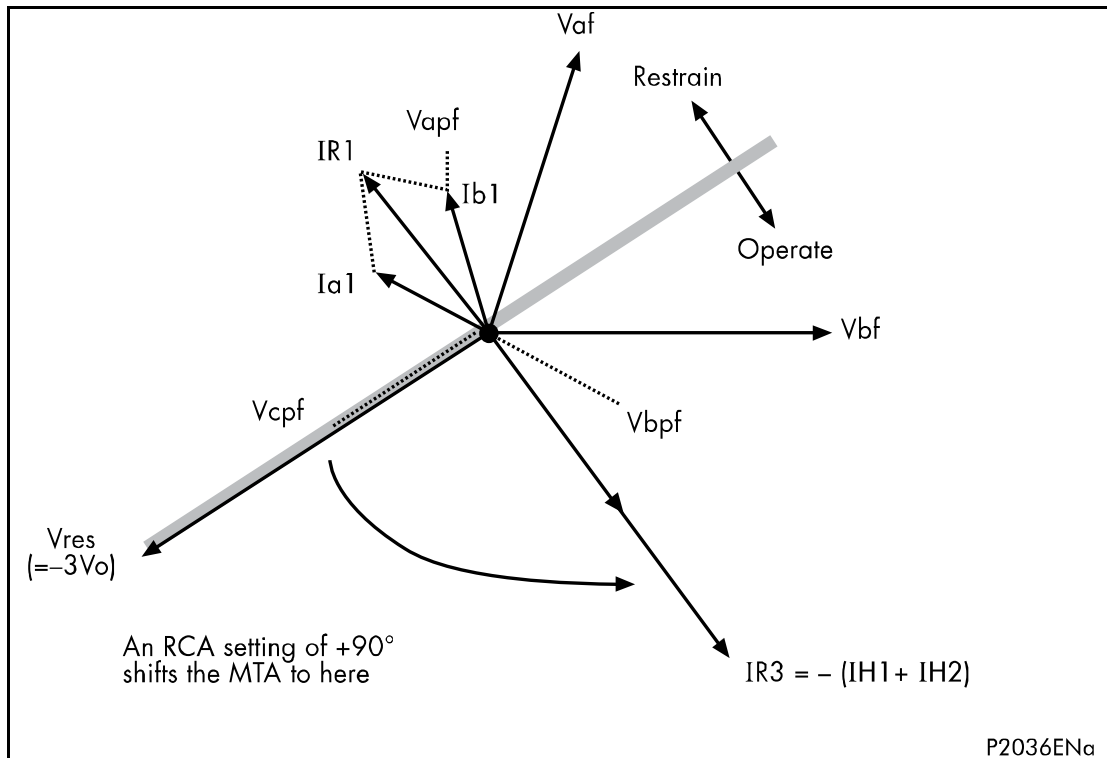
Figure 10: Phasor diagrams for insulated system with C phase fault

With reference to the associated vector diagram, it can be seen that the C phase to earth

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 current inbalance detected by a core balance current transformer on the healthy motor feeders is the vector addition of Ia1 and Ib1. This gives a residual current which lags the polarising voltage (–3Vo) by 90°. 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 times the steady state per phase charging current.

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

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

> **Note:** The actual residual voltage used as a reference signal for the directional earth fault protection in the P24x relay is internally phase shifted by 180° and is therefore shown as -3Vo in the vector diagrams.

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

> **Note:** The recommended setting corresponds to the relay being connected such that its direction of current flow for operation is from the motor feeder into the busbar. The correct relay connections to give a defined direction for operation are shown in the relay connection diagrams in the Installation chapter, *P24x/EN IN.*

The P24x 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 types allow the passage of residual flux through the VT and therefore permit the relay to derive the required residual voltage. A three limb VT provides no path for the flow of residual flux and is therefore 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.

2.5.2.1 Setting Guidelines

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. The use of the P24x relays comprehensive measurement and fault recording facilities may 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.

2.5.3 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.

2.5.3.1 Setting Guidelines

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

For such an 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. Figure 9 shows the healthy feeder sees this value of charging current regardless of the method of earthing.

Similar guidelines to those given for solidly earthed systems (section 2.5.1) are applicable with regard to the required time delay setting.

Note: If the above 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.

2.5.3.2 High Resistance Earthing

For certain applications, the fault current may 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 Figure 10).

> **Note:** This recommended setting corresponds to the relay being connected such 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 x steady state value). The correct relay connections to give a defined direction for operation are shown on the relay connection diagram the Installation chapter, *P24x/EN IN*.

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 apply with respect to those given in section 2.5.2 regarding the VT requirements for the P24x relay when directionalizing earth fault elements (R.C.A = relay characteristic angle).
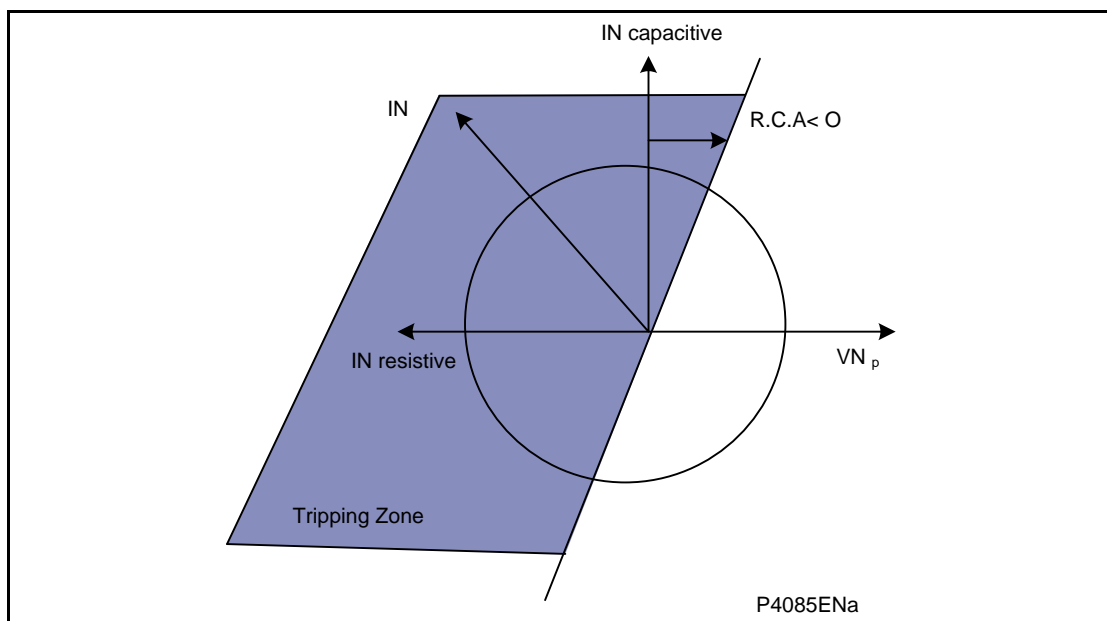
Figure 11: Directional tripping characteristic

2.5.3.3 Petersen Coil Earthed Systems Principle

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

If a high impedance device is used for earthing the system, 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 earth fault 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.

Figure 12 shows a source of generation earthed through a Petersen Coil, with an earth fault applied on the A Phase. Under this situation, it can be seen 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.
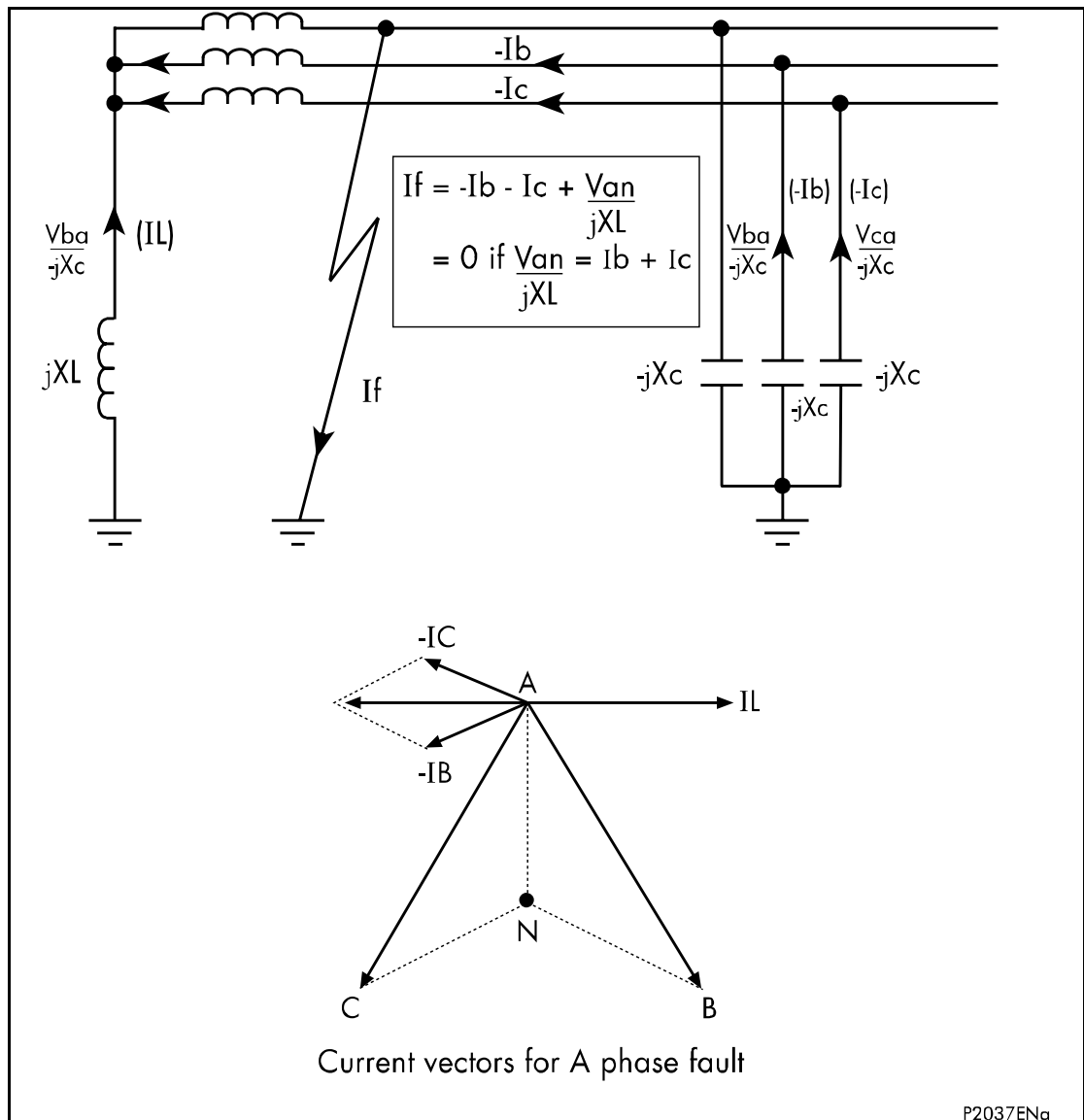
Figure 12: Current distribution in Petersen coil earthed system

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 knowledge, it is

then possible to decide on the type of relay that may be applied, ensuring that it is both set and connected correctly.

Figure 13 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 13: Distribution of currents during a C phase to earth fault

Figure 14 (a, b and c) 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 14: Theoretical case - no resistance present in XL or XC

Referring to the vector diagram shown in Figure 14a, the C phase to earth fault causes the voltages on   ents (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 (Figure 14 b). As the healthy phase   are also √3 times larger than their steady state values. Therefore, the magnitude of residual current, IR1, is equal to 3 x 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 24x 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, as shown in Figure 14 c.

This situation may be more readily observed by considering the zero sequence network for this fault condition. This is shown in Figure 15 below:
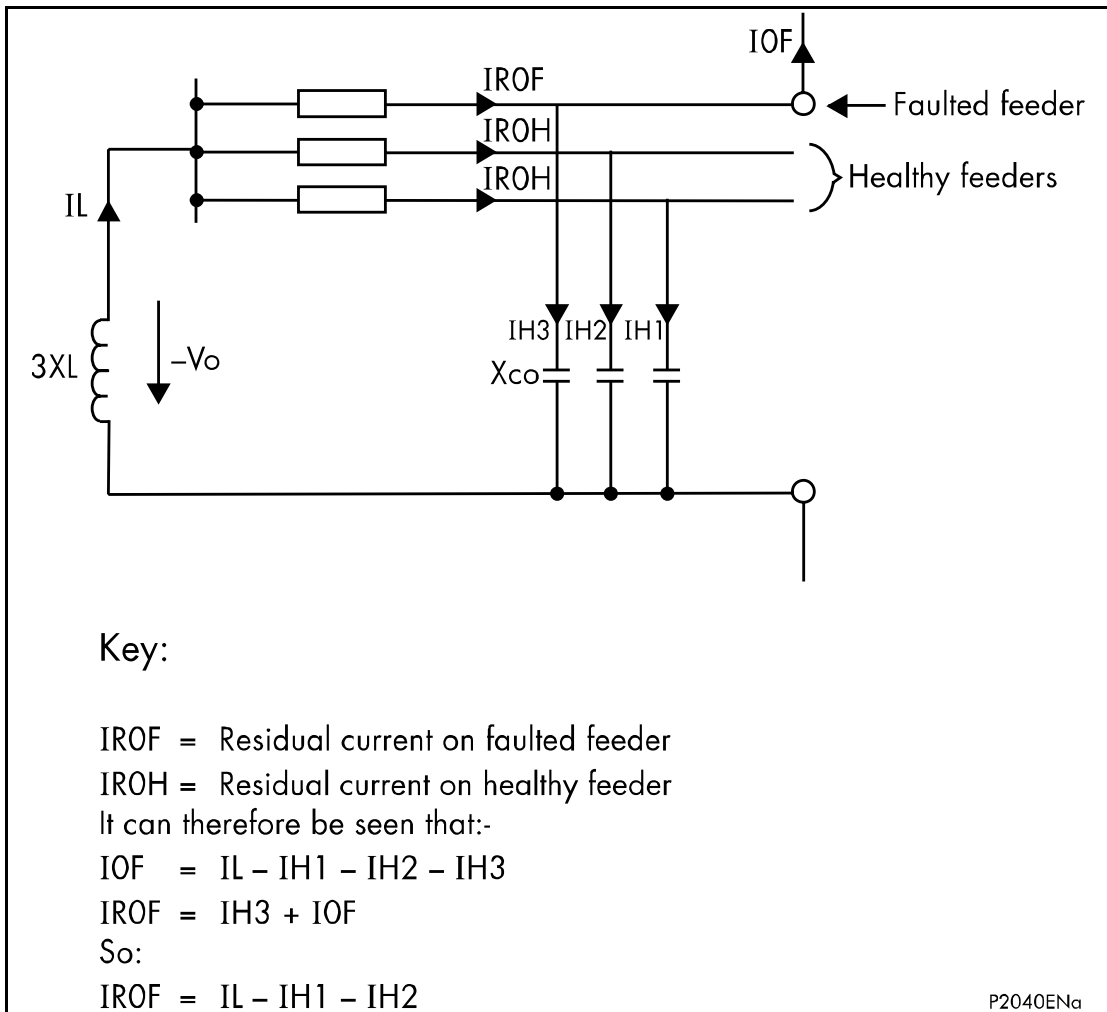
Figure 15: Zero sequence network showing residual currents

In comparing the residual currents occurring on the healthy and on the faulted feeders (Figure 16 b & 16c), it can be seen that the currents would be similar in both magnitude and phase; so it would not be 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 therefore needs to be given to a practical application in which the resistive component is no longer ignored, see Figure 16.
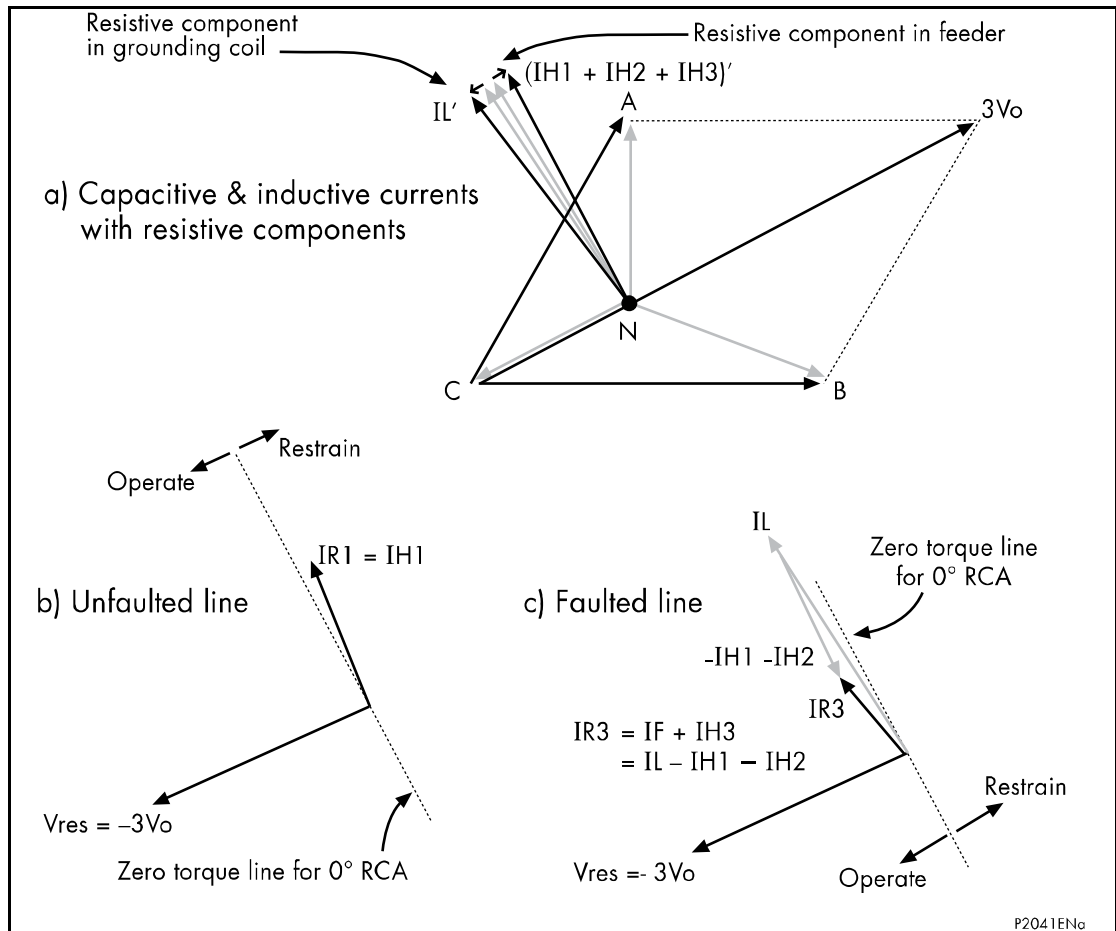
Figure 16: Practical case:- resistance present in XL and Xc

Figure 16a again shows the relationship between the capacitive currents, coil current and residual voltage. It can now be seen that 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 Figure 16b and 16c.

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.

2.5.3.4   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.

Both stages 1 and 2 of the sensitive earth fault element of the P24x relay are settable down to 0.2% of rated current and would therefore fulfill the requirements of the first method listed above and could therefore 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.

2.5.4 Wattmetric Characteristic Principle

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.
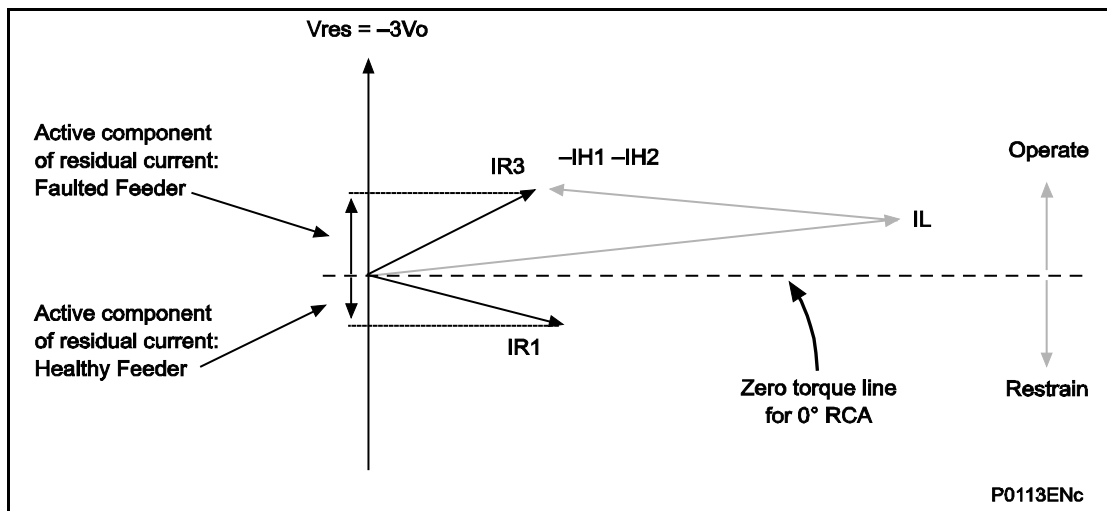
Figure 17: Resistive components of spill current

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 (**P0>Current Set**), the voltage (**P0>Voltage Set**) and the power (**P0>Coef. K Set**). The directional decision within the relays is based on current rather than power. The 'Coef. K' threshold is simply present as an additional level that must be exceeded before a trip is initiated.

The wattmetric power formula is calculated using residual rather than zero sequence quantities. Residual quantities are three times their respective zero sequence values and so the complete formula for operation is shown below:-

The wattmetric element setting corresponds to:

Vres x Ires x Cos (Φ-Φc)= 9 x Vo x Io x Cos (Φ - Φc)

Where;

Φ = Angle between the Polarizing Voltage (**-Vres**) and the Residual Current

Φc = Relay Characteristic Angle (RCA) Setting (**ISEF> Char Angle**)

Vres = Residual Voltage

Ires = Residual Current

Vo = Zero Sequence Voltage

Io = Zero Sequence Current

2.5.4.1   Application Considerations

Required relay current and voltage connections:

Referring to the relevant application diagram for the P24x relay, it should be applied such that its direction for forward operation is looking down into the protected feeder (away from the busbar), with a 0° RCA setting.

The relay application diagram shows it is usual for the earth fault element to be driven from a core balance current transformer (CBCT). This eliminates the possibility of spill current that may arise from slight mismatches between residually connected line CT's. It also enables a much lower CT ratio to be applied, thereby allowing the required protection sensitivity to be more easily achieved.

2.5.4.2   Calculation of Required Relay Settings:

As has been previously shown, 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, as stated in the previous section, 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 total unbalance current detected by the relay is equal to three times the per phase charging current of the faulted circuit. A typical relay 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. Practically though, the required setting may well be determined on site, where system faults can be applied and suitable settings can be adopted based on practically obtained results.

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

The above also holds true regarding the required Relay Characteristic Angle (RCA) setting. As has been shown earlier, a nominal RCA setting of 0° is required. However, fine tuning of this setting is required on site to obtain the optimum setting in accordance with the levels of coil and feeder resistances present. The loading and performance of the CT has an effect in this regard. The effect of CT magnetizing current creates phase lead of current. While this assists with operation of faulted feeder relays it reduces the stability margin of healthy feeder relays. A compromise can therefore be reached through fine adjustment of the RCA. This is adjustable in 1° steps on the P24x relays.

2.6   Residual Overvoltage (Neutral Displacement) Protection (59N)

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.

Therefore, it can be seen that the detection of a residual overvoltage condition is an alternative means of earth fault detection which does not require any measurement of current. This may be particularly advantageous in high impedance earthed / insulated systems, where the provision of core balance CT's on each feeder may be either impractical or uneconomic.

Note: Where residual overvoltage protection is applied, such a voltage is generated for a fault occurring anywhere on that section of the system and so the applied protection must be discriminative. The NVD element within the P24x relay is of two stage design, each stage having separate voltage and time delay settings. Stage 1 may be set to operate on either an IDMT or DT characteristic, whilst stage 2 may be set to DT only.

The IDMT characteristic available on the first stage is defined by the following formula:

$t = TMS / (1 - M)$

Where;

TMS = Time Multiplier Setting

t = Operating Time in Seconds

M = Derived Residual Voltage / Relay Setting Voltage

Two stages are included for this NVD protection to account for applications which require both alarm and trip stages. In such applications, an alarm is usually required to be generated soon after the condition is detected which simply serves to indicate the presence of an earth fault on the system. The system has been designed to withstand the associated healthy phase overvoltages for several hours following fault inception. This therefore gives time for system operators to find and remove the fault condition.

This element should be driven from residual voltage (-3Vo). This can be derived from either the three phase VT inputs to the relay or the residual voltage input. The **VT Connect Mode, 3VT, 2VT+VResidual, 2VT+Vremanent** can be selected in the **CT and VT Ratios** menu.

Different VT ratio settings for the three modes of connection are available.
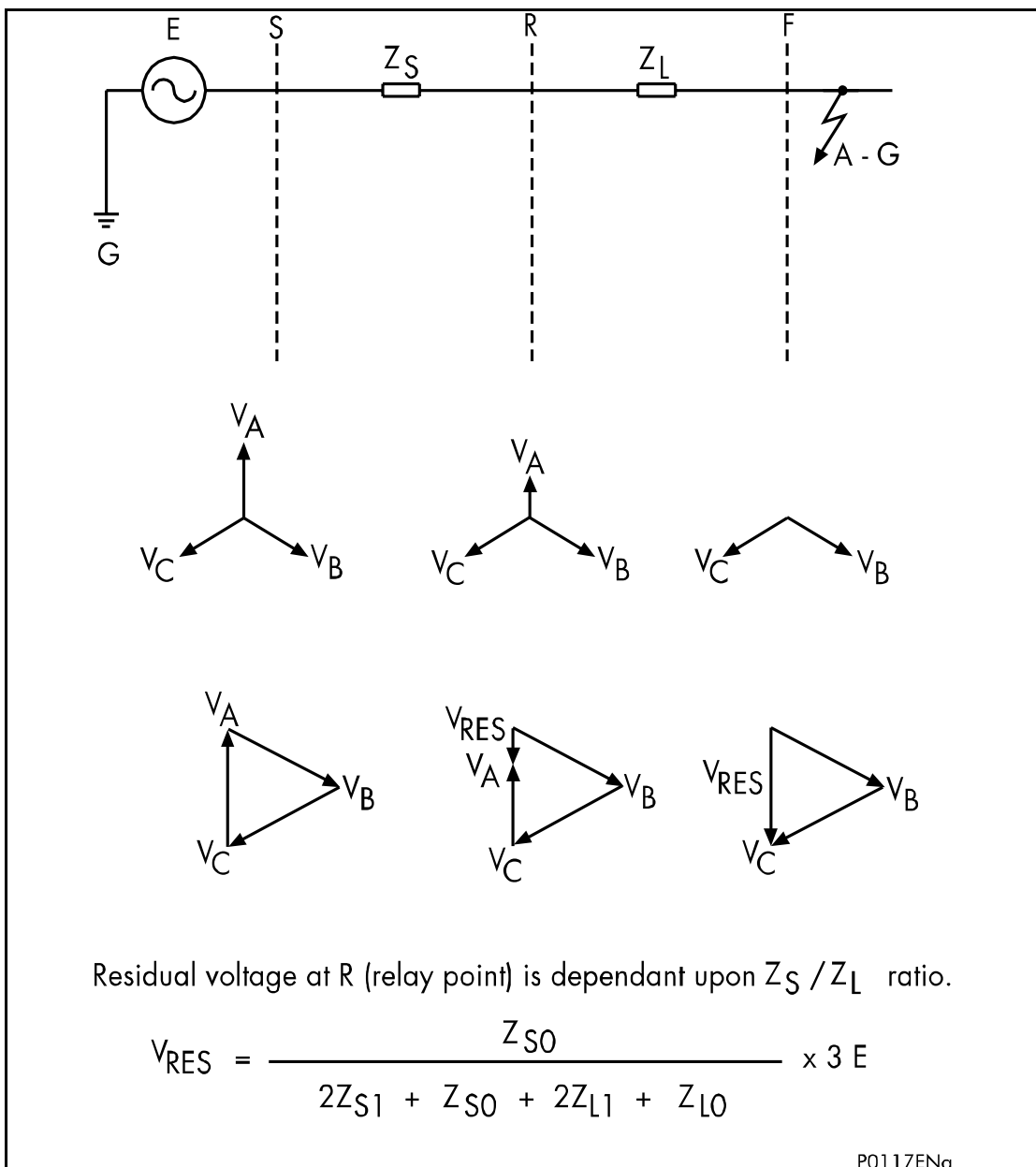
Figure 18: Residual voltage

$$V_{RES} = \frac{Z_{S0} + 3Z_E}{2Z_{S1} + Z_{S0} + 2Z_{L1} + Z_{L0} + 3Z_E} \times 3E$$

P0118ENa
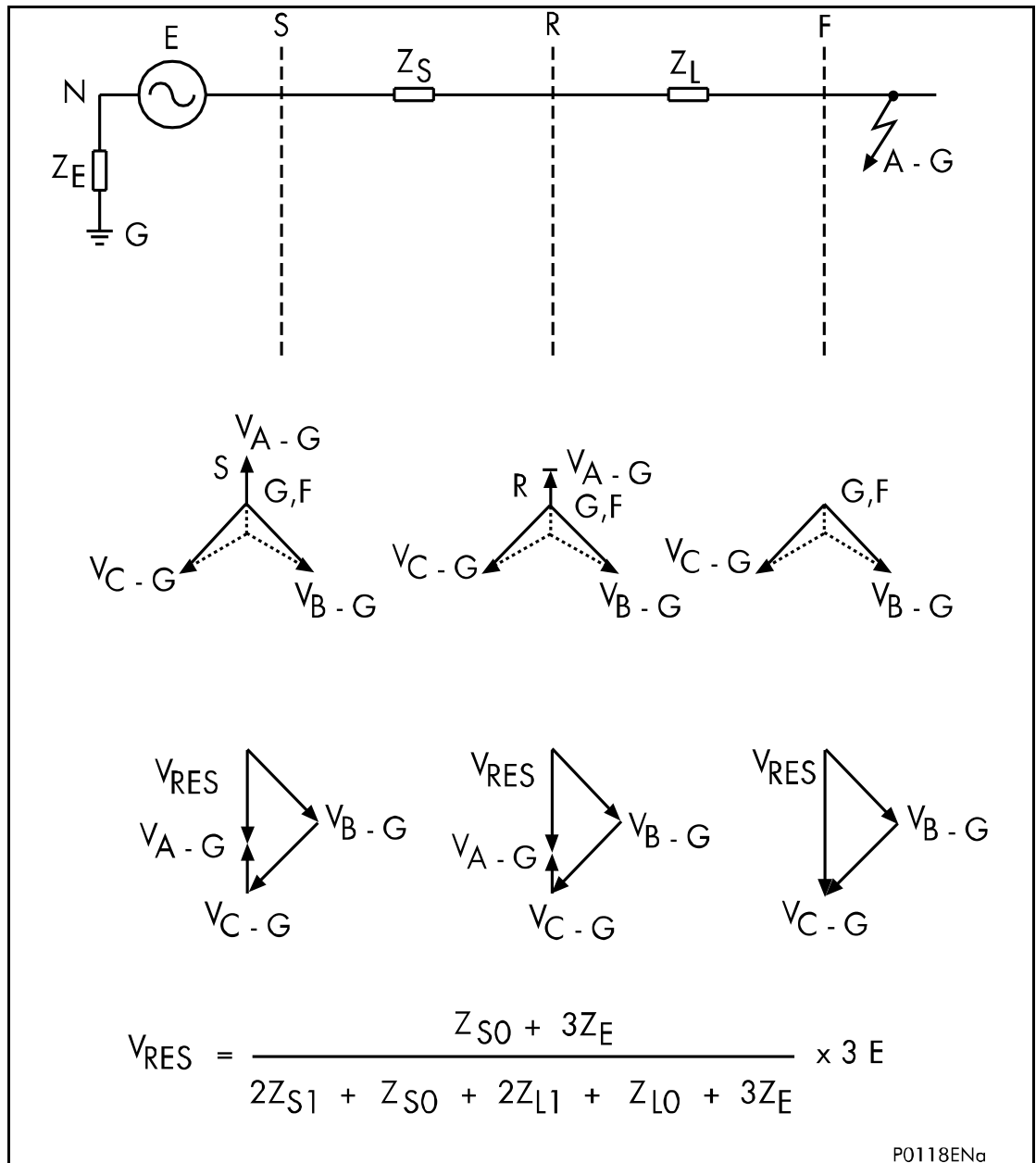
Figure 19: Residual voltage

2.6.1 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 and is therefore application dependent. Figure 18 shows the formula used in calculating the expected residual voltage occurring for an earth fault on a resistance earthed system.

Note: The IDMT characteristics are selectable on the first stage of NVD so that elements located at various points on the system may be time graded with one another.

2.7 **Negative Sequence Protection (46)**

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 Figure 20, the magnetizing impedance being neglected.
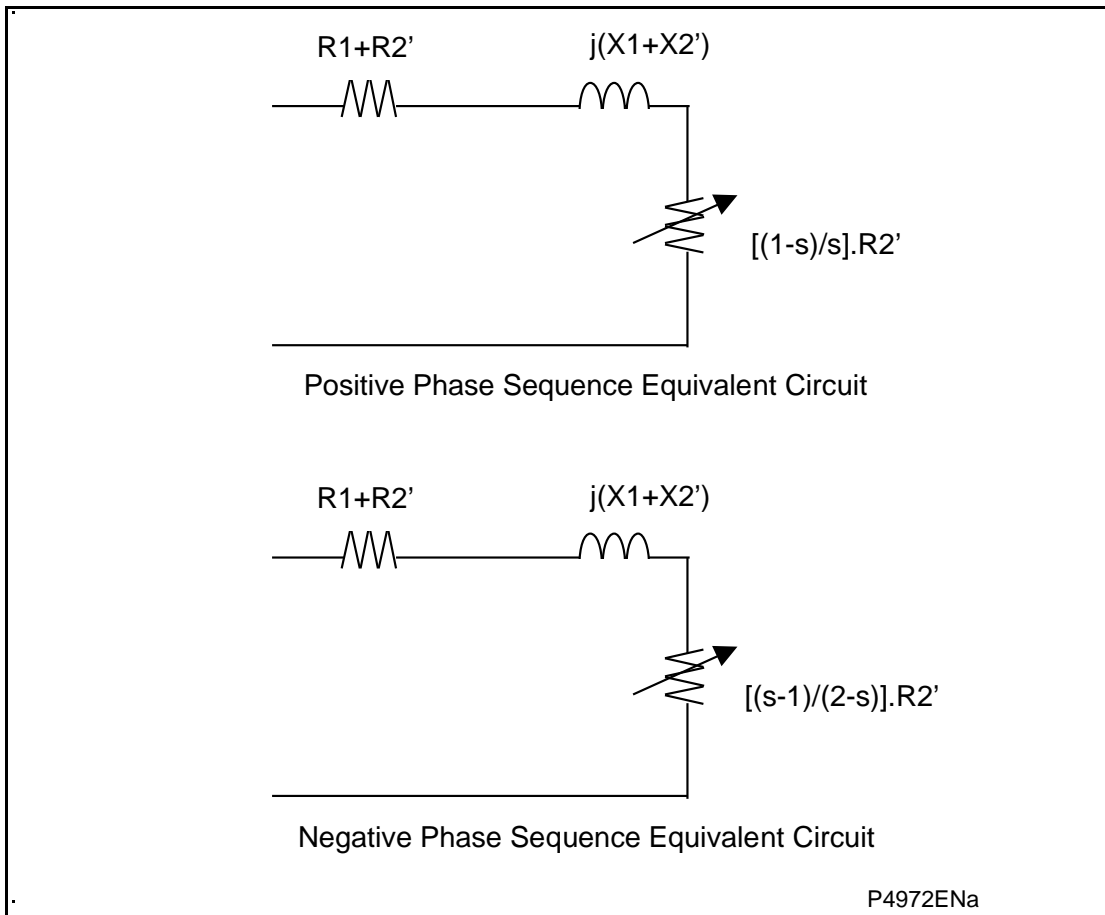
Figure 20: Equivalent circuits

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:

$[(R_1 + R'_2/2\text{-}s)^2 + (X_1 + X'_2)^2]^{0.5}$

That means: $[(R_1 + R'_2)^2 + (X_1 + X'_2)^2]^{0.5}$ when s = 1 at standstill.

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

$[(R_1 + R'_2/s)^2 + (X_1 + X'_2)^2]^{0.5}$

That means: $[(R_1 + R'_2/2)^2 + (X_1 + X'_2)^2]^{0.5}$ when s << 1 at normal running speed.

Where;

PPS   = positive phase sequence

NPS   = negative phase sequence

R_1 = PPS Stator Resistance

R'_1 = PPS Rotor Resistance Referred to Stator

X_1 = PPS Rotor Reactance

X'_1 = PPS Rotor Reactance Referred to Stator

R_2 = NPS Stator Resistance

R'$_2$ = NPS Rotor Resistance Referred to Stator

X$_2$ = 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 P24x 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.

2.7.1 Loss of One Phase While Starting & 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 P24x 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)]   for I2/Is ≤ 2

t = TMS * 0.6   for I2/Is >2

The element may be selectively enabled or disabled.

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

2.7.1.1   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.

2.8   3 Phase Voltage Check (Reverse Phase Detection) (47/27) 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 P24x 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.

2.8.1   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.

2.9   Start / Stall Protection (48/51LR/50S/14)

When a motor is started, 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 this condition it is possible to discriminate on a time basis between the two conditions and therefore provide protection against stalling.

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However, where motors are used to drive high inertia loads, the stall withstand time may be less than the starting time. In such cases, it is not possible to discriminate between start and stall conditions by time alone.

The P24x relay provides extensive start and stall protection, in order that all of the aforementioned conditions may 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.

2.9.1 Excessive Start Time/Locked Rotor Protection - Stall Time > Start Time (51LR)

A motor may fail to accelerate for several 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: DDB 104) 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. See the Operation chapter, *P24x/EN OP*, for detailed information.

2.9.1.1 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 x Ith = 882A

Prolonged start time   = 12 seconds.

These settings are shown in Figure 1.

2.9.2 Stall Protection (50S) Principle

An induction motor may stall for several 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.

2.9.2.1 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 x I_{th} = 882 A

Stall Time   = 6 seconds

These settings are shown in Figure 1.

2.9.3 Excessive Start Time/Locked Rotor Protection - Stall Time < Start Time (14)

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, therefore 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 therefore able to tolerate starting current for the starting time, but not locked rotor current.

The above description explains why, for certain applications, such as motors driving high inertia loads, the stall withstand time may be safely exceeded during starting, without resulting in an overtemperature condition within the motor. Therefore , 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: DDB 104) in conjunction with measurement of the phase current to detect a safe start.

2.9.3.1 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-str** needs to be set to **Enabled** for this function to operate.

2.9.4 Number of Starts Limitation (66)

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

The P24x relay incorporates several starts limitation facilities. This limitation is fully programmable and is applicable to both hot and cold start conditions. A hot start is defined by a thermal state greater than 50% and a cold start is defined as a thermal state lower than 50%.

Restarting the motor from a hot thermal state:

For certain applications, it is not desirable to allow the motor time to cool down to a specified thermal state before a re-start is permitted. The P24x 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 "Measurement 3" menu is initiated each time the switching device is closed and remains closed.

2.9.5 Anti-Backspin Protection (27 Abs)

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 **2 VT + Vremanent**, then the function uses an undervoltage with the connected Phase-Phase remanent voltage. If not, the function uses only a time delay.

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2.9.6   ABS Protection Setting Guidelines

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

If the **VT connecting mode** is set to **2 VT + Vremanent** the time delay **Antibacks Delay** must be set to an adequate time for the motor to stop after and the remanent voltage has dropped below the **VRem Antibacks** setting following a trip.

If **the VT connecting mode is not set to 2 VT + Vremanent** then the time delay **Antibacks 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.

2.9.7   Momentary Reduction in System Voltage During Running of the Motor

In cases 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 (corresponding to "Reac Time", "Reac Long Time" and "Reac Shed Time" respectively of P24x relay designations).

- Short falls are intended to cover situations when it is appropriate to authorize reacceleration of the rotor and not to issue a trip order after voltage restoration is detected via a settable under voltage threshold.

- Medium falls are intended to cover situations for when the voltage has not been recovered within a set short time detected via a settable over voltage threshold and the motor has tripped as a result, but 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 are intended to 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 of approximately the same value as that of the locked rotor current, its duration being relative to the magnitude of the fall in voltage and the duration of the fall in voltage.

2.9.7.1 Low Voltage Protection (Reacceleration Authorization)

Following a transient dip in the supply voltage, a motor will attempt to re-accelerate. Under these circumstances it will draw a level of current exceeding the relay stall protection threshold, (**Stall Setting**). Therefore , for successful re-acceleration the P24x 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 would result in each of them attempting reacceleration. Subsequently, a large current is drawn from the supply, therefore further reducing the supply voltage, resulting in potential stalling of all machines. This would 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.

2.9.7.2 AUTO RE-START Authorization: Re-start/load restoration

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 for 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 for 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) and after a trip order has been issued (due to the supply voltage not being restored within the time interval of T_{reac}), the P24x relay initiates $T_{reac-long}$ time-delay.

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.

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2.10 Undervoltage Protection Function (27) Principle

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

The undervoltage protection included within the P24x relays consists of two independent phase to phase measuring stages.

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

The inverse characteristic is given by the following formula;

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

Where;

TMS = Time Multiplier Setting

t = operating time in seconds

M = Applied input voltage/Relay setting voltage

2.10.1 Setting Guidelines

The voltage threshold setting for the undervoltage protection should be set at some value below the voltage excursions which 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.

Similar comments apply with regard to a time setting for this element that is the required time delay is dependent on the time for which the motor is able to withstand depressed voltage. A typical time setting may be 0.5 seconds.

The setting **Inhibit 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.

2.11 Loss-of-load Protection (37) Principle

To detect loss of motor load the P24x relay includes a low forward power element. It can be used to protect electric pumps against becoming unprimed or to stop a motor in the event of a failure in the mechanical transmission.

> **Note:** A low forward power condition can only be established when the circuit breaker is closed and the active power calculated is above zero.

Where rated power cannot be reached during starting (for example where the motor is started with no connected load) it is necessary to inhibit this function for a set time.

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

2.11.1 Setting Guidelines

The setting of this element is very much system dependent. However, it is typically set to 10-20% below minimum load.

Referring to the previous example details, the motor rated power is:

$P = \sqrt{3} \times 293 \times 11000 = 5.6$ MVA

Assuming that minimum loading may be 70%, the minimum power threshold may be set to 80% of this value i.e. 300 kW.

P< Power Set = 300 kW

The time delay, **P<Drop-off time**, should be set in excess of the time between motor starting and the load being established.

The time delay on pickup, **P<Time Delay**, is application dependent.

2.12 Synchronous Motor Protection

In the majority of applications, a synchronous motor would be started as an induction motor. If this is the case the aforementioned protection elements apply equally to both induction and synchronous motors. However, for the complete protection of synchronous motors, additional protective features are required. These features are discussed in the following sections.

2.12.1 Out-of-step Protection (Under Power Factor) (55)

A synchronous motor may decelerate and fall out of step when it is subjected to a mechanical overload exceeding its maximum available output. It may also lose synchronism from a fall in the field current or supply voltage. An out-of-step condition subjects the motor to undesirable overcurrent and pulsating torque, leading to eventual stalling.

When loss of synchronism is detected the motor must be disconnected from the supply.

On loss of synchronism a heavy current at a very low power factor is drawn from the supply. The P24x is able to monitor this change in power factor when the motor pole slips, therefore allowing appropriate action to be taken. If the power factor passes under a defined threshold for a defined time, a trip is generated.

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

2.12.2 Setting Guidelines:

The ability of a motor to run at a low power factor is design dependent.

For a unity power factor machine, the following settings are typical:

Power factor = 0.9,

Time delay = 50 ms,

Drop-off time delay = 1 or 2 seconds above the start time of the machine.

However, some machines are designed to operate at power factors as low as 0.7, in this case the settings have to be adjusted accordingly.

2.12.3 Reverse Power (loss-of-supply) (32R)

On loss of supply, a synchronous motor should be disconnected if the supply is restored automatically or without the machine operator's knowledge. This is to avoid the possibility of the supply being restored out of phase with the motor generated emf.

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

2.12.4 Underfrequency (81U)

If the motor is loaded, it decelerates fairly quickly on loss of supply and the frequency of the terminal voltage falls. The P24x relay can detect the fall in frequency and take appropriate action. This underfrequency element is a two stage device, which can be used for both alarm and trip purposes.

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

2.12.4.1 Setting Guidelines:

This setting is very much system dependent, since it may be possible for the frequency of the supply to deviate during normal conditions.

Small source frequency changes may arise following power transmission disturbances or immediately following a sudden increase in system loading. Significant frequency variations are relatively rare for large interconnected power systems. In some regions of the world, significant drops in system frequency have been experienced due to unavoidable deficit of generation during peak load periods.

So as not to trip the motor unnecessarily, it is therefore important to determine the minimum system frequency and set the underfrequency element below this value.

2.12.5 Overvoltage (59)

If the supply busbars have no other load connected and the motor is not loaded, on loss-of-supply the motor terminal voltage could rise instantaneously to 20-30% due to the open circuit regulation of the machine.

The P24x relay has an overvoltage feature which can be used to detect this condition. It consists of two independent definite time measuring elements which measure phase-phase voltage.

2.12.5.1 Setting Guidelines:

The setting is very much system dependent. However, it would typically be set to 15% above rated voltage. Therefore for a 110 V VT, the relay setting would be 1.15 x 110 = 126.5 V. The timer would be motor design and application dependent.

2.13 Field Failure Protection Function (40)

Complete loss of excitation may arise as a result of accidental tripping of the excitation system, an open circuit or short circuit occurring in the excitation DC circuit, flashover of any slip rings or failure of the excitation power source. The field failure protection of the P24x consists of two elements, an impedance element with two time delayed stages and a power factor alarm element.

When the excitation of a synchronous motor fails not enough synchronizing torque is provided to keep the rotor locked in step with the stator rotating magnetic field. The machine would then be excited from the power system and so be operating as an induction motor.

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This results in an increasing level of reactive power being drawn from the power system at a highly lagging power factor. If the field excitation is too low to meet the load requirements the synchronous motor can pole slip. An out-of-step (pole slip) condition subjects the motor to undesirable overcurrent and pulsating torque, leading to eventual stalling.

Operation as an induction motor under field failure conditions relies on the ability of the rest of the system being able to supply the required reactive power to the machine. If the system cannot supply enough reactive power the system voltage drops and the system may become unstable. This could occur if a large motor running at high power suffers a loss of field when connected to a relatively weak system. To ensure fast tripping under this condition one of the impedance elements can be used with a short time delay. This can trip the machine quickly to preserve system stability. This element should have a small diameter to prevent tripping under power swinging conditions. The second impedance element, set with a larger diameter, can provide detection of field failure under lightly loaded conditions. This second element should be time delayed to prevent operation during power swing conditions.

The P24x offers a power factor alarm element in the field failure protection which can operate when the motor is running at a lagging power factor caused by a loss of excitation. There is also a dedicated out of step protection function based on power factor measurement, see section 2.11.1

For large motors impedance based loss of excitation is recommended which provides improved protection for partial loss of field in addition to complete loss.

The field failure protection impedance elements are also provided with an adjustable delay on reset (delayed drop off) timer. This time delay can be set to avoid delayed tripping that may arise as a result of cyclic operation of the impedance measuring element, during the period of pole slipping following loss of excitation.

Some care would need to be exercised in setting this timer, since it could make the field failure protection function more likely to give an unwanted trip in the case of stable power swinging. The impedance element trip time delay should therefore be increased when setting the reset time delay.

2.13.1 Setting Guidelines

Each stage of field failure protection may be selected as **Enabled** or **Disabled**, within the **FFail1 Status, FFail2 Status** cells. The power factor alarm element may be selected as Enabled or Disabled within the **FFail Alm** Status cell.

2.13.1.1 Impedance Element 1

To quickly detect a loss-of field condition, the diameter of the field failure impedance characteristic (**FFail1 Xb1**) should be set as large as possible, without conflicting with the impedance that might be seen under normal stable conditions or during stable power swing conditions.

Where a motor is operated with a rotor angle of less than 90° and never at a leading power factor, it is recommended that the diameter of the impedance characteristic, **FFail1 Xb1**, is set equal to the machine direct-axis synchronous reactance. The characteristic offset, **FFail1 Xa1** should be set equal to half the direct-axis transient reactance (0.5Xd') in secondary ohms.

FFail1 Xb1   = Xd

FFail1 Xa1   = 0.5 Xd'

Where:

Xd = machine direct-axis synchronous reactance in ohms

Xd' = machine direct-axis transient reactance in ohms

Where high-speed voltage regulation equipment is used it may be possible to operate motors at rotor angles up to 120°. In this case, the impedance characteristic diameter, **FFail1 Xb1**, should be set to 50% of the direct-axis synchronous reactance (0.5Xd) and the offset, **FFail1 Xa1**, should be set to 75% of the direct axis transient reactance (0.75Xd').

FFail1 Xb1   = 0.5 Xd

FFail1 Xa1 = 0.75 Xd'

The field failure protection time delay, **FFail1 Time Delay**, should be set to minimize the risk of operation of the protection function during stable power swings following system disturbances. However, make sure the time delay is not so long that stator winding or rotor thermal damage occurs. A typical stator winding should be able to withstand a current of 2.0 p.u. to t 15 s. It may also take some time for the impedance seen at the generator terminals to enter the characteristic of the protection. A time delay less than 10 s would typically be applied. The minimum permissible delay, to avoid problems of false tripping due to stable power swings with the above impedance settings, would be of the order of 0.5 s.

The protection reset (delayed drop off) timer, **FFail1 DO Timer**, would typically be set to 0 s to give instantaneous reset of the stage. A setting other than 0 s can be used to provide an integrating function for instances when the impedance may cyclically enter and exit the characteristic. This can allow detection of pole slipping conditions. When settings other than 0 s are used the protection pick-up time delay, **FFail1 Time Delay**, should be increased to prevent mal-operation during stable power swing conditions.

It is desirable not to trip on the impedance field failure element until the field has been applied. Therefore, this feature can be selectively blocked in the PSL (**FFail Block**: DDB 117) until the motor comes up to speed and the field is applied.

2.13.1.2 Impedance Element 2

The second impedance element can be set to give fast operation when the field fails under high load conditions. The diameter of the characteristic, **FFail2 Xb2**, should be set to 1 p.u. The characteristic offset, **FFail2 Xa2**, should be set equal to half the direct-axis transient reactance (0.5Xd').

$$\text{FFail2 Xb2} = \frac{kV^2}{MVA}$$

FFail2 -Xa2 = 0.5 Xd'

This setting detects a field failure condition from full load to about 30% load.

The time delay, **FFail2 Time Delay**, can be set to instantaneous, such as 0 s.

The protection reset (delayed drop off) timer, **FFail2 DO Timer**, would typically be set to 0 s to give instantaneous reset of the stage. A setting other than 0 s can be used to provide an integrating function for instances when the impedance may cyclically enter and exit the characteristic. This can allow detection of pole slipping conditions. When settings other than 0 s are used the protection pick-up time delay, **FFail2 Time Delay**, should be increased to prevent mal-operation during stable power swing conditions.

It is desirable not to trip on the impedance field failure element until the field has been applied. Therefore, this feature can be selectively blocked in the PSL (FFail Block: DDB 117) until the motor comes up to speed and the field is applied.

2.13.1.3 Power Factor Element

The power factor alarm can be used to signal to the operator that excitation has failed.

The angle setting, **FFail Alm Angle**, should be set to greater than any angle that the machine could be operated at in normal running. A typical setting would be 25°, equivalent to a power factor of 0.9 lagging. The power factor element time delay, **FFail Alm. Delay**, should be set longer than the (**FFail1 Time Delay**). This is to prevent operation of the alarm element under transient conditions such as power swinging and to provide discrimination with the conventional field failure impedance elements.

2.14   Circuit Breaker Failure Protection (50BF)

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.

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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.

2.14.1 Breaker Failure Protection Configurations

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, **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 backtrip upstream switchgear, generally tripping all infeeds connected to the same busbar section.

- A re-tripping scheme, plus delayed backtripping. Here, **CB Fail 1 Timer** is used to route a trip to a second trip circuit of the same circuit breaker. This requires duplicated circuit breaker trip coils, and is known as re-tripping. Should re-tripping fail to open the circuit breaker, a backtrip may be issued following an additional time delay. T he backtrip uses **CB Fail 2 Timer**, which is also started at the instant of the initial protection element trip.

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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.

2.14.2 Reset Mechanisms for Breaker Fail Timers

It is common practice to use low set undercurrent elements in protection relays to indicate that circuit breaker poles have interrupted the fault or load current, as required. 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 relay uses operation of undercurrent elements (I<) 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 circuit breaker fail in all applications. For example:

Where non-current operated protection, such as under/overvoltage or underfrequency, 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. 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.

You can reset the CBF from a breaker open indication or from a protection reset. In these cases resetting is only allowed if the undercurrent elements have also been reset.

The resetting options are summarized in the following table:

Initiation (menu selectable)	CB fail timer reset mechanism
Current based protection	The resetting mechanism is fixed (50/51/46/87..) IA< operates AND IB< operates AND IC< operates AND
Non-current based protection (27/59/81/32R..)	Three options are available: operate operate
External protection	Three options are available: operate ip reset AND all I< and IN< elements operate operate

Table 8: CBF resetting options

2.14.3   Typical Breaker Fail Timer Settings

Typical timer settings to use are as follows:

CB fail reset mechanism	tBF time delay	Typical delay for 2½ 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 + safety margin	50 + 10 + 50 = 110 ms in tBF timer
Undercurrent elements	CB interrupting time + undercurrent element (max.) + operating time	50 + 12 + 50 = 112 ms safety margin

Table 9: Typical CBF timer settings

Note: All CB Fail resetting involves the operation of the undercurrent elements. Where element reset or CB open resetting is used the undercurrent time setting should still be used if this proves to be the worst case.

The examples above consider direct tripping of a 2½ cycle circuit breaker.

Note: Where auxiliary tripping relays are used, an additional 10-15 ms must be added to allow for trip relay operation.

2.15   Current Loop Inputs and Outputs

2.15.1   Current Loop Inputs

Four analog inputs are provided for transducers with ranges of 0 - 1 mA, 0 - 10 mA, 0 - 20 mA or 4 - 20 mA. Each input can be configured to accept any one of these ranges. Associated with each input are two protection stages; one for alarming and the other for tripping. Each stage can be individually enabled or disabled and each stage has a definite time delay setting.

2.15.1.1 Setting Guidelines

For each analog input, you can define the following:

- The current input range: 0 - 1 mA, 0 - 10 mA, 0 - 20 mA, 4 - 20 mA

- The analog input unit (A, V, Hz, W, Var, VA, °C, F, %, s, none)
- Analog input minimum value
- Analog input maximum value
- Alarm threshold, range within the maximum and minimum set values
- Alarm delay
- Trip threshold, range within maximum and minimum set values
- Trip delay

Each current loop input can be selected as Enabled or Disabled. The Alarm and Trip stages operate when the input current is above the input value. One of four types of analog inputs can be selected for transducers with ranges of 0 - 1 mA, 0 - 10 mA, 0 - 20 mA or 4 - 20 mA.

The Maximum and Minimum settings allows you to enter the range of physical or electrical quantities measured by the transducer.

The user can select the unit of the measurement - None, A, V, Hz, W, Var, VA, °C, F, %, s. For example, if the analog input is used to monitor a power measuring transducer, the appropriate unit would be W.

You need to set the alarm and trip thresholds within the range of physical or electrical quantities. The device will convert the current input value to its corresponding transducer measuring value for the protection calculation.

For example if the Minimum is −1000 and the Maximum is 1000 for a 0 - 10 mA input, an input current of 10 mA is equivalent to a measurement value of 1000, 5 mA is 0 and 1mA is −800. If the Minimum is 1000 and the Maximum is -1000 for a 0 - 10 mA input, an input current of 10 mA is equivalent to a measurement value of −1000, 5 mA is 0 and 1 mA is 800.

These values are available for display in the **Analog Input 1/2/3/4** cells in the **MEASUREMENTS 3** menu.

2.15.2   Current Loop Outputs

Four analog current outputs are provided with ranges of 0 - 1 mA, 0 - 10 mA, 0 - 20 mA or 4 - 20 mA which can alleviate the need for separate transducers. These may be used to feed standard moving coil ammeters for analog indication of certain measured quantities or into a SCADA using an existing analog RTU.

The outputs can be assigned to any of the following relay measurements:

- Magnitudes of IA, IB, IC, IN
- IA RMS, IB RMS, IC RMS
- Magnitudes of VAB, VBC, VCA, VAN, VBN, VCN, VN
- VAN RMS, VBN RMS, VCN RMS
- Frequency
- Three-phase active, reactive and apparent power, Three-phase power factor
- RTD temperatures
- Number of Hot Starts Allowed, Thermal State, Time to Thermal Trip, Time to Next Start

The user can set the measuring range for each analog output. The range limits are defined by the Maximum and Minimum settings. This allows the user to "zoom in" and monitor a restricted range of the measurements with the desired resolution. The voltage, current and power quantities are in primary quantities.

2.15.3   Setting Guidelines

One of four types of analog output can be selected for transducers with ranges of 0 - 1 mA, 0 - 10 mA, 0 - 20 mA or 4 - 20 mA. The 4 - 20 mA range is often used so that an output current is still present when the measured value falls to zero. This is to give a fail safe indication and may be used to distinguish between the analog transducer output becoming faulty and the measurement falling to zero.

The Maximum and Minimum settings allow you to enter the measuring range for each analog output. The range, step size and unit corresponding to the selected parameter is shown in

the table in the Operating chapter, *P24x/EN OP*. This allows the user to "zoom in" and monitor a restricted range of the measurements with the desired resolution.

The voltage, current and power quantities are in primary quantities. The relationship of the output current to the value of the measurand is of vital importance and needs careful consideration. Any receiving equipment must be used within its rating but, if possible, some kind of standard should be established.

One of the objectives is to monitor the voltage over a range of values, so you need an upper limit, for example, 120%. However, this may lead to difficulties in scaling an instrument.

The same considerations apply to current transducers outputs and with added complexity to watt transducers outputs, where both the voltage and current transformer ratios must be taken into account.

Some of these difficulties do not need to be considered if the transducer is only feeding, for example, a SCADA outstation. Any equipment which can be programmed to apply a scaling factor to each input individually can accommodate most signals. The main consideration is to ensure that the transducer is capable of providing a signal right up to the full-scale value of the input.

2.16   Phase Rotation

A facility is provided in the P241/242/243 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 two setting groups.

The default phase sequence for P24x 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). The motor differential protection is not affected, since the phase reversal applies to CT1 and CT2 in the same way.

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3   APPLICATION OF NON-PROTECTION FUNCTIONS

3.1   VT 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 device 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.

3.1.1   Setting the VT Supervision Element

If the VT supervision is enabled the following operations occur on detection of VTS.

- VTS provides alarm indication.
- Blocking of voltage dependent protection elements.
- The VTS block is latched after a user settable time delay 'VTS Time Delay'. Once the signal has latched then resetting is available, provided the VTS condition has been removed and the 3 phase voltages have been restored above the phase level detector settings or CB has been opened.

The **VTS I> Inhibit** overcurrent setting is used to inhibit the voltage transformer supervision in the event of a loss of all 3 phase voltages caused by a close up 3 phase fault occurring on the system following closure of the CB to energize the line. This element should be set in excess of any non-fault based currents on line energization (load, line charging current, transformer inrush current if applicable) but below the level of current produced by a close up three-phase fault.

This **VTS I2> Inhibit** NPS overcurrent setting is used to inhibit the voltage transformer supervision in the event of a fault occurring on the system with negative sequence current above this setting

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

The delta (superimposed) phase current setting is used to distinguish between a close up 3 phase fault and a 3 phase VT failure condition under load conditions. For a close up 3 phase fault there is a loss of 3 phase voltage but there will be a delta change in the measured current. For a 3 phase VT failure where there will a loss of 3 phase voltage but no delta change in the measured current.

The **Delta I>** superimposed current setting is used to detect the change in current for a close up 3 phase fault when the CB is closed and block the VTS. This element should be set less than the superimposed current due to a 3 phase fault. The default setting of 0.1In is adequate for the majority of applications.

The **Threshold 3P** undervoltage setting is used to indicate a loss of 3 phase voltage that could be caused by a 3 phase VT fail condition or a close up 3 phase fault. The default setting of 30 V is adequate for the majority of applications.

3.2   CT 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.

3.2.1   Setting the CT Supervision Element

The residual voltage setting, **CTS1/2 Vn< Inhibit** and the residual current setting, **CTS1/2 In> set**, should be set to avoid unwanted operation during healthy system conditions.

For example **CTS1/2 Vn< Inhibit** should be set to 120% of the maximum steady state residual voltage. The **CTS1/2 In> set** is typically set below minimum load current. The time-delayed alarm, **CTS1/2 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 a protection elements being blocked during fault conditions.

3.3   Trip Circuit Supervision (TCS)

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.

Several trip circuit supervision schemes with various features can be produced with the P24x range. Although there are no dedicated settings for TCS, in the P24x, the following schemes can be produced using the programmable scheme logic (PSL). A user alarm is used in the PSL to issue an alarm message on the relay front display. If necessary, the user alarm can be renamed using the menu text editor to indicate that there is a fault with the trip circuit.

3.3.1   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 contact is the opposite.

Figure 21: 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.

3.3.1.1 Resistor Values

Resistor R1 is an optional resistor that can be fitted to prevent mal-operation of the circuit breaker if the opto input is inadvertently shorted, by limiting the current to <60 mA. The resistor should not be fitted for auxiliary voltage ranges of 30/34 volts or less, as satisfactory operation can no longer be guaranteed. The table below shows the appropriate resistor value and voltage setting (OPTO CONFIG menu) for this scheme.

This TCS scheme functions correctly even without resistor R1, since the opto input automatically limits the supervision current to less that 10 mA. However, if the opto is accidentally shorted the circuit breaker may trip.

Auxiliary voltage (Vx)	Resistor R1 (ohms)	Opto voltage setting with R1 fitted
24/27	-	-
30/34	-	-
48/54	1.2 k	24/27
110/250	2.5 k	48/54
220/250	5.0 k	110/125

Table 10: Recommended resistor value and opto voltage settings

> **Note:** When R1 is not fitted the opto voltage setting must be set equal to supply voltage of the supervision circuit.

3.3.2 PSL for TCS Scheme 1
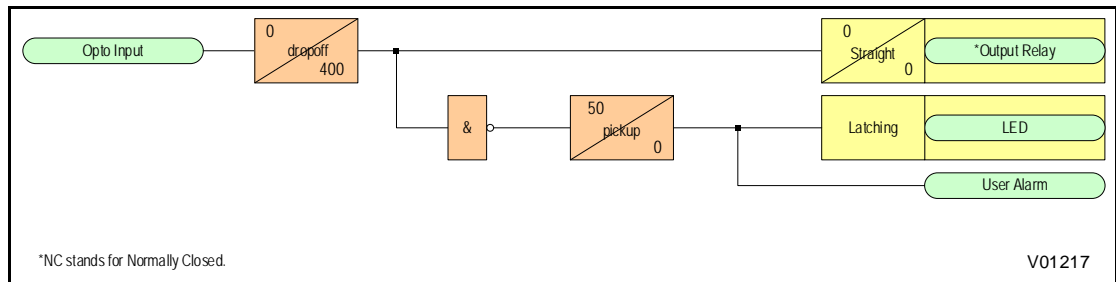
Figure 22: PSL for TCS schemes 1

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 relay power up time, following an auxiliary supply interruption.

3.3.3 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 device to correctly monitor the circuit breaker status since they are connected in series with the CB auxiliary contacts. This is achieved by assigning one option put to the 52a contact and another opto-input to the 52b contact. Provided opto's A and B are connected to **CB Closed 3 Ph** (DDB 105) and **CB Open 3ph** (DDB 106) the device will correctly monitor the status of the breaker. This scheme is also fully compatible with latched contacts as the supervision current is maintained through the 52b contact when the trip contact is closed.
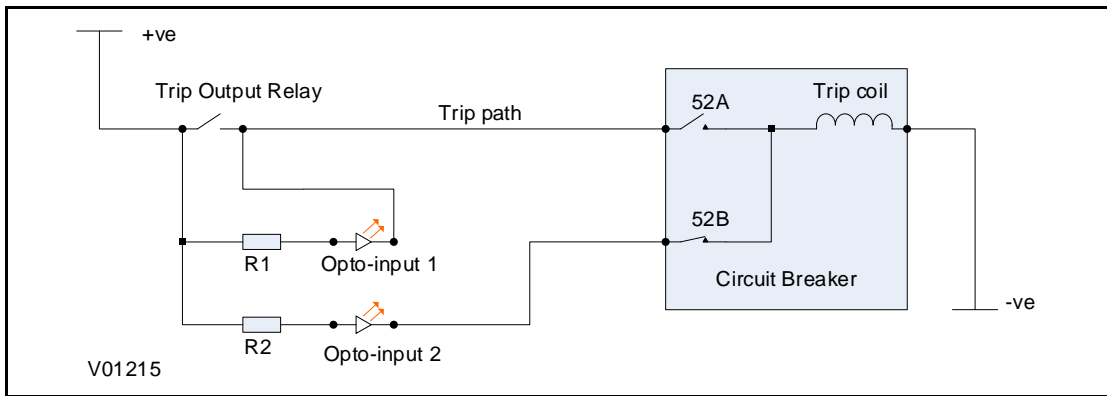
Figure 23: TCS scheme 2

When the breaker is closed, supervision current passes through opto input A and the trip coil. When the breaker is open current flows through opto input B 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.

3.3.3.1   Resistor Values

Optional resistors R1 and R2 can be added to prevent tripping of the CB if either opto is shorted. The resistor values of R1 and R2 are equal and can be set the same as R1 in scheme 1.

3.3.4   PSL for TCS Scheme 2
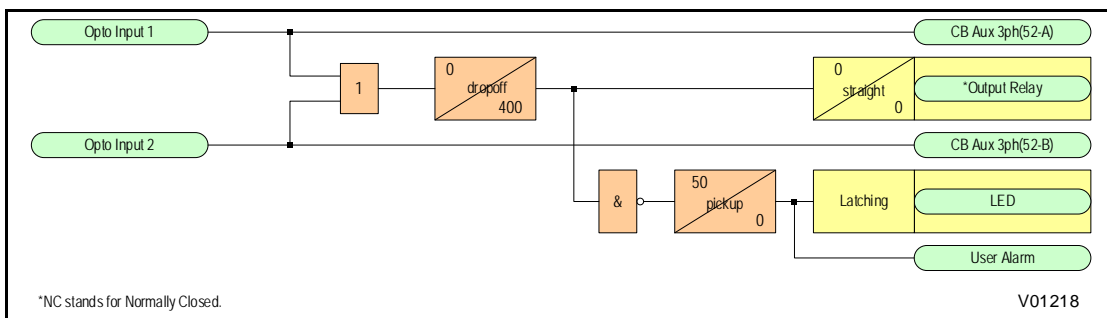
Figure 24: PSL for TCS scheme 2

In TCS scheme 2, both opto-inputs must be low before a trip circuit fail alarm is given.

3.3.5   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 preclosing 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.
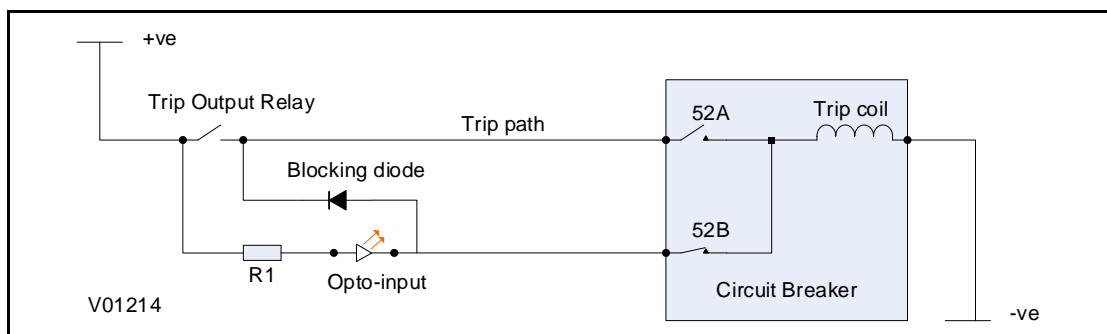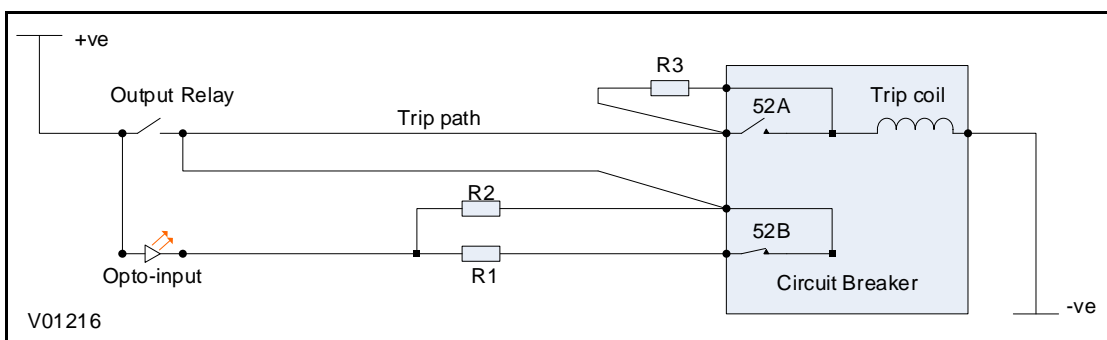

Figure 25: TCS scheme 3

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.

3.3.5.1 Resistor Values

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.

Auxiliary voltage (Vx)	Resistor R1 & R2 (ohms)	Resistor R3 (ohms)	Opto voltage setting
24/27	-	-	-
30/34	-	-	-
48/54	1.2 k	0.6 k	24/27
110/250	2.5 k	1.2 k	48/54
220/250	5.0 k	2.5 k	110/125

Table 11: Recommended resistor value and opto voltage settings

Note: Scheme 3 is not compatible with auxiliary supply voltages of 30/34 volts and below.

3.3.6 PSL for TCS Scheme 3
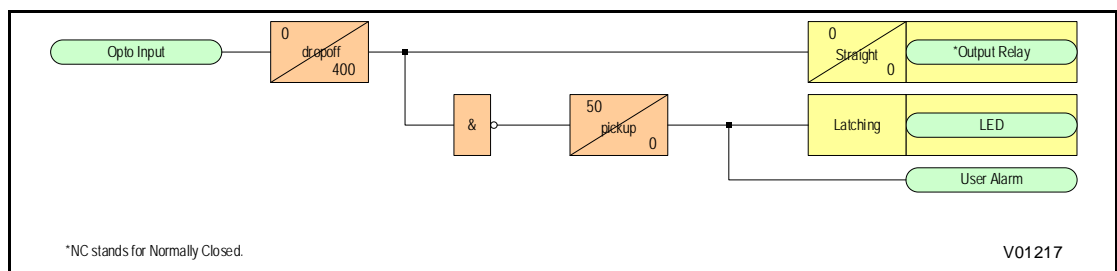
Figure 26: PSL for TCS schemes 3

4   CURRENT TRANSFORMER REQUIREMENTS

The current transformer requirements for each current input depend on the protection function with which they are related and whether the line current transformers are being shared with other current inputs. Where current transformers are being shared by multiple current inputs, the kneepoint voltage requirements should be calculated for each input and the highest calculated value used.

The CT requirements for the P24x protection functions except the current differential are shown below. The P243 is the only model which includes differential protection and for this relay the highest calculated value from the general protection and differential protection CT requirements should be used. The differential CT requirements are shown in Table 12.

The general current transformer requirements are based on a maximum prospective fault current of 50 times the relay rated current (In) and the relay having an instantaneous setting of 25 times rated current (In). The current transformer requirements are designed to provide operation of all protection elements except the differential protection.

Where the criteria for a specific application are in excess of those detailed above, or the actual lead resistance exceeds the limiting value quoted, the CT requirements may need to be increased according to the formulae in sections 4.2/3/4.

Nominal rating	Nominal output	Accuracy class	Accuracy limited factor	Limiting lead resistance
1 A	2.5 VA	10P	20	1.3 ohms
5 A	7.5 VA	10P	20	0.11 ohms

Table 12: The CT requirements for the P24x protection functions excluding differential protection

4.1   Motor Differential Function (P243)

4.1.1   Biased Differential Protection

The kneepoint voltage requirements for the current transformers used for the current inputs of the motor differential function based on settings of Is1 = 0.05 In, k1 = 0%, Is2 = 1.2 In, k2 = 150%, and with a boundary condition of starting current $\leq$ 10In, are:

Where the motor is not earthed or resistance earthed at the motor neutral point then the CT knee point voltage requirements are:

$$V_k \geq 30I_n \ (R_{ct} + R_L + R_r) \text{ with a minimum of } \frac{60}{In}$$

Where the motor is solidly earthed at the motor neutral point then the CT knee point voltage requirements are:

$$V_k \geq 40I_n \ (R_{ct} + 2R_L + R_r) \text{ with a minimum of } \frac{60}{In}$$

Where

V_k	=	Minimum current transformer kneepoint voltage for through fault stability.
I_n	=	Relay rated current.
R_{ct}	=	Resistance of current transformer secondary winding (Ω).
R_L	=	Resistance of a single lead from relay to current transformer (Ω).
R_r	=	Resistance of any other protective relays sharing the current transformer (Ω).

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For Class-X current transformers, the excitation current at the calculated kneepoint voltage requirement should be less than 2.5In (<5% of the maximum perspective fault current 50 In, on which these CT requirements are based). For IEC standard protection class current transformers, it should be ensured that class 5P are used.

High impedance differential protection

If the motor differential protection function is used to implement high impedance differential protection, then the current transformer requirements are as follows:

$$R_S = [1.5 \times (I_f) * (R_{CT} + 2RL)] / I_{S1}$$

$$V_K \geq 2 \times I_{s1} * R_s$$

Where

R_s = Value of stabilizing resistor (ohms)

I_f = Maximum starting current (amps)

V_K = CT knee point voltage (volts)

I_{S1} = Current setting of differential element (amps)

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

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

Self Balanced differential protection

If the motor differential protection function is used to implement self balanced differential protection, then the current transformer requirements are as follows:

$$V_K \geq (1.5 \times I_f \times (R_{CT} + 2R_L))/I_S$$

Where

I_f = Maximum starting current (amps)

V_K = CT knee point voltage (volts)

I_S = Current setting of differential element (amps)

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

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

4.2　Non-directional Definite Time/IDMT Short Circuit and Definite Time/IDMT Derived Earth Fault Protection

4.2.1　Definite Time/IDMT Delayed Short Circuit Elements

$$V_K \geq I_{cp}/2 \times (R_{CT} + R_L + R_{rp})$$

4.2.2　Definite Time Delayed/IDMT Derived Earth Fault Elements

$$V_K \geq I_{cn}/2 \times (R_{CT} + 2_{RL} + R_{rp} + R_{rn})$$

4.3　Non-directional Instantaneous Short Circuit and Derived Earth Fault Protection

4.3.1　Instantaneous Short Circuit Elements

$$V_K \geq I_{sp} \times (R_{CT} + R_L + R_{rp})$$

4.3.2　Instantaneous Derived Earth Fault Elements

$$V_K \geq I_{sn} \times (R_{CT} + 2R_L + R_{rp} + R_{rn})$$

4.4 Directional Definite Time/IDMT Derived Earth Fault Protection

4.4.1 Directional Time Delayed Derived Earth Fault Protection

$$VK \geq Icn/2 \times (R_{CT} + 2_{RL} + R_{rp} + R_{rn})$$

4.4.2 Directional Instantaneous Derived Earth Fault Protection

$$VK \geq Ifn/2 \times (R_{CT} + 2R_L + R_{rp} + R_{rn})$$

4.5 Non-directional/Directional Definite Time/IDMT Sensitive Earth Fault (SEF) Protection

4.5.1 Non-directional Time Delayed SEF Protection (residually connected)

$$VK \geq Icn/2 \times (R_{CT} + 2R_L + R_{rp} + R_{rn})$$

4.5.2 Non-directional Instantaneous SEF Protection (residually connected)

$$VK \geq Isn/2 \times (R_{CT} + 2R_L + R_{rp} + R_{rn})$$

4.5.3 Directional Time Delayed SEF Protection (residually connected)

$$VK \geq Icn/2 \times (R_{CT} + 2R_L + R_{rp} + R_{rn})$$

4.5.4 Directional Instantaneous SEF Protection (residually connected)

$$VK \geq Ifn/2 \times (R_{CT} + 2R_L + R_{rp} + R_{rn})$$

4.5.5 SEF Protection - as fed from a core-balance CT

Core balance current transformers of metering class accuracy are required and should have a limiting secondary voltage satisfying the formulae given below:

Directional non-directional time delayed element:

$$VK \geq Icn/2 \times (R_{CT} + 2R_L + R_{rn})$$

Directional instantaneous element:

$$VK \geq Ifn/2 \times (R_{CT} + 2R_L + R_{rn})$$

Non-directional instantaneous element

$$VK \geq Isn/2 \times (R_{CT} + 2R_L + R_{rn})$$

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> **Note:** In addition, it should be ensured 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.

Abbreviations used in the previous formulae are explained below:

Where

V_K	=	Required CT knee-point voltage (volts)
Ifn	=	Maximum prospective secondary earth fault current (amps)
Ifp	=	Maximum prospective secondary phase fault current (amps)
Icn	=	Maximum prospective secondary earth fault current or 31 times I> setting (whichever is lower) (amps)
Icp	=	Maximum prospective secondary phase fault current or 31 times I> setting (whichever is lower) (amps)
Isn	=	Stage 2 Earth Fault setting (amps)
Isp	=	Stage 2 setting (amps)
RCT	=	Resistance of current transformer secondary winding (ohms)
RL	=	Resistance of a single lead from relay to current transformer (ohms)

Rrp   =   Impedance of relay phase current input at 30 In (ohms)

Rrn   =   Impedance of the relay neutral current input at 30 In (ohms)

4.6 Converting an IEC185 Current Transformer Standard Protection Classification to a Kneepoint Voltage

The suitability of an IEC standard protection class current transformer can be checked against the kneepoint voltage requirements specified previously.

For example, if the available current transformers have a 15 VA 5P 10 designation, then an estimated kneepoint voltage can be obtained as follows:

$$V_k = \frac{VA \times ALF}{In} + ALF \times I_n \times R_{ct}$$

Where:

V_k =   Required kneepoint voltage

VA   =   Current transformer rated burden (VA)

ALF   =   Accuracy limit factor

I_n =   Current transformer secondary rated current (A)

R_{ct} =   Resistance of current transformer secondary winding (Ω)

If Rct is not available, then the second term in the above equation can be ignored.

Example: 400/5A, 15VA 5P 10, Rct = 0.2Ω

$$V_k = \frac{15 \times 10}{5} + 10 \times 5 \times 0.2$$

$$= 40 \text{ V}$$

4.7 Converting IEC185 Current Transformer Standard Protection Classification to an ANSI/IEEE Standard Voltage Rating

MiCOM Px40 series protection is compatible with ANSI/IEEE current transformers as specified in the IEEE C57.13 standard. The applicable class for protection is class "C", which specifies a non air-gapped core. The CT design is identical to IEC class P, or British Standard class X, but the rating is specified differently.

The ANSI/IEEE "C" Class standard voltage rating required is lower than an IEC knee point voltage. This is because the ANSI/IEEE voltage rating is defined in terms of useful output voltage at the terminals of the CT, whereas the IEC knee point voltage includes the voltage drop across the internal resistance of the CT secondary winding added to the useful output. The IEC/BS knee point is also typically 5% higher than the ANSI/IEEE knee point.

Therefore:

Vc   =   [Vk .- Internal voltage drop] / 1.05

=   [Vk - (In . RCT . ALF)] / 1.05

Where:

Vc   =   "C" Class standard voltage rating

Vk   =   IEC Knee point voltage required

In   =   CT rated current = 5 A in USA

RCT   =   CT secondary winding resistance

(for 5 A CTs, the typical resistance is 0.002 ohms/secondary turn)

ALF = The CT accuracy limit factor, the rated dynamic current output of a "C" class
CT (Kssc) is always 20 x In

The IEC accuracy limit factor is identical to the 20 times secondary current ANSI/IEEE rating.

Therefore:

$$Vc \quad = \quad [\, Vk \; - \; (100 \, . \, RCT\,)\,] \; / \; 1.05$$

5   AUXILIARY SUPPLY FUSE RATING

In the Safety section, the maximum allowable fuse rating of 16 A is quoted. To allow time grading with fuses upstream, a lower fuselink current rating is often preferable. The standard ratings of between 6 A and 16 A is recommended. Low voltage fuselinks, rated at 250 V minimum and compliant with IEC 60269-2 general application type gG are acceptable, with high rupturing capacity. This gives equivalent characteristics to HRC "red spot" fuses type NIT/TIA often specified historically.

The table below recommends advisory limits on relays connected per fused spur. This applies to MiCOM Px40 series devices with hardware suffix C and higher, as these have inrush current limitation on switch-on, to conserve the fuse-link.

Maximum number of MiCOM Px40 relays recommended per fuse				
Battery nominal voltage	6 A	10 A fuse	15 or 16 A fuse	Fuse rating > 16 A
24 to 54 V	2	4	6	Not permitted
60 to 125 V	4	8	12	Not permitted
138 to 250 V	6	10	16	Not permitted

Table 13: Auxiliary supplies and the corresponding fuse ratings

Alternatively, miniature circuit breakers (MCB) may be used to protect the auxiliary supply circuits.

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PROGRAMMABLE LOGIC

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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 internal logic. This is done by combining the IED's digital inputs with internally generated digital signals using logic gates and timers, then mapping the resultant signals to the IED's digital outputs and LEDs.

The Programmable Scheme Logic (PSL) Editor allows you to create and edit scheme logic diagrams to suit your own particular application.

1.1 Loading Schemes From Files

The product is shipped with default scheme files. These can be used as a starting point for changes to a scheme. To create a new blank scheme, select **File** then **New** then **'Blank scheme...** to open the default file for the appropriate IED. This deletes the diagram components from the default file to leave an empty diagram but with the correct configuration information loaded.

1.2 How to Use the PSL Editor

With the MiCOM Px40 PSL Module you can:

- Start a new PSL diagram
- Extract a PSL file from a MiCOM Px40 IED
- Open a diagram from a PSL file
- Add logic components to a PSL file
- Move components in a PSL file
- Edit link of a PSL file
- Add link to a PSL file
- Highlight path in a PSL file
- Use a conditioner output to control logic
- Download PSL file to a MiCOM Px40 IED
- Print PSL files

1.3 Warnings

Checks are made before a scheme is downloaded to the relay. Various warning messages may be displayed as a result of these checks.

In most cases, the model number of the unit will match that of the model number stored in the PSL software on the PC. The Editor first reads in the model number of the connected unit, then compares it with its stored model number using a "wildcard" comparison. If a model mismatch occurs, a warning is generated before sending starts. Both the stored model number and the number read from the IED are displayed with the warning.

It is up to the user to decide whether the settings to be downloaded are compatible, and to be aware that incompatible settings could lead to undesirable behavior of the unit.

If there are any obvious potential problems, a list is generated. The types of potential problems that the program attempts to detect are:

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- One or more gates, LED signals, contact signals, or timers have their outputs linked directly back to their inputs. An erroneous link of this sort could lock up the IED, or cause other problems to arise.

- A programmable gate has its ITT (Inputs To Trigger) value set to greater than the number of actual inputs. This will mean the gate can never activate. There is no check for the case where the ITT value is lower than the number of inputs. A 0-value does not generate a warning.

- Too many gates. There is a theoretical upper limit of 256 gates in a scheme, but the practical limit is determined by the complexity of the logic. In practice the scheme would have to be very complex, and this error is unlikely to occur.

- Too many links. There is no fixed upper limit to the number of links in a scheme. However, as with the maximum number of gates, the practical limit is determined by the complexity of the logic. In practice the scheme would have to be very complex, and this error is unlikely to occur.

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2 PSL EDITOR TOOLBAR

There are a number of toolbars available for easy navigation and editing of PSL.

Toolbar	Description
	Standard tools: For file management and printing
	Alignment tools: To snap logic elements into horizontally or vertically aligned groupings
	Drawing tools : To add text comments and other annotations, for easier reading of PSL schemes
	Nudge tools: To move logic elements
	Rotation tools: Tools to spin, mirror and flip
	Structure tools: To change the stacking order of logic components
	Zoom and pan tools: For scaling the displayed screen size, viewing the entire PSL, or zooming to a selection

2.1 Logic Symbols

The logic symbol toolbar provides icons to place each type of logic element into the scheme diagram. Not all elements are available in all devices. Icons will only be displayed for those elements available in the selected device.

Symbol	Function	Explanation
	Link	Create a link between two logic symbols
	Opto Signal	Create an opto signal
	Input Signal	Create an input signal
	Output Signal	Create an output signal
	GOOSE In	Create an input signal to logic to receive a GOOSE message transmitted from another IED. Used in either UCA2.0 or IEC 61850 GOOSE applications only
	GOOSE Out	Create an output signal from logic to transmit a GOOSE message to another IED. Used in either UCA2.0 or IEC 61850 GOOSE applications only.
	Control In	Create an input signal to logic that can be operated from an external command.
	InterMiCOM In	Create an input signal to logic to receive an InterMiCOM command transmitted from another IED.
	InterMiCOM Out	Create an output signal from logic to transmit an InterMiCOM command to another IED.
	Function Key	Create a function key input signal.
	Trigger Signal	Create a fault record trigger
	LED Signal	Create an LED input signal that repeats the status of tri-color LED
	Contact Signal	Create a contact signal

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Symbol	Function	Explanation
	LED Conditioner	Create an LED conditioner
	Contact Conditioner	Create a contact conditioner
	Timer	Create a timer
	AND Gate	Create an AND Gate
	OR Gate	Create an OR Gate
	Programmable Gate	Create a programmable gate
	Counter	Gate that can add pulses to a configurable threshold

Table 1: Logic symbol toolbar

3   LOGIC SIGNAL PROPERTIES

1. Use the logic toolbar to select logic signals. This is enabled by default but to hide or show it, select **View** then **Logic Toolbar**.

2. Zoom in or out of a logic diagram using the toolbar icon or select **View** then **Zoom Percent**.

3. Right-click any logic signal and a context-sensitive menu appears.

Certain logic elements show the **Properties** option. If you select this, a **Component Properties** window appears. The contents of this window and the signals listed will vary according to the logic symbol selected. The actual DDB numbers are dependent on the model and are provided in the DDB signals table.

3.1   Link Properties

Links form the logical link between the output of a signal, gate or condition and the input to any element. Any, which is connected to the input of a gate, can be inverted. To do this:

1. Right-click the input

2. Select **Properties….** The Link Properties window appears.

3. Check the box to invert the link. Or uncheck for a non-inverted link

An inverted link is shown with a small circle on the input to a gate. A link must be connected to the input of a gate to be inverted.

Links can only be started from the output of a signal, gate, or conditioner, and must end at an input to any element.

Signals can only be an input or an output. To follow the convention for gates and conditioners, input signals are connected from the left and output signals to the right. The Editor automatically enforces this convention.

A link is refused for the following reasons:

- There has been an attempt to connect to a signal that is already driven. The reason for the refusal may not be obvious because the signal symbol may appear elsewhere in the diagram. In this case you can right-click the link and select Highlight to find the other signal. Click anywhere on the diagram to disable the highlight.

- An attempt has been made to repeat a link between two symbols. The reason for the refusal may not be obvious because the existing link may be represented elsewhere in the diagram.

3.2   Opto Signal Properties

Each opto input can be selected and used for programming in PSL. Activation of the opto input will drive an associated DDB signal.

For example, activating opto input L1 will assert DDB 064 in the PSL.
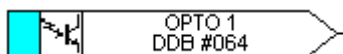
3.3   Input Signal Properties

Relay logic functions provide logic output signals that can be used for programming in PSL. Depending on the relay functionality, operation of an active relay function will drive an associated DDB signal in PSL.

For example, DDB 298 will be asserted in the PSL on a successful motor start.

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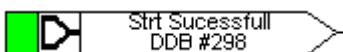
3.4 Output Signal Properties

Relay logic functions provide logic input signals that can be used for programming in PSL. Depending on the relay functionality, activation of the output signal will drive an associated DDB signal in PSL and cause an associated response to the relay function.

For example, if DDB 108 is asserted in the PSL, an emergency start of the motor will be initiated.
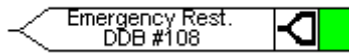
3.5 GOOSE Input Signal Properties

The PSL interfaces with the GOOSE Scheme Logic (see S1 Studio user's manual) by means of 32 Virtual inputs. The Virtual Inputs can be used in much the same way as the Opto Input signals.

The logic that drives each of the Virtual Inputs is in the relay's GOOSE Scheme Logic file. Any number of bit-pairs, from any enrolled device, can be mapped using logic gates onto a Virtual Input.

For example, DDB 544 will be asserted in PSL should virtual input 1 and its associated bit pair operate.

3.6 GOOSE Output Signal Properties

The PSL interfaces with the GOOSE Scheme Logic using 32 Virtual outputs.

You can map Virtual Outputs to bit-pairs for transmitting to any subscribed devices.

For example, if DDB 512 is asserted in PSL, Virtual Output 1 and its associated bit-pair mappings will operate.
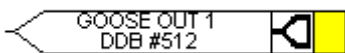
3.7 Control Input Signal Properties

There are 32 control inputs which can be activated using the relay menu, 'hotkeys' or using rear communications. Depending on the programmed setting (latched or pulsed), an associated DDB signal is activated in PSL when a control input is operated.

For example, operate control input 1 to assert DDB 608 in the PSL.

3.8 Function Key Properties (P242/3 only)

Each function key can be selected and used for programming in PSL. Activation of the function key drives an associated DDB signal and the DDB signal remains active depending on the programmed setting (toggled or normal). Toggled mode means the DDB signal will remain latched or unlatched on key press and normal means the DDB will only be active for the duration of the key press.

For example, operate function key 1 to assert DDB 676 in the PSL.

3.9   Fault Recorder Trigger Properties

The fault recording facility can be activated by driving the fault recorder trigger DDB signal.

For example, assert DDB 468 to activate the fault recording in the PSL.

3.10   LED Signal Properties

All programmable LEDs drive associated DDB signal when the LED is activated.

For example, DDB 652 is asserted when tri-color LED 7 is activated (P242/3) and DDB 102 for red LED 7 (P241).
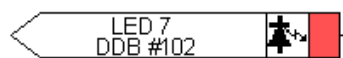
3.11   Contact Signal Properties

All relay output contacts will drive associated DDB signal when the output contact is activated.

For example, DDB 000 will be asserted when output R1 is activated.
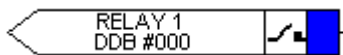
3.12   LED Conditioner Properties

1. Select the LED name from the list (only shown when inserting a new symbol).
2. Configure the LED output to be Red, Yellow or Green.
3. Configure a Green LED by driving the Green DDB input.
4. Configure a RED LED by driving the RED DDB input.
5. Configure a Yellow LED by driving the RED and GREEN DDB inputs simultaneously.
6. Configure the LED output to be latching or non-latching.
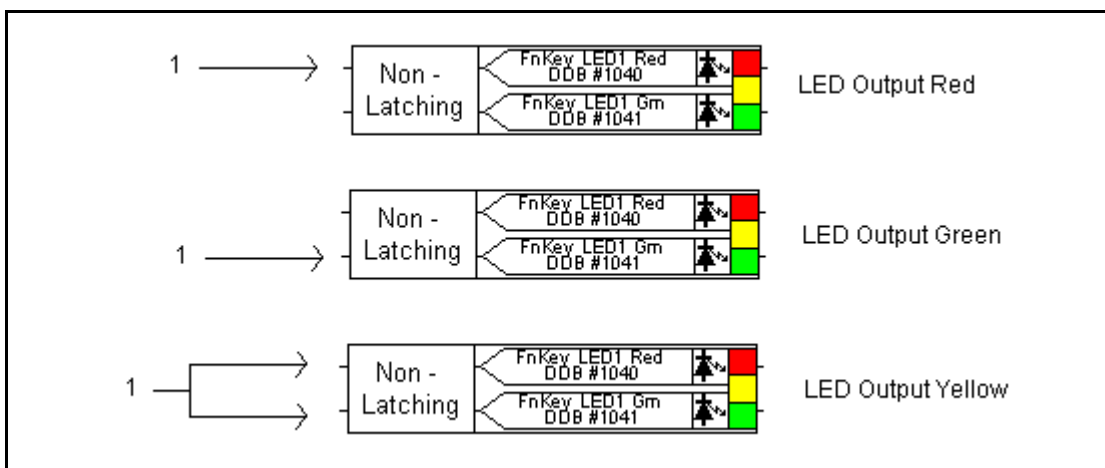
Figure 1: Tri-color LED conditioning (P242/3)

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3.13 Red LED Conditioner (P241)

1. Select the LED name from the list (only shown when inserting a new symbol).
2. Configure the LED output to be latching or non-latching
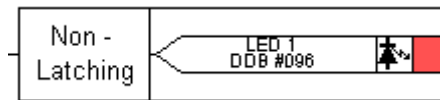
3.14 Contact Conditioner Properties

Each contact can be conditioned with an associated timer that can be selected for pick up, drop off, dwell, pulse, pick-up/drop-off, straight-through, or latching operation.

Straight-through means it is not conditioned at all whereas **Latching** is used to create a sealed-in or lockout type function.

To set contact properties,

1. Select the contact name from the Contact Name list (only shown when inserting a new symbol).
2. Choose the conditioner type required in the Mode tick list.
3. Set the Pick-up Value (in milliseconds), if required.
4. Set the Drop-off Value (in milliseconds), if required.

3.15 Counter Properties

Each PSL counter has an increment (+), a decrement (-) and Reset (R) input and a count output (Q) which goes high when the count threshold value is exceeded.

To set counter properties:

1. From the **Trigger Type** tick list, choose either, **Rising edge triggered** or **Falling edge triggered**.
2. Set the **Trigger threshold value**, if required.
3. Set the **Invert output** tick box, if required.
4. From the **Available counters** list, choose the counter required. Note: The counter number will autoincrement when adding counters.
5. Click **OK**.

3.16 Timer Properties

Each timer can be selected for pick up, drop off, dwell, pulse or pick-up/drop-off operation.

1. From the **Timer Mode** tick list, choose the mode.
2. Set the **Pick-up Value** (in milliseconds), if required.
3. Set the **Drop-off Value** (in milliseconds), if required.
4. From the **Available timers** list (not in all products), choose the timer required. Note: The timer number will auto-increment when adding timers.
5. Click **OK**.

3.17 Gate Properties

A gate can be an AND, OR, or programmable gate.

1. An **AND Gate** requires that all inputs are TRUE for the output to be TRUE.
2. An **OR Gate** requires that one or more input is TRUE for the output to be TRUE.
3. A **Programmable Gate** requires that the number of inputs that are TRUE is equal to or greater than its **Inputs to Trigger** setting for the output to be TRUE.

To set gate properties:

1. Select the gate type: **AND Gate**, **OR Gate**, or **Programmable Gate**.
2. If you select **Programmable Gate**, set the number of **Inputs to Trigger**.

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3. If you want the output of the gate to be inverted, check the **Invert Output** check box. An inverted output appears as a "bubble" on the gate output.

4. Click **OK**

3.18 Description of Logic Nodes

DDB no.	English text	Source	Description
0	Relay 1 (Output Label Setting)	Relay conditioner	Relay 1 is on
6	Relay 7 (Output Label Setting)	Relay conditioner	Relay 7 is on
15	Relay 16 (Output Label Setting)	Relay conditioner	Relay 16 is on (P242/3 only)
16 to 63	Not Used		
64	Opto 1 (Input Label Setting)	Opto Isolator Input	Opto 1 is on
71	Opto 8 (Input Label Setting)	Opto Isolator Input	Opto 8 is on
79	Opto 16 (Input Setting)	Opto Isolator Input	Opto 16 is on (P242/3 only)
96	LED1 Red	PSL	LED 1 Red is on (P241 only)
103	LED8 Red.	PSL	LED 8 Red is on (P241 only)
104	Speed Input	PSL	Speed Switch input is on
105	CB Aux 3Ph - 52A	PSL	CB1 Closed
106	CB Aux 3Ph - 52B	PSL	CB1 Open
107	Setting Group.	PSL	Setting Group change (Off = Group1, On = Group 2)
108	Emergency Rest.	PSL	Initiates Emergency Restart of motor
109	Reset Thermal	PSL	Resets Thermal State to 0%
110	Dist Rec Trig	PSL	Triggers the Disturbance Recorder
111	Close	PSL	Initiates a breaker close command
112	Trip	PSL	Initiates a breaker trip command
113	Reset Latches	PSL	Reset all latched LEDs and output relays
114	Test Mode	PSL	Commissioning Tests - automatically places relay in Test Mode which takes the relay out of service and allows secondary injection testing of the relay. For IEC 60870-5-103 protocol spontaneous events and cyclic measured data transmitted whilst the relay is in test mode will have a COT of 'test mode'
115	External Trip	PSL	External Trip 3 phase - allows external protection to initiate breaker fail and circuit breaker condition monitoring counters.
116	Time Synch	PSL	Time Synchronism by opto Input pulse
117	FFail Block	PSL	Blocks operation of the Field Failure protection
118	Trip LED	PSL	Signal to switch on the Trip LED
119	MCB/VTS	PSL	VT supervision input - signal from external Miniature Circuit Breaker showing MCB tripped
120	Monitor Blocking DDB	PSL	Monitor Blocking DDB
121	Command Blocking DDB	PSL	Command Blocking DDB
122	RP1 Read Only DDB	PSL	Rear communications Port 1 read only mode selection

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DDB no.	English text	Source	Description
123	RP2 Read Only DDB	PSL	Rear communications Port 1 read only mode selection
124	NIC Read Only DDB	PSL	Rear Ethernet communications port read only mode selection
125	V2>1 Timer Block	PSL	Block 1st stage Negative Phase Sequence Overvoltage Timer
126	V2>1 Inhibit	PSL	Inhibit 1st stage Negative Phase Sequence Overvoltage
127	V2>2 Timer Block	PSL	Block 2nd stage Negative Phase Sequence Overvoltage Timer
128	V2>2 Inhibit	PSL	Inhibit 2nd stage Negative Phase Sequence Overvoltage
129	V<1 Timer Block	PSL	Block 1st stage Undervoltage Timer
130	V<1 Inhibit	PSL	Inhibit 1st stage Undervoltage
131	V<2 Timer Block	PSL	Block 2nd stage Undervoltage Timer
132	V<2 Inhibit	PSL	Inhibit 2nd stage Undervoltage
133	I>1 Timer Block	PSL	Block 1st stage Overcurrent Timer
134	I>1 Inhibit	PSL	Inhibit 1st stage Overcurrent
135	I>2 Timer Block	PSL	Block 2nd stage Overcurrent Timer
136	I>2 Inhibit	PSL	Inhibit 2nd stage Overcurrent
137	I>3 Timer Block	PSL	Block 3rd stage Overcurrent Timer
138	I>3 Inhibit	PSL	Inhibit 3rd stage Overcurrent
139	I>4 Timer Block	PSL	Block 4th stage Overcurrent Timer
140	I>4 Inhibit	PSL	Inhibit 4th stage Overcurrent
141 to 173	Not Used		
174	General Alarm		Any Alarm is operated
175	Prot'n Disabled	Commissioning Test	Protection Disabled - typically out of service due to test mode
176	F Out of Range	Frequency Tracking	Frequency Out of bandwidth Range (45-60 Hz)
177	3Ph Volt Alarm	Rev Ph Seq	Phase rotation is incorrect (V2>V1) or phase voltages are below Start Voltage threshold
178	Thermal Alarm	Thermal Overload	Thermal State has exceeded alarm threshold
179	Thermal Lockout	Thermal Overload	Used to inhibit a motor start until Thermal State < Thermal Lockout threshold
180	Time Betwe Start	Start Protection	Used to inhibit a motor start for the Time Between Starts setting following a trip
181	Hot Start Nb	Start Protection	Used to inhibit a motor start if Number of Hot Starts setting is exceeded
182	Cold Start Nb	Start Protection	Used to inhibit a motor start if Number of Cold Starts setting is exceeded
183	Man CB Trip Fail	CB Control	Circuit Breaker Failed to Trip (after a manual/operator trip command)
184	Man CB Cls Fail	CB Control	Circuit Breaker Failed to Close (after a manual/operator close command)
185	CB Status Alarm	CB Status	Indication of a fault with the Circuit Breaker state monitoring – example: defective auxiliary contacts
186	I^ Maint Alarm	CB Monitoring	Circuit Breaker cumulative broken current has exceeded the maintenance alarm setting.

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DDB no.	English text	Source	Description
187	CB Ops Maint	CB Monitoring	Number of Circuit Breaker trips has exceeded maintenance alarm setting.
188	CB OP Time Maint	CB Monitoring	Circuit Breaker operating time has exceeded maintenance alarm setting (slow interruption time)
189	3 Ph W Alarm	Measurement setup	3 Phase Watts Alarm
190	3 Ph Var Alarm	Measurement setup	3 Phase Var Alarm
191	RTD 1 Alarm	RTD Protection	RTD 1 Alarm
200	RTD 10 Alarm	RTD Protection	RTD 10 Alarm
201	RTD Short Cct	RTD Protection	RTD Short Circuit circuit (the RTD Short Cct cell in Measurements 3 indicates which RTD is open circuit)
202	RTD Open Cct	RTD Protection	RTD Open Circuit (the RTD Open Cct cell in Measurements 3 indicates which RTD is open circuit)
203	RTD Data Error	RTD Protection	RTD Data inconsistency Error (the RTD Data Error cell in Measurements 3 indicates which RTD has a data error)
204	Invalid Set Grp	Group Selection	Invalid Setting Group
205	Dist Rec. Conf	Disturbance Recorder	Disturbance Recorder Configuration is not compliant with "connecting mode", for example if "VT connecting mode" = "2VT+antibackspin"
206	CB Fail Alarm	CB Fail	Circuit Breaker Fail Alarm
207	W Fwd Alarm	Measurement setup	Watt Forward Alarm
208	W Rev Alarm	Measurement setup	Watt Reverse Alarm
209	VAr Fwd Alarm	Measurement setup	Var Forward Alarm
210	VAr Rev Alarm	Measurement setup	Var Reverse Alarm
211	Analo Inp1 Alarm	Current Loop Inputs	Current Loop Input (Transducer input) 1 Alarm
214	Analo Inp4 Alarm	Current Loop Inputs	Current Loop Input (Transducer input) 4 Alarm
215	MR User Alarm 1	PSL	User Alarm 1 (Manual-Resetting)
221	MR User Alarm 7	PSL	User Alarm 7 (Manual-Resetting)
222	SR User Alarm 8	PSL	User Alarm 8 (Self-Resetting)
228	SR User Alarm 14	PSL	User Alarm 14 (Self-Resetting)
229	CT-1 Fail Alarm	CT Supervision	CTS Indication Alarm for IA/IB/IC (CT supervision alarm).
230	CT-2 Fail Alarm	CT Supervision	CTS Indication Alarm for IA-2/IB-2/IC-2 (CT supervision alarm). (P243)
231	Hour Run Alarm 1	Measurement setup	Hour Run Alarm 1
232	Hour Run Alarm 2	Measurement setup	Hour Run Alarm 2
233	Antibkspin Alarm	Anti-Backspin	Anti-Backspin Alarm
234	Field Fail Alarm	Field Failure	Field Failure Alarm
235	VTS Block	VTS Supervision	Confirmed block
236	Thermal Trip	Thermal Overload	Thermal State has exceeded trip threshold
237	Trip I>1	Short Circuit	1st stage Short Circuit Trip, 3-phase
238	I>1 A Phase	Short Circuit	As per DDB#242
239	I>1 B Phase	Short Circuit	As per DDB#243
240	I>1 C Phase	Short Circuit	As per DDB#244
241	Start I>1	Short Circuit	1st stage Short Circuit Start, 3 Phase
242	Start I>1 A Ph	Short Circuit	1st stage Short Circuit Start, A Phase

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DDB no.	English text	Source	Description
243	Start I>1 B Ph	Short Circuit	1st stage Short Circuit Start, B Phase
244	Start I>1 C Ph	Short Circuit	1st stage Short Circuit Start, C Phase
245	Trip I>1 A Ph	Short Circuit	1st stage Short Circuit Trip, A Phase
246	Trip I>1 B Ph	Short Circuit	1st stage Short Circuit Trip, B Phase
247	Trip I>1 C Ph	Short Circuit	1st stage Short Circuit Trip, C Phase
248	Trip I>2	Short Circuit	2nd stage Short Circuit Trip, 3 Phase
249	I>2 A Phase	Short Circuit	As per DDB#253
250	I>2 B Phase	Short Circuit	As per DDB#254
251	I>2 C Phase	Short Circuit	As per DDB#255
252	Start I>2	Short Circuit	2nd stage Short Circuit start, 3 Phase
253	Start I>2 A Ph	Short Circuit	2nd stage Short Circuit start, A Phase
254	Start I>2 B Ph	Short Circuit	2nd stage Short Circuit start, B Phase
255	Start I>2 C Ph	Short Circuit	2nd stage Short Circuit start, C Phase
256	Trip I>2 A Ph	Short Circuit	2nd stage Short Circuit trip, A Phase
257	Trip I>2 B Ph	Short Circuit	2nd stage Short Circuit trip, B Phase
258	Trip I>2 C Ph	Short Circuit	2nd stage Short Circuit trip, C Phase
259	Trip F<1	Underfrequency	1st stage Underfrequency Trip
260	Trip F<2	Underfrequency	2nd stage Underfrequency Trip
261	Trip ISEF>1	Earth Fault	1st stage Sensitive Earth Fault Trip
262	Start ISEF>1	Earth Fault	1st stage Sensitive Earth Fault Start
263	Trip ISEF>2	Earth Fault	2nd stage Sensitive Earth Fault Trip
264	Start ISEF>2	Earth Fault	2nd stage Sensitive Earth Fault Start
265	Trip IN>1	Derived Earth Fault	1st stage Derived Earth Fault Trip
266	Start IN>1	Derived Earth Fault	1st stage Derived Earth Fault Start
267	Trip IN>2	Derived Earth Fault	2nd stage Derived Earth Fault Trip
268	Start IN>2	Derived Earth Fault	2nd stage Derived Earth Fault Start
269	Trip P<1	Loss of Load	1st stage Underpower Trip
270	Trip P<2	Loss of Load	2nd stage Underpower Trip
271	Trip PF< Lead	Under Power Factor	Out of Step Trip (leading power factor)
272	Trip PF< Lag	Under Power Factor	Out of Step Trip (lagging power factor)
273	Trip Rev Power	Reverse Power	Reverse Power Trip
274	Trip I2>1	Negative sequence O/C	1st stage NPS Trip
275	Tip I2>2	Negative sequence O/C	2nd stage NPS Trip
276	V<1 AB Phase	Volt Protection	1st stage Undervoltage Start, AB Phase
277	V<1 BC Phase	Volt Protection	1st stage Undervoltage Start, BC Phase
278	V<1 CA Phase	Volt Protection	1st stage Undervoltage Start, CA Phase
279	Trip V<1	Volt Protection	1st stage Undervoltage Trip, 3 Phase
280	V>1 AB Phase	Volt Protection	1st stage Overvoltage Start, AB Phase
281	V>1 BC Phase	Volt Protection	1st stage Overvoltage Start, BC Phase
282	V>1 CA Phase	Volt Protection	1st stage Overvoltage Start, CA Phase
283	Trip V>1	Volt Protection	1st stage Overvoltage Trip, 3 Phase
284	V<2 AB Phase	Volt Protection	2nd stage Undervoltage Start, AB Phase
285	V<2 BC Phase	Volt Protection	2nd stage Undervoltage Start, BC Phase
286	V<2 CA Phase	Volt Protection	2nd stage Undervoltage Start, CA Phase
287	Trip V<2	Volt Protection	2nd stage Undervoltage Trip, 3 Phase
288	V>2 AB Phase	Volt Protection	2nd stage Overvoltage Start, AB Phase

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DDB no.	English text	Source	Description
289	V>2 BC Phase	Volt Protection	2nd stage Overvoltage Start, BC Phase
290	V>2 CA Phase	Volt Protection	2nd stage Overvoltage Start, CA Phase
291	Trip V>2	Volt Protection	2nd stage Overvoltage Trip, 3 Phase
292	Trip NVD VN>1	Residual O/V NVD	1st stage Neutral Voltage Displacement/Residual Overvoltage Trip
293	Trip NVD VN>2	Residual O/V NVD	2nd Neutral Voltage Displacement/Residual Overvoltage Trip
294	Trip PO>	Earth Fault	Wattmetric directional Earth Fault Trip
295	Start PO>	Earth Fault	Wattmetric directional Earth Fault Start
296	Reacc Low Volt	Stalling	Voltage has dipped below 'Reacc Low Voltage Setting'
297	Strt in Progress	Stalling	Start in Progress
298	Strt Successful	Stalling	Successful Start
299	Prolonged Start	Stalling	Prolonged Start – stall condition when the motor is starting (current > Starting Current setting for time > Prolonged Start Time)
300	Reac in Progress	Stalling	Reacceleration in Progress
301	Stall Rotor-run	Stalling	Stall Rotor condition when the motor is running
302	Stall Rotor-Strt	Stalling	Stall Rotor condition when the motor is starting (current > Starting Current setting and Speed Input is off for time > Stall Time)
303	Control Trip	CB Control	Manual Trip command
304	Control Close	CB Control	Manual Close command
305	Trip RTD 1	RTD Protection	RTD 1 Trip
314	Trip RTD 10	RTD Protection	RTD 10 Trip
315	Diff Trip A	Differential	Motor Differential Trip, A Phase. (P243)
316	Diff Trip B	Differential	Motor Differential Trip, B Phase. (P243)
317	Diff Trip C	Differential	Motor Differential Trip, C Phase. (P243)
318	Trip Diff	Differential	Motor Differential Trip (P243)
319	Trip CBF 1	CB Fail	CB Fail Timer 1 Trip
320	Trip CBF 2	CB Fail	CB Fail Timer 2 Trip
321	Trip Analog Inp 1	Current Loop Inputs	Current Loop Input (Analog/transducer input) 1 Trip
324	Trip Analog Inp 4	Current Loop Inputs	Current Loop Input (Analog/transducer input) 4 Trip
325	Pwd UI Level 0	System Data	Access Level 0 is enabled for the User Interface (HMI)
326	Pwd UI Level 1	System Data	Access Level 1 is enabled for the User Interface (HMI)
327	Pwd UI Level 2	System Data	Access Level 2 is enabled for the User Interface (HMI)
328	Pwd Front Level 0	System Data	Access Level 0 is enabled for the Front Comms Port
329	Pwd Front Level 1	System Data	Access Level 1 is enabled for the Front Comms Port
330	Pwd Front Level 2	System Data	Access Level 2 is enabled for the Front Comms Port
331	Pwd Rear Level 0	System Data	Access Level 0 is enabled for the Main Rear Comms Port
332	Pwd Rear Level 1	System Data	Access Level 1 is enabled for the Main Rear Comms Port

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DDB no.	English text	Source	Description
333	Pwd Rear Level 2	System Data	Access Level 2 is enabled for the Main Rear Comms Port
334	FFail1 Start	Field Failure	1st Stage Field Failure Start
335	FFail2 Start	Field Failure	2nd Stage Field Failure Start
336	FFail1 Trip	Field Failure	1st Stage Field Failure Trip
337	FFail2 Trip	Field Failure	2nd Stage Field Failure Trip
338	Trip I>3	Short Circuit	3rd stage Short Circuit Trip, 3-phase
339	I>3 A Phase	Short Circuit	As per DDB#343
340	I>3 B Phase	Short Circuit	As per DDB#344
341	I>3 C Phase	Short Circuit	As per DDB#345
342	Start I>3	Short Circuit	3rd stage Short Circuit Start, 3 Phase
343	Start I>3 A Ph	Short Circuit	3rd stage Short Circuit Start, A Phase
344	Start I>3 B Ph	Short Circuit	3rd stage Short Circuit Start, B Phase
345	Start I>3 C Ph	Short Circuit	3rd stage Short Circuit Start, C Phase
346	Trip I>3 A Ph	Short Circuit	3rd stage Short Circuit Trip, A Phase
347	Trip I>3 B Ph	Short Circuit	3rd stage Short Circuit Trip, B Phase
348	Trip I>3 C Ph	Short Circuit	3rd stage Short Circuit Trip, C Phase
349	Trip I>4	Short Circuit	4th stage Short Circuit Trip, 3-phase
350	I>4 A Phase	Short Circuit	As per DDB#354
351	I>4 B Phase	Short Circuit	As per DDB#355
352	I>4 C Phase	Short Circuit	As per DDB#356
353	Start I>4	Short Circuit	4th stage Short Circuit Start, 3 Phase
354	Start I>4 A Ph	Short Circuit	4th stage Short Circuit Start, A Phase
355	Start I>4 B Ph	Short Circuit	4th stage Short Circuit Start, B Phase
356	Start I>4 C Ph	Short Circuit	4th stage Short Circuit Start, C Phase
357	Trip I>4 A Ph	Short Circuit	4th stage Short Circuit Trip, A Phase
358	Trip I>4 B Ph	Short Circuit	4th stage Short Circuit Trip, B Phase
359	Trip I>4 C Ph	Short Circuit	4th stage Short Circuit Trip, C Phase
360	CTS-1 Block	CT Supervision	CT Supervision Block for IA/IB/IC (current transformer supervision). CTS-1 Block and CTS-2 Block DDBs can be used to block protection functions.
361	CTS-2 BLOCK	CT Supervision	
362	MCB/VTS	PSL	VT supervision input - signal from external Miniature Circuit Breaker showing MCB tripped
363	VTS Confirmed Block	VT Supervision	VT Supervision Fast Block - blocks elements which would otherwise mal-operate immediately after a fuse failure event occurs
364	VTS Fast Block	VT Supervision	VT Supervision Fast Block - blocks elements which would otherwise mal-operate immediately after a fuse failure event occurs
365 to 368	Not Used		
369	Any Start	All Protection	Any Start
370	Protection Trip	All Protection	Any Protection Trip
371	Any Trip	All Protection	Any Trip
372	Start F<1	Underfrequency	1st Stage Under Frequency Start
373	Start F<2	Underfrequency	2nd Stage Under Frequency Start
374	Start P<1	Loss of Load	1st Stage Loss Of Load Start

DDB no.	English text	Source	Description
375	Start P<2	Loss of Load	2nd Stage Loss Of Load Start
376	Start PF< Lead	Under Power Factor	Power Factor Lead Start
377	Start PF< Lag	Under Power Factor	Power Factor Lag Start
378	Start Rev Power	Reverse Power	Reverse Power Start
379	Start I2>2	Negative sequence O/C	1st stage Negative Sequence O/C Start
380	Start I2>2	Negative sequence O/C	2nd stage Negative Sequence O/C Start
381	Start NVD VN>1	Residual O/V NVD	1st stage Residual O/V Start
382	Start NVD VN>2	Residual O/V NVD	2nd stage Residual O/V Start
383	V<1 A Phase	Volt Protection	1st stage Undervoltage Start, A Phase
384	V<1 B Phase	Volt Protection	1st stage Undervoltage Start, B Phase
385	V<1 C Phase	Volt Protection	1st stage Undervoltage Start, C Phase
386	V>1 A Phase	Volt Protection	1st stage Overvoltage Start, A Phase
387	V>1 B Phase	Volt Protection	1st stage Overvoltage Start, B Phase
388	V>1 C Phase	Volt Protection	1st stage Overvoltage Start, C Phase
389	V<2 A Phase	Volt Protection	2nd stage Undervoltage Start, A Phase
390	V<2 B Phase	Volt Protection	2nd stage Undervoltage Start, B Phase
391	V<2 C Phase	Volt Protection	2nd stage Undervoltage Start, C Phase
392	V>2 A Phase	Volt Protection	2nd stage Overvoltage Start, A Phase
393	V>2 B Phase	Volt Protection	2nd stage Overvoltage Start, B Phase
394	V>2 C Phase	Volt Protection	2nd stage Overvoltage Start, C Phase
395	V2>1 Start	Neg Seq O/V	1st stage Negative Phase Sequence Overvoltage Start
396	V2>1 Trip	Neg Seq O/V	1st stage Negative Phase Sequence Overvoltage Trip
397	V2>2 Start	Neg Seq O/V	2nd stage Negative Phase Sequence Overvoltage Start
398	V2>2 Trip	Neg Seq O/V	2nd stage Negative Phase Sequence Overvoltage Trip
399	Vdip<1 AB Phase	Stall Detection	Voltage is below 'Reac Low V Set' for re-acceleration function, AB phase
400	Vdip<1 BC Phase	Stall Detection	Voltage is below 'Reac Low V Set' for re-acceleration function, BC phase
401	Vdip<1 CA Phase	Stall Detection	Voltage is below 'Reac Low V Set' for re-acceleration function, CA phase
402	Trip Vdip<1	Stall Detection	During a motor re-acceleration condition when the 'Reac Time' timer is timed out and the voltage has not been restored, the relay trips on "Vdip DDB#402".
403	Auto Re-Start OK	Stall Detection	When the auto-restart logic is authorized, DDBs "Auto Re-Start #404" and "Auto Re-Start OK #403" are asserted
404	Auto Re-Start	Stall Detection	When the auto-restart logic is authorized, DDBs "Auto Re-Start #404" and "Auto Re-Start OK #403" are asserted
405	Auto Re-Start KO	Stall Detection	If voltage is not restored within "Reac Long Time" duration or falls below "High V Set" threshold before "Reac Shed Time" timer has timed out (in case where "Reac Shed Time" timer is set to a value other than zero for sequence start scheme), DDB "Auto Re-Start KO #405 becomes asserted.

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DDB no.	English text	Source	Description
406	All Poles Dead	Stall Detection	Pole dead logic detects 3 phase breaker open
407	Any Pole Dead	Stall Detection	Pole dead logic detects at least one breaker pole open
408	Pole Dead A	Stall Detection	Phase A Pole Dead
409	Pole Dead B	Stall Detection	Phase B Pole Dead
410	Pole Dead C	Stall Detection	Phase C Pole Dead
411 to 427	Not Used		
428	LED 1 Con	PSL	Input signal driving LED 1 Red is on (P241 only)
435	LED 8 Con	PSL	Input signal driving LED 8 Red is on (P241 only)
436	Timer in 1	Auxiliary Timer In	Input to Auxiliary Timer 1 is on
451	Timer in 16	Auxiliary Timer In	Input to Auxiliary Timer 16 is on
452	Timer out 1	Auxiliary Timer out	Output from Auxiliary Timer 1 is on
467	Timer out 16	Auxiliary Timer out	Output from Auxiliary Timer 16 is on
468	Fault Recorder Trigger	PSL	Trigger for Fault Recorder
469	Battery Fail	PSL	Front panel miniature Battery Failure - either battery removed from slot, or low voltage.
470	Field Volt Fail	PSL	48 V Field Voltage Fail
471	Comm2 H/W FAIL	Communications	Second Rear Comms port failure
472	Goose IED Absent	Communications	
473	NIC Not Fitted	Communications	
474	NIC No Response	Communications	
475	NIC Fatal Error	Communications	
476	NIC Soft Reload	Communications	
477	Bad TCP/IP Cfg	Communications	
478	Bad OSI Config	Communications	
479	NIC Link Fail	Communications	
480	NIC SW Mis-Match	Communications	
481	IP Addr Conflict	Communications	
482-500	Not Used		
501	Block Contacts	PSL	Input DDB signal used to drive IED to be contacts blocked If the device has been put into 'Contact Blocked' mode using this input signal then the Apply Test command will not execute. This is to prevent a device that has been blocked by an external process having its contacts operated by a local operator using the HMI. If the Block Contacts DDB is not set and the Apply Test command in is issued, the contacts will change state.
502	Contacts Blocked	PSL	Indicates contacts blocked mode enabled. Can be mapped in PSL and sent via InterMiCOM to block contacts at the remote end.
503-511	Not Used		

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DDB no.	English text	Source	Description
512	Virtual Output 1	PSL	Virtual Output 1 - output allows user to control a binary signal which can be mapped via SCADA protocol output to other devices
543	Virtual Output 32	PSL	Virtual Output 32 - output allows user to control a binary signal which can be mapped via SCADA protocol output to other devices
544	GOOSE VIP 1	GOOSE Input Command	Virtual Input 1 - allows binary signals that are mapped to virtual inputs to interface into PSL
575	GOOSE VIP 32	GOOSE Input Command	Virtual Input 32 - allows binary signals that are mapped to virtual inputs to interface into PSL
576 to 607	Not Used		
608	Control Input 1	Control Input Command	Control Input 1 - for SCADA and menu commands into PSL
639	Control Input 32	Control Input Command	Control Input 32 - for SCADA and menu commands into PSL
640	LED1 Red	PSL	Programmable LED 1 Red is on (P242/3 only)
641	LED1 Grn.	PSL	Programmable LED 1 Green is on (P242/3 only)
654	LED8 Red	PSL	Programmable LED 8 Red is on (P242/3 only)
655	LED8 Grn.	PSL	Programmable LED 8 Green is on (P242/3 only)
656	FnKey LED1 Red	PSL	Programmable Function Key LED 1 Red is on (P242/3 only)
657	FnKey LED1 Grn.	PSL	Programmable Function Key LED 1 Green is on (P242/3 only)
674	FnKey LED10 Red	PSL	Programmable Function Key LED 10 Red is on (P345)
675	FnKey LED10 Grn.	PSL	Programmable Function Key LED 10 Green is on (P242/3 only)
676	Function Key 1	User Control	Function Key 1 is on. In 'Normal' mode it is high on keypress and in 'Toggle' mode remains high/low on single keypress (P242/3 only)
685	Function Key 10	User Control	Function Key 10 is on. In 'Normal' mode it is high on keypress and in 'Toggle' mode remains high/low on single keypress (P242/3 only)
686 to 699	Not Used		
700	Output Con 1	PSL	Input signal driving Relay 1 is on
715	Output Con 16	PSL	Input signal driving Relay 16 is on
716 to 763	Not Used		
764	LED1 Con Red	PSL	Input signal driving LED 1 Red is on (P242/3 only)
765	LED1 Con Green	PSL	Input signal driving LED 1 Green is on. To make LED 1 Yellow DDB 640 and DDB 641 must on at the same time. (P242/3 only))
778	LED8 Con Red	PSL	Input signal driving LED 8 Red is on (P242/3 only)

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DDB no.	English text	Source	Description
779	LED8 Con Green	PSL	Input signal driving LED 8 Green is on. To make LED 8 Yellow DDB 778 and DDB 779 must be on at the same time (P242/3 only)
780	FnKey LED1 ConR	PSL	Input signal driving Function Key LED 1 Red is on. This LED is associated with Function Key 1 (P242/3 only)
781	FnKey LED1 ConG	PSL	Input signal driving Function Key LED 1 Green is on. This LED is associated with Function Key 1. To make function key 1 LED yellow, DDB 780 and DDB 781 must be on at the same time (P242/3 only)
798	FnKey LED10 ConR	PSL	Input signal driving Function Key LED 10 Red is on. This LED is associated with Function Key 10 (P242/3 only)
799	FnKey LED10 ConG	PSL	Input signal driving Function Key LED 10 Green is on. This LED is associated with Function Key 10. To make function key LED 10 yellow, DDB 798 and DDB 799 must be on at the same time (P242/3 only)
800 to 922	Not Used		
923	PSL Int 1	PSL	PSL Internal Node
1023	PSL Int 101	PSL	PSL Internal Node
1024	Virtual Input 1	GOOSE Input Command	Virtual Input 1 - allows binary signals that are mapped to virtual inputs to interface into PSL
1087	Virtual Input 64	GOOSE Input Command	Virtual Input 64- allows binary signals that are mapped to virtual inputs to interface into PSL

Table 2: Description of available logic nodes

3.19   Default PSL

The following section details the default settings of the PSL.

Model	Opto inputs	Relay outputs
P241xxxxxxxxxxxJ	8	7
P242xxxxxxxxxxxK	16	16
P243xxxxxxxxxxxK	16	16

Table 3: Default settings

3.20   Logic Input Mapping

The default mappings for each model of the opto-isolated inputs are shown in the following tables:

Opto-Input number	P241 relay text	Function
1	Input L1	L1 CB Closed 3-Ph (52a), LED #1
2	Input L2	L2 CB Open 3-Ph (52b), LED #2
3	Input L3	L3 Speed Input, LED #3
4	Input L4	L4 Emergency Restart
5	Input L5	L5 Reset Thermal
6	Input L6	L6 Reset Latches
7	Input L7	L7 Close
8	Input L8	L8 Trip

Table 4: P241 opto inputs default mappings

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Opto-Input number	P242/3 relay text	Function
1	Input L1	L1 CB Closed 3-Ph (52a), LED #1 (Green)
2	Input L2	L2 CB Open 3-Ph (52b), LED #1 (Red)
3	Input L3	L3 Speed Input, LED #3 (Yellow)
4	Input L4	L4. Not Used
5	Input L5	L5 Not Used
6	Input L6	L6 Not Used
7	Input L7	L7 Not Used
8	Input L8	L8. Not Used
9	Input L9	L9 Not Used
10	Input L10	L10 Not Used
11	Input L11	L11 Not Used
12	Input L12	L12 Not Used
13	Input L13	L13 Not Used
14	Input L14	L14 Not Used
15	Input L15	L15 Not Used
16	Input L16	L16 Not Used

Table 5: P242/3 opto inputs default mappings

3.21   Relay Output Contact Mapping

The default mappings for each model of the output contacts are shown in the following tables:

Relay contact number	P241 relay text	P241 relay conditioner	Function
1	Output R1	Straight Through	R1 Control Close and Auto-Restart
2	Output R2	Straight Through	R2 Any Protection Start
3	Output R3	Straight Through	R3 Any Protection Trip, Control Trip
4	Output R4	Straight Through	R4 Start Protection (Number of hot/cold starts, time between starts), Thermal Trip, 3Ph Volt Alarm
5	Output R5	N/A	R5 Not Used
6	Output R6	N/A	R6 Not Used
7	Output R7	N/A	R7 Not Used

Table 6: P241 relay output contacts default mappings

Relay contact number	P242/3 relay text	P242/3 relay conditioner	Function
1	Output R1	Straight Through	R1 Control Close and Auto-Restart
2	Output R2	Straight Through	R2 Any Protection Start
3	Output R3	Straight Through	R3 Any Protection Trip, Control Trip
4	Output R4	Straight Through	R4 Start Protection (Number of hot/cold starts, time between starts), Thermal Trip, 3Ph Volt Alarm
5	Output R5	N/A	R5 Not Used
6	Output R6	N/A	R6 Not Used
7	Output R7	N/A	R7 Not Used
8	Output R8	N/A	R8 Not Used
9	Output R9	N/A	R9 Not Used

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Relay contact number	P242/3 relay text	P242/3 relay conditioner	Function
10	Output R10	N/A	R10 Not Used
11	Output R11	N/A	R11 Not Used
12	Output R12	N/A	R12 Not Used
13	Output R13	N/A	R13 Not Used
14	Output R14	N/A	R14 Not Used
15	Output R15	N/A	R15 Not Used
16	Output R16	N/A	R16 Not Used

Table 7: P242/3 relay output contacts default mappings

> **Note:** A fault record can be generated by connecting one or a number of contacts to the "Fault Record Trigger" in PSL. It is recommended that the triggering contact be 'self reset' and not a latching. If a latching contact were chosen the fault record would not be generated until the contact had fully reset.

3.22 Programmable LED Output Mappings

The default mappings for each model of the programmable LEDs are shown in the following tables. P241 has red LEDs and P242/3 have tri-colour LEDs.

LED number	LED input connection/text	Latched	P241 LED function indication
1	LED 1 Red	No	Opto Input 1 (CB Closed, 52a)
2	LED 2 Red	No	Opto Input 2 (CB Open, 52b)
3	LED 3 Red	No	Opto Input 3 (Speed Switch)
4	LED 4 Red	No	Start in Progress
5	LED 5 Red	No	Re-acceleration in Progress
6	LED 6 Red	No	Start Successful
7	LED 7 Red	No	Re-acceleration Low Voltage Detected
8	LED 8 Red	No	Start Protection (Number of hot/cold starts, time between starts), Thermal Trip, 3Ph Volt Alarm

Table 8: P241 programmable LED default mappings

LED number	LED input connection/text	Latched	P242/3 LED function indication
1	LED 1 Green	No	Opto Input 1 (CB Closed, 52a)
1	LED 1 Red	No	Opto Input 2 (CB Open, 52b)
2	LED 2 Green	No	Auto Restart OK
2	LED 2 Red	No	Auto Restart Fail
2	LED2 Yellow	No	Auto Restart in progress
3	LED 3 Yellow	No	Opto Input 3 (Speed Switch)
4	LED 4 Yellow	No	Start in Progress
5	LED 5 Yellow	No	Re-acceleration in Progress
6	LED 6 Green	No	Start Successful
7	LED 7 Yellow	No	Re-acceleration Low Voltage Detected
8	LED 8 Red	No	Start Protection (Number of hot/cold starts, time between starts), Thermal Trip, 3Ph Volt Alarm
9	FnKey LED1 (Yellow)	N/A	Emergency Restart
10	FnKey LED2 (Yellow)	N/A	Trip

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LED number	LED input connection/text	Latched	P242/3 LED function indication
11	FnKey LED3 (Yellow)	N/A	Close
12	FnKey LED4	N/A	Not Used
13	FnKey LED5 (Red)	N/A	Setting Group
14	FnKey LED6	N/A	Not Used
15	FnKey LED7	N/A	Not Used
16	FnKey LED8 (Yellow)	N/A	Reset Thermal
17	FnKey LED9 (Yellow)	N/A	Reset Latches
18	FnKey LED10 (Yellow)	N/A	Disturbance Recorder Trigger

Table 9: P242/3 programmable LED default mappings

3.23 Fault Recorder Start Mapping

The default mapping for the signal which initiates a fault record is shown in the following table:

Initiating signal	Fault trigger
Any Trip (DDB 371)	Initiate fault recording from any protection trip

Table 10: Default fault record initiation

3.24 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. PSL Ref.
```

Date/time: This cell displays the date and time when the PSL scheme was downloaded to the IED.

Example:

```
18 Nov 2002
08:59:32.047
```

Grp(n) PSL ID: This cell displays a unique ID number for the downloaded PSL scheme.

Example:

```
Grp. 1 PSL
ID - 2062813232
```

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4 VIEWING AND PRINTING PSL DIAGRAMS

You can view and print the PSL diagrams for the device. Typically these diagrams allow you to see the following mappings:

- Opto Input Mappings
- Output Relay Mappings
- LED Mappings
- Start Indications
- Phase Trip Mappings
- System Check Mapping

To download the default PSL diagrams for the device and to print them:

1. Close the Settings Application Software.
2. Start the **Data Model Manager**.
3. Click **Add** then **Next**.
4. Click **Internet** then **Next**.
5. Select your language then click Next.
6. From the tree view, select the model and software version.
7. Click **Install**. When complete click **OK**.
8. Close the Data Model Manager and start the Settings Application Software.
9. Select Tools then **PSL Editor (Px40).**
10. In the PSL Editor select **File** then **New** then **Default Scheme**.
11. Select the IED type
12. Use the advance button to select the software, then select the model number.
13. Highlight the required PSL diagram and select **File** then **Print**.

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MEASUREMENTS AND RECORDING

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CONTENTS

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1 MEASUREMENTS AND RECORDING

1.1 Event Records

GE 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 relay's non-volatile memory. Each event is time tagged.

The event records can be displayed on an relay'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		No
Right hand column header	VIEW RECORDS → Event Text		No
Description	SYSTEM DATA → Description		Yes
Plant reference	SYSTEM DATA → Plant Reference		Yes
Model number	SYSTEM DATA → Model Number		No
Address	Displays the Courier address relating to the event		No
Event type	VIEW RECORDS → Menu Cell Ref		No
Event value	VIEW RECORDS → Event Value		No
Evt Unique Id	VIEW RECORDS → Evt Unique ID		No

The **Select Event** setting allows access to individual event records, with the latest event stored at position 0. This setting also defines the maximum number of records available.

In addition to the event log, there are two logs which contain duplicates of the last 5 maintenance records and the last 5 fault records. The purpose of this is to provide convenient access to the most recent fault and maintenance events.

1.2 Event Types

There are several different types of event:

- Opto-input events (change of state of opto-input)
- Contact events (change of state of output relay contact)
- Alarm events
- 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.

1.2.1 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.

1.2.2 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.

1.2.3 Alarm Events

The relay 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.

1.2.4 Fault Record Events

An event record is created for every fault the relay 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

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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:
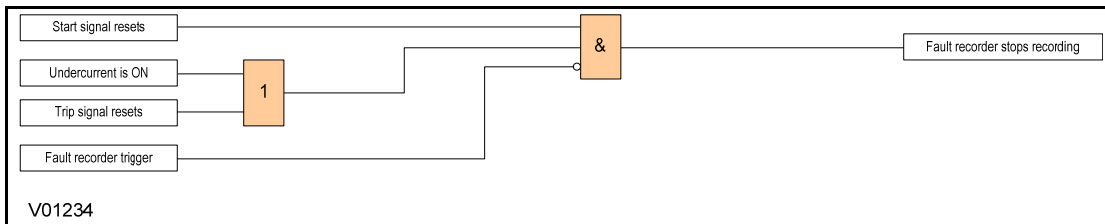
Figure 1: Fault recorder stop conditions

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.

1.2.5   Maintenance Events

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

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

The **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.

1.2.6   Protection Events

The relay 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.

1.2.7 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.

1.2.8 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.

1.2.9 Setting Changes

Changes to any setting in the relay are logged as an event. Two examples are shown in the following table:

Type of setting change	Displayed text in event record	Displayed value
Control/Support Setting	C & S Changed	22
Group # Change	Group # Changed	#

Where # = 1 to 2

> **Note:**   Control/Support settings are communications, measurement, CT/VT ratio settings etc, which are not duplicated within the two setting groups. When any of these settings are changed, the event record is created simultaneously. However, changes to protection or disturbance recorder settings will only generate an event once the settings have been confirmed at the 'setting trap'.

1.2.10 Event Filtering

Event reporting can be disabled from all interfaces that supports setting changes. The settings that control the various types of events are in the record control column. The effect of setting each to disabled is as follows:

Menu text	Default setting	Available settings
RECORD CONTROL		
Clear Events	No	No or Yes
Selecting **Yes** will cause the existing event log to be cleared and an event will be generated indicating that the events have been erased.		
Clear Faults	No	No or Yes
Selecting **Yes** will cause the existing fault records to be erased from the relay.		
Clear Test Log	No	No or Yes
Selecting **Yes** will cause the existing maintenance records to be erased from the relay.		
Alarm Event	No	No/Yes
Disabling this setting means that no event will be generated for all alarms.		
Output Event	No	No/Yes
Disabling this setting means that no event will be generated for any change in relay output contact state.		
Opto Input Event	No	No/Yes
Disabling this setting means that no event will be generated for any change in logic input state.		
Relay Sys Event	No	No/Yes
Disabling this setting means that no General Events will be generated.		
Fault Rec Event	No	No/Yes
Disabling this setting means that no event will be generated for any fault that produces a fault record.		
Maint. Rec Event	No	No/Yes
Disabling this setting means that no event will be generated for any maintenance records.		
Protection Event	No	No/Yes

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Menu text	Default setting	Available settings
Disabling this setting means that no event will be generated for any operation of the protection elements.		
DDB 31 - 0	11111111111111111111111111111111	
32 bit setting to enable or disable the event recording for DDBs 0-31. For each bit 1 = event recording Enabled, 0 = event recording Disabled.		
DDB 1022 - 992	11111111111111111111111111111111	
32 bit setting to enable or disable the event recording for DDBs 1022 – 992. For each bit 1 = event recording Enabled, 0 = event recording Disabled. There are similar cells showing 32 bit binary strings for all DDBs from 0 – 1022. The first and last 32 bit binary strings only are shown here.		
Clear Dist Recs	No	No/Yes
Clears all stored disturbance records from the relay		

Note: Some occurrences will result in more than one type of event, for example a battery failure will produce an alarm event and a maintenance record event.

If the Protection Event setting is Enabled a further set of settings is revealed which allow the event generation by individual DDB signals to be enabled or disabled.

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2   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 relay'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.

This process is fully explained in the SCADA Communications chapter, *P24x/EN SC*.

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3 MEASUREMENTS

3.1 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:

- Phase Voltages and Currents
- Phase to Phase Voltage and Currents
- Sequence Voltages and Currents
- Power and Energy Quantities
- Rms. Voltages and Currents
- Peak and Fixed Demand Values

3.1.1 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.

3.1.2 Sequence Voltages and Currents

Sequence quantities are produced by the relay from the measured Fourier values; these are displayed as magnitude values.

3.1.3 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 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.

3.1.4 Rms. Voltages and Currents

Rms. phase voltage and current values are calculated by the relay using the sum of the samples squared over a cycle of sampled data.

3.1.5 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.

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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.

3.2 Measurement Setup

You can define the way measurements are set up and displayed using the **MEASURE'T SETUP** column. Measurements are shown in the relevant **MEASUREMENTS** tables.

3.3 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.

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FIRMWARE DESIGN

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CONTENTS

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FIGURES

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1 HARDWARE ARCHITECTURE

The main components comprising devices based on the Px4x 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)
- A selection of plug-in boards and modules with presentation at the rear for the power supply, communication functions, digital I/O, analogue inputs, and time synchronisation connectivity

All boards and 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.
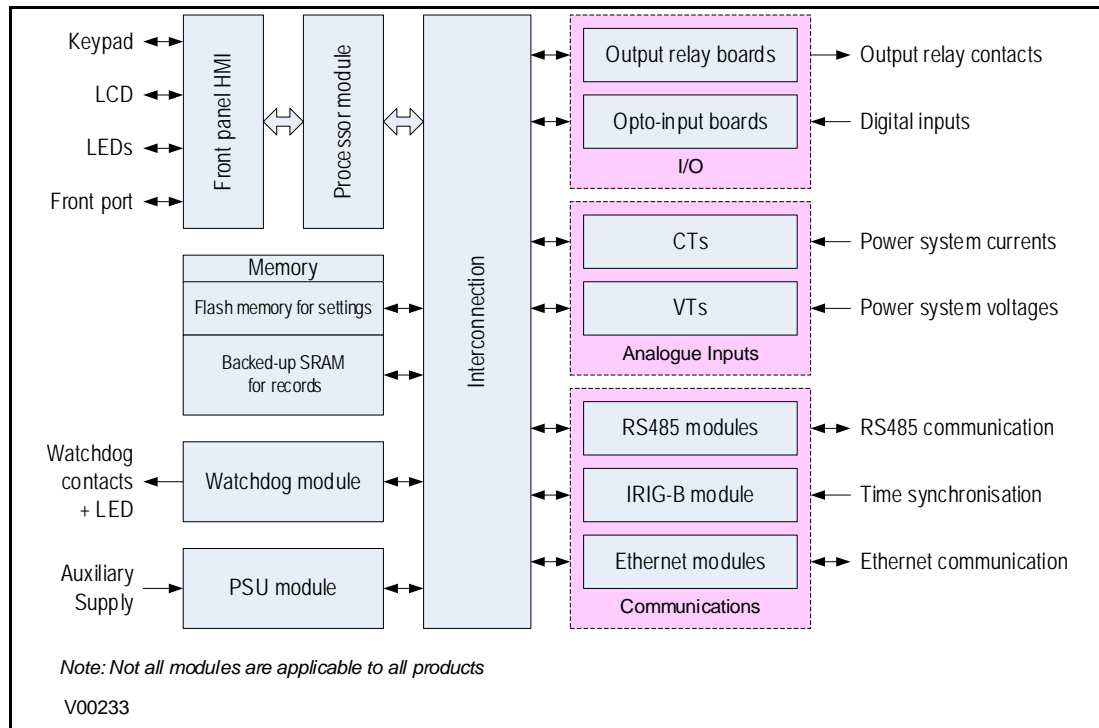
Figure 1: Hardware architecture

2   MECHANICAL IMPLEMENTATION

All products based on the Px4x platform have common hardware architecture. The hardware is modular and consists of the following main parts:

- Case and terminal blocks
- Boards and modules
- Front panel

The case comprises the housing metalwork and terminal blocks at the rear. The boards fasten into the terminal blocks and are connected together by a ribbon cable. This ribbon cable connects to the processor in the front panel.

2.1   Housing Variants

The Px4x range of products are implemented in a range of 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: 40TE, 60TE and 80TE. The case dimensions and compatibility criteria are as follows:

Case width (TE)	Case width (mm)	Case width (inches)
40TE	203.2	8
40TE	304.8	12
40TE	406.4	16

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> **Note:**   Not all case sizes are available for all models.

2.2   List of Boards

The product's hardware consists of several modules drawn from a standard range. The exact specification and number of hardware modules depends on the model number and variant. Depending on the exact model, the product in question will use a selection of the following boards.

Board	Use
Main Processor board – 40TE or smaller	Main Processor board – without support for function keys
Main Processor board – 60TE or larger	Main Processor board – with support for function keys
Power supply board 24/54V DC	Power supply input. Accepts DC voltage between 24V and 54V
Power supply board - 48/125V DC	Power supply input. Accepts DC voltage between 48V and 125V
Power supply board 110/250V DC	Power supply input. Accepts DC voltage between 110V and 125V
Transformer board	Contains the voltage and current transformers
Input board	Contains the A/D conversion circuitry
Input board with opto-inputs	Contains the A/D conversion circuitry + 8 digital opto-inputs
Redundant Ethernet RSTP + PRP + HSR + Failover + universal IRIG-B	Redundant Ethernet running RSTP + PRP + HSR + Failover (two fibre pairs), with onboard universal IRIG-B
Redundant Ethernet RSTP + PRP + HSR + Failover + universal IRIG-B	Redundant Ethernet running RSTP + PRP + HSR + Failover (two copper pairs), with on-board universal IRIG-B
Redundant Ethernet RSTP + PRP + HSR + Failover + universal IRIG-B	Redundant Ethernet running RSTP + PRP + HSR + Failover (one copper, one multimode fibre), with on-board universal IRIG-B
Output relay output board (8 outputs)	Standard output relay board with 8 outputs

Board	Use
RTD board	Contains 10 Resistive Temperature Device inputs
CLIO board	Contains 4 current loop inputs and 4 current loop outputs

3 BOARDS AND MODULES

Each product comprises a selection of PCBs (Printed Circuit Boards) and subassemblies, depending on the chosen configuration.

3.1 PCBs

A PCB typically consists of the components, a front connector for connecting into the main system parallel bus via a ribbon cable, and an interface to the rear. This rear interface may be:

- Directly presented to the outside world (as is the case for communication boards such as Ethernet Boards)

- Presented to a connector, which in turn connects into a terminal block bolted onto the rear of the case (as is the case for most of the other board types)

R00226
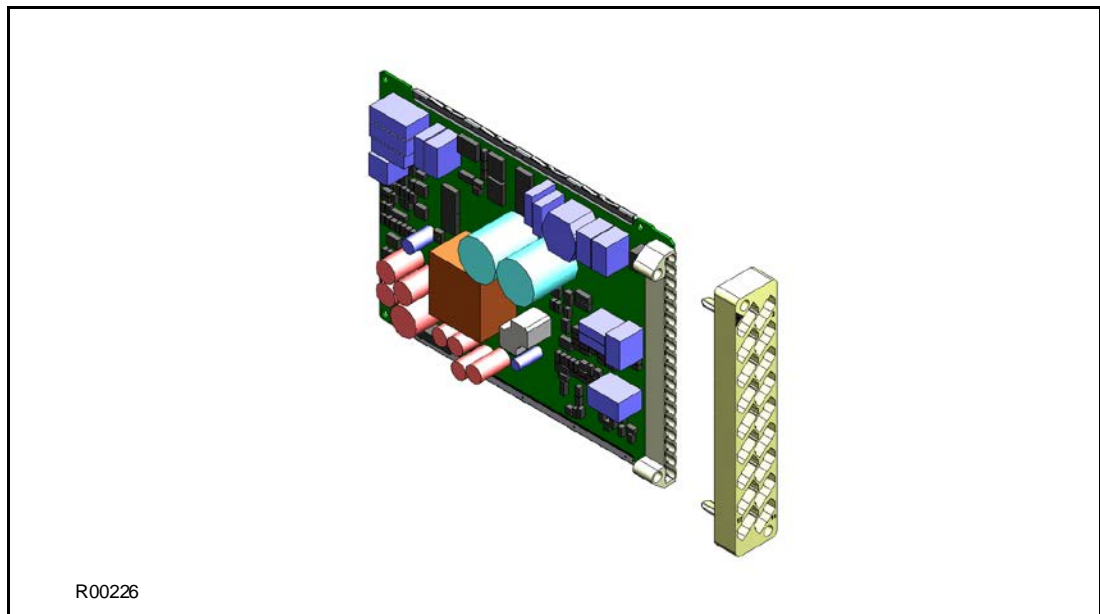
Figure 2: Rear connection to terminal block

3.2 Subassemblies

A sub-assembly consists of two or more boards bolted together with spacers and connected with electrical connectors. It may also have other special requirements such as being encased in a metal housing for shielding against electromagnetic radiation.

Boards are designated by a part number beginning with ZN, whereas pre-assembled sub-assemblies are designated with a part number beginning with GN. Sub-assemblies, which are put together at the production stage, do not have a separate part number.

The products in the Px40 series typically contain two sub-assemblies:

- The power supply assembly comprising:
  - A power supply board
  - An output relay board
- The input module comprising:
  - One or more transformer boards, which contains the voltage and current transformers (partially or fully populated)
  - One or more input boards
  - Metal protective covers for EM (electromagnetic) shielding

The input module is pre-assembled and is therefore assigned a GN number, whereas the power supply module is assembled at production stage and does not therefore have an individual part number.

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3.3 Main Processor Board
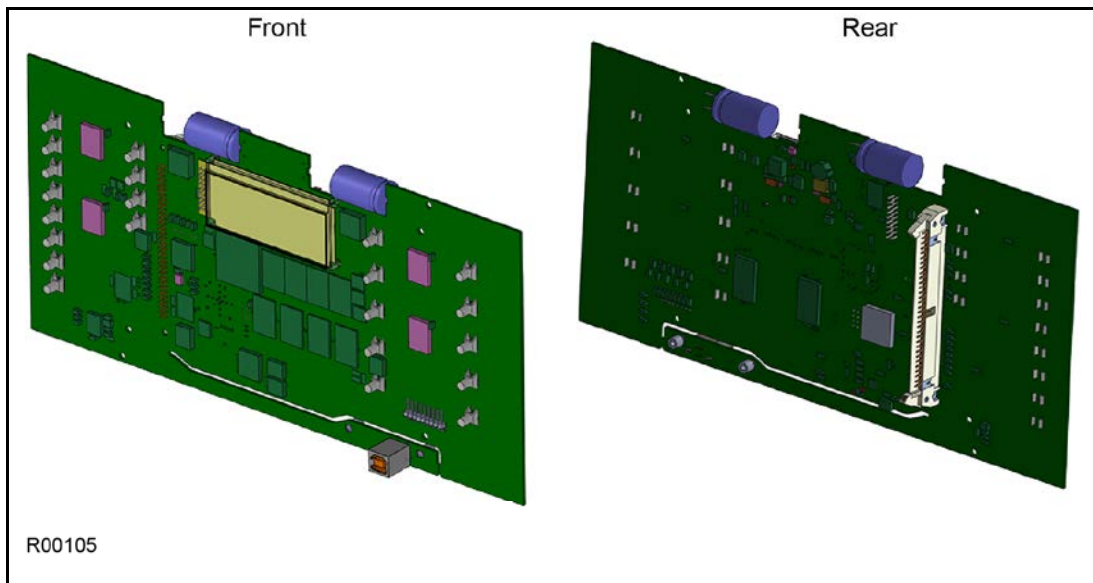
Figure 3: Main processor board

The main processor board performs all calculations and controls the operation of all other modules in the relay, including the data communication and user interfaces. This is the only board that does not fit into one of the slots.

It resides in the front panel and connects to the rest of the system using an internal ribbon cable.

The LCD and LEDs are mounted on the processor board along with the front panel communication ports.

The memory on the main processor board is split into two categories: volatile and non-volatile. The volatile memory is fast access SRAM, used by the processor to run the software and store data during calculations. The non-volatile memory is sub-divided into two groups:

- Flash memory to store software code, text and configuration data including the present setting values.
- Battery/supercapacitor* backed SRAM to store disturbance, event, fault and maintenance record data.

There are two board types available depending on the size of the case:

- For models in 40TE cases
- For models in 60TE cases and larger

Note: *Battery fitted to white front panel versions, supercapacitor fitted to black and silver front panel versions. For details, refer to the Ordering Options Appendix.

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3.4   Power Supply Board
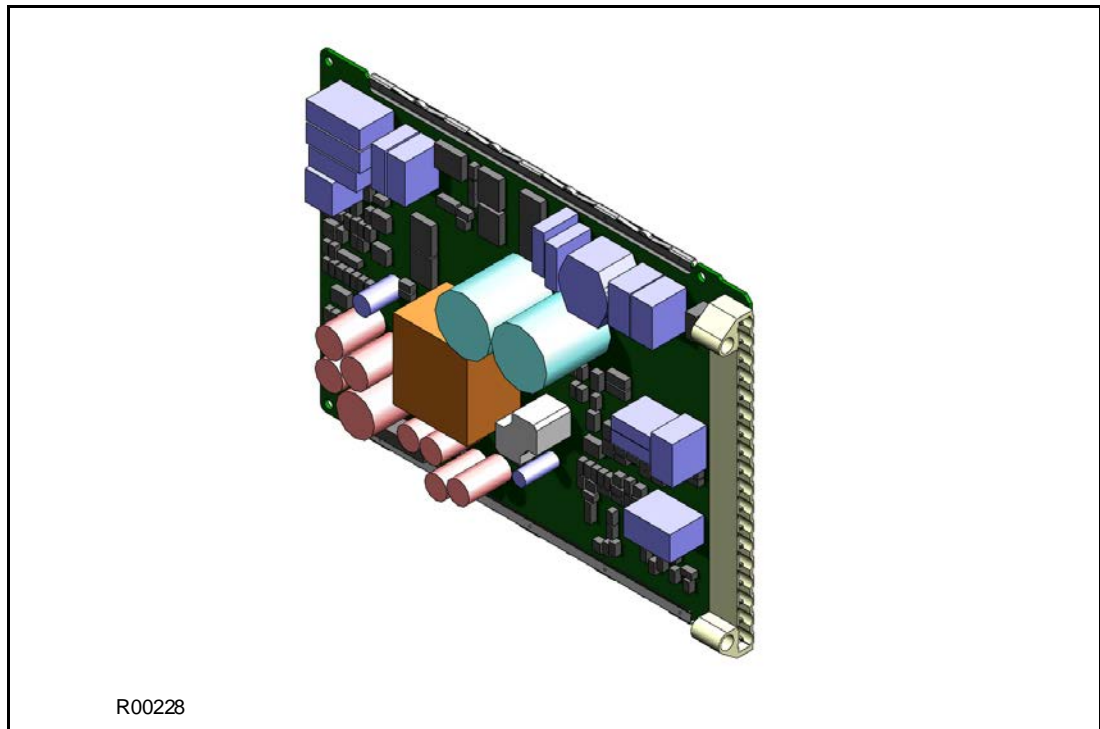
Figure 4: Power supply board

The power supply board provides power to the unit. One of three different configurations of the power supply board can be fitted to the unit. This is specified at the time of order and depends on the magnitude of the supply voltage that will be connected to it.

There are three board types, which support the following voltage ranges:

- 24/54 V DC
- 48/125 V DC or 40-100V AC
- 110/250 V DC or 100-240V AC

The power supply board connector plugs into a medium duty terminal block. This terminal block is always positioned on the right hand side of the unit looking from the rear.

The power supply board is usually assembled together with a relay output board to form a complete subassembly, as shown in the following diagram.

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R00229
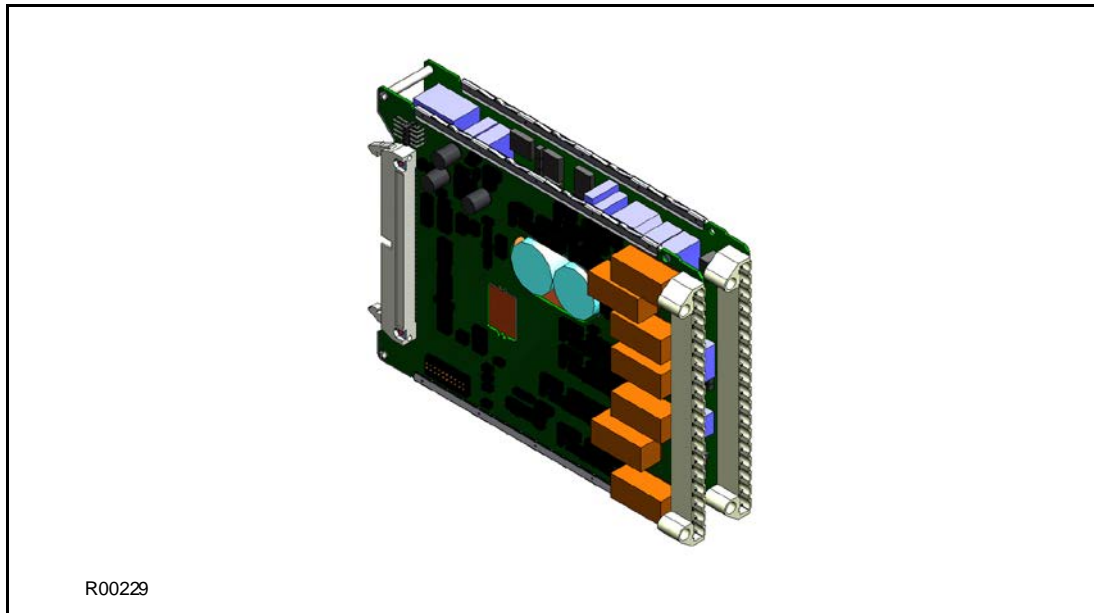
Figure 5: Power supply assembly

The power supply outputs are used to provide isolated power supply rails to the various modules within the unit.

Three voltage levels are used by the unit's modules:

- 5.1 V for all of the digital circuits
- +/- 16 V for the analogue electronics such as on the input board
- 22 V for driving the output relay coils.

All power supply voltages, including the 0 V earth line, are distributed around the unit by the 64-way ribbon cable.

The power supply board incorporates inrush current limiting. This limits the peak inrush current to approximately 10 A.

Power is applied to pins 1 and 2 of the terminal block, where pin 1 is negative and pin 2 is positive. The pin numbers are clearly marked on the terminal block as shown in the following diagram.

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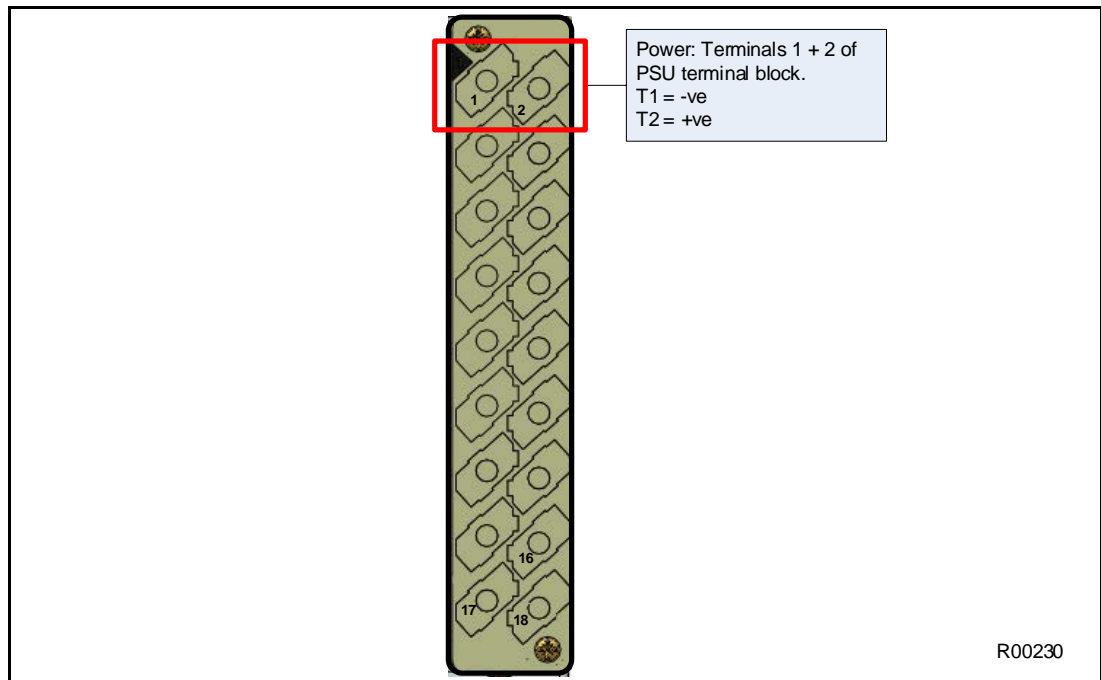
Figure 6: Power supply terminals

3.4.1 Watchdog

The Watchdog contacts are also hosted on the power supply board. The Watchdog facility provides two output relay contacts, one normally open and one normally closed. These are used to indicate the health of the device and are driven by the main processor board, which continually monitors the hardware and software when the device is in service.
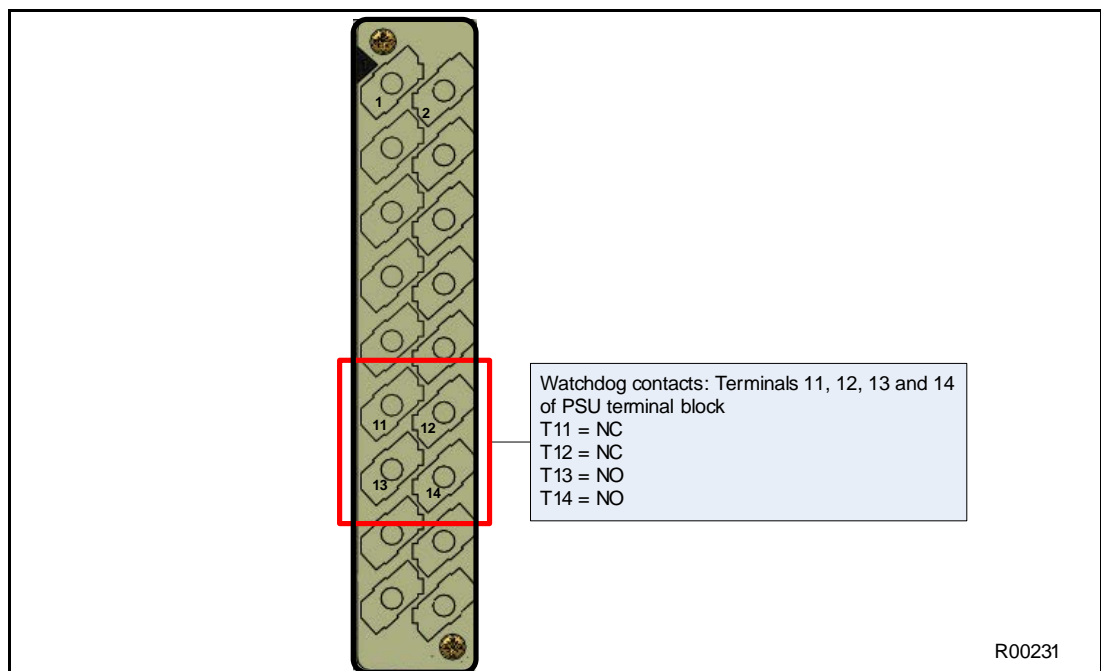
Figure 7: Watchdog contact terminals

3.5 Rear serial port

The rear serial port (RP1) is housed on the power supply board. This is a three-terminal EIA(RS)485 serial communications port and is intended for use with a permanently wired connection to a remote control centre for SCADA communication. The interface supports half-duplex communication and provides optical isolation for the serial data being transmitted and received.

The physical connectivity is achieved using three screw terminals; two for the signal connection, and the third for the earth shield of the cable. These are located on pins 16, 17 and 18 of the power supply terminal block, which is on the far right looking from the rear. The interface can be selected between RS485 and K-bus. When the K-Bus option is selected, the two signal connections are not polarity conscious.

The polarity independent K-bus can only be used for the Courier data protocol. The polarity conscious MODBUS, IEC 60870-5-103 and DNP3.0 protocols need RS485.

The following diagram shows the rear serial port. The pin assignments are as follows:

- Pin 16: Earth shield
- Pin 17: Negative signal
- Pin 18: Positive signal
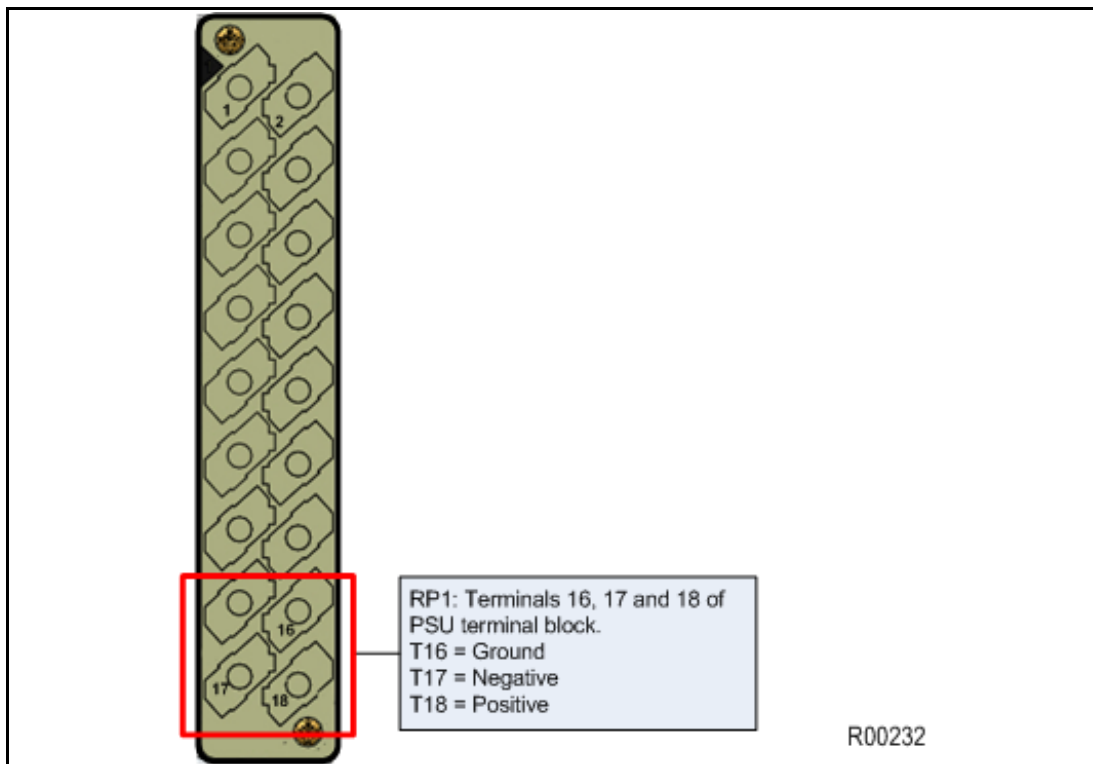
Figure 8: Rear serial port terminals

An additional serial port with D-type presentation is available as an optional board, if required.

3.5.1   Input module – 1 transformer board
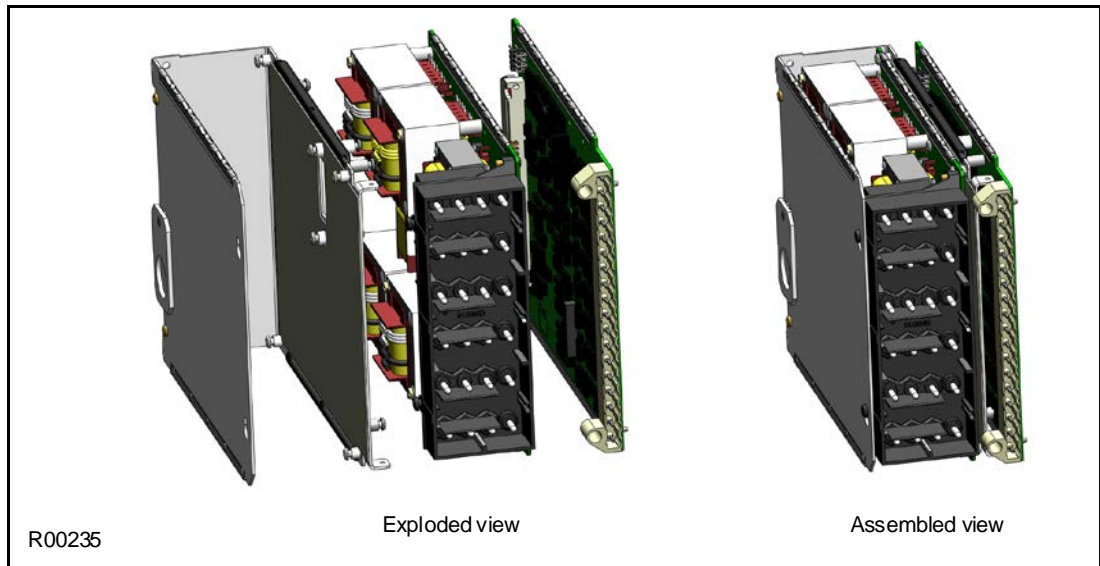
Figure 9: Input module – 1 transformer board

The input module consists of the main input board coupled together with an instrument transformer board. The instrument transformer board contains the voltage and current transformers, which isolate and scale the analogue input signals delivered by the system transformers. The input board contains the A/D conversion and digital processing circuitry, as well as eight digital isolated inputs (opto-inputs).

The boards are connected together physically and electrically. The module is encased in a metal housing for shielding against electromagnetic interference.

3.5.2   Input Module Circuit Description
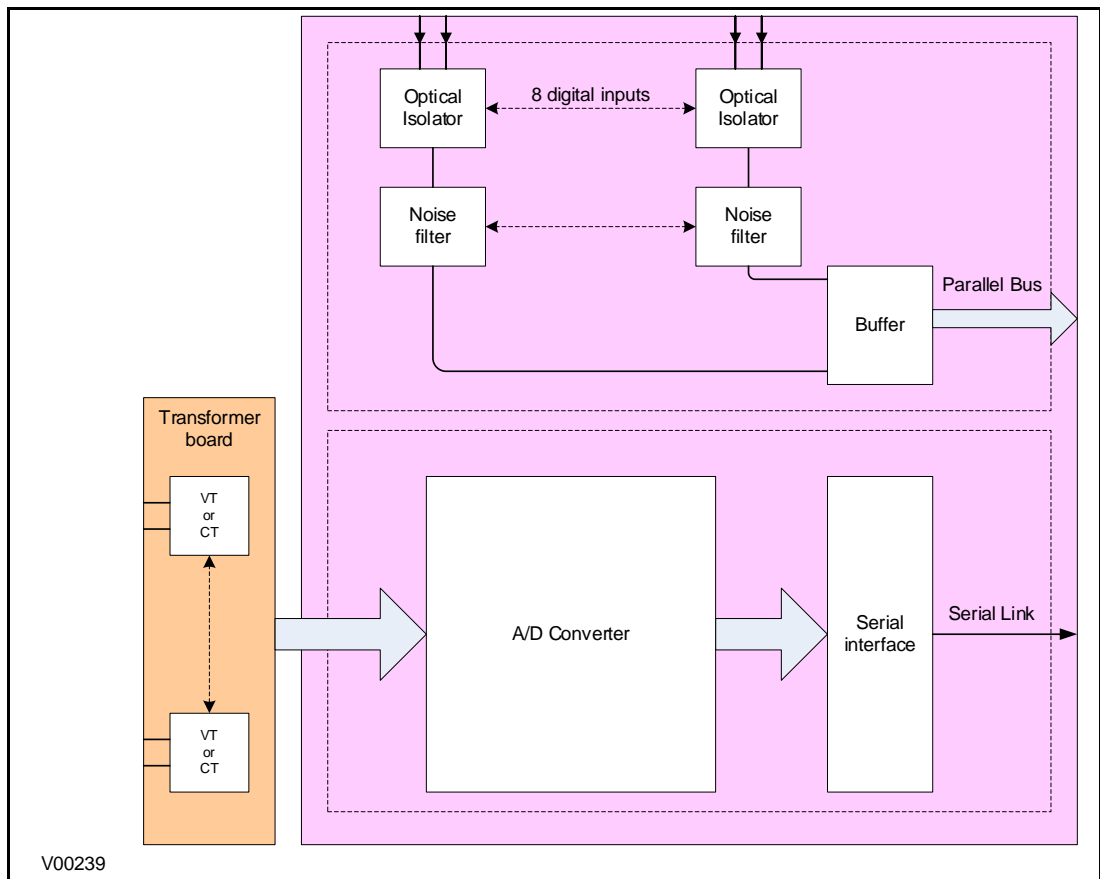
Figure 10: Input module schematic

A/D Conversion

The differential analogue inputs from the CT and VT transformers are presented to the main input board as shown. Each differential input is first converted to a single input quantity referenced to the input board's earth potential. The analogue inputs are sampled and converted to digital, then filtered to remove unwanted properties. The samples are then passed through a serial interface module which outputs data on the serial sample data bus.

The calibration coefficients are stored in non-volatile memory. These are used by the processor board to correct for any amplitude or phase errors introduced by the transformers and analogue circuitry.

Opto-isolated inputs

The other function of the input board is to read in the state of the digital inputs. As with the analogue inputs, the digital inputs must be electrically isolated from the power system. This is achieved by means of the 8 on-board optical isolators for connection of up to 8 digital signals. The digital signals are passed through an optional noise filter before being buffered and presented to the unit's processing boards in the form of a parallel data bus.

This selectable filtering allows the use of a pre-set filter of ½ cycle which renders the input immune to induced power-system noise on the wiring. Although this method is secure it can be slow, particularly for inter-tripping. This can be improved by switching off the ½ cycle filter, in which case one of the following methods to reduce ac noise should be considered.

- Use double pole switching on the input
- Use screened twisted cable on the input circuit

The opto-isolated logic inputs can be configured for the nominal battery voltage of the circuit for which they are a part, allowing different voltages for different circuits such as signalling and tripping.

> Note: The opto-input circuitry can be provided without the A/D circuitry as a separate board, which can provide supplementary opto-inputs.

3.6   Transformer Board

R00237
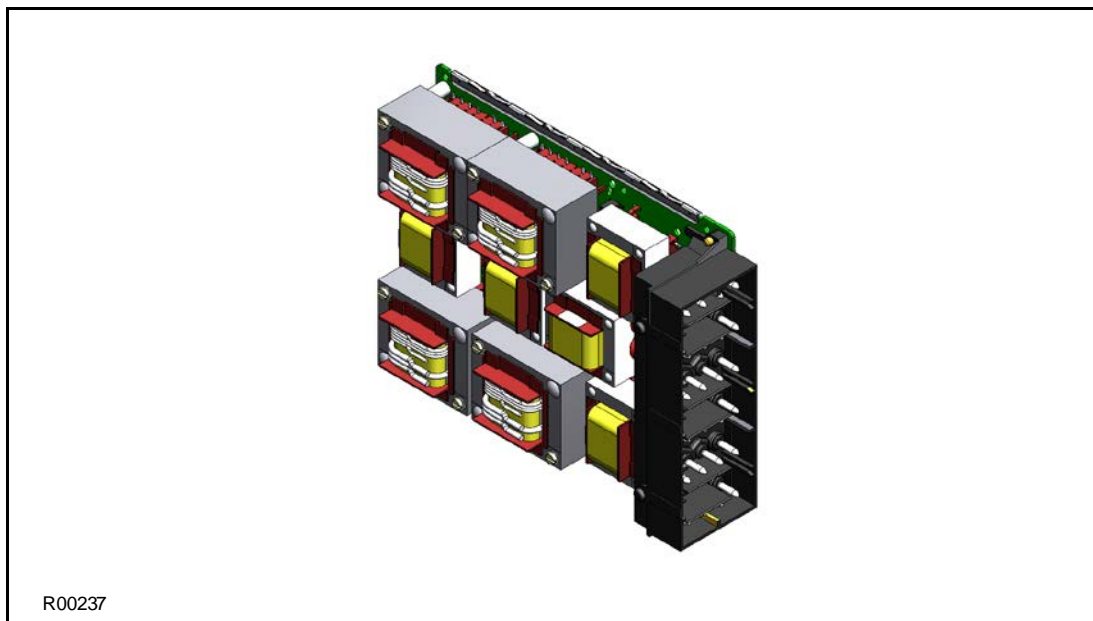
Figure 11: Transformer board

The transformer board hosts the current and voltage transformers. These are used to step down the currents and voltages originating from the power systems' current and voltage transformers to levels that can be used by the devices' electronic circuitry. In addition to this, the on-board CT and VT transformers provide electrical isolation between the unit and the power system.

The transformer board is connected physically and electrically to the input board to form a complete input module.

For terminal connections, please refer to the wiring diagrams.

3.7   Input Board

R00238
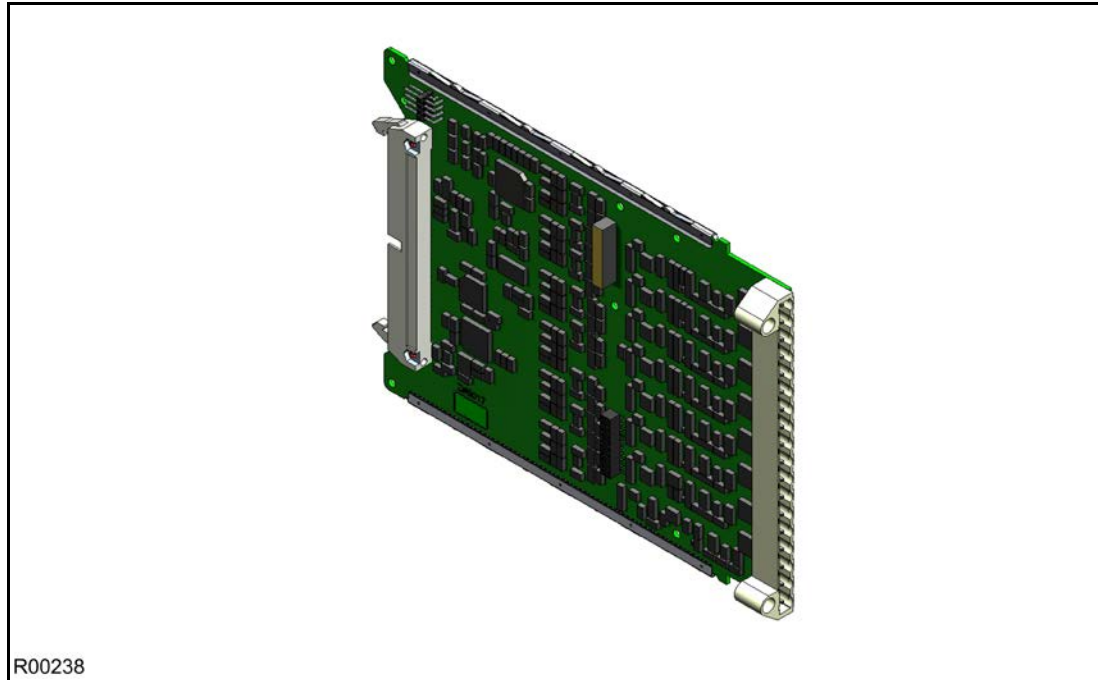
Figure 12: Input board

The input board is used to convert the analogue signals delivered by the current and voltage transformers into digital quantities used by the relay. This input board also has on-board opto-input circuitry, providing eight optically-isolated digital inputs and associated noise filtering and buffering. These opto-inputs are presented to the user by means of a MD terminal block, which sits adjacent to the analogue inputs HD terminal block.

The input board is connected physically and electrically to the transformer board to form a complete input module.

The terminal numbers of the opto-inputs are as follows:

Terminal Number	Opto-input
Terminal 1	Opto 1 -ve
Terminal 2	Opto 1 +ve
Terminal 3	Opto 2 -ve
Terminal 4	Opto 2 +ve
Terminal 5	Opto 3 -ve
Terminal 6	Opto 3 +ve
Terminal 7	Opto 4 -ve
Terminal 8	Opto 4 +ve
Terminal 9	Opto 5 -ve
Terminal 10	Opto 5 +ve
Terminal 11	Opto 6 -ve
Terminal 12	Opto 6 +ve
Terminal 13	Opto 7 –ve
Terminal 14	Opto 7 +ve
Terminal 15	Opto 8 –ve
Terminal 16	Opto 8 +ve

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Terminal Number	Opto-input
Terminal 17	Common
Terminal 18	Common

3.8 Standard Output Relay Board

R00234
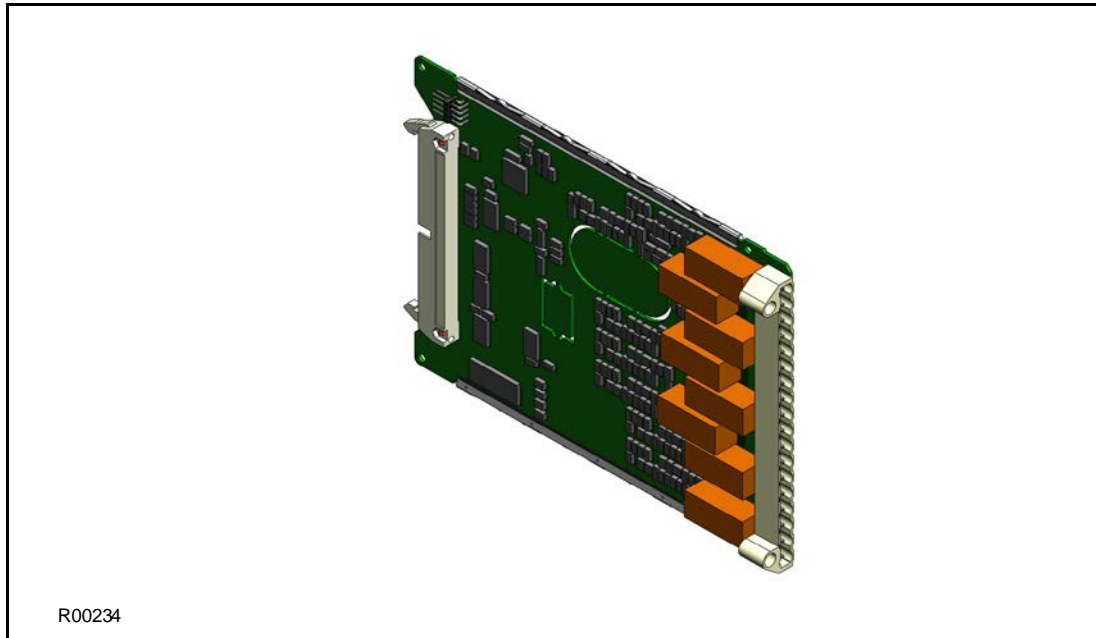
Figure 13: Standard output relay board - 8 contacts

This output relay board has 8 relays with 6 Normally Open contacts and 2 Changeover contacts.

The output relay board is provided together with the power supply board as a complete assembly, or independently for the purposes of relay output expansion.

There are two cut-out locations in the board. These can be removed to allow power supply components to protrude when coupling the output relay board to the power supply board. If the output relay board is to be used independently, these cut-out locations remain intact.

The terminal numbers are as follows:

Terminal Number	Output Relay
Terminal 1	Relay 1 NO
Terminal 2	Relay 1 NO
Terminal 3	Relay 2 NO
Terminal 4	Relay 2 NO
Terminal 5	Relay 3 NO
Terminal 6	Relay 3 NO
Terminal 7	Relay 4 NO
Terminal 8	Relay 4 NO
Terminal 9	Relay 5 NO
Terminal 10	Relay 5 NO
Terminal 11	Relay 6 NO
Terminal 12	Relay 6 NO
Terminal 13	Relay 7 changeover
Terminal 14	Relay 7 changeover
Terminal 15	Relay 7 common
Terminal 16	Relay 8 changeover
Terminal 17	Relay 7 changeover

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Terminal Number	Output Relay
Terminal 18	Relay 8 common

3.9 Internal Communication Buses

The relay has two internal buses for the communication of data between different modules. The main bus is a parallel link that is part of a 64-way ribbon cable. The ribbon cable carries the data and address bus signals in addition to control signals and all power supply lines. Operation of the bus is driven by the main processor board that operates as a master while all other modules within the relay are slaves.

The second bus is a serial link that is used exclusively for communicating the digital sample values from the input module to the main processor board. The DSP processor has a built-in serial port that is used to read the sample data from the serial bus. The serial bus is also carried on the 64-way ribbon cable.

3.10 Redundant Ethernet Board
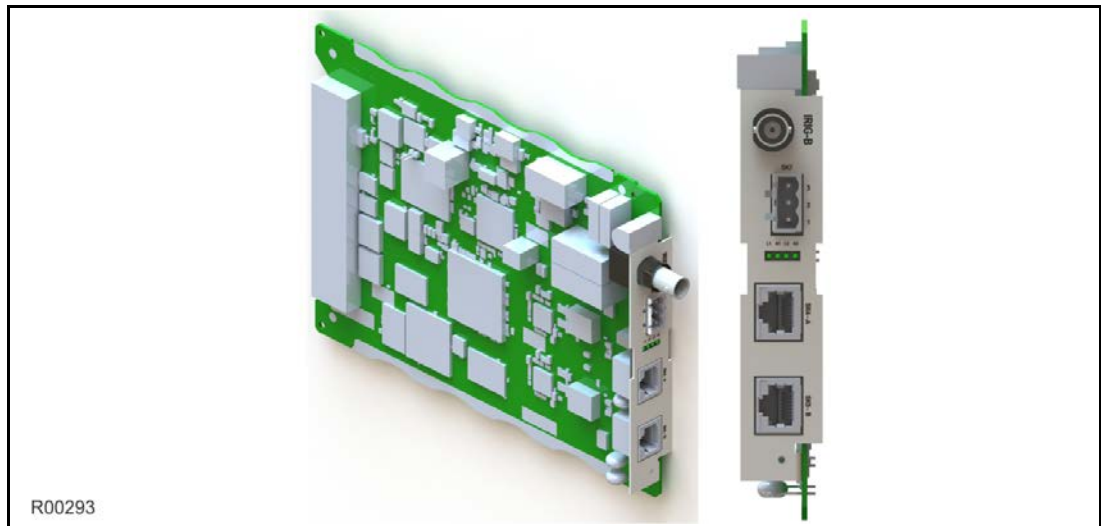
Figure 14: Redundant Ethernet board

This board provides dual redundant Ethernet (supported by two fibre pairs) together with an IRIG-B interface for timing.

Different board variants are available, depending on the redundancy protocol and the type of IRIG-B signal (unmodulated or modulated). The available redundancy protocols are:

- PRP (Parallel Redundancy Protocol)
- HSR (High-availability Seamless Redundancy)
- Failover

There are several variants for this board as follows:

- 100 Mbps redundant Ethernet running RSTP + PRP + HSR + Failover (two fibre pairs), with on-board universal IRIG-B
- 100 Mbps redundant Ethernet running RSTP + PRP + HSR + Failover (two copper pairs), with on-board universal IRIG-B100 Mbps redundant Ethernet running RSTP + PRP + HSR (two fibre pairs), with on-board universal IRIG-B
- 100 Mbps redundant Ethernet running RSTP + PRP + HSR + Failover (one copper, one multi-mode fibre), with on-board universal IRIG-B

The Ethernet and other connection details are described below:

IRIG-B Connector
- Centre connection: Signal
- Outer connection: Earth

Link Fail Connector (Ethernet Board Watchdog Relay)

Pin	Closed	Open
1-2	Link fail Channel 1 (A)	Link ok Channel 1 (A)
2-3	Link fail Channel 2 (B)	Link ok Channel 2 (B)

LEDs

LED	Function	On	Off	Flashing
Green	Link	Link ok	Link broken	
Yellow	Activity	SHP running		PRP, RSTP or DHP traffic

Optical Fibre Connectors (ST)

Connector	DHP	RSTP	SHP	PRP
A	RXA	RX1	RS	RXA
B	TXA	TX1	ES	TXA
C	RXB	RX2	RP	RXB
D	TXB	TX2	EP	TXB

RJ45 Connector

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

3.11 RTD Board
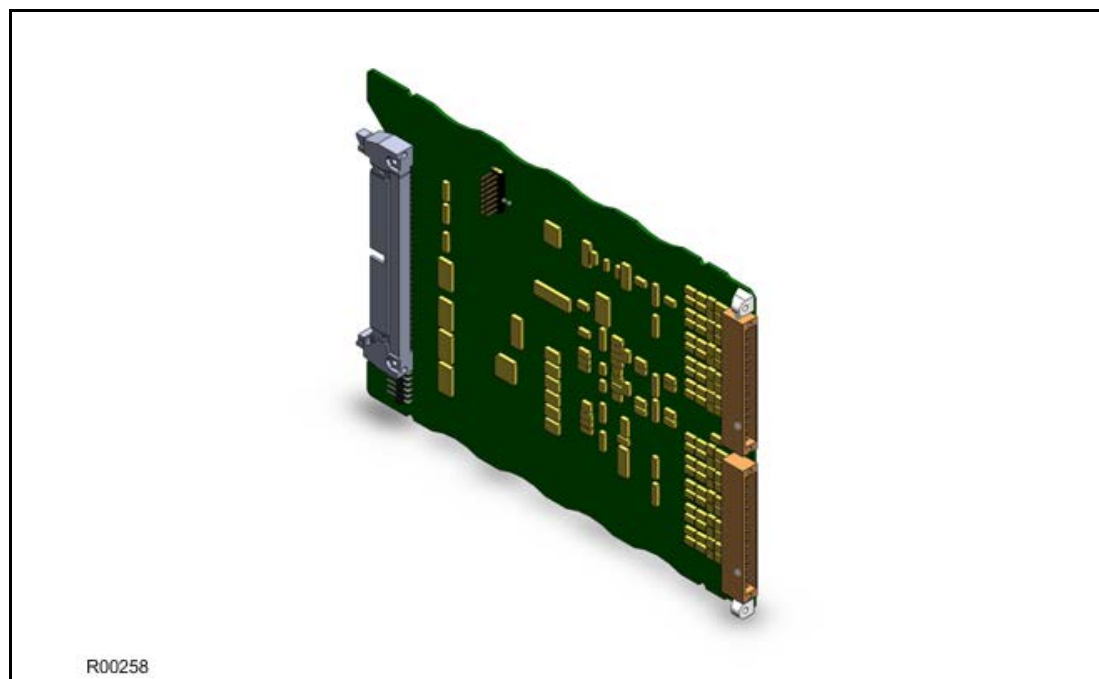
Figure 15: RTD board

The RTD board provides two banks of 15 terminals to support ten RTD inputs, of the type PT100, Ni100, or Ni120, depending on the product. There are three terminals for each RTD,

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therefore 30 terminals altogether. The RTD board fits into slot B or slot C, depending on the model variant.

The terminal numbers of the RTDs are as follows:

Terminal Number	RTD connection
Terminal 1	RTD1 wire 1
Terminal 2	RTD1 wire 2
Terminal 3	RTD1 wire 3
Terminal 4	RTD2 wire 1
Terminal 5	RTD2 wire 2
Terminal 6	RTD2 wire 3
Terminal 7	RTD3 wire 1
Terminal 8	RTD3 wire 2
Terminal 9	RTD3 wire 3
Terminal 10	RTD4 wire 1
Terminal 11	RTD4 wire 2
Terminal 12	RTD4 wire 3
Terminal 13	RTD5 wire 1
Terminal 14	RTD5 wire 2
Terminal 15	RTD5 wire 3
Terminal 16	RTD6 wire 1
Terminal 17	RTD6 wire 2
Terminal 18	RTD6 wire 3
Terminal 19	RTD7 wire 1
Terminal 20	RTD7 wire 2
Terminal 21	RTD7 wire 3
Terminal 22	RTD8 wire 1
Terminal 23	RTD8 wire 2
Terminal 24	RTD8 wire 3
Terminal 25	RTD9 wire 1
Terminal 26	RTD9 wire 2
Terminal 27	RTD9 wire 3
Terminal 28	RTD10 wire 1
Terminal 29	RTD10 wire 2
Terminal 30	RTD10 wire 3

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3.12 CLIO Board

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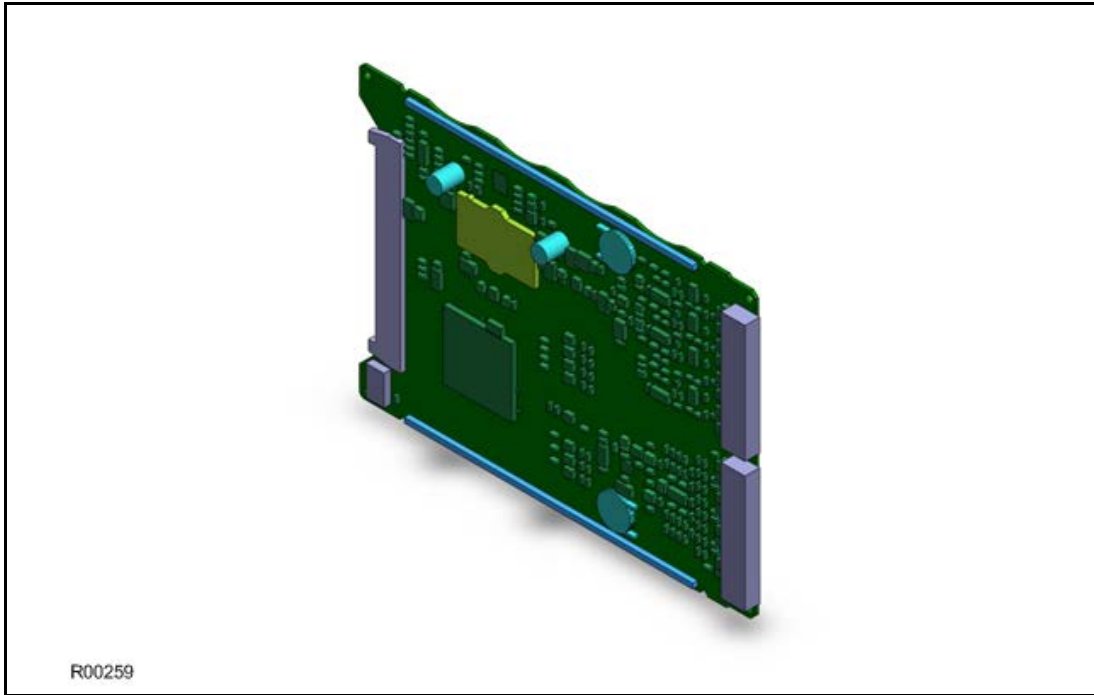
Figure 16: CLIO board

The CLIO board provides two banks of 15 terminals to support four current loop inputs and four current loop outputs. There are three terminals for each input and three for each output, therefore 24 of the terminals are used altogether. The CLIO board fits into slot B or slot C, depending on the model variant.

The terminal numbers of the current loop inputs and outputs are as follows:

Terminal Number	RTD connection
Terminal 1	CLO1 - 20 mA input
Terminal 2	CLO1 - 1 mA input
Terminal 3	CLO1 - common input
Terminal 4	Not used
Terminal 5	CLO2 - 20 mA input
Terminal 6	CLO2 - 1 mA input
Terminal 7	CLO2 - common input
Terminal 8	Not used
Terminal 9	CLO3 - 20 mA input
Terminal 10	CLO3 - 1 mA input
Terminal 11	CLO3 - common input
Terminal 12	Not used
Terminal 13	CLO4 - 20 mA input
Terminal 14	CLO4 - 1 mA input
Terminal 15	CLO4 - common input
Terminal 16	CLI1 - 20 mA input
Terminal 17	CLI1 - 1 mA input
Terminal 18	CLI1 - common input
Terminal 19	Not used
Terminal 20	CLI2 - 20 mA input
Terminal 21	CLI2 - 1 mA input
Terminal 22	CLI2 - common input

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Terminal Number	RTD connection
Terminal 23	Not used
Terminal 24	CLI3 - 20 mA input
Terminal 25	CLI3 - 1 mA input
Terminal 26	CLI3 - common input
Terminal 27	Not used
Terminal 28	CLI4 - 20 mA input
Terminal 29	CLI4 - 1 mA input
Terminal 30	CLI4 - common input

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4 SOFTWARE DESIGN OVERVIEW

The device software can be conceptually categorized 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. The following figure shows the software architecture.
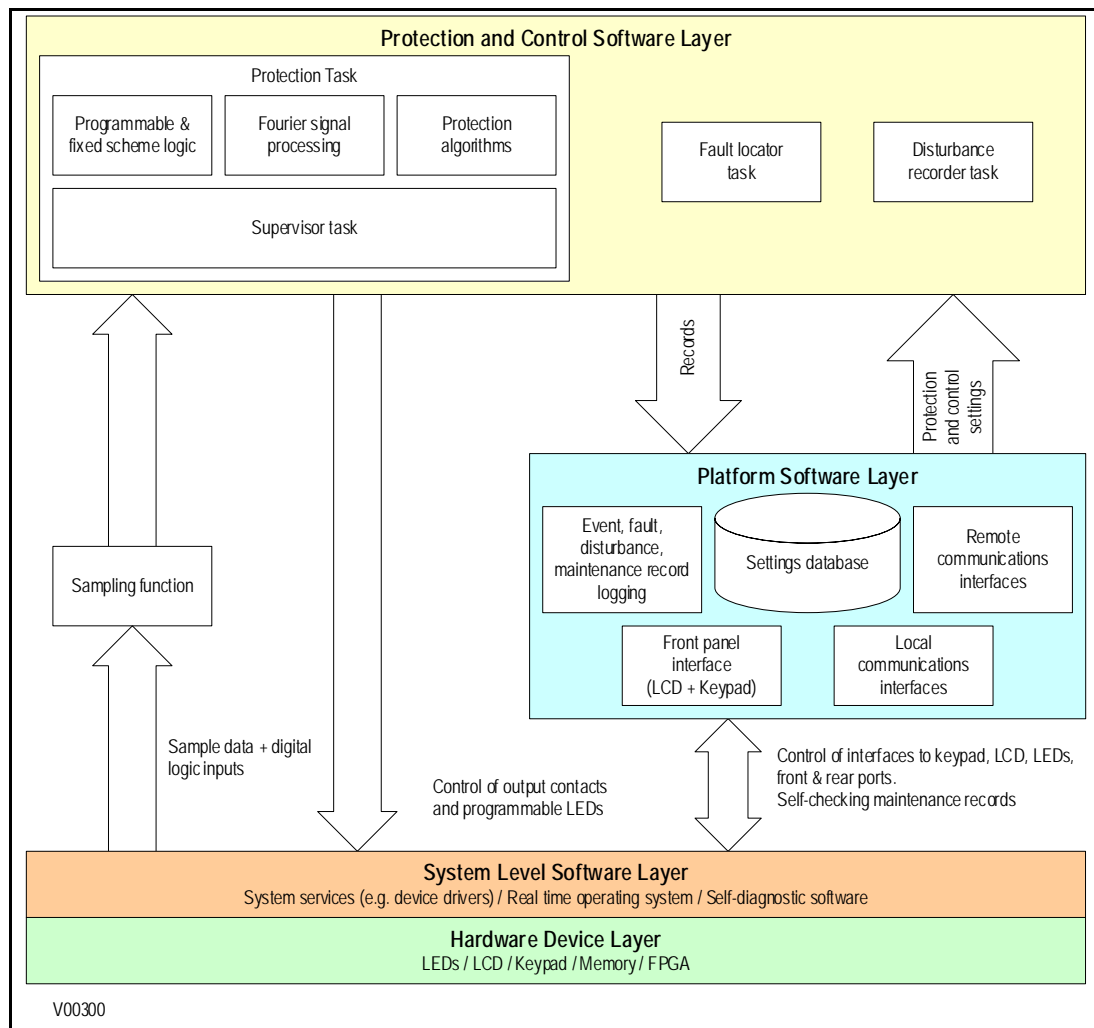
Figure 17: Software architecture

The software, which executes on the main processor, 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 and when required.

5   SYSTEM LEVEL SOFTWARE

5.1   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, through the use of operating system messages.

5.2   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.

5.3   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 bootup, and secondly a continuous self-checking operation, which checks the operation of the critical functions whilst it is in service.

5.4   Startup Self-Testing

The self-testing takes a few seconds to complete, during which time the relay'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

5.4.1   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 relay's initialisation code.

5.4.2   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 initialisation process the device checks the following:

- The status of the battery/supercapacitor*

- The integrity of the battery/supercapacitor* backed SRAM that 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.

> **Note:** *Battery fitted to white front panel versions, supercapacitor fitted to black and silver front panel versions. For details, refer to the Ordering Options Appendix.

5.4.3 Platform Software Initialization & Monitoring

When starting the platform software, the relay 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.

5.5 Continuous Self-Testing

When the device 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-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 battery status, supercapacitor or the 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 relay 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.

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Primary Self Tests
- User Boot
- Bus Integrity SRAM Test
- Data SRAM Test
- Watchdog Self Test
- System Initialization
- Flash Checksum Test
- Code Verify Test Between Flash and SRAM

Secondary Self Tests
- BBRAM Self Test
- Bus Reset Test
- Battery Self Test
- Field Voltage Status

Check → Pass → Start Secondary Self Test

Check → Fail → Critical/Major Primary Self Test Fault
1) Start-up Terminated
   Relay Lockout
   Error Message
   Healthy LED is off

Check → Pass → & → Healthy LED On (In Service)

Check → Fail → Critical/Major Secondary Test Fault
2) Log Maintenance Record
   Start-up Terminated
   Relay Lockout
   Error Code Message
   Healthy LED is off

Check → Pass

Check → Fail → Trivial/Minor Secondary Test Fault
3) Log Maintenance Record
   Continues Start-up Sequence
   Error Message
   Healthy LED is on
   Yellow Alarm LED is Flashing

1) Critical, Primary Self Test Error Messages

Error Message on User Interface	Description
Bus Fail	Integrity Bus Test Error
SRAM Fail	SRAM Test Error
Flash Fail (Checksum)	Flash test error detected in the flash structure
Code Verify Fail	Error in code comparison test flash
Watchdog Fail	Watchdog circuit fails to operate

2) Critical, Secondary Self Test Error Messages

Error Code	Description
0x0C170017	The secondary self tests detected an error in the Battery Backed SRAM (BBRAM)
0x0C170018	The secondary self tests detected an error in the Bus Circuit

3) Trivial, Secondary Power on Self Tests Alarm Indications

Alarm	Description
Battery Failure	The secondary self tests detected battery self test has failed
Field Volt Fail	The secondary self tests detected Field Voltage failure

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Figure 18: Start-up self-testing logic

Data SRAM Test

Flash Checksum Test

Code Verify Test Between Flash and SRAM

BBRAM Test

Analog Data Acquisition

Digital Input/output

Battery Status Test

Field Voltage Status

Check

Check

Pass

Fail

Pass

Fail

&

Relay Healthy LED is on

(In Service)

Critical/Major Self Test Fault

1) Log Maintenance Record
   Error Code Message
   Healthy LED Turns off
   Relay Reboots => Power on Tests
   Watchdog Contact operates

Watchdog Contact

Trvial/Minor Self Test Fault

2) Log Maintenance Record
   Error Message
   Healthy LED Remains on
   Yellow Alarm LED

1) Critical, Continuous Self-Test Error codes

Error Code	Description
0x0C160011	The continuous self-tests detected an error in SRAM
0x0C160012	The continuous self-tests detected an error in the Flash memory checksum
0x0C160013	The continuous self-tests detected an error in the code comparison
0x0C160014	The continuous self-tests detected an error in the Battery Backed RAM
0x0C1600A0	The continuous self-tests detected an error in the acquisition card
0x0C1600Bn	The continuous self-tests detected an error in relay card n (number from 0)
0x01600Cn	The continuous self-tests detected an error in opto card n (number from 0)

2) Trivial, Continuous Self-Test alarm indications

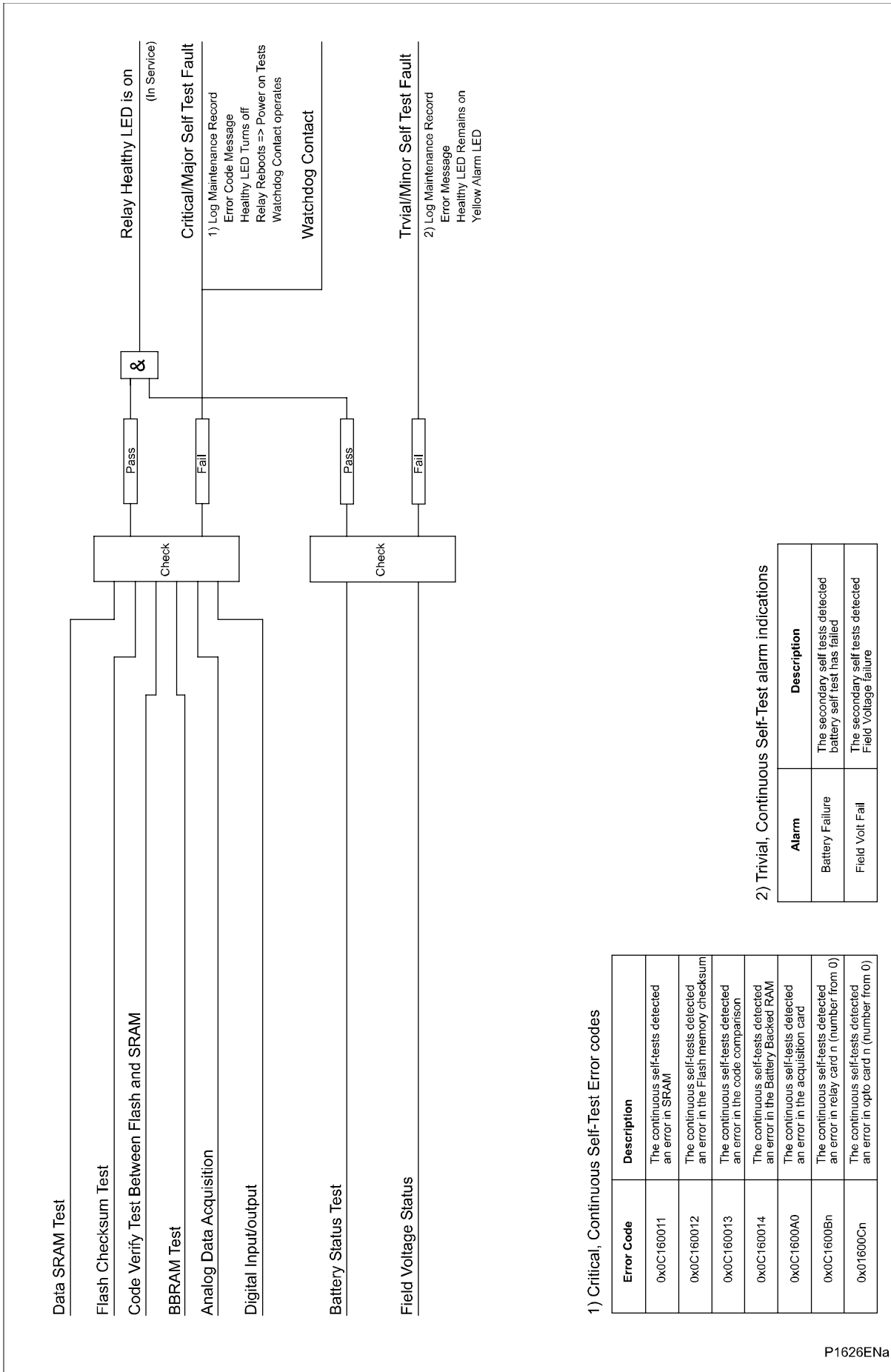| Alarm	Description
Battery Failure	The secondary self tests detected battery self test has failed
Field Volt Fail	The secondary self tests detected Field Voltage failure

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Figure 19: Continuous self-testing logic

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6 PLATFORM SOFTWARE

The platform software has three main functions:

- To control the logging of records generated by the protection software, including alarms, faults and maintenance records.
- To store and maintain a database of all 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.

6.1.1 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 relay 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 a relay 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.

6.1.2 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.

6.1.3 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).

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7 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.

7.1 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.

7.2 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.

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7.3 Direct Use of Sample Values

Most of the relay's protection functionality uses the Fourier components calculated by the device's signal processing software. However RMS measurements and some special protection algorithms available in some products use the sampled values directly.

The disturbance recorder also uses the samples from the input module, in an unprocessed form. This is for waveform recording and the calculation of true RMS values of current, voltage and power for metering purposes.

In the case of special protection algorithms, using the sampled values directly provides exceptionally fast response because you do not have to wait for the signal processing task to calculate the fundamental. You can act on the sampled values immediately.

7.4 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) x (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:
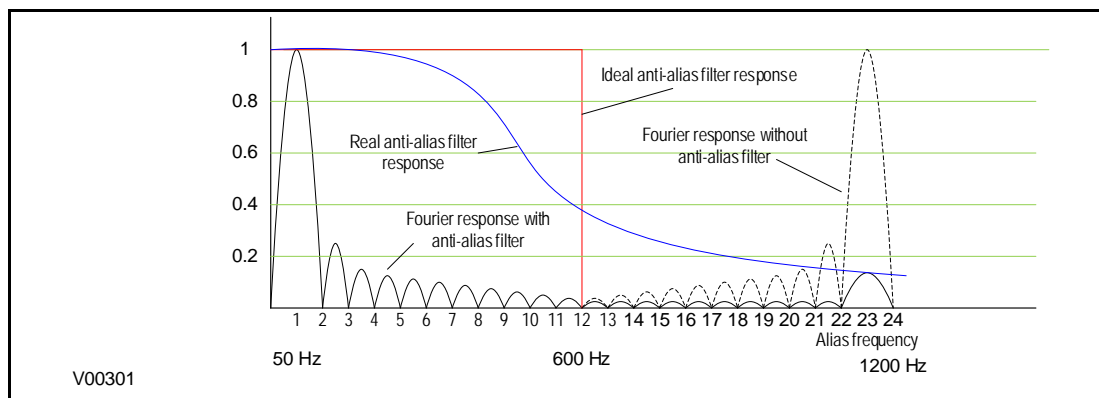
Figure 20: Frequency response (indicative only)

7.5 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.

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7.6 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 (backed-up SRAM). The operation of the record logging to backed-up 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 backed-up 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.

7.7 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.

7.8 Function Key Interface (P242/3 only)

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 powerup, should power be inadvertently lost.

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COMMISSIONING

CM

CONTENTS

CM

CM

FIGURES

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1   GENERAL GUIDELINES

GE devices are self-checking 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.

Before carrying out any work on the equipment the user 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.

With the exception of the CT shorting contacts check, do not disassemble the device during commissioning.

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2   SETTING FAMILIARIZATION

When commissioning the device for the first time, allow sufficient time to become familiar with the method in which the settings are applied.

The Settings chapter contains a detailed description of the menu structure of P24x relays.

With the secondary front cover in place all keys except the **enter** key are accessible. All menu cells can be read. LEDs and alarms can be reset. However, no protection or configuration settings can be changed, or fault and event records cleared.

Removing the secondary front cover allows access to all keys so that settings can be changed, LEDs and alarms reset, and fault and event records cleared. However, menu cells that have access levels higher than the default level requires the appropriate password to be entered before changes can be made.

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3 COMMISSIONING TEST MENU

The device 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

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

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 relay 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 relay was in-service. It does not show the actual status of the output relays, as they are blocked.

3.3 Test Port Status

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 relay. This allows you to test the Programmable Scheme Logic (PSL).

3.4 Monitor Bits 1 to 8

The eight Monitor Bit cells allows you to select eight DDB signals that can be observed in the Test Port Status cell or downloaded via the front port.

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.

The pins of the monitor/download port used for monitor bits are as follows:

Monitor bit	1	2	3	4	5	6	7	8
Monitor/download port pin	11	12	15	13	20	21	23	24

The signal ground is available on pins 18, 19, 22 and 25.

⚠ **The monitor/download port is not electrically isolated against induced voltages on the communications channel. It should only be used for local communications.**

3.5 Test Mode

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 relay 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.

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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**.

> ⚠ **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

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

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

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 Red and Green LED Status (P242/3)

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.

3.10 Using a Monitor Port Test Box

A test box containing eight LEDs and a switchable audible indicator is available. It is housed in a small plastic box with a 25-pin male D-connector that plugs directly into the monitor/download port*. There is also a 25-pin female D-connector which allows other connections to be made to the monitor/download port while the monitor/download port test box is in place.

Each LED corresponds to one of the monitor bit pins on the monitor/download port. Monitor Bit 1 is on the left hand side when viewed from the front of the relay. The audible indicator can be selected to sound if a voltage appears on any of the eight monitor pins. Alternatively it can be set to remain silent, using only the LEDs.

Note: *The 25 pin parallel port is only available on white front panels with the appropriate options. This is dependent on model/version--for full details, see the Ordering Options Appendix.

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
- Minimum equipment required

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

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- 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.

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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 relay 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 relay 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 GE.

5.1   With the Relay De-Energized

The following group of tests should be carried out without the auxiliary supply being applied to the relay and, if applicable, with the trip circuit isolated.

The current and voltage transformer connections must be isolated from the relay 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, 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.

DANGER: Never open-circuit the secondary circuit of a current transformer since the high voltage produced may be lethal and could damage insulation.

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If a test block is not provided, the voltage transformer supply to the relay should be isolated by means of the panel links or connecting blocks. The line current transformers should be short-circuited and disconnected from the relay 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

Check the rating information under the top access cover on the front of the relay.
Check that the relay being tested is correct for the line or circuit.
Record the circuit reference and system details.
Check the CT secondary current rating and record the CT tap which is in use.

Carefully examine the relay 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 relay case) are used to connect the relay to a local earth bar using an adequate conductor.

5.1.2 Current Transformer Shorting Contacts

Check the current transformer shorting contacts to ensure that they close when the heavy-duty terminal block is disconnected from the current input board.

The heavy-duty terminal blocks are fastened to the rear panel using four crosshead screws. These are located two at the top and two at the bottom.

Note: Use a magnetic bladed screwdriver to minimize the risk of the screws being left in the terminal block or lost.

Pull the terminal block away from the rear of the case and check with a continuity tester that all the shorting switches being used are closed.

5.1.3 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 relay.

5.1.4 External Wiring

Check that the external wiring is correct according to the relevant relay and scheme diagrams. Ensure that phasing/phase rotation appears to be as expected.

5.1.5 Watchdog contacts

Using a continuity tester, check that the Watchdog contacts are in the following states when energized and healthy.

Terminals	Contact state with product de-energized
11 – 12 on power supply board	Closed
13 - 14 on power supply board	Open

5.1.6 Power Supply

Depending on its nominal supply rating, the relay can be operated from either a DC only or an AC/DC auxiliary supply. The incoming voltage must be within the operating range specified below.

Without energising the relay measure the auxiliary supply to ensure it is within the operating range.

Nominal supply rating DC	Nominal supply rating AC RMS	DC operating range	AC operating range
24 - 48 V	N/A	19 - 65 V	N/A
48 - 110 V	30 - 100 V	37 - 150 V	24 - 110 V
110 - 240 V	100 - 240 V	87 - 300 V	80 - 265 V

Note: The relay can withstand an AC ripple of up to 12% of the upper rated voltage on the DC auxiliary supply.

Do not energize the relay or interface using the battery charger with the battery disconnected as this can irreparably damage the power supply circuitry.

Energize the relay only if the auxiliary supply is within the operating range. 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 relay.

5.2 Product Checks with the Relay Energized

⚡ **The current and voltage transformer connections must remain isolated from the relay for these checks. The trip circuit should also remain isolated to prevent accidental operation of the associated circuit breaker.**

The following group of tests verify that the relay hardware and software is functioning correctly and should be carried out with the auxiliary supply applied to the relay.

5.2.1 Watchdog contacts

Using a continuity tester, check the watchdog contacts are in the following states when energized.

Terminals	Contact state with product energized
11 – 12 on power supply board	Open
13 – 14 on power supply board	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 relays 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.

⚠ **Care:** **Before applying a contrast setting, make sure that it will not make the display so light or dark that the 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 memory, which is backed up by a supercapacitor or battery*. situated at the front of the device behind the lower access cover. When delivered, this battery is isolated to prevent battery drain during transportation and storage.

Before setting the date and time, ensure that the isolation strip has been removed. With the lower access cover open, the battery isolation strip can be identified by a red tab protruding from the positive side of the battery compartment. Pull the red tab to remove the isolation strip.

The method for setting the date and time depends on whether an IRIG-B signal is being used or not. The IRIG-B signal will override the time, day and month settings, but not the initial year setting. For this reason, you must ensure you set the correct year, even if the device is using IRIG-B to maintain the internal clock.

You set the Date and Time by one of the following methods:

- Using the front panel to set the **Date and Time** cells respectively
- By sending a courier command to the **Date/Time** cell (Courier reference 0801)

    Note: If the auxiliary supply fails, the time and date will be maintained by the supercapacitor or the battery*. Therefore, when the auxiliary supply is restored, you should not have to set the time and date again. To test this, remove the IRIG-B signal, and then remove the auxiliary supply. Leave the device de-energised for approximately 30 seconds. On re energisation, the time should be correct.

    Note: *Battery fitted to white front panel versions, supercapacitor fitted to black and silver front panel versions. For details, refer to the Ordering Options Appendix.

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When using IRIG-B to maintain the clock, the relay 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 relay 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 **DATE and TIME** column is set to **Disabled**

1.   Set the date and time to the correct local time and date using the Date/Time cell or using the serial protocol.

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 relay'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.

5.2.4.1   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.

5.2.4.2   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.

5.2.4.3   Test User-Programmable LEDs

To test these LEDs, set the Test LEDs cell to **Apply Test**. Check that all user-programmable LEDs illuminate.

5.2.5   Field Voltage Supply

The relay generates a field voltage of nominally 48 V that can be used to energise the opto-inputs (alternatively the substation battery may be used).

1.   Measure the field voltage across the terminals 7 and 9 of the power supply terminal block
2.   Check that the field voltage is within the range 40 V to 60 V when no load is connected and that the polarity is correct.
3.   Repeat for terminals 8 and 10.

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Supply rail	Terminals		
	P241 (40TE)	P242 (60TE)	P243 (80TE)
+ve	F7 & F8	J7 & J8	M7 & M8
-ve	F9 & F10	J9 & J10	M9 & M10

5.2.6   Test Opto-Inputs

This test checks that all the opto-inputs on the relay 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.

5.2.7   Test Output Relays

This test checks that all the output relays are functioning correctly.

1. Ensure that the relay 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 relay to service by setting the Test Mode cell in the **COMMISSION TESTS** menu to **Disabled**.

5.2.8   RTD Inputs

This test checks that all the RTD inputs are functioning correctly, if the RTD board is fitted.

Please refer to the wiring diagrams for details of the terminal connections.

1. You should connect a 100 ohm resistor across each RTD in turn. The resistor needs to have a very small tolerance (0.1%). You must connect the RTD common return terminal to the correct RTD input, otherwise the device will report an RTD error.
2. Check that the corresponding temperature displayed in the **MEASUREMENTS 3** column of the menu is 0°C +/-2°C. This range takes into account the 0.1% resistor tolerance and device accuracy of +/-1°C. If a resistor of lower accuracy is used during testing, the acceptable setting range needs to be increased.

5.2.9   Current Loop Outputs

This test checks that all the current loop outputs are functioning correctly if the board is fitted.

Please refer to the wiring diagrams for details of the terminal connections. Note that for the current loop outputs, the physical connection of the 1 mA output is different from that of the other types.

1. Enable the current loop output to be tested.
2. Note the current loop output type (**CLO Type**) for the application.
3. Note the current loop output parameter (**CLO Parameter**)

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4.   Note the current loop output minimum and maximum settings (**CLO Minimum** and **CLO Maximum**)

5.   Apply the appropriate analog input quantity to match the CLO Parameter at a value equal to (CLO maximum + CLO minimum)/2. The current loop output should be at 50% of its maximum rated output.

6.   Using a precision resistive current shunt and a high-resolution voltmeter, check that the current loop output is at 50% of its maximum rated output according to the range as follows:

0.5 mA (0 to 1 mA CLO)

5 mA (0 to 10 mA CLO)

10 mA (0 to 20, 4 to 20 mA CLO)

7.   The accuracy should be within +/-0.5% of full scale + meter accuracy.

5.2.10   Current Loop Inputs

This test checks that all the current loop inputs are functioning correctly if the board is fitted.

Please refer to the wiring diagrams for details of the terminal connections. Note that for the current loop inputs, the physical connection of the 1 mA input is different from that of the other types.

You can use an accurate DC current source to apply various current levels to the current loop inputs. One approach to this is to use a current loop output as a DC current sources. If you stimulate the current loop output by applying an appropriate signal to the input to which it has been assigned with the **CLO Parameter** setting, you will get an appropriate DC signal if the output is enabled.

1.   Enable the current loop input to be tested.

2.   Note the CLIx minimum and maximum settings and the CLIx Input type for the application.

3.   Apply a DC current to the current loop input at 50% of the CLI input maximum range, 0.5 mA (0 to 1 mA CLI), 5 mA (0 to 10 mA CLI) or 10 mA (0 to 20, 4 to 20 mA CLI).

4.   Check the accuracy of the current loop input using the CLIO Input 1/2/3/4 cells in the **MEASUREMENTS 3** column. The display should show (CLIx maximum + CLIx minimum)/2 +/-1% full scale accuracy.

5.2.11   Test Serial Communication Port RP1

You need only perform this test if the relay 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 supplied protocol converter. It verifies operation of the rear communication port (and if applicable the protocol converter) and varies according to the protocol fitted.

5.2.11.1   Check Physical Connectivity

The rear communication port RP1 is presented on terminals 16, 17 and 18 of the power supply terminal block. Screened twisted pair cable is used to make a connection to the port. The cable screen should be connected to pin 16 and pins 17 and 18 are for the communication signal:

RP1: Terminals 16, 17 and 18 of
PSU terminal block.
T16 = Ground
T17 = Negative
T18 = Positive

R00232
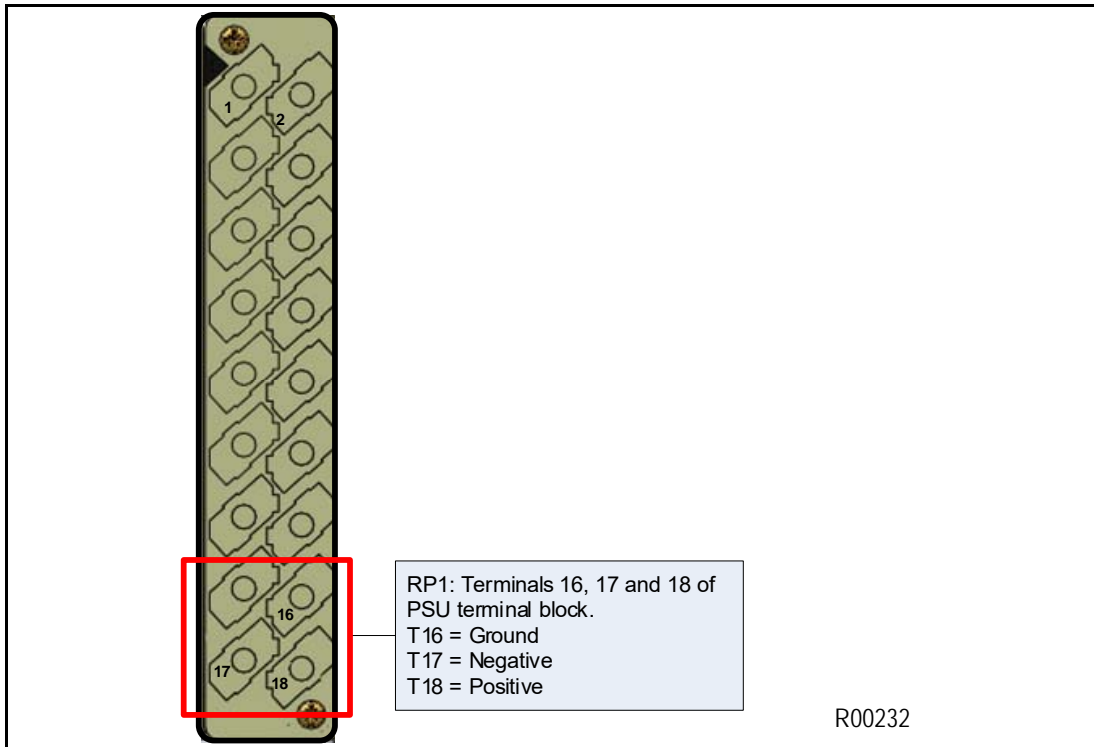
Figure 1: RP1 physical connection

For K-Bus applications, pins 17 and 18 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 18 is positive, pin 17 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.

IED   IED   IED

RS232   K-Bus

Computer   RS232-USB converter   KITZ protocol converter

V01001
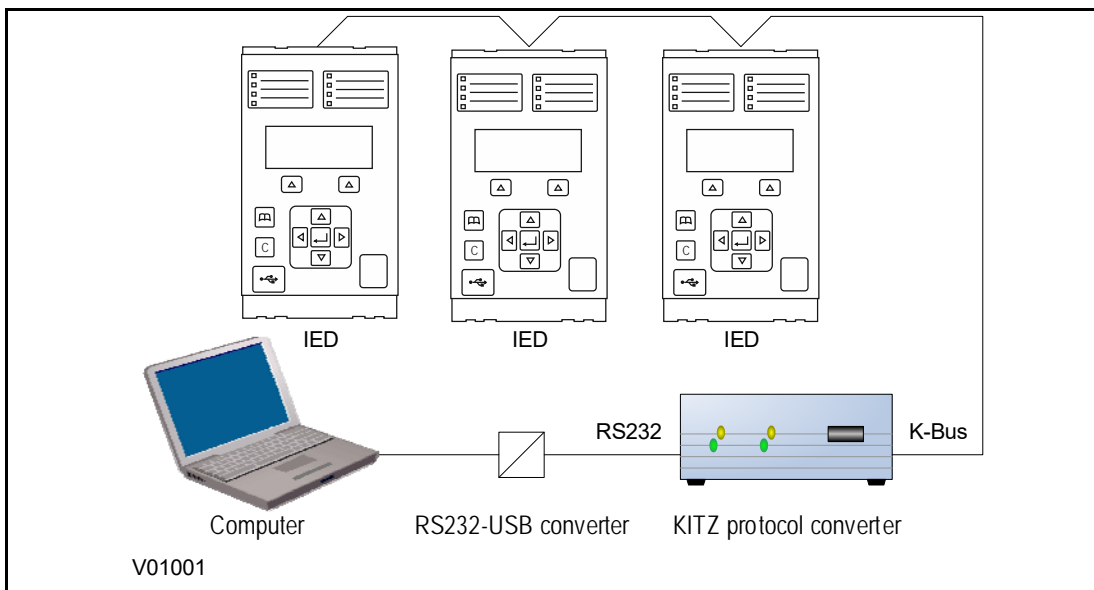
Figure 2: Remote communication using K-bus

Fibre Connection

Some models have an optional fibre optic communications port fitted (on a separate communications board). The communications port to be used is selected by setting the Physical Link cell in the **COMMUNICATIONS** column, the values being Copper or K-Bus for the RS485/K-bus port and Fibre Optic for the fibre optic port.

5.2.11.2 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 relay using the portable PC/Master Station.

5.2.11.3 Test Serial Communication Port RP2

RP2 is an optional second serial port board providing additional serial connectivity. It provides two 9-pin D-type serial port connectors SK4 and SK5. Both ports are configured as DTE (Date Terminal Equipment) ports. That means they can be connected to communications equipment such as a modem with a straight-through cable.

SK4 can be configured as an EIA(RS232), EIA(RS485), or K-Bus connection for Courier protocol only, whilst SK5 is fixed to EIA(RS)232 for InterMiCOM signaling only.

It is not the intention of this test to verify the operation of the complete communication link between the relay and the remote location, just the relay's rear communication port and, if applicable, the protocol converter.

The only checks that need to be made are as follows:

1. Set the **RP2 Port Config** cell in the **COMMUNICATIONS** column to the required physical protocol; (K-Bus, EIA(RS)485, or EIA(RS)232.
2. Set the relay's Courier address to the correct value (it must be between 1 and 254).

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).

5.3   Secondary Injection Tests

Secondary injection testing is carried out to verify the integrity of the VT and CT readings. All devices leave the factory set for operation at a system frequency of 50 Hz. If operation at 60 Hz is required, you must set this in the Frequency cell in the **SYSTEM DATA** column.

The PMU must be installed and connected to a 1pps fibre optic synchronising signal and a demodulated IRIG-B signal, provided by a device such as a P594 or a REASON RT430.

Connect the current and voltage outputs of the test set to the appropriate terminals of the first voltage and current channel and apply nominal voltage and current with the current lagging the voltage by 90 degrees.

5.3.1 Test Current Inputs

This test verifies that the current measurement inputs are configured correctly

1. Using secondary injection test equipment such as an Omicron, apply and measure nominal rated current to each CT in turn.
2. Check its magnitude using a multi-meter or test set readout. Check this value against the value displayed on the HMI panel (usually in **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). 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 relay 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 relay is +/-1%. However, an additional allowance must be made for the accuracy of the test equipment being used.

5.3.2   Test Voltage Inputs

This test verifies that the voltage measurement inputs are configured correctly.

1. Using secondary injection test equipment, apply and measure the rated voltage to each voltage transformer input in turn.
2. Check its magnitude using a multimeter or test set readout. Check this value against the value displayed on the HMI panel (usually in **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). 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 relay 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 relay is +/- 1%. However, an additional allowance must be made for the accuracy of the test equipment being used.

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6   SETTING CHECKS

The setting checks ensure that all of the application-specific settings (both the relay'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 relay:

- Transferring settings to the relay from a pre-prepared setting file using MiCOM S1 Agile
- Enter the settings manually using the relay's front panel HMI

6.2   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 relay'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 relay
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 relay, 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.

6.2.1   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.

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```
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 relay's front panel HMI.

⚠️ **Care:** **Where the installation needs application-specific PSL, the relevant .psl files, must be transferred to the relay, 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.**

6.3 Demonstrate Correct Relay Operation

Tests 5.2.9 and 5.2.10 have already demonstrated that the relay is within calibration; therefore the purpose of these tests is as follows:

- To determine that the primary protection function of the P241/2/3 relay, the thermal protection, can trip according to the correct application settings.
- To determine that the differential protection function of the P243 relay can trip according to the correct application settings.
- To verify correct setting of the sensitive earth fault protection (P241/2/3).
- To verify correct assignment of the trip contacts, by monitoring the response to a selection of fault injections.

6.3.1 Motor Differential Protection (P243)

To avoid spurious operation of any other protection elements all protection elements except the motor differential protection should be disabled for the duration of the differential element tests. This is done in the relay's **CONFIGURATION** column. Make a note of which elements need to be re-enabled after testing.

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For testing the biased differential protection select the **Percentage Bias** setting in the Diff Function, Differential menu and perform the tests described in section 6.3.1.2, 6.3.1.3 and 6.3.2. For testing the high impedance differential protection select the **High Impedance** setting in the Diff Function, Differential menu and perform the tests described in section 6.3.2.

The P243 motor differential protection has three elements, one for each phase. The biased differential protection uses the maximum bias current in the three phases to bias the elements. The detailed bias characteristic is described in sub-document - Installation. The following instructions are for testing the bias characteristic of the B phase element. The bias current is applied to the A phase element.

6.3.1.1 Connect the Test Circuit

The following tests require a variable transformer and two resistors connected as shown in Figure 3. Alternatively an injection test set can be used to supply Ia and Ib currents.
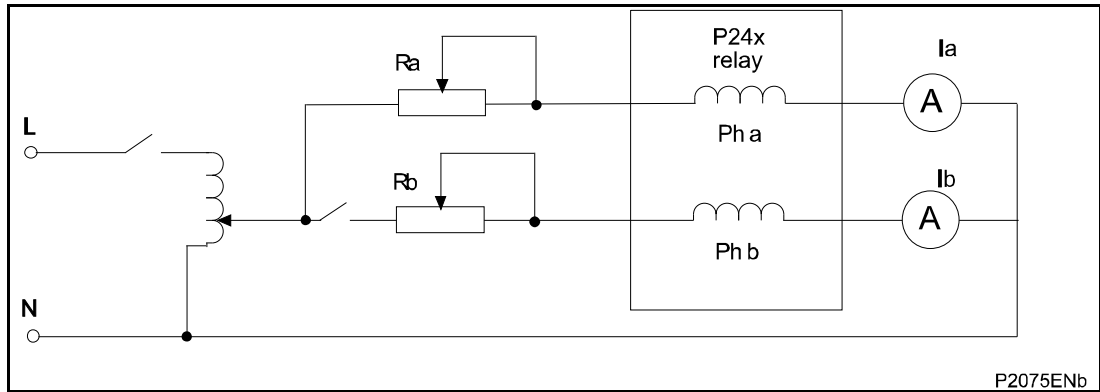
Figure 3: Connection for testing

For the biased differential protection a current is injected into the A phase IA-2 input,

F3 - F2 (1A), F1 - F2 (5A), which is used as the bias current, IBias = (IA + IA-2)/2 = IA-2/2 as IA=0. Another current is injected into the B phase IB-2 input F6 - F5 (1A), F4 - F5 (5A) which is used as the differential current, Differential = IB-2 - IB = IB-2 as IB=0. Ia is always greater than Ib.

6.3.1.2   Biased Differential Protection Lower Slope

If three LEDs have been assigned to give phase segregated trip information, Diff Trip A, Diff Trip B and Diff Trip C (DDB 315, 316, 317), these may be used to indicate correct per-phase operation. If not, monitor options are needed - see the next paragraph.

Go to the COMMISSION TESTS column in the menu, scroll down and change cells [0F05: Monitor Bit 1] to 315, [0F06: Monitor Bit 2] to 316 and [0F07: Monitor Bit 3] to 317. Cell [0F04: Test Port Status] will now appropriately set or reset the bits that now represent Phase A Trip (DDB 315), Phase B Trip (DDB 316) and Phase C Trip (DDB 317) with the rightmost bit representing Phase A Trip. From now on you should monitor the indication of [0F04: Test Port Status].

Adjust the variac and the resistor to inject 1 pu into IA-2 to give a bias current of 0.5 pu in the A-phase.

> **Note:**   1 pu = 1 A into terminals, F3 - F2 for 1 A applications; or 1 pu = 5 A into terminals F1-F2 for 5 A applications.

The relay trips and any contacts associated with the A-phase operates, and bit 1 (rightmost) of [0F04: Test Port Status] are set to 1. Some LEDs, including the yellow alarm LED, will come on, but ignore them for the moment.

Slowly increase the current in the B-phase IB-2 input F6 - F5 (1A), F4 - F5 (5 A) until phase B trips (Bit 2 of [0F04: Test Port Status] is set to 1). Record the phase B current magnitude and check that it corresponds to the information below. Switch OFF the ac supply and reset the alarms.

Bias current (IA-2/2)		Differential current (IB)	
Phase	Magnitude	Phase	Magnitude
A	0.5 pu	B	0.05 pu +/-10%

Assumption: Is1 = 0.05 pu, k1 = 0%, Is2 = 1.2 pu

For other differential settings the formula below can be used (enter k1 slope in pu form, for example percentage/100):

B phase operate current is (Is1 + IBias x k1) pu +/- 10%

6.3.1.3   Biased Differential Protection Upper Slope

Repeat the test in 6.3.1.2 with the A phase, IA-2, current set to be 3.4 pu (Ibias = 1.7 pu).

Slowly increase the current in the B phase until phase B trips (bit 2 of [0F04: Test Port Status] is set to 1). Record the phase B current magnitude and check that it corresponds to the information below.

Switch OFF the ac supply and reset the alarms.

Bias current (IA-2/2)		Differential current (IB)	
Phase	Magnitude	Phase	Magnitude
A	1.7 pu	B	0.8 pu +/-20%

Assumption: Is1 = 0.05 pu, k1 = 0%, Is2 = 1.2 pu, k2 =150%as above

For other differential settings the formula below can be used (enter k1 and k2 slopes in pu form, for example percentage/100):

Operate current is [(IBias x k2) + {(k1 − k2) x Is2} + Is1] pu +/- 20%

> **Note:** Particularly for 5 A applications the duration of current injections should be short to avoid overheating of the variac or injection test set.

6.3.2 Motor Differential Operation and Contact Assignment

6.3.2.1 Phase A

Retaining the same test circuit as before, prepare for an instantaneous injection of 4 x I_{s1} pu current in the A phase, with no current in the B phase (B phase switch open). Connect a timer to start when the fault injection is applied, and to stop when the trip occurs.

Determine which output relay has been selected to operate when a Diff. Trip occurs by viewing the relay's programmable scheme logic. The programmable scheme logic can only be changed using the appropriate software. If this software is not available then the default output relay allocations are still applicable. In the default PSL, relay 3 is the designated protection trip contact and DDB 371 Any Trip is assigned to this contact.

Ensure that the timer is reset.

Apply a current of 4 x the setting in cell [3002: GROUP 1 DIFFERENTIAL, Diff Is1] to the relay and note the time displayed when the timer stops.

After applying the test check the red trip led and yellow alarm led turns on when the relay operates. Check 'Alarms/Faults Present - Tripped Phase A, Diff Trip' is on the display. Reset the alarms.

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Three Pole Tripping	DDB 318	Diff Trip
Single Pole Tripping	DDB 315:	Diff Trip A
	DDB 316:	Diff Trip B
	DDB 317:	Diff Trip C

6.3.2.2 Phase B

Reconfigure the test equipment to inject fault current into the B phase. Repeat the test in 6.3.2.1, this time ensuring that the breaker trip contacts relative to B phase operation close correctly. Record the phase B trip time. Check the red trip led and yellow alarm led turns on when the relay operates. Check 'Alarms/Faults Present - Tripped Phase B, Diff Trip' is on the display. Reset the alarms.

6.3.2.3 Phase C

Repeat 6.3.2.2 for the C phase.

The average of the recorded operating times for the three phases should be less than 30 ms. Switch OFF the ac supply and reset the alarms.

On completion of the tests any protection elements which were disabled for testing purposes must have their original settings restored in the **CONFIGURATION** column.

6.3.3   Sensitive Earth Fault Protection

This test, performed on stage 1 of the sensitive earth fault protection function in setting Group 1, demonstrates that the relay is operating correctly at the application-specific settings.

It is not considered necessary to check the boundaries of operation where cell [3202: **SENSITIVE E/F** GROUP 1, **ISEF>1 Direction**] is set to **Directional Fwd** as the test detailed already confirms the correct functionality between current and voltage inputs, processor and outputs and earlier checks confirmed the measurement accuracy is within the stated tolerance.

To avoid spurious operation of any other protection elements all protection elements except the overcurrent protection should be disabled for the duration of the overcurrent element tests. This is done in the relay's **CONFIGURATION column**. Make a note of which elements need to be re-enabled after testing.

CM

7   IEC 61850 EDITION 2 TESTING

7.1   Using IEC 61850 Edition 2 Test Modes

In a conventional substation, functionality typically resides in a single device. It is usually easy to physically isolate these functions, as the hardwired connects can simply be removed. Within a digital substation architecture however, functions may be distributed across many devices. This makes isolation of these functions difficult, because there are no physical wires that can be disconnected on a Ethernet network. Logical isolation of the various functions is therefore necessary.

With devices that support IEC 61850 Edition 2, it is possible to use a test mode to conduct online testing, which helps with the situation. The advantages of this are as follows:

- The device can be placed into a test mode, which can disable the relay outputs when testing the device with test input signals.
- Specific protection and control functions can be logically isolated.
- GOOSE messages can be tagged so that receiving devices can recognise they are test signals.
- An IED receiving simulated GOOSE or Sampled Value messages from test devices can differentiate these from normal process messages, and be configured to respond appropriately.

7.1.1   IED Test Mode Behaviour

Test modes define how the device responds to test messages, and whether the relay outputs are activated or not.

You can select the mode of operation by:

- Using the front panel HMI, with the setting **IED Test Mode** under the **COMMISSION TESTS** column.
- Using an IEC 61850 control service to **System/LLN0.Mod**
- Using an opto-input via PSL with the signal **Block Contacts**

The following table summarises the IED behaviour under the different modes:

IED Test Mode Setting	Result
Disabled	Normal IED behaviour
Test	Protection remains enabled
	Output from the device is still active
	IEC 61850 message output has the 'quality' parameter set to 'test'
	The device only responds to IEC61850 MMS messages from the client with the'test' flag set
Contacts Blocked	Protection remains enabled
	Output from the device is disabled
	IEC 61850 message output has quality set to 'test'
	The device only responds to IEC 61850 MMS messages from the client with the 'test' flag set

Setting the Test or Contacts Blocked mode puts the whole IED into test mode. The IEC 61850 data object Beh in all Logical Nodes (except LPHD and any protection Logical Nodes that have Beh = 5 (off) due to the function being disabled) will be set to 3 (test) or 4 (test/blocked) as applicable.

7.1.2   Sampled Value Test Mode Behaviour

The SV Test Mode defines how the device responds to test sampled value messages. You can select the mode of operation by using the front panel HMI, with the setting **SV Test Mode** under the **IEC 61850-9.2LE** column.

The following table summarises the behaviour for sampled values under the different modes:

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SV Test Mode Setting	Result
Disabled	Normal IED behaviour
	All sampled value data frames received with an IEC 61850 Test quality bit set are treated as invalid
	The IED will display the measurement values for sampled values with the Simulated flag set but the protection elements within the IED will be blocked
Enabled	All sampled value data frames received are treated as good, no matter if they have an IEC 61850-9-2 Simulated flag set or not

7.2   Simulated Input Behaviour

Simulated GOOSE messages and sampled value streams can be used during testing.

The **Subscriber Sim** setting in the **COMMISSION TESTS** column controls whether a device listens to simulated signals or to real ones. An IEC 61850 control service to System/LPHD.Sim can also be used to change this value.

The device may be presented with both real signals and test signals. An internal state machine is used to control how the device switches between signals:

- The IED will continue subscribing to the 'real' GOOSE1 (in green) until it receives the first simulated GOOSE 1 (in red). This will initiate subscription changeover.

- After changeover to this new state, the IED will continue to subscribe to the simulated GOOSE 1 message (in red). Even if this simulated GOOSE 1 message disappears, the real GOOSE 1 message (in green) will still not be processed. This means all Virtual Inputs derived from the GOOSE 1 message will go to their default state.

- The only way to bring the IED out of this state is to set the **Subscriber Sim** setting back to False. The IED will then immediately stop processing the simulated messages and start processing real messages again.

- During above steps, IED1 will continuously process the real GOOSE 2 and GOOSE 3 messages as normal because it has not received any simulated messages for these that would initiate a changeover.

The process is represented in the following figure:

CM
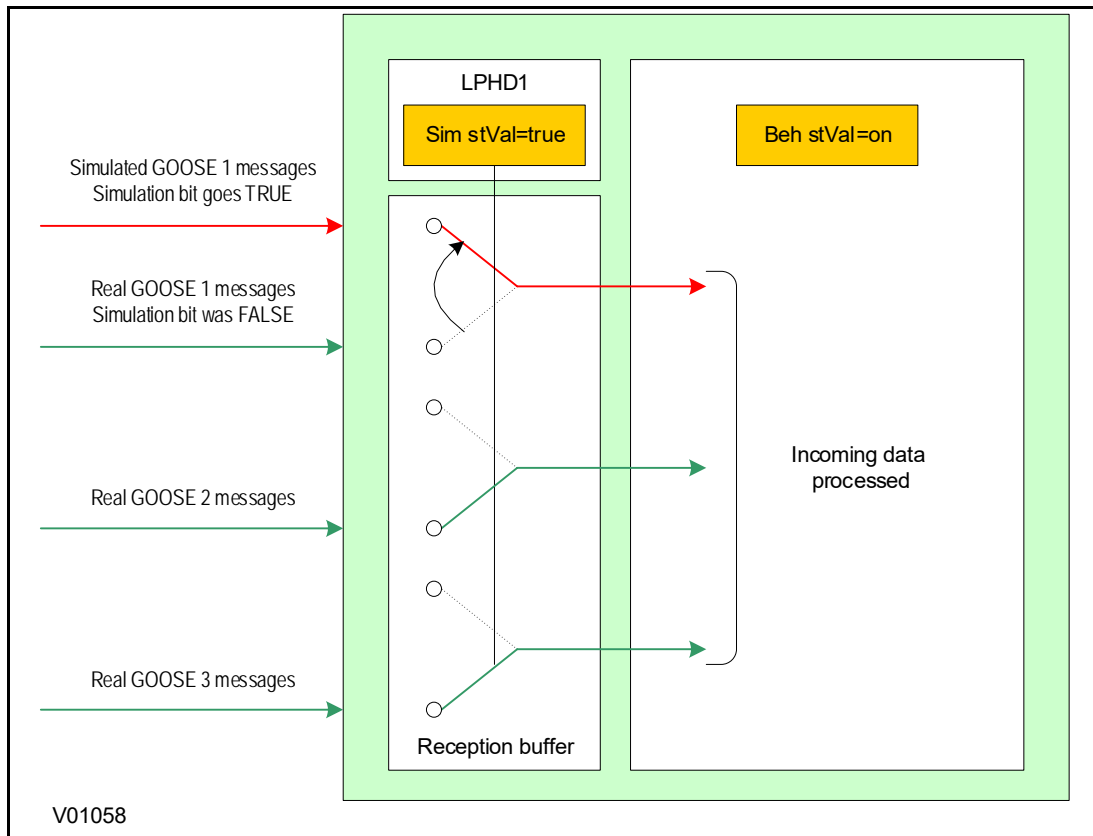
Figure 4: Simulated input behaviour

7.3 Testing Examples

These examples show how you test the IED with and without simulated values. Depending on the IED Test Mode, it may respond by operating plant (for example by tripping the circuit breaker) or it may not operate plant.

7.3.1 Test Procedure for Real Values

This procedure is for testing with real values without operating plant.

1. Set device into 'Contacts Blocked' Mode
   Select **COMMISSION TESTS** → **IED Test Mode** → **Contacts Blocked**
2. Confirm new behaviour has been enabled
   View **COMMISSION TESTS** → **IED Mod/Beh**, and check that it shows **Test-blocked**
3. Set device into Simulation Listening Mode
   Select **COMMISSION TESTS** → **Subscriber Sim** = **Disabled**
4. If using sampled values set the sampled values test mode
   Select **IEC 61850-9.2LE** → **SV Test Mode** → **Disabled**
5. Inject real signals using a test device connected to the merging units. The device will continue to listen to 'real' GOOSE messages and ignore simulated messages received.
6. Verify function based on test signal outputs

Binary outputs (e.g. CB trips) will not operate. All transmitted GOOSE and MMS data items will be tagged with the 'quality' parameter set to 'test', so that the receiver understands that they have been issued by a device under test and can respond accordingly. This is summarised in the following diagram:

CM
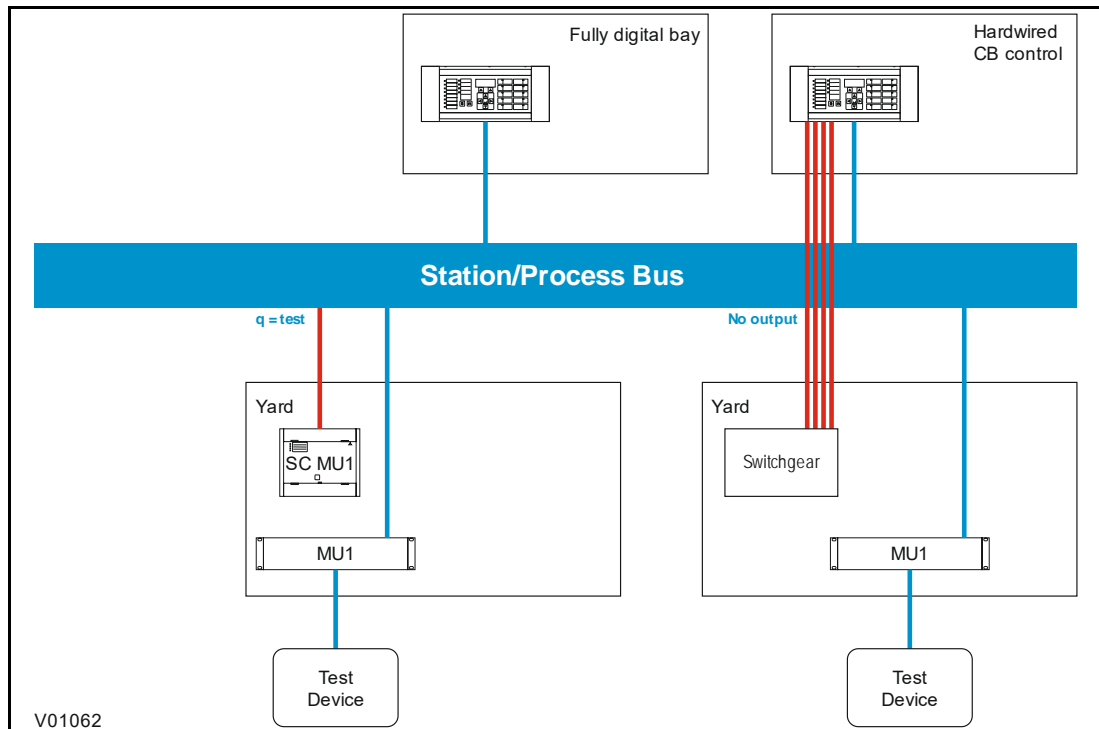
Figure 5: Test example 1

7.3.2   Test Procedure for Simulated Values - No Plant

This procedure is for testing with simulated values without operating plant.

1.   Set device into 'Contacts Blocked' Mode
      Select **COMMISSION TESTS** → **IED Test Mode** → Contacts Blocked
2.   Confirm new behaviour has been enabled
      View **COMMISSION TESTS** → **IED Mod/Beh**, and check that it shows **test-blocked**
3.   Set device into Simulation Listening Mode
      Select **COMMISSION TESTS** → **Subscriber Sim** = **Enabled**
4.   If using sampled values set the sampled values test mode
      Select **IEC 61850-9.2LE** → **SV Test Mode** → **Enabled**
5.   Inject simulated signals using a test device connected to the Ethernet network. The
      device will continue to listen to 'real' GOOSE messages until a simulated message is
      received. Once the simulated messages are received, the corresponding 'real'
      messages are ignored until the device is taken out of test mode. Each message is
      treated separately, but sampled values are considered as a single message.
6.   Verify function based on test signal outputs

Binary outputs (e.g. CB trips) will not operate. All transmitted GOOSE and MMS data items
will be tagged with the 'quality' parameter set to 'test', so that the receiver understands that
they have been issued by a device under test and can respond accordingly. This is
summarised in the following diagram:
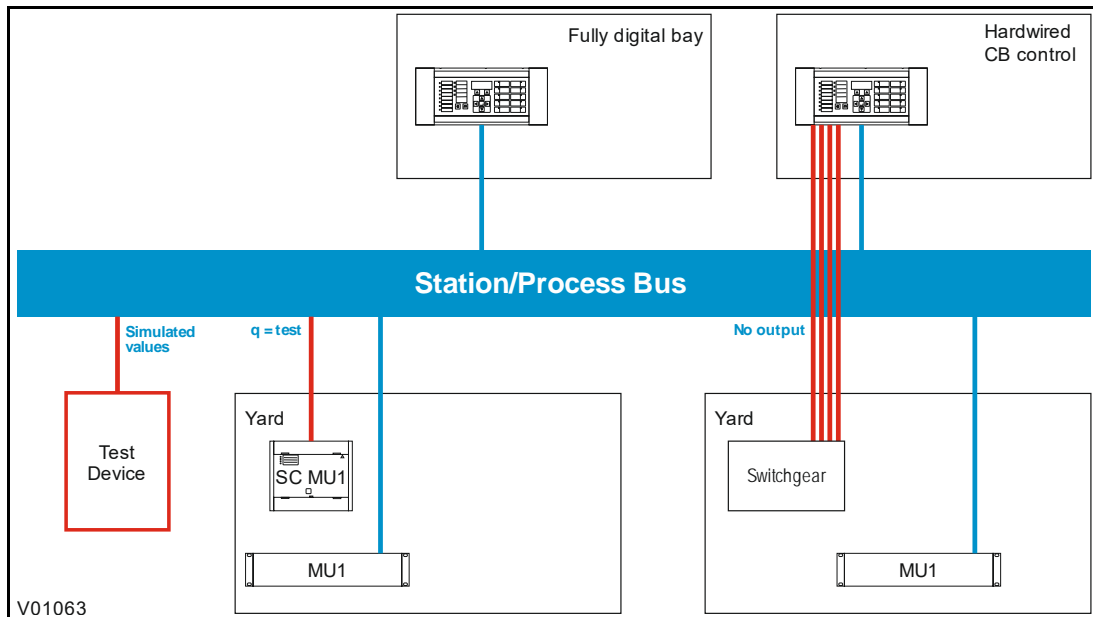
Figure 6: Test example 2

7.3.3   Test Procedure For Simulated Values - With Plant

This procedure is for testing with simulated values with operating plant.

1.   Set device into 'Contacts Blocked' Mode

     Select **COMMISSION TESTS → IED Test Mode → Test**

2.   Confirm new behaviour has been enabled

     View **COMMISSION TESTS → IED Mod/Beh**, and check that it shows **Test**

3.   Set device into Simulation Listening Mode

     Select **COMMISSION TESTS → Subscriber Sim** = **Enabled**

4.   If using sampled values set the sampled values test mode

     Select **IEC 61850-9.2LE → SV Test Mode → Enabled**

5.   Inject simulated signals using a test device connected to the Ethernet network.

     The device will continue to listen to 'real' GOOSE messages until a simulated message
     is received. Once the simulated messages are received, the corresponding 'real'
     messages are ignored until the device is taken out of IED test mode. Each message is
     treated separately, but sampled values are considered as a single message.

6.   Verify function based on test signal outputs.

     Binary outputs (e.g. CB trips) will operate as normal. All transmitted GOOSE and MMS
     data items will be tagged with the 'quality' parameter set to 'test', so that the receiver
     understands that they have been issued by a device under test and can respond
   accordingly. This is summarised in the following diagram:

CM
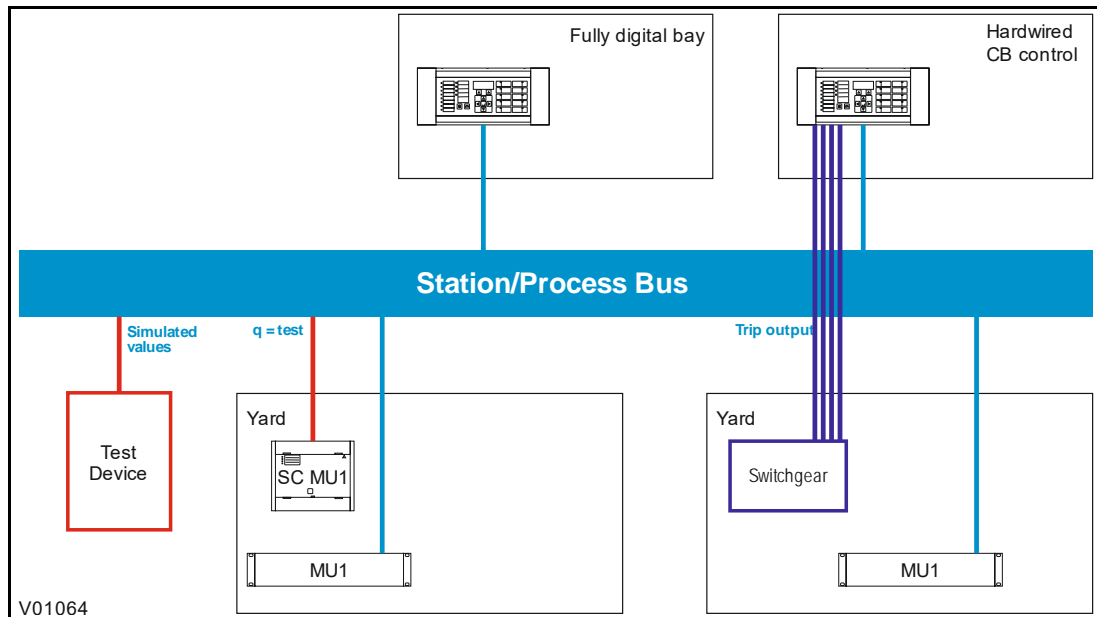
Figure 7: Test example 3

7.3.4   Contact Test

The **Apply Test** command in this cell is used to change the state of the contacts set for operation.

If the device has been put into 'Contact Blocked' mode using an input signal (via the **Block Contacts** DDB signal) then the **Apply Test** command will not execute. This is to prevent a device that has been blocked by an external process having its contacts operated by a local operator using the HMI.

If the **Block Contacts** DDB is not set and the **Apply Test** command in this cell is issued, contacts change state and the command text on the LCD changes to **No Operation**. The contacts remain in the Test state until reset by issuing the **Remove Test** command. The command text on the LCD shows **No Operation** after the **Remove Test** command has been issued.

Note: When the IED **Test Mode** cell is set to **Contacts Blocked**, the **Relay O/P Status** cell does not show the current status of the output relays so cannot be used to confirm operation of the output relays. Therefore it is necessary to monitor the state of each contact in turn.

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8 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.

8.1 Bypassing the All Pole Dead Blocking Condition

Some protection functions and control functions are blocked when all poles are dead. When these conditions are met, an **All Poles Dead** signal is asserted, blocking the said conditions. If you wish to test these these elements during commissioning, you must bypass this blocking condition. You can do this by modifying the default PSL, placing a NOT gate between the **CB1 Closed** signal and opto-input 7, so that when this input is not energised, CB1 is assumed to be closed.

8.2 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.

8.2.1.1 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 2. If set to **Directional Rev**, it should flow into terminal 2.

   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 20 and 21.

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.

8.2.1.2 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.

8.2.1.3 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.

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Characteristic	Operating time at twice current setting and time multiplier/time dial setting of 1.0	
	Nominal (seconds)	Range (seconds)
DT	ISEF>1 T Delay setting	Setting ±5%
IEC S Inverse	10.03	9.53 - 10.53
IEC V Inverse	13.50	12.83 - 14.18
IEC E Inverse	26.67	25.34 - 28
UK LT Inverse	120.00	114.00 - 126.00
IEEE M Inverse	3.8	3.61 - 3.99
IEEE V Inverse	7.03	6.68 - 7.38
IEEE E Inverse	9.52	9.04 - 10
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.

On completion of the tests, restore all settings to customer specifications.

8.2.2   Thermal Overload Protection

P24x relays model the time-current thermal characteristic of a motor by internally generating a thermal replica of the machine. The aim of this test is to check:

- The presence of a thermal alarm as soon as the thermal state reaches the set threshold
- The time to a thermal trip in case of a thermal overload
- The measurements of the thermal load and thermal state

The settings of this function are listed in the **THERMAL OVERLOAD, GROUP 1** menu column. Check these settings before the test.

To avoid spurious operation of any other protection elements all protection elements except the thermal protection should be disabled for the duration of the thermal element tests. This is done in the relay's CONFIGURATION column. Make a note of which elements need to be re-enabled after testing.

8.2.2.1   Connecting the Test Circuit

Determine which output relay has been selected to operate when a thermal trip occurs by viewing the relays programmable scheme logic.

The programmable scheme logic can only be changed using the appropriate software. If this software is not available then the default output relay allocations are still applicable.

If the **Thermal Trip** (DDB 236) is not mapped directly to an output relay in the programmable scheme logic, output relay 3 should be used for the test as it operates for any trip condition, DDB 371 Any Trip is assigned to this contact. The **Thermal Alarm** (DDB 178) should be mapped directly to an output relay in the programmable scheme logic if this feature is to be tested.

The associated terminal numbers can be found in the wiring diagram, located in Appendix B

Connect the output relay so that its operation trips the test set and stops the timer.

Connect the current output of the test set to the **A** phase current transformer input of the relay (terminals C3 – C2 (1 A, 40TE case), D3 – D2 (1 A, 60TE case), F3 – F2 (1 A, 80TE case), C1 – C2 (5 A, 40TE case), D1 – D2 (5 A, 60TE case) F1 – F2 (5 A, 80TE case)).

Ensure that the timer starts when the current is applied to the relay.

> **Note:** If the timer does not start when the current is applied, the connections may be incorrect for the direction of operation set. Try again with the current connections reversed.

8.2.2.2 Performing the Test

Ensure that the timer on the test set is reset.

Ensure that the thermal state is reset (see in cell [0402: MEASUREMENTS 3, Thermal State]: if not, this reset can be done through the cell [0404: MEASUREMENTS 3, Reset Th State] by selecting YES.

Check the position of the interrupting device by viewing the status of the two opto-inputs (52a and 52b status inputs) used to indicate the device position. The 52a input must be energized to simulate the closed position of the interrupting device to enable the thermal protection heating time constants. The cooling time constant is used when the interrupting device is open.

Apply a current of twice the setting [in cell 3001: THERMAL OVERLOAD, GROUP1, Ith Current Set] to the relay and note the time displayed when the timer stops. If it is required to repeat the test, make sure to disable Thermal Lockout [in cell 3009]. Also make sure to disable the inhibit during start setting **Inh Trip Dur St** [in cell 300B]. Since most portable secondary injection test sets have limited current output capability, it is suggested to change the **I**th **Current Set** to 1 A (after the as found value is recorded) and use the 1 A phase current input terminals. To save time during testing, it is advisable to set all the thermal time constants to 5 minutes.

Ensure that the thermal state is reset to 0 (see cell [0402: MEASUREMENTS 3, ThermalState]. If not, the thermal state can be reset through the cell [0404: MEASUREMENTS 3, Reset Th State] by selecting YES.

On completion of the tests any protection elements that were disabled for testing purposes must have their original settings restored in the CONFIGURATION column.

8.2.2.3 Verify the Operating Time

This test is done by a single-phase injection on the A phase current input, it results in that the relay sees equal current magnitudes for both positive and negative phase sequence quantities. On injection of a single phase current value equal to Iinject, the relay sees current magnitudes of Iinject/3 for both positive and negative phase sequences quantities and Iinject for I_{rms}. The equivalent thermal current value I_{eq} calculated by the relay is given by the following:

$$I_{eq} = \sqrt{(I_1^2 + K\,I_2^2)}$$

> **Note:** This equation is used in software version A4.x(09) and before

or

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

> **Note:** This equation is used in software version B1.0(20) or later

> Where:

I_1 = Positive sequence current

I_{rms}: root mean square current

I_2: negative sequence current

K is a constant proportional to the thermal capacity of the motor
(**K Coefficient** default setting = 3)

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The equivalent motor heating current assuming K = 3 for (1) becomes:

$$I_{eq} = \sqrt{[4 * (I_{inject} / 3)\, 2]}$$

$$= (2\, I_{inject} / 3) \qquad\qquad (3)$$

The equivalent motor heating current assuming K = 3 for (2) becomes:

$$I_{eq} = \sqrt{[4/3 * (I_{inject})\, 2]}$$

$$= (2\, I_{injected} / \sqrt{3}) \qquad\qquad (4)$$

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

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

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

$\tau = T_1$ (**Thermal Const T1**) if $I_{th} < I_{eq} < = 2*I_{th}$ overload time constant

$\tau = T_2$ (**Thermal Const T2**) if $I_{eq} > 2*I_{th}$ start-up time constant

$\tau = Tr$ (**Cooling Const Tr**) if interrupting device is opened cooling time constant

I_{th} = thermal setting in cell [3001: THERMAL OVERLOAD, GROUP1, **I_{th} Current Set**]

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

A = initial state of the machine, in percentage of the thermal state = 0 for this test.

The time to a thermal trip becomes:

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

The equation used to calculate the time to the thermal alarm is:

$t_{alarm} = \tau\, \ln(k^2/(k^2 - \text{Thermal Alarm} /100))$

Thermal alarm = (**Thermal Alarm**) thermal alarm setting in percentage of the thermal state

Since a current of twice the setting I_{th} is applied, consequently one of the following thermal constants is used:

- T1 (overload time constant) if the interrupting device is closed.
- T_r (cooling time constant) if the interrupting device is opened.

Apply a current of twice the setting [in cell 3001: THERMAL OVERLOAD, GROUP1, I_{th} Current Set] to the relay and note the time displayed when the timer stops. Check that the operating time recorded by the timer is within the range (calculated trip time ±5% or 40 ms whichever is the greater). For all characteristics, allowance must be made for the accuracy of the test equipment being used.

Example

For **I_{th} Current Set** = 0.5 A and **A** phase I_{inject} = 2 A, T1 = 5 mins

Using (3) $k = I_{eq} / I_{th} = (2 \times 2 /3) / 0.5 = 8/3$ A

$top = 5 \times 60\, \ln ((8/3)^2 / ((8/3)^2 - 1)) = 45.465$ s

Using (4) $k = I_{eq} / I_{th} = (2 \times 2 /\sqrt{3}) / 0.5 = 8/\sqrt{3}$ A

$top = 5 \times 60\, \ln ((8/\sqrt{3})^2 / ((8/\sqrt{3})^2 - 1)) = 14.4$ s

For a thermal alarm setting = 90% using (3) $t_{alarm} = 40.59$ s

For a thermal alarm setting = 90% using (4) $t_{alarm} = 12.96$ s

If the injection is done equally on the 3 phases current transformers, the equation used to evaluate I_{eq} will be:

$$I_{eq} = \sqrt{(I_1{}^2 + K\ I_2{}^2)}$$

Note: This equation is used in software version A4.x(09) and before

or

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

Note: This equation is used in software version B1.0(20) or later

And provided the phase currents are balanced, I2 is zero.

On completion of the tests any protection elements that were disabled for testing purposes must have their original settings restored in the CONFIGURATION column.

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9 ON-LOAD CHECKS

⚠️ **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.

⚠️ **If any external wiring has been disconnected for the commissioning process, replace it in accordance with the relevant external connection or scheme diagram**

9.1 Confirm Current Connections

1. Measure the current transformer secondary values for each input either by:

   a. reading from the device's HMI panel (providing it has first been verified by a secondary injection test)

   b. using a current clamp meter

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.

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 & 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.

Note: If a P241/2/3 relay is applied with a single dedicated current transformer for the earth fault function, it may not be possible to check the relay's measured values as the neutral current is almost zero.

9.2 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 voltage magnitude values, which can be found in the **MEASUREMENTS 1** menu column.

Cell in MEASUREMENTS 1 column	Corresponding VT ratio in CT/VT RATIO column
VAB Magnitude	Main VT Primary/Main VT Sec'y
VBC Magnitude	
VCA Magnitude	
VAN Magnitude	
VBN Magnitude	
VCN Magnitude	
Vr AntiBacks Magnitude	

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Cell in MEASUREMENTS 1 column	Corresponding VT ratio in CT/VT RATIO column
VN Measured Mag	NVD VT Primary/NVD VT Sec'y

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 & 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.

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10   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 relay has been restored to service by checking that the **Test Mode** cell in the **COMMISSION TESTS** column is set to **Disabled**.

6. If the relay 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.

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MAINTENANCE

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1 MAINTENANCE

1.1 Maintenance Checks

In view of the critical nature of the application, GE products should be checked at regular intervals to confirm they are operating correctly. GE 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.

⚠ **Before carrying out any work on the equipment the user should be familiar with the contents of the Safety Section or Safety Guide SFTY/4 as well as the ratings on the equipment's rating label.**

1.1.1 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.

1.1.2 Opto-Isolators

Check the opto-inputs by repeating the commissioning test detailed in the Commissioning chapter.

1.1.3 Output Relays

Check the output relays by repeating the commissioning test detailed in the Commissioning chapter.

1.1.4 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.

1.2 Replacing the Device

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

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of a fault, you can replace either the complete device or just the faulty PCB, identified by the in-built diagnostic software.

If possible you should replace the complete device, as this reduces the chance of damage due to electrostatic discharge and also eliminates the risk of fitting an incompatible replacement PCB. However, we understand it may be difficult to remove an installed product and you may be forced to replace the faulty PCB on-site. The case and rear terminal blocks are designed to allow removal of the complete device, without disconnecting the scheme wiring.

⚠️ **Replacing PCBs requires the correct on-site environment (clean and dry) as well as suitably trained personnel.**

⚠️ **If the repair is not performed by an approved service centre, the warranty will be invalidated.**

⚠️ **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.**

⚡ **Before working at the rear of the relay, isolate all voltage and current supplies to the relay.**

Note: The current transformer inputs are equipped with integral shorting switches which will close for safety reasons, when the terminal block is removed.

To replace the complete device:

1.   Carefully disconnect the cables not connected to the terminal blocks (e.g. IRIG-B, fibre optic cables, earth), as appropriate, from the rear of the device.
2.   Remove the terminal block screws using a magnetic screwdriver to minimise the risk of losing the screws or leaving them in the terminal block.
3.   Without exerting excessive force or damaging the scheme wiring, pull the terminal blocks away from their internal connectors.
4.   Remove the terminal block screws that fasten the device to the panel and rack. These are the screws with the larger diameter heads that are accessible when the access covers are fitted and open.
5.   Withdraw the device from the panel and rack. Take care, as the device will be heavy due to the internal transformers.
6.   To reinstall the device, follow the above instructions in reverse, ensuring that each terminal block is relocated in the correct position and the chassis ground, IRIG-B and fibre optic connections are replaced. The terminal blocks are labelled alphabetically with 'A' on the left hand side when viewed from the rear.

Once the device has been reinstalled, it should be re-commissioned as set out in the Commissioning chapter.

⚠️ **If the top and bottom access covers have been removed, do not remove the screws with the smaller diameter heads which are accessible. These screws hold the front panel on the relay.**

Note: There are three types of terminal block used on the relay, RTD/CLIO input, heavy duty and medium duty. The terminal blocks are fastened to the rear panel using slotted screws on RTD/CLIO input blocks and crosshead on the heavy and medium duty blocks

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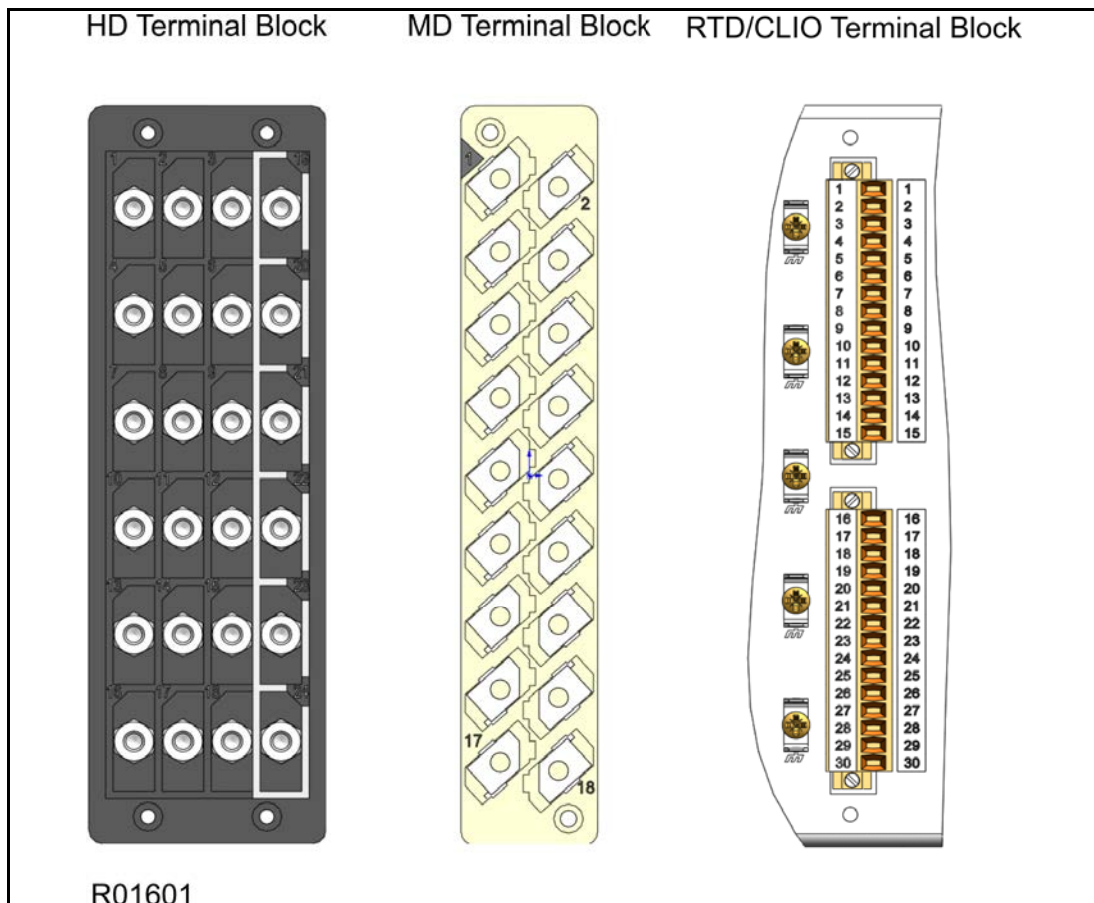
Figure 1: Terminal block types

1.3 Repairing the Device

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, either the complete unit or just the faulty PCB, identified by the in-built diagnostic software, should be replaced.

Replacement of printed circuit boards and other internal components must be undertaken by approved Service Centres. Failure to obtain the authorization of after-sales engineers prior to commencing work may invalidate the product warranty.

We recommend that you entrust any repairs to Automation Support teams, which are available world-wide.

1.4 Removing the Front Panel

⚡ **Before removing the front panel to replace a PCB, you must first remove the auxiliary power supply and wait 5 seconds for the internal capacitors to discharge. You should also isolate voltage and current transformer connections and trip circuit.**

⚠ **Before removing the front panel, you should be familiar with the contents of the Safety section 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.**

To remove the front panel:

1. Open the top and bottom access covers. You must open the hinged access covers by more than 90° before they can be removed.
2. If fitted, remove the transparent secondary front cover.
3. Apply outward pressure to the middle of the access covers to bow them and disengage the hinge lug, so the access cover can be removed. The screws that fasten the front panel to the case are now accessible.

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4. Undo and remove the screws. The 40TE case has four cross-head screws fastening the front panel to the case, one in each corner, in recessed holes. The 60TE/80TE cases have an additional two screws, one midway along each of the top and bottom edges of the front plate.

5. When the screws have been removed, pull the complete front panel forward to separate it from the metal case. The front panel is connected to the rest of the circuitry by a 64-way ribbon cable.

6. The ribbon cable is fastened to the front panel using an IDC connector; a socket on the cable and a plug with locking latches on the front panel. Gently push the two locking latches outwards which eject the connector socket slightly. Remove the socket from the plug to disconnect the front panel.

> ⚠ **Do not remove the screws with the larger diameter heads which are accessible when the access covers are fitted and open. These screws hold the relay in its mounting (panel or cubicle).**

> ⚠ **The internal circuitry is now exposed and is not protected against electrostatic discharge and dust ingress. Therefore ESD precautions and clean working conditions must be maintained at all times.**

1.5   Replacing a PCB

Replacing printed circuit boards and other internal components of protective relays must be undertaken only by Service Centers approved by GE. Failure to obtain the authorization of GE After Sales Engineers prior to commencing work may invalidate the product warranty.

GE support teams are available world-wide and it is recommended that any repairs be entrusted to these trained personnel.

1. To replace any of the PCBs, first remove the front panel.

2. Once the front panel has been removed, the PCBs are accessible. The numbers above the case outline identify the guide slot reference for each printed circuit board. Each printed circuit board has a label stating the corresponding guide slot number to ensure correct relocation after removal. To serve as a reminder of the slot numbering there is a label on the rear of the front panel metallic screen.

3. Remove the 64-way ribbon cable from the PCB that needs replacing

4. Remove the PCB in accordance with the board-specific instructions detailed later in this section.

> **Note:**   To ensure compatibility, always replace a faulty PCB with one of an identical part number.

1.5.1   Replacing the Main Processor Board

The main processor board is situated in the front panel. This board contains application-specific settings in its nonvolatile memory. You may wish to take a backup copy of these settings. This could save time in the recommissioning process.

To replace the main processor board:

1. Remove front panel.

2. Place the front panel with the user interface face down and remove the six screws from the metallic screen, as shown in the figure below. Remove the metal plate.

3. Remove the two screws either side of the rear of the battery compartment recess*. These are the screws that hold the main processor board in position.

4. Carefully disconnect the ribbon cable. Take care as this could easily be damaged by excessive twisting.

5. Replace the main processor board

6. Reassemble the front panel using the reverse procedure. Make sure the ribbon cable is reconnected to the main processor board and that all eight screws are refitted.

7. Refit the front panel.

8. Refit and close the access covers then press the hinge assistance T-pieces so they click back into the front panel moulding.

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9. Once the unit has been reassembled, carry out the standard commissioning procedure as defined in the Commissioning chapter.

Note: After replacing the main processor board, all the settings required for the application need to be re-entered. This may be done either manually or by downloading a settings file.
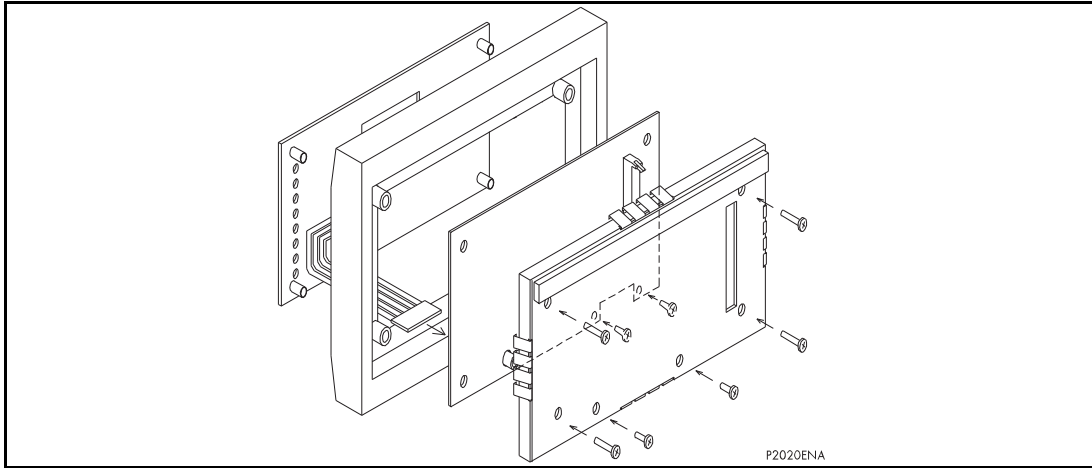
Figure 2: Front panel assembly

Note: *Battery fitted to white front panel versions, supercapacitor fitted to black and silver front panel versions. For details, refer to the Ordering Options Appendix.

1.5.2   Replacement of Communications Boards

Most products will have at least one communications board of some sort fitted. There are several different boards available offering various functionality, depending on the application. Some products may even be fitted two boards of different types.

To replace a faulty communications board:

1. Remove front panel.
2. Disconnect all connections at the rear.
3. The board is secured in the relay case by two screws, one at the top and another at the bottom. Remove these screws carefully as they are not captive in the rear panel.
4. Gently pull the communications board forward and out of the case.
5. Before fitting the replacement PCB check that the number on the round label next to the front edge of the PCB matches the slot number into which it will be fitted. If the slot number is missing or incorrect, write the correct slot number on the label.
6. Fit the replacement PCB carefully into the correct slot. Make sure it is pushed fully back and that the securing screws are refitted.
7. Reconnect all connections at the rear.
8. Refit the front panel.
9. Refit and close the access covers then press the hinge assistance T-pieces so they click back into the front panel moulding.
10. Once the unit has been reassembled, commission it according to the Commissioning chapter.

1.5.3   Replacement of the Input Module

The input module comprises of two or three boards fastened together and is contained within a metal housing. In the P241/2 relays the input module consists of a transformer board and an input board. The P243 input module has three boards; input, transformer and auxiliary transformer.

1. Remove front panel.

2. The module is secured in the case by two screws on its right-hand side, accessible from the front. Move these screws carefully as they are not captive in the front plate of the module.

3. On the right-hand side of the module there is a small metal tab which brings out a handle (on some modules there is also a tab on the left). Grasp the handle(s) and pull the module firmly forward, away from the rear terminal blocks. A reasonable amount of force is needed due to the friction between the contacts of the terminal blocks.

4. Remove the module from the case. The module may be heavy, because it contains the input voltage and current transformers.

5. Slot in the replacement module and push it fully back onto the rear terminal blocks. To check that the module is fully inserted, make sure the v-shaped cut-out in the bottom plate of the case is fully visible.

6. Refit the securing screws.

7. Refit the front panel.

8. Refit and close the access covers then press the hinge assistance T-pieces so they click back into the front panel moulding.

9. Once the unit has been reassembled, commission it according to the Commissioning chapter.

⚠ **With non-mounted relays, the case needs to be held firmly while the module is withdrawn. Withdraw the input module with care as it suddenly comes loose once the friction of the terminal blocks is overcome.**

Note: If individual boards within the input module are replaced, recalibration will be necessary. We therefore recommend replacement of the complete module to avoid on-site recalibration.

1.5.4   Replacement of the Power Supply Board

⚠ **Before removing the front panel, you should be familiar with the contents of the Safety section 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.**

The power supply board is fastened to an output relay board with push fit nylon pillars. This doubled-up board is secured on the extreme left hand side, looking from the front of the unit.

1. Remove front panel.

2. Pull the power supply module forward, away from the rear terminal blocks and out of the case. A reasonable amount of force is needed due to the friction between the contacts of the terminal blocks.

3. Separate the boards by pulling them apart carefully. The power supply board is the one with two large electrolytic capacitors.

4. Before reassembling the module, check that the number on the round label next to the front edge of the PCB matches the slot number into which it will be fitted. If the slot number is missing or incorrect, write the correct slot number on the label

5. Reassemble the module with a replacement PCB. Push the inter-board connectors firmly together. Fit the four push fit nylon pillars securely in their respective holes in each PCB.

6. Slot the power supply module back into the housing. Push it fully back onto the rear terminal blocks.

7. Refit the front panel.

8. Refit and close the access covers then press the hinge assistance T-pieces so they click back into the front panel moulding.

9. Once the unit has been reassembled, commission it according to the Commissioning chapter.

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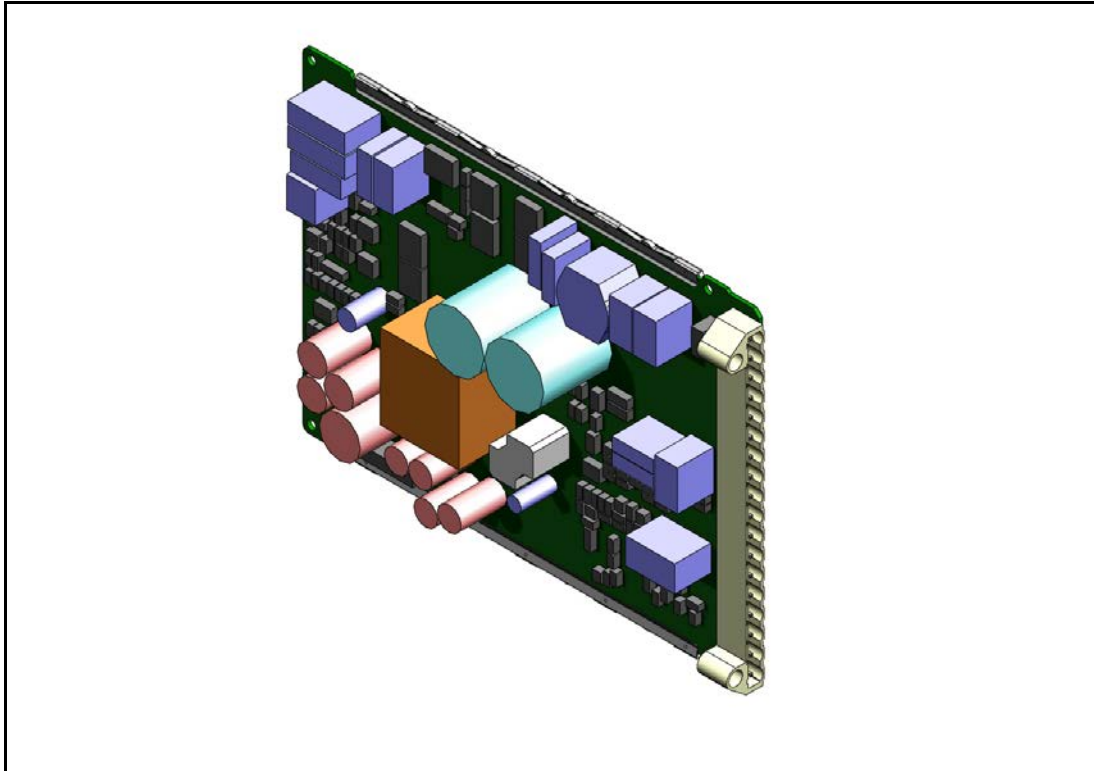
Figure 3: Power supply board

1.5.5   Replacement of the I/O Boards

There are several different types of I/O boards, which can be used, depending on the product and application.

Some boards have opto-inputs, some have relay outputs and others have a mixture of both.

1.   Remove front panel.
2.   Gently pull the board forward and out of the case
3.   If replacing the I/O board, make sure the setting of the link above IDC connector on the replacement board is the same as the one being replaced.
4.   Before fitting the replacement board check the number on the round label next to the front edge of the board matches the slot number into which it will be fitted. If the slot number is missing or incorrect, write the correct slot number on the label.
5.   Carefully slide the replacement board into the appropriate slot, ensuring that it is pushed fully back onto the rear terminal blocks.
6.   Refit the front panel.
7.   Refit and close the access covers then press at the hinge assistance T-pieces so they click back into the front panel moulding.
8.   Once the unit has been reassembled, commission it according to the Commissioning chapter.

1.6   Recalibration

Recalibration is not needed when a PCB is replaced, unless it is one of the boards in the input module. If any of the boards in the input module is replaced, the unit must be recalibrated.

Although recalibration is needed when a board inside the input module is replaced, it is not needed if the input module is replaced in its entirety.

Although it is possible to carry out recalibration on site, this requires special test equipment and software. We therefore recommend that the work be carried out by the manufacturer, or entrusted to an approved service centre.

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1.7   Changing the Battery

Each device has a battery/supercapacitor* to maintain status data and the correct time when the auxiliary supply voltage fails. The data maintained includes event, fault and disturbance records and the thermal state at the time of failure.

As part of the product's continuous self-monitoring, an alarm is given if the battery condition becomes poor. Nevertheless, you should change the battery periodically to ensure reliability.

To replace the battery*:

1.   Open the bottom access cover on the front of the relay.
2.   Gently remove the battery. If necessary, use a small insulated screwdriver.
3.   Make sure the metal terminals in the battery socket are free from corrosion, grease and dust.
4.   Remove the replacement battery from its packaging and insert it in the battery holder, ensuring correct polarity.
5.   Ensure that the battery is held securely in its socket and that the battery terminals make good contact with the socket terminals.
6.   Close the bottom access cover.

⚠️   **Only use a type ½AA Lithium battery with a nominal voltage of 3.6 V and safety approvals such as UL (Underwriters Laboratory), CSA (Canadian Standards Association) or VDE (Vereinigung Deutscher Elektrizitätswerke).**

Note: Events, disturbance and maintenance records will be lost if the battery is replaced whilst the IED is de-energised.

*Battery fitted to legacy/white front panel version only--see mounting options in the Cortec in the Ordering Options Appendix for details.

1.7.1   Post Modification Tests

To ensure that the replacement battery* maintains the time and status data if the auxiliary supply fails, scroll across to the **DATE AND TIME** cell, then scroll down to Battery Status which should read Healthy.

Note: *Battery fitted to legacy/white front panel version only--see mounting options in the Cortec in the Ordering Options Appendix for details.

1.7.2   Battery Disposal

Dispose the removed battery* according to the disposal procedure for Lithium batteries in the country in which the relay is installed.

Note: *Battery fitted to legacy/white front panel version only--see mounting options in the Cortec in the Ordering Options Appendix for details.

1.8   Supercapacitor Discharged

The supercapacitor maintains charge for two weeks with the relay de-energised. When first energising the relay after this time there may be a Battery Alarm due to the supercapacitor voltage dropping below a pre-defined threshold. The battery alarm will clear after approximately 30 minutes of the relay being energised, and once cleared there will be enough charge in the supercapacitor to backup status data.

Note: Events, disturbance and maintenance records will be lost if the supercapacitor is fully discharged.

Supercapacitor fitted to black and silver front panel version only--see mounting options in the Cortec in the Ordering Options Appendix for details.

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1.9 Cleaning

⚠️ **Before cleaning the relay ensure that all ac and dc supplies, current transformer and voltage 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 relay's surface and leave a conductive residue.

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TROUBLESHOOTING

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TABLES

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1   INTRODUCTION

⚠ **Before carrying out any work on the equipment the user 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.**

The troubleshooting chapter allows an error condition on the device 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.

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2   TROUBLESHOOTING

2.1   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 bootup, and secondly a continuous self-checking operation, which checks the operation of the critical functions whilst it is in service.

2.2   Power Up Errors

If the device does not appear to power up, use the following table to determine whether the fault is in the external wiring, auxiliary fuse, relay power supply module or the relay front panel.

Test	Check	Action
1	Measure the auxiliary voltage on terminals 1 and 2. Verify the voltage level and polarity against rating the label on front. Terminal 1 is –dc, 2 is +dc	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 watchdog contact for closing.	If the LEDs and LCD backlight switch ON or the contact closes and no error code is displayed, the error is probably on the main processor board in the front panel. If the LEDs and LCD backlight do not switch ON and the contact does not close, go to test 3.
3	Check Field voltage output (nominally 48 V DC)	If there is no field voltage, the fault is probably in the relay power supply module.

Table 1: Failure of relay to power up

2.3   Error Message or Code On Power Up

The device 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 device application software is running, a maintenance record is created and the relay reboots.

Test	Check	Action
1	Is an error message or code permanently displayed during power up?	If relay locks up and displays an error code permanently, go to test 2. If the relay prompts for user input, go to test 4. If the relay reboots automatically, go to test 5
2	Record displayed error, then remove and re-apply relay auxiliary supply.	Record whether the same error code is displayed when the relay is rebooted. If no error code is displayed, contact the local service center stating the error code and relay information. If the same code is displayed, go to test 3.

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Test	Check	Action
3	Error code Identification The following text messages (in English) are displayed if a fundamental problem is detected, preventing the system from booting: Bus Fail – address lines SRAM Fail – data lines FLASH Fail format error FLASH Fail checksum Code Verify Fail The following hex error codes relate to errors detected in specific relay modules:	These messages indicate that a problem has been detected on the relay's main processor board of in the front panel.
	0c140005/0c0d0000	Input Module (inc. Opto-isolated inputs)
	0c140006/0c0e0000	Output Relay Cards
	The last 4 digits provide details on the actual error.	Other error codes relate to problems within the main processor board hardware or software. Contact GE with details of the problem for a full analysis.
4	The relay displays a message for corrupt settings and prompts for default values to be restored for the affected settings.	The power-up tests have detected corrupted relay settings. Restore the default settings to allow the power-up to be complete, reapply the application-specific settings.
5	The relay resets when the power-up is complete. A record error code is displayed	Error 0x0E080000, programmable scheme logic error due to excessive execution time. If relay powers up successfully, check programmable logic for feedback paths. Other error codes will relate to software errors on the main processor board, contact GE.

Table 2: Power-up self-test error

2.4   Out of Service LED on at Power Up

Test	Check	Action		
1	Using the relay menu, confirm the Commission Test/Test Mode setting is Enabled. If it is not enabled, got to test 2.	If the setting is Enabled, disable the test mode and make sure the Out of Service LED is OFF.		
2	Select **View Records**, then view the last maintenance record from the menu.	Check for **H/W Verify Fail**. This indicates a discrepancy between the relay model number and the hardware. Examine the **Maint. Data**; this indicates the causes of the failure using bit fields: Bit Meaning		
			0	The application type field in the model number does not match the software ID
			1	The application field in the model number does not match the software ID
			2	The variant 1 field in the model number does not match the software ID
			3	The variant 2 field in the model number does not match the software ID
			4	The protocol field in the model number does not match the software ID

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Test	Check	Action	
		5	The language field in the model number does not match the software ID
		6	The VT type field in the model number is incorrect (110 V VTs fitted)
		7	The VT type field in the model number is incorrect (440 V VTs fitted)
		8	The VT type field in the model number is incorrect (no VTs fitted)

Table 3: Out of service LED illuminated

2.5 Error Code During Operation

The relay performs continuous self-checking. If the device 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, then the relay displays an error code and halts. If the problem was transient, the relay reboots correctly and continues operation. By examining the maintenance record logged, the nature of the detected fault can be determined.

2.5.1 Backup Battery

If the device's self-check detects a failure of the lithium battery*, the device displays an alarm message and logs a maintenance record but the device does not reset.

To prevent the device from issuing an alarm when there is a battery failure, select **DATE AND TIME** then **Battery Alarm** then **Disabled**. The device can then be used without a battery and no battery alarm message appears.

> **Note:** *Battery fitted to legacy/white front panel version only--see mounting options in the Cortec in the Ordering Options Appendix for details.

2.6 Mal-Operation of the Relay During Testing

2.6.1 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 coil of the contact has been energized. An error is displayed if there is a fault in the output relay board.

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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 (see Table 4).
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 by 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/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.

Table 4: Failure of output contacts

2.6.2   Failure of Opto Inputs

The opto-isolated inputs are mapped onto the device's internal DDB signals using the programmable scheme logic. If an input is not recognised 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 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 Data chapter for opto pick-up levels).

If the signal is correctly applied, this indicates failure of an opto-input, which may be situated on standalone opto input board, or on an opto-input board that is part of the input module. Separate opto-input boards can simply be replaced. If, however, the faulty opto-input board is part of the input module, the complete input module should be replaced. This is because the analogue input module cannot be individually replaced without dismantling the module and recalibration of the device.

2.7   Incorrect Analog 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.

2.8   PSL Editor Troubleshooting

A failure to open a connection could be due to one or more of the following:

- The device 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 device or the type of connection
- The connection cable is not wired correctly or broken.
- The option switches on any protocol converter may be incorrectly set

2.8.1   Diagram Reconstruction

Although a scheme can be extracted from an device, 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.

2.8.2   PSL Version Check

The PSL is saved with a version reference, time stamp and CRC check. This gives a visual check whether the default PSL is in place or whether a new application has been downloaded.

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3   REPAIR AND MODIFICATION PROCEDURE

Please follow these steps to return an Automation product to us:

1.   Get the Repair and Modification Authorization Form (RMA)
      An electronic version of the RMA form is available from the following:
      contact.centre@ge.com

2.   Fill in 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
      Your local service contact provides you with all the information needed to ship the product:

- Pricing details

- RMA n°

- Repair center address

If required, an acceptance of the quote must be delivered before going to next stage.

5.   Send the product to the repair center

- Address the shipment to the repair center specified by your local contact

- Ensure all items are protected by appropriate packaging: anti-static bag and foam protection

- Ensure a copy of the import invoice is attached with the unit being returned

- Ensure a copy of the RMA form is attached with the unit being returned

- E-mail or fax a copy of the import invoice and airway bill document to your local contact.

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SCADA COMMUNICATIONS

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TABLES

1   INTRODUCTION

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.

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2   COMMUNICATION INTERFACES

The 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	RS232/USB Type B	Local settings	Courier
Rear Port 1 (RP1 copper)	Standard	RS232 / RS485 / K-Bus	SCADA Remote settings	Courier, MODBUS, IEC60870-5-103, DNP3.0 (order option)
Rear Port 1 (RP1 fibre)	Optional	Fibre	SCADA Remote settings	Courier, MODBUS, IEC60870-5-103, DNP3.0 (order option)
Rear Port 2 (RP2)	Optional	RS232 / RS485 / K-Bus	SCADA Remote settings	SK4: Courier only SK5: InterMicom only
Ethernet	Optional	Ethernet	IEC 61850 or DNP3 Remote settings	IEC 61850, Courier (tunnelled) or DNP3.0 (order option)

Note: Optional communications boards are always fitted into slot A.

It is only possible to fit one optional communications board, therefore RP2 and Ethernet communications are mutually exclusive.

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3 SERIAL COMMUNICATION

The physical layer standards that are used for serial communications for SCADA purposes are:

- EIA(RS)485 (often abbreviated to RS485)
- K-Bus (a proprietary customization of RS485)

EIA(RS)232/USB* is used for local communication with the IED (for transferring settings and downloading firmware updates).

RS485 is similar to RS232 but for longer distances and it allows daisy-chaining and multi-dropping of IEDs.

K-Bus is a proprietary protocol quite similar to RS485, but it cannot be mixed on the same link as RS485. Unlike RS485, K-Bus signals applied across two terminals are not polarised.

It is important to note that these are not data protocols. They only describe the physical characteristics required for two devices to communicate with each other.

For a description of the K-Bus standard see *K-Bus* (on page **Error! Bookmark not defined.**) and GE's K-Bus interface guide reference R6509.

A full description of the RS485 is available in the published standard.

> **Note:** *Legacy/white front panel options are fitted with serial and parallel ports, black and silver front panel options are fitted with USB type B ports. For details, refer to the Ordering Options Appendix.

3.1 USB Front Port

The USB interface uses the proprietary Courier protocol for local communication with the MiCOM S1 Agile settings application software.

This is intended for temporary local connection and is not suitable for permanent connection. This interface uses a fixed baud rate of 19200 bps, 11-bit frame (8 data bits, 1 start bit, 1 stop bit, even parity bit), and a fixed device address of '1'.

The USB interface is a Type B connector. Normally a Type A to Type B USB cable will be required to communicate between MiCOM S1 Agile and the device.

3.2 EIA(RS)232 Bus

The EIA(RS)232 interface uses the IEC 60870-5 FT1.2 frame format.

The device supports an IEC 60870-5 FT1.2 connection on the front-port. This is intended for temporary local connection and is not suitable for permanent connection. This interface uses a fixed baud rate of 19200 bps, 11-bit frame (8 data bits, 1 start bit, 1 stop bit, even parity bit), and a fixed device address of '1'.

EIA(RS)232 interfaces are polarised.

3.3 EIA(RS)485 Bus

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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 mm2 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.

3.3.1 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.
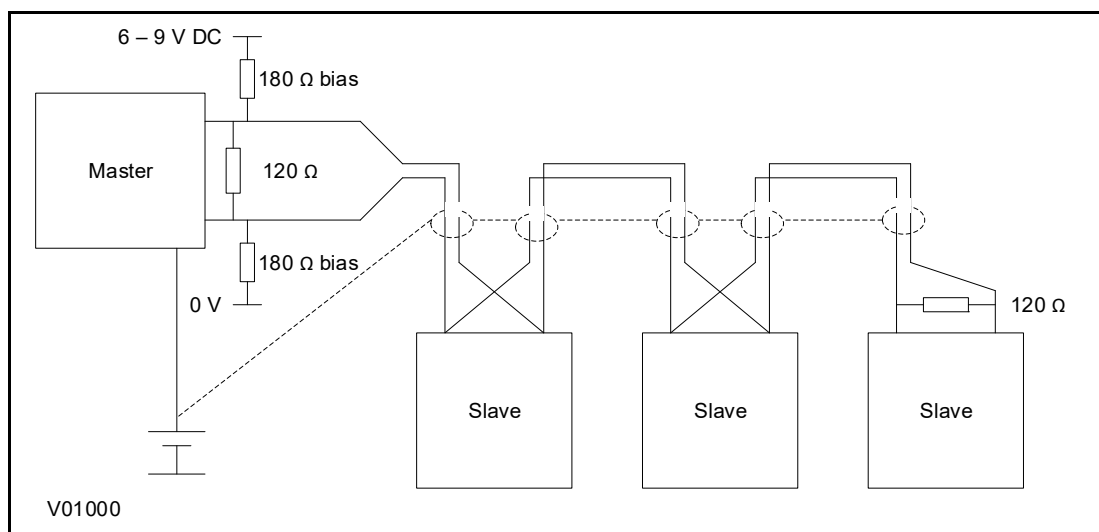
Figure 1: RS485 biasing circuit

> ⚠ **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.**

3.4   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 GE for information regarding the specification and supply of KITZ devices. The following figure demonstrates a typical K-Bus connection.
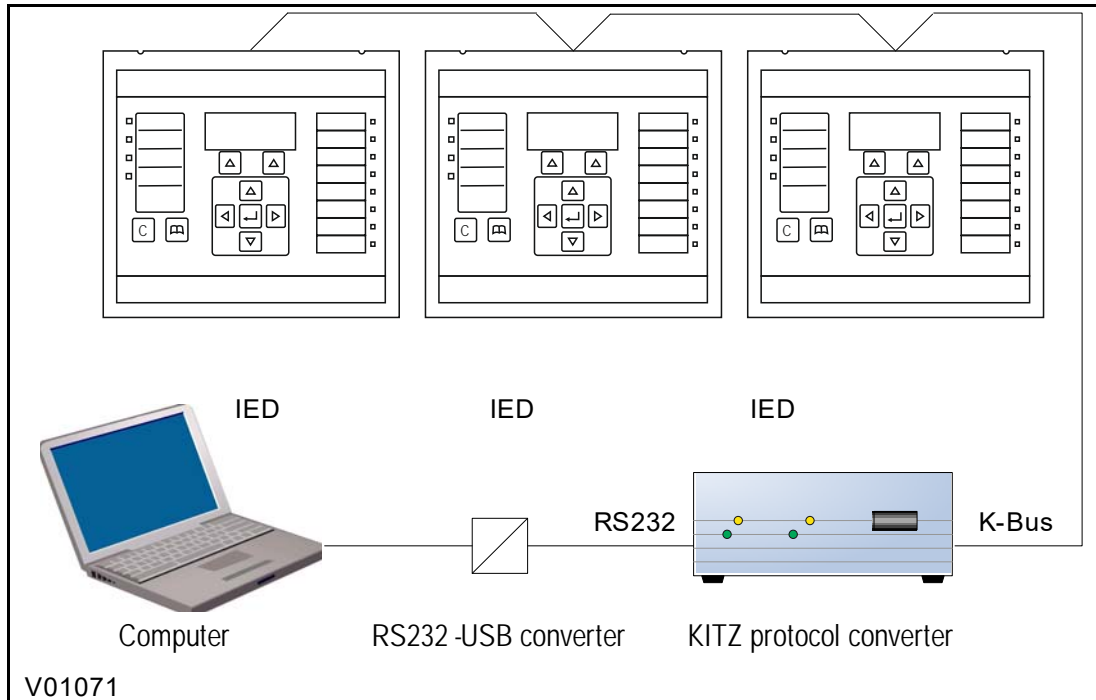
Figure 2: Remote communication using K-Bus

> **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.

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4 STANDARD ETHERNET COMMUNICATION

The type of Ethernet board depends on the chosen model. The available boards and their features are described in the Firmware Design chapter of this manual.

The Ethernet interface is required for either IEC 61850 or DNP3 over Ethernet (protocol must be selected at time of order). With either of these protocols, the Ethernet interface also offers communication with the settings application software 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 BFOC 2.5 (ST) connectors. Fibres should be suitable for 1300 nm transmission and be multimode 50/125 μm or 62.5/125 μm.

Connection can also be made to a 10Base-T or a 100Base-TX Ethernet switch using the RJ45 port.

4.1 Hot-Standby Ethernet Failover

This is used for products which are fitted with a standard Ethernet board. The standard Ethernet board has one fibre and one copper interface. If there is a fault on the fibre channel it can switch to the copper channel, or vice versa.

When this function detects a link failure, it generates the NIC Fail Alarm. The failover timer then starts, which has a settable timeout. During this time, the Hot Standby Failover function continues to check the status of the other channel. If the link failure recovers before the failover timer times out, the channels are not swapped over. If there is still a fail when the failover timer times out and the other channel status is ok, the channels are swapped over. The Ethernet controller is then reconfigured and the link is renegotiated.

To set the function, use the IEC 61850 Configurator tool in the Settings Application Software.

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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 GE products, using a Redundant Ethernet Board (REB). The REB is a Network Interface Card (NIC), which incorporates an integrated Ethernet switch. The board provides two Ethernet transmitter/receiver pairs.

By ordering option, a number of different protocols are available to provide the redundancy according to particular system requirements.

In addition to the two Ethernet transmitter/receiver pairs, the REB provides link activity indication in the form of LEDs, link fail indication in the form of watchdog contacts, and a dedicated time synchronisation input.

The dedicated time synchronisation input is designed to connect to an IRIG-B signal. Both modulated and un-modulated IRIG-B formats are supported according to the selected option. Simple Network Time Protocol (SNTP) is supported over the Ethernet communications.

5.1 Supported Protocols

A range of Redundant Ethernet Boards are available to support different protocols for different requirements. 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.

As well as supporting standard non-bumpless protocols such as RSTP, the REB was originally designed to support bumpless redundancy, using proprietary protocols before the standard protocols became available. Since then, variants have been produced for the newer standard protocols.

REB variants for each of the following protocols are available:

- PRP (Parallel Redundancy Protocol)
- HSR (High-availability Seamless Redundancy)
- RSTP (Rapid Spanning Tree Protocol)
- Failover

PRP and HSR are open standards, so their implementation is compatible with any standard PRP or HSR device respectively. PRP provides "bumpless" redundancy. RSTP is also an open standard, so its implementation is compatible with any standard RSTP devices. RSTP provides redundancy, however, it is not "bumpless".

Note: The protocol you require must be selected at the time of ordering.

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5.2 Parallel Redundancy Protocol

PRP (Parallel Redundancy 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.

E01028
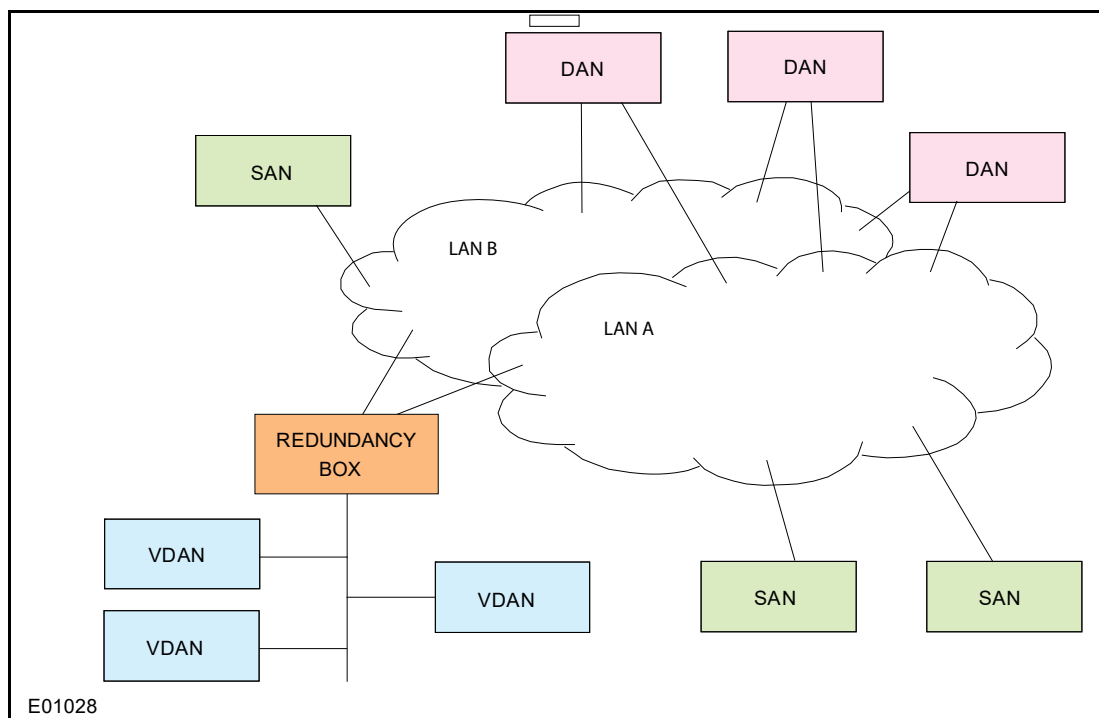
Figure 3: IED attached to separate LANs

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.

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5.2.1   PRP Application in the Substation
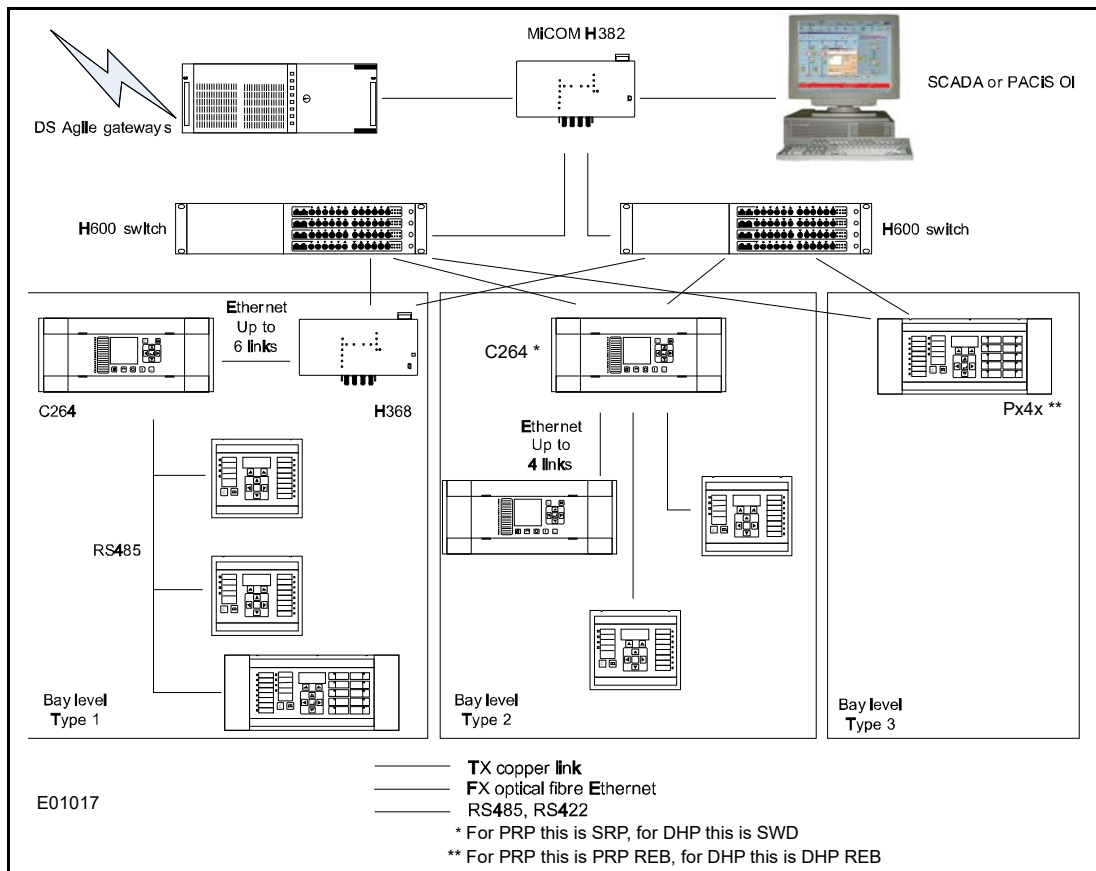
Figure 4: PRP application in the substation

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.

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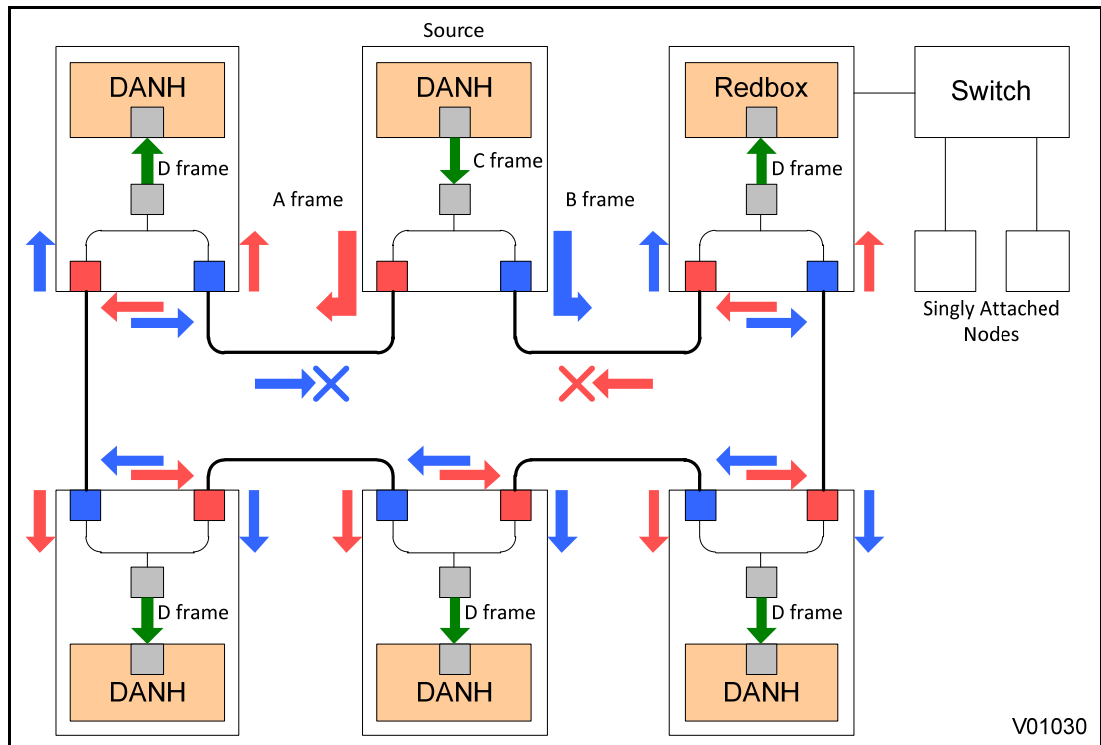
Figure 5: HSR multicast topology

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.
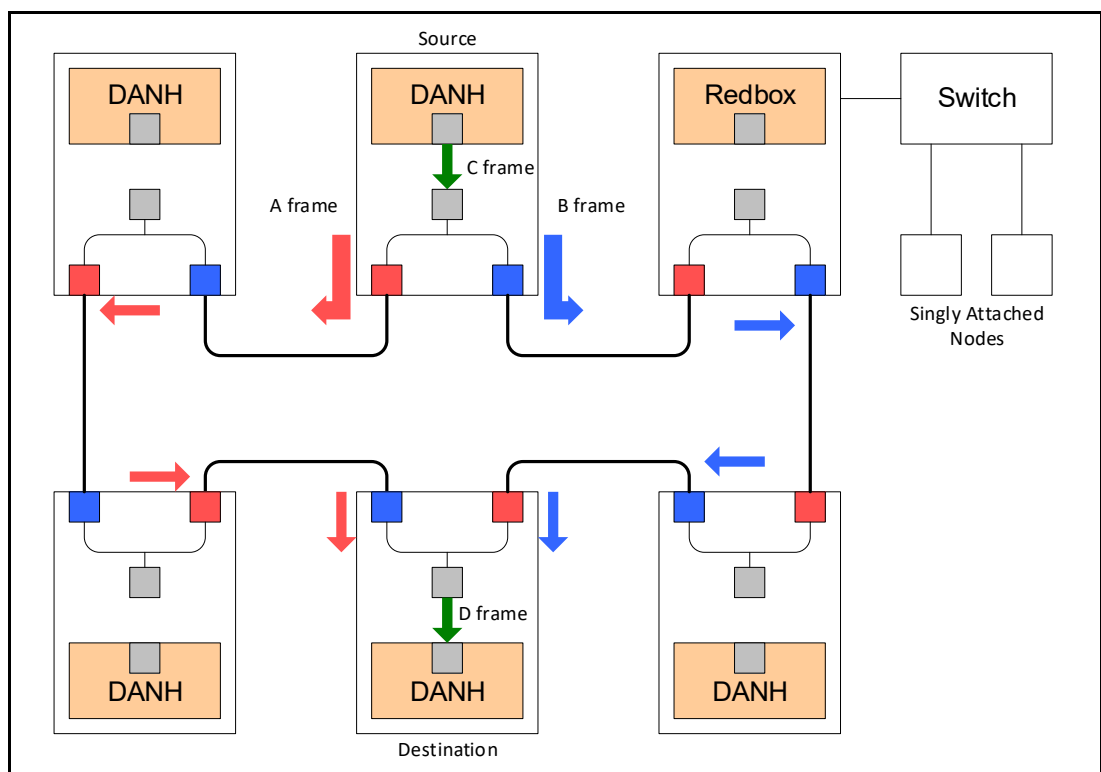
Figure 6: HSR unicast topology

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
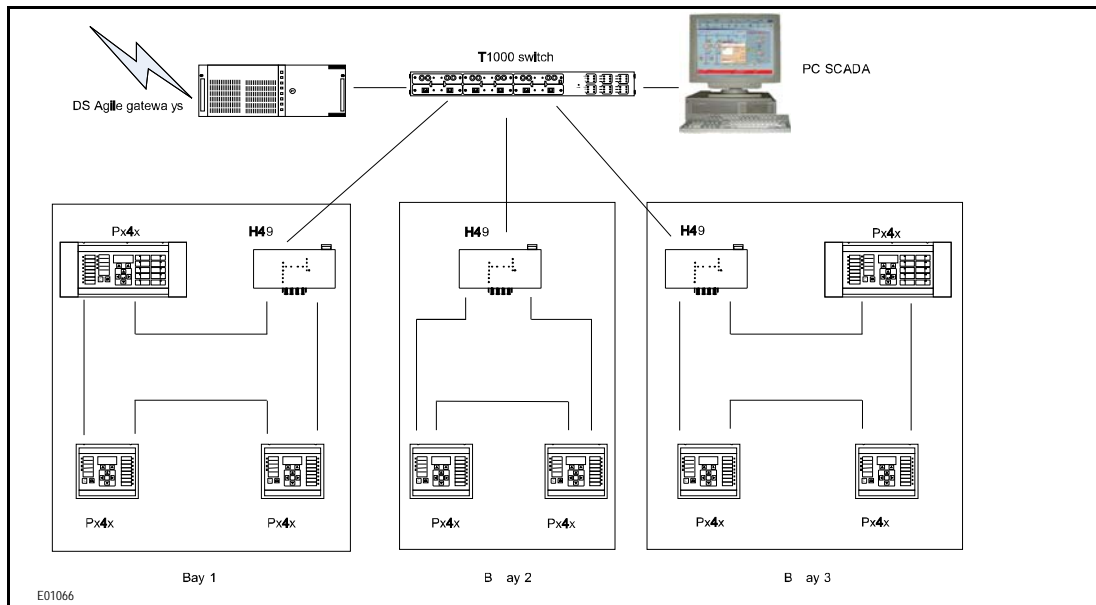
Figure 7: HSR application in the substation

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.
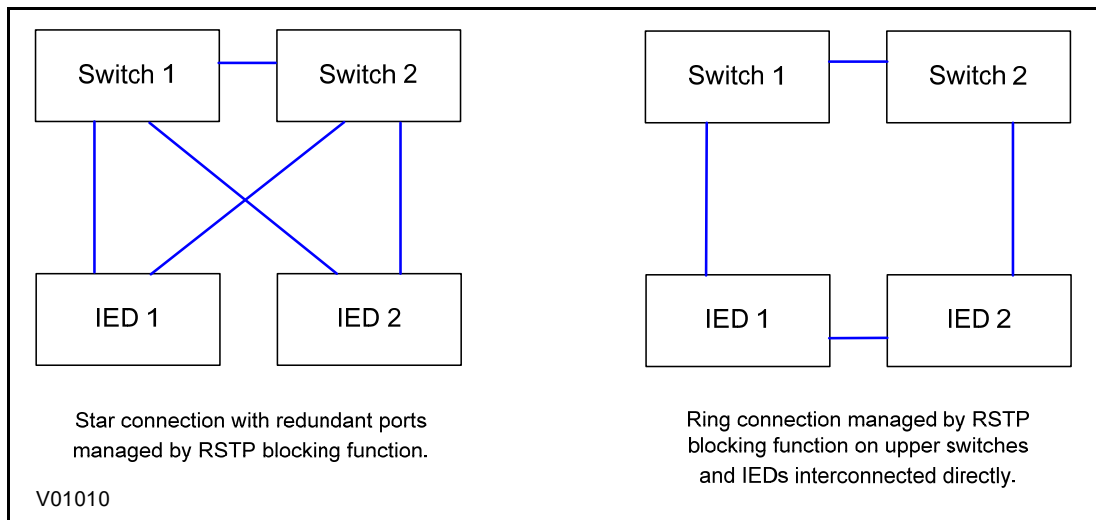
Figure 8: IED attached to redundant Ethernet star or ring circuit

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 operation of the protocol.

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5.5 Configuring IP Addresses

An IP address is a logical address assigned to a device that uses the Internet Protocol (IP) for communication with other devices. IP addresses are represented using Decimal Dot Notation where four sets of decimal numbers are separated by dots as follows:

XXX.XXX.XXX.XXX

For example: 10.86.254.85

An IP address in a network is usually associated with a subnet mask. The subnet mask defines which network the device belongs to. A subnet mask has the same form as an IP address.

For example:

255.255.255.0

Both the IED and the REB each have their own IP address. The following diagram shows the IED as IP1 and the REB as IP2.

> **Note:** IP1 and IP2 are different but use the same subnet mask.

The switch IP address must be configured through the Ethernet network.
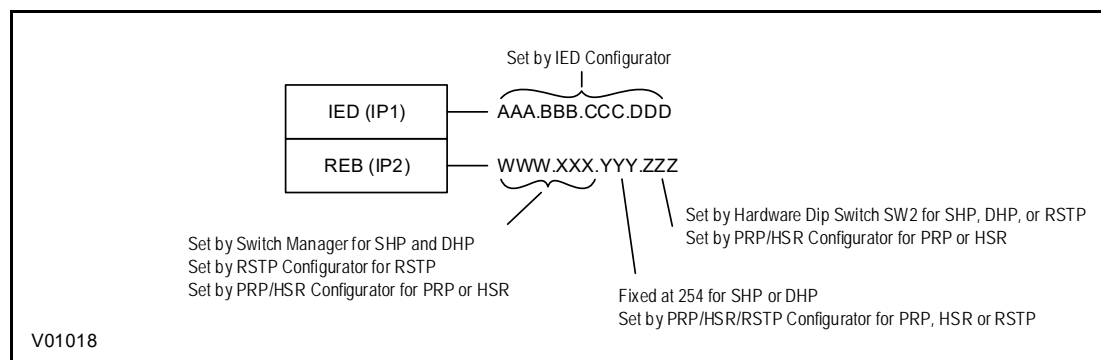
Figure 9: IED and REB IP Address Configuration

5.5.1 Configuring the IED IP Address

If you are using IEC 61850, set the IED IP address using the IEC 61850 Configurator software. In the IEC 61850 Configurator, set **Media** to **Single Copper or Redundant Fibre**.

If you are using DNP3 over Ethernet, set the IED IP address by editing the DNP3 file, using the DNP3 Configurator software. In the DNP3 Configurator, set **Ethernet Media** to **Copper**, even though the redundant Ethernet network uses fibre optic cables.

5.5.2 Configuring the REB IP Address

The board IP address must be configured before connecting the IED to the network to avoid an IP address conflict. The way you configure the IP address depends on the redundancy protocol you have chosen.

PRP/HSR/RSTP

If using PRP, HSR or RSTP, you configure the REB IP address using the Redundant Ethernet Configurator software.

5.6 Redundant Ethernet Configurator

The Redundant Ethernet Configurator tool is intended for MiCOM Px4x IEDs with redundant Ethernet using PRP (Parallel Redundancy Protocol), HSR (High-availability Seamless Redundancy) or RSTP. This tool is used to identify IEDs, switch between PRP/HSR/RSTP or configure their parameters, configure the redundancy IP address, or configure the SNTP IP address.
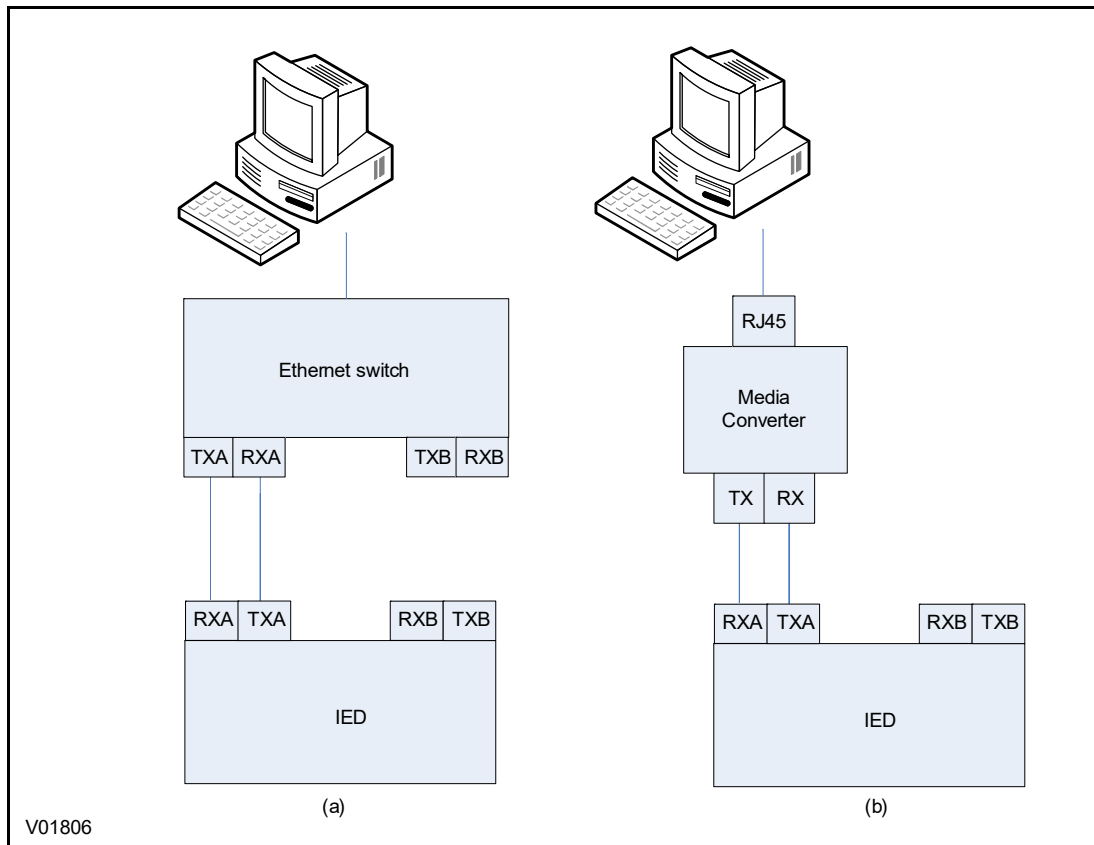
Figure 10: Connection using (a) an Ethernet switch and (b) a media converter

5.6.1   Starting the Configurator

To start the configurator:

1. Select the Redundant Ethernet Configurator from the 'Ethernet Configuration' tile in MiCOM S1 Agile.

2. The Login screen appears. For user mode login, enter the **Login name** as **User** and click **OK** with no password.

3. If the login screen does not appear, check all network connections.

4. The main window appears. In the bottom right-hand corner of the main window, click the **Language** button to select the language.

5. The **Network Board** drop-down list shows the Network Board, IP Address and MAC Address of the PC in which the Configurator is running.

5.6.2   PRP/HSR Device identification

To configure the redundant Ethernet board, go to the main window and click the **Identify Device** button. A list of devices are shown with the following details:

- Device address

- MAC address

- Version number of the firmware

- SNTP IP address

- Date & time of the real-time clock, from the board.

Select the device you wish to configure. The MAC address of the selected device is highlighted.

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5.6.3   Selecting the Device Mode

You must now select the device mode that you wish to use. This will be either PRP or HSR. To do this, select the appropriate radio button then click the **Update** button. You will be asked to confirm a device reboot. Click **OK** to confirm.

5.6.4   PRP/HSR IP Address Configuration

To change the network address component of the IP address:

1. From the main window click the **IP config** button. The **Device Setup** screen appears.

2. Enter the required board IP address and click **OK**. This is the redundancy network address, not the IEC 61850 IP address.

3. The board network address is updated and displayed in the main window.

5.6.5   SNTP IP Address Configuration

To Configure the SNTP server IP address:

1. From the main window click the **SNTP Config** button. The Device setup screen appears.

2. Enter the required **MAC SNTP** address and server **IP SNTP Address**. Click **OK**.

3. The updated MAC and IP SNTP addresses appear in the main screen.

5.6.6   Check for Connected Equipment

To check what devices are connected to the device being monitored:

1. From the main window, select the device.

2. Click the **Equipment** button.

3. At the bottom of the main window, a box shows the ports where devices are connected and their MAC addresses.

5.6.7   PRP Configuration

To view or configure the PRP Parameters:

1. Ensure that you have set the device mode to **PRP**.

2. Click the **PRP/HSR Config** button. The **PRP Config** screen appears.

3. To view the available parameters, click the **Get PRP Parameters** button.

4. To change the parameters, click the **Set Parameters** button and modify their values.

If you need to restore the default values of the parameters, click the Restore Defaults button.

The configurable parameters are as follows:

- **Multicast Address**: Use this field to configure the multicast destination address. All DANPs in the network must be configured to operate with the same multicast address for the purpose of network supervision.

- **Node Forget Time**: This is the time after which a node entry is cleared in the nodes table.

- **Life Check Interval**: This defines how often a node sends a PRP_Supervision frame. All DANPs shall be configured with the same Life Check Interval.

5.6.8   HSR Configuration

To view or configure the HSR Parameters:

1. Click the **PRP/HSR Config** button. The **HSR Config** screen appears.

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2. To view the available parameters in the board that is connected, click the **Retrieve HSR Parameters** from IED button.

3. To change the parameters, click the **Set Parameters** button and modify their values.

If you need to restore the default values of the parameters, click the **Restore Defaults** button.

The configurable parameters are as follows:

- **Multicast Address**: Use this field to configure the multicast destination address. All DANPs in the network must be configured to operate with the same multicast address for the purpose of network supervision.

- **Node Forget Time**: This is the time after which a node entry is cleared in the nodes table.

- **Life Check Interval**: This defines how often a node sends a PRP_Supervision frame. All DANPs must be configured with the same Life Check Interval.

- **Proxy Node Table Forget Time**: This is the time after which a node entry is cleared in the ProxyTable

- **Proxy Node Table Max Entries**: This is the maximum number of entries in the ProxyTable

- **Entry Forget Time**: This is the time after which an entry is removed from the duplicates

- **Node Reboot Interval**: This is the minimum time during which a node that reboots remains silent

5.6.9 Filtering Database

The Filtering Database is used to determine how frames are forwarded or filtered across the on-board Ethernet switch. Filtering information specifies the set of ports to which frames received from a specific port are forwarded.

The Ethernet switch examines each received frame to see if the frame's destination address matches a source address listed in the Filtering Database. If there is a match, the device uses the filtering/forwarding information for that source address to determine how to forward or filter the frame. Otherwise the frame is forwarded to all the ports in the Ethernet switch (broadcast).

General tab

The Filtering Database contains two types of entry; static and dynamic. The Static Entries are the source addresses entered by an administrator. The Dynamic Entries are the source addresses learnt by the switch process. The Dynamic Entries are removed from the Filtering Database after the Ageing Time. The Database holds a maximum of 1024 entries.

1. To access the forwarding database functions, if required, click the Filtering Database button in the main window.

2. To view the Forwarding Database Size, Number of Static Entries and Number of Dynamic Entries, click **Read Database Info**.

3. To set the Aging Time, enter the number of seconds in the text box and click the Set button.

Filtering Entries tab

The Filtering Database configuration pages are used to view, add or delete entries from the Filtering Database. This feature is available only for the administrator. This Filtering Database is mainly used during the testing to verify the PRP/HSR functionality. To add an entry in the forwarding database, click the **Filtering Entries** tab. Configure as follows:

1. Select the Port Number and MAC Address

2. Set the Entry type (Dynamic or Static)

SC

3. Set the cast type (Unicast or Multicast)

4. Set the MGMT and Rate Limit

5. Click the **Create** button. The new entry appears in the forwarding database.

To delete an entry from the forwarding database, select the entry and click the **Delete Entry** button.

Goose Filtering tab

This page configures the source MACs from which GOOSE messages will be allowed or blocked. The filtering can be configured by either the MAC address range boxes or by selecting or unselecting the individual MAC addresses in the MAC table. After you have defined the addresses to be allowed or blocked you need to update the table and apply the filter:

- **Update Table**: This updates the MAC table according to the filtering range entered in the MAC address range boxes.

- **Apply Filter**: This applies the filtering configuration in the MAC table to the HSR/PRP board.

5.6.10   End of Session

To finish the session:

1. In the main window, click the **Quit** button, a new screen appears.

2. If a database backup is required, click **Yes**, a new screen appears.

3. Click the ... button to browse the path. Enter the name in the text box.

5.7   RSTP Configurator

The RSTP Configurator tool is intended for MiCOM Px4x IEDs with redundant Ethernet using RSTP (Rapid Spanning Tree Protocol). This tool is used to identify IEDs, configure the redundancy IP address, configure the SNTP IP address and configure the RSTP parameters.

5.7.1   Connecting the IED to a PC

Connect the IED to the PC on which the Configurator tool is used. This connection is done through an Ethernet switch or through a media converter.

SC
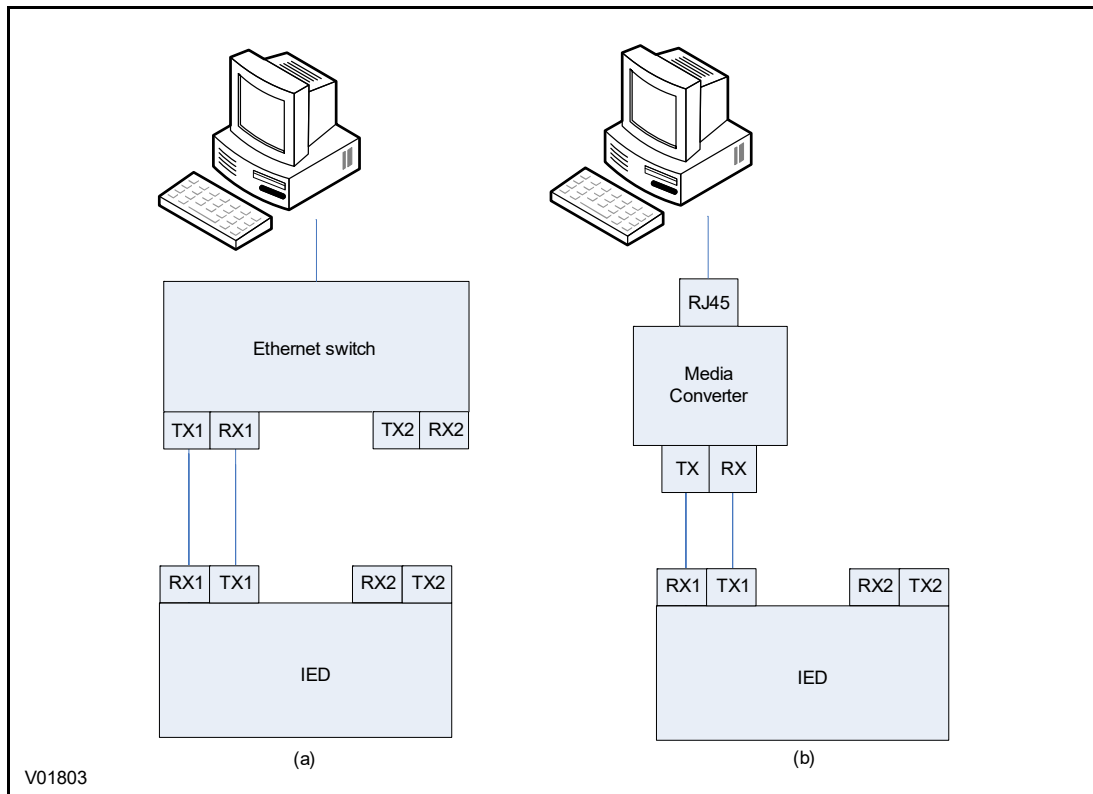
Figure 11: Connection using (a) an Ethernet switch and (b) a media converter

5.7.2   Installing the Configurator

To install the configurator:

1. Double click the WinPcap installer.

2. Double click the Configurator installer.

3. Click **Next** and follow the on-screen instructions.

5.7.3   Starting the Configurator

To start the configurator:

1. Select the Configurator from the Windows **Programs** menu.

2. The Login screen appears. For user mode login, enter the **Login name** as **User** and click **OK** with no password.

3. If the login screen does not appear, check all network connections.

4. The main window appears. In the bottom right-hand corner of the main window, click the **Language** button to select the language.

5. The **Network Board** drop-down list shows the Network Board, IP Address and MAC Address of the PC in which the Configurator is running.

5.7.4   RSTP Device Identification

To configure the redundant Ethernet board, go to the main window and click Identify Device.

> **Note:**   Due to the time needed to establish the RSTP protocol, wait 25 seconds between connecting the PC to the IED and clicking the Identify Device button.

The redundant Ethernet board connected to the PC is identified and its details are listed.

- Device address

- MAC address

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- Version number of the firmware
- SNTP IP address
- Date & time of the real-time clock, from the board.

5.7.5   RSTP IP Address Configuration

To change the network address component of the IP address,

From the main window click the **IP Config** button.

1. The **Device Setup** screen appears showing the **IP Base Address**. This is the board redundancy network address, not the IEC 61850 IP address.
2. Enter the required board IP address.
3. Click **OK**. The board network address is updated and displayed in the main window.

5.7.6   SNTP IP Address Configuration

To Configure the SNTP server IP address:

1. From the main window click the **SNTP Config** button. The Device setup screen appears.
2. Enter the required **MAC SNTP** address and server IP SNTP Address. Click **OK**.
3. The updated MAC and IP SNTP addresses appear in the main screen.

5.7.7   Check for Connected Equipment

To check what devices are connected to the device being monitored:

1. From the main window, select the device.
2. Click the **Equipment** button.
3. At the bottom of the main window, a box shows the ports where devices are connected and their MAC addresses.

5.7.8   RSTP Configuration

1. To view or configure the RSTP Bridge Parameters, from the main window, click the device address to select the device. The selected device MAC address appears highlighted.
2. Click the **RSTP Config** button. The **RSTP Config** screen appears.
3. To view the available parameters in the board that is connected, click the **Get RSTP Parameters** button.
4. To set the configurable parameters such as Bridge Max Age, Bridge Hello Time, Bridge Forward Delay, and Bridge Priority, modify the parameter values according to the following table and click **Set RSTP Parameters**.

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S.No	Parameter	Default value (second)	Minimum value (second)	Maximum value (second)
1	Bridge Max Age	20	6	40
2	Bridge Hello Time	2	1	10
3	Bridge Forward Delay	15	4	30
4	Bridge Priority	32768	0	61440
5	Bridge Max Age	20	6	40

5.7.8.1   Bridge Parameters

To read the RSTP bridge parameters from the board,

1. From the main window click the device address to select the device. The **RSTP Config** window appears and the default tab is **Bridge Parameters**.

2. Click the **Get RSTP Parameters** button. This displays all the RSTP bridge parameters from the Ethernet board.

3. To modify the RSTP parameters, enter the values and click **Set RSTP Parameters**.

4. To restore the default values, click **Restore Default** and click **Set RSTP Parameters**.

5. The grayed parameters are read-only and cannot be modified.

Note: When assigning the bridge priority, make sure the root of the network is the Ethernet switch, not the IEDs. This reduces the number of hops to reach all devices in the network. Also make sure the priority values for all IEDs are higher than that of the switch.

5.7.8.2 Port Parameters

This function is useful if you need to view the parameters of each port.

1. From the main window, click the device address to select the device. The **RSTP Config** window appears.

2. Select the **Port Parameters** tab, then click **Get Parameters** to read the port parameters. Alternatively, select the port numbers to read the parameters.

5.7.8.3 Port States

This is used to see which ports of the board are enabled or disabled.

1. From the main window, click the device address to select the device. The **RSTP Config** window appears.

2. Select the **Port States** tab then click the **Get Port States** button. This lists the ports of the Ethernet board. A tick shows they are enabled.

5.7.8.4 End of Session

To finish the session:

1. In the main window, click the **Quit** button, a new screen appears.

2. If a database backup is required, click **Yes**, a new screen appears.

3. Click the ... button to browse the path. Enter the name in the text box.

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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	USB, K-Bus, RS232, RS485, Ethernet	Standard for SCADA communications developed by GE.
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.

Note: Not all protocols are available. This software version only supports IEC 61850 edition 2.

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 Courier	Courier	Courier	Courier
Data Link Layer	EIA(RS)485	Ethernet	EIA(RS)232	K-Bus	USB
Physical Layer	Copper or Optical Fibre				USB Type B

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 GE 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.

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6.1.1   Physical Connection and Link Layer

Courier can be used with four physical layer protocols: USB, K-Bus, EIA(RS)232 or EIA(RS)485.

Several connection options are available for Courier

- The front serial RS232/USB Type-B port* (for connection to Settings application software on, for example, a laptop
- Rear Port 1 (RP1) - for permanent SCADA connection via RS485 or K-Bus
- Optional fibre port (RP1 in slot A) - for permanent SCADA connection via optical fibre
- Optional Rear Port 2 (RP2) - for permanent SCADA connection via RS485, K-Bus, or RS232

For either of the rear ports, both the IED address and baud rate can be selected using the front panel menu or by the settings application software.

> **Note:** *Legacy/white front panel options are fitted with serial and parallel ports, black and silver front panel options are fitted with USB type B ports. For details, refer to the Ordering Options Appendix.

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 directly change a setting. 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 from the relay. This method is therefore most suitable for off-line setting editors such as MiCOM S1 Agile, or for issuing pre-configured 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.

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6.1.5.1   Automatic Event 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 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.

6.1.6   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

6.1.7   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.

6.1.8 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.

6.1.9 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.

6.1.10 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.

6.1.11 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.

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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**.

```
┌─────────────────────────────┐
│                             │
│        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.

```
┌─────────────────────────────┐
│                             │
│        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 revoking any password access that was enabled and discarding any changes. For the rear port this can be set between 1 and 30 minutes.

```
┌─────────────────────────────┐
│                             │
│       RP1 Inactiv timer     │
│         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).

```
┌─────────────────────────────┐
│                             │
│       RP1 Physical link     │
│           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

```
┌─────────────────────────────┐
│                             │
│       RP1 Card status       │
│          K-Bus OK           │
│                             │
└─────────────────────────────┘
```

SC

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

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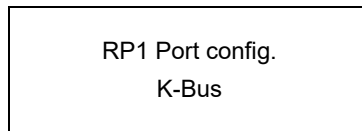
9. If using EIA(RS)485, the next cell (**RP1 Comms Mode**) selects the communication mode. The choice is either IEC 60870 FT1.2 for normal operation with 11-bit modems, or 10-bit no parity. If using K-Bus this cell will not appear.

```
┌─────────────────────────────────┐
│                                 │
│        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.

```
┌─────────────────────────────────┐
│                                 │
│          RP1 Baud rate          │
│                                 │
│             19200               │
│                                 │
└─────────────────────────────────┘
```
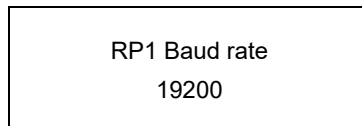
6.2 IEC 60870-5 103

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

Two connection options are available for IEC 60870-5-103:

- Rear Port 1 (RP1) - for permanent SCADA connection via RS485
- Optional fibre port (RP1 in slot A) - for permanent SCADA connection via optical fibre

If the optional fibre optic port is fitted, a menu item appears in which the active port can be selected. However the selection is only effective following the next power up.

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The IED address and baud rate can be selected using the front panel menu or by the settings application software.

6.2.2 Initialization

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 GE separately if required.

In addition to the above identification message, it will also produce a power up event.

6.2.3 Time Synchronization

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

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 are 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

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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 an 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

The relay supports a facility to block messages in the Monitor direction and also in the Command direction. Messages can be blocked in the Monitor and Command directions using the menu commands, Communications - CS103 Blocking - Disabled/Monitor Blocking/Command Blocking or 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.

```
┌─────────────────────────┐
│      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.

```
┌─────────────────────────┐
│      RP1 address        │
│          162            │
└─────────────────────────┘
```

SC

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.

```
┌─────────────────────────┐
│                         │
│      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.

```
┌─────────────────────────┐
│                         │
│     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).

```
┌─────────────────────────┐
│                         │
│     RP1 Physical link   │
│        Copper           │
│                         │
└─────────────────────────┘
```
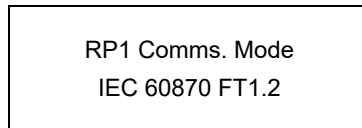
8. The next cell down (**RP1 CS103Blcking**) can be used for monitor or command blocking.

```
┌─────────────────────────┐
│                         │
│    RP1 CS103 Blocking   │
│                         │
└─────────────────────────┘
```

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.

SC

6.3 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).

6.3.1 Physical Connection and Link Layer

Two connection options are available for MODBUS

*   Rear Port 1 (RP1) - for permanent SCADA connection via RS485
*   Optional fibre port (RP1 in slot A) - for permanent SCADA connection via optical fibre

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 the settings application software.

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 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)

6.5 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 product is presented in the Relay Menu Database.

A complete map of the MODBUS addresses supported by the device is contained in the relevant menu database, which is available on request.

SC

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.

6.5.1   Event Extraction

The device supports two methods of event extraction providing either automatic or manual extraction of the stored event, fault, and maintenance records.

6.5.1.1   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.

6.5.1.2   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.

6.5.2   Record Data

The location and format of the registers used to access the record data is the same whether they have been selected using either automatic or manual extraction.

Event Description	Modbus Address	Length	Comments
Time and Date	30103	4	See G12 data type description
Event Type	30107	1	See G13 data type description
Event Value	30108	2	Nature of value depends on event type. This will contain the status as a binary flag for contact, opto-input, alarm, and protection events.
MODBUS Address	30110	1	This indicates the MODBUS register address where the change occurred. Alarm 30011 Relays 30723 Optos 30725 Protection events – like the relay and opto addresses this will map onto the MODBUS address of the appropriate DDB status register depending on which bit of the DDB the change occurred. These will range from 30727 to 30785. For platform events, fault events and maintenance events the default is 0.

SC

Event Description	Modbus Address	Length	Comments
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.

6.5.3 Disturbance Record Extraction

The product 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 product 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	Number of stored disturbances	Indicates the total number of disturbance records currently stored in the product, 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 product. This is an integer value used in conjunction with the 'Number of stored disturbances' value to calculate a value for manually selecting records.

SC

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 No 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 to 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 to 3x00929	Data page registers	These 127 registers are used to transfer data from the product to the master station.
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 reports 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 product is currently processing data.
Page ready	The data page has been populated and the master 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 unextracted disturbances	An attempt was made by the master station to automatically select the next oldest unextracted 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 product.
Command out of sequence	The master station issued a command to the product that was not expected during the extraction process.

6.5.3.1   Manual Extraction Procedure

The procedure used to extract a disturbance manually is shown in the figure below The manual method of extraction does not allow for the acceptance of disturbance records.

SC
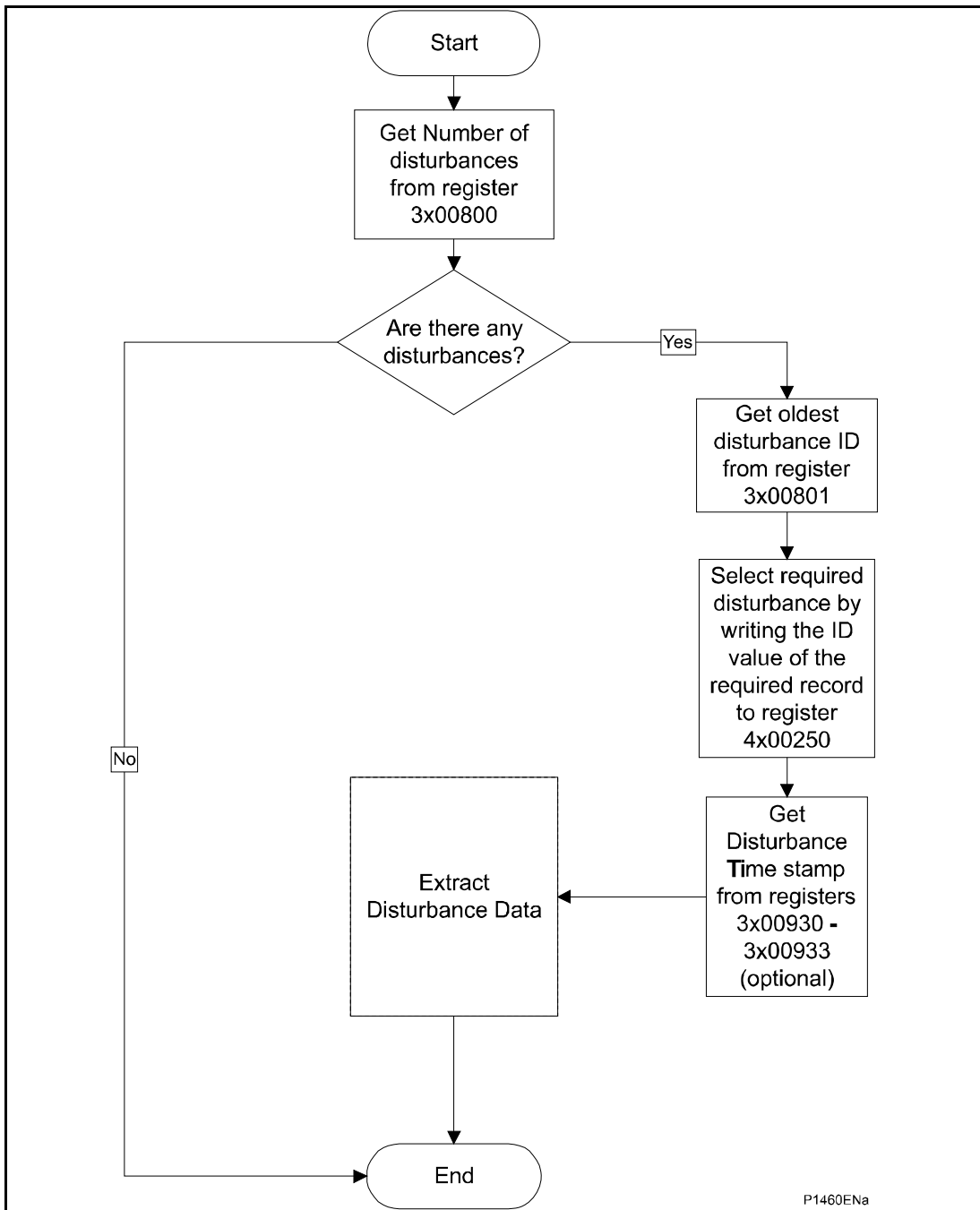
Figure 12: Manual selection of a disturbance record

6.5.3.2 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).

SC
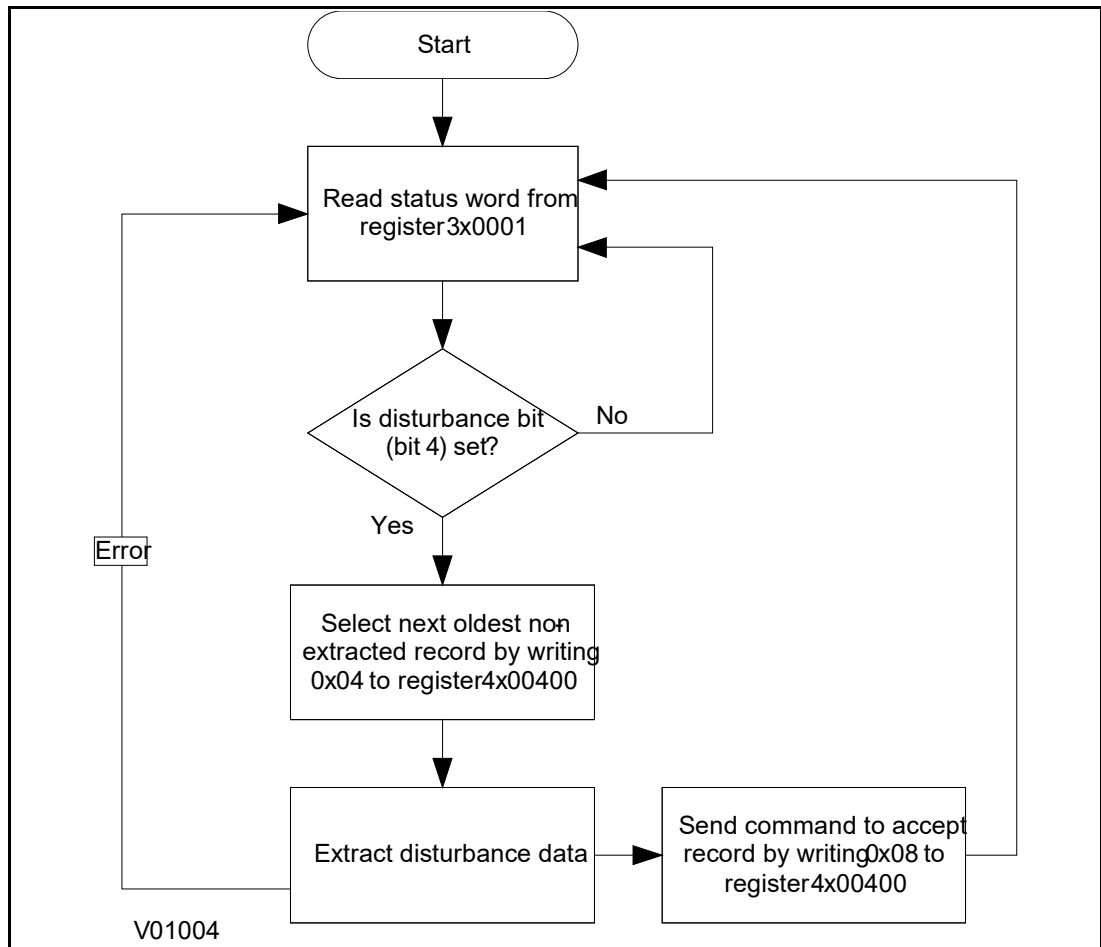
Figure 13: Automatic selection of disturbance record - method 1

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.

SC
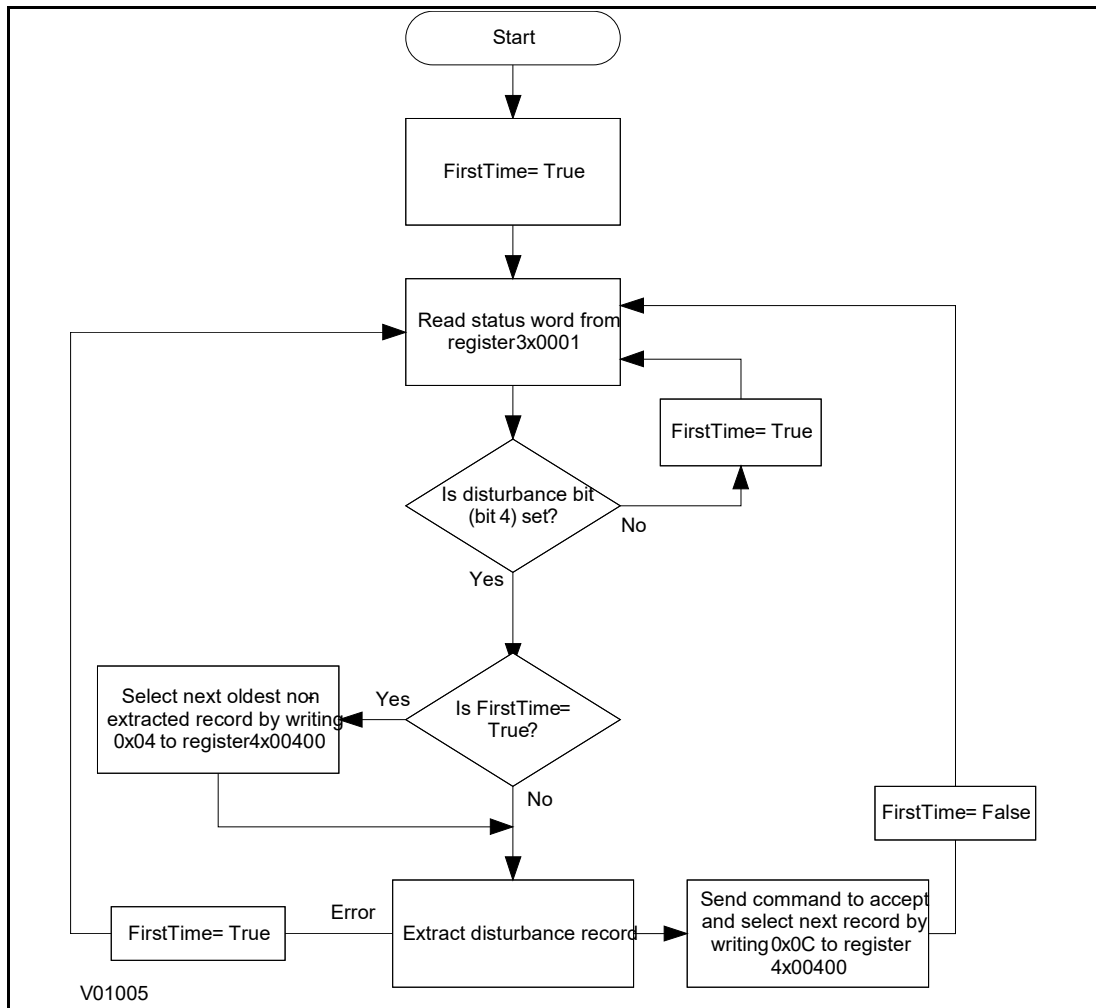
Figure 14: Automatic selection of disturbance record - method 2

6.5.3.3   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:

SC

Extracting the Comtrade configuration file
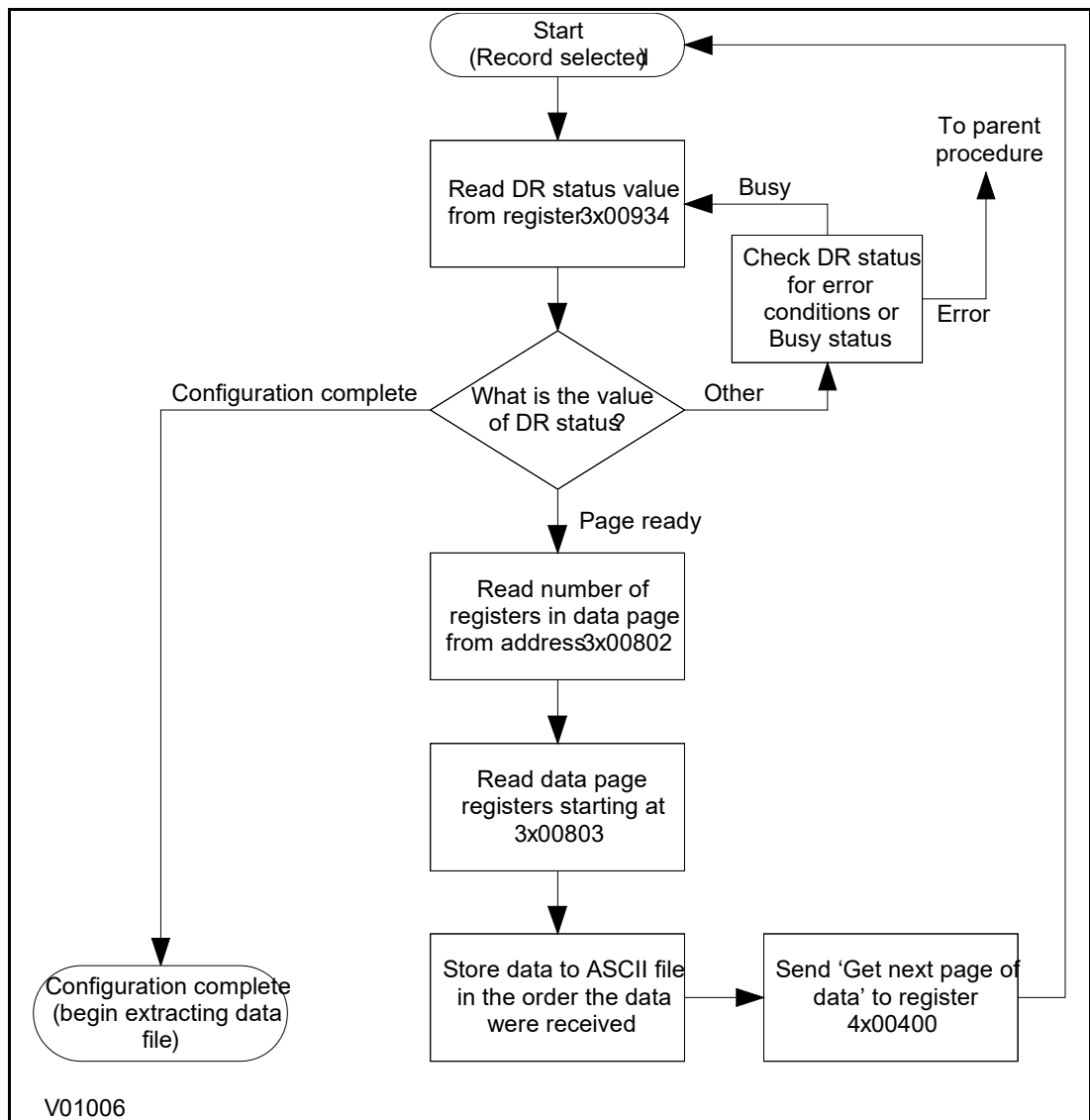
Figure 15: Configuration file extraction

Extracting the comtrade data file
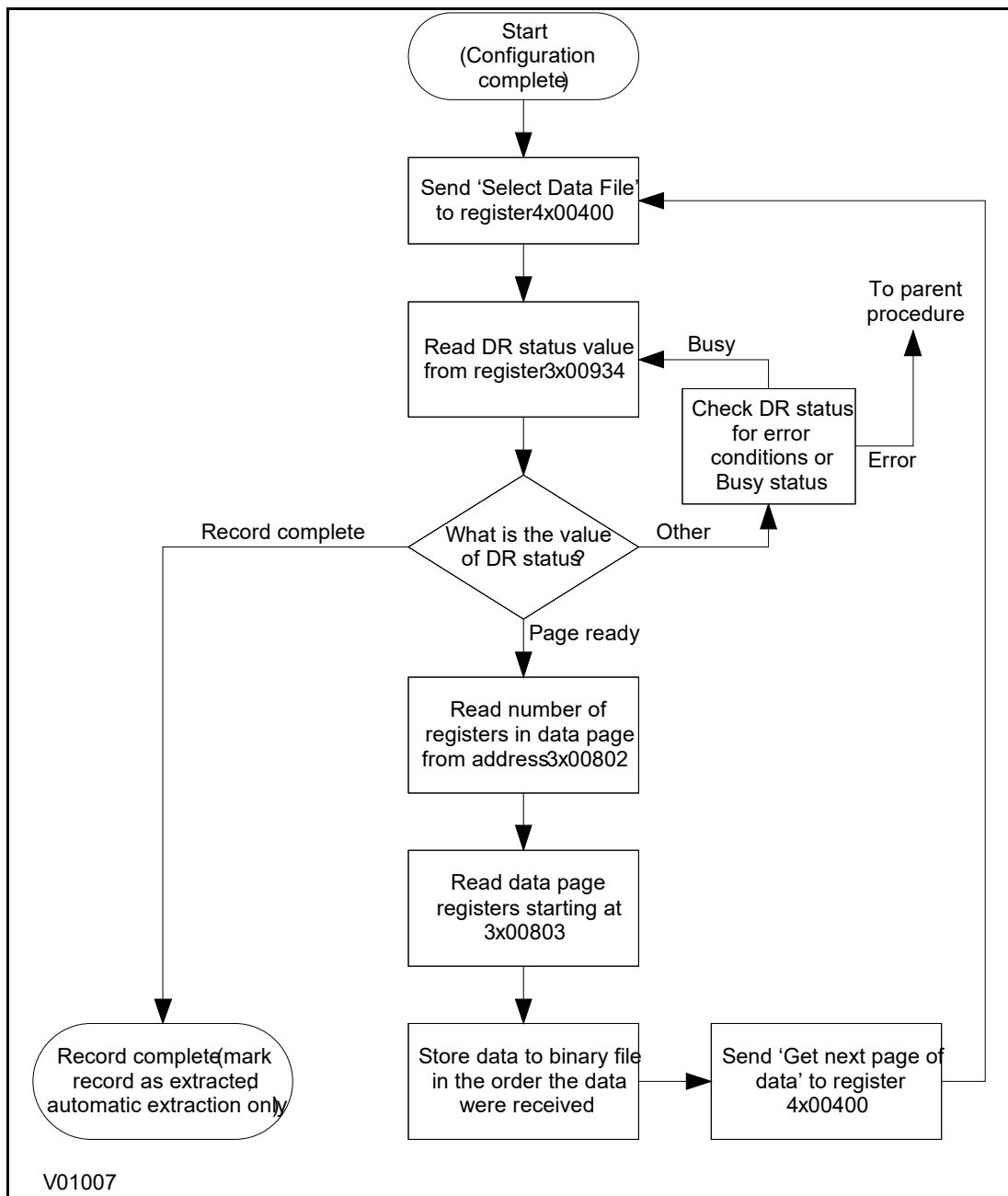
Figure 16: Data file extraction

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 product is currently processing data.
2	Page ready	The data page has been populated and the master 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.

SC

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 product.
8	Command out of sequence	The master station issued a command to the product that was not expected during the extraction process.

6.5.4 Setting Changes

All the device 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 code 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.

6.5.5 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

6.5.6 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.

SC

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.

6.5.7   Time Synchronization

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.

SC

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 coordinated time).

6.5.8   Power and Energy Measurement Data Formats

The power and energy measurements are available in two data formats:

Data Type G29: an integer format using 3 registers

Data Type G125: a 32 bit floating point format using 2 registers

The G29 registers are listed in the first part of the *MEASUREMENTS 2* column of the Courier database. The G125 equivalents appear at the end of the *MEASUREMENTS 2* column.

Data type G29

Data type G29 consists of three registers:

The first register is the per unit (or normalised) power or energy measurement. It is a signed 16 bit quantity. This register is of Data Type G28.

The second and third registers contain a multiplier to convert the per unit value to a real value. These are unsigned 32-bit quantities. These two registers together are of Data Type G27.

Thee overall power or energy value conveyed by the G29 data type is therefore G29 = G28 x G27.

The IED calculates the G28 per unit power or energy value as:

> *G28 = (measured secondary* quantity/CT *secondary)(110V/(VT secondary).*

Since data type G28 is a signed 16-bit integer, its dynamic range is constrained to +/- 32768. You should take this limitation into consideration for the energy measurements, as the G29 value will saturate a long time before the equivalent G125 does.

The associated G27 multiplier is calculated as:

> *G27 = (CT primary)(VT primary/110V)* when primary value measurements are selected

and

> *G27 = (CT secondary)(VT secondary/110V)* when secondary value measurements are selected.

Due to the required truncations from floating point values to integer values in the calculations of the G29 component parts and its limited dynamic range, we only recommend using G29 values when the MODBUS master cannot deal with the G125 IEEE754 floating point equivalents.

> **Note:**   The G29 values must be read in whole multiples of three registers. It is not possible to read the G28 and G27 parts with separate read commands.

Example of Data Type G29

Assuming the CT/VT configurations are as follows:

- Main VT Primary 6.6 kV
- Main VT Secondary 110 V
- Phase CT Primary 3150 A
- Phase CT Secondary 1 A

The Three-phase Active Power displayed on the measurement panel on the front display of the IED would be 21.94 MW

The registers related to the Three-phase Active Power are: 3x00327, 3x00328, 3x00329

Register Address	Data read from these registers	Format of the data
3x00327	116	G28
3x00328	2	G27
3x00329	57928	G27

The Equivalent G27 value = [2^{16} * Value in the address 3x00328 + Value in the address 3x00329] = 216*2 + 57928 = 189000

The Equivalent value of power G29 = G28 * Equivalent G27 =116 * 189000 =21.92 MW

> **Note:** The above calculated value (21.92 MW) is same as the power value measured on the front panel display.

Data type G125

Data type G125 is a short float IEEE754 floating point format, which occupies 32 bits in two consecutive registers. The high order byte of the format is in the first (low order) register and the low order byte in the second register.

The value of the G125 measurement is as accurate as the IED's ability to resolve the measurement after it has applied the secondary or primary scaling factors. It does not suffer from the truncation errors or dynamic range limitations associated with the G29 data format.

6.5.9   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**.

```
RP1 Protocol
MODBUS
```
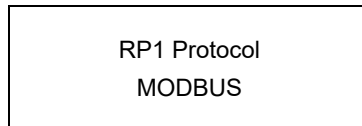
4. Move down to the next cell (**RP1 Address**). This cell controls the Modbus address of the IED. Up to 32 IEDs can be connected to one spur, therefore it is necessary for each IED to have a unique address so that messages from the master control station are accepted by only one IED. Modbus uses a decimal number between 1 and 247 for the Relay Address. It is important that no two IEDs have the same address.
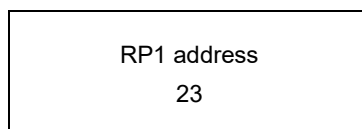
```
RP1 address
23
```

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.

```
RP1 Inactiv timer
10.00 mins.
```

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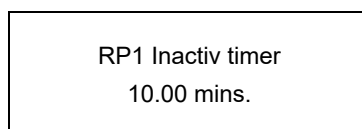
6. Move down to the next cell (RP1 Baud Rate). This cell controls the baud rate to be used. Six baud rates are supported by the IED 1200 bits/s, 2400 bits/s, 4800 bits/s, 9600 bits/s, 19200 bits/s and 38400 bits/s. Make sure that the baud rate selected on the IED is the same as that set on the master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

```
┌─────────────────────────┐
│                         │
│     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.

```
┌─────────────────────────┐
│                         │
│       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.

```
┌─────────────────────────┐
│                         │
│    MODBUS IEC time       │
│      standard           │
│                         │
└─────────────────────────┘
```

6.6   IEC 61850

This section describes how the IEC 61850 standard is applied to GE 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 most parts of the IEC 61850 standard; edition 1 and edition 2. The edition which this product supports depends on the Software Version.

From Software Version 70 onwards, it is possible to select between edition 1 and edition 2. Switching between edition 1 and edition 2 is described in the Selection of the IEC 61850 Edition section.

An additional section detailing the enhancements in edition 2 models is documented later in this chapter, if applicable.

6.7   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)

6.7.1 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.

6.7.2 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.
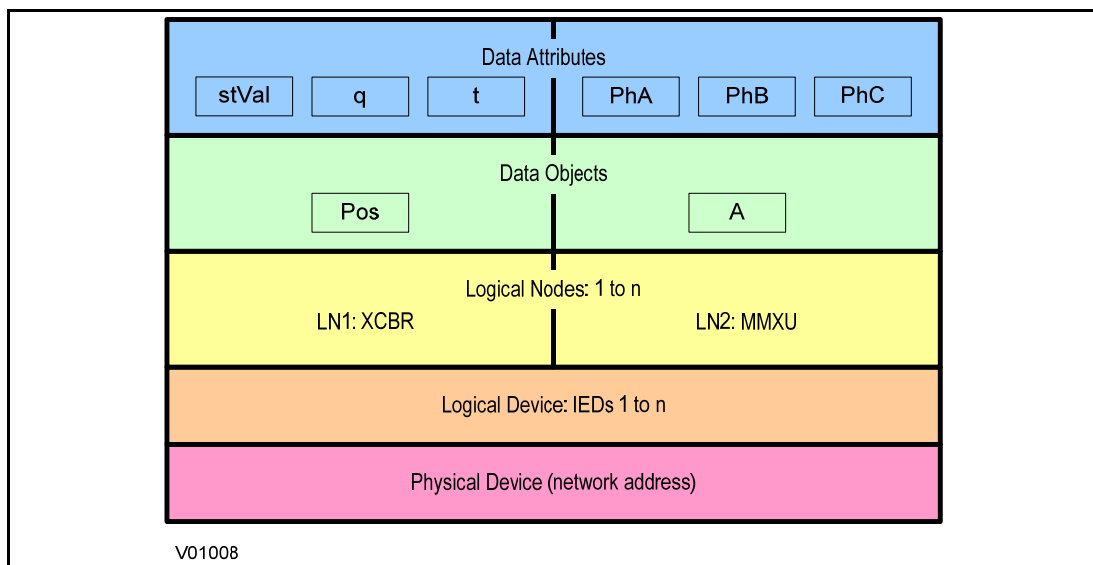
Figure 17: Data model layers in IEC 61850

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.

6.8 IEC 61850 in MiCOM Relays

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.

6.8.1 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.

6.8.2 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

6.8.3 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

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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.

6.8.4 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

6.8.4.1 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.

6.8.5 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.

6.8.6 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

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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.

6.8.6.1 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.

6.8.6.2 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 alafrm 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.

6.8.6.3 IEC 61850 Edition 2

Many parts of the IEC 61850 standard have now been released as the second edition. This offers some significant enhancements including:

- Improved interoperability
- Many new logical nodes
- Better defined testing; it is now possible to perform off-line testing and simulation of functions

Edition 2 implementation requires use of version 3.2 of the IEC 61850 configurator, which is installed with version 1.2 of MiCOM S1 Agile.

IEC61850 system - backward compatibility

An Edition 1 IED can operate with an Edition 2 IEC 61850 system, provided that the Edition 1 IEDs do not subscribe to GOOSE messages with data objects or data attributes which are only available in Edition 2.

The following figure explains this concept:
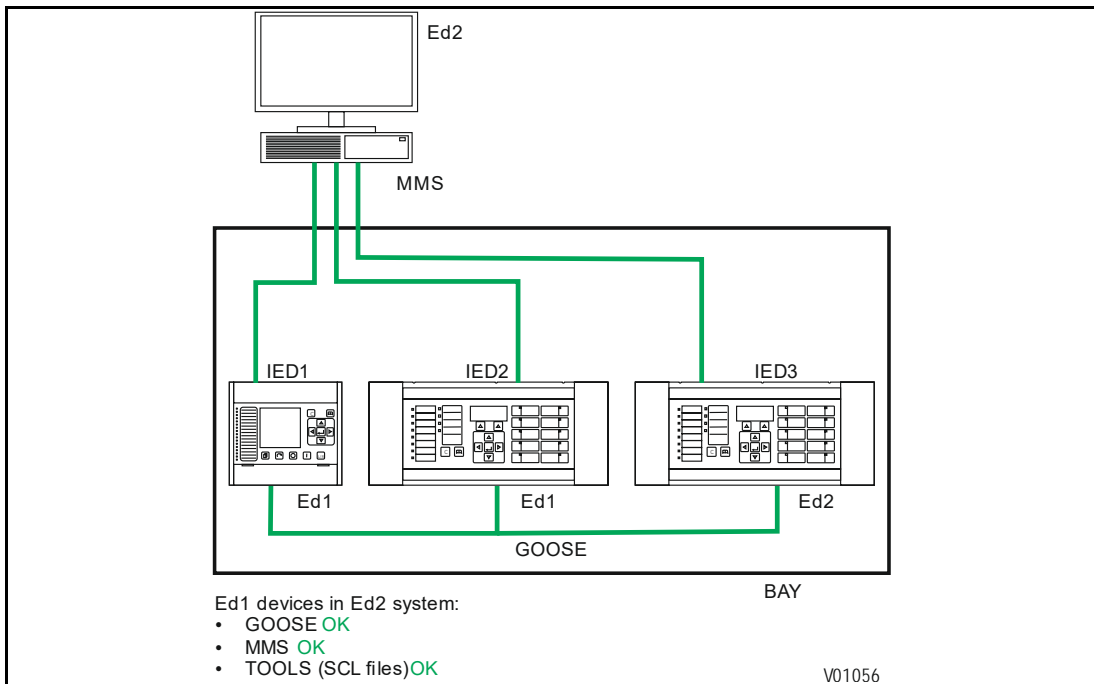
Figure 18:   2 system - backward compatibility

An Edition 2 IED cannot normally operate within an Edition 1 IEC 61850 system. An Edition 2 IED can work for GOOSE messaging in a mixed system, providing the client is compatible with Edition 2.
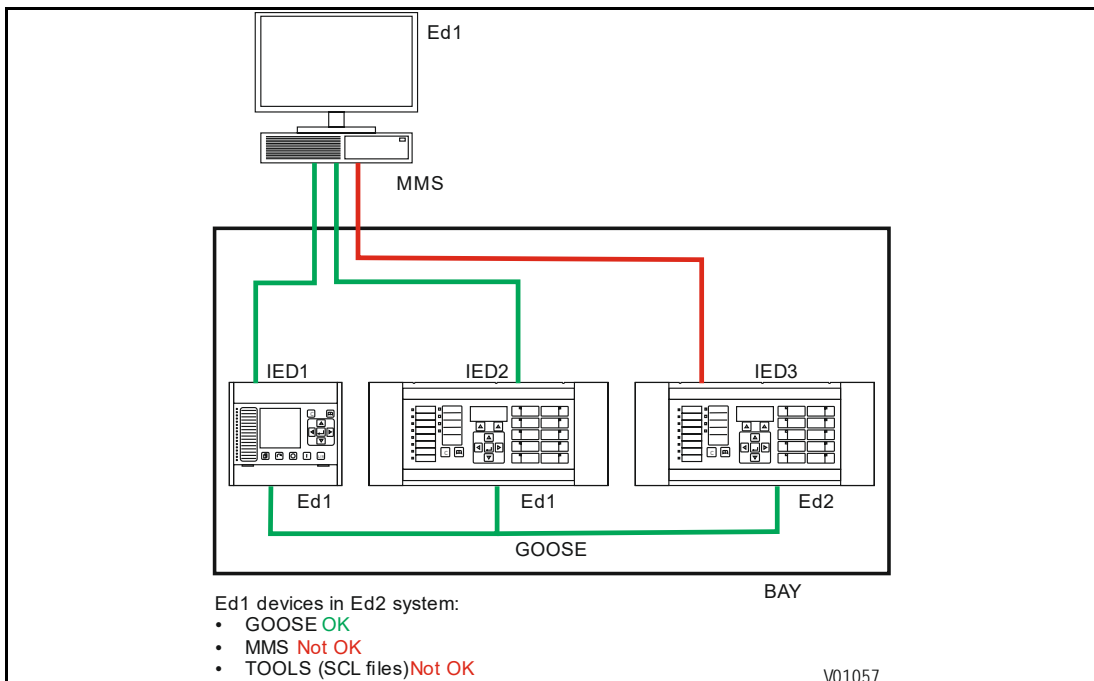
Figure 19:   Edition 1 system - forward compatibility issues

6.8.6.4   Edition-2 Common Data Classes

The following common data classes (CDCs) are new to Edition 2 and therefore should not be used in GOOSE control blocks in mixed Edition 1 and Edition 2 systems

- Histogram (HST)

- Visible string status (VSS)

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- Object reference setting (ORG)
- Controllable enumerated status (ENC)
- Controllable analogue process value (APC)
- Binary controlled analogue process value (BAC)
- Enumerated status setting (ENG)
- Time setting group (TSG)
- Currency setting group (CUG)
- Visible string setting (VSG)
- Curve shape setting (CSG)

Of these, only ENS and ENC types are available from a MiCOM P40 IED when publishing GOOSE messages, so Data Objects using these Common Data Classes should not be published in mixed Edition 1 and Edition 2 systems.

For compatibility between Edition 1 and Edition 2 IEDs, SCL files using SCL schema version 2.1 must be used. For a purely Edition 2 system, use the schema version 3.1.

6.8.6.5 Standby Protection Redundancy

With digital substation architectures, measurements can be shared freely on the process bus across the substation and between different devices without any additional wiring. This is because there are no longer any electrical connections to instruments transformers that restrict the location of IEDs.

The new IEC 61850 Edition 2 test modes enable the introduction of standby protection IEDs at any location within the substation, which has access to both station and process buses. In the case of failure, these devices can temporarily replace the protection functions inside other IEDs.
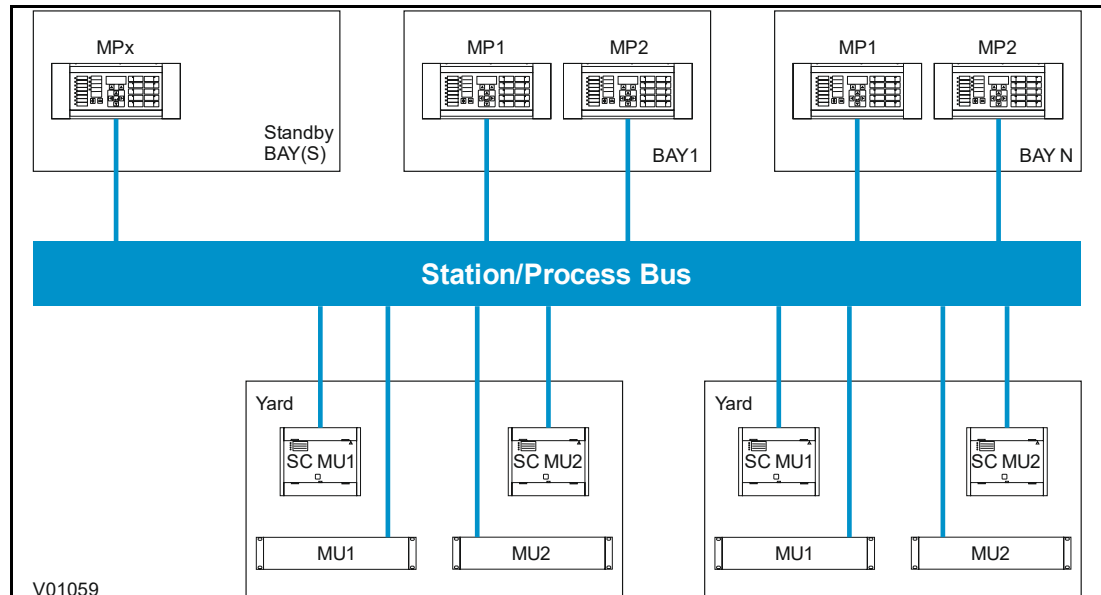
Figure 20:   Example of Standby IED

See the example below. If a failure occurs in the Bay 1 protection IED (MP2), we could disable this device and activate a standby protection IED to replace its functionality.
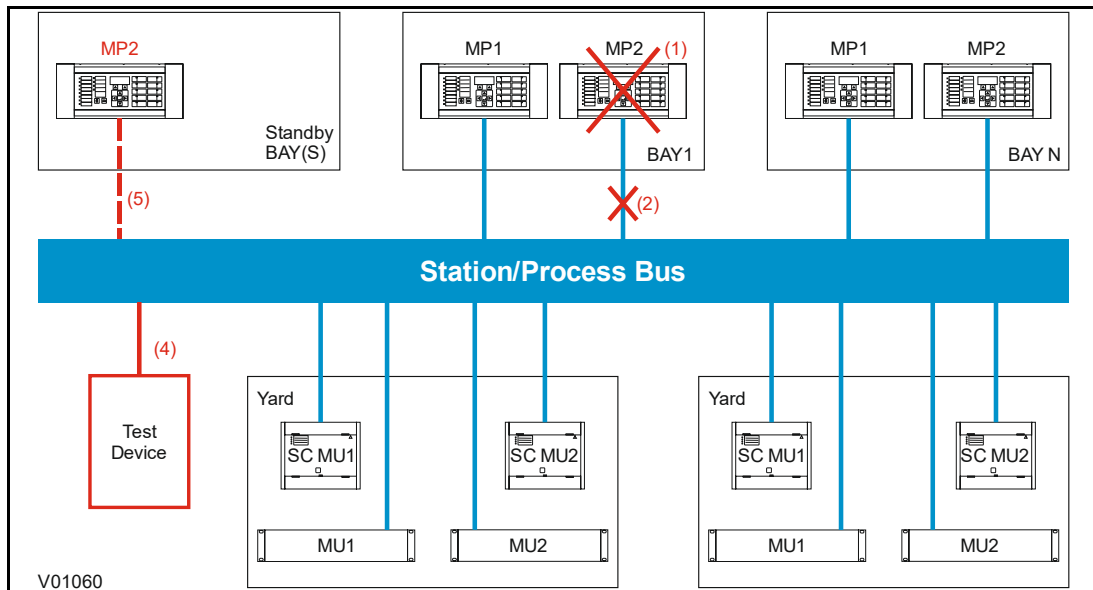
Figure 21: Standby IED Activation Process

The following sequence would occur under this scenario:

1. During the installation phase, a spare standby IED is installed in the substation. This can remain inactive, until it is needed to replace functions in one of several bays. The device is connected to the process bus, but does not have any subscriptions enabled.

2. If a failure occurs (in this example, bay 1), first isolate the faulty device by disabling its process bus and station bus interfaces. You do this by turning off the attached network interfaces.

3. Retrieve the configuration that the faulty device normally uses, and load this into the standby redundant IED.

4. Place the IED into the "Test Blocked" mode, as defined in IEC 61850-7-4 Edition Two. This allows test signals to be injected into the network, which will check that the configuration is correct. GOOSE signals issued by the device will be flagged as "test" so that subscribing switchgear controllers know not to trip during this testing. In this way the protection can be tested all the way up to the switchgear control merging units without having to operate primary circuit breakers, or by carrying out any secondary injection.

5. Take the standby IED out of "Test-Blocked" mode and activate it so that it now replaces the protection functions that were disabled from the initial device failure.

The standby IED reduces downtime in the case of device failure, as protection functions can be restored quickly before the faulted device is replaced.

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7   READ ONLY MODE

With IEC 61850 and Ethernet/Internet communication capabilities, security has become an important issue. For this reason, all relevant GE devices 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

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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.

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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.
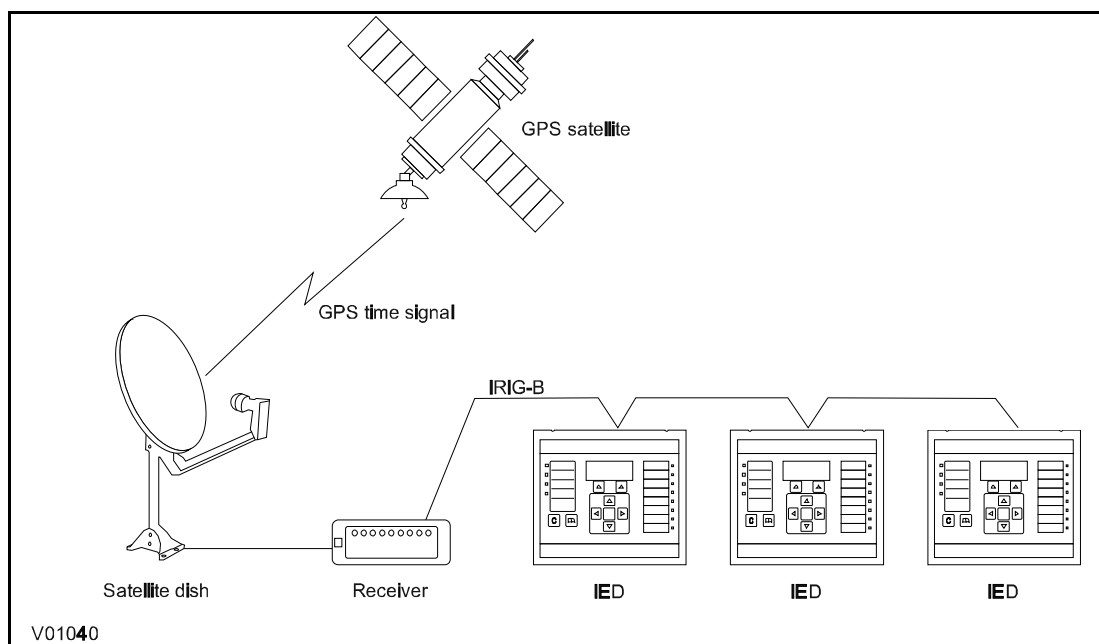
Figure 22:   GPS Satellite timing signal

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   IRIG-B Implementation

Depending on the chosen hardware options, the product can be equipped with an IRIG-B input for time synchronisation purposes. The IRIG-B interface is implemented either on a dedicated card, or together with other communication functionality such as Ethernet. The IRIG-B connection is presented by a connector is a BNC connector. IRIG-B signals are usually presented as an RF-modulated signal. There are two types of input to our IRIG-B boards: demodulated or modulated. A board that accepts a demodulated input is used where the IRIG-B signal has already been demodulated by another device before being fed to the IED. A board that accepts a modulated input has an on-board demodulator.

To set the device to use IRIG-B, use the setting **IRIG-B Sync** cell in the **DATE AND TIME** column.

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.

8.2.1   Loss of SNTP Server Signal Alarm

This function issues an alarm when there is a loss of time synchronization on the SNTP server. It is issued when the SNTP sever has not detected a valid time synchronisation response within its 5 second window. This is because there is no response or no valid clock. The alarm is mapped to IEC 61850.

8.2.2   Accuracy and Delay Calculation

A time synchronisation accuracy of within 5 ms is possible. Both peer-to-peer or end-to-end mode delay measurement can be used.

In peer-to-peer mode, delays are measured between each link in the network and are compensated for. This provides greater accuracy, but requires that every device between the Grand Master and Slaves supports the peer-to-peer delay measurement.

In end-to-end mode, delays are only measured between each Grand Master and Slave. The advantage of this mode is that the requirements for the switches on the network are lower; they do not need to independently calculate delays. The main disadvantage is that more inaccuracy is introduced, because the method assumes that forward and reverse delays are always the same, which may not always be correct.

When using end-to-end mode, the IED can be connected in a ring or line topology using RSTP or Self Healing Protocol without any additional Transparent Clocks. But because the IED is a slave-only device, additional inaccuracy is introduced. The additional error will be less than 1ms for a network of eight devices.

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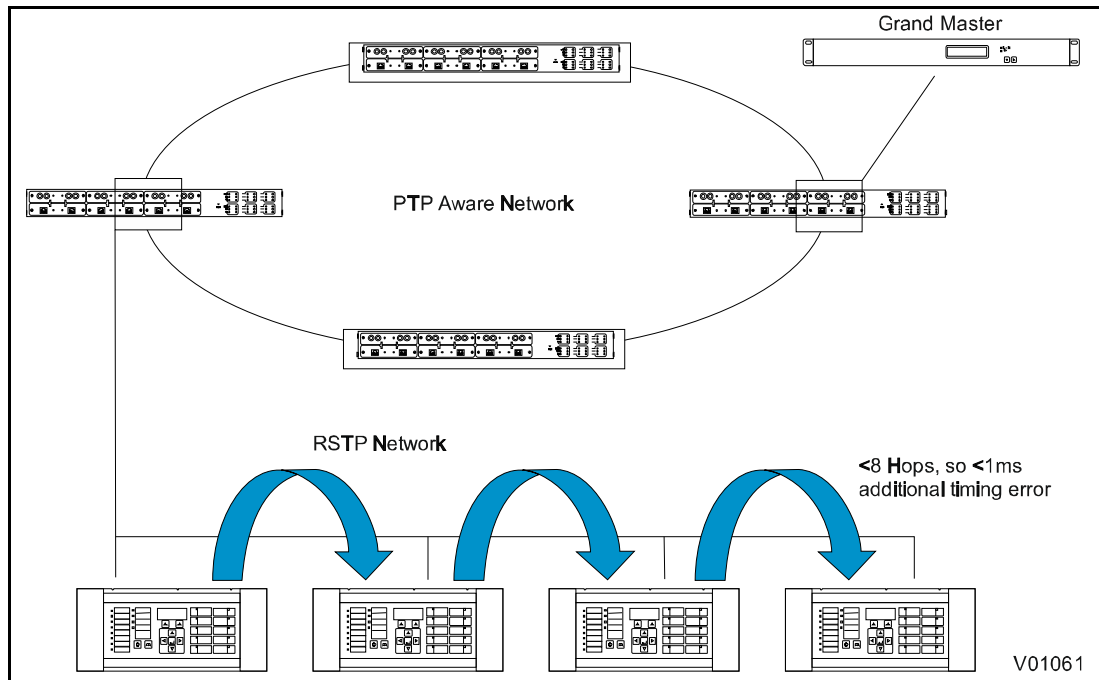
Figure 23:   Timing error using ring or line topology

8.2.3   PTP Domains

PTP traffic can be segregated into different domains using Boundary Clocks. These allow different PTP clocks to share the same network while maintaining independent synchronisation within each grouped set.

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.

9   COURIER INTERFACE

9.1   Measurement and Binary Status 3x Register Sets

The data available from the 3x input registers is arranged into register sets. A register set is a fixed collection of values in a contiguous block of register addresses. The advantage of this is that multiple values may be read with a single MODBUS query, function code 4 "Read Input Registers", up to the maximum data limits of the query (see section **Error! Reference source not found.**).

The definition of a register-set is specified by the selection of a start and end address, which can span multiple contiguous values in the 3x Register. The only rule being that a register set must not result in an attempt to read only part of a multi-register data type (see section 9.4). It is permissible for a register set to span unused register locations, in which case a value of zero is returned for each such register location.

Some examples of useful register sets are:

- 3x200 to 3x288 provides a selection of measurements.
- 311023 to 311150 provide the DDB status
- 3x404 to 3x413 provide the ten RTD measurement values

There are many other possibilities dependent on your application and an appraisal of the 3x Register Map. The capabilities of the MODBUS master device, performance targets, and communications latencies may also influence the degree to which multiple values are read as register sets, as opposed to individually.

9.2   Controls

The following table presents MODBUS 4x "Holding Registers" that allow the external system to control aspects of the product's behavior, configuration, records, or items of plant connected to the product such as circuit breakers.

The column **Command or setting** indicates whether the control is a self-resetting "Command" or a state based "Setting".

"Command" controls automatically return to their default value when the control action has been completed. For example, writing the "trip" value to the "CB Trip/Close" control will result in the controlled circuit breaker opening (if CB remote control is enabled, the CB has a valid state, and it was closed). The value of the "CB Trip/Close" register will automatically return to "no operation". This may lead to problems with masters that attempt to verify write requests by reading back the written value.

"Setting" controls maintain the written value, assuming that it was accepted. For example the "Active Setting Group" register reports the current active group on reads and accepts writes with a valid setting group number to change the active group to the one specified. (This assumes that setting group selection by optically isolated status inputs has not been enabled and that the specified group is enabled).

Entries without a defined setting range, as per the "min.", "max." and "step" columns, are binary-string values whose pattern is defined by its stated data type.

9.3   Event Extraction

The product is capable of storing 512 event records in battery backed memory. An event record consists of a time stamp, a record type, and a set of information fields. The record type and the information fields record the event that occurred at the time captured by the time stamp.

The product has several classes of event record:

- Alarm events
- Opto-isolated status input events
- Relay contact output events
- Protection/DDB operation events

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- Fault data capture events
- General events

    Note: The product provides an "event filtering" feature that may be used to prevent specific events from being logged. The event filter is configured in the "Record Control" section of the product's menu database in the MiCOM S1 Studio configuration tool.

The product supports two methods of event extraction providing either automatic or manual extraction of the stored event, fault, and maintenance records.

It is important to appreciate that the product stores event, fault, and maintenance records in three separate queues. As entries are added to the fault and maintenance queues a corresponding event is added to the event queue. Each queue is of different length and each queue may be individually cleared (see section **Error! Reference source not found.**). It is therefore possible to have a fault event or a maintenance event entry in the event queue with no corresponding entry in the associated queue because it has been overwritten or deleted.

The manual extraction procedure (section **Error! Reference source not found.**) allows each of these three queues to be read independently.

The automatic extraction procedure (section **Error! Reference source not found.**) reads records from the event queue. If the event record is either a fault or a maintenance record then the records extended data is read too, if it is available from their queues.

    Note: Version 31 of the product introduced a new set of 3x registers for the presentation of the event and fault record data. These registers are used throughout the text of the following sub-sections. For legacy compatibility, the original registers are still provided. These are described as previous MODBUS address in the Relay Menu Database. They should not be used for new installations. See section **Error! Reference source not found.** for additional information.

9.4 Register Data Types

The product maps one or more MODBUS registers to data-typed information contained within an internal database. These data-types are referred to as G-Types since they have a 'G' prefixed identifier. The Relay Menu Database gives a complete definition of the all of the G-Types used in the product.

In general, the data types are transmitted in high byte to low byte order, which is some times called "Big Endian format". This may require the MODBUS master to reorder the received bytes into a format compliant with its byte-order and register order (for multi-register G-Types) conventions. Most MODBUS masters provide byte-swap and register-swap device (or data point) configuration to cope with the plethora of implementations.

The product's data-types are atomic in nature. This means that the multi-register types cannot be read (or written) on an individual register basis. All of the registers for a multi-register data-typed item must be read (or written) with a single block read (or write) command.

The following subsections provide some additional notes for a few of the more complex G-Types.

9.5 Numeric Setting (data types G2 & G35)

Numeric settings are integer representations of real (non-integer) values. The register value is the number of setting increments (or steps) that the real value is away from the settings real minimum value. This is expressed by the following formula:

$$S_{real} = S_{min.} + (S_{inc.} \times S_{numeric})$$

Where:

- S_{real} -   Setting real value
- $S_{min.}$ -   Setting real minimum value

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- $S_{inc.}$ - Setting real increment (step) value
- $S_{numeric}$ - Setting numeric (register) value

For example, a setting with a real value setting range of 0.01 to 10 in steps of 0.01 would have the following numeric setting values:

Real value (Sreal)	Numeric value (Snumeric)
0.01	0
0.02	1
1.00	99

Table 1: Example of numeric settings

The G2 numeric data type uses 1 register as an unsigned 16-bit integer, whereas the G35 numeric data type uses 2 registers as an unsigned 32-bit integer. The G2 data type therefore provides a maximum setting range of 2^{16} x S_{inc}. Similarly the G35 data type provides a maximum setting range of 232 x S_{inc}.

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SYMBOLS AND GLOSSARY

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TABLES

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Symbols	Explanation
<	**Less than:**
	Used to indicate an "under" threshold, such as undercurrent (current dropout).
< 1	**First stage (under)**
< 2	**Second stage (under)**
>	**Greater than:**
	Used to indicate an "over" threshold, such as overcurrent (current overload).
> 1	**First stage (over)**
> 2	**Second stage (under)**
&	**Logical "AND":**
	Used in logic diagrams to show an AND-gate function.
1	**Logical "OR":**
	Used in logic diagrams to show an OR-gate function.
o	**A small circle on the input or output of a logic gate:**
	Indicates a NOT (invert) function.
52a	**A circuit breaker closed auxiliary contact:**
	The contact is in the same state as the breaker primary contacts.
52b	**A circuit breaker open auxiliary contact:**
	The contact is in the opposite state to the breaker primary contacts.
Σ	**"Sigma":**
	Used to indicate a summation, such as cumulative current interrupted.
τ	**"Tau":**
	Used to indicate a time constant, often associated with thermal characteristics.
Θn	**Nth thermal state of the machine**
A	**Initial thermal state of the machine in percentage of full thermal capacity**
Antibkspin	Anti Backspin
ADC	**Analog to Digital Converter**
BU	**Backup:**
	Typically a back-up protection element.
C/O	**A changeover contact having normally closed and normally open connections:**
	Often called a "form C" contact.
CB	Circuit breaker.
CB Aux.	**Circuit breaker auxiliary contacts:**
	Indication of the breaker open/closed status.
CBF	Circuit breaker failure protection.
Cct	**Circuit**
Char Angle	Characteristic angle
CLIO	**Current loop Input /Output:**
	0-1 mA/0-10 mA/0-20 mA/4-20 mA transducer inputs and outputs
	CLI = current loop input - 0-1 mA/0-10 mA/0-20 mA/4-20 mA transducer input
	CLO = current loop output - 0-1 mA/0-10 mA/0-20 mA/4-20 mA transducer output
CT	Current transformer.
CTRL.	**Abbreviation of "Control":**
	As used for the Control Inputs function.
CTS	**Current transformer supervision:**
	To detect CT input failure.
DDB	**Digital data bus within the programmable scheme logic:**
	A logic point that has a zero or 1 status. DDB signals are mapped in logic to customize the relay's operation.

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Symbols	Explanation
DEF	**Directional earth fault protection:** A directionalized earth (ground) fault aided scheme.
DIy	Time delay.
DT	**Abbreviation of "Definite Time":** An element which always responds with the same constant time delay on operation.
E/F	**Earth fault:** Directly equivalent to ground fault.
EMC	Electro magnetic compatibility
FFail	**A field failure (loss of excitation) element:** Could be labeled 40 in ANSI terminology.
FLC	**Full load current:** The nominal rated current for the circuit.
Flt.	**Abbreviation of "Fault":** Typically used to indicate faulted phase selection.
FN	Function.
Fwd.	Indicates an element responding to a flow in the "Forward" direction.
F<	**An underfrequency element:** Could be labeled 81U in ANSI terminology.
Gnd.	**Abbreviation of "Ground":** Used to identify settings that relate to ground (earth) faults.
GRP.	Abbreviation of "Group": Typically an alternative setting group.
I	Current.
I∧	**Current raised to a power:** Such as when breaker statistics monitor the square of ruptured current squared (∧ power = 2).
I<	**An undercurrent element:** Responds to current dropout.
I>	**A phase over current element:** Could be labeled 50/51 in ANSI terminology.
IED	Intelligent Electronic Device
I0	**Zero sequence current:** Equals one third of the measured neutral/residual current.
I1	Positive sequence current.
I2	Negative sequence current.
I1	Positive sequence current.
I2	Negative sequence current.
I_{eq}	Equivalent thermal current
I_{th}	Thermal current threshold
I2>	Negative sequence over current element Could be labeled 46OC in ANSI terminology.
I2pol	Negative sequence polarizing current.
IA	**Phase A current:** Might be phase L1, red phase.. or other, in customer terminology.
IB	**Phase B current:** Might be phase L2, yellow phase.. or other, in customer terminology.
IC	**Phase C current:** Might be phase L3, blue phase.. or other, in customer terminology.

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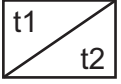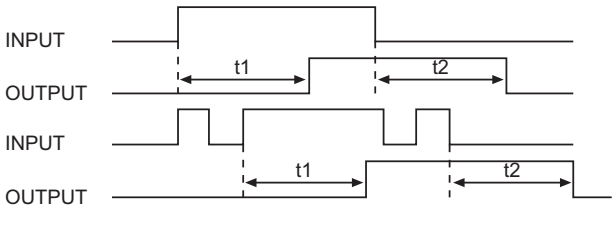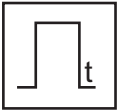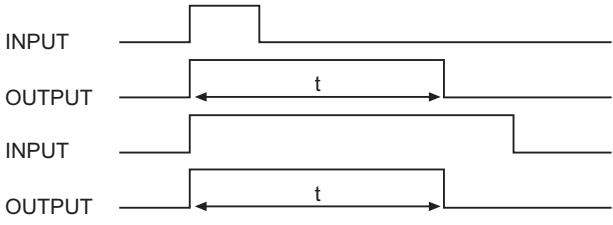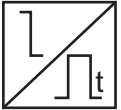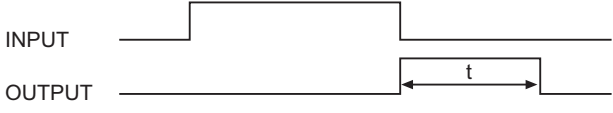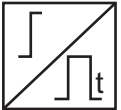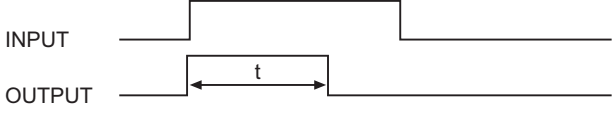
Symbols	Explanation
ID	**Abbreviation of "Identifier":**
	Often a label used to track a software version installed.
IDMT	**Inverse definite minimum time:**
	A characteristic whose trip time depends on the measured input (e.g. current) according to an inverse-time curve.
In	**The rated nominal current of the relay:**
	Software selectable as 1 amp or 5 amp to match the line CT input.
IN	**Neutral current, or residual current:**
	This results from an internal summation of the three measured phase currents.
IN>	**A neutral (residual) over current element:**
	Detects earth (ground) faults. Could be labeled 50N/51N in ANSI terminology.
Inh	An inhibit signal.
ISEF>	**A sensitive Earth Fault over current element:**
	Detects earth (ground) faults. Could be labeled 50N/51N in ANSI terminology.
Inst.	**An element with "instantaneous" operation:**
	i.e. having no deliberate time delay.
I/O	**Abbreviation of "Inputs and Outputs":**
	Used in connection with the number of opto coupled inputs and output contacts within the relay.
I/P	Abbreviation of "Input".
K	Thermal coefficient
LCD	**Liquid crystal display:**
	The front-panel text display on the relay.
LD	**Abbreviation of "Level Detector":**
	An element responding to a current or voltage below its set threshold.
LED	**Light emitting diode:**
	Red or green indicator on the relay front-panel.
MCB	**A "miniature circuit breaker":**
	Used instead of a fuse to protect VT secondary circuits.
Mot Diff	**A motor differential element:**
	Could be labeled 87 in ANSI terminology.
N	**Indication of "Neutral" involvement in a fault:**
	i.e. a ground (earth) fault.
Nb	**Number**
N/A	Not applicable.
N/C	**A normally closed or "break" contact:**
	Often called a "form B" contact.
NLR	**Non Linear Resistor** (Metrosil)
N/O	**A normally open or "make" contact:**
	Often called a "form A" contact.
NPS	Negative phase sequence.
NXT	**Abbreviation of "Next":**
	In connection with hotkey menu navigation.
NVD	**Neutral voltage displacement:**
	Equivalent to residual over voltage protection.
O/P	Abbreviation of "output".
Opto	**An opto coupled logic input:**
	Alternative terminology: binary input.

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Symbols	Explanation
-P>	**A reverse power (W) element:**
	Could be labeled 32R in ANSI terminology.
P>	**An overpower (W) element:**
	Could be labeled 32O in ANSI terminology.
P<	**A low forward power (W) element:**
	Could be labeled 32L in ANSI terminology.
P1	**Used in IEC terminology to identify the primary CT terminal polarity:**
	Replace by a dot when using ANSI standards.
P2	**Used in IEC terminology to identify the primary CT terminal polarity:**
	The non-dot terminal.
PCB	Printed Circuit Board.
Ph	**Abbreviation of "Phase":**
	Used in distance settings to identify settings that relate to phase-phase faults.
Pol	**Abbreviation of "Polarizing":**
	Typically the polarizing voltage used in making directional decisions.
PN>	**A Wattmetric earth fault element:**
	Calculated using residual voltage and current quantities.
PSL	**Programmable scheme logic:**
	The part of the relay's logic configuration that can be modified by the user, using the graphical editor within MiCOM S1 software.
Prol	**Prolonged**
Pu	**Per Unit**
R	Resistance (Ω).
R Gnd.	**A distance zone resistive reach setting:**
	Used for ground (earth) faults.
RCA	**Abbreviation of "Relay Characteristic Angle":**
	The center of the directional characteristic.
Rev.	Indicates an element responding to a flow in the "reverse" direction.
RMS	**The equivalent a.c. current:**
	Taking into account the fundamental, plus the equivalent heating effect of any harmonics. Abbreviation of "root mean square".
RP	**Abbreviation of "Rear Port":**
	The communication ports on the rear of the relay.
RTD	Resistance temperature device.
Rx	**Abbreviation of "Receive":**
	Typically used to indicate a communication receive line/pin.
Reacc	**Reacceleration**
R$_L$	**Lead/Wire resistance**
R$_{st}$	**Stabilizing resistor**
RTU	**Remote Terminal Unit**
S1	**Used in IEC terminology to identify the secondary CT terminal polarity:**
	Replace by a dot when using ANSI standards.
S2	**Used in IEC terminology to identify the secondary CT terminal polarity:**
	The non-dot terminal.
	Also used to signify negative sequence apparent power, S2 = V2 x I2.
Sen	Sensitive
SEF	Sensitive Earth Fault Protection.
SCADA	**Supervisory Control and Data Acquisition**
Start	**Same as Pickup**

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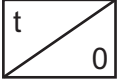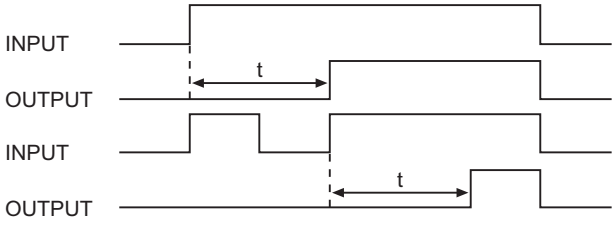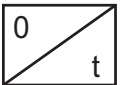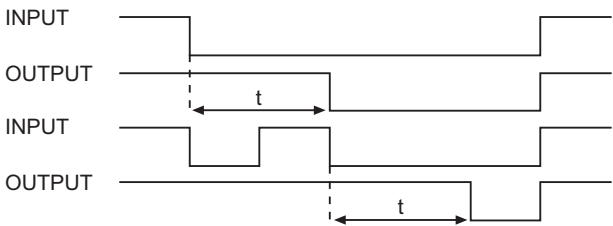| Symbols	Explanation
t	A time delay.
T	Ambient temperature in degrees Celsius
T1	Thermal characteristic time constant during over load
T2	Thermal characteristic time constant during start up period
Tr	Thermal characteristic time constant during cooling down period (stopping)
top	Operating time
tn	Elapsed time often used in comparison with a set time
TCS	Trip circuit supervision.
TD	**The time dial multiplier setting:** Applied to inverse-time curves (ANSI/IEEE).
TE	**A standard for measuring the width of a relay case:** One inch = 5TE units.
Thermal I>	A stator thermal overload element: Could be labeled 49 in ANSI terminology.
TMS	The time multiplier setting applied to inverse-time curves (IEC).
Tx	**Abbreviation of "Transmit":** Typically used to indicate a communication transmit line/pin.
V	Voltage.
V<	**An undervoltage element:** Could be labeled 27 in ANSI terminology.
V>	**An overvoltage element:** Could be labeled 59 in ANSI terminology.
V0	**Zero sequence voltage:** Equals one third of the measured neutral/residual voltage.
V1	Positive sequence voltage.
V2	Negative sequence voltage.
V2>	**A negative phase sequence (NPS) over voltage element:** Could be labeled 47 in ANSI terminology.
V2pol	Negative sequence polarizing voltage.
VA	**Phase A voltage:** Might be phase L1, red phase.. or other, in customer terminology.
VB	**Phase B voltage:** Might be phase L2, yellow phase.. or other, in customer terminology.
VC	**Phase C voltage:** Might be phase L3, blue phase.. or other, in customer terminology.
Vk	IEC knee point voltage of a current transformer.
Vn	**The rated nominal voltage of the relay:** To match the line VT input.
VN	Neutral voltage displacement, or residual voltage.
VN>	**A residual (neutral) over voltage element:** Could be labeled 59N in ANSI terminology.
Vrem.	Remanent voltage, phase to phase measurement, connected on the Motor side, used in Antibackspin protection.
Vres.	Neutral voltage displacement, or residual voltage.
Vr	Residual voltage- Voltage output of an open delta VT secondary
Vs	Voltage setting used for high impedance differential protection
VT	Voltage transformer.

SG

Symbols	Explanation
Vx	**An auxiliary supply voltage:** Typically the substation battery voltage used to power the relay.
Z<	**An under impedance element:** Could be labeled 21 in ANSI terminology.
Z0	Zero sequence impedance.
Z1	Positive sequence impedance.
Z2	Negative sequence impedance.

Table 1: List of principle symbols

Logic symbols	Explanation	Time chart
t / 0	Delay on pick-up timer, t	INPUT OUTPUT INPUT OUTPUT — with delays t
0 / t	Delay on drop-off timer, t	INPUT OUTPUT INPUT OUTPUT — with delays t
t1 / t2	Delay on pick-up/drop-off timer	INPUT OUTPUT INPUT OUTPUT — with delays t1, t2
⊓ t	Pulse timer	INPUT OUTPUT INPUT OUTPUT — with delays t
⌐ / ⊓ t	Pulse pick-up falling edge	INPUT OUTPUT — with delay t
⌐ / ⊓ t	Pulse pick-up raising edge	INPUT OUTPUT — with delay t
Latching	Latch	INPUT OUTPUT
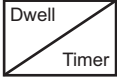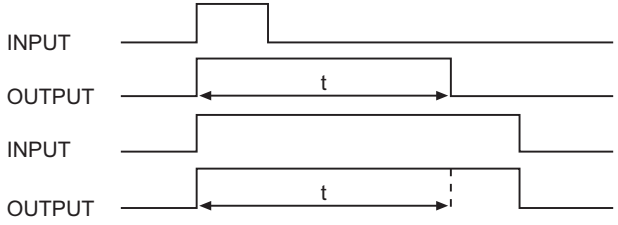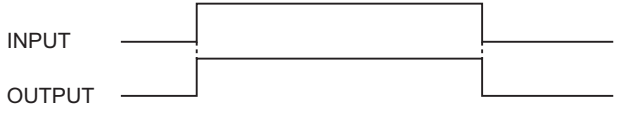
Logic symbols	Explanation	Time chart
Dwell / Timer	Dwell timer	INPUT OUTPUT (t) INPUT OUTPUT (t)
Straight	Straight (non latching): Hold value until input reset signal	INPUT OUTPUT

Table 2: Logic timers

AND GATE

Symbol	Truth Table	Symbol	Truth Table	Symbol	Truth Table
A —[&]— Y (B)	IN: A B / OUT: Y — 0 0 0 / 0 1 0 / 1 0 0 / 1 1 1	A —o[&]— Y (B)	IN: A B / OUT: Y — 0 0 0 / 0 1 0 / 1 0 0 / 1 1 0	A —[&]o— Y (B)	IN: A B / OUT: Y — 0 0 1 / 0 1 1 / 1 0 1 / 1 1 0

OR GATE

Symbol	Truth Table	Symbol	Truth Table	Symbol	Truth Table
A —[1]— Y (B)	IN: A B / OUT: Y — 0 0 0 / 0 1 1 / 1 0 1 / 1 1 1	A —o[1]— Y (B)	IN: A B / OUT: Y — 0 0 1 / 0 1 1 / 1 0 0 / 1 1 0	A —[1]o— Y (B)	IN: A B / OUT: Y — 0 0 1 / 0 1 0 / 1 0 0 / 1 1 0

S – R FLIP-FLOP

Symbol	Truth Table	Symbol	Truth Table	Symbol	Truth Table
A —[S R]— Q —Y Standard S-R gate	A B Q_0 Q_1: 0 0 0 0 / 0 0 1 1 / 0 1 0 0 / 0 1 1 0 / 1 0 0 1 / 1 0 1 1 / 1 1 0 0 / 1 1 1 1	A —[SD R]— Q —Y SD = Set Dominant	A B Q_0 Q_1: 0 0 0 0 / 0 0 1 1 / 0 1 0 0 / 0 1 1 0 / 1 0 0 1 / 1 0 1 1 / 1 1 0 1 / 1 1 1 1	A —[S RD]— Q —Y RD = Reset Dominant	A B Q_0 Q_1: 0 0 0 0 / 0 0 1 1 / 0 1 0 0 / 0 1 1 0 / 1 0 0 1 / 1 0 1 1 / 1 1 0 0 / 1 1 1 0

Warning: To avoid ambiguity, do not use the standard S-R gate unless specifically required

EXCLUSIVE OR GATE

Symbol	Truth Table	Symbol	Truth Table	Symbol	Truth Table
A —[XOR]— Y (B)	IN: A B / OUT: Y — 0 0 0 / 0 1 1 / 1 0 1 / 1 1 0	A —[XOR]— Y (B)	IN: A B / OUT: Y — 0 0 1 / 0 1 0 / 1 0 0 / 1 1 1	A —[XOR]o— Y (B)	IN: A B / OUT: Y — 0 0 1 / 0 1 0 / 1 0 0 / 1 1 1

PROGRAMMABLE GATE

Symbol	Truth Table	Symbol	Truth Table	Symbol	Truth Table
A B C —[2]— Y	A B C / Y: 0 0 0 0 / 0 0 1 0 / 0 1 0 0 / 0 1 1 1 / 1 0 0 0 / 1 0 1 1 / 1 1 0 1 / 1 1 1 1	A B C —[2]— Y	A B C / Y: 0 0 0 0 / 0 0 1 1 / 0 1 0 1 / 0 1 1 1 / 1 0 0 0 / 1 0 1 0 / 1 1 0 0 / 1 1 1 1	A B C —[2]o— Y	A B C / Y: 0 0 0 1 / 0 0 1 1 / 0 1 0 1 / 0 1 1 0 / 1 0 0 1 / 1 0 1 0 / 1 1 0 0 / 1 1 1 0

NOT GATE

Symbol	Truth Table
A ——[>o]—— Y Inverter (NOT)	IN: A / OUT: Y — 0 1 / 1 0

V02400

Table 3: Logic gates

SG

INSTALLATION

IN

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FIGURES

IN

1   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.

⚠   **Before lifting or moving the equipment you should be familiar with the Safety Information chapter of this manual.**

1.1   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.

1.2   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.

1.3   Storing the Goods

If the unit is not installed immediately, store it in a place free from dust and moisture in its original packaging. Keep any de-humidifier bags included in the packing. The de-humidifier crystals lose their efficiency if the bag is exposed to ambient conditions. Restore the crystals before replacing it in the carton. Ideally regeneration should be carried out in a ventilating, circulating oven at about 115°C. Bags should be placed on flat racks and spaced to allow circulation around them. The time taken for regeneration will depend on the size of the bag. If a ventilating, circulating oven is not available, when using an ordinary oven, open the door on a regular basis to let out the steam given off by the regenerating silica gel.

On subsequent unpacking, make sure that any dust on the carton does not fall inside. Avoid storing in locations of high humidity. In locations of high humidity the packaging may become impregnated with moisture and the de-humidifier crystals will lose their efficiency.

The device can be stored between –25º to +70ºC for unlimited periods or between -40°C to + 85°C for up to 96 hours (see technical specifications).

To avoid deterioration of electrolytic capacitors, power up units that are stored in a de-energised state once a year, for one hour continuously.

1.4   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.

IN

2   MOUNTING THE DEVICE

The products are dispatched either individually or as part of a panel or rack assembly.

Individual products are normally supplied with an outline diagram showing the dimensions for panel cut-outs and hole centres.

The products are designed so the fixing holes in the mounting flanges are only accessible when the access covers are open.

If you use a P991 or MMLG test block with the product, when viewed from the front, position the test block on the right-hand side of the associated product. This minimises the wiring between the product and test block, and allows the correct test block to be easily identified during commissioning and maintenance tests.

If you need to test the product for correct operation during installation, open the lower access cover, hold the battery in place and pull the red tab to remove the battery isolation strip*.

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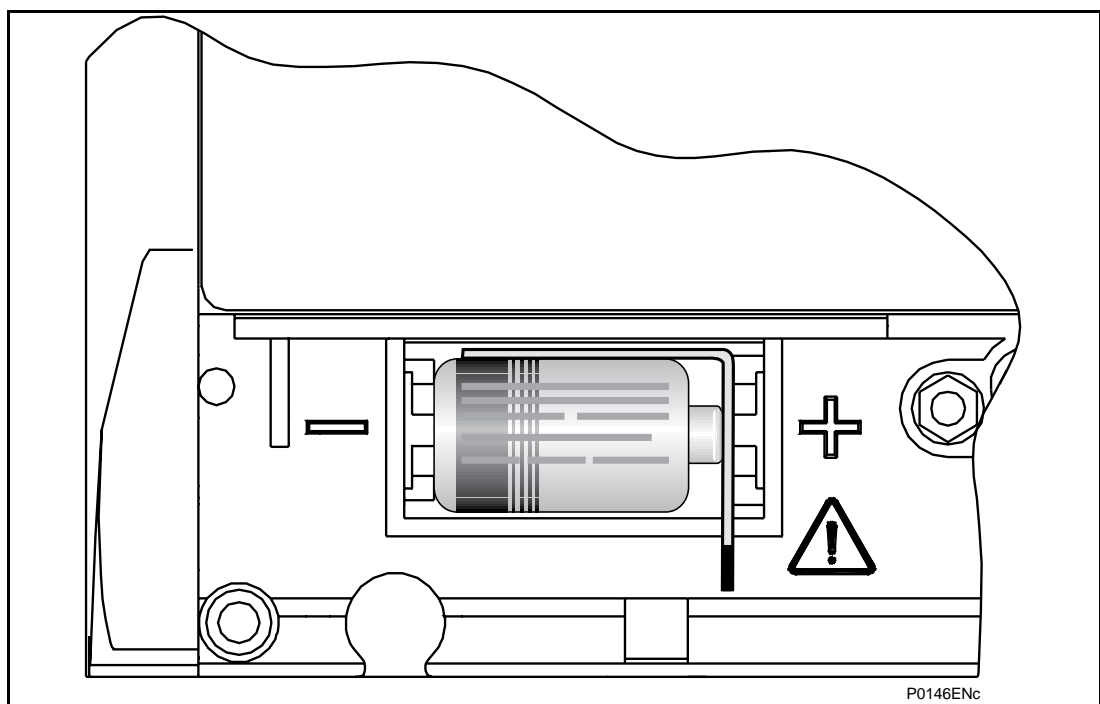
Figure 1: Location of battery isolation strip

> **Note:**   *Battery fitted to white front panel versions, supercapacitor fitted to black and silver front panel versions. For details, refer to the Ordering Options Appendix.

2.1   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).

⚠ **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.

IN

> ⚠ **Do not fasten products with pop rivets because this makes them difficult to remove if repair becomes necessary.**

2.2 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).

> ⚠ **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.

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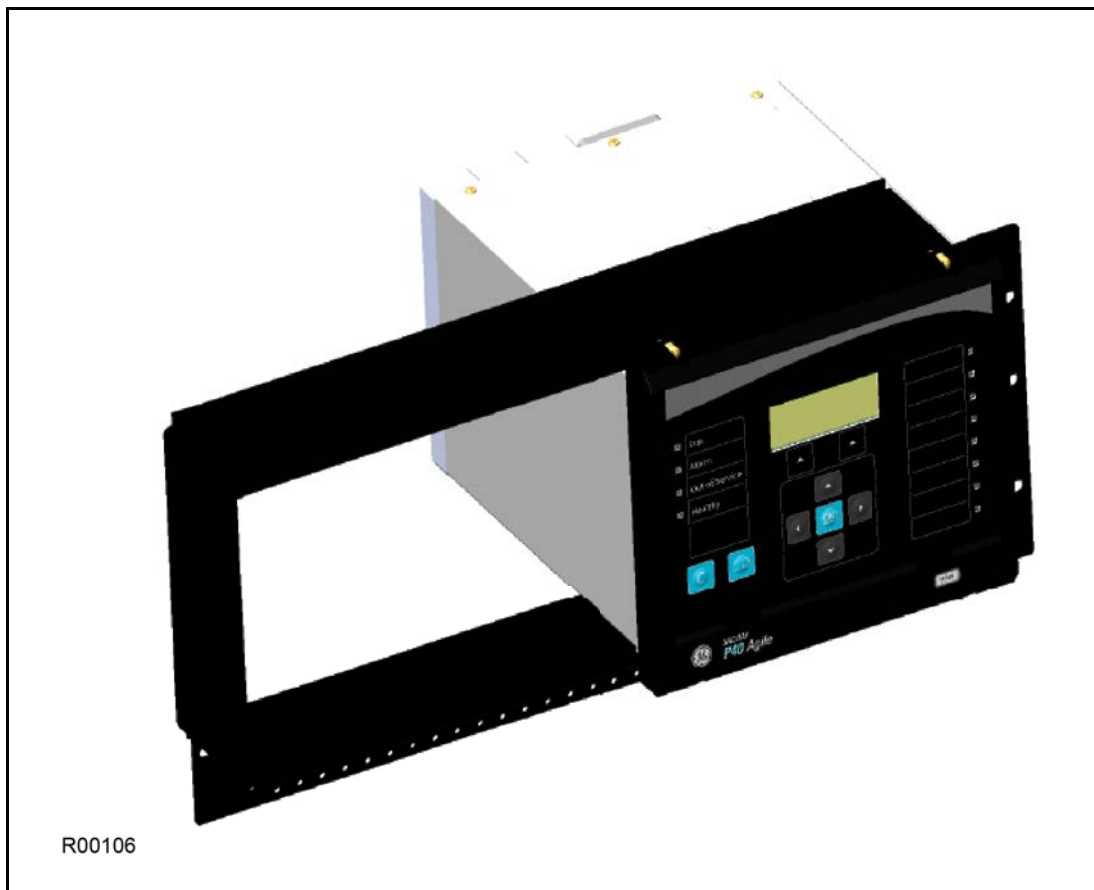
Figure 2: Rack mounting of products

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 to 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:

IN

Case size summation	Blanking plate part number	
	White (RAL 9002)	Black and Silver
5TE	GJ2028 101	GJ2028 001
10TE	GJ2028 102	GJ2028 002
15TE	GJ2028 103	GJ2028 003
20TE	GJ2028 104	GJ2028 004
25TE	GJ2028 105	GJ2028 005
30TE	GJ2028 106	GJ2028 006
35TE	GJ2028 107	GJ2028 007
40TE	GJ2028 108	GJ2028 008
60TE	GJ2028 112	GJ2028 012
80TE	GJ2028 116	GJ2028 016

IN

3 CABLES AND CONNECTIONS

This section describes the type of wiring and connections that should be used when installing the device.

⚠ **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.**

3.1 Terminal Blocks

The device may use one or more of the terminal block types shown in the following diagram. The terminal blocks are fastened to the rear panel with screws.
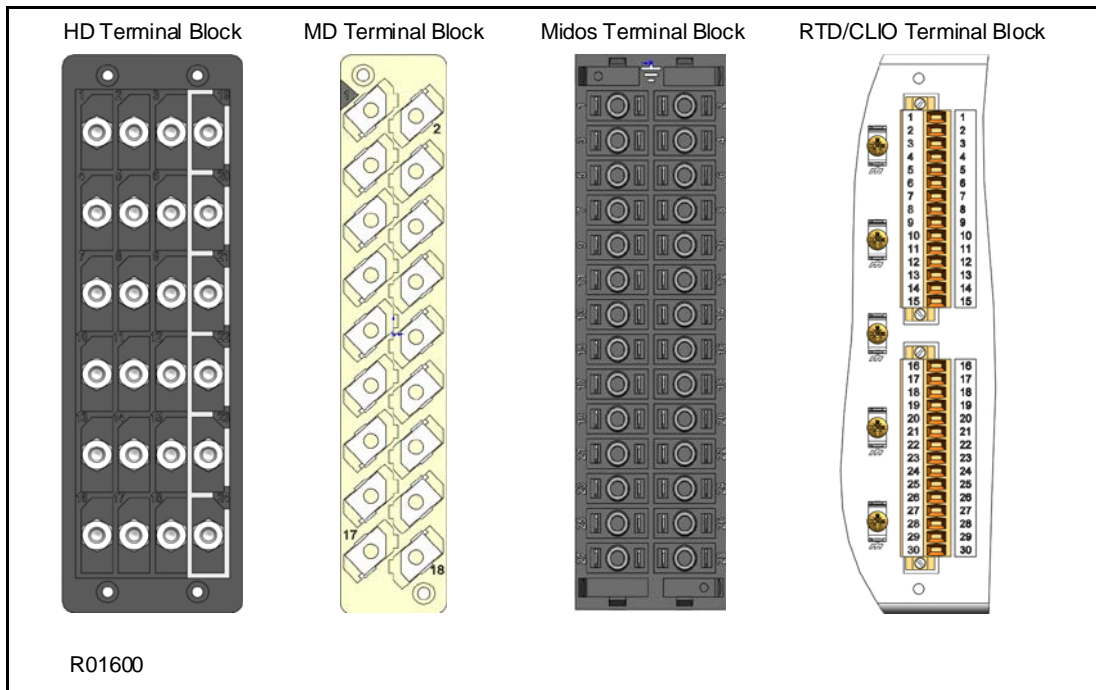
Figure 3: Terminal block types

MiCOM products are supplied with sufficient M4 screws for making connections to the rear mounted terminal blocks using ring terminals, with a recommended maximum of two ring terminals per terminal.

If required, M4 90° crimp ring terminals can be supplied in three different sizes depending on 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

3.1.1 Terminal Block Ingress Protection

IP2x shields and side cover panels are designed to provide IP20 ingress protection for MiCOM terminal blocks. The shields and covers may be attached during installation or retrofitted to upgrade existing installations—see figure below. More information is available at your local sales office or through our Contact Centre.

IN
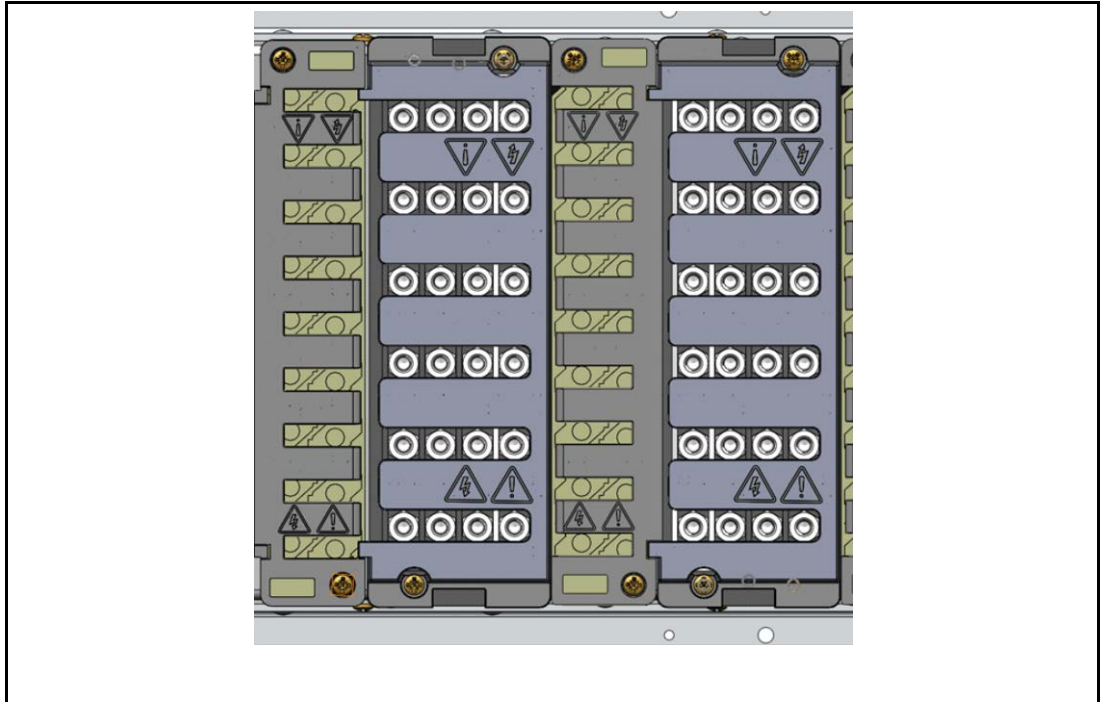
Figure 4: Example—fitted IP2x shields (cabling omitted for clarity)

3.2   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.

⚠️ **Protect the auxiliary power supply wiring with a maximum 16 A high rupture capacity (HRC) type NIT or TIA fuse**

3.3   Earth Connection

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.

3.4   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.

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⚠ **Current transformer circuits must never be fused.**

Note: If there are CTs present, spring-loaded shorting contacts ensure that the terminals into which the CTs connect are shorted before the CT contacts are broken.

Note: For 5A CT secondaries, we recommend using 2 x 2.5 mm2 PVC insulated multi-stranded copper wire.

3.5 Voltage Transformer Connections

Voltage transformers should be wired with 2.5 mm2 PVC insulated multi-stranded copper wire terminated with M4 ring terminals.

The wire should have a minimum voltage rating of 300 V RMS.

3.6 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.

3.7 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.

To guarantee the performance specifications, you must ensure continuity of the screen, when daisy chaining the connections.

Two-core screened twisted pair cable should be used. It is important to avoid circulating currents, which can cause noise and interference, especially when the cable runs between buildings. For this reason, the screen should be continuous and connected to ground at one end only, normally at the master connection point.

The K-Bus signal is a differential signal and there is no signal ground connection. If a signal ground connection is present in the bus cable then it must be ignored. At no stage should this be connected to the cable's screen or to the product's chassis. This is for both safety and noise reasons.

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

3.8 IRIG-B Connection (if applicable)

The IRIG-B input and BNC connector have a characteristic impedance of 50 ohms. We recommend that connections between the IRIG-B equipment and the product are made using coaxial cable of type RG59LSF with a halogen free, fire retardant sheath.

3.9 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.

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Protect the opto-inputs and their wiring with a maximum 16 A high rupture capacity (HRC) type NIT or TIA fuse.

3.10 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

3.11 Ethernet Fibre Connections (if applicable)

We recommend the use of fibre-optic connections for permanent connections in a substation environment. The 100 Mbps fibre optic port uses type ST connectors (one for Tx and one for

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The screen of each cable must only be earthed (grounded) at one end, preferably at the IED end and must be continuous. Multiple earthing (grounding) of the screen can cause circulating current to flow along the screen. This induces noise and is also unsafe.

You should minimize the noise pick-up in the RTD cables by keeping them close to earthed (grounded) metal casings and avoid areas of high electromagnetic and radio interference. The RTD cables should not be run adjacent to or in the same conduit as other high voltage or current cables.

A typical cable specification would be:

- Each core: 7/0.2 mm copper conductors heat resistant PVC insulated
- Nominal conductor area: 0.22 mm2 per core
- Screen: Nickel-plated copper wire braid heat resistant PVC sheathed

The following extract may be useful in defining cable recommendations for the RTDs:

Noise pick up by cables can be categorized into three types:

- Resistive
- Capacitive
- Inductive

Resistive coupling requires an electrical connection to the noise source. Assuming the wire and cable insulation are in good condition and the junctions are clean, this can be dismissed. Capacitive coupling requires sufficient capacitance to the noise source. This is a function of the dielectric strength between the signal cable on the noise source and the power of the noise source. Inductive coupling occurs when the signal cable is adjacent to a wire carrying the noise or it is exposed to a radiated EMF.

Standard screened cable is normally used to protect against capacitively-coupled noise. However for this to be effective, the screen should only be bonded to the system ground at one point. Otherwise a current could flow and the noise would be coupled into the signal wires of the cable. There are different types of screening available, but the most commonly used are aluminium foil wrap, or tin-copper braid. Foil screens are good for low to medium frequencies and braid is good for high frequencies. High-fidelity screen cables provide both types.

Protection against inductive coupling requires careful cable routing and magnetic shielding. The latter can be achieved with steel-armoured cable and steel cable trays. The cable armour must be grounded at both ends so the EMF of the induced current cancels the field of the noise source and shields the cables conductors from it.

However, the system ground must be designed such that it does not bridge two isolated ground systems. This could be hazardous and defeat the objectives of the original grounding design. The cable should be laid in the cable trays as close as possible to the metal of the tray. Under no circumstance should any power cable be in or near to the tray. Power cables should only cross the signal cables at 90 degrees and never be adjacent to them.

Both the capacitive and inductive screens must be contiguous from the RTD probes to the IED terminals. The best types of cable are those provided by the RTD manufacturers. These are usually three conductors, known as a triad, which are screened with foil. Such triad cables are available in armoured forms as well as multi-triad armoured forms.

3.16 Current Loop Input Output (CLIO) Connections (if applicable)

Current Loop Inputs and Outputs (CLIO) use screw clamp connectors. The connection block is situated at the rear of the IED. It can accept wire sizes from 0.1 mm2 to 1.5 mm2. We recommend screened cable, and it should have a minimum voltage rating of 300 V RMS.

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4   ANALOGUE INPUTS

The MiCOM P241/2 relay has 3 phase current inputs, one earth current input and 3 phase voltage inputs. The P243 has 6 phase current inputs, one earth current input and 3 phase voltage inputs.

4.1   CTs Inputs for the Phase and Earth Currents

The phase and earth current inputs can be set independently to 1 A or 5 A. The choice of the CTs ratio is done in the menu 'CT and VT ratios' of the MiCOM P24x relay.

The following figures present different configurations of CTs and VTs: only the 5 A current inputs are indicated.

> ⚠ **Connections of the earth and phase cts must be done in accordance with the ct ratio selected in the "CT and VT Ratios" menu.**
>
> **Each time a change is realized, the relay must be reset and then restarted (power supply must be cut off and then restored).**

4.1.1   3 CTs and Core Balance CT Configuration

This configuration is a classical configuration, P241 example:
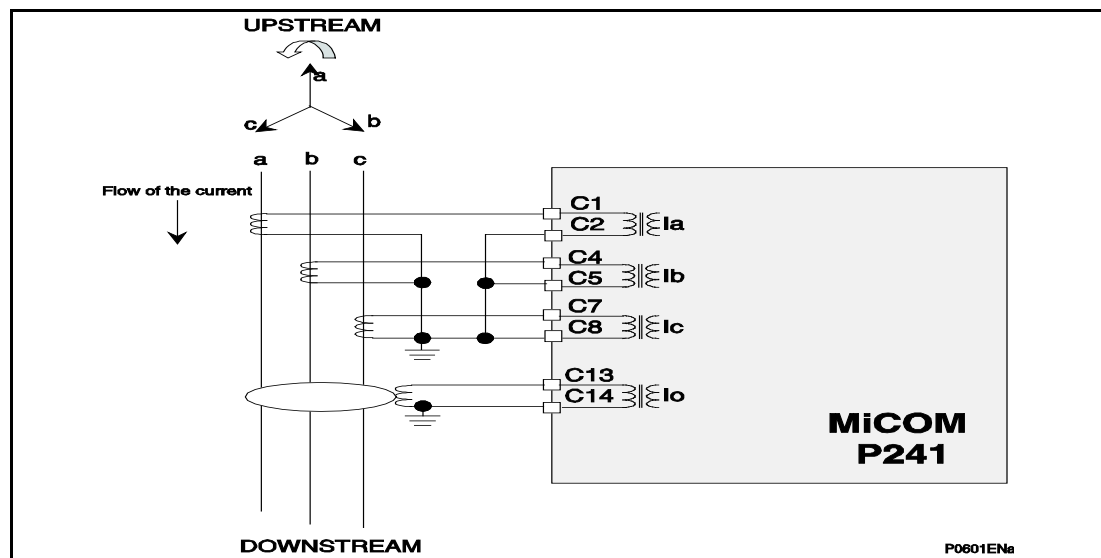
Figure 5: 3 CT and core balance CT configuration

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4.1.2 3 CTs Configuration

Due to this configuration, the earth current input is the arithmetic sum of the 3 phase currents. This configuration is mainly used when a core balanced CT is not available. P241 example:
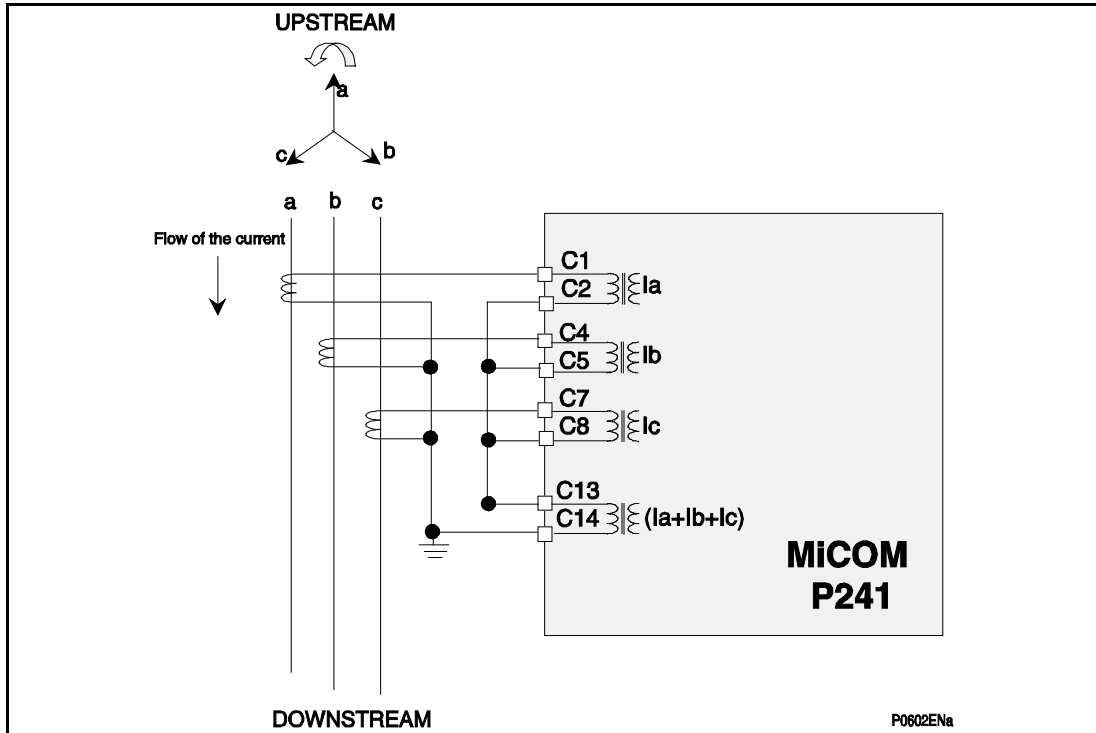
Figure 6: 3 CT configuration

It is possible to realize the summation of the 3 phase currents internally. The protection function is called **Derived E/F** and must be selected in the **CONFIGURATION** menu.

4.1.3 2 CTs and Core Balance CT Configuration

The proper configuration for the use of 2 CTs to detect phase current is shown below, P241 example:
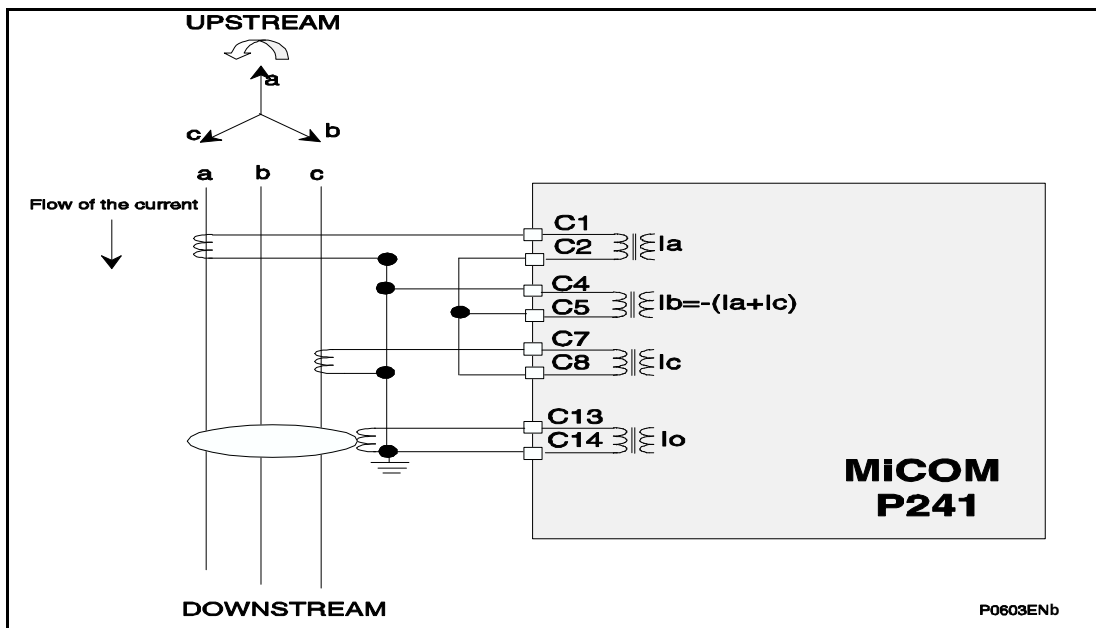
Figure 7: 2 CTs and core balance CT configuration

⚠ **This type of configuration will create a negative phase sequence current in case of unbalanced conditions due to an external fault. The protection functions "thermal overload" and "Neg.Seq.O/C" will then be affected by this configuration, since they take into account the negative phase sequence current component.**

4.2 VT Inputs

Three configurations can be used for the phase voltage inputs : the choice of the configuration is realized in the **CT AND VT RATIOS** – **VT connecting mode** menu of the MiCOM P24x relay.

4.2.1 Three Phase VTs Configuration

P241 example:
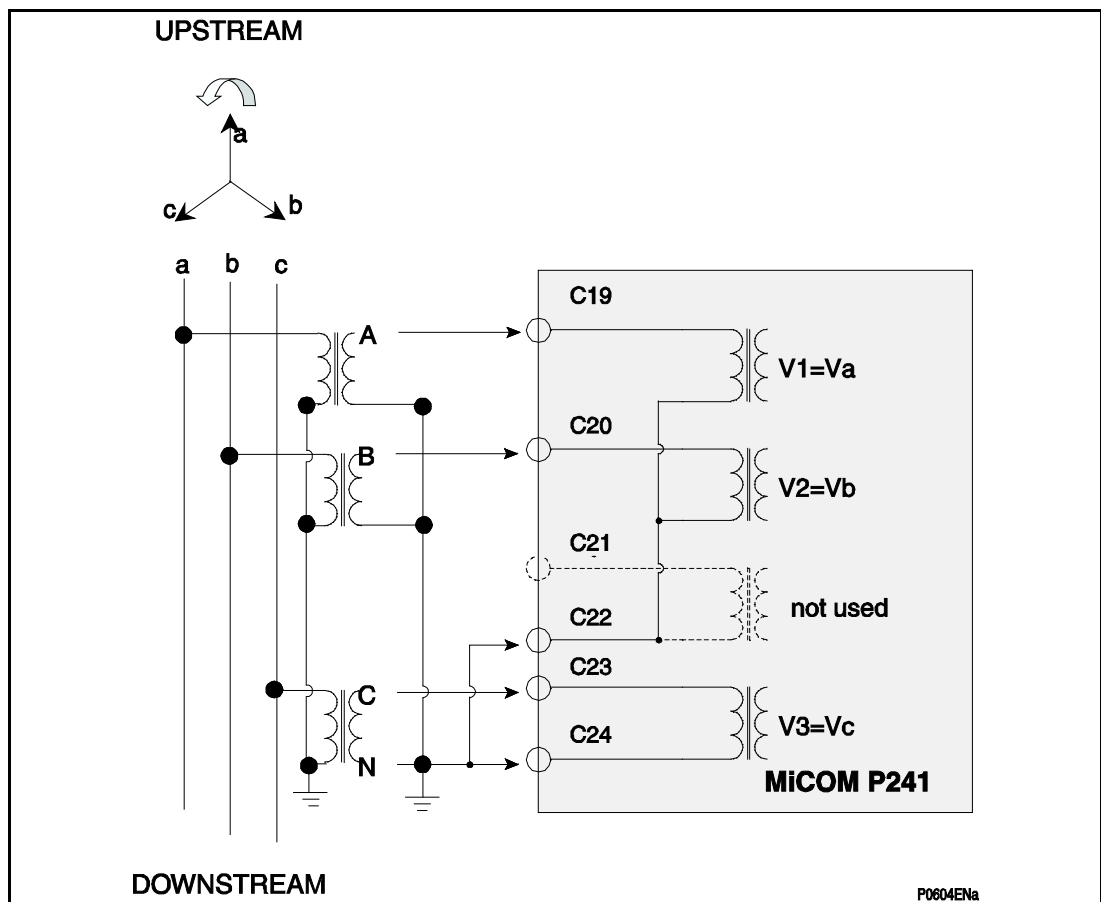
Figure 8: Three phase VTs configuration

4.2.2 Two Phase VTs and Residual VT Configuration
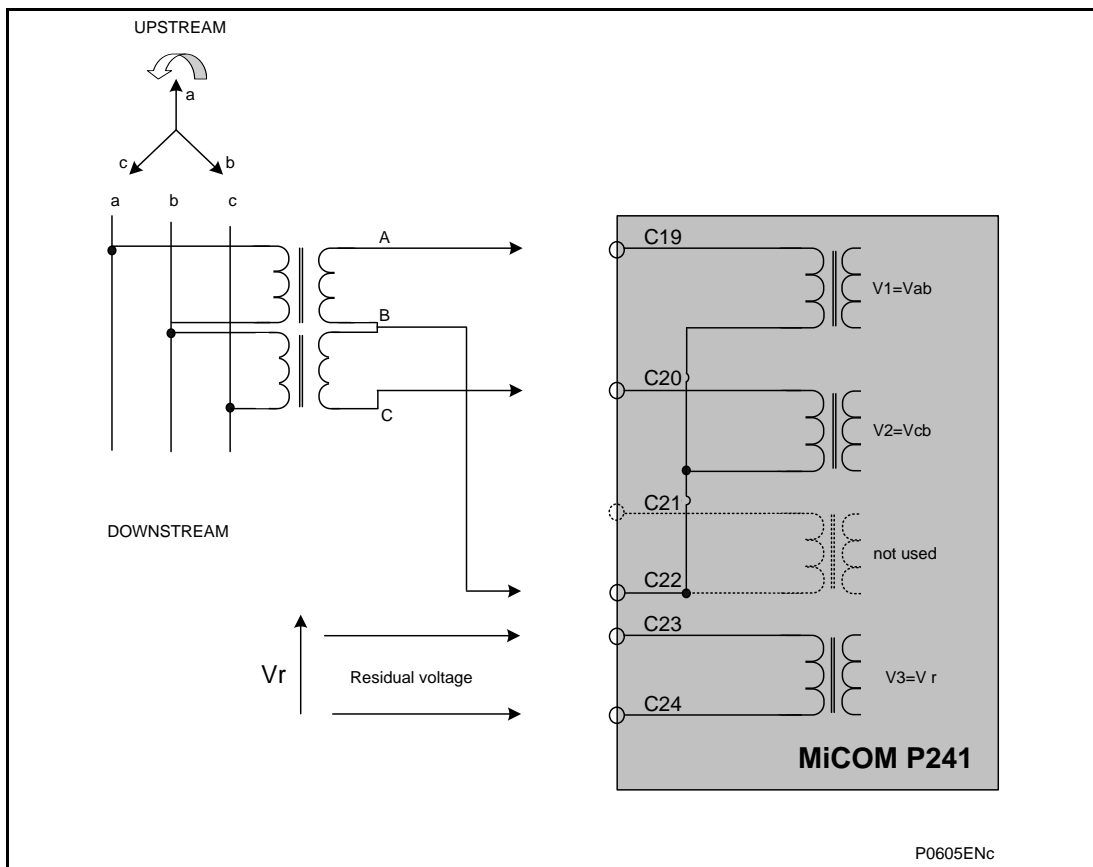
P241 example:

Figure 9: Two phase VTs and residual VT configuration

4.2.3 Two Phase VTs and Anti-Backspin (Vremanent phase-phase) VT Configuration

P241 example:
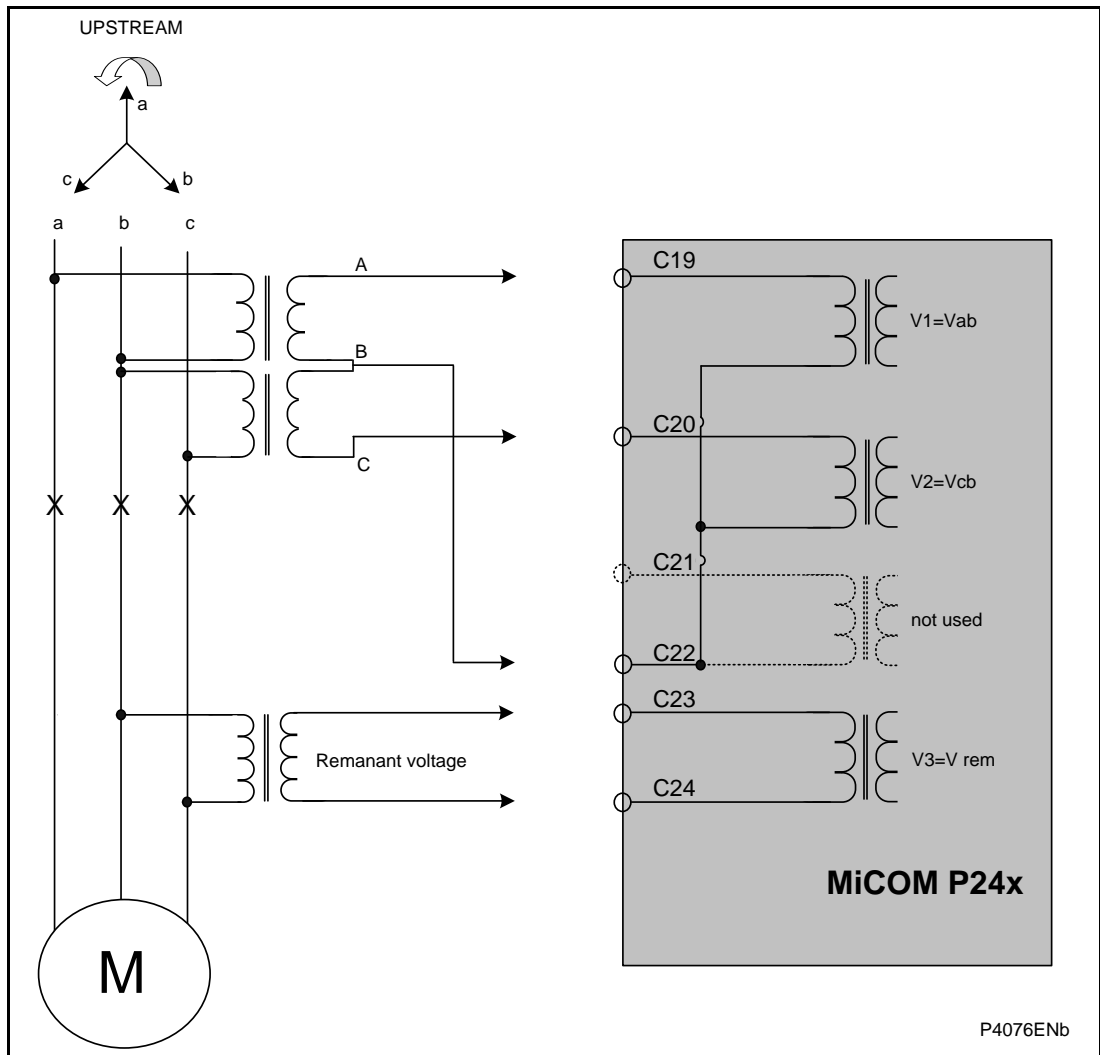
**Figure 10: Two phase VTs and Anti-Backspin (remnant phase-phase) VT
configuration**

Note: To measure the motor generated voltage when under backspin condition
(back emf), the VT used for remnant voltage measurement should be
connected upstream the motor and downstream the motor CB.

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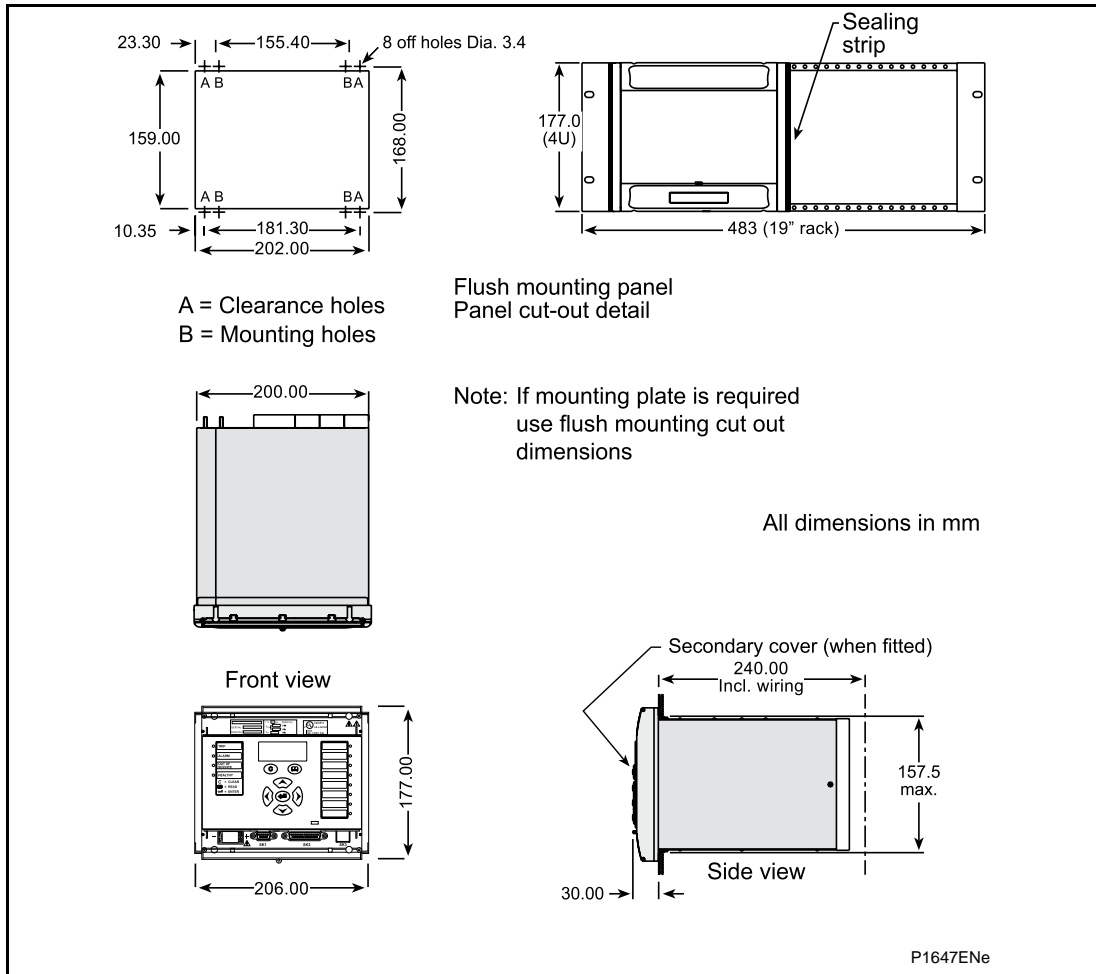
5 CASE DIMENSIONS

Figure 11: P241 case dimensions (40TE case)
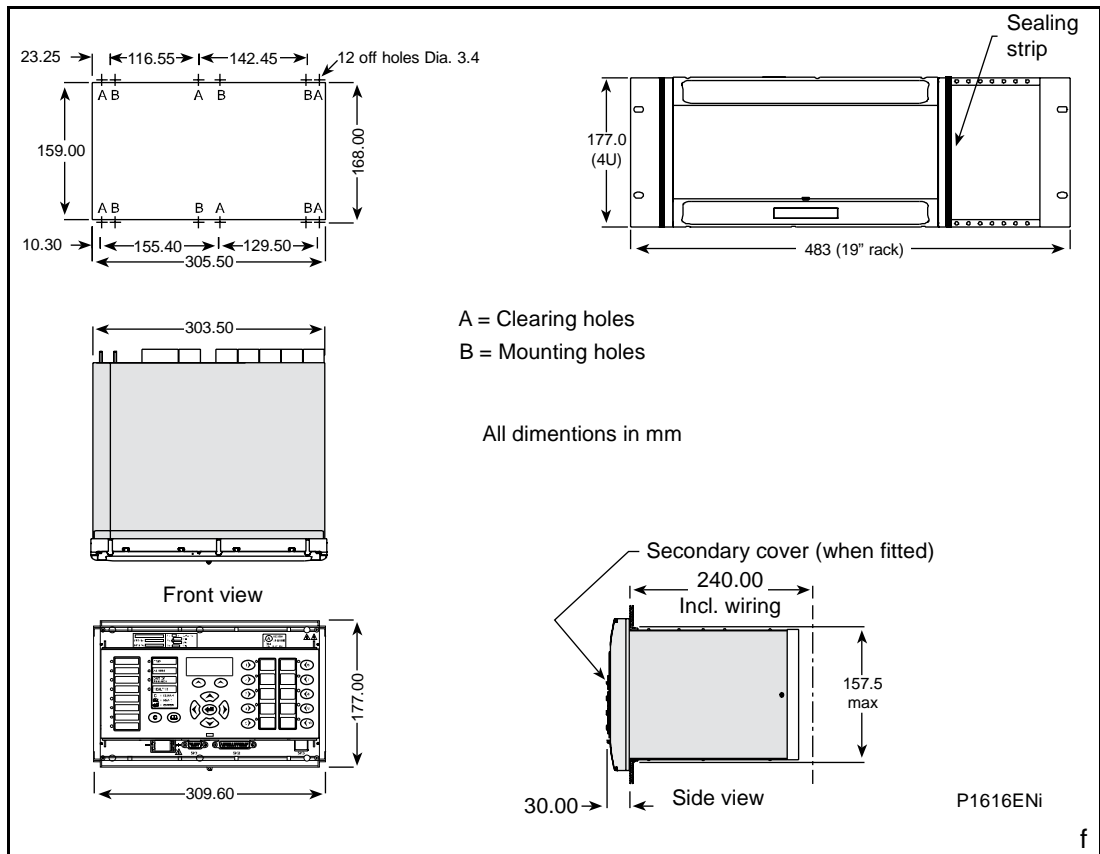
Figure 12: P242 case dimensions (60TE case)
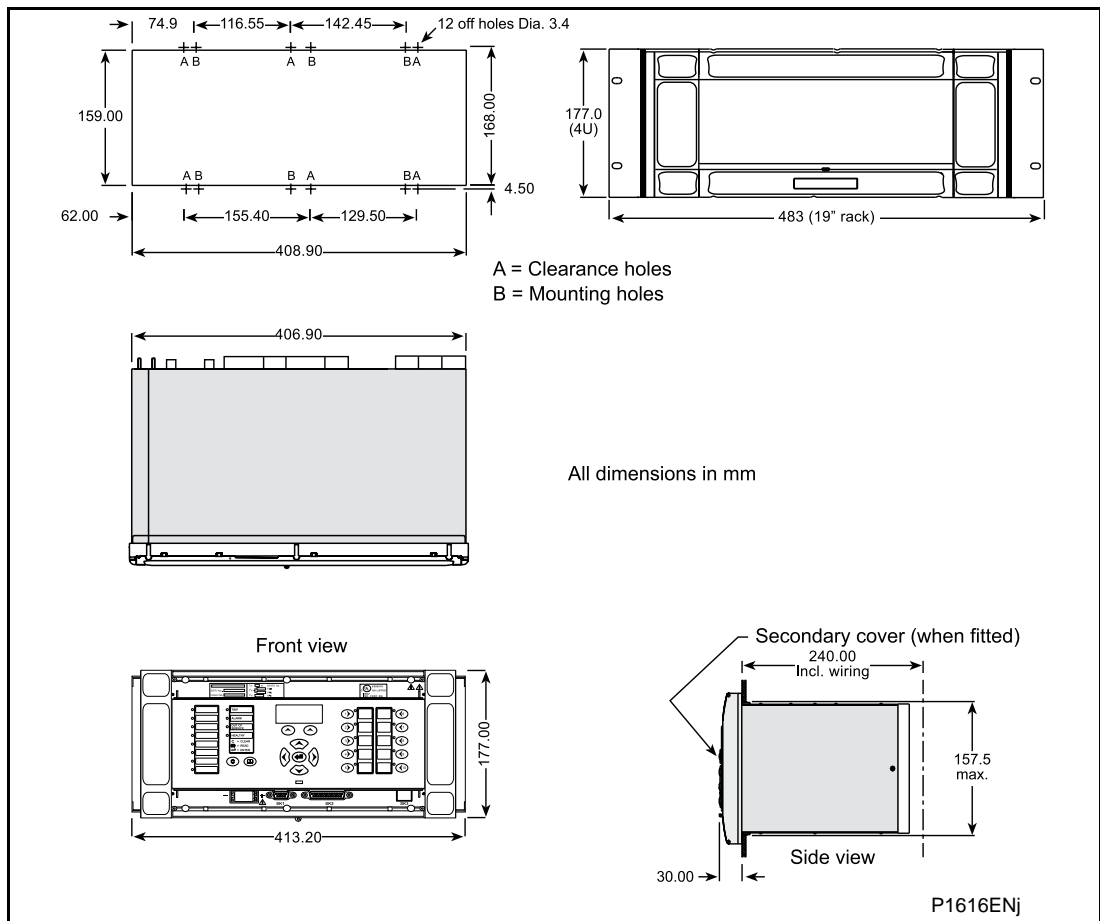
Figure 13: P243 case dimensions (80TE case)

6 ASSEMBLY DIAGRAMS
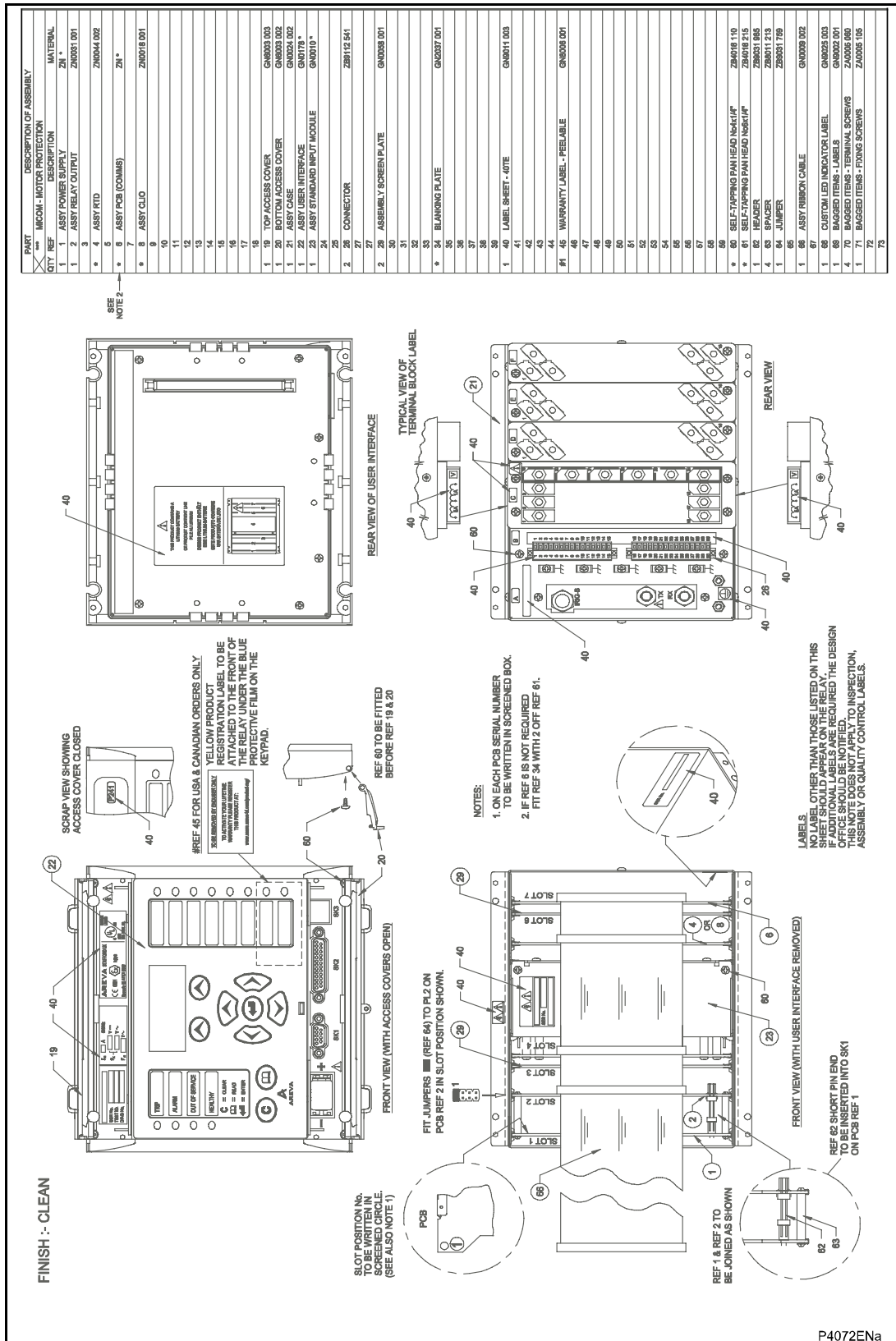
Figure 14: Assembly P241 motor protection relay (40TE) (8 I/P & 7 O/P with optional RTD & CLIO
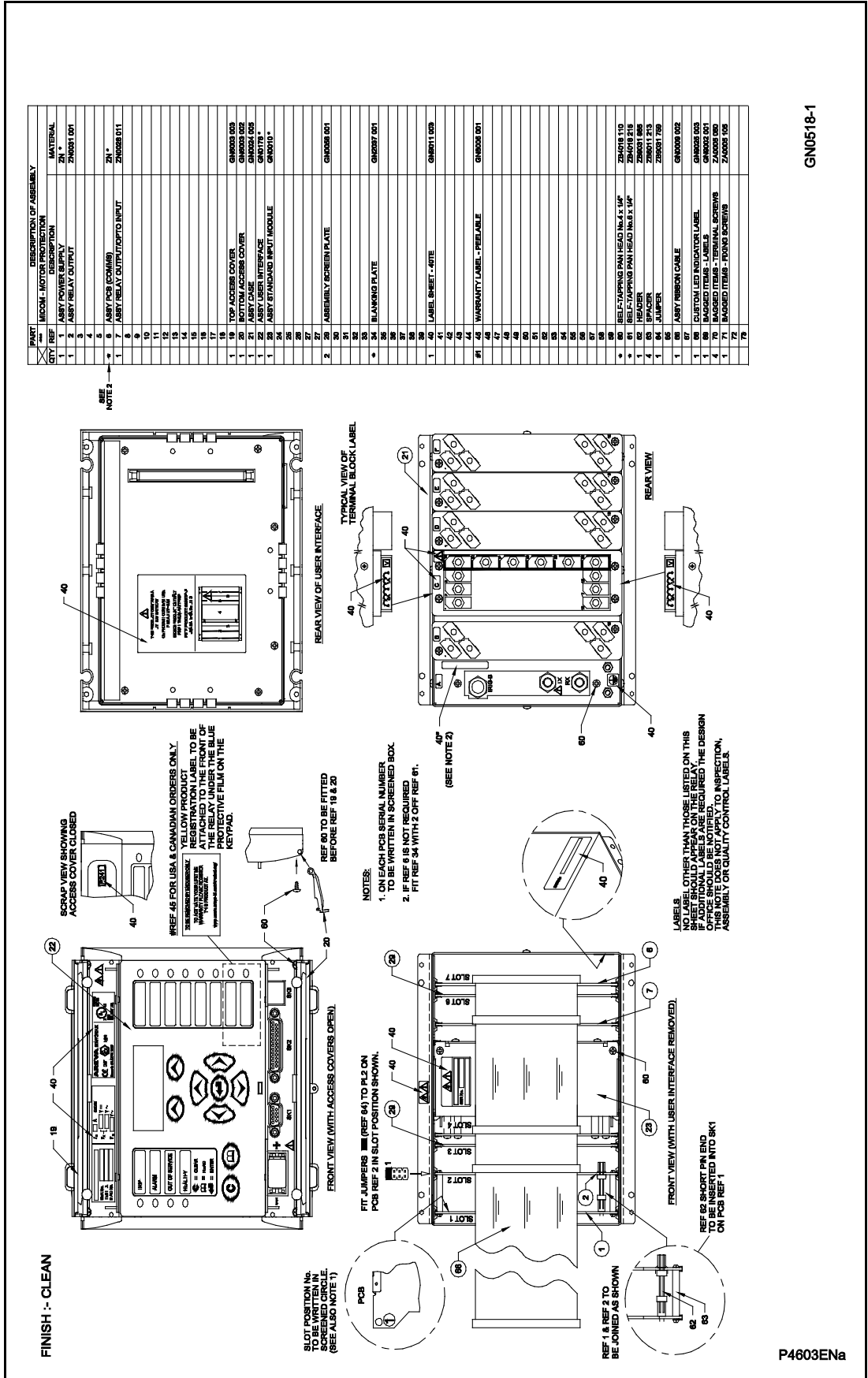
Figure 15: Assembly P241 motor protection relay (40TE) (8 I/P & 7 O/P with optional RTD & CLIO

7   EXTERNAL CONNECTION DIAGRAMS

Refer to Appendix B for the full list of wiring diagrams.

FIRMWARE AND SERVICE MANUAL VERSION HISTORY

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Relay type: P241/2/3/…						
Software Version		**Hardware Suffix**	**Original Date of Issue**	**Description of Changes**	**S1 Compatibility**	**Technical Documentation**
Major	**Minor**					
A3.0 (00) P241 only		A	Jul1999	✓ Original issue of software	V2.09 or later	TG1.1555
A3.1 (00) P241 only		A	Jul1999	✓ Inclusion of momentary warning message on the user interface if there is an error correlating ambient air by RTD to the RTD number by the user ✓ Modification of texts in language file(.dfn) regarding "stall-rotor-start/run" and "RTD invalid conf" ✓ Resolved dependency of active group and it's relevant data during fault on MiCOM S1 ✓ Addition of cells and modbus addresses required by south park and SINCOR ✓ Alteration of platform task priorities to comply with common architecture. CO 50300.C0642 ✓ Resolved overflow problem in zero volt check to offset DC in system platform	V2.09 or later	TG1.1555

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Relay type: P241/2/3/…						
Software Version		Hardware Suffix	Original Date of Issue	Description of Changes	S1 Compatibility	Technical Documentation
Major	Minor					
A3.1(02) P241 only	A	A	Nov1999	✓ Resolved problem of asynchronomism between analog and digital channels on disturbance record (10 ms time shift was corrected) ✓ Resolved resetting RTD trip and alarm flags when RTD protection is disabled ✓ Resolved problem of filtering of some of the measured quantities in fault record column ✓ Minimum delay setting on loss of load protection function is changed and step size is reduced to 0.01 s (initially 0.1 s) ✓ Resolved problem of 3 phase power factor calculation ✓ Bug fix related to reset number of start ✓ Bug fix related to RTD trip counters ✓ Resolved problem of correlation of the motor running hours with mapping of opto CB closed ✓ Resolved problem of saving the fan number for VDEW in BBRAM (every 3 seconds) ✓ Resolved problem when disabling the commissioning test with the port status ✓ Resolved problem on default language for MiCOM S1 front port courier ✓ Resolved problem of not including accountability of secondary phase CT ratio in normalization table ✓ Corrected for calculation of thermal coefficient K	V2.09 or later	TG1.1555
	B	A	Nov1999	✓ Resolved problem of restoring state of trip LED after re-boot of relay ✓ Resolved incorrect dependency of emergency re-start cell on courier ✓ Resolved problem in the out-of-step element to take into account the sign of Sin(θ) as well ✓ Resolved problem in display of negative power factor	V2.09 or later	TG1.1555

Relay type: P241/2/3/…						
Software Version		Hardware Suffix	Original Date of Issue	Description of Changes	S1 Compatibility	Technical Documentation
Major	Minor					
	C	A	Dec1999	✓ Resolved incorrect dependency of emergency re-start cell on courier ✓ Resolved problem of 3 phase reactive power calculation	V2.09 or later	TG1.1555
				✓ Inclusion of an alarm threshold on energy measurement facility ✓ Inclusion of a second stage in short circuit protection function ✓ Inclusion of derived earth fault protection function ✓ Inclusion of a second stage in loss of load/under power protection function ✓ Inclusion of reverse power protection function		

Relay type: P241/2/3/…						
Software Version		**Hardware Suffix**	**Original Date of Issue**	**Description of Changes**	**S1 Compatibility**	**Technical Documentation**
Major	**Minor**					
A4.0(03) P241 only		A	Feb2000	✓ Power supply regulator for RTD circuit is changed to 78M05 to establish secure supply ✓ Modification to RTD PCB (01-ZN001001 issue D) ✓ Resolved sequencing errors on platform RTD PCB ZN0010001 for acquisition of measurement at the boundary of 25 degree Celsius ✓ Resolved problem in a modbus method function to cater for data type G10 ✓ Resolved problem of restoring trip LED state after re-boot of relay ✓ Resolved initialization problem related to state of LEDs during the first boot of relay ✓ Resolved problem of text inversion in stall protection function	V2.09 or later	TG1.1555
A3.1(04) P241 only	D	A	Jul2000	✓ Inclusion of two new cells to describe events: location and index ✓ Modification to modbus address for event recorder ✓ Modification of modbus address in "System Data" column ✓ Modification of modbus address in "RTD protection" column ✓ Data type G29 (three 16 bit registers) is replaced with data type G125 (short float IEEE754 floating point format) to avoid truncation error on measurements ✓ Default text is changed ✓ Modbus cell address dedicated to Ubc phase angle measurement is changed to 30266 ✓ Resolved problem of inappropriate measurement algorithm of reverse 3 phase active and reactive power measurement	V2.09 or later	TG1.1555

Relay type: P241/2/3/…						
Software Version		Hardware Suffix	Original Date of Issue	Description of Changes	S1 Compatibility	Technical Documentation
Major	Minor					
				✓ Two new cells for describing events (location and index) are Added		
				✓ Modbus addresses are modified in system data column		
				✓ Modbus addresses are modified in RTD protection column		
				✓ Data type G29 (three 16 bit registers) is replaced with data type G125 (short float IEEE754 floating point format) to avoid truncation error on measurements such as KWh		
				✓ Default text is changed		
				✓ Data types G4, G18 and G26 are modified		
				✓ Modbus cell address dedicated to Ubc phase angle measurement is changed to 30266		
				✓ Modbus addressing problem for event file is resolved to be compliant with other Px40 products		
				✓ Data types G4, G18 and G26 are modified		
				✓ Modbus cell address dedicated to Ubc phase angle measurement is changed to 30266		

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Relay type: P241/2/3/…						
Software Version		Hardware Suffix	Original Date of Issue	Description of Changes	S1 Compatibility	Technical Documentation
Major	Minor					
A4.0(06) P241 only	A	A	Oct2000	✓ Modbus addressing problem for event file is resolved to be compliant with other Px40 products ✓ Resolved problem of opto reset latches not turning off trip LED to be compliant with other Px40 products ✓ Resolved problem of inappropriate measurement algorithm of reverse 3 phase active and reactive power measurement ✓ Resolved problem of timer initialization on 51LR protection function ✓ Inclusion of the option "reset energies" in " measurement 2" column ✓ Resolved problem of incorrect calculation methodology in measurement of time to next start ✓ Resolved problem of not resetting on software counter used for "emergency re-start" ✓ Resolved problem of counting methodology for the "number of hot(cold) starts" ✓ Resolved problem of visibility on LCD ✓ Resolved missing modbus address (operand) of the cell 091D ✓ Resolved courier coordinate cell error regarding second stage overcurrent pickup setting ✓ Resolved correlation problem between relay output 3 operation and CB operating time counter ✓ Hysterisis for under/over frequency protection function is reduced to 0.05 Hz	V2.09 or later	TG1.1555
A3.1(07) P241 only Cont..	E	A		✓ Inclusion of filters for event recorder ✓ RDF file is modified ✓ Courier co-ordinates in the communication column are modified to relieve inconsistency in courier communication cell [0Exx] numbering	V2.09 or later	TG1.1555

Relay type: P241/2/3/…						
Software Version		Hardware Suffix	Original Date of Issue	Description of Changes	S1 Compatibility	Technical Documentation
Major	Minor					
A4.1 (08) P241 only	B	A	Dec2000	✓ Resolved problem of inaccuracies in KWh measurement which arises after a long period of operation ✓ The two thresholds of the overcurrent protection function are changed from 1 A to 0.2 A. Also the second threshold of the I2 overcurrent protection function is changed from 0.2 A to 0.05 A	V2.09 or later	TG1.1555
	C	A	Feb2001	✓ Resolved problem of timer start initialization for drop off time of the out-of-step protection function ✓ Resolved problem of opto command to change setting group ✓ Resolved problem of cold(hot) number of start after re-boot of relay ✓ Resolved problem of inaccuracies in KWh measurement	V2.09 or later	TG1.1555
	D	A	Apr2001	✓ Correction for number of registers declared in the modbus (2 instead of 3 on G125 only) ✓ Resolved problem of fault current measurement via modbus with G125 format	V2.09 or later	TG1.1555
	E	A	Sep2001	✓ Resolved incorrect generation of error code 0x9300ffd2 which occurred during short circuit test at 70 Hz ✓ Corrected for wrong phase indication at the time of undervoltage protection activity	V2.09 or later	TG1.1555
	F	A	Nov2001	✓ Corrected for proper RTD number indication when corresponding RTD trip cell is active ✓ Correction for intermittent twice resetting requirement of trip LED ✓ Resolved initialization problem related to protection/PSL programs secondary effect on LEDs and output relays	V2.09 or later	TG1.1555
	G	A	Nov2001	✓ Resolved initialization problem related to protection/PSL programs secondary effect on LEDs and output relays	V2.09 or later	TG1.1555
	H	A	Nov2001	✓ Resolved incorrect timing for trip operation under second stage negative phase sequence protection function	V2.09 or later	TG1.1555

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Relay type: P241/2/3/…						
Software Version		Hardware Suffix	Original Date of Issue	Description of Changes	S1 Compatibility	Technical Documentation
Major	Minor					
A4.1 (08) P241 only		A	Mar2002	✓ Resolved generation of plerr error code on MODBUS to enhance data access method ✓ Courier co-ordinates in the communication column are modified to relieve inconsistency in courier communication cell [0Exx] numbering ✓ Corrected for mal-operation of thermal over load function after battery back-up RAM initialization when no RTD module is present	V2.09 or later	TG1.1555
A4.1(09) P241 only	A	A	Mar2002	✓ Correction of the method by which I2 magnitude is calculated when "D E/F" function is enabled ✓ Resolved incorrect correlation between CT ratio and derived E/F threshold	V2.09 or later	TG1.1555
	B	A	Jun2002	✓ Resolved problem of continuous EEPROM test (P241 only) ✓ Resolved problem of long polling duration of thermal protection function as well as correction for IMAX on the same function (P241 only)	V2.09 or later	TG1.1555
	C	A	Aug2002	✓ Resolved problem of unwanted disabling of I2>1 when thermal overload function is enabled (P241 only)	V2.09 or Later	TG1.1555
	E	A	Apr2004	✓ Resolved intermittent locking out the user interface and COMMS and loss of data when disturbance recorder is triggered ✓ Resolved modbus frame reception problem due to timer mismanagement	V2.09 or later	TG1.1555
	F	A	Dec-04	✓ Resolved problem of resolution on analog channels ✓ Resolved problem of correct acquisition of 5 A CT choice	V2.09 or later	TG1.1555
	E	A	Aug 2004	✓ Resolved problem with disturbance recorder triggering which could cause loss of record data ✓ Resolved unreliable MODBUS framing	V2.09 or Later	TG1.1555

Relay type: P241/2/3/…						
Software Version		Hardware Suffix	Original Date of Issue	Description of Changes	S1 Compatibility	Technical Documentation
Major	Minor					
	F	A	Jan 2005	✓ Software enhanced to reduce CPU usage during Event log ✓ Correction for 5 A CT connection ✓ Correction for flickering effect on LCD at low input current	V2.09 or Later	TG1.1555
	G	A	Apr 2005	✓ Correction of missing error codes during re-boots when S/W is upgraded from A 4.1F	V2.09 or Later	TG1.1555
B1.0 (20)		C	Jul 2004	✓ Addition of 2 new P24x relay models P242 and P243. P242 is the same as P241 but with additional inputs/outputs. P243 is the same as P242 except it has additional differential protection. P242/3 use Eight channel OPTO input card and Eight channel Relay Output card, increasing the total programmable inputs to 16 and the total programmable outputs to 16 ✓ User alarms are added and number of existing alarms are increased by 32 ✓ Addition of Circuit Breaker Failure function ✓ Optional addition of 4 analog inputs and 4 analog outputs (current loop input output - CLIO) function. Each analog/transducer input and output selectable as 0-1/0-10/0-20/4-20 mA ✓ Addition of measurement of I2/I1 to " measurement 1 " column ✓ Addition of hottest RTD measurement and its assigned number to "measurement 1" column ✓ Addition of Clear Event selection to "record control" column ✓ Extra disturbance recorder channel is added to the disturbance recorder to increase the total to Eight ✓ Addition of numeric alarm setting to all four WHr and VArHr energy measurement functions in the "measurement setup" column ✓ Relay OUTPUTs and LEDs test facility via MODBUS is disabled to improve safety	V2.09 or later	TG1.1555 & P24x/EN T/A11

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Relay type: P241/2/3/…						
Software Version		Hardware Suffix	Original Date of Issue	Description of Changes	S1 Compatibility	Technical Documentation
Major	Minor					
Firmware and Service Manual				✓ Minimum current threshold for the second stage unbalance protection function is changed from 200 mA to 50 mA		
				✓ Enhancement of motor start detection method by including current in conjunction with circuit breaker auxiliary contact		
				✓ Inclusion of temperature measurement in Fahrenheit unit as well as Ni100 and Ni120 options to RTDs temperature measurement		
				✓ Enhancement of programmable opto input module to operate at a wider range of voltage supply		
				✓ Inclusion of ddb signal DDB_ALARM_BATTERY_FAIL		
				✓ Inclusion of ddb signal for password control		
				✓ Number of available DDB elements increased to 1024		
				✓ Average current is replaced with RMS current in calculation of Ieq in thermal protection algorithm		
				✓ Resolved generation of plerr error code on MODBUS to enhance data access method		
				✓ Minor navigation bug (in cell 0804) removed		
				✓ Addition of third setting "test mode" in the commissioning tests column with options disable/enable		
				✓ Courier co-ordinates in the communication column are modified to relieve inconsistency in Courier communication cell numbering		
				✓ Resolved incorrect generation of error code 0x9300ffd2 which occurred during short circuit test at 70 Hz		
				✓ Correction for wrong phase indication at the time of undervoltage protection function activity		
				✓ Correction for RTD temperature measurement in MODBUS fault records		
				✓ Correction for proper operation of the counter used for "number of start" function when the function is disabled and "stall detection" function is enabled at the same time		

Relay type: P241/2/3/…						
Software Version		Hardware Suffix	Original Date of Issue	Description of Changes	S1 Compatibility	Technical Documentation
Major	Minor					
	P24x/EN VH/I72			✓ Correction for proper RTD number indication when corresponding RTD trip cell is active		
				✓ Correction for intermittent twice-resetting requirement of trip LED		
				✓ Resolved initialization of protection/PSL programs secondary effect on LEDs and output relays		
				✓ Resolved re-scaling problem for I^ maintenance and I^ lockout settings arising from a change in Broken I^ setting in the MICOM S1 setting file		
				✓ Resolved incorrect timing for trip operation under second stage negative phase sequence function		
				✓ Resolved zero sequence current measurement algorithm. The quantity was obtained from derived nominal current rather than measured nominal current		
				✓ Correction for mal-operation of thermal over load function after battery back-up RAM initialization when no RTD module is present		
				✓ Correction of the method by which negative phase sequence current magnitude is calculated when "derived E/F" function in the "configuration" column is enabled		
				✓ Resolved incorrect correlation between CT ratio and derived E/F threshold		
				✓ Removal of undesirable command for continuous test of EEPROM		
				✓ Change of the acquisition time for thermal protection function from 50 ms to 20 ms		
				✓ Resolved momentary miss-representation of positive and negative phase sequence current magnitudes and mal-functioning of first stage I2 trip function when thermal over load function is enabled		
				✓ Resolved mal-operation of Derived E/F function when under test condition due to missing I2 polarizing quantity		
				✓ Resolved improper dependency rules concerning RTD label in second group setting column		

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Relay type: P241/2/3/…						
Software Version		Hardware Suffix	Original Date of Issue	Description of Changes	S1 Compatibility	Technical Documentation
Major	Minor					
	A	C	Aug2005	✓ Correction to acquisition of voltage inputs	V2.09 or later	TG1.1555 & P24x/EN T/A11
	B	C	Jan2005	✓ Resolved scaling problem of analog outputs on CLIO board write register ✓ Resolved problem of correct acquisition of 5 A CT choice ✓ Resolved problem of resolution on analog channels ✓ Resolved scaling problem of analog outputs on CLIO board write register ✓ Resolved problem of correct acquisition of 5 A CT choice ✓ Resolved problem of not recording the IA2 data on disturbance recorder ✓ Resolved problem of resolution on analog channels ✓ Resolved problem of downloading default PSL via front port of P241 due to incompatibility of the platform version	V2.09 or later	TG1.1555 & P24x/EN T/A11
	A	C	Jun2005	✓ Resolved problem of upgrading software version from A4.1e to A4.1f on P241 which caused cyclic reboot ✓ Resolved problem on MODBUS driver giving rise to cyclic reboot at 60 Hz	V2.11 or later	TG1.1555 & P24x/EN T/A11
B1.2 (31)	A	C	Mar2006	✓ Resolved display of IA2,IB2 and IC2 differential bias on measurement 1 column of P242 ✓ Resolved problem of resetting trip relay and led after protection function operation and function is disabled ✓ Resolved intermittent problem of not recognizing RTD module. 30 ms delay was included ✓ Resolved problem of re-setting back to default setting (24/27 V) of universal Vcc setting of programmable inputs following a reboot ✓ Resolved problem of re-setting LED alarm for "CB failed trip" on the front panel ✓ Resolved error code 0x8439007C - unexpected event related to "Watt Fwd Alarm"	V2.11 or later	TG1.1555 & P24x/EN T/A11

Relay type: P241/2/3/…						
Software Version		Hardware Suffix	Original Date of Issue	Description of Changes	S1 Compatibility	Technical Documentation
Major	Minor					
				✓ Resolved "IN Derived Mag" measurement problem, CT ratio dependency was using the SEF CT ratio instead of phase CT ratio, Derived E/F protection is not affected		
B1.3 (32)	A	C	Mar2007	✓ Addition of Hour run meter feature ✓ Resolved conflict between "commissioning test" being enabled "test mode" blocked and operation of output relays ✓ Resolved initialization problem of KWh metering after relay is powered down and back to ON	V2.14 (requires modification)	TG1.1555 & P24x/EN T/A11
B1.4 (33)	B	C	Mar2007	✓ Resolved re-boot error code 0x8232ffd2 which was generated on P243 set at 60Hz ✓ Resolved initialization problem of KWh metering after relay is powered down and back to ON	V2.14 (requires modification)	TG1.1555 & P24x/EN T/A11
B1.5 (33)		A	Apr2007	✓ Adaptation to recognize new RTD board ZN0044-1 (and of course previous board ZN0010-1). ZN0044 design has improved filtering ✓ Resolved initialization problem of KWh metering after relay is powered down and back to ON	V2.09 or later	TG1.1555 & P24x/EN T/A11
A4.3 (09) P241 only		C	Oct2007	✓ Resolved problem of events extraction by PACiS system via modbus communication due to the system being unable to synchronize P24x	V2.14 (requires modification)	TG1.1555 & P24x/EN T/A11
B1.6(33)		C	Nov2007	✓ Resolved problem of all latched relay contacts dropping off for 5 ms on relay board 2 if another relay contact is set ON. This only affects P242/3 relays which have 2 relay boards of 8 contacts ✓ Resolved problem of relay contacts dropping off for 3ms when another relay is set on after a relay reboot ✓ Resolved problem of Out Of Service LEDs not turning off after Commission Tests Test Mode setting is disabled	V2.14 (requires modification)	TG1.1555 & P24x/EN T/A11
B1.7(33)		C	Dec 2008	✓ Fixes major bug (when using multiple setting groups, changes of setting group using Courier or PAST will not update PSL group after first change)	V2.14 (requires modification)	TG1.1555 & P24x/EN T/A11

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Relay type: P241/2/3/…						
Software Version		Hardware Suffix	Original Date of Issue	Description of Changes	S1 Compatibility	Technical Documentation
Major	Minor					
B1.8(33)		C	July 2009	✓ Control inputs have been included (remote CB control using IEC 103 is now possible) ✓ Resolved issue of Modbus error when master station requests "Motor Run time" and the corresponding value is greater than 328 hours	V2.14 and S1 Studio 3.1.0	TG1.1555 & P24x/EN T/A11
B2.0(34)		J(P241) K(P242/3)	Jan 08	✓ Includes Field Failure protection function (40) ✓ Includes Anti Backspin protection function (27 remanant) ✓ Hot keys and programmable function keys (P242/3 only) have been added ✓ Second rear communication port (EIA(RS)232/EIA(RS)485) has been added ✓ Tri-State color LED`s (P242/3 only) have been added ✓ Dual characteristics optos and opto filter control have been added ✓ Control inputs have been included (remote CB control using IEC 103 is now possible)	V2.14 or later	TG1.1555 & P24x/EN M/A11
C1.1 (40)		J(P241) K(P242/3)	May 08	✓ A new DDB#118 Trip LED has been added ✓ Default PSL is modified to include new DDB#118 Trip LED ✓ Trip relay 3 restriction is removed ✓ 3 Phase volt check to ensure correct phase sequence before start has been added ✓ Measurement 4 menu is amended to include Number of Field Failure 1 Trip, Number of Field Failure 2 Trip, Number of I>3 Trip and Number of I>4 trip ✓ PSL positional data extraction facility has been included	V2.14 or later	TG1.1555 & P24x/EN M/A11

Relay type: P241/2/3/…						
Software Version		Hardware Suffix	Original Date of Issue	Description of Changes	S1 Compatibility	Technical Documentation
Major	Minor					
C2.0 (41)		J(P241) K(P242/3)	Aug 08	✓ Short Circuit Protection function is enhanced to include 2 stages of IDMT and 2 stages of DT ✓ A new non-protection function "Phase Rotation" has been added ✓ Visibility conflict between Out of Step and Field Failure protection functions is removed	V2.14 or later	TG1.1555 & P24x/EN M/A11
C3.0 (45)		J(P241) K(P242/3)	Dec 08	✓ Inclusion of CT and VT supervision ✓ Supports Chinese and Russian HMI ✓ Additional 4 opto inputs and 4 relay outputs as an option (P241 only) ✓ Migrate DDB from 1024 to 2048 ✓ Resolved Emergency Restart problem ✓ Resolved RTD calibration problem ✓ Resolved visibility issue between "Nb Emergency Rst" and "Reset Nb.Em.Rst" cells in Measurement 3 column not being coherent with "Emergency Rest." Cell ✓ Resolved problem of changing field failure cell In configuration column not being taken into account by the relay ✓ Resolved visibility issues with Micom S1 on Derived E/F and Sensitive E/F: reset characteristics should be always DT (for IEC/UK curves) ✓ Resolved inconsistency between the PSL used and the active setting group when changing setting group via the commands in S&R Courier or PAST ✓ Removed dependency of "Limit Nb Starts" on "Stall detection" start criteria. Hence no need to enable "Stall Detection" to activate "Limit Nb Starts" Relay 4 in the default PSL and associated default LEDs on front panel will now operate correctly	V2.14 and S1 Studio 3.1.0	TG1.1555 & P24x/EN M/A11
C4.0 (46)		J(P241) K(P242/3)	Aug 09	✓ Resolved issue of incorrect file headers in data model 46. Data model 46 has been removed from cortec configurator	V2.14 and S1 Studio 3.1.0	P24x/EN M/C22

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Relay type: P241/2/3/…						
Software Version		**Hardware Suffix**	**Original Date of Issue**	**Description of Changes**	**S1 Compatibility**	**Technical Documentation**
Major	**Minor**					
C4.0 (47)		J(P241) K(P242/3)	Jan 09	✓ IEC 61850 Phase II Enhancements ✓ Read Only Mode ✓ Resolved problem with Stall detection threshold ✓ Resolved problem of CLIO output over flow	V2.14 and S1 Studio 3.1.0	P24x/EN M/C32
C5.1 (51)		K (P243)	November 2011	✓ Rebranded to Alstom. Released for P243 and IEC61850 only ✓ Integration of platform L1.7 (L1.2 changed to L1.7) to resolve the issues of "discrepancy in the DR analogue signals magnitudes if the CT and VT ratios (primary/secondary) are not integers" "NIC no response." "IEC61850 communication terminating after operating a control with control status in RCB" and "change of state of Opto Inputs getting lost occasionally between main card and Ethernet card." ✓ Resolved issue of max Pre-Time duration too short in Disturbance Record ✓ Resolved issue of Disturbance Record not handling DDB elements > 1024 ✓ Resolved issue of "when « Virtual Output x » DDB is disabled in « Record Control » column, any change in « Virtual Output x » is not reported in gooses." ✓ Resolved issue of incorrect display of angle in Measurement Viewer / Courier Device Browser/PAST ✓ Resolved issue of some Short Circuit settings changed using front panel not being taken into account ✓ Resolved issue of Browsing /DR folder intermittent fail using IEC 61850 ✓ Resolved issue of Information concerning RTD inputs state not being updated in "Measurements 3" column ✓ Removal of some labels not required In Digital Input X cells ("Disturb Recorder" column)	V2.14 and S1 Studio 3.1.0	P24x/EN M/C32

Relay type: P241/2/3/…						
Software Version		Hardware Suffix	Original Date of Issue	Description of Changes	S1 Compatibility	Technical Documentation
Major	Minor					
				✓ Resolved issue of some Start elements missing When displaying Fault Record on LCD		
				✓ Resolved issue of distorted waveform in the DR		
				✓ Resolved issue of CTS IN pickup not matching CTS setting		
				✓ Resolved issue of I0 and IN measurement		
C5.1a_A (51)		J(P241) K(P242/3)	November 09	✓ User programmable curve facility enhancement for Thermal, Short Circuit, Derived Earth Fault and Sensitive Earth Fault protection ✓ IEC 61850 Phase 2.1 enhancement. Phase 2.1 includes; Energy measurements and Reset controls for demand and thermal measurements using the MMTR Logical Node. Also Unit multipliers are provided for all measurements ✓ Redundant Ethernet communication enhancement ✓ Opto inputs 1 ms time stamping accuracy enhancement ✓ Resolved the issue of maximum pre-time duration being too short in the Disturbance Recorder (DR). Pre fault trig time in DR increased to 5 sec at 50 HZ ✓ Resolved problem of DR not handling DDBs > 1024 ✓ Resolved issue of Modbus error when master station requests "Motor Run time" and the corresponding value is greater than 328 hours ✓ Dependency of "No. of Starts" with "Thermal Protection" function is removed. Thermal state will be evaluated whether or not "Thermal Protection" function is enabled ✓ Minimum current and voltage thresholds (20 mA and 1 V for In =1A and Vn = 100/120 V, 100 mA and 1 V for In = 5A and Vn = 100/120 V) are included in the "Out of Step" protection function. This function is blocked if current and voltage are less than threshold ✓ Dependency of "Stall detection" threshold with I$_{th}$ setting is removed	V2.14 and S1 Studio 3.1.0	P24x/EN M/C52

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Relay type: P241/2/3/…						
Software Version		Hardware Suffix	Original Date of Issue	Description of Changes	S1 Compatibility	Technical Documentation
Major	Minor					
C6.2 or C6.3_A (57)		J(P241) K(P242/3)	November 09	✓ CLIO output "maximum power" setting is increased to 30 MW, MVA and MVAR ✓ Resolved problem of reading negative angles in Measurement Viewer, Courier Device browser and PAST ✓ Resolved problem of reading non zero Active, reactive and apparent power when breaker is open. These measurements will read zero when current is less than 5% Inom and voltage is less than 10% Unom ✓ Resolved issue of non-trip when 1<I/Ith<1.1 in IDMT curves. Trip time will be the the same as when I/Ith = 1.1 ✓ Resolved issue of not reporting in Gooses when "Virtual Output x" DDB is disabled in "Record Control" ✓ IEEE TD setting range is changed from 0.5~15 to 0.01~100 ✓ Resolved problem of Short Circuit setting changes via LCD or Courier device browser not taking effect before reboot or another Short Circuit column change ✓ Resolved problem of missing "Hz" and "%" characters in default display when language is set to Chinese. ✓ I2> function corrected (In replaced by Is)	V2.14 and S1 Studio 3.1.0	P24x/EN M/C52

Relay type: P241/2/3/…						
Software Version		**Hardware Suffix**	**Original Date of Issue**	**Description of Changes**	**S1 Compatibility**	**Technical Documentation**
Major	**Minor**					
60	A	J(P241) K(P242/3)	July 2011	✓ V2> (2 stages) added ✓ Adjustable reacceleration and auto restart added ✓ Selection of volt measurement as phase-phase or ph-earth added ✓ I>, V< and V2> inhibit and block DDBs added ✓ Dependency between Field Failure and Out of Step removed, both functions can be independently Enabled. ✓ Zero power logic changed to include effect of I as well as V (and function) ✓ Resolved problem when displaying Fault Record on LCD, some Start elements may be missing ✓ ✓ Resolved problem of discrepancy in the disturbance recorder analogue signal magnitudes if the CT and VT ratios are not integers ✓ Resolved problem of some start elements not being displayed on the LCD ✓ Non existent labels removed from "Disturbance Recorder" column ✓ Resolved issue of not being able to read some of the fault record information via MODBUS ✓ Resolved missing MODBUS address for cell [0A11] VT connecting mode ✓ Resolved MODBUS overlap address between IN derived and IA2 Magnitude ✓ Maximum setting range for V<1, V<2, V>1 and V>2 time delay reduced to 600 sec from 7200 sec ✓ Maximum setting range of I2> increased to 4In from 0.8In ✓ New platform integration (L6.2) ✓ Resolved issue of Trip Element 2 display on LCD in case of fault	V2.14 and S1 Studio 3.1.0 and S1 Agile	P24x/EN M/D62

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Relay type: P241/2/3/…						
Software Version		Hardware Suffix	Original Date of Issue	Description of Changes	S1 Compatibility	Technical Documentation
Major	Minor					
	B	J(P241) K(P242/3)	October 2011	✓ CS103 Measurements (generic services) added ✓ Resolved issue of not blocking V2> when VTS condition exists ✓ Resolved visibility issue in the menu structure between Auto-Restart and CBF ✓ Resolved issue of I_0 and I_N measurement ✓ Resolved issue of distorted waveform in the DR ✓ Resolved issue of CTS IN pickup not matching CTS setting	V2.14 and S1 Studio 3.1.0 and S1 Agile	P24x/EN M/E62
	C	J(P241) K(P242/3)	January 2013	✓ Minimum setting range of I> is reduced from 0.2In to 0.08In ✓ If PSL of non existent Group 3 or 4 is requested to be extracted via MiCOM S1 (Studio or Agile), Group 1 PSL will be extracted automatically ✓ Menu Text translations are harmonized with other Px40 products ✓ Resolved "Reac.Time" unit issue when setting value is changed to primary ✓ Resolved Issue related to the user operation of "Extract all configuration"	V2.14 and S1 Studio 3.1.0	P24x/EN M/F72
	D	J(P241) K(P242/3)	October 2014	✓ Resolved Issues related to "Abs" and "FF" ✓ Resolved Issues related to IEC61850 application and flash memory	V2.14 and S1 Studio 3.1.0	P24x/EN M/F72
	E	J(P241) K(P242/3)	February 2016	✓ Resolved issue related to Field Failure. Setting range is corrected so that this element can use standard wiring. ✓ Resolved issue related the "start criteria" when chosen as current only and "I+52A". ✓ Resolved issue related to the change of state of the output contact when setting is extracted from the relay. ✓ Resolved issue related to "Time to next Start". ✓ Resolve issue of saturation of energy values after 2^{32}	V2.14 and S1 Studio 3.1.0	P24x/EN M/G72

Relay type: P241/2/3/…						
Software Version		**Hardware Suffix**	**Original Date of Issue**	**Description of Changes**	**S1 Compatibility**	**Technical Documentation**
Major	**Minor**					
	F	J(P241) K(P242/3)	September 2017	✓ Bug fixes	MiCOM S1 agile 1.3.1	P24x/EN M/H72
	H	J(P241) K(P242/3)	July 2018	✓ Bug fixes and improvement ✓ Resolved data model issue related to Russian language	MiCOM S1 agile 1.4	P24x/EN M/I72
70	B	J(P241) K(P242/3	Jan 2020	✓ IEC61850 ED2 ✓ GOOSE Performance Enhancement Phase 2 ✓ Test mode and simulation feature in IEC61850 (ed2) ✓ Some new Logical Nodes extend in IEC61850 (ed2) ✓ EB Heartbeat ✓ Compress the image file of EB ✓ Editable Logical Device and Logical Node ✓ Fast GOOSE ✓ New Ethernet card support ✓ New Duplicate GOOSE Functionality ✓ Uniqueness of Control ✓ Reset delay for Under voltage characteristic ✓ Inclusion of Pole dead logic for Undervoltage	MiCOM S1 agile 1.4.1	P24x/EN M/J82

Setting File Software Version	Relay Software Version (P24x)																			
	B1.0 (20)	B1.0 (20A)	B1.0 (20B)	B1.2 (31)	B1.3 (32)	B1.4 (33)	B1.5 (33)	B1.6 (33)	B1.7 (33)	B1.8 (33)	B2.0 (34)	C1.1 (40)	C2.0 (41)	C3.0 (45)	C4.0 (46)	C4.0 (47)	C5.1 (51)	C6.2 (57)	60	70
20	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×	×	×	×	×	×	×	×
30	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×	×	×	×	×	×	×	×
31	×	×	×	✓	✓	✓	✓	✓	✓	✓	✓	×	×	×	×	×	×	×	×	×
32	×	×	×	×	✓	✓	✓	✓	✓	✓	✓	×	×	×	×	×	×	×	×	×
33	×	×	×	×	×	×	✓	✓	✓	✓	✓	×	×	×	×	×	×	×	×	×
34	×	×	×	×	×	×	×	×	×	×	✓	×	×	×	×	×	×	×	×	×
40	×	×	×	×	×	×	×	×	×	×	×	✓	✓	✓	✓	✓	✓	✓	×	×
41	×	×	×	×	×	×	×	×	×	×	×	✓	✓	✓	✓	✓	✓	✓	×	×
45	×	×	×	×	×	×	×	×	×	×	×	×	✓	✓	✓	✓	✓	✓	×	×
46	×	×	×	×	×	×	×	×	×	×	×	×	×	×	✓	✓	✓	✓	×	×
47	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	✓	✓	✓	×	×
51	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	✓	✓	×	×
57	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	✓	×	×
60	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	✓	✓	×
70	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	✓

		Relay Software Version (P241 only)																					
		A3.0 (00)	A3.1 (00)	A3.1 (02)	A3.1 (04)	A3.1 (07)	A4.0 (03)	A4.0 (06)	A4.0 (08)	A4.1 (08)	A4.1 (09)	A4.2 (09)	A4.3 (09)										
	00	✓	✓	×	×	×	×	×	×	×	×	×	×										
	02	×	×	✓	×	×	×	×	×	×	×	×	×										
	04	×	×	×	✓	×	×	×	×	×	×	×	×										
	07	×	×	×	×	✓	×	×	×	×	×	×	×										
	03	×	×	×	×	×	✓	×	×	×	×	×	×										
	06	×	×	×	×	×	×	✓	×	×	×	×	×										
	08	×	×	×	×	×	×	×	✓	✓	×	×	×										
	09	×	×	×	×	×	×	×	×	×	✓	✓	✓										

Setting File Software Version

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PSL File Software Version	Relay Software Version (P24x)																			
	B1.0 (20)	B1.0 (20A)	B1.0 (20B)	B1.2 (31)	B1.3 (32)	B1.4 (33)	B1.5 (33)	B1.6 (33)	B1.7 (33)	B1.8 (33)	B2.0 (34)	C1.1 (40)	C2.0 (41)	C3.0 (45)	C4.0 (46)	C4.0 (47)	C5.1 (51)	C6.2 (57)	60	70
20	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×	×	×	×	×	×	×	×
30	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×	×	×	×	×	×	×	×
31	×	×	×	✓	✓	✓	✓	✓	✓	✓	✓	×	×	×	×	×	×	×	×	×
32	×	×	×	×	✓	✓	✓	✓	✓	✓	✓	×	×	×	×	×	×	×	×	×
33	×	×	×	×	×	✓	✓	✓	✓	✓	✓	×	×	×	×	×	×	×	×	×
34	×	×	×	×	×	×	✓	✓	✓	✓	✓	×	×	×	×	×	×	×	×	×
40	×	×	×	×	×	×	×	×	×	×	×	✓	✓	×	×	×	×	×	×	×
41	×	×	×	×	×	×	×	×	×	×	×	×	✓	×	×	×	×	×	×	×
45	×	×	×	×	×	×	×	×	×	×	×	×	×	✓	×	×	×	×	×	×
46	×	×	×	×	×	×	×	×	×	×	×	×	×	×	✓	✓	✓	✓	×	×
47	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	✓	✓	✓	×	×
51	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	✓	✓	×	×
57	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	✓	×	×
60	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	✓	×
70	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	✓

		Relay Software Version (P241 only)																																
		A3.0 (00)	A3.1 (00)	A3.1 (02)	A3.1 (04)	A3.1 (07)	A4.0 (03)	A4.0 (06)	A4.0 (08)	A4.1 (08)	A4.1 (09)	A4.2 (09)	A4.3 (09)																					
PSL File Software Version	00	✓	✓	×	×	×	×	×	×	×	×	×	×																					
	02	×	×	✓	×	×	×	×	×	×	×	×	×																					
	04	×	×	×	✓	×	×	×	×	×	×	×	×																					
	07	×	×	×	×	✓	×	×	×	×	×	×	×																					
	03	×	×	×	×	×	✓	×	×	×	×	×	×																					
	06	×	×	×	×	×	×	✓	×	×	×	×	×																					
	08	×	×	×	×	×	×	×	✓	✓	×	×	×																					
	09	×	×	×	×	×	×	×	×	×	✓	✓	✓																					

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Menu Text File Software Version	Relay Software Version (P24x)																			
	B1.0 (20)	B1.0 (20A)	B1.0 (20B)	B1.2 (31)	B1.3 (32)	B1.4 (33)	B1.5 (33)	B1.6 (33)	B1.7 (33)	B1.8 (33)	B2.0 (34)	C1.1 (40)	C2.0 (41)	C3.0 (45)	C4.0 (46)	C4.0 (47)	C5.1 (51)	C6.2 (57)	60	70
20	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×	×	×	×	×	×	×	×
30	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×	×	×	×	×	×	×	×
31	×	×	×	✓	✓	✓	✓	✓	✓	✓	✓	×	×	×	×	×	×	×	×	×
32	×	×	×	×	✓	✓	✓	✓	✓	✓	✓	×	×	×	×	×	×	×	×	×
33	×	×	×	×	×	✓	✓	✓	✓	✓	✓	×	×	×	×	×	×	×	×	×
34	×	×	×	×	×	✓	✓	✓	✓	✓	✓	×	×	×	×	×	×	×	×	×
40	×	×	×	×	×	×	×	×	×	×	×	✓	✓	×	×	×	×	×	×	×
41	×	×	×	×	×	×	×	×	×	×	×	✓	×	×	×	×	×	×	×	×
45	×	×	×	×	×	×	×	×	×	×	×	×	×	✓	×	×	×	×	×	×
46	×	×	×	×	×	×	×	×	×	×	×	×	×	×	✓	✓	✓	✓	×	×
47	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	✓	✓	✓	×	×
51	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	✓	✓	×	×
57	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	✓	×	×
60	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	✓	×
70	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	✓

Menu text remains compatible within each software version but is not compatible across different versions

Menu Text File Software Version	Relay Software Version (P241 only)											
	A3.0 (00)	A3.1 (00)	A3.1 (02)	A3.1 (04)	A3.1 (07)	A4.0 (03)	A4.0 (06)	A4.0 (08)	A4.1 (08)	A4.1 (09)	A4.2 (09)	A4.3 (09)
00	✓	✓	×	×	×	×	×	×	×	×	×	×
02	×	×	✓	×	×	×	×	×	×	×	×	×
04	×	×	×	✓	×	×	×	×	×	×	×	×
07	×	×	×	×	✓	×	×	×	×	×	×	×
03	×	×	×	×	×	✓	×	×	×	×	×	×
06	×	×	×	×	×	×	✓	✓	✓	×	×	×
08	×	×	×	×	×	×	×	✓	✓	×	×	×
09	×	×	×	×	×	×	×	×	×	✓	✓	✓

VH

APPENDIX A

ORDERING OPTIONS

P241	Motor Protection Relay (40TE Case)	P241											
Vx Aux Rating													
24-54 Vdc		7											
48-125 Vdc (40-100 Vac)		8											
110-250 Vdc (100-240 Vac)		9											
In/Vn Rating													
In = 1A/5A, Vn = 100/120V			1										
Hardware Options													
Nothing				1									
IRIG-B only (Modulated)				2									
Fiber Optic Rear Comms Port (withdrawn)				3									
IRIG-B (Modulated) & Fiber Optic Rear Comms Port				4									
Ethernet (100 Mbits/s) without IRIG-B				6									
2nd Rear Comms. Board				7									
IRIG-B (Modulated) & 2nd Rear Comms Board				8									
Ethernet (100Mbit/s) plus IRIG-B (Modulated)				A									
Ethernet (100Mbit/s) plus IRIG-B (Un-modulated)				B									
IRIG-B (Un-modulated)				C									
Redundant Ethernet Self-Healing Ring, 2 multi-mode fibre ports + Modulated IRIG-B				G									
Redundant Ethernet Self-Healing Ring, 2 multi-mode fibre ports + Un-modulated IRIG-B				H									
Redundant Ethernet RSTP, 2 multi-mode fibre ports + Modulated IRIG-B				J									
Redundant Ethernet RSTP, 2 multi-mode fibre ports + Un-modulated IRIG-B				K									
Redundant Ethernet Dual-Homing Star, 2 multi-mode fibre ports + Modulated IRIG-B				L									
Redundant Ethernet Dual-Homing Star, 2 multi-mode fibre ports + Un-modulated IRIG-B				M									
Redundant Ethernet PRP/HSR, 2 fibre ports + Modulated IRIG-B				N									
Redundant Ethernet PRP/HSR, 2 fibre ports + Unmodulated IRIG-B				P									
Redundant Ethernet PRP/HSR/RSTP/Hot Standby, 2 multi-mode fibre ports + Modulated/Un-Modulated IRIG-B				R									
Redundant Ethernet PRP/HSR/RSTP/Hot Standby, 2 copper ports RJ45 + Modulated/Un-Modulated IRIG-B				S									
Single Ethernet, PRP/HSR/RSTP/Hot Standby, 1 copper port RJ45 & 1 multi-mode fibre port + Modulated/Un-Modulated IRIG-B				T									
Product Specific													
8 Logic Inputs + 7 Relay Outputs					A								
8 Logic Inputs + 7 Relay Outputs + RTDs					B								
8 Logic Inputs + 7 Relay Outputs + CLIO					C								
12 Logic Inputs + 11 Relay Outputs					E								
Protocol Options													
K-bus						1							
Modbus						2							
IEC 60870-5-103 (VDEW)						3							
IEC 61850 + Courier (via rear RS485 port)						6							
Mounting													
Flush/Panel Mounting with Harsh Env.Coating, White Front Panel							M						
Flush/Panel Mounting with Harsh Env. Coating, with USB Port, Black and Silver Front Panel							S						
Panel Mounting, with harsh environment coating							P						
Language													
Multilingual - English, French, German, Spanish								0					
Multilingual - English, French, German, Russian								5					
Multilingual - English, French, Chinese								C					
Software Issue													
Unless specified the latest version will be delivered									*	*			
Customisation													
Default											0		
Customer specific											A		
Design Suffix													

P242	Motor Protection Relay (60TE Case)	P242											
Vx Aux Rating													
24-54 Vdc		7											
48-125 Vdc (40-100 Vac)		8											
110-250 Vdc (100-240 Vac)		9											
In/Vn Rating													
In = 1A/5A, Vn = 100/120V			1										
Hardware Options													
Nothing				1									
IRIG-B only (Modulated)				2									
Fiber Optic Rear Comms Port (withdrawn)				3									
IRIG-B (Modulated) & Fiber Optic Rear Comms Port				4									
Ethernet (100 Mbits/s) without IRIG-B				6									
2nd Rear Comms Port				7									
IRIG-B (Modulated) plus 2nd Rear Comms Port				8									
Ethernet (100Mbit/s) plus IRIG-B (Modulated)				A									
Ethernet (100Mbit/s) plus IRIG-B (Un-modulated)				B									
IRIG-B (Un-modulated)				C									
Redundant Ethernet Self-Healing Ring, 2 multi-mode fibre ports + Modulated IRIG-B				G									
Redundant Ethernet Self-Healing Ring, 2 multi-mode fibre ports + Un-modulated IRIG-B				H									
Redundant Ethernet RSTP, 2 multi-mode fibre ports + Modulated IRIG-B				J									
Redundant Ethernet RSTP, 2 multi-mode fibre ports + Un-modulated IRIG-B				K									
Redundant Ethernet Dual-Homing Star, 2 multi-mode fibre ports + Modulated IRIG-B				L									
Redundant Ethernet Dual-Homing Star, 2 multi-mode fibre ports + Un-modulated IRIG-B				M									
Redundant Ethernet PRP/HSR, 2 fibre ports + Modulated IRIG-B				N									
Redundant Ethernet PRP/HSR, 2 fibre ports + Unmodulated IRIG-B				P									
Redundant Ethernet PRP/HSR/RSTP/Hot Standby, 2 multi-mode fibre ports + Modulated/Un-Modulated IRIG-B				R									
Redundant Ethernet PRP/HSR/RSTP/Hot Standby, 2 copper ports RJ45 + Modulated/Un-Modulated IRIG-B				S									
Single Ethernet, PRP/HSR/RSTP/Hot Standby, 1 copper port RJ45 & 1 multi-mode fibre port + Modulated/Un-Modulated IRIG-B				T									
Product Specific													
16 Logic inputs & 16 Relay Outputs					A								
16 Logic inputs & 16 Relay Outputs + RTDs					B								
16 Logic inputs & 16 Relay Outputs + CLIO					C								
16 Logic inputs & 16 Relay Outputs + RTDs & CLIO					D								
Protocol Options													
K-bus						1							
Modbus						2							
IEC 60870-5-103 (VDEW)						3							
IEC 61850 + Courier (via rear RS485 port)						6							
Mounting													
Flush/Panel Mounting with Harsh Env.Coating, White Front Panel							M						
Flush/Panel Mounting with Harsh Env. Coating, with USB Port, Black and Silver Front Panel							S						
Panel Mounting, with harsh environment coating							P						
Language													
Multilingual - English, French, German, Spanish								0					
Multilingual - English, French, German, Russian								5					
Multilingual - English, French, Chinese								C					
Software Version													
Unless specified the latest version will be delivered									*	*			
Customisation													
Default											0		
Customer specific											A		
Design Suffix													
													*

P243	Motor Protection Relay (80TE Case)	P243										
Vx Aux Rating												
24-54 Vdc		7										
48-125 Vdc (40-100 Vac)		8										
110-250 Vdc (100-240 Vac)		9										
In/Vn Rating												
In = 1A/5A, Vn = 100/120V			1									
Hardware Options												
Nothing				1								
IRIG-B only (Modulated)				2								
Fiber Optic Rear Comms Port (withdrawn)				3								
IRIG-B (Modulated) & Fiber Optic Rear Comms Port				4								
Ethernet (100 Mbits/s) without IRIG-B				6								
2nd Rear Comms Port				7								
IRIG-B (Modulated) & 2nd Rear Comms Port				8								
Ethernet (100Mbit/s) plus IRIG-B (Modulated)				A								
Ethernet (100Mbit/s) plus IRIG-B (Un-modulated)				B								
IRIG-B (Un-modulated)				C								
Redundant Ethernet Self-Healing Ring, 2 multi-mode fibre ports + Modulated IRIG-B				G								
Redundant Ethernet Self-Healing Ring, 2 multi-mode fibre ports + Un-modulated IRIG-B				H								
Redundant Ethernet RSTP, 2 multi-mode fibre ports + Modulated IRIG-B				J								
Redundant Ethernet RSTP, 2 multi-mode fibre ports + Un-modulated IRIG-B				K								
Redundant Ethernet Dual-Homing Star, 2 multi-mode fibre ports + Modulated IRIG-B				L								
Redundant Ethernet Dual-Homing Star, 2 multi-mode fibre ports + Un-modulated IRIG-B				M								
Redundant Ethernet PRP/HSR, 2 fibre ports + Modulated IRIG-B				N								
Redundant Ethernet PRP/HSR, 2 fibre ports + Unmodulated IRIG-B				P								
Redundant Ethernet PRP/HSR/RSTP/Hot Standby, 2 multi-mode fibre ports + Modulated/Un-Modulated IRIG-B				R								
Redundant Ethernet PRP/HSR/RSTP/Hot Standby, 2 copper ports RJ45 + Modulated/Un-Modulated IRIG-B				S								
Single Ethernet, PRP/HSR/RSTP/Hot Standby, 1 copper port RJ45 & 1 multi-mode fibre port + Modulated/Un-Modulated IRIG-B				T								
Product Specific												
16 Logic inputs & 16 Relay Outputs					A							
16 Logic inputs & 16 Relay Outputs + RTDs					B							
16 Logic inputs & 16 Relay Outputs + CLIO					C							
16 Logic inputs & 16 Relay Outputs + RTDs & CLIO					D							
Protocol Options												
K-bus						1						
Modbus						2						
IEC 60870-5-103 (VDEW)						3						
IEC 61850 + Courier (via rear RS485 port)						6						
Mounting												
Flush/Panel Mounting with Harsh Env.Coating, White Front Panel							M					
19" Rack Mounting with Harsh Env. Coating, White Front Panel							N					
Flush/Panel Mounting with Harsh Env. Coating, with USB Port, Black and Silver Front Panel							S					
19" Rack Mounting with Harsh Env. Coating, with USB Port, Black and Silver Front Panel							T					
Panel Mounting, with harsh environment coating							P					
Rack Mounting, with harsh environment coating							Q					
Language												
Multilingual - English, French, German, Spanish								0				
Multilingual - English, French, German, Russian								5				
Multilingual - English, French, Chinese								C				
Software Version												
Unless specified the latest version will be delivered									*	*		
Customisation												
Default											0	
Customer specific											A	
Design Suffix												
												*

APPENDIX B

WIRING DIAGRAMS

Model	External Connection Diagram Title	Drawing-Sheet	Issue
All	COMMS OPTIONS MICOM Px40 PLATFORM	10Px4001-1	K
P241	EXTERNAL CONNECTION DIAG: MOTOR PROTECTION RELAY 40TE (8 I/P & 7 0/P)	10P24101-1	R
	EXTERNAL CONNECTION DIAG: MOTOR PROTECTION RELAY 40TE (8 I/P & 7 0/P)	10P24101-2	S
	EXTERNAL CONNECTION DIAG: MOTOR PROTECTION RELAY 40TE (8 I/P & 7 0/P)	10P24101-3	G
	EXTERNAL CONNECTION DIAG: MOTOR PROTECTION RELAY 40TE (8 I/P & 7 0/P + CLIO)	10P24102-1	H
	EXTERNAL CONNECTION DIAG: MOTOR PROTECTION RELAY 40TE (8 I/P & 7 O/P + CLIO)	10P24102-2	F
	EXTERNAL CONNECTION DIAG: MOTOR PROTECTION RELAY 40TE (12 I/P & 11 O/P)	10P24103-1	D
	EXTERNAL CONNECTION DIAG: MOTOR PROTECTION RELAY 40TE (12 I/P & 11 O/P)	10P24103-2	C
P242	EXTERNAL CONNECTION DIAG: MOTOR PROTECTION RELAY 60TE (16 I/P & 16 0/P + RTD & CLIO)	10P24201-1	I
	EXTERNAL CONNECTION DIAG: MOTOR PROTECTION RELAY 60TE (16 I/P & 16 0/P + RTD & CLIO)	10P24201-2	H
P243	EXT. CONNECTION DIAG: MOTOR PROTECTION RELAY (80TE) WITH BIASED DIFFERENTIAL (16 I/P & 16 0/P + CLIO & RTD)	10P24301-1	I
	EXTERNAL CONNECTION DIAG: MOTOR PROTECTION RELAY 80TE (16 I/P & 16 0/P + RTD & CLIO)	10P24301-2	G
	EXT. CONNECTION DIAG: MOTOR PROTECTION RELAY (80TE) WITH HIGH IMPEDANCE DIFF' TIAL (16 I/P & 16 0/P + RTD & CLIO)	10P24301-3	F
	EXT. CONNECTION DIAG: MOTOR PROTECTION RELAY (80TE) WITH HIGH IMPEDANCE DIFF' TIAL (16 I/P & 16 0/P + RTD & CLIO)	10P24301-4	F
	EXT. CONN. DIAG: MOTOR PROTECTION RELAY (80TE) BIASED WITH DIFF' TIAL VEE CONNECT VTs (16 I/P & 16 0/P + RTD & CLIO)	10P24301-5	F

* When selecting the applicable wiring diagram(s), refer to appropriate model's Cortec.

MATERIAL

DESCRIPTION

PART

IRIG-B INPUT

FAULT STATUS RELAY

SK7 1 2 3

RVA TXA } 100 BASE-FX

RXB TXB } 100 BASE-FX

DUAL PORT REDUNDANT ETHERNET BOARD

SK7 STATUS

Pin	Closed	Open
1 - 2	CHANNEL A FAIL	CHANNEL A OK
2 - 3	CHANNEL B FAIL	CHANNEL B OK

OR

IRIG-B INPUT (OPTIONAL)

FAULT STATUS RELAY

SK7 1 2 3

RVA TXA } 100 BASE-FX PORT A

RJ45 1 TX+ 2 TX- 3 RX+ 6 RX- } 10 BASE-T/ 100 BASE-TX PORT B

SK6

REDUNDANT ETHERNET BOARD WITH MIXED MEDIA OR SINGLE PORT ETHERNET BOARD

SK7 STATUS

Pin	Closed	Open
1 - 2	CHANNEL A FAIL	CHANNEL A OK
2 - 3	CHANNEL B FAIL	CHANNEL B OK

OR

IRIG-B INPUT

FAULT STATUS RELAY

SK7 1 2 3

RJ45 1 TX+ 2 TX- 3 RX+ 4 5 6 RX- 7 8 } 10 BASE-T/ 100 BASE-TX PORT A

SK4

RJ45 1 TX+ 2 TX- 3 RX+ 4 5 6 RX- 7 8 } 10 BASE-T/ 100 BASE-TX PORT B

SK5

REDUNDANT COPPER PORT ETHERNET BOARD

SK7 STATUS

Pin	Closed	Open
1 - 2	CHANNEL A FAIL	CHANNEL A OK
2 - 3	CHANNEL B FAIL	CHANNEL B OK

OR

IRIG-B INPUT (OPTIONAL)

SERIAL PORT

	EIA232	EIA485
1	N.C.	N.C.
2	RXD	N.C.
3	TXD	N.C.
4	DTR#	TXRXA
5	-0V	-0V
6	N.C.	N.C.
7	RTS	TXRXB
8	CTS	N.C.
9	N.C.	N.C.

SK4

EIA232 SERIAL PORT

1	DCD
2	RXD
3	TXD
4	DTR#
5	0V
6	N.C.
7	RTS#
8	N.C.
9	N.C.

SK5

PERMANENTLY ACTIVE

REAR COMMS BOARD

OR

FIBRE OPTIC COMMUNICATION (OPTIONAL)

TX

RX

IRIG-B INPUT (OPTIONAL)

IRIG-B BOARD

REAR PORT 1:

EIA485/ KBUS PORT

- 17
+ 18
16 SCN
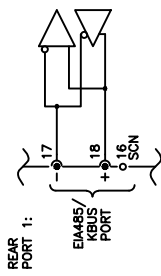
NOTE: FOR TERMINAL BLOCK CONNECTION REFER TO RELEVANT EXTERNAL CONNECTION DIAGRAM. (ALWAYS ON PSU BLOCK)

SK2

DATA READY	1
DATA ACKNOWLEDGE	10
EXTERNAL RESET	16
DOWNLOAD COMMAND	17
D0-D7	2-9
T0-T7	11,12,15,13, 20,21,23,24
0V	19,18,22,25
NOT CONNECTED	14

FRONT TEST/ DOWNLOAD

SK1

TX	1
RX	2
	3
0V	4
	5
CTS	6
RTS	7
N.C.	8
	9

FRONT EIA232 SERIAL PORT

MiCOM P241 (PART)

WATCHDOG CONTACT
WATCHDOG CONTACT
RELAY 1
RELAY 2
RELAY 3
RELAY 4
RELAY 5
RELAY 6
RELAY 7

F11 F12 F13 F14 E1 E2 E3 E4 E5 E6 E7 E8 E9 E10 E11 E12 E13 E14 E15 E16 E17 E18

RTD 1 — B1 B2 B3
RTD 2 — B4 B5 B6
RTD 3 — B7 B8 B9
RTD 10 — B28 B29 B30

COMMS NOTE 5

SEE DRAWING 10Px4001

F17 F18 F16 SCN
EIA485/ KBUS PORT

F1 F2
V_x AC OR DC AUX SUPPLY

CASE EARTH

* POWER SUPPLY VERSION 24-48V (NOMINAL) D.C. ONLY

OPTO 1 — D1 D2
OPTO 2 — D3 D4
OPTO 3 — D5 D6
OPTO 4 — D7 D8
OPTO 5 — D9 D10
OPTO 6 — D11 D12
OPTO 7 — D13 D14
OPTO 8 — D15 D16
COMMON CONNECTION — D17 D18

NOTE 4

MiCOM P241 (PART)

5A 1A 5A 1A 5A 1A 5A 1A

C1 C2 C3 C4 C5 C6 C7 C8 C9 C13 C14 C15 C19 C20 C22 C23 C24

I_A I_B I_C I_N SENSITIVE V_A V_B V_C

NOTE 3

NOTE 2

A B C
PHASE ROTATION

DIRECTION OF FORWARD CURRENT FLOW. NOTE 6

P1 P1 P2 P2 S1 S1 S2 S2 P1 S1 S2 P2

A B C N
a b c n

M

C.T. SHORTING LINKS

(a)

PIN TERMINAL (P.C.B. TYPE)

(b)

NOTES 1.

2. RESIDUAL VOLTAGE MEASUREMENT REQUIRES A 5 LIMB VT OR 3 SINGLE PHASE VT'S.

3. C.T. CONNECTIONS ARE SHOWN 1A CONNECTED AND ARE TYPICAL ONLY.

4. OPTO INPUTS 1 AND 2 MUST BE USED FOR SETTING GROUP CHANGES IF THIS OPTION IS SELECTED IN THE RELAY MENU.

5. FOR COMMS OPTIONS SEE DRAWING 10Px4001.

6. DIRECTION OF FORWARD CURRENT FLOW FOR OPERATION OF THE DIRECTIONAL EF + SEF PROTECTION.

Title:	EXTERNAL CONNECTION DIAG: MOTOR PROTECTION RELAY 40TE (8 I/P & 7 O/P)	Sht: 1
		Next Sht: 2
Drg No:	10P24101	

Issue:	Revision: FIELD VOLTAGE REMOVED. CID HONG-95RDV7		
R		Name: N.JOHNSON	CAD DATA 1:1 DIMENSIONS: mm
Date: 24/06/2013		Chkd:	DO NOT SCALE
Date:			

MiCOM P241 (PART)

WATCHDOG CONTACT
WATCHDOG CONTACT
RELAY 1
RELAY 2
RELAY 3
RELAY 4
RELAY 5
RELAY 6
RELAY 7
RTD 1
RTD 2
RTD 3
RTD 10

F11 F12 F13 F14 E1 E2 E3 E4 E5 E6 E7 E8 E9 E10 E11 E12 E13 E14 E15 E16 E17 E18 B1 B2 B3 B4 B5 B6 B7 B8 B9 B28 B29 B30

COMMS NOTE 5

F17 — SEE DRAWING 10Px4001
F18 +
F16 SCN ○

EIA485/ KBUS PORT

V_x AC OR DC AUX SUPPLY

F1 −
F2 +

CASE EARTH

* POWER SUPPLY VERSION 24-48V (NOMINAL) D.C. ONLY

OPTO 1 NOTE 4.
OPTO 2
OPTO 3
OPTO 4
OPTO 5
OPTO 6
OPTO 7
OPTO 8
COMMON CONNECTION

D1 D2 D3 D4 D5 D6 D7 D8 D9 D10 D11 D12 D13 D14 D15 D16 D17 D18

MiCOM P241 (PART)

5A 1A
5A 1A
5A 1A
5A 1A

C1 C2 C3 C4 C5 C6 C7 C8 C9 C13 C14 C15 C19 C20 C21 C22 C23 C24

I_A I_B I_C I_N SENSITIVE

NOTE 3

NOTE 2

A
B
C
PHASE ROTATION

DIRECTION OF FORWARD CURRENT FLOW. NOTE 6

A
B
C

P1
S1
S2
P2

A B C N
a b c n

dn
da

M

NOTES 1.

(a) C.T. SHORTING LINKS

(b) PIN TERMINAL (P.C.B. TYPE)

2. RESIDUAL VOLTAGE MEASUREMEMT REQUIRES A 5 LIMB VT OR 3 SINGLE PHASE VT'S.

3. C.T. CONNECTIONS ARE SHOWN 1A CONNECTED AND ARE TYPICAL ONLY.

4. OPTO INPUTS 1 AND 2 MUST BE USED FOR SETTING GROUP CHANGES IF THIS OPTION IS SELECTED IN THE RELAY MENU.

5. FOR COMMS OPTIONS SEE DRAWING 10Px4001.

6. DIRECTION OF FORWARD CURRENT FLOW FOR OPERATION OF THE DIRECTIONAL EF + SEF PROTECTION.

Issue: S	Revision: FIELD VOLTAGE OUTPUT REMOVED. CID HONG-98JC6A.		Title: EXTERNAL CONNECTION DIAG: MOTOR PROTECTION RELAY 40TE (8 I/P & 7 0/P)
Date: 24/06/2013	Name: N.JOHNSON	CAD DATA 1:1 DIMENSIONS: mm	Drg No: 10P24101
Date:	Chkd:	DO NOT SCALE	Sht: 2 Next Sht: 3

CUSTOMER SETTING

DEFAULT SETTING	CUSTOMER SETTING
RTD 1	
RTD 2	
RTD 3	
RTD 4	
RTD 5	
RTD 6	
RTD 7	
RTD 8	
RTD 9	
RTD 10	

	DEFAULT SETTING	CUSTOMER SETTING
WATCHDOG CONTACT		
WATCHDOG CONTACT		
RELAY 1	Control Close	
RELAY 2	General Start	
RELAY 3	General Trip	
RELAY 4	Time between Start Hot Start Nb. Cold Start Nb. 3Ph Volt. Alarm Thermal lockout	
RELAY 5	Not Used	
RELAY 6	Not Used	
RELAY 7	Not Used	

F11
F12
F13
F14
E1
E2
E3
E4
E5
E6
E7
E8
E9
E10
E11
E12
E13
E14
E15
E16
E17
E18

SEE NOTE 4

MiCOM P241 (PART)

D1
D2
D3
D4
D5
D6
D7
D8
D9
D10
D11
D12
D13
D14
D15
D16
D17
D18

OPTO 1
OPTO 2
OPTO 3
OPTO 4
OPTO 5
OPTO 6
OPTO 7
OPTO 8
COMMON CONNECTION

4. OPTO INPUTS 1 AND 2 MUST BE USED FOR SETTING GROUP CHANGES IF THIS OPTION IS SELECTED IN THE RELAY MENU.

CUSTOMER SETTING	DEFAULT SETTING	CUSTOMER SETTING
	CB closed 3ph	
	CB open 3ph	
	Speed input	
	Emergency Restart	
	Reset Thermal	
	Reset Latches	
	Close	
	Trip	

Title: EXTERNAL CONNECTION DIAG: MOTOR PROTECTION RELAY 40TE (8 I/P & 7 0/P)

Drg No: 10P24101

Sht: 3
Next Sht: -

MiCOM P241 (PART)

WATCHDOG CONTACT
WATCHDOG CONTACT
RELAY 1
RELAY 2
RELAY 3
RELAY 4
RELAY 5
RELAY 6
RELAY 7

V_X AC OR DC AUX SUPPLY

CASE EARTH

F11 F12 F13 F14 E1 E2 E3 E4 E5 E6 E7 E8 E9 E10 E11 E12 E13 E14 E15 E16 E17 E18

F1 F2

* POWER SUPPLY VERSION 24-48V (NOMINAL) D.C. ONLY

OUTPUT 1 OUTPUT 2 OUTPUT 3 OUTPUT 4 INPUT 1 INPUT 2 INPUT 3 INPUT 4

20mA 1mA

B1 B2 B3 B5 B6 B7 B9 B10 B11 B13 B14 B15 B16 B17 B18 B20 B21 B22 B24 B25 B26 B28 B29 B30

CLIO
CURRENT LOOP
INPUTS & OUTPUTS
NOTE 7

COMMS NOTE 5

SEE DRAWING 10Px4001

F17 F18 F16 SCN

EIA485/ KBUS PORT

MiCOM P241 (PART)

OPTO 1 OPTO 2 OPTO 3 OPTO 4 OPTO 5 OPTO 6 OPTO 7 OPTO 8
NOTE 4

COMMON CONNECTION

D1 D2 D3 D4 D5 D6 D7 D8 D9 D10 D11 D12 D13 D14 D15 D16 D17 D18

5A 1A 5A 1A 5A 1A 5A 1A

I_A I_B I_C I_N SENSITIVE V_A V_B V_C

C1 C2 C3 C4 C5 C6 C7 C8 C9 C13 C14 C15 C19 C20 C22 C23 C24

NOTE 3

NOTE 2

A B C
PHASE ROTATION

DIRECTION OF FORWARD CURRENT FLOW. NOTE 6

P1 P1 P2 P1 P2

S1 S1 S2 S1 S2

M

A B C N
a b c n

NOTES 1.
(a) C.T. SHORTING LINKS
(b) PIN TERMINAL (P.C.B. TYPE)

2. RESIDUAL VOLTAGE MEASUREMEMT REQUIRES A 5 LIMB VT OR 3 SINGLE PHASE VT'S.

3. C.T. CONNECTIONS ARE SHOWN 1A CONNECTED AND ARE TYPICAL ONLY.

4. OPTO INPUTS 1 AND 2 MUST BE USED FOR SETTING GROUP CHANGES IF THIS OPTION IS SELECTED IN THE RELAY MENU.

5. FOR COMMS OPTIONS SEE DRAWING 10Px4001.

6. DIRECTION OF FORWARD CURRENT FLOW FOR OPERATION OF THE DIRECTIONAL EF + SEF PROTECTION.

7. FOR 0-10mA, 0-20mA, 4-20mA RANGE USE 20mA INPUTS & OUTPUTS FOR 0-1mA RANGE USE 1mA INPUTS & OUTPUTS.

Issue:	H	Revision: FIELD VOLTAGE OUTPUT REMOVED. CID HONG-98JC6A.		Title:	EXTERNAL CONNECTION DIAG: MOTOR PROTECTION RELAY 40TE (8 I/P & 7 0/P + CLIO)		
Date:	24/06/2013	Name:	N.JOHNSON	CAD DATA 1:1 DIMENSIONS: mm	Drg No:	10P24102	Sht: 1
Date:		Chkd:		DO NOT SCALE			Next Sht: 2

MiCOM P241
(PART)

SEE NOTE 4

4. OPTO INPUTS 1 AND 2 MUST BE USED FOR SETTING GROUP
   CHANGES IF THIS OPTION IS SELECTED IN THE RELAY MENU.

Top table (CLIO inputs):

	DEFAULT SETTING	CUSTOMER SETTING
	CLIO INPUT 1	
	CLIO INPUT 2	
	CLIO INPUT 3	
	CLIO INPUT 4	

Relay outputs (right side):

	CUSTOMER SETTING	DEFAULT SETTING	
F11/F12 WATCHDOG CONTACT			
F13/F14 WATCHDOG CONTACT			
E1/E2 RELAY 1		Control Close	
E3/E4 RELAY 2		General Start	
E5/E6 RELAY 3		General Trip	
E7/E8/E9 RELAY 4		Time between Start / Hot Start Nb. / Cold Start Nb. / 3Ph Volt. Alarm / Thermal lockout	
E10/E11/E12 RELAY 5		Not Used	
E13/E14/E15 RELAY 6		Not Used	
E16/E17/E18 RELAY 7		Not Used	

Opto inputs (left/bottom):

	CUSTOMER SETTING	DEFAULT SETTING
D1(-)/D2(+) OPTO 1		CB closed 3ph
D3(-)/D4(+) OPTO 2		CB open 3ph
D5(-)/D6(+) OPTO 3		Speed input
D7(-)/D8(+) OPTO 4		Emergency Restart
D9(-)/D10(+) OPTO 5		Reset Thermal
D11(-)/D12(+) OPTO 6		Reset Latches
D13(-)/D14(+) OPTO 7		Close
D15(-)/D16(+) OPTO 8		Trip
D17(-)/D18(+) COMMON CONNECTION		

Title: EXTERNAL CONNECTION DIAG: MOTOR PROTECTION RELAY 40TE (8 I/P & 7 O/P + CLIO)

Drg No: 10P24102

Sht: 2   Next Sht: -

Issue: F

Revision: DRAWING OUTLINE UPDATED . CID BLIN-8BHLDT

Date: 25/11/2010   Name: W.LINTERN   CAD DATA 1:1 DIMENSIONS: mm   DO NOT SCALE

Date: Chkd:

MiCOM P241 (PART)

WATCHDOG CONTACT
WATCHDOG CONTACT
RELAY 1
RELAY 2
RELAY 3
RELAY 4
RELAY 5
RELAY 6
RELAY 7

V_X AC OR DC AUX SUPPLY

F11 F12 F13 F14 E1 E2 E3 E4 E5 E6 E7 E8 E9 E10 E11 E12 E13 E14 E15 E16 E17 E18

F1 F2

OPTO 9
OPTO 10
OPTO 11
OPTO 12

B1 B2 B3 B4 B5 B6 B7 B8

RELAY 8
RELAY 9
RELAY 10
RELAY 11

B9 B10 B11 B12 B13 B14 B15 B16 B17 B18

COMMS NOTE 4

EIA485/ KBUS PORT

F17 F18 F16 SCN

SEE DRAWING 10Px4001

* POWER SUPPLY VERSION 24-48V (NOMINAL) D.C. ONLY

MiCOM P241 (PART)

A B C PHASE ROTATION

OPTO 1
OPTO 2
OPTO 3
OPTO 4
OPTO 5
OPTO 6
OPTO 7
OPTO 8
COMMON CONNECTION

D1 D2 D3 D4 D5 D6 D7 D8 D9 D10 D11 D12 D13 D14 D15 D16 D17 D18

CASE EARTH

5A 1A 5A 1A 5A 1A 5A 1A

C1 C2 C3 C4 C5 C6 C7 C8 C9 C13 C14 C15 C19 C20 C22 C23 C24

I_A I_B I_C I_N SENSITIVE V_A V_B V_C

NOTE 3

NOTE 2

DIRECTION OF FORWARD CURRENT FLOW. NOTE 5

P1 P1 P2 P1 P2 S1 S1 S2 S2

P2

A B C N
n c b a
A B C

M

NOTES 1.

C.T. SHORTING LINKS

(a)

(b)   PIN TERMINAL (P.C.B. TYPE)

2. RESIDUAL VOLTAGE MEASUREMEMT REQUIRES A 5 LIMB VT OR 3 SINGLE PHASE VT'S.

3. C.T. CONNECTIONS ARE SHOWN 1A CONNECTED AND ARE TYPICAL ONLY.

4. FOR COMMS OPTIONS SEE DRAWING 10Px4001.

5. DIRECTION OF FORWARD CURRENT FLOW FOR OPERATION OF THE DIRECTIONAL EF + SEF PROTECTION.

Issue:	Revision: FIELD VOLTAGE OUTPUT REMOVED. CID HONG-98JC6A.		Title:	EXTERNAL CONNECTION DIAG: MOTOR PROTECTION RELAY 40TE (12 I/P & 11 O/P)	
D					
Date: 24/06/2013	Name: N.JOHNSON	CAD DATA 1:1 DIMENSIONS: mm	Drg No:	10P24103	Sht: 1
Date:	Chkd:	DO NOT SCALE			Next Sht: 2

MiCOM P241 (PART)

CUSTOMER SETTING	DEFAULT SETTING		
	CB closed 3ph	D1	OPTO 1
	CB open 3ph	D3	OPTO 2
	Speed input	D5	OPTO 3
	Emergency Restart	D7	OPTO 4
	Reset Thermal	D9	OPTO 5
	Reset Latches	D11	OPTO 6
	Close	D13	OPTO 7
	Trip	D15	OPTO 8
		D17	COMMON CONNECTION
	Not Used	B1	OPTO 9
	Not Used	B3	OPTO 10
	Not Used	B5	OPTO 11
	Not Used	B7	OPTO 12

DEFAULT SETTING	CUSTOMER SETTING		
	F11	WATCHDOG CONTACT	
	F13	WATCHDOG CONTACT	
Control Close	E1	RELAY 1	
General Start	E3	RELAY 2	
General Trip	E5	RELAY 3	
Time between Start Hot Start Nb. Cold Start Nb. 3Ph Volt. Alarm Thermal lockout	E7	RELAY 4	
Not Used	E10	RELAY 5	
Not Used	E13	RELAY 6	
Not Used	E16	RELAY 7	
Not Used	B9	RELAY 8	
Not Used	B11	RELAY 9	
Not Used	B14	RELAY 10	
Not Used	B17	RELAY 11	

Title: EXTERNAL CONNECTION DIAG: MOTOR PROTECTION RELAY 40TE (12 I/P & 11 O/P)

Drg No: 10P24103

Sht: 2   Next Sht: -

MiCOM P242 (PART) — Relay connections (top section)

WATCHDOG CONTACT — J11, J12
WATCHDOG CONTACT — J13, J14
RELAY 1 — H1, H2
RELAY 2 — H3
RELAY 3 — H4, H5
RELAY 4 — H6, H7
RELAY 5 — H8, H9
RELAY 6 — H10, H11
RELAY 7 — H12, H13
RELAY 8 — H14, H15
RELAY 9 — H16, H17, H18
RELAY 10 — G1, G2
RELAY 11 — G3, G4
RELAY 12 — G5, G6
RELAY 13 — G7, G8
RELAY 14 — G9, G10
RELAY 15 — G11, G12, G13
RELAY 16 — G14, G15, G16, G17, G18

RTD 1 — B1, B2, B3
RTD 2 — B4, B5, B6
RTD 3 — B7, B8, B9
RTD 10 — B28, B29, B30

CLIO — CURRENT LOOP INPUTS & OUTPUTS NOTE 7

OUTPUT 1 — 20mA C1, C2 / 1mA C3
OUTPUT 2 — 20mA C5, C6 / 1mA C7
OUTPUT 3 — 20mA C9, C10 / 1mA C11
OUTPUT 4 — 20mA C13, C14 / 1mA C15
INPUT 1 — C16, C17, C18
INPUT 2 — C20, C21, C22
INPUT 3 — C24, C25, C26
INPUT 4 — C28, C29, C30

COMMS NOTE 5
EIA485/ KBUS PORT — J17 (−), J18 (+), J16 SCN
SEE DRAWING 10Px4001

Vx AC OR DC AUX SUPPLY — J1 (−), J2 (+)
CASE EARTH

* POWER SUPPLY VERSION 24-48V (NOMINAL) D.C. ONLY

MiCOM P242 (PART) — Opto inputs (lower section)

OPTO 1 — E1 (−), E2 (+)
OPTO 2 — E3 (−), E4 (+)
OPTO 3 — E5 (−), E6 (+)
OPTO 4 — E7 (−), E8 (+)
OPTO 5 — E9 (−), E10 (+)
OPTO 6 — E11 (−), E12 (+)
OPTO 7 — E13 (−), E14 (+)
OPTO 8 — E15 (−), E16 (+)
COMMON CONNECTION — E17, E18
OPTO 9 — F1 (−), F2 (+)
OPTO 10 — F3 (−), F4 (+)
OPTO 11 — F5 (−), F6 (+)
OPTO 12 — F7 (−), F8 (+)
OPTO 13 — F9 (−), F10 (+)
OPTO 14 — F11 (−), F12 (+)
OPTO 15 — F13 (−), F14 (+)
OPTO 16 — F15 (−), F16 (+)
COMMON CONNECTION — F17, F18
NOTE 4

DIRECTION OF FORWARD CURRENT FLOW. NOTE 6

PHASE ROTATION — A, B, C

IA — 5A D1, D2 / 1A D3
IB — 5A D4, D5 / 1A D6
IC — 5A D7, D8 / 1A D9
IN SENSITIVE — 5A D13, D14 / 1A D15
VA — D19, D20
VB — D22, D23
VC — D24

NOTE 3
NOTE 2

NOTES:

1.
(a) C.T. SHORTING LINKS
(b) PIN TERMINAL (P.C.B. TYPE)

2. RESIDUAL VOLTAGE MEASUREMEMT REQUIRES A 5 LIMB OR 3 SINGLE PHASE VT'S.

3. C.T. CONNECTIONS ARE SHOWN 1A CONNECTED AND ARE TYPICAL ONLY.

4. OPTO INPUTS 1 AND 2 MUST BE USED FOR SETTING GROUP CHANGES IF THIS OPTION IS SELECTED IN THE RELAY MENU.

5. FOR COMMS OPTIONS SEE DRAWING 10Px4001.

6. DIRECTION OF FORWARD CURRENT FLOW FOR OPERATION OF THE DIRECTIONAL EF + SEF PROTECTION.

7. FOR 0-10mA, 0-20mA, 4-20mA RANGE USE 20mA INPUTS & OUTPUTS FOR 0-1mA RANGE USE 1mA INPUTS & OUTPUTS.

Issue: I	Revision: FIELD VOLTAGE OUTPUT REMOVED. CID HONG-98JC6A	Title: EXTERNAL CONNECTION DIAG: MOTOR PROTECTION RELAY 60TE (16 I/P & 16 0/P + RTD & CLIO)
Date: 25/06/2013	Name: N.JOHNSON	Drg No: **10P24201**
Date:	Chkd:	

CAD DATA 1:1 DIMENSIONS: mm
DO NOT SCALE

Sht: 1
Next Sht: 2

MiCOM P242
(PART)

SEE NOTE 4

4. OPTO INPUTS 1 AND 2 MUST BE USED FOR SETTING GROUP CHANGES IF THIS OPTION IS SELECTED IN THE RELAY MENU.

	DEFAULT SETTING	CUSTOMER SETTING
OPTO 1	CB closed 3ph	
OPTO 2	CB open 3ph	
OPTO 3	Speed input	
OPTO 4	Emergency Restart	
OPTO 5	Reset Thermal	
OPTO 6	Reset Latches	
OPTO 7	Close	
OPTO 8	Trip	
COMMON CONNECTION		
OPTO 9	Not Used	
OPTO 10	Not Used	
OPTO 11	Not Used	
OPTO 12	Not Used	
OPTO 13	Not Used	
OPTO 14	Not Used	
OPTO 15	Not Used	
OPTO 16	Not Used	
COMMON CONNECTION		

	DEFAULT SETTING	CUSTOMER SETTING	
RTD 1			
RTD 2			
RTD 3			
RTD 4			
RTD 5			
RTD 6			
RTD 7			
RTD 8			
RTD 9			
RTD 10			

	DEFAULT SETTING	CUSTOMER SETTING
WATCHDOG CONTACT		
WATCHDOG CONTACT		
RELAY 1	Control Close	
RELAY 2	General Start	
RELAY 3	General Start	
RELAY 4	Not Used	
RELAY 5	Not Used	
RELAY 6	Not Used	
RELAY 7	Not Used	
RELAY 8	Not Used	
RELAY 9	Not Used	
RELAY 10	Not Used	
RELAY 11	Not Used	
RELAY 12	Not Used	
RELAY 13	Not Used	
RELAY 14	Not Used	
RELAY 15	Not Used	
RELAY 16	Not Used	

	DEFAULT SETTING	CUSTOMER SETTING
CLIO INPUT 1		
CLIO INPUT 2		
CLIO INPUT 3		
CLIO INPUT 4		

Title:	EXTERNAL CONNECTION DIAG: MOTOR PROTECTION RELAY 60TE (16 I/P & 16 0/P + RTD & CLIO)		
Drg No:	10P24201	Sht: 2	Next Sht: -

Issue: H	Revision: DRAWING OUTLINE UPDATED . CID BLIN-8BHLDT		
Date: 25/11/2010	Name: W.LINTERN	CAD DATA 1:1 DIMENSIONS: mm	
Date:	Chkd:	DO NOT SCALE	

MiCOM P243 (PART)

WATCHDOG CONTACT — M11, M12
WATCHDOG CONTACT — M13, M14
RELAY 1 — L1, L2
RELAY 2 — L3, L4
RELAY 3 — L5, L6
RELAY 4 — L7, L8
RELAY 5 — L9, L10
RELAY 6 — L11, L12
RELAY 7 — L13, L14
RELAY 8 — L15, L16
RELAY 9 — L17, L18
RELAY 10 — K1, K2
RELAY 11 — K3, K4
RELAY 12 — K5, K6
RELAY 13 — K7, K8
RELAY 14 — K9, K10
RELAY 15 — K11, K12
RELAY 16 — K13, K14

RTD 1 — B1, B2, B3
RTD 2 — B4, B5, B6
RTD 3 — B7, B8, B9
RTD 10 — B28, B29, B30

CLIO
CURRENT LOOP INPUTS & OUTPUTS NOTE 7

OUTPUT 1 — 20mA C1, C2 / 1mA C3
OUTPUT 2 — 20mA C5, C6 / 1mA C7
OUTPUT 3 — 20mA C9, C10 / 1mA C11
OUTPUT 4 — 20mA C13, C14 / 1mA C15
INPUT 1 — 20mA C16, C17 / 1mA C18
INPUT 2 — 20mA C20, C21 / 1mA C22
INPUT 3 — 20mA C24, C25 / 1mA C26
INPUT 4 — 20mA C28, C29 / 1mA C30

COMMS NOTE 5

EIA485/ KBUS PORT — M17 (-), M18 (+), M16 SCN
SEE DRAWING 10PX4001

V_X AC OR DC AUX SUPPLY — M1 (-), M2 (+)

CASE EARTH

* POWER SUPPLY VERSION 24-48V (NOMINAL) D.C. ONLY

PHASE ROTATION

NOTE 2
NOTE 4

V_A D19
V_B D20
V_C D22, D23, D24

OPTO 1 — E1(-), E2(+), E3
OPTO 2 — E4(-), E5(+), E6
OPTO 3 — E7(-), E8(+), E9
OPTO 4 — E10(-), E11(+)
OPTO 5 — E12(-), E13(+)
OPTO 6 — E14(-), E15(+)
OPTO 7 — E16(-)
OPTO 8 — E17
COMMON CONNECTION — E18
OPTO 9 — G1(-), G2(+), G3
OPTO 10 — G4(-), G5(+), G6
OPTO 11 — G7(-), G8(+), G9
OPTO 12 — G10(-), G11(+)
OPTO 13 — G12(-), G13(+)
OPTO 14 — G14(-), G15(+)
OPTO 15 — G16(-)
OPTO 16 — G17
COMMON CONNECTION — G18

MiCOM P243 (PART)

I_A — 5A D1, D2 / 1A D3
I_B — 5A D4, D5 / 1A D6
I_C — 5A D7, D8 / 1A D9
I_N SENSITIVE — 5A D13, D14 / 1A D15
I_A (2) — 5A F1, F2 / 1A F3
I_B (2) — 5A F4, F5 / 1A F6
I_C (2) — 5A F7, F8 / 1A F9

DIRECTION OF FORWARD CURRENT FLOW. NOTE 6
BUSBAR
NEUTRAL
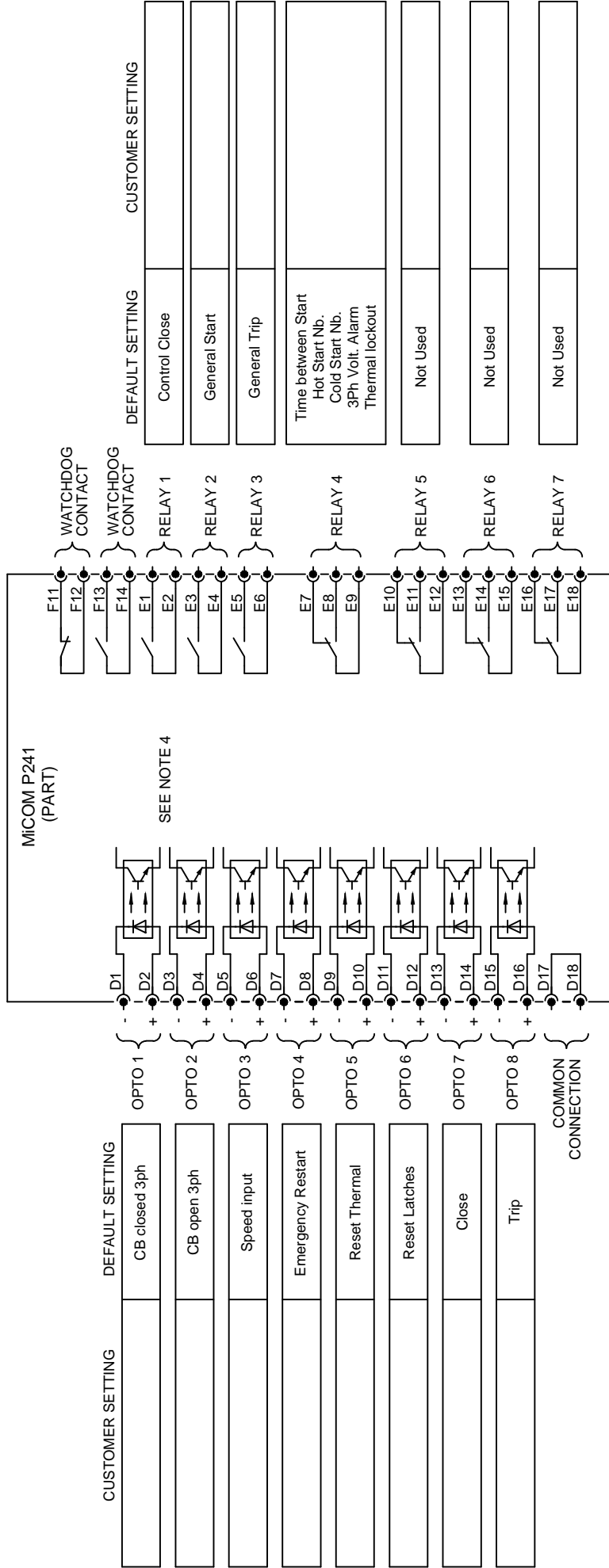
M

NOTE 3

P1 P2 S1 S2

NOTES:

1. C.T. SHORTING LINKS

(a)

(b) PIN TERMINAL (P.C.B. TYPE)

2. RESIDUAL VOLTAGE MEASUREMEMT REQUIRES A 5 LIMB VT OR 3 SINGLE PHASE VTS.

3. C.T. CONNECTIONS ARE SHOWN 1A CONNECTED AND ARE TYPICAL ONLY.

4. OPTO INPUTS 1 AND 2 MUST BE USED FOR SETTING GROUP CHANGES IF THIS OPTION IS SELECTED IN THE RELAY MENU.

5. FOR COMMS OPTIONS SEE DRAWING 10PX4001.

6. DIRECTION OF FORWARD CURRENT FLOW FOR OPERATION OF THE DIRECTIONAL EF + SEF PROTECTION.

7. FOR 0-10mA, 0-20mA, 4-20mA RANGE USE 20mA INPUTS & OUTPUTS. FOR 0-1mA RANGE USE 1mA INPUTS & OUTPUTS.

Title:	EXT. CONNECTION DIAG: MOTOR PROTECTION RELAY (80TE) WITH BIASED DIFFERENTIAL (16 I/P & 16 O/P + CLIO & RTD)
Drg No:	10P24301

Sht: 1
Next Sht: 2

Issue: **I**

Revision: FIELD VOLTAGE OUTPUT REMOVED. CID HONG-98JC6A

Date: 25/06/2013 Name: N.JOHNSON
Date: Chkd:

CAD DATA 1:1 DIMENSIONS: mm
DO NOT SCALE

MiCOM P243 (PART)

EXTERNAL CONNECTION DIAG: MOTOR PROTECTION RELAY 80TE (16 I/P & 16 0/P + RTD & CLIO)

Title: EXTERNAL CONNECTION DIAG: MOTOR PROTECTION RELAY 80TE (16 I/P & 16 0/P + RTD & CLIO)

Drg No: 10P24301

Sht:	2
Next Sht:	3

Issue: G

Revision: DRAWING OUTLINE UPDATED. CID BLIN-8BHLDT

Date:	25/11/2010	Name:	W.LINTERN	CAD DATA 1:1 DIMENSIONS: mm	DO NOT SCALE
Date:		Chkd:			

4. OPTO INPUTS 1 AND 2 MUST BE USED FOR SETTING GROUP CHANGES IF THIS OPTION IS SELECTED IN THE RELAY MENU.

CAD DATA: CID BLIN-8BHLDT

Opto inputs default settings: OPTO 1 CB closed 3ph, OPTO 2 CB open 3ph, OPTO 3 Speed input, OPTO 4 Emergency Restart, OPTO 5 Reset Thermal, OPTO 6 Reset Latches, OPTO 7 Close, OPTO 8 Trip, OPTO 9 L9 Not Used, OPTO 10 L10 Not Used, OPTO 11 L11 Not Used, OPTO 12 L12 Not Used, OPTO 13 L13 Not Used, OPTO 14 L14 Not Used, OPTO 15 L15 Not Used, OPTO 16 L16 Not Used.

Relay default settings: RELAY 1 Control Close, RELAY 2 General Start, RELAY 3 General Alarm, RELAY 4 General Alarm, RELAY 5 Not Used, RELAY 6 Not Used, RELAY 7 Not Used, RELAY 8 Not Used, RELAY 9 Not Used, RELAY 10 Not Used, RELAY 11 Not Used, RELAY 12 Not Used, RELAY 13 Not Used, RELAY 14 Not Used, RELAY 15 Not Used, RELAY 16 Not Used.

WATCHDOG CONTACT.

RTD 1 - RTD 10, CLIO INPUT 1 - CLIO INPUT 4.

SEE NOTE 4

Title: EXT. CONNECTION DIAG: MOTOR PROTECTION RELAY (80TE) WITH HIGH IMPEDANCE DIFF' TIAL (16 I/P & 16 0/P + RTD & CLIO)

Drg No: 10P24301

Sht: 3
Next Sht: 4

Issue: **F**

Revision: FIELD VOLTAGE OUTPUT REMOVED. CID HONG-98JC6A

Date: 25/06/2013 Name: N.JOHNSON CAD DATA 1:1 DIMENSIONS: mm
Date: Chkd: DO NOT SCALE

MICOM P243 (PART)

WATCHDOG CONTACT
WATCHDOG CONTACT
RELAY 1
RELAY 2
RELAY 3
RELAY 4
RELAY 5
RELAY 6
RELAY 7
RELAY 8
RELAY 9
RELAY 10
RELAY 11
RELAY 12
RELAY 13
RELAY 14
RELAY 15
RELAY 16

RTD 1
RTD 2
RTD 3
RTD 10

OUTPUT 1
OUTPUT 2
OUTPUT 3
OUTPUT 4
INPUT 1
INPUT 2
INPUT 3
INPUT 4

CLIO
CURRENT LOOP
INPUTS & OUTPUTS
NOTE 7

COMMS
NOTE 5

EIA485/ KBUS PORT

SEE DRAWING 10Px4001

AC OR DC AUX SUPPLY

CASE EARTH

* POWER SUPPLY VERSION 24-48V (NOMINAL) D.C. ONLY

PHASE ROTATION

NOTE 2

MICOM P243 (PART)

NOTE 4

OPTO 1
OPTO 2
OPTO 3
OPTO 4
OPTO 5
OPTO 6
OPTO 7
OPTO 8
COMMON CONNECTION
OPTO 9
OPTO 10
OPTO 11
OPTO 12
OPTO 13
OPTO 14
OPTO 15
OPTO 16
COMMON CONNECTION

NOTE 3

I_A
I_B
I_C
I_N SENSITIVE
I_A (2)
I_B (2)
I_C (2)

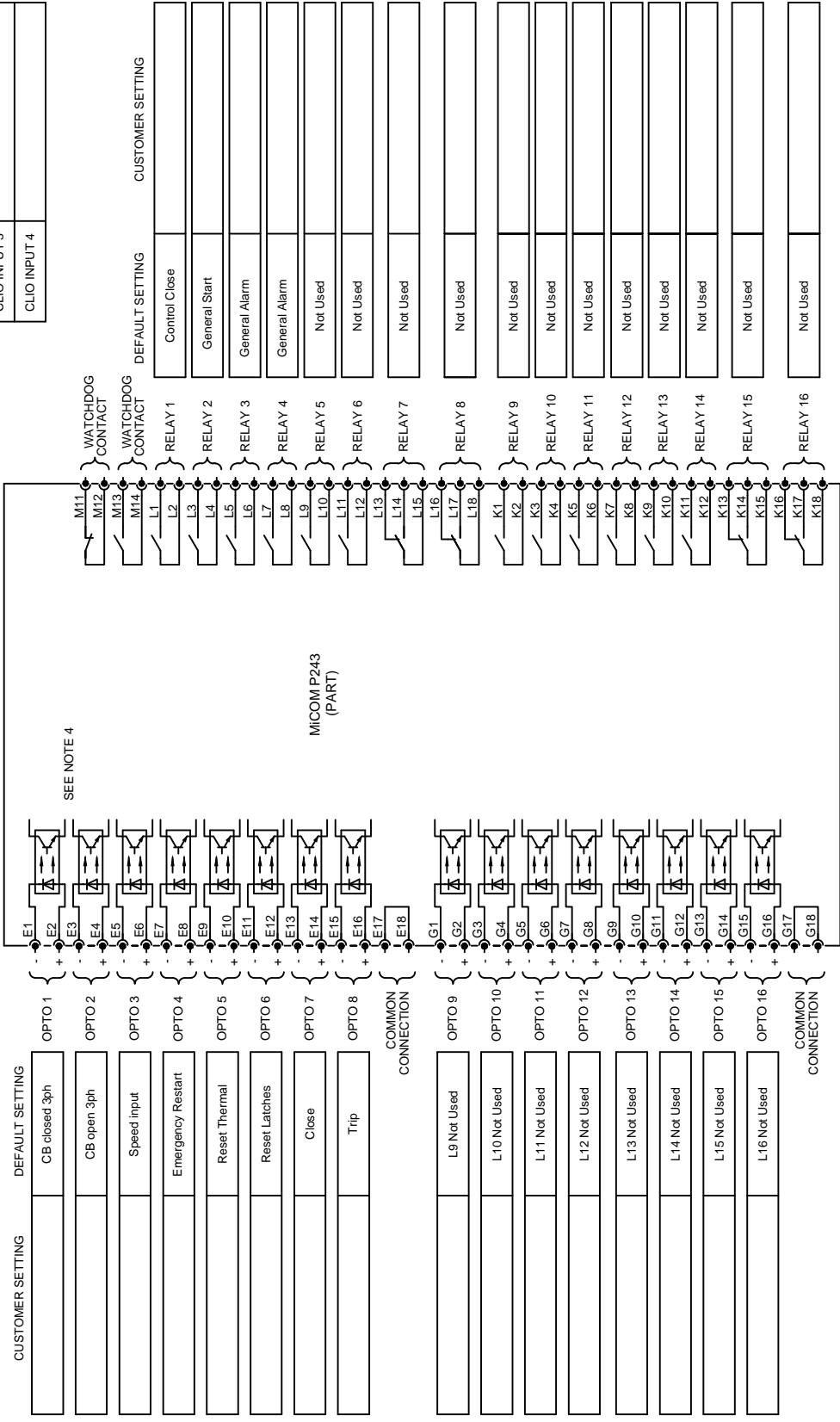DIRECTION OF FORWARD CURRENT FLOW. NOTE 6

BUSBAR

NEUTRAL

NLR

R^{ST}

NOTES:
1.
(a) C.T. SHORTING LINKS
(b) PIN TERMINAL (P.C.B. TYPE)
2. RESIDUAL VOLTAGE MEASUREMEMT REQUIRES A 5 LIMB VT OR 3 SINGLE PHASE VTS.
3. C.T. CONNECTIONS ARE SHOWN 1A CONNECTED AND ARE TYPICAL ONLY.
4. OPTO INPUTS 1 AND 2 MUST BE USED FOR SETTING GROUP CHANGES IF THIS OPTION IS SELECTED IN THE RELAY MENU.
5. FOR COMMS OPTIONS SEE DRAWING 10Px4001.
6. DIRECTION OF FORWARD CURRENT FLOW FOR OPERATION OF THE DIRECTIONAL EF + SEF PROTECTION.
7. FOR 0-10mA, 0-20mA, 4-20mA RANGE USE 20mA INPUTS & OUTPUTS. FOR 0-1mA RANGE USE 1mA INPUTS & OUTPUTS.

MiCOM P243 (PART)

WATCHDOG CONTACT
WATCHDOG CONTACT
RELAY 1
RELAY 2
RELAY 3
RELAY 4
RELAY 5
RELAY 6
RELAY 7
RELAY 8
RELAY 9
RELAY 10
RELAY 11
RELAY 12
RELAY 13
RELAY 14
RELAY 15
RELAY 16

M11
M12
M13
M14
L1
L3
L5
L7
L8
L10
L12
L13
L15
L17
L18
K1
K2
K3
K4
K5
K6
K7
K8
K9
K10
K11
K12
K13
K14
K15
K16
K17
K18

RTD 1 B1 B2 B3
RTD 2 B4 B5 B6
RTD 3 B7 B8 B9
RTD 10 B28 B29 B30

C1
C2
C3
C5
C6
C7
C9
C10
C11
C13
C14
C15
C16
C17
C18
C20
C21
C22
C24
C25
C26
C28
C29
C30

20mA 1mA — OUTPUT 1
20mA 1mA — OUTPUT 2
20mA 1mA — OUTPUT 3
20mA 1mA — OUTPUT 4
20mA 1mA — INPUT 1
20mA 1mA — INPUT 2
20mA 1mA — INPUT 3
20mA 1mA — INPUT 4

CLIO
CURRENT LOOP INPUTS & OUTPUTS
NOTE 7

COMMS NOTE 5

SEE DRAWING 10Px4001

M17 M18 M16 SCN
EIA485/ KBUS PORT

M1 M2
V_X AC OR DC AUX SUPPLY

CASE EARTH

* POWER SUPPLY VERSION 24-48V (NOMINAL) D.C. ONLY

B
A
C
PHASE ROTATION

A B C
N
a b c
n

NOTE 2

V_A D19
V_B D20
D22
V_C D23
D24

OPTO 1 E1 E2
OPTO 2 E3 E4
OPTO 3 E5 E6
OPTO 4 E7 E8
OPTO 5 E9 E10
OPTO 6 E11 E12
OPTO 7 E13 E14
OPTO 8 E15 E16
COMMON CONNECTION E17 E18
OPTO 9 G1 G2
OPTO 10 G3 G4
OPTO 11 G5 G6
OPTO 12 G7 G8
OPTO 13 G9 G10
OPTO 14 G11 G12
OPTO 15 G13 G14
OPTO 16 G15 G16
COMMON CONNECTION G17 G18

NOTE 4

MiCOM P243 (PART)

5A 1A D1 D2 D3 I_A
5A 1A D4 D5 D6 I_B
5A 1A D7 D8 D9 I_C
5A 1A D13 D14 D15 I_N SENSITIVE
5A 1A F1 F2 F3 I_A (2)
5A 1A F4 F5 F6 I_B (2)
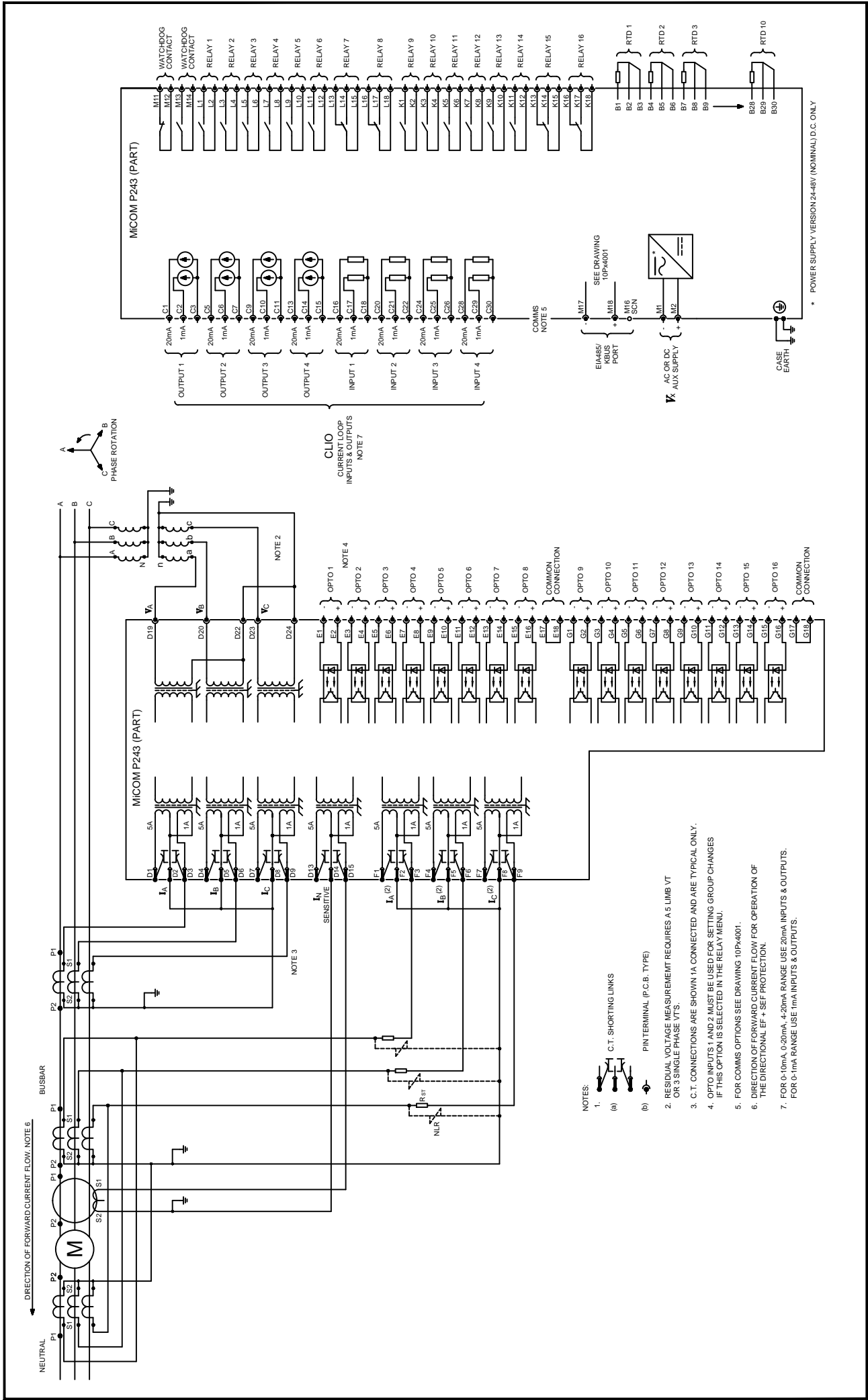5A 1A F7 F8 F9 I_C (2)

NOTE 3

NOTES:
1.
(a)   C.T. SHORTING LINKS
(b)   PIN TERMINAL (P.C.B. TYPE)

2. RESIDUAL VOLTAGE MEASUREMEMT REQUIRES A 5 LIMB VT OR 3 SINGLE PHASE VTS.

3. C.T. CONNECTIONS ARE SHOWN 1A CONNECTED AND ARE TYPICAL ONLY.

4. OPTO INPUTS 1 AND 2 MUST BE USED FOR SETTING GROUP CHANGES IF THIS OPTION IS SELECTED IN THE RELAY MENU.

5. FOR COMMS OPTIONS SEE DRAWING 10Px4001.

6. DIRECTION OF FORWARD CURRENT FLOW FOR OPERATION OF THE DIRECTIONAL EF + SEF PROTECTION.

7. FOR 0-10mA, 0-20mA, 4-20mA RANGE USE 20mA INPUTS & OUTPUTS. FOR 0-1mA RANGE USE 1mA INPUTS & OUTPUTS.

R_{ST}
NLR

BUSBAR

P1 P2
S1 S2

NEUTRAL

DIRECTION OF FORWARD CURRENT FLOW. NOTE 6

M

MiCOM P243 (PART)

WATCHDOG CONTACT — M11, M12
WATCHDOG CONTACT — M13, M14
RELAY 1 — L1
RELAY 2 — L2, L3
RELAY 3 — L4
RELAY 4 — L5, L6
RELAY 5 — L7
RELAY 6 — L8, L9
RELAY 7 — L10
RELAY 8 — L11, L12
RELAY 9 — L13
RELAY 10 — L14, L15
RELAY 11 — L16
RELAY 12 — L17, L18
RELAY 13 — K1
RELAY 14 — K2, K3
RELAY 15 — K4
RELAY 16 — K5, K6
RELAY 16 — K7, K8

K9, K10, K11, K12, K13, K14, K15, K16, K17, K18

RTD 1 — B1, B2, B3
RTD 2 — B4, B5, B6
RTD 3 — B7, B8, B9
RTD 10 — B28, B29, B30

* POWER SUPPLY VERSION 24-48V (NOMINAL) D. C. ONLY

CLIO
CURRENT LOOP
INPUTS & OUTPUTS
NOTE 7

OUTPUT 1 — C1 (20mA), C2 (1mA), C3
OUTPUT 2 — C5 (20mA), C6 (1mA), C7
OUTPUT 3 — C9 (20mA), C10 (1mA), C13
OUTPUT 4 — C14 (20mA), C15 (1mA)
INPUT 1 — C16 (20mA), C17 (1mA), C18
INPUT 2 — C20 (20mA), C21 (1mA), C22
INPUT 3 — C25 (20mA), C26 (1mA)
INPUT 4 — C28 (20mA), C29 (1mA), C30

COMMS NOTE 5

SEE DRAWING 10Px4001
EIA485/KBUS PORT — M17, M18 (+), M16 SCN

V_X AC OR DC AUX SUPPLY — M1, M2 (+)

CASE EARTH

MiCOM P243 (PART)

PHASE ROTATION

V_A — D19
V_B — D20
V_C — D22, D23
V_N — D24

NOTE 2
NOTE 4

OPTO 1 — E1 (-), E2 (+)
OPTO 2 — E3 (-), E4 (+)
OPTO 3 — E5 (-), E6 (+)
OPTO 4 — E7, E8
OPTO 5 — E9, E10
OPTO 6 — E11, E12
OPTO 7 — E13, E14
OPTO 8 — E15, E16
COMMON CONNECTION — E17, E18
OPTO 9 — G1, G2
OPTO 10 — G3, G4
OPTO 11 — G5, G6
OPTO 12 — G7, G8
OPTO 13 — G9, G10
OPTO 14 — G11, G12
OPTO 15 — G13, G14
OPTO 16 — G15, G16
COMMON CONNECTION — G17, G18

I_A — 5A, 1A — D1, D2, D3
I_B — 5A, 1A — D4, D5, D6
I_C — 5A, 1A — D7, D8, D9
I_N SENSITIVE — 5A, 1A — D13, D14, D15
I_A (2) — 5A, 1A — F1, F2, F3
I_B (2) — 5A, 1A — F4, F5, F6
I_C (2) — 5A, 1A — F7, F8, F9

NOTE 3

BUSBAR

DIRECTION OF FORWARD CURRENT FLOW. NOTE 6

NEUTRAL

M

NOTES:
1.
(a) C.T. SHORTING LINKS
(b) PIN TERMINAL (P.C.B. TYPE)

2. DERIVED NEUTRAL POINT. SEE P24X/EN TP/- FOR DETAILS OF RESISTORS

3. C.T. CONNECTIONS ARE SHOWN 1A CONNECTED AND ARE TYPICAL ONLY.

4. OPTO INPUTS 1 AND 2 MUST BE USED FOR SETTING GROUP CHANGES IF THIS OPTION IS SELECTED IN THE RELAY MENU.

5. FOR COMMS OPTIONS SEE DRAWING 10Px4001.

6. DIRECTION OF FORWARD CURRENT FLOW FOR OPERATION OF THE DIRECTIONAL EF + SEF PROTECTION.

7. FOR 0-10mA, 0-20mA, 4-20mA RANGE USE 20mA INPUTS & OUTPUTS. FOR 0-1mA RANGE USE 1mA INPUTS & OUTPUTS.

Title: EXT. CONN. DIAG: MOTOR PROTECTION RELAY (80TE) BIASED WITH DIFF' TIAL VEE CONNECT VTs (16 I/P & 16 0/P + RTD & CLIO)

Drg No: 10P24301

Sht: 5
Next Sht: -

Issue: F
Revision: FIELD VOLTAGE OUTPUT REMOVED. CID HONG-98JC6A
Date: 25/06/2013
Name: N.JOHNSON
Chkd:
Date:
CAD DATA 1:1 DIMENSIONS: mm
DO NOT SCALE

Imagination at work

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P24x/EN M/J82