# MiCOM P145

## Feeder Management Relay

**Software Version 31**
**Hardware Suffix J**

## Technical Manual

**P145/EN M/A11**

**Note:** The technical manual for this device gives instructions for its installation, commissioning, and operation. However, the manual cannot cover all conceivable circumstances or include detailed information on all topics. In the event of questions or specific problems, do not take any action without proper authorization. Contact the appropriate AREVA technical sales office and request the necessary information.

Any agreements, commitments, and legal relationships and any obligations on the part of AREVA including settlements of warranties, result solely from the applicable purchase contract, which is not affected by the contents of the technical manual.

This device MUST NOT be modified. If any modification is made without the express permission of AREVA, it will invalidate the warranty, and may render the product unsafe.

# PRODUCT SAFETY AND AWARENESS

## Introduction

This guide and the relevant operating or service manual documentation for the equipment provide full information on safe handling, commissioning and testing of this equipment and also includes descriptions of equipment label markings.

Documentation for equipment ordered from AREVA T&D is dispatched separately from manufactured goods and may not be received at the same time. Therefore this guide is provided to ensure that printed information normally present on equipment is fully understood by the recipient.

Before carrying out any work on the equipment the user should be familiar with the contents of this Safety Guide.

Reference should be made to the external connection diagram before the equipment is installed, commissioned or serviced.

## Health and safety

The information in the Safety Section of the equipment documentation is intended to ensure that equipment is properly installed and handled in order to maintain it in a safe condition.

When electrical equipment is in operation, dangerous voltages will be present in certain parts of the equipment. Failure to observe warning notices, incorrect use, or improper use may endanger personnel and equipment and cause personal injury or physical damage.

Before working in the terminal strip area, the equipment must be isolated.

Proper and safe operation of the equipment depends on appropriate shipping and handling, proper storage, installation and commissioning, and on careful operation, maintenance and servicing. For this reason 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 of the system to which it is being connected;
- Are able to safely perform switching operations in accordance with accepted safety engineering practices and are authorized to energize and de-energize equipment and to isolate, ground, and label it;
- Are trained in the care and use of safety apparatus in accordance with safety engineering practices;
- Are trained in emergency procedures (first aid).

## Symbols and external labels on the equipment

For safety reasons the following symbols and external labels, which may be used on the equipment or referred to in the equipment documentation, should be understood before the equipment is installed or commissioned.

Symbols

Caution: refer to equipment documentation

Caution: risk of electric shock

Protective Conductor (*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 e.g. power supply.

*NOTE: THE TERM EARTH USED THROUGHOUT THIS GUIDE IS THE DIRECT EQUIVALENT OF THE NORTH AMERICAN TERM GROUND.

**Installing, commissioning and servicing**

**Equipment connections**

Personnel undertaking installation, commissioning or servicing work for this equipment should be aware of the correct working procedures to ensure safety.

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

Any disassembly of the equipment may expose parts at hazardous voltage, also electronic parts may be damaged if suitable electrostatic voltage discharge (ESD) precautions are not taken.

If there is unlocked access to the rear of the equipment, care should be taken by all personnel to avoid electric shock or energy hazards.

Voltage and current connections should be made using insulated crimp terminations to ensure that terminal block insulation requirements are maintained for safety.

To ensure that wires are correctly terminated the correct crimp terminal and tool for the wire size should be used.

The equipment must be connected in accordance with the appropriate connection diagram.

Protection Class I Equipment

- Before energizing the equipment it must be earthed using the protective conductor terminal, if provided, or the appropriate termination of the supply plug in the case of plug connected equipment.
- The protective conductor (earth) connection must not be removed since the protection against electric shock provided by the equipment would be lost.

The recommended minimum protective conductor (earth) wire size is 2.5 mm² (3.3 mm² for North America) unless otherwise stated in the technical data section of the equipment documentation, or otherwise required by local or country wiring regulations.

The protective conductor (earth) connection must be low-inductance and as short as possible.

**Equipment use**

If the equipment is used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired.

**Removal of the equipment front panel/cover**

Removal of the equipment front panel/cover may expose hazardous live parts, which must not be touched until the electrical power is removed.

**UL and CSA listed or recognized equipment**

To maintain UL and CSA approvals the equipment should be installed using UL and/or CSA listed or recognized parts of the following type: connection cables, protective fuses/fuseholders or circuit breakers, insulation crimp terminals, and replacement internal battery, as specified in the equipment documentation.

**Equipment operating conditions**

The equipment should be operated within the specified electrical and environmental limits.

**Current transformer circuits**

Do not open the secondary circuit of a live CT since the high voltage produced may be lethal to personnel and could damage insulation. Generally, for safety, the secondary of the line CT must be shorted before opening any connections to it.

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

For equipment with pin-terminal connections, the threaded terminal block for current transformer termination does NOT have automatic CT shorting on removal of the module.

**External resistors, including voltage dependent resistors (VDRs)**

Where external resistors, including voltage dependent resistors (VDRs), are fitted to the equipment, these may present a risk of electric shock or burns, if touched.

**Battery replacement**

Where internal batteries are fitted they should be replaced with the recommended type and be installed with the correct polarity to avoid possible damage to the equipment, buildings and persons.

**Insulation and dielectric strength testing**

Insulation testing may leave capacitors charged up to a hazardous voltage. At the end of each part of the test, the voltage should be gradually reduced to zero, to discharge capacitors, before the test leads are disconnected.

**Insertion of modules and pcb cards**

Modules and PCB cards must not be inserted into or withdrawn from the equipment whilst it is energized, since this may result in damage.

**Insertion and withdrawal of extender cards**

Extender cards are available for some equipment. If an extender card is used, this should not be inserted or withdrawn from the equipment whilst it is energized. This is to avoid possible shock or damage hazards. Hazardous live voltages may be accessible on the extender card.

**External test blocks and test plugs**

Great care should be taken when using external test blocks and test plugs such as the MMLG, MMLB and MiCOM P990 types, hazardous voltages may be accessible when using these. *CT shorting links must be in place before the insertion or removal of MMLB test plugs, to avoid potentially lethal voltages.

*Note: When a MiCOM P992 Test Plug is inserted into the MiCOM P991 Test Block, the secondaries of the line CTs are automatically shorted, making them safe.

**Fiber optic communication**

Where fiber optic communication devices are fitted, these should not be viewed directly. Optical power meters should be used to determine the operation or signal level of the device.

**Cleaning**

The equipment may be cleaned using a lint free cloth dampened with clean water, when no connections are energized. Contact fingers of test plugs are normally protected by petroleum jelly, which should not be removed.

**DANGER - CTs must NOT be fused since open circuiting them may produce lethal hazardous voltages.**

**This equipment must not be modified. If any modification is made without the express permission of AREVA T&D, it will invalidate the warranty, and may render the product unsafe.**

## De-commissioning and disposal

**De-commissioning**

The supply input (auxiliary) for the equipment may include capacitors across the supply or to earth. To avoid electric shock or energy hazards, after completely isolating the supplies to the equipment (both poles of any dc supply), the capacitors should be safely discharged via the external terminals prior to de-commissioning.

**Disposal**

It is recommended that incineration and disposal to water courses is avoided. The equipment should be disposed of in a safe manner. Any equipment containing batteries should have them removed before disposal, taking precautions to avoid short circuits. Particular regulations within the country of operation, may apply to the disposal of batteries.

AREVA

# EC Declaration of Conformity

**We** AREVA T&D UK Ltd - Automation & Information Systems
**of** St. Leonards Avenue, Stafford, ST17 4LX, England
**hereby declare that the following product(s) :**

**Product type :** MiCOM

**Description :** Feeder Management Relay

**Models :** P145**********J

**Conform(s) with the protection requirements of the following directive(s) :**

**1.** European Community (EC) directive 89/336/EEC on EMC. Transposed into UK law by The Electromagnetic Compatibility Regulations 1992 (SI 1992/2372), amended by CE Marking directive 93/68/EEC (SI 1994/3080) *SI=Statutory Instrument*

**2.** EC directive 73/23/EEC on Low Voltage (LVD), amended by CE Marking directive 93/68/EEC and transposed into UK law by The UK Electrical Equipment (Safety) Regulations 1994 (SI 1994/3260).

**The following route(s) were used to establish conformity :**

**1. 89/336/EEC :**

Self Certification supported by a Technical Construction File

**Technical Construction File No.:** 50409.3701.001

**Dated** : 8 March 2005

**2. 73/23/EEC :**

Self certification supported by a Technical File (TF).

**Technical File No. :** PSTF 0016

**Dated :** 27 September 2003

**Reference Number :** DOCR 0157 **Issue :** A

**Date of issue :** 8 April 2005

## 3. The following standards were used for reference and to establish conformity :

| | |
|---|---|
| **EN50263 : 2000** | Electromagnetic compatibility - Product standard for measuring relays and protection equipment. |
| **EN61010-1 : 2001** | Safety requirements for electrical equipment for measurement, control, and laboratory use.<br>Part 1 – General requirements - |
| **EN60950-1 : 2001** | Information technology equipment - Safety<br>Part 1 – General requirements - |

**Signed on behalf of the Company :**

B R J Caunce CEng MIEE
Certification Director: Protection Products
AREVA T&D UK Ltd - Automation & Information Systems

**Year CE Mark First Applied :** 05

**Reference Number :** DOCR 0157

**Issue :** A

**Date of issue :** 8 April 2005

# CONTENTS

IT

# INTRODUCTION

| | |
|---|---|
| **Date:** | **7th July 2005** |
| **Hardware Suffix:** | **J** |
| **Software Version:** | **31** |
| **Connection Diagrams:** | **10P145xx (xx = 01 to 07)** |

# CONTENTS

**(IT) 1-**



# FIGURES

IT

# 1. MiCOM DOCUMENTATION STRUCTURE

The manual provides a functional and technical description of the MiCOM protection relay and a comprehensive set of instructions for the relay's use and application.

The section contents are summarized below:

**P145/EN IT Introduction**

A guide to the MiCOM range of relays and the documentation structure. General safety aspects of handling Electronic Equipment is discussed with particular reference to relay safety symbols. Also a general functional overview of the relay and brief application summary is given.

**P145/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.

**P145/EN GS Getting Started**

A guide to the different user interfaces of the protection relay describing how to start using it. This section provides detailed information regarding the communication interfaces of the relay, including a detailed description of how to access the settings database stored within the relay.

**P145/EN ST Settings**

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

**P145/EN OP Operation**

A comprehensive and detailed functional description of all protection and non-protection functions.

**P145/EN AP Application Notes**

This section 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.

**P145/EN PL Programmable Logic**

Overview of the programmable scheme logic and a description of each logical node. This section includes the factory default (PSL) and an explanation of typical applications.

**P145/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.

**P145/EN FD Firmware Design**

Overview of the operation of the relay's hardware and software. This section includes information on the self-checking features and diagnostics of the relay.

**P145/EN CM Commissioning**

Instructions on how to commission the relay, comprising checks on the calibration and functionality of the relay.

**P145/EN MT Maintenance**

A general maintenance policy for the relay is outlined.

**P145/EN TS Troubleshooting**

Advice on how to recognize failure modes and the recommended course of action. Includes guidance on whom within AREVA T&D to contact for advice.

**P145/EN SC SCADA Communications**

This section 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.

**P145/EN SG Symbols and Glossary**

List of common technical abbreviations found within the product documentation.

**P145/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. All external wiring connections to the relay are indicated.

**P145/EN VH Firmware and Service Manual Version History**

History of all hardware and software releases for the product.

# 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 AREVA T&D.

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:

www.areva-td.com

IT

# 3. PRODUCT SCOPE

The MiCOM P145 feeder management relay has been designed for the protection of a wide range of overhead lines and underground cables from distribution to transmission voltage levels. The relay includes a comprehensive range of non-protection features to aid with power system diagnosis and fault analysis. The P145 offers integral overcurrent and earth-fault protection and is suitable for application on solidly grounded, impedance grounded, Petersen coil grounded and isolated systems. The relay is especially suitable where a complete scheme solution is required and has 10 function keys for integral scheme or operator control functionality such as circuit breaker control, auto-reclose control and remote communications control.

## 3.1 Functional overview

The P145 feeder management relay contains a wide variety of protection functions. The protection features are summarized below:

| PROTECTION FUNCTIONS OVERVIEW | | P145 |
|---|---|---|
| 50/51/67 | Four overcurrent measuring stages are provided for each phase and is selectable to be either non-directional, directional forward or directional reverse. Stages 1 and 2 may be set Inverse Definite Minimum Time (IDMT) or Definite Time (DT); stages 3 and 4 may be set DT only. | X |
| 50N/51N/67N | Three independent earth fault elements are provided; derived, measured and sensitive earth fault protection. Each element is equipped with four stages which are independently selectable to be either non-directional, directional forward or directional reverse. Either Zero sequence or negative sequence polarizing are available for the earth fault elements. | X |
| 67N/67W | The Sensitive Earth Fault element can be configured as an $I\cos\phi$, $I\sin\phi$ or $VI\cos\phi$ (Wattmetric) element for application to isolated and compensated networks. | X |
| 51V | Voltage controlled overcurrent functionality is available on the first two stages of the overcurrent function. It provides backup protection for remote phase to phase faults by increasing the sensitivity of stages 1 and 2 of the overcurrent protection. | X |
| YN | Neutral admittance protection - operates from either the SEF CT or EF CT to provide single stage admittance, conductance and susceptance elements. | X |
| 64 | Restricted earthfault is configurable as a high impedance or low impedance element. | X |
| BOL | Blocked overcurrent logic is available on each stage of the overcurrent and earth fault, including sensitive earth fault elements. This consists of start outputs and block inputs that can be used to implement busbar blocking schemes for example. | X |
| SOL | Selective overcurrent provides the capability of temporarily altering (e.g. raise) the time settings of stages 3 and 4 of the phase overcurrent, earth fault and sensitive earth fault elements. | X |
| CLP | Cold load pick-up may be used to transiently raise the settings, for both overcurrent and earth fault protection elements, following closure of the circuit breaker. | X |
| 46 | Four stages are provided and can be selected to be either non-directional, directional forward or directional reverse and provides remote backup protection for both phase to earth and phase to phase faults. | X |

| PROTECTION FUNCTIONS OVERVIEW | | P145 |
|---|---|---|
| 49 | RMS thermal overload (single/dual time constant) protection that provides thermal characteristics, which is suitable for both cables and transformers. Both Alarm and trip stages are provided. | X |
| 37P/37N | Phase, neutral and sensitive earth fault undercurrent elements are available for use with for example the circuit breaker fail function. | X |
| 27 | Undervoltage 2-stage element, configurable as either phase to phase or phase to neutral measuring. Stage 1 may be selected as either IDMT or DT and stage 2 is DT only. | X |
| 59 | Overvoltage (2-stage), configurable as either phase to phase or phase to neutral measuring. Stage 1 may be selected as either IDMT or DT and stage 2 is DT only. | X |
| 59N | Residual overvoltage (Neutral displacement) is a two-stage element selectable as either IDMT or DT. | X |
| 47 | Negative sequence overvoltage protection with a definite time delayed element, to provide either a tripping or interlocking function upon detection of unbalanced supply voltages. | X |
| 81U/O/R | A 4-stage underfrequency, 2-stage overfrequency and an advanced 4-stage rate of change of frequency element as well. | X |
| 46BC | Broken conductor (open jumper) used to detect open circuit faults using the ratio of I2/I1. | X |
| 50BF | A 2-stage circuit breaker failure with 1 or 3 pole initiation inputs. | X |
| VTS | Voltage transformer supervision (1, 2 & 3 phase fuse failure detection) to prevent mal-operation of voltage dependent protection elements upon loss of a VT input signal. | X |
| CTS | Current transformer supervision to prevent mal-operation of current dependent protection elements upon loss of a CT input signal. | X |
| 49SR | Silicon rectifier overload protection. | X |
| 79 | 4 shot three pole auto-reclose with check sync., external initiation and sequence co-ordination capability. | X |
| 25 | Check synchronizing (2-stage) with advanced system spilt features and breaker closing compensation time. | X |
| | Programmable function keys | 10 |
| | Programmable LED’s (tri-color) | 18 |
| | Digital inputs (order option) | 12 to 32 |
| | Output relays (order option) | 12 to 32 |
| | Front communication port (EIA(RS)232) | X |
| | Rear communication port (KBUS/EIA(RS)485) | X |
| | Rear communication port (EIA(RS)485/Optic/Ethernet) | Option |
| | Second rear communication port (EIA(RS)232/EIA(RS)485) | Option |
| | Time synchronization port (IRIG-B) | Option |

IT

The P145 supports the following relay management functions in addition to the functions illustrated above.

- Measurement of all instantaneous & integrated values
- Circuit breaker control, status & condition monitoring
- Trip circuit and coil supervision
- 4 Alternative setting groups
- Programmable function keys
- Control inputs
- Fault locator
- Programmable scheme logic
- Programmable allocation of digital inputs and outputs
- Sequence of event recording
- Comprehensive disturbance recording (waveform capture)
- Fully customizable menu texts
- Multi-level password protection
- Power-up diagnostics and continuous self-monitoring of relay

**Application overview**

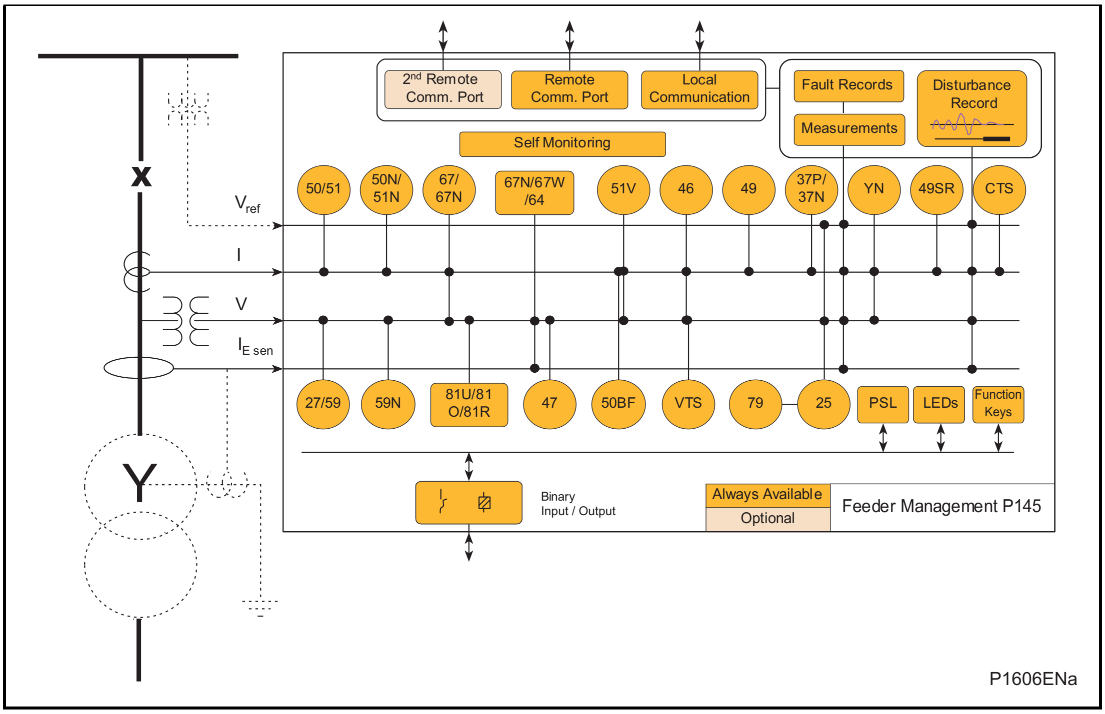



**Figure 1: Functional diagram**

IT

## 3.2 Ordering options

### Information Required with Order

Relay Type (Feeder Management Relay) **P145**

| Auxiliary Voltage Rating | |
|---|---|
| 24 – 48V dc only | 1 |
| 48 – 125V dc (30 – 110V ac) | 2 |
| 110 – 250V dc (100 – 240V ac) | 3 |

| **Vn rating** | |
|---|---|
| 100 – 120V ac | 1 |
| 380 – 480V ac | 2 |

| **Hardware options** | |
|---|---|
| Nothing | 1 |
| IRIG-B only | 2 |
| Fiber optic converter only (not UCA2.0) | 3 |
| IRIG-B & fiber optic converter (not UCA2.0) | 4 |
| Rear Comms. | 7 |
| IRIG-B + Rear Comms. | 8 |

| **Product Specific** | |
|---|---|
| Version with 16 output contacts & 16 digital inputs | A |
| Version with 12 output contacts & 12 digital inputs | B |
| Version with 16 output contacts & 24 digital inputs | C |
| Version with 24 output contacts & 16 digital inputs | D |
| Version with 24 output contacts & 24 digital inputs | E |
| Version with 16 output contacts & 32 digital inputs | F |
| Version with 32 output contacts & 16 digital inputs | G |

| **Protocol Options** | |
|---|---|
| K-Bus/Courier | 1 |
| MODBUS | 2 |
| IEC60870-5-103 | 3 |
| DNP3.0 | 4 |
| UCA2.0 | 5 |

| **Mounting** | |
|---|---|
| Panel Mounting | M |

| **Language** | |
|---|---|
| Multilingual – English, French, German, Spanish | 0 |
| Multilingual – English, French, German, Russian | 5 |

| **Software Version** | | |
|---|---|---|
| Unless specified the latest version will be delivered | 3 | 1 |

| **Settings File** | |
|---|---|
| Default | 0 |
| Customer Specific | 1 |

| **Hardware Suffix** | |
|---|---|
| Original | J |

TD

# TECHNICAL DATA

| | |
|---|---|
| **Date:** | **7th July 2005** |
| **Hardware Suffix:** | **J** |
| **Software Version:** | **31** |
| **Connection Diagrams:** | **10P145xx (xx = 01 to 07)** |

# Technical Data

## Mechanical Specifications

**Design**
Modular MiCOM Px40 platform relay, P141/142-40TE (206mm (8“)) case and P143/P145 (309.6mm (12“)) case. Mounting is front of panel flush mounting, or 19“ rack mounted (ordering options).

**Enclosure Protection**
Per IEC 60529: 1989
IP 52 Protection (front panel) against dust and dripping water.
IP 30 Protection for sides of the case.
IP 10 Protection for the rear.

**Weight**
Case 40TE: approx. 7.3 kg
Case 60TE: approx. 9.2 kg

## 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 COM1 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 2.5mm$^2$.

**Front Port Serial PC Interface**
EIA(RS)232 DTE, 9 pin D-type female connector.
Courier protocol for interface to MiCOM S1 software.
Isolation to ELV level.
Maximum cable length 15m.

**Front Download/Monitor Port**
EIA(RS)232, 25 pin D-type female connector.
For firmware downloads.
Isolation to ELV level.

**Rear Communications Port**
EIA(RS)485 signal levels, two wire
Connections located on general purpose block, M4 screw.
For screened twisted pair cable, multi-drop, 1000m max.
For K-Bus, IEC-870-5-103, or DNP3 protocol (ordering options).
Isolation to SELV level.

**Optional Second Rear Communications Port**
EIA(RS)232, 9 pin D-type female connector, socket SK4.
Courier protocol: K-Bus, EIA(RS)232, or EIA(RS)485 connection.
Isolation to SELV level.

**Optional Rear IRIG-B Interface**
BNC plug
Isolation to SELV level.
50 ohm coaxial cable.

**Optional Rear Fiber Connection for SCADA/DCS**
BFOC 2.5 -(ST®)-interface for glass fiber, as per IEC 874-10.
850nm short-haul fibers, one Tx and one Rx.
For Courier, IEC-870-5-103, DNP3 or MODBUS protocol (ordering options).

**Optional Rear Ethernet Connection for SCADA/DCS**
10/100Mbs RJ45 copper with 10Mbs fiber optic connection (ST type)
10/100Mbs RJ45 copper with 100Mbs fiber optic connection (SC type).
Both options compatible with 850nm.
Multi-mode fiber-optic cable.
For use with UCA2.0 protocol.

## Ratings

**AC Measuring Inputs**
Nominal frequency: 50 and 60 Hz (settable)
Operating range: 45 to 65Hz
Phase rotation: ABC

**AC Current**
Nominal current (In): 1 and 5 A dual rated.
(1A and 5A inputs use different transformer tap connections, check correct terminals are wired).
Nominal burden per phase: < 0.15 VA at In
Thermal withstand:
continuous 4 In
for 10s: 30 In
for 1s; 100 In
Linear to 64 In (non-offset AC current).

TD

TD

**AC Voltage**
Nominal voltage (Vn): 100 to 120 V or 380 to 480V phase-phase.
Nominal burden per phase: < 0.02 VA at Vn.
Thermal withstand:
continuous 2 Vn
for 10s: 2.6 Vn

## Power Supply

**Auxiliary Voltage (Vx)**
Three ordering options:
(i) Vx: 24 to 48 Vdc
(ii) Vx: 48 to 110 Vdc, and 30 to 100Vac (rms)
(iii) Vx: 110 to 250 Vdc, and 100 to 240Vac (rms)

**Operating Range**
(i) 19 to 65V (dc only for this variant)
(ii) 37 to 150V (dc), 24 to 110V (ac)
(iii) 87 to 300V (dc), 80 to 265V (ac)
With a tolerable ac ripple of up to 12% for a dc supply, per IEC 60255-11: 1979.

**Nominal Burden**
Quiescent burden: 11W. (Extra 1.25W when fitted with second rear Courier)
Additions for energized binary inputs/outputs:
Per opto input:
0.09W (24 to 54V),
0.12W (110/125V),
0.19W (220/120V).
Per energized output relay: 0.13W

**Power-up Time**
Time to power up < 11s.

**Power Supply Interruption**
Per IEC 60255-11: 1979
The relay will withstand a 20ms interruption in the DC auxiliary supply, without de-energizing.
Per IEC 61000-4-11: 1994
The relay will withstand a 20ms interruption in an AC auxiliary supply, without de-energizing.

**Battery Backup**
Front panel mounted
Type ½ AA, 3.6V

**Field Voltage Output**
Regulated 48Vdc
Current limited at 112mA maximum output

**Digital ("Opto") Inputs**
Universal opto inputs with programmable voltage thresholds. May be energized from the 48V field voltage, or the external battery supply.
Rated nominal voltage: 24 to 250Vdc
Operating range: 19 to 265Vdc
Withstand: 300Vdc.
Nominal pick-up and reset thresholds:
Pick-up: approx. 75% of battery nominal set,
Reset: approx. 64% of battery nominal set.
Recognition time:
<2ms with long filter removed,
<12ms with half-cycle ac immunity filter on.

## Output Contacts

**Standard Contacts**
General purpose relay outputs for signalling, tripping and alarming:
Rated voltage: 300 V
Continuous current: 10 A
Short-duration current: 30 A for 3s
Making capacity: 250A for 30ms
Breaking capacity:
DC: 50W resistive
DC: 62.5W inductive (L/R = 50ms)
AC: 2500VA resistive (cos $\phi$ = unity)
AC: 2500VA inductive (cos $\phi$ = 0.7)
Response to command: < 5ms
Durability:
Loaded contact: 10 000 operations minimum,
Unloaded contact: 100 000 operations minimum.

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

**IRIG-B Interface**
External clock synchronization per IRIG standard 200-98, format B.
Input impedance 6kΩ at 1000Hz
Modulation ratio: 3:1 to 6:1
Input signal, peak-peak: 200mV to 20V

## 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).

**Ambient Humidity Range**
Per IEC 60068-2-3: 1969:
56 days at 93% relative humidity and +40°C
Per IEC 60068-2-30: 1980:
Damp heat cyclic, six (12 + 12) hour cycles, 93% RH, +25 to +55°C

## Type Tests

**Insulation**
Per IEC 60255-5: 2000,
Insulation resistance > 100MΩ at 500Vdc
(Using only electronic/brushless insulation tester).

**Creepage Distances and Clearances**
Per EN 61010-1: 2001
Pollution degree 2,
Overvoltage category III,
Impulse test voltage 5 kV.

**High Voltage (Dielectric) Withstand**
EIA(RS)232 ports excepted.
(i) Per IEC 60255-5: 2000, 2 kV rms AC, 1 minute:
Between all case terminals connected together, and the case earth.
Also, between all terminals of independent circuits.
1kV rms AC for 1 minute, across open watchdog contacts.
1kV rms AC for 1 minute, across open contacts of changeover output relays.
(ii) Per ANSI/IEEE C37.90-1989 (reaffirmed 1994):
1.5 kV rms AC for 1 minute, across open contacts of changeover output relays.

**Impulse Voltage Withstand Test**
Per IEC 60255-5: 2000
Front time: 1.2 µs, Time to half-value: 50 µs,
Peak value: 5 kV, 0.5J
Between all terminals, and all terminals and case earth.

## Electromagnetic Compatibility (EMC)

**1 MHz Burst High Frequency Disturbance Test**
Per IEC 60255-22-1: 1988, Class III,
Common-mode test voltage: 2.5 kV,
Differential test voltage: 1.0 kV,
Test duration: 2s, Source impedance: 200Ω
EIA(RS)232 ports excepted.

**Immunity to Electrostatic Discharge**
Per IEC 60255-22-2: 1996, Class 4,
15kV discharge in air to user interface, display, and exposed metalwork.
Per IEC 60255-22-2: 1996, Class 3,
8kV discharge in air to all communication ports.
6kV point contact discharge to any part of the front of the product.

**Electrical Fast Transient or Burst Requirements**
Per IEC 60255-22-4: 2002. Test severity Class III and IV:
Amplitude: 2 kV, burst frequency 5kHz (Class III),
Amplitude: 4 kV, burst frequency 2.5kHz (Class IV).
Applied directly to auxiliary supply, and applied to all other inputs. EIA(RS)232 ports excepted.

**Surge Withstand Capability**
IEEE/ANSI C37.90.1:2002:
4kV fast transient and 2.5kV oscillatory applied common mode and differential mode to opto inputs (filtered), output relays, CTs, VTs, power supply, field voltage.
4kV fast transient and 2.5kV oscillatory applied common mode to communications, IRIG- B.

**Surge Immunity Test**
EIA(RS)232 ports excepted.
Per IEC 61000-4-5: 2002 Level 4,
Time to half-value: 1.2/50 µs,
Amplitude: 4kV between all groups and case earth,
Amplitude: 2kV between terminals of each group.

**Immunity to Radiated Electromagnetic Energy**
Per IEC 60255-22-3: 2000, Class III:
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: 1995:
25MHz to 1000MHz, zero and 100% square wave modulated.
Field strength of 35V/m.

**Radiated Immunity from Digital Communications**
Per EN61000-4-3: 2002, Level 4:
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 ENV 50204: 1995
10 V/m, 900MHz and 1.89GHz.

**Immunity to Conducted Disturbances Induced by Radio Frequency Fields**
Per IEC 61000-4-6: 1996, Level 3,
Disturbing test voltage: 10 V

TD

**Power Frequency Magnetic Field Immunity**
Per IEC 61000-4-8: 1994, Level 5,
100A/m applied continuously,
1000A/m applied for 3s.
Per IEC 61000-4-9: 1993, Level 5,
1000A/m applied in all planes.
Per IEC 61000-4-10: 1993, Level 5,
100A/m applied in all planes at
100kHz/1MHz with a burst duration of 2s.

**Conducted Emissions**
Per EN 55022: 1998:
0.15 - 0.5MHz, 79dBµV (quasi peak)
66dBµV (average)
0.5 - 30MHz, 73dBµV (quasi peak) 60dBµV (average).

**Radiated Emissions**
Per EN 55022: 1998:
30 - 230MHz, 40dBµV/m at 10m measurement distance
230 - 1GHz, 47dBµV/m at 10m measurement distance.

## EU Directives

**EMC Compliance**
Per 89/336/EEC:
Compliance to the European Commission Directive on EMC is claimed via the Technical Construction File route. Product Specific Standards were used to establish conformity:
EN50263: 2000

**Product Safety**
Per 73/23/EEC:
Compliance with European Commission Low Voltage Directive.
Compliance is demonstrated by reference to generic safety standards:
EN61010-1: 2001
EN60950-1: 2002

## Mechanical Robustness

**Vibration Test**
Per IEC 60255-21-1: 1996
Response Class 2
Endurance Class 2

**Shock and Bump**
Per IEC 60255-21-2: 1995
Shock response Class 2
Shock withstand Class 1
Bump Class 1

**Seismic Test**
Per IEC 60255-21-3: 1995
Class 2

# Protection Functions

## Three Phase Overcurrent Protection

**Accuracy**
Additional tolerance X/R ratios:
±5% over X/R 1…90
Overshoot: <30ms

## Inverse Time Characteristic

**Accuracy**
Pick-up: ±5%
Drop-off: 0.95 x setting ±5%
Minimum IDMT level:
1.05 x setting ±5%
IDMT shape: ±5% or 40ms whichever is greater
IEEE reset: ±5% or 50ms whichever is greater
DT operation: ±2% or 50ms, whichever is greater
DT reset: ±5%
Directional boundary (RCA ±90%):
±2% hysteresis 2o
Characteristic: UK curves
IEC 60255-3 …1998
US curves:
IEEEC37.112…1996

## Earth/Sensitive Fault Protection

**Earth Fault 1**
Pick-up: Setting ±5%
Drop-off: 1.05 x Setting ±5%
Trip level: 0.95 x Setting ±5%
IDMT shape:
±5% or 40ms whichever is greater *
IEEE reset:
±5% or 50ms whichever is greater
DT operation:
±2% or 50ms whichever is greater
DT reset: ±5%
Repeatability: 2.5%
** Reference conditions TMS = 1, TD = 1 and IN> setting of 1A operating range 2-20In*

**Earth Fault 2**
Pick-up: Setting ±5%
Drop-off: 0.95 x Setting ±5%
Trip level: 1.05 x Setting ±5%
IDMT shape:
±5% or 40ms whichever is greater *
IEEE reset:
±10% or 40ms whichever is greater
DT operation:
±2% or 50ms whichever is greater
DT reset:
±2% or 50ms whichever is greater
Repeatability: ±5%
** Reference conditions TMS = 1, TD = 1 and IN > setting of 1A, operating range 2-20In*

**SEF**
Pick-up: Setting ±5%
Drop-off: 0.95 x Setting ±5%
Trip level: 1.05 x Setting ±5%
IDMT shape:
±5% or 40ms whichever is greater *
IEEE reset:
±7.5% or 60ms whichever is greater
DT operation:
±2% or 50ms whichever is greater
DT reset: ±5%
Repeatability: ±5%
** Reference conditions TMS = 1, TD = 1 and IN > setting of 100mA, operating range 2-0In*

**REF**
Pick-up: Setting formula ±5%
Drop-off: 0.80 x setting formula ±5%
Operating time: <60ms
High pick up: Setting ±5%
High operating time: <30ms
Repeatability: <15%

**Wattmetric SEF**
Pick-up For P=0W
ISEF> ±5% or P> ±5%
Drop off: For P>0W
(0.95 x ISEF>) ±5% or 0.9 x P> ±5%
Boundary accuracy:
±5% with 1° hysteresis
Repeatability: 5%

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

**Negative Polarising**
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%

## Negative Sequence Overcurrent

**Accuracy**
I2> Pick-up: Setting ±5%
I2> Drop-off: 0.95 x Setting ±5%
Operating Pick-up: ±2%o of RCA ±90%

TD

Operating hysteresis: <1°
DT Operating: ±2% or 60ms
Whichever is greater
Reset: <35ms
Repeatability: 1%
Instant operating time: <70ms

## Under Voltage Protection

**Accuracy**
Pick-up: Setting ±1% or 1.05 x Setting ±5%
Drop-off: 0.95 x Setting ±5%
IDMT shape: ±2% or 50ms whichever is greater
DT operation: ±2% or 50ms whichever is greater
Reset: <75ms
Repeatability: <1%



## Neutral Displacement/Residual Voltage

**Accuracy**
Pick-up: Setting ±5% or 1.05 x Setting ±5%
Drop-off: 0.95 x Setting ±5%
IDMT shape: ±5% or 65ms whichever is greater
DT operation: ±2% or 20ms whichever is greater <55ms
Reset: <35ms
Repeatability: <10%

## Under-frequency Protection

**Accuracy**
Pick-up: Setting ±0.025Hz
Drop-off: 1.05 x Setting ±0.025Hz
DT operation: ±2% or 50ms whichever is greater *
** The operating will also include a time for the relay to frequency track (20Hz/ second)*

## Over-frequency Protection

**Accuracy**
Pick-up: Setting ±0.025Hz
Drop-off: 0.95 x Setting ±0.025Hz
DT operation: ±2% or 50ms whichever is greater *
** The operating will also include a time for the relay to frequency track (20Hz/ second)*

## Broken Conductor Logic

**Accuracy**
Pick-up: Setting ±2.5%
Drop-off: 0.95 x Setting ±2.5%
DT operation: ±2% or 40ms whichever is greater

## Thermal Overload

**Accuracy**
Thermal alarm pick-up:
Calculated trip time ±10%
Thermal overload pick-up:
Calculated trip time ±10%
Cooling time accuracy:
±15% of theoretical
Repeatability: <5%
** Operating time measured with applied current of 20% above thermal setting.*

## Voltage Controlled Overcurrent

**Accuracy**
VCO threshold Pick-up:
Setting ±5%
Overcurrent Pick-up:
(K factor x Setting) ±5%
VCO threshold Drop-off:
1.05 x Setting ±5%
Overcurrent Drop-off:
0.95 x (K factor x Setting) ±5%
Operating time:
±5% or 60ms whichever is greater
Repeatability: <5%

## Cold Load Pick-up Setting

**Accuracy**
I> Pick-up: Setting ±1.5%
I> Pick-up: Setting ±2.5%
IN> Pick-up: Setting ±1.5%
I> Drop-off: 0.95 x Setting ±1.5%
I> Drop-off: 0.95 x Setting ±2.5%
IN> Drop-off: 0.95 x Setting ±1.5%
DT operation:
±0.5% or 40ms whichever is greater
Repeatability: <1%

## Negative Sequence Overvoltage Protection

**Accuracy**
Pick-up: Setting ±5%
Drop-off: 0.95 x Setting ±5%
DT operation: ±2% or 50ms whichever is greater
Repeatability: <5%

## Admittance, Conductance and Susceptance

**Accuracy**
YN, BN and BN measurements: ±5%
YN, BN, BN Pick-up: Setting ±5%
YN, BN, BN Drop-off: >0.85 x Setting
Operating time:
Start <100ms Trip Setting ±2% or 50 ms
Operating boundary: ±2o
VN: Setting ±5%

## Selective Overcurrent Protection

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

## Voltage Transformer Supervision

**Accuracy**
Fast block operation: <25ms
Fast block reset: <30ms
Time delay: Setting ±2% or 20ms 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 1V whichever is greater
Time delay operation: Setting ±2% or 20ms whichever is greater
CTS block operation: <1 cycle
CTS reset: <35ms

## Programmable Scheme Logic

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

TD

## Measurements and Recording Facilities

**Measurements**
Current: 0.05… 3In
Accuracy: ±1.0% of reading
Voltage: 0.05…2Vn
Accuracy: ±1.0% of reading
Power (W): 0.2…2Vn 0.05…3In
Accuracy: ±5.0% of reading at unity power factor
Reactive Power (Vars): 0.2…2Vn, 0.05…3In
Accuracy: ±5.0% of reading at zero power factor
Apparent Power (VA): 0.2…2Vn 0.05…3In
Accuracy: ±5% of reading
Energy (Wh): 0.2…2Vn 0.2…3In
Accuracy: ±5% of reading at zero power factor
Energy (Varh): 0.2…2Vn 0.2…3In
Accuracy: ±5% of reading at zero power factor
Phase accuracy: 0°…36°
Accuracy: ±0.5%°
Frequency: 45…65Hz
Accuracy: ±0.025Hz

**Performance**
Year 2000: Compliant
Real time clock accuracy: <±2% seconds/day
Modulation ratio: 1/3 or 1/6
Input signal peak-peak amplitude: 200mV…20V
Input impedance at 1000Hz: 6000Ω
External clock synchronization: Conforms to IRIG standard 200-98, format B

## Disturbance Records

**Accuracy**
Magnitude and relative phases: ±5% of applied quantities
Duration: ±2%
Trigger position: ±2% (minimum Trigger 100ms)
Line length: 0.01…1000kn **
Line impedance (100/110V): 0.1/In…250/In Ý
Line impedance (380/480V): 0.4/In…1000/In Ý

Line angle: 20°…85°
KZN residual: 0…7.00
KZN res. angle: -90°…+90°

## Plant Supervision

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



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

**Undercurrent Accuracy**
Pick-up: ±10% or 25mA whichever is greater
Operating time: <20ms
Reset: <25ms

# Settings, Measurements and Records List

## Settings List

### Global Settings (System Data)

Language: English/French/German/Spanish
Frequency: 50/60Hz

### Circuit Breaker Control (CB Control)

CB Control by:
- Disabled
- Local
- Remote
- Local+Remote
- Opto
- Opto+local
- Opto+Remote
- Opto+Rem+local

Close Pulse Time: 0.10…10.00s
Trip Pulse Time: 0.10…5.00s
Man Close t max: 0.01…9999.00s
Man Close Delay: 0.01…600.00s
CB Healthy Time: 0.01…9999.00s
Check Sync. Time: 0.01…9999.00s
Reset Lockout by: User Interface/CB Close
Man Close RstDly: 0.10…600.00s
CB Status Input:
- None
- 52A
- 52B
- 52A & 52B

### Date and Time

IRIG-B Sync.: Disabled/Enabled
Battery Alarm: Disabled/Enabled

### Configuration

Setting Group:
- Select via Menu
- Select via Opto

Active Settings: Group 1/2/3/4
Setting Group 1: Disabled/Enabled
Setting Group 2: Disabled/Enabled
Setting Group 3: Disabled/Enabled
Setting Group 4: Disabled/Enabled
Overcurrent: Disabled/Enabled
Negative Sequence O/C: Disabled/Enabled
Broken Conductor: Disabled/Enabled
Earth Fault 1: Disabled/Enabled
Earth Fault 2: Disabled/Enabled
SEF/REF Prot: Disabled/Enabled
Residual O/V NVD: Disabled/Enabled
Thermal Overload: Disabled/Enabled
Neg. Sequence O/V: Disabled/Enabled
Cold Load Pick-up: Disabled/Enabled
Selective Logic: Disabled/Enabled
Admit. Protection: Disabled/Enabled
Df/dt Protection: Disabled/Enabled
Volt Protection: Disabled/Enabled
Freq. Protection: Disabled/Enabled
CB Fail: Disabled/Enabled
Supervision: Disabled/Enabled
Fault Locator: Disabled/Enabled
System Checks: Disabled/Enabled
Auto-Reclose: Disabled/Enabled
Setting Values: Primary/Secondary
Direct Access:
- Disabled
- Enabled
- Hotkey only
- CB Cntrl. only

LCD Contrast: *(Factory pre-set)*

### CT and VT Ratios

Main VT Primary: 100V...1MV
Main VT Sec'y: 80...140V
C/S VT Primary: 100V...1MV
C/S VT Secondary: 80...140V
Phase CT Primary: 1A…30kA
Phase CT Sec'y: 1A/5A
E/F CT Primary: 1A…30kA
E/F CT Sec'y: 1A/5A
SEF CT Primary: 1A…30kA
SEF CT Sec'y: 1A/5A
C/S Input:
- A-N
- B-N
- C-N
- A-B
- B-C
- C-A

Main VT Location: Line/Bus

### Sequence of Event Recorder (Record Control)

Alarm Event: Disabled/Enabled
Relay O/P Event: Disabled/Enabled
Opto Input Event: Disabled/Enabled
General Event: Disabled/Enabled
Fault Rec. Event: Disabled/Enabled
Maint. Rec. Event: Disabled/Enabled
Protection Event: Disabled/Enabled
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 (Disturb. Recorder)

Duration: 0.10…10.50s
Trigger Position: 0.0…100.0%
Trigger Mode: Single/Extended
Analog Channel 1: *(up to):*

TD

Analog Channel 8:
*Disturbance channels selected from:*
VA/VB/VC/Vchecksync./IA/IB/IC/IN/IN Sensitive
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 L/H/Trigger H/L
*(up to):*
Input 32 Trigger: No Trigger/Trigger L/H/ Trigger H/L

## Measured Operating Data (Measure't. Setup)

Default Display:
3Ph + N Current
3Ph Voltage
Power
Date and Time
Description
Plant Reference
Frequency
Access Level
Local Values: Primary/Secondary
Remote Values: Primary/Secondary
Measurement Ref: VA/VB/VC/IA/IB/IC
Measurement Mode: 0/1/2/3
Fix Dem. Period: 1…99mins
Roll Sub Period: 1…99mins
Num. Sub Periods: 1…15
Distance Unit: Miles/Kilometres
Fault Location:
Distance
Ohms
% of Line
Remote2 Values: Primary/Secondary

## Communications

RP1 Protocol:
Courier
IEC870-5-103
DNP 3.0
RP1 Address: *(Courier or IEC870-5-103):*
0…255
RP1 Address: *(DNP3.0):*
0…65519
RP1 InactivTimer: 1…30mins
RP1 Baud Rate: *(IEC870-5-103):*
9600/19200 bits/s
RP1 Baud Rate: *(DNP3.0):*
1200 bits/s
2400 bits/s
4800 bits/s
9600 bits/s
19200 bits/s
38400 bits/s
RP1 Parity:
Odd/Even/None
RP1 Meas Period: 1…60s
RP1 PhysicalLink:
Copper
Fiber Optic *(IEC870-5-103, DNP3.0, Courier, MODBUS)*
K-Bus *(Courier only)*
RP1 Time Sync: Disabled/Enabled
RP1 CS103 Blocking:
Disabled
Monitor Blocking
Command Blocking
RP1 Port Config. *(Courier):*
K Bus
EIA(RS)485
RP1 Comms. Mode:
IEC60870 FT1.2 Frame 10-Bit No Parity

## Optional Additional Second Rear Communication (Rear Port2 (RP2))

RP2 Protocol: Courier (fixed)
RP2 Port Config:
Courier over EIA(RS)232
Courier over EIA(RS)485
K-Bus
RP2 Comms. Mode:
IEC60870 FT1.2 Frame
10-Bit NoParity
RP2 Address: 0…255
RP2 InactivTimer: 1…30mins
RP2 Baud Rate:
9600 bits/s
19200 bits/s
38400 bits/s

## Optional Ethernet Port

IP Address: 000.000.000.000)
Subnet Mask: 000.000.000.000)
Number of Routes: 0…4
Router Address 1: 000.000.000.000)
Target Network 1: 000.000.000.000)
Router Address 2: 000.000.000.000
Target Network 2: 000.000.000.000)
Router Address 3: 000.000.000.000)
Target Network 3: 000.000.000.000)
Router Address 4: 000.000.000.000)
Target Network 4: 000.000.000.000)
NIC Inactivity Timer: 1…30 minutes
Default Pass Lvl: 0…2
Goose Min. Cycle: 1…50ms
Goose Max. Cycle: 1…60s
Goose Increment: 0…999
Goose Startup:
Promiscuous/Broadcast
Ethernet Media: Copper/ Fiber
IED View Select: 0…32
IED Stats Reset:
None
Enrolled + Local IED
Enrolled IED

Viewed IED
Local IED
Report Link Test: None/Alarm/
Event
Link Time-Out: 0.10…60.00s

## 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.*
Static Test Mode: Disabled/Enabled

## Circuit Breaker Condition Monitoring (CB Monitor Setup)

Broken I^: 1.0…2.0
I^ Maintenance: Alarm
Disabled/Enabled
I^ Maintenance: 1…25000
I^ Lockout: Alarm Disabled/Enabled
I^ Lockout: 1…25000
No. CB Ops Maint: Alarm
Disabled/Enabled
No. CB Ops Maint: 1…10000
No. CB Ops Lock: Alarm
Disabled/Enabled
No. CB Ops Lock: 1…10000
CB Time Maint: Alarm
Disabled/Enabled
CB Time Maint: 0.005…0.500s
CB Time Lockout: Alarm
Disabled/Enabled
CB Time Lockout: 0.005…0.500s
Fault Freq. Lock: Alarm
Disabled/Enabled
Fault Freq. Count: 1…9999
Fault Freq. Time: 0…9999s

## Optocoupled Binary Inputs (Opto Config.)

Global threshold:
24 - 27V
30 - 34V
48 - 54V
110 - 125V
220 - 250V
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.*
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%

## 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*

## 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 4.*

TD

TD

# Protection Functions

## Phase Overcurrent (Overcurrent)

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 Direction:
Non-Directional
Directional Fwd
Directional Rev
I>1 Current Set: 0.08…4.00 In
I>1 Time Delay: 0.00…100.00s
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…100.00s
I>2 Status
*(up to):*
I>2 tRESET
*All settings and options chosen from the same ranges as per the first stage overcurrent, I>1.*
I>3 Status:
Disabled
Enabled
I>3 Direction:
Non-Directional
Directional Fwd
Directional Rev
I>3 Current Set: 0.08…32.00 In
I>3 Time Delay: 0.00…100.00s
I>4 Status
*(up to):*
I>4 Time Delay
*All settings and options chosen from the same ranges as per the third stage overcurrent, I>3.*
I> Char Angle: -95…95 o
I> Blocking:
*Binary function link string, selecting which overcurrent elements (stages 1 to 4) will be blocked if VTS detection of fuse failure occurs.*

## Voltage Controlled Overcurrent

VCO Status:
Disabled
I>1
I>2
Both I>1 & I>2
VCO V<Setting:
20…120V (100/120V)
80…480V (380/440V)
VCO k Setting: 0.25…1.00

## Negative Sequence Overcurrent

I2>1 Status: Disabled/Enabled
I2>1 Direction:
Non-Directional
Directional Fwd
Directional Rev
I2>1 Current Set: 0.08…4.00 In
I2>1 Time Delay: 0.00 …100.00s
I2>2 Status
*(up to):*
I2>4 Time Delay
*All settings and options chosen from the same ranges as per the third stage overcurrent, I2>1.*
I2> Blocking:
*Binary function link string, selecting which Neg. Seq. O/C elements (stages 1 to 4) will be blocked if VTS detection of fuse failure occurs*
I2> Char Angle: -95…95 o
I2> V2pol Set:
0.5…25.0 (100 – 110V):
2…100 (380 – 480V):

## Broken Conductor

Broken Conductor: Disabled/Enabled
I2/I1 Setting: 0.20…1.00
I2/I1 Time Delay: 0.0…100.0s

## Ground Overcurrent (Earth Fault 1 & 2)

IN1>1 Function
Disabled
DT
IEC S Inverse
IEC V Inverse
IEC E Inverse
UK LT Inverse
RI
IEEE M Inverse
IEEE V Inverse
IEEE E Inverse
US Inverse
US ST Inverse
IDG
IN1>1 Directional
Non-Directional
Directional Fwd
Directional Rev
IN1>1 Current Set: 0.08…4.00 In

IN1>1 IDG Is: 1.0…4.0 In
IN1>1 Time Delay: 0.00…200.00s
IN1>1 TMS: 0.025…1.200
IN1>1 Time Dial: 0.01…100.00
IN1>1 K(RI): 0.10..10.00
IN1>1 IDG Time: 1.00..2.00
IN1>1 Reset Char.: DT/Inverse
IN1>1 tRESET: 0.00…100.00s
IN1>2 Status
*(up to):*
IN1>2 tRESET
*All settings and options chosen from the same ranges as per the first stage ground overcurrent, IN>1.*
IN1>3 Status:
Disabled
Enabled
IN1>3 Directional:
Non-Directional
Directional Fwd
Directional Rev
IN1>3 Current Set: 0.08…32.00 In
IN1>3 Time Delay: 0.00…200.00s
IN1>4 Status
*(up to):*
IN1>4 Time Delay
*All settings and options chosen from the same ranges as per the third stage ground overcurrent, IN>3.*
IN1> Blocking:
*Binary function link string, selecting which ground overcurrent elements (stages 1 to 4) will be blocked if VTS detection of fuse failure occurs.*
IN1> Char Angle: -95…95 o
IN1> Polarization:
Zero Sequence
Neg. Sequence
IN1> VNpol Set:
0.5…80.0V (100 – 110V)
2…320V (380 – 480V)
IN1> V2pol Set:
0.5…25.0V (100 – 110V)
2…100V (380 – 480V)
IN1> I2pol Set: 0.08…1.00 In

## Sensitive Earth Fault Protection/ Restricted Earth Fault Protection

SEF/REF Options:
SEF
SEF cos (PHI)
SEF sin (PHI)
Wattmetric
Hi Z REF
Lo Z REF
Lo Z REF + SEF
Lo Z REF + Wattmetric
ISEF>1 Function
Disabled
DT
IEC S Inverse
IEC V Inverse
IEC E Inverse
UK LT Inverse
RI
IEEE M Inverse
IEEE V Inverse
IEEE E Inverse
US Inverse
US ST Inverse
IDG
ISEF>1 Directional
Non-Directional
Directional Fwd
Directional Rev.
ISEF>1 Current Set: 0.08…4.00 In
ISEF>1 IDG Is: 1.0…4.0 In
ISEF>1 Time Delay: 0.00…200.00s
ISEF>1 TMS: 0.025…1.200
ISEF>1 Time Dial: 0.5…100.0
IN1>1 K(RI): 0.10..10.00
ISEF>1 IDG Time: 1.00..2.00
ISEF>1 Reset Char: DT/Inverse
ISEF>1 tRESET: 0.00…100.00s
ISEF>2 Status
*(up to):*
ISEF>2 tRESET
*All settings and options chosen from the same ranges as per the first stage ground overcurrent, IN>1.*
ISEF>3 Status:
Disabled
Enabled
ISEF>3 Directional:
Non-Directional
Directional Fwd
Directional Rev
ISEF>3 Current Set: 0.005….2.000 In
ISEF>3 Time Delay: 0.00…200.00s
ISEF>4 Status
*(up to):*
ISEF>4 Time Delay
*All settings and options chosen from the same ranges as per the third stage ground overcurrent, IN>3.*
ISEF> Blocking:
*Binary function link string, selecting which ground overcurrent elements (stages 1 to 4) will be blocked if VTS detection of fuse failure occurs.*
ISEF> Char. Angle: -95…95 o
ISEF> VNpol Set:
0.5…80.0V (100 – 110V)
2…320V (380 – 480V)
WATTMETRIC SEF:
PN> Setting: 0…20W (1A, 100/120V)
PN> Setting: 0…100W (5A, 100/120V)
PN> Setting: 0 …80W (1A, 380/440V)
PN> Setting: 0…400W (5A, 380/440V)
**RESTRICTED EARTH-FAULT (Low Impedance)**
IREF > K1: 0 …20%
IREF > K2: 0 …150%
IREF > Is1: 0.08…1.00 In
IREF > Is2: 0.1…1.50 In

**(High Impedance)**
IREF > K1: 0.05…1.00 In

## Neutral Voltage Displacement (Residual O/V NVD)

VN>1 Function:
Disabled
DT
IDMT
VN>1 Voltage Set: 1…50V
VN>1 Time Delay: 0.00…100.00s
VN>1 TMS: 0.5…100.0
VN>1 tReset: 0.00…100.00s
VN>2 Status: Disabled/Enabled
VN>2 Voltage Set:
1…80V (100/110V)
4…320V (380/440V)
VN>2 Time Delay: 0.00…100.00s

## Thermal Overload

Characteristic:
Disabled
Single
Dual
Thermal Trip: 0.08…4.00 In
Thermal Alarm: 50…100%
Time Constant 1: 1…200mins
Time Constant 2: 1…200mins

## Negative Sequence Overvoltage Protection

V2> Status: Disabled/Enabled
V2> Voltage Set:
1V…110V (100/120V)
4V – 440V (380/440V)
V2> Time Delay: 0.00…100.00s

## Cold Load Pick-up Setting

tcold Time Delay: 0…14 400s
tclp Time Delay: 0…14 400s
Overcurrent
I>1 Status: Block/Enabled
I>1 Current Set: 0.08…4.00 In
I>1 Time delay: 0.00…100.00s
I>1 TMS: 0.025….2.000
I>1 Time Dial: 0.5…15.0
I>2 Status
*(up to):*
I>2 Time Dial
*All settings and options chosen from the same ranges as per the 1st stage*
I>3 Status: Block/Enabled
I>3 Current Set: 0.08…32.00 In
3 Time delay: 0.00…100.00s
I>4 Status
*(up to):*
I>4 Time Delay
*All settings and options chosen from the same ranges as per the 1st stage*
E/F1
IN1>1 Status: Block/Enabled
IN1>1 Current Set: 0.08…4.00 In
IN1>1 IDG Is: 1.0…4.0 In
IN1>1 Time Delay: 0.00…200.00s
IN1>1 TMS: 0.025….2.000
IN1>1 Time Dial: 0.5…15.0
IN1>1 K(RI): 0.10..10.00
IN1>2 Status
*(up to):*
IN2> 1 K(RI)
*All settings and options chosen from the same ranges as per the E/F1 stage*

## Selective Overcurrent Logic

Overcurrent
I>3 Time Delay: 0.00…100.00s
I>4 Time Delay: 0.00…100.00s
Earth Fault1
IN1>3 Time Delay: 0.00…200.00s
IN1>4 Time Delay: 0.00…200.00s
Earth Fault2
IN2>3 Time Delay: 0.00…200.00s
IN2>4 Time Delay: 0.00…200.00s
Sensitive E/F
ISEF>3 Time Delay: 0.00…200.00s
ISEF>4 Time Delay: 0.00…200.00s

## Neutral Admittance Protection

VN Threshold:
1…40V (100/120V)
4…160V (380/440V)
CT Input Type: SEF CT/E/F CT
Correction angle: 30…30o
Overadmittance
YN Status: Disabled/Enabled
YN> Set (SEF):
0.1…10mS (100/110V)
0.025…2.5mS (380/440V)
YN> Set (EF):
1…100mS (100/110V)
0.25…25mS (380/440V)
YN> Time Delay: 0.05s…100.00s
YN> tRESET: 0.00…100.00s
Over Conductance
GN Status: Disabled/Enabled
GN>Direction
Non-Directional
Directional Fwd
Directional Rev.
GN> Set (SEF):
0.1…5mS (100/110V)
0.25…1.25mS (380/440V)
GN> Set (E/F):
1…50mS (100/110V)
0.25…12.5mS (380/440V)
GN> Time Delay: 0.05s…100s
GN>tRESET: 0s…100s
Over Susceptance
BN Status: Disabled/Enabled
GN>Direction
Non-Directional
Directional Fwd

Directional Rev.
BN> Set (SEF)
0.1…5mS (100/110V)
0.025…1.25mS (380/440V))
BN> Set (E/F):
1…50mS (100/110V)
0.25…12.5mS (380/440V)
BN> Time Delay: 0.05…100s
BN> tRESET: 0s…100s

## Undervoltage Protection

V< Measur't. Mode:
Phase-Phase
Phase-Neutral
V< Operate Mode:
Any Phase
Three Phase
V<1 Function:
Disabled
DT
IDMT
V<1 Voltage Set:
10…120V (100/110V)
40…480V (380/440V)
V<1 Time Delay: 0.00…100.00s
V<1 TMS: 0.5…100.0
V<1 Poledead Inh: Disabled/Enabled
V<2 Status: Disabled/Enabled
V<2 Voltage Set:
10…120V (100/110V)
40…480V (380/440V)
V<2 Time Delay: 0.00…100.00s
V<2 Poledead Inh: Disabled/Enabled

## Overvoltage Protection

V> Measur't. Mode:
Phase-Phase
Phase-Neutral
V> Operate Mode:
Any Phase
Three Phase
V>1 Function:
Disabled
DT
IDMT
V>1 Voltage Set:
60…185V (100/110V)
240…740V (380/440V)
V>1 Time Delay: 0.00…100.00s
V>1 TMS: 0.5…100.0
V>2 Status: Disabled/Enabled
V>2 Voltage Set:
60…185V (100/110V)
240…740V (380/440V)
V>2 Time Delay: 0.00…100.00s

## Under-frequency Protection

F<1 Status: Disabled/Enabled
F<1 Setting: 45.00…65.00Hz
F<1 Time Delay: 0.00…100.00s
F<2 Status
*(up to):*
F<4 Time Delay
*All settings and options chosen from the same ranges as per the 1st stage*
F> Blocking:
*Binary function link string, selecting which frequency elements (stages 1 to 4) will be blocked by the pole-dead logic*

## Over-frequency Protection

F>1 Status: Disabled/Enabled
F>1 Setting: 45.00…65.00Hz
F>1 Time Delay: 0.00…100.00s
F<2 Status
*(up to):*
F<2 Time Delay
*All settings and options chosen from the same ranges as per the 1st stage*

## Rate-of-Change of Frequency Protection (df/dt Protection)

df/dt Avg. Cycles: 6…12
df/dt>1 Status: Disabled/Enabled
df/dt>1 Setting: 0.1…10.0Hz
df/dt>1 Dir'n.: Negative/Positive/Both
df/dt>1 Time: 0.00…100.00s
df/dt>2 Status:
*(up to):*
df/dt>4 Time
*All settings and options chosen from the same ranges as per the 1st stage.*

## Circuit Breaker Fail

CB Fail 1 Status: Disabled/Enabled
CB Fail 1 Timer: 0.00…10.00s
CB Fail 2 Status: Disabled/Enabled
CB Fail 2 Timer: 0.00…10.00s
Volt Prot. Reset:
I< Only
CB Open & I<
Prot. Reset & I<
Ext Prot. Reset:
I< Only
CB Open & I<
Prot. Reset & I<

## Undercurrent

I< Current Set: 0.02…3.20 In
IN< Current Set: 0.02…3.20 In
ISEF< Current Set: 0.001…0.800 In
BLOCKED O/C
Remove I> Start: Disabled/Enabled
Remove IN> Start: Disabled/Enabled

## Fuse Failure (VT Supervision)

VTS Status:
Blocking/Indication
VTS Reset Mode: Manual/Auto

TD

VTS Time Delay: 1.0…10.0s
VTS I> Inhibit: 0.08…32.00 In
VTS I2> Inhibit: 0.05…0.50 In

## CT Supervision

CTS Status: Disabled/Enabled
CTS VN< Inhibit:
0.5…22.0V (100/110V)
2…88V (380/440V)
CTS IN> Set: 0.08…4.00 In
CTS Time Delay: 0…10s

## Fault Locator

Line Length (km): 0.001…1000.000km
Line Length (mi): 0.20…625.00mi
Line Impedance: 0.10…250.00Ω
Line Angle: 20…85 o
KZN Residual: 0.00…7.00
KZN Res. Angle: -90…90 o

## Bus-line Synchronism and Voltage Checks (System Checks)

VOLTAGE MONITORS
Live Voltage:
1.0…132.0V (100/110V)
22…528V (380/440V)
Dead Voltage:
1.0…132.0V (100/110V)
22…528V (380/440V)

## Synchrocheck (Check Sync.)

CS1 Status: Disabled/Enabled
CS1 Phase Angle: 5…90 o
CS1 Slip Control:
None
Timer
Frequency
Both
CS1 Slip Freq.: 0.01…1.00Hz
CS1 Slip Timer: 0.0…99.0s
CS2 Status
*(up to):*
CS2 Slip Timer
*All settings and options chosen from the same ranges as per the first stage CS1 element.*
CS Undervoltage:
10.0…132.0V (100/110V)
40…528V (380/440V)
CS Overvoltage:
60.0…185.0V (100/110V
240…740V (380/440V)
CS Diff Voltage:
1.0…132.0V (100/110V)
4…528V (380/440V)
CS Voltage Block:
None
Undervoltage
Overvoltage
Differential
UV & OV
UV & DiffV
OV & DiffV
UV, OV & DiffV

## System Split

SS Status: Disabled/Enabled
SS Phase Angle: 90…175 o
SS Under V Block: Disabled/Enabled
SS Undervoltage:
10.0…132.0V (100/110V)
40…528V (380/440V)
SS Timer: 0.0…99.0s
CB Close Time: 0.000…0.500s

## Autoreclose

AR Mode Select:
Command Mode
Opto Set Mode
User Set Mode
Pulse Set Mode
Number of Shots: 1…4
Number of SEF Shots: 0…4
Sequence Co-ord.: Disabled/Enabled
CS AR Immediate: Disabled/Enabled
Dead Time 1: 0.01…300.00s
Dead Time 2: 0.01…300.00s
Dead Time 3: 0.01…9999.00s
Dead Time 4: 0.01…9999.00s
CB Healthy Time: 0.01s…9999.00s
Start Dead ↑ on:
Protection Resets/CB Trips
↑Reclaim Extend:
No Operation/On Prot. Start
Reclaim Time: 1.00…600.00s
AR Inhibit Time: 0.01…600.00s
AR Lockout: No Block/Block Inst. Prot.
EFF Maint. Lock:
No Block/Block Inst. Prot.
AR Deselected:
No Block/Block Inst. Prot.
Manual close:
No Block/Block Inst. Prot.
Trip 1 Main: No Block/Block Inst. Prot.
Trip 2 Main: No Block/Block Inst. Prot.
Trip 3 Main: No Block/Block Inst. Prot.
Trip 4 Main: No Block/Block Inst. Prot.
Trip 5 Main: No Block/Block Inst. Prot.
Trip 1 SEF: No Block/Block Inst. Prot.
Trip 2 SEF: No Block/Block Inst. Prot.
Trip 3 SEF: No Block/Block Inst. Prot.
Trip 4 SEF: No Block/Block Inst. Prot.
Trip 5 SEF: No Block/Block Inst. Prot.
Man. Close on Flt.:
No Lockout/Lockout
Trip AR Inactive:
No Lockout/Lockout
Reset Lockout by:
User Interface/Select Non-Auto
AR on Man. Close: Enabled/Inhibited
Sys. Check Time: 0.01…9999.00s
AR INITIATION
I>1, I>2:

No Action/Initiate Main AR
I>3 and I>4:
No Action/Initiate Main AR/Block AR
IN1>1 and IN1>2:
No Action/Main AR
IN1>3 and IN1>4:
No Action/Initiate Main AR/Block AR
IN2>1, IN2>2:
No Action/Initiate Main AR
IN2>3 and IN2>4:
No Action/Initiate Main AR/Block AR
ISEF>1, ISEF>2, ISEF>3 and ISEF>4:
No Action/Initiate Main AR/Initiate SEF AR/ Block AR
YN/GN/ BN>:
No Action/Initiate Main AR
Ext. Prot.:
No Action/Initiate Main AR
SYSTEM CHECKS
AR with ChkSync.: Disabled/Enabled
AR with SysSync.: Disabled/ Enabled
Live/Dead Ccts: Disabled/Enabled
No System Checks:
Enabled/Disabled
SysChk on Shot 1: Disabled/ Enabled

## Opto Input Labels

Opto Input 1:
*(up to):*
Opto Input 24:
*User defined text string to describe the function of the particular opto input.*

## Output Labels

Relay 1:
*(up to):*
Relay 32:
*User defined text string to describe the function of the particular relay output contact.*

# Measurements List

## Measurements 1

Iφ Magnitude
Iφ Phase Angle
*Per phase (φ = A, B, C) current measurements*
IN Measured Mag.
IN Measured Ang.
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)*
VN Derived Mag.
VN Derived Ang.
V1 Magnitude.
V2 Magnitude
V0 Magnitude
Vφ RMS
*All phase-neutral voltages (φ = A, B, C)*
Frequency
C/S Voltage Mag.
C/S Voltage Ang.
C/S Bus-line Ang.
Slip Frequency
IM Magnitude
IM Phase Angle
I1 Magnitude
I1 Phase Angle
I2 Magnitude
I2 Phase Angle
I0 Magnitude
I0 Phase Angle
V1 Magnitude
V1 Phase Angle
V2 Magnitude
V2 Phase Angle
V0 Magnitude
V0 Phase Angle

## Measurements 2

φ Phase Watts
φ Phase VArs
φ Phase VA
*All phase segregated power measurements, real, reactive and apparent (φ = A, B, C)*
3 Phase Watts
3 Phase VArs
3 Phase VA
Zero Seq. Power
3Ph Power Factor
φPh Power Factor
*Independent power factor measurements for all three phases (φ = A, B, C)*
3Ph WHours Fwd
3Ph WHours Rev.
3Ph VArHours Fwd
3Ph VArHours Rev.
3Ph W Fix Demand
3Ph VArs Fix Dem.
Iφ Fixed Demand
*Maximum demand currents measured on a per phase basis (φ = A, B, C)*
3Ph W Roll Dem.
3Ph VArs Roll Dem.
Iφ Roll Demand
*Maximum demand currents measured on a per phase basis (φ = A, B, C)*

TD

3Ph W Peak Dem.
3Ph VAr Peak Dem.
Iφ Peak Demand
*Maximum demand currents measured on a per phase basis (φ = A, B, C)*
Reset Demand: Yes/No

## Measurements 3

Highest Phase I
Thermal State
Reset Thermal
IREF Diff.
IREF Bias
Admittance
Conductance
Susceptance
Admittance
Conductance
Susceptance
I2/I1 Ratio
SEF Power
df/dt

## Circuit Breaker Monitoring Statistics

CB Operations
CB φ Operations
*Circuit breaker operation counters on a per phase basis (φ = A, B, C)*
Total Iφ Broken
*Cumulative breaker interruption duty on a per phase basis (φ = A, B, C)*
CB Operate Time

CB CONTROL
Total Reclosures

## Fault Record Proforma

*The following data is recorded for any relevant elements that operated during a fault, and can be viewed in each fault record.*
Time & Date
Event Text
Event Value
Select Fault: [0...n]
Started Phase: A/B/C
Tripped Phase: A/B/C
Overcurrent
Start I> 1234
Trip I> 1234
Neg. Seq. O/C
Start I2> 1234
Trip I2> 1234
Broken ConductorTrip
Earth Fault 1
Start IN1> 1234
Trip IN1> 1234
Earth Fault 2
Start IN2> 1234
Trip IN2> 1234
Sensitive E/F
Start ISEF> 1234
Trip ISEF> 1234
Restricted E/F
Trip IREF>
Residual O/V NVD
Start VN> 1 2
Trip VN> 1 2
Thermal Overload: Alarm/Trip
Neg. Seq. O/V
V2> Start Trip
U/Voltage Start
V< 1 2 AB BC CA
U/Voltage Trip
V< 1 2 AB BC CA
O/Voltage Start
V> 1 2 AB BC CA
O/Voltage Trip
V> 1 2 AB BC CA
Underfrequency
Start F< 1234
Trip F< 1234
Overfrequency
Start F> 1 2
Trip F> 1 2
df/dt Protection
Start df/dt>1234
Trip df/dt>1234
Overadmittance
YN> Start Trip
Overconductance
GN> Start Trip
Oversusceptance
BN> Start Trip
Breaker Fail:
CB Fail 1 2
Supervision
VTS/CTS/VCO/CLP
A/R State: Trip 1/2/3/4/5
Faulted Phase: A/B/C
Start Elements:
Trip Elements:
*Binary data strings for fast polling of which protection elements started or tripped for the fault recorded.*
Fault Alarms:
*Binary data strings for fast polling of alarms for the fault recorded.*
Fault Time:
Active Group: 1/2/3/4
System Frequency: Hz
Fault Duration: s
CB Operate Time: s
Relay Trip Time: s
Fault Location: km/miles/Ω/%
*The current magnitudes and phase angles stored before the fault inception.*
Iφ
Vφ:
*Per phase record of the current and voltage magnitudes during the fault.*
IN Measured
IN Derived
IN Sensitive
IREF Diff.

IREF Bias
VAN
VBN
VCN
VN Derived
Admittance
Conductance
Susceptance

GS

# GETTING STARTED

**Date:** **7th July 2005**
**Hardware Suffix:** **J**
**Software Version:** **31**
**Connection Diagrams:** **10P145xx (xx = 01 to 07)**

GS

# CONTENTS



GS

# FIGURES

# 1. GETTING STARTED

## 1.1 User interfaces and menu structure

The settings and functions of the MiCOM protection relay can be accessed both from the front panel keypad and LCD, and via the front and rear communication ports. Information on each of these methods is given in this section to describe how to start using the relay.

## 1.2 Introduction to the relay

### 1.2.1 Front panel



The front panel of the relay is shown in Figure 1, with the hinged covers at the top and bottom of the relay shown open. Extra physical protection for the front panel can be provided by an optional transparent front cover. With the cover in place read only access to the user interface is possible. Removal of the cover does not compromise the environmental withstand capability of the product, but allows access to the relay settings. When full access to the relay keypad is required, for editing the settings, the transparent cover can be unclipped and removed when the top and bottom covers are open. If the lower cover is secured with a wire seal, this will need to be removed. Using the side flanges of the transparent cover, pull the bottom edge away from the relay front panel until it is clear of the seal tab. The cover can then be moved vertically down to release the two fixing lugs from their recesses in the front panel.

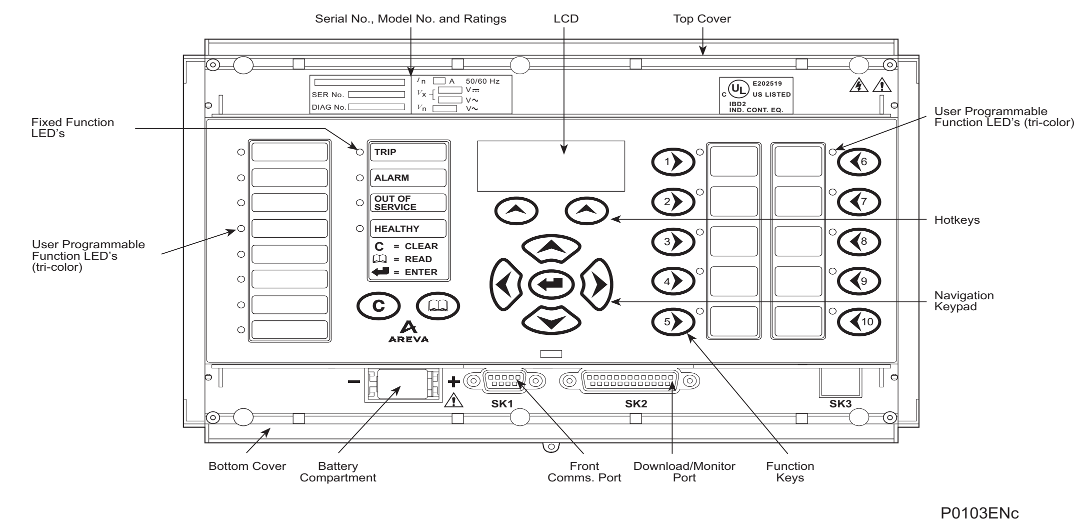



**Figure 1: Relay front view**

The front panel of the relay includes the following, as indicated in Figure 1:

– a 16-character by 3-line alphanumeric liquid crystal display (LCD)

– a 19-key keypad comprising 4 arrow keys (◁, ▷, △ and ▽), an enter key (↵), a clear key (C), a read key (📖), 2 hot keys (⑦) and 10 (① – ⑩) programmable function keys

– Function key functionality:

  – The relay front panel features control pushbutton switches with programmable LEDs that facilitate local control. Factory default settings associate specific relay functions with these 10 direct-action pushbuttons and LEDs e.g. Enable/Disable the auto-recloser function. Using programmable scheme logic, the user can readily change the default direct-action pushbutton functions and LED indications to fit specific control and operational needs.

- Hotkey functionality:
  - SCROLL

    Starts scrolling through the various default displays.
  - STOP

    Stops scrolling the default display.
  - For control of setting groups, control inputs and circuit breaker operation
- 22 LEDs; 4 fixed function LEDs, 8 tri-color programmable function LEDs on the left hand side of the front panel and 10 tri-color programmable function LEDs on the right hand side associated with the function keys



- Under the top hinged cover:
  - The relay serial number, and the relay's current and voltage rating information
- Under the bottom hinged cover:
  - Battery compartment to hold the 1/2 AA size battery which is used for memory back-up for the real time clock, event, fault and disturbance records
  - A 9-pin female D-type front port for communication with a PC locally to the relay (up to 15m distance) via an EIA(RS)232 serial data connection
  - A 25-pin female D-type port providing internal signal monitoring and high speed local downloading of software and language text via a parallel data connection

#### 1.2.1.1 LED indications

Fixed Function

The 4 fixed function LEDs on the left-hand side of the front panel are used to indicate the following conditions:

Trip (Red) indicates that the relay has issued a trip signal. It is reset when the associated fault record is cleared from the front display. (Alternatively the trip LED can be configured to be self-resetting)*.

Alarm (Yellow) flashes to indicate that the relay has registered an alarm. This may be triggered by a fault, event or maintenance record. The LED will flash until the alarms have been accepted (read), after which the LED will change to constant illumination, and will extinguish, when the alarms have been cleared.

Out of service (Yellow) indicates that the relay's protection is unavailable.

Healthy (Green) indicates that the relay is in correct working order, and should be on at all times. It will be extinguished if the relay's self-test facilities indicate that there is an error with the relay's hardware or software. The state of the healthy LED is reflected by the watchdog contact at the back of the relay.

To improve the visibility of the settings via the front panel, the LCD contrast can be adjusted using the "LCD Contrast" setting in the CONFIGURATION column. This should only be necessary in very hot or cold ambient temperatures.

Programmable LEDs

All the programmable LEDs are tri-color and can be programmed to indicate RED, YELLOW or GREEN depending on the requirements. The 8 programmable LEDs on the left are suitable for programming alarm indications and the default indications and functions are indicated in the table below. The 10 programmable LEDs physically associated with the function keys, are used to indicate the status of the associated pushbutton's function and the default indications are shown below:

The default mappings for each of the programmable LEDs are as shown in the following table:

| LED Number | Default Indication | P145 Relay |
|---|---|---|
| 1 | Red | E/F Trip |
| 2 | Red | I>1/2 Trip |
| 3 | Red | I>3/4 Trip |
| 4 | Red | A/R in Progress |
| 5 | Red | A/R Lockout |
| 6 | Red | Any Start |
| 7 | Green | CB Open |
| 8 | Red | CB Closed |
| F1 | Red | Remote CB Control Enable/Disabled |
| F2 | Yellow | CB Trip Enable/Disabled |
| F3 | Yellow | CB Close Enable/Disabled |
| F4 | Red | SEF Enable/Disabled |
| F5 | Red | SG2 Enable/Disabled |
| F6 | Red | Auto-reclose Enable/Disabled |
| F7 | Red | Live Line Mode Enable/Disabled |
| F8 | Red | Not in Use |
| F9 | Yellow | LED Reset |
| F10 | Yellow | Auto-reclose Lockout Reset |

### 1.2.2 Relay rear panel

The rear panel of the relay is shown in Figure 2 and Figure 3 for two variants of the P145 relay. All current and voltage signals, digital logic input signals and output contacts are connected at the rear of the relay. Shown at the rear is the twisted pair wiring for the rear EIA(RS)485 communication port and in Figure 2 the optional optical fiber rear communication port with IRIG-B time synchronizing input. Figure 3 indicates the relay with optional Ethernet rear communications port with copper or fiber optic connections.

GS

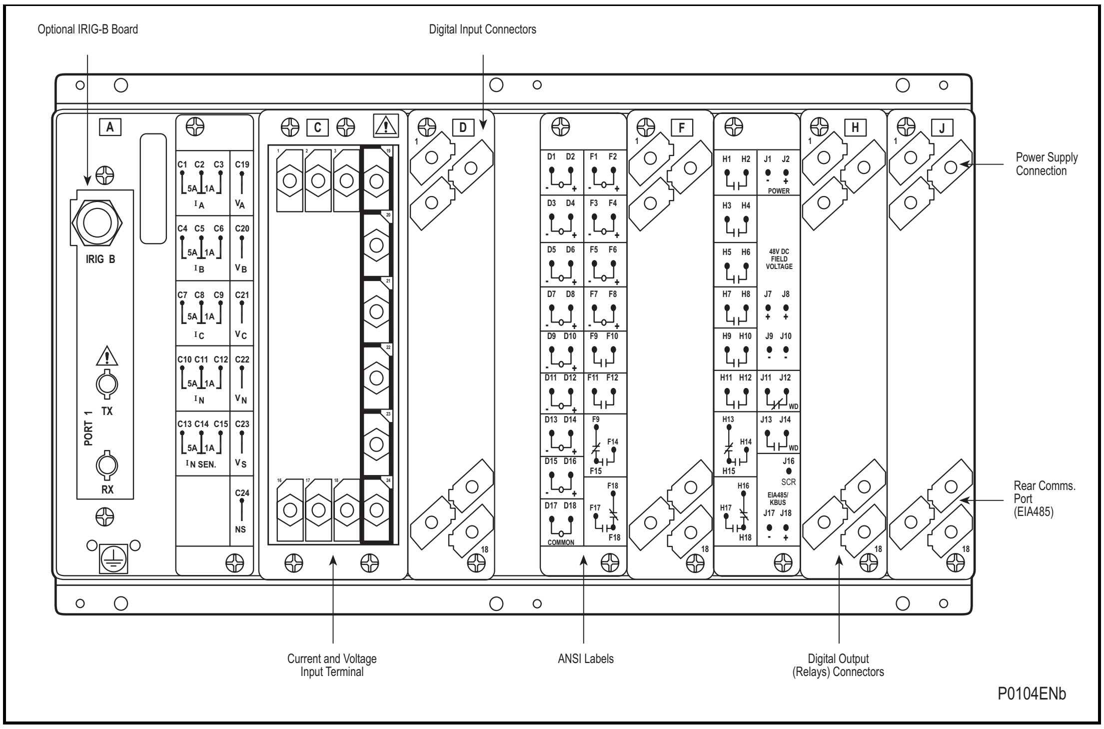



**Figure 2: Relay rear view for B-variant**

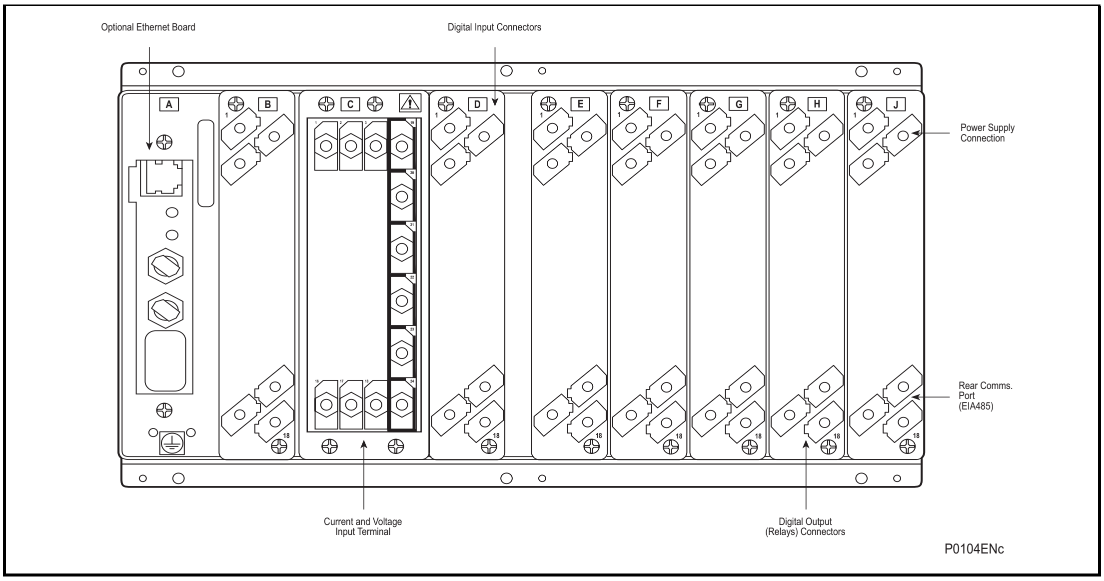



**Figure 3: Relay rear view for G-variant**

Refer to the wiring diagram in the Installation section for complete connection details.

## 1.3 Relay connection and power-up

Before powering-up the relay, confirm that the relay power supply voltage and nominal ac signal magnitudes are appropriate for your application. The relay serial number, and the relay's current and voltage rating, power rating information can be viewed under the top hinged cover. The relay is available in the following auxiliary voltage versions and these are specified in the table below:

| Nominal Ranges | Operative dc Range | Operative ac Range |
|---|---|---|
| 24 - 48V dc | 19 to 65V | - |
| 48 - 110V dc (30 - 100V ac rms) ** | 37 to 150V | 24 to 110V |
| 110 - 250V dc (100 - 240V ac rms) ** | 87 to 300V | 80 to 265V |

** rated for ac or dc operation

Please note that the label does not specify the logic input ratings. The P145 relay is fitted with universal opto isolated logic inputs that can be programmed for the nominal battery voltage of the circuit of which they are a part. See 'Universal Opto input' in the Firmware section for more information on logic input specifications. Please note that the opto inputs have a maximum input voltage rating of 300V dc at any setting.

Once the ratings have been verified for the application, connect external power capable of delivering the power requirements specified on the label to perform the relay familiarization procedures. Figure 2 and 3 indicates the location of the power supply terminals but please refer to the wiring diagrams in the Installation section for complete installation details ensuring that the correct polarities are observed in the case of dc supply.

GS

### 1.4 Introduction to the user interfaces and settings options

The relay has three user interfaces:

– The front panel user interface via the LCD and keypad

– The front port which supports Courier communication

– The rear port which supports one protocol of either Courier, MODBUS, IEC 60870-5-103 or DNP3.0. The protocol for the rear port must be specified when the relay is ordered

– UCA2.0, 2$^{nd}$ rear port

The measurement information and relay settings that can be accessed from the three interfaces are summarized in Table 1.

| | Keypad/ LCD | Courier | MODBUS | IEC870-5-103 | DNP3.0 | UCA2.0 |
|---|---|---|---|---|---|---|
| Display & modification of all settings | • | • | • | | | • |
| Digital I/O signal status | • | • | • | • | • | • |
| Display/extraction of measurements | • | • | • | • | • | • |
| Display/extraction of fault records | • | • | • | • | • | • |
| Extraction of disturbance records | | • | • | • | | • |
| Programmable scheme logic settings | | • | | | | |
| Reset of fault & alarm records | • | • | • | • | • | • |
| Clear event & fault records | • | • | • | | • | • |
| Time synchronization | | • | • | • | • | • |
| Control commands | • | • | • | • | • | • |

Table 1

### 1.5 Menu structure

The relay's menu is arranged in a tabular structure. Each setting in the menu is referred to as a cell, and each cell in the menu may be accessed by reference to a row and column address. The settings are arranged so that each column contains related settings, for example all of the disturbance recorder settings are contained within the same column. As shown in Figure 4, the top row of each column contains the heading that describes the settings contained within that column. Movement between the columns of the menu can only be made at the column heading level. A complete list of all of the menu settings is given in the Menu Content Map at the end of this section.

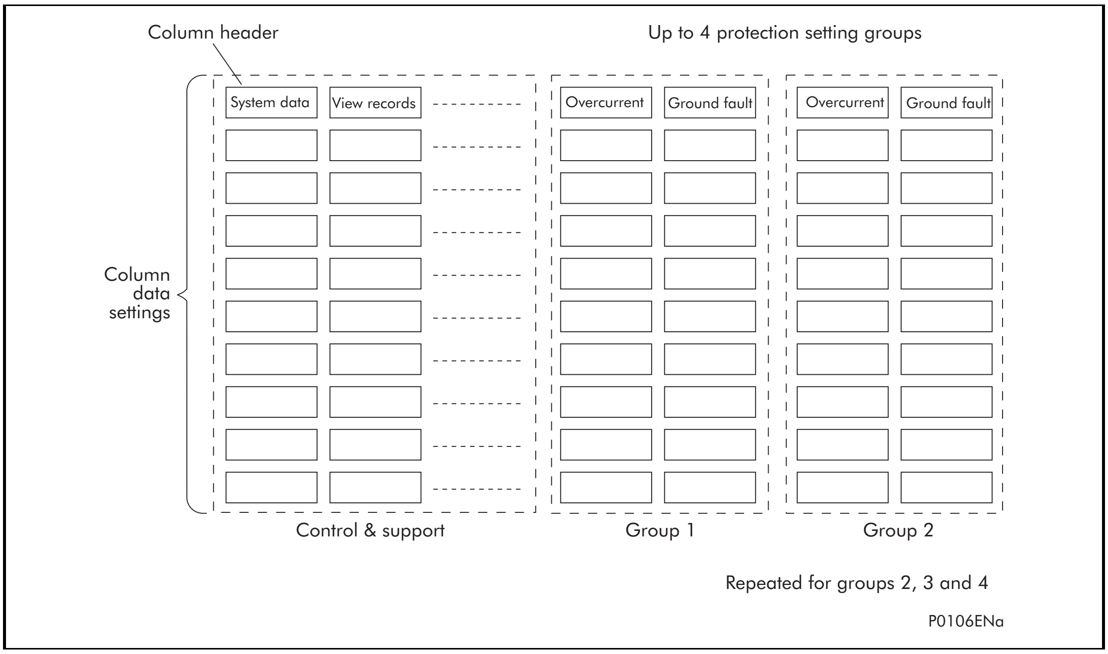



**Figure 4: Menu structure**

All of the settings in the menu fall into one of three categories; protection settings, disturbance recorder settings, or control and support (C&S) settings. One of two different methods is used to change a setting depending on which category the setting falls into. Control and support settings are stored and used by the relay immediately after they are entered. For either protection settings or disturbance recorder settings, the relay stores the new setting values in a temporary 'scratchpad'. It activates all the new settings together, but only after it has been confirmed that the new settings are to be adopted. This technique is employed to provide extra security, and so that several setting changes that are made within a group of protection settings will all take effect at the same time.

#### 1.5.1 Protection settings

The protection settings include the following items:

– Protection element settings

– Scheme logic settings

– Auto-reclose and check synchronization settings

– Fault locator settings

There are four 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.

### 1.5.2 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.

### 1.5.3 Control and support settings

The control and support settings include:

- Relay 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
- User interface settings
- Commissioning settings

GS

## 1.6 Password protection

The menu structure contains three levels of access. The level of access that is enabled determines which of the relay's settings can be changed and is controlled by entry of two different passwords. The levels of access are summarized in Table 2.

| Access level | Operations enabled |
|---|---|
| Level 0<br>No password required | Read access to all settings, alarms, event records and fault records |
| Level 1<br>Password 1 or 2 required | As level 0 plus:<br>Control commands, e.g.<br>Circuit breaker open/close.<br>Reset of fault and alarm conditions.<br>Reset LEDs.<br>Clearing of event and fault records. |
| Level 2<br>Password 2 required | As level 1 plus:<br>All other settings |

Table 2

Each of the two passwords are 4 characters of upper case text. The factory default for both passwords is AAAA. Each password is user-changeable once it has been correctly entered. Entry of the password is achieved either by a prompt when a setting change is attempted, or by moving to the 'Password' cell in the 'System data' column of the menu. The level of access is independently enabled for each interface, that is to say if level 2 access is enabled for the rear communication port, the front panel access will remain at level 0 unless the relevant password is entered at the front panel. The access level enabled by the password entry will time-out independently for each interface after a period of inactivity and revert to the default level. If the passwords are lost an emergency password can be supplied - contact AREVA T&D with the relay's serial number. The current level of access enabled for an interface can be determined by examining the 'Access level' cell in the 'System data' column, the access level for the front panel User Interface (UI), can also be found as one of the default display options.

The relay is supplied with a default access level of 2, such that no password is required to change any of the relay settings. It is also possible to set the default menu access level to either level 0 or level 1, preventing write access to the relay settings without the correct password. The default menu access level is set in the 'Password control' cell which is found in the 'System data' column of the menu (note that this setting can only be changed when level 2 access is enabled).

## 1.7 Relay configuration

The relay is a multi-function device that supports numerous different protection, control and communication features. In order to simplify the setting of the relay, there is a configuration settings column which can be used to enable or disable many of the functions of the relay. The settings associated with any function that is disabled are made invisible, i.e. they are not shown 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 four 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.

## 1.8 Front panel user interface (keypad and LCD)

When the keypad is exposed it provides full access to the menu options of the relay, with the information displayed on the LCD.

The ⟨, ⟩, ⌃ and ⌄ keys which are used for menu navigation and setting value changes include an auto-repeat function that comes into operation if any of these keys are held continually pressed. This can be used to speed up both setting value changes and menu navigation; the longer the key is held depressed, the faster the rate of change or movement becomes.

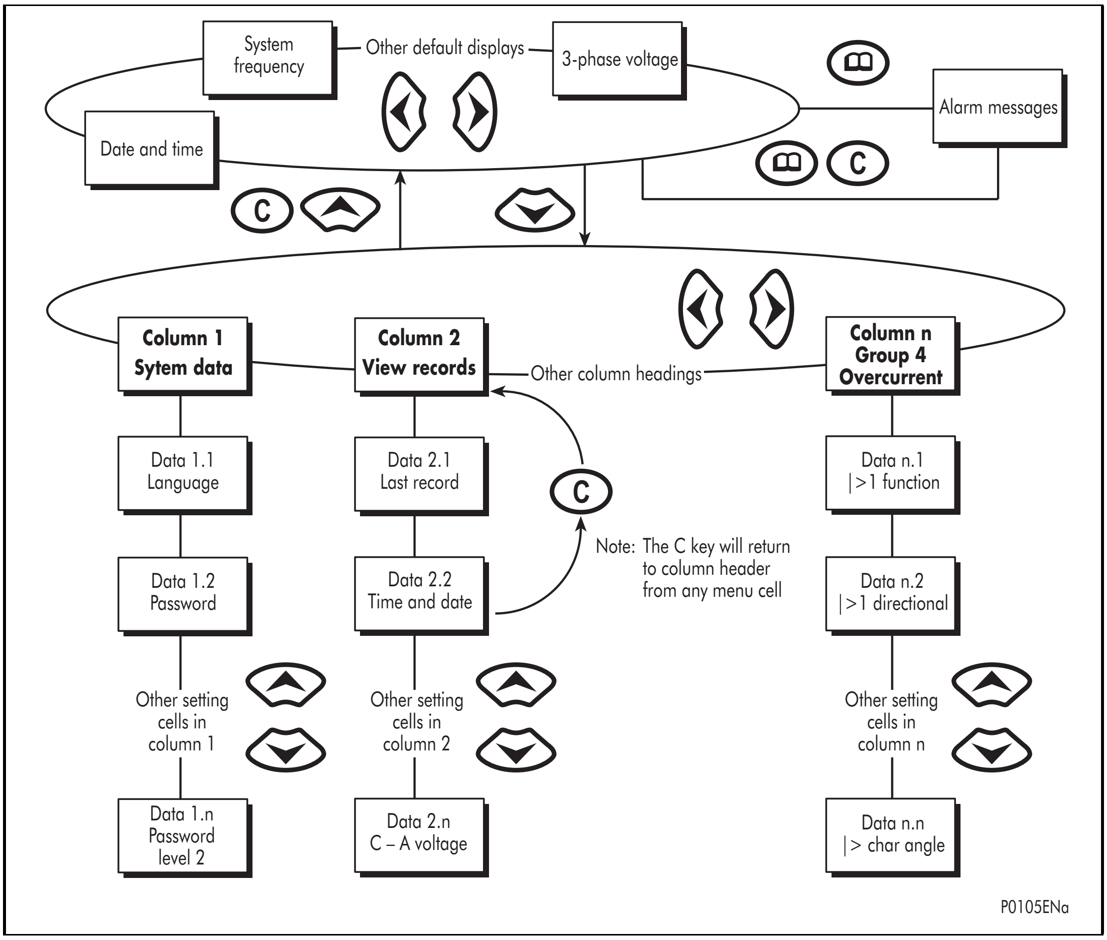



**Figure 5: Front panel user interface**

### 1.8.1 Default display and menu time-out

The front panel menu has a default display, the contents of which can be selected from the following options in the ‘default display’ cell of the ‘Measure’t. setup’ column:

– Date and time

– Relay description (user defined)

– Plant reference (user defined)

– System frequency

– 3 phase voltage

– 3-phase and neutral current

– Access level

From the default display it is also possible to view the other default display options using the ← and → keys. However, if there is no keypad activity for the 15 minute timeout period, the default display will revert to that selected by the setting and the LCD backlight will turn off. If this happens any setting changes that have not been confirmed will be lost and the original setting values maintained.

Whenever there is an uncleared alarm present in the relay (e.g. fault record, protection alarm, control alarm etc.) the default display will be replaced by:

| |
|---|
| Alarms/Faults<br>Present |

Entry to the menu structure of the relay is made from the default display and is not affected if the display is showing the ‘Alarms/Faults present’ message.

### 1.8.2 Menu navigation and setting browsing

The menu can be browsed using the four arrow keys, following the structure shown in Figure 5. Thus, starting at the default display the ↑ key will display the first column heading. To select the required column heading use the ← and → keys. The setting data contained in the column can then be viewed by using the ↓ and ↑ keys. It is possible to return to the column header either by holding the [up arrow symbol] key down or by a single press of the clear key Ⓒ. It is only possible to move across columns at the column heading level. To return to the default display press the ↑ key or the clear key Ⓒ from any of the column headings. It is not possible to go straight to the default display from within one of the column cells using the auto-repeat facility of the ↑ key, as the auto-repeat will stop at the column heading. To move to the default display, the ↑ key must be released and pressed again.

### 1.8.3 Hotkey menu navigation

The hotkey menu can be browsed using the two keys directly below the LCD. These are known as direct access keys. The direct access keys perform the function that is displayed directly above them on the LCD. Thus, to access the hotkey menu from the default display the direct access key below the “HOTKEY” text must be pressed. Once in the hotkey menu the ⇐ and ⇒ keys can be used to scroll between the available options and the direct access keys can be used to control the function currently displayed. If neither the ⇐ or ⇒ keys are pressed with 20 seconds of entering a hotkey sub menu, the relay will revert to the default display. The clear key Ⓒ will also act to return to the default menu from any page of the hotkey menu. The layout of a typical page of the hotkey menu is described below:

- The top line shows the contents of the previous and next cells for easy menu navigation
- The center line shows the function
- The bottom line shows the options assigned to the direct access keys

The functions available in the hotkey menu are listed below:

### 1.8.3.1 Setting group selection

The user can either scroll using <<NXT GRP>> through the available setting groups or <<SELECT>> the setting group that is currently displayed.

When the SELECT button is pressed a screen confirming the current setting group is displayed for 2 seconds before the user is prompted with the <<NXT GRP>> or <<SELECT>> options again. The user can exit the sub menu by using the left and right arrow keys.

For more information on setting group selection refer to “Changing setting group” section in the Operation section (P145/EN OP).



### 1.8.3.2 Control inputs – user assignable functions

The number of control inputs (user assignable functions – USR ASS) represented in the hotkey menu is user configurable in the “CTRL I/P CONFIG” column. The chosen inputs can be SET/RESET using the hotkey menu.

For more information refer to the “Control Inputs” section in the Operation section (P145/EN OP).

### 1.8.3.3 CB control

The CB control functionality varies from one Px40 relay to another. For a detailed description of the CB control via the hotkey menu refer to the “Circuit breaker control” section of the Operation section (P145/EN OP).

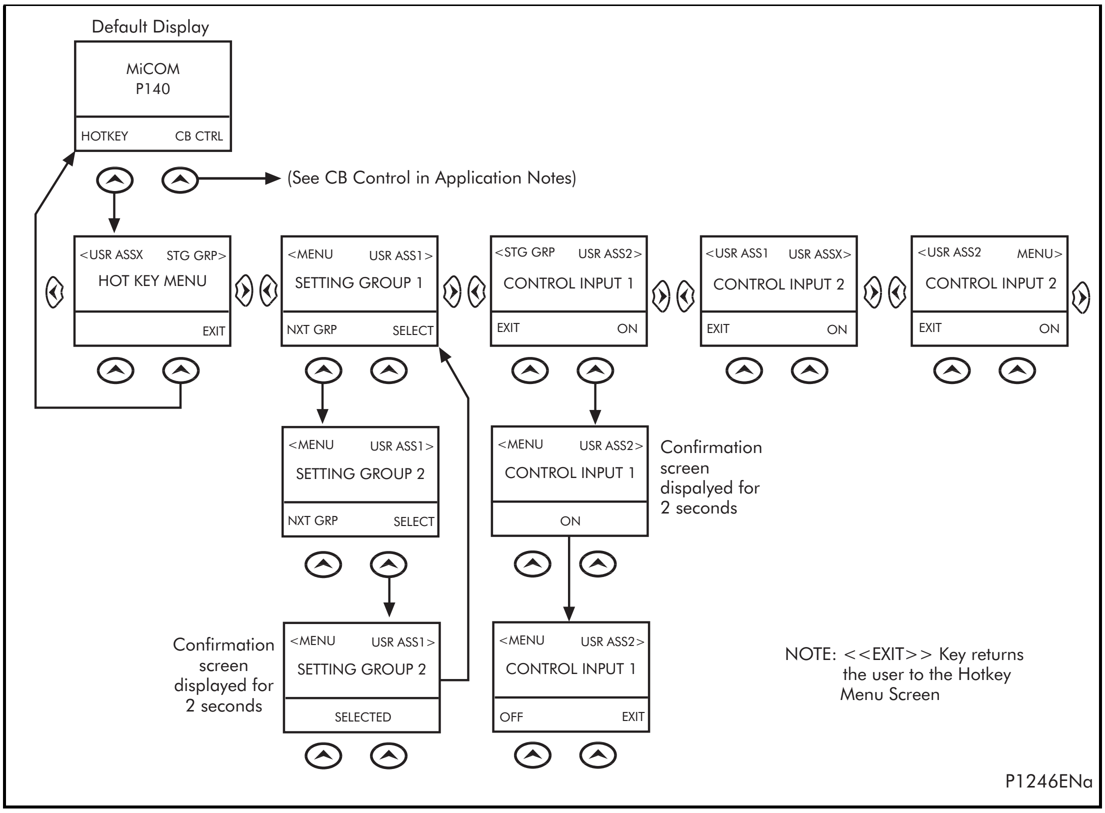



**Figure 6: Hotkey menu navigation**

### 1.8.4 Password entry

When entry of a password is required the following prompt will appear:

```
Enter password
**** Level 1
```

Note: The password required to edit the setting is the prompt as shown above.

A flashing cursor will indicate which character field of the password may be changed. Press the ⇑ and ⇓ keys to vary each character between A and Z. To move between the character fields of the password, use the ⇐ and ⇒ keys. The password is confirmed by pressing the enter key ↵. The display will revert to 'Enter Password' if an incorrect password is entered. At this point a message will be displayed indicating whether a correct password has been entered and if so what level of access has been unlocked. If this level is sufficient to edit the selected setting then the display will return to the setting page to allow the edit to continue. If the correct level of password has not been entered then the password prompt page will be returned to. To escape from this prompt press the clear key Ⓒ. Alternatively, the password can be entered using the 'Password' cell of the 'System data' column.

GS

For the front panel user interface the password protected access will revert to the default access level after a keypad inactivity time-out of 15 minutes. It is possible to manually reset the password protection to the default level by moving to the 'Password' menu cell in the 'System data' column and pressing the clear key Ⓒ instead of entering a password.

### 1.8.5 Reading and clearing of alarm messages and fault records

The presence of one or more alarm messages will be indicated by the default display and by the yellow alarm LED flashing. The alarm messages can either be self-resetting or latched, in which case they must be cleared manually. To view the alarm messages press the read key 📖. When all alarms have been viewed, but not cleared, the alarm LED will change from flashing to constant illumination and the latest fault record will be displayed (if there is one). To scroll through the pages of this use the 📖 key. When all pages of the fault record have been viewed, the following prompt will appear:

```
Press clear to
reset alarms
```

To clear all alarm messages press Ⓒ; to return to the alarms/faults present display and leave the alarms uncleared, press 📖. Depending on the password configuration settings, it may be necessary to enter a password before the alarm messages can be cleared (see section on password entry). When the alarms have been cleared the yellow alarm LED will extinguish, as will the red trip LED if it was illuminated following a trip.

Alternatively it is possible to accelerate the procedure, once the alarm viewer has been entered using the 📖 key, the Ⓒ key can be pressed, and this will move the display straight to the fault record. Pressing Ⓒ again will move straight to the alarm reset prompt where pressing Ⓒ once more will clear all alarms.

### 1.8.6 Setting changes

To change the value of a setting, first navigate the menu to display the relevant cell. To change the cell value press the enter key ↵, which will bring up a flashing cursor on the LCD to indicate that the value can be changed. This will only happen if the appropriate password has been entered, otherwise the prompt to enter a password will appear. The setting value can then be changed by pressing the ⇓ or ⇑ keys. If the setting to be changed is a binary value or a text string, the required bit or character to be changed must first be selected using the ⇐ and ⇒ keys. When the desired new value has been reached it is confirmed as the new setting value by pressing ↵. Alternatively, the new value will be discarded either if the clear button ⓒ is pressed or if the menu time-out occurs.

For protection group settings and disturbance recorder settings, the changes must be confirmed before they are used by the relay. To do this, when all required changes have been entered, return to the column heading level and press the ⌃ key. Prior to returning to the default display the following prompt will be given:

| |
|---|
| Update settings?<br>Enter or clear |

Pressing ↵ will result in the new settings being adopted, pressing ⓒ will cause the relay to discard the newly entered values. It should be noted that, the setting values will also be discarded if the menu time out occurs before the setting changes have been confirmed. Control and support settings will be updated immediately after they are entered, without the 'Update settings?' prompt.

GS

### 1.9 Front communication port user interface

The front communication port is provided by a 9-pin female D-type connector located under the bottom hinged cover. It provides EIA(RS)232 serial data communication and is intended for use with a PC locally to the relay (up to 15m distance) as shown in Figure 7. This port supports the Courier communication protocol only. Courier is the communication language developed by AREVA T&D to allow communication with its range of protection relays. The front port is particularly designed for use with the relay settings program MiCOM S1 that is a Windows 98, Windows NT4.0, Windows 2000 or Windows XP based software package.

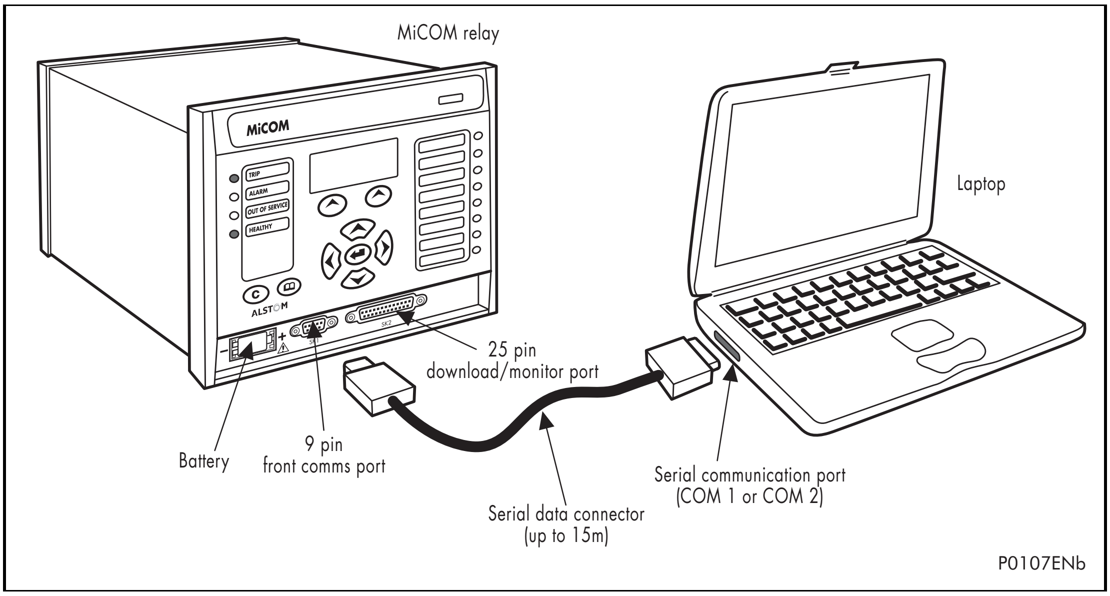



**Figure 7: Front port connection**

The relay is a Data Communication Equipment (DCE) device. Thus the pin connections of the relay's 9-pin front port are as follows:

| | |
|---|---|
| Pin no. 2 | Tx Transmit data |
| Pin no. 3 | Rx Receive data |
| Pin no. 5 | 0V Zero volts common |

None of the other pins are connected in the relay. The relay should be connected to the serial port of a PC, usually called COM1 or COM2. PCs are normally Data Terminal Equipment (DTE) devices which have a serial port pin connection as below (if in doubt check your PC manual):

| | 25 Way | 9 Way | |
|---|---|---|---|
| Pin no. 2 | 3 | 2 | Rx Receive data |
| Pin no. 3 | 2 | 3 | Tx Transmit data |
| Pin no. 5 | 7 | 5 | 0V Zero volts common |

For successful data communication, the Tx pin on the relay must be connected to the Rx pin on the PC, and the Rx pin on the relay must be connected to the Tx pin on the PC, as shown in Figure 7. Therefore, providing that the PC is a DTE with pin connections as given above, a 'straight through' serial connector is required, i.e. one that connects pin 2 to pin 2, pin 3 to pin 3, and pin 5 to pin 5. Note that a common cause of difficulty with serial data communication is connecting Tx to Tx and Rx to Rx. This could happen if a 'cross-over' serial connector is used, i.e. one that connects pin 2 to pin 3, and pin 3 to pin 2, or if the PC has the same pin configuration as the relay.

GS

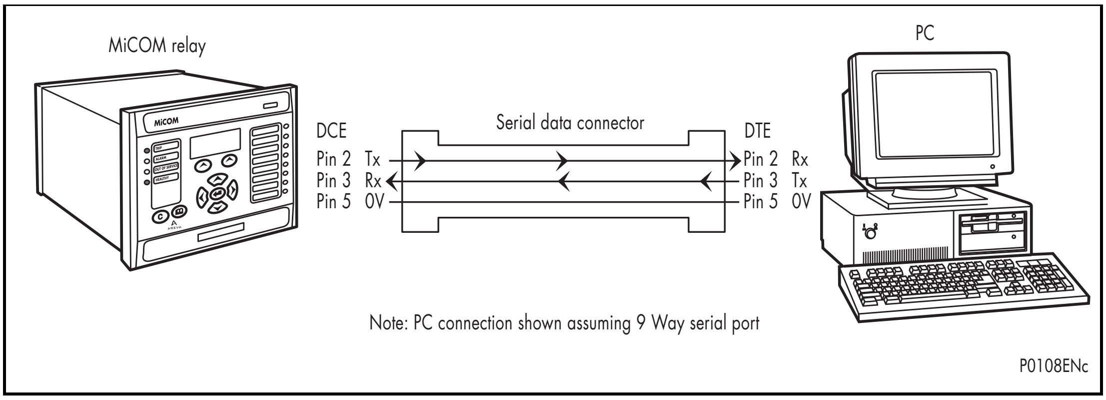



**Figure 8: PC – relay signal connection**

Having made the physical connection from the relay to the PC, the PC's communication settings must be configured to match those of the relay. The relay's communication settings for the front port are fixed as shown in the table below:

| | |
|---|---|
| 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 |

The inactivity timer for the front port is set at 15 minutes. This controls how long the relay will maintain its level of password access on the front port. If no messages are received on the front port for 15 minutes then any password access level that has been enabled will be revoked.

### 1.9.1 Front courier port

The front EIA(RS)232[1] 9 pin port supports the Courier protocol for one to one communication. It is designed for use during installation and commissioning/maintenance and is not suitable for permanent connection. Since this interface will not be used to link the relay to a substation communication system, some of the features of Courier are not implemented. These are as follows:

[1] This port is actually compliant to EIA(RS)574; the 9-pin version of EIA(RS)232, see www.tiaonline.org.

Automatic Extraction of Event Records:

– Courier Status byte does not support the Event flag

– Send Event/Accept Event commands are not implemented

Automatic Extraction of Disturbance Records:

– Courier Status byte does not support the Disturbance flag

Busy Response Layer:

– Courier Status byte does not support the Busy flag, the only response to a request will be the final data

Fixed Address:



– The address of the front courier port is always 1, the Change Device address command is not supported.

Fixed Baud Rate:

– 19200 bps

It should be noted that although automatic extraction of event and disturbance records is not supported it is possible to manually access this data via the front port.

## 1.10 MiCOM S1 relay communications basics

The front port is particularly designed for use with the relay settings program MiCOM S1 that is a Windows 98, Windows NT4.0, Windows 2000 or Windows XP based software package. MiCOM S1 is the universal MiCOM IED Support Software and provides users a direct and convenient access to all stored data in any MiCOM IED using the EIA(RS)232 front communication port.

MiCOM S1 provides full access to:

- MiCOM Px20, Px30, Px40 relays
- MiCOM Mx20 measurements units

### 1.10.1 PC requirements

The following minimum requirements must be met for the MiCOM S1 software to properly work on a PC.

- IBM computer or 100% compatible,
- WindowsTM 98 or NT 4.0 (Not WindowsTM 95)
- Pentium II 300 Mhz minimum,
- Screen VGA 256 colours minimum,
- Resolution 640 x 400 minimum (1024 x 768 recommended),
- 48Mb RAM minimum,
- 500Mb free on computer hard-disk.

### 1.10.2 Connecting to the P145 relay using MiCOM S1

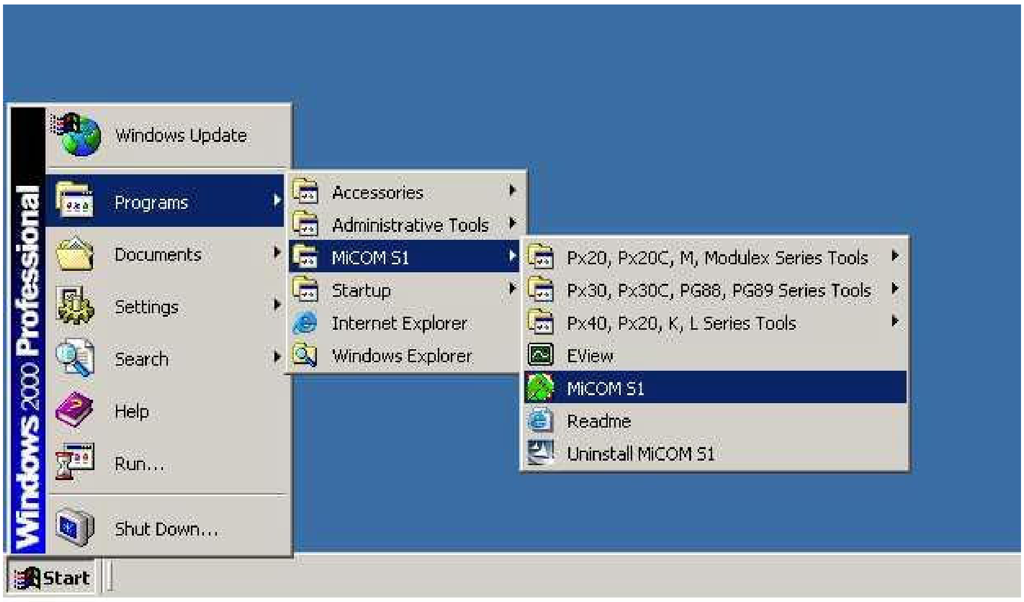
Before starting, verify that the EIA(RS)232 serial cable is properly connected to the EIA(RS)232 port on the front panel of the relay. Please follow the instructions in section 1.9 to ensure a proper connection is made between the PC and the relay before attempting to communicate with the relay.

GS

This section is intended as a quick start guide to using MiCOM S1 and assumes you have a copy of MiCOM S1 installed on your PC. Please refer to the MiCOM S1 User Manual for more detailed information.

To start MiCOM S1, click on the icon: 

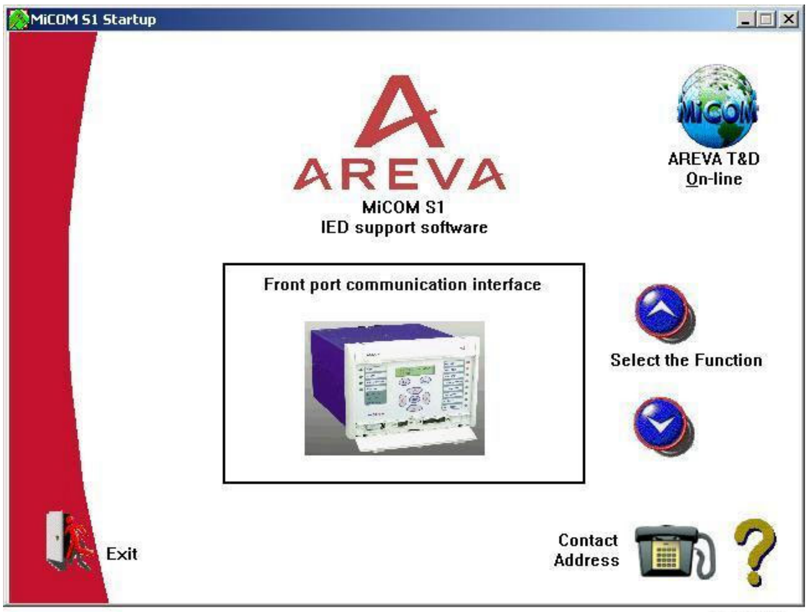

In the "Programs" menu, select "MiCOM S1" then "MiCOM S1 Start-up".




S0013ENb

WARNING: CLICKING ON "UNINSTALL MiCOM S1", WILL UNINSTALL MiCOM S1, AND ALL DATA AND RECORDS USED IN MiCOM S1.

You access the MiCOM S1 launcher screen.

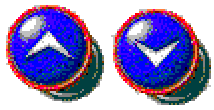



S0114ENa

The MiCOM S1 launcher is the software that gives access to the different application programs:

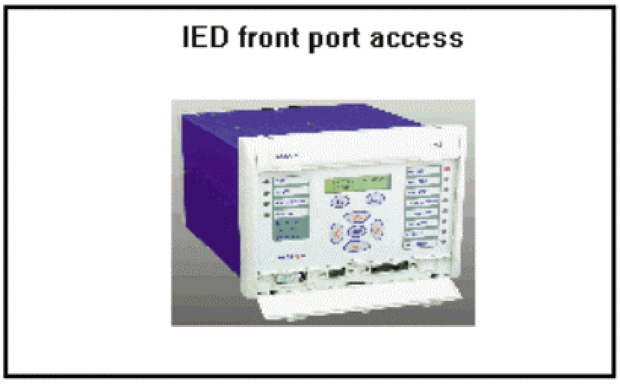
- MiCOM S1 for MiCOM M/Px20 IEDs
- MiCOM S1 for MiCOM Px30 IEDs
- MiCOM S1 for MiCOM Px40 IEDs
- MiCOM S1 disturbance application

To access these different programs, use the blue arrows,





Click on the desired type of access



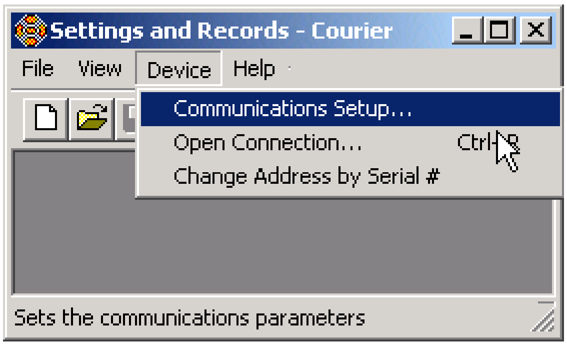

S0015ENa

and click on the required MiCOM Px40 series


1.10.3 Open communication link with relay

To open the communications link from S1 to the P145 relay the following procedure must be followed:

First the communication setup must be adjusted if necessary. In the "Device" menu, select "Communications Setup…"




This brings up the following screen:



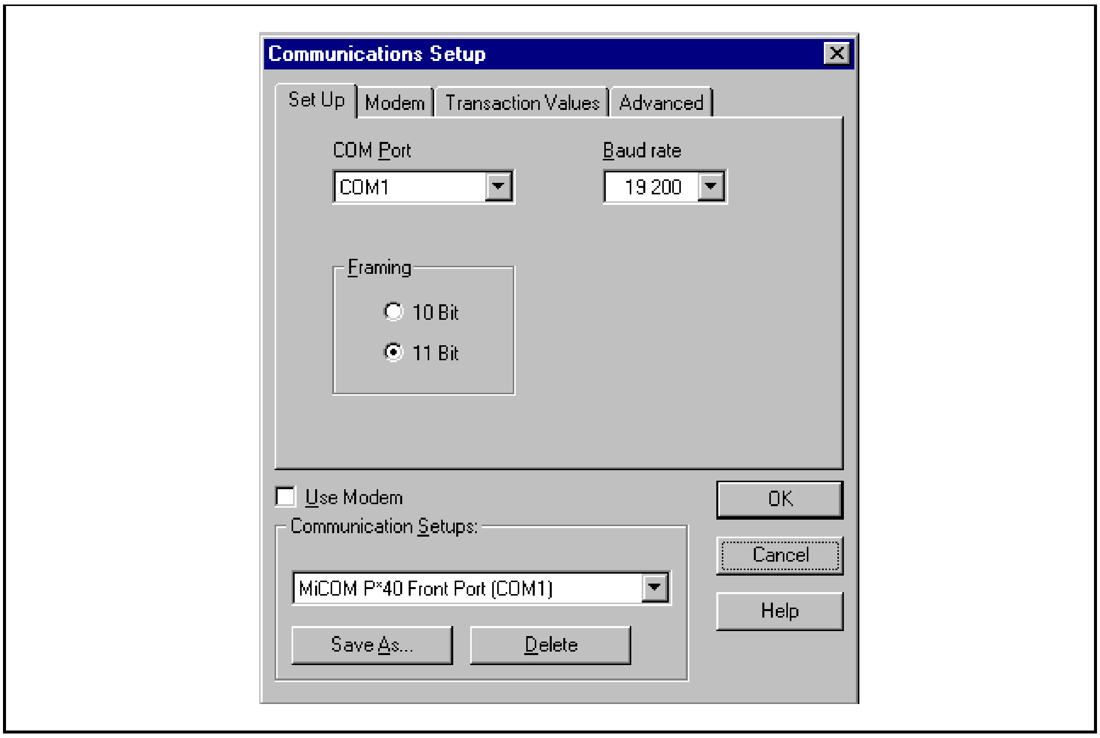
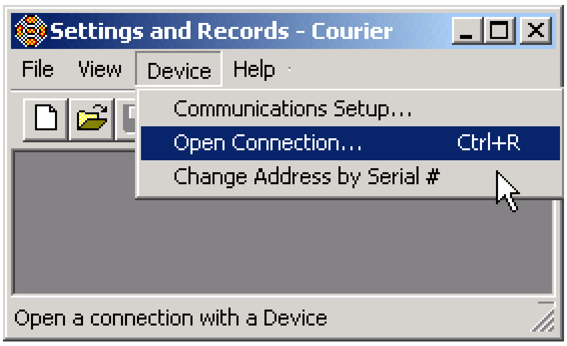
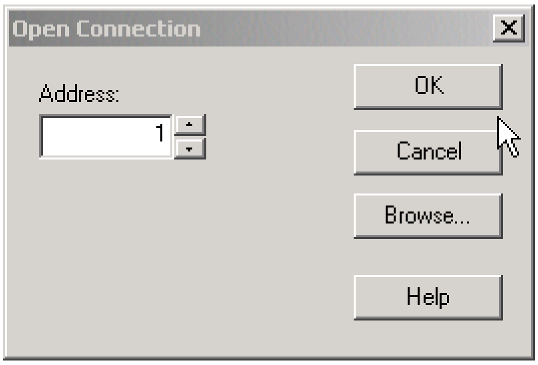



**Figure 9: Communication set-up screen**

When the communications setup is correct the link with the relay can be initialized. In the "Device" menu, select "Open Connection…"



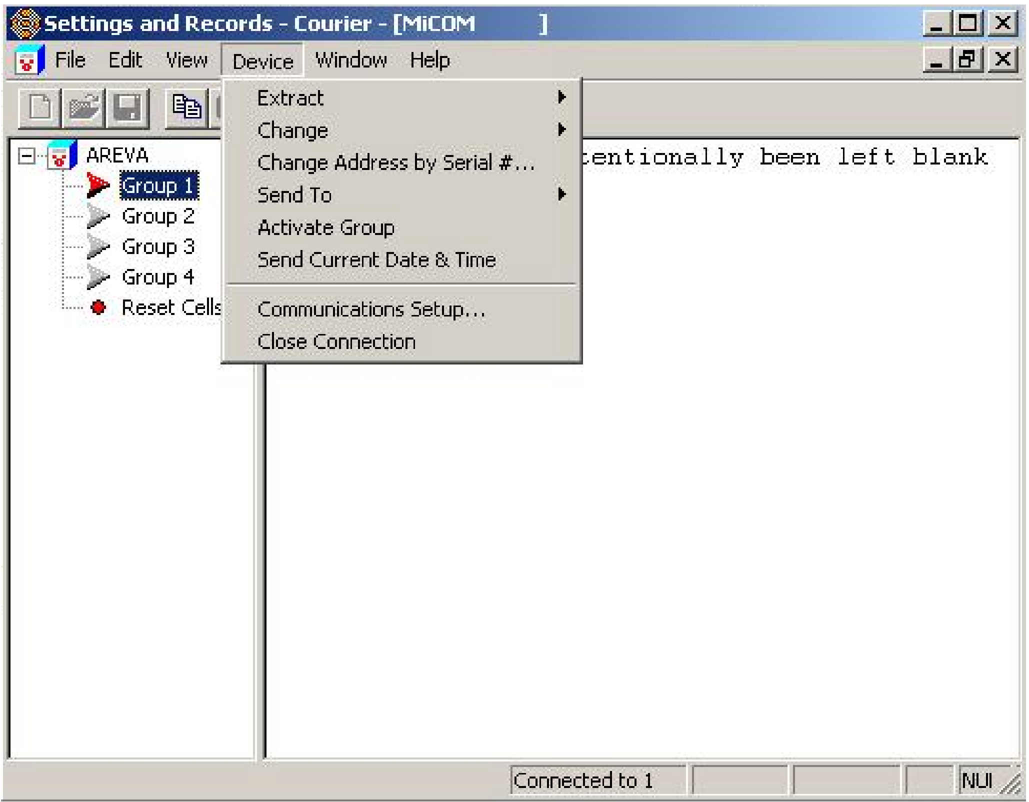
This brings up a prompt for the address of the relay to be interrogated (for front port access, the relay address is always “1” – regardless of any address settings for the rear ports).




GS

When this has been entered a prompt for the password appears.

When these have been entered satisfactorily the relay is then able to communicate with MiCOM S1. When a communication link has been established between the PC and a MiCOM IED, both are said to be online. Data and information can be directly transferred from and to the IED using the menu available under the “DEVICE” menu.

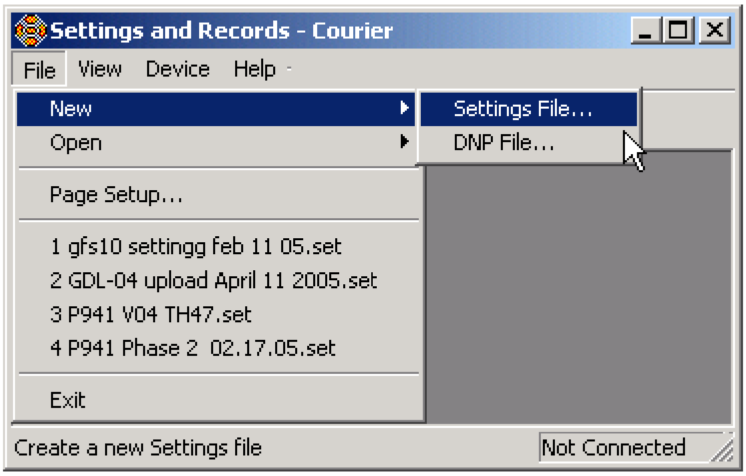



S0057ENb

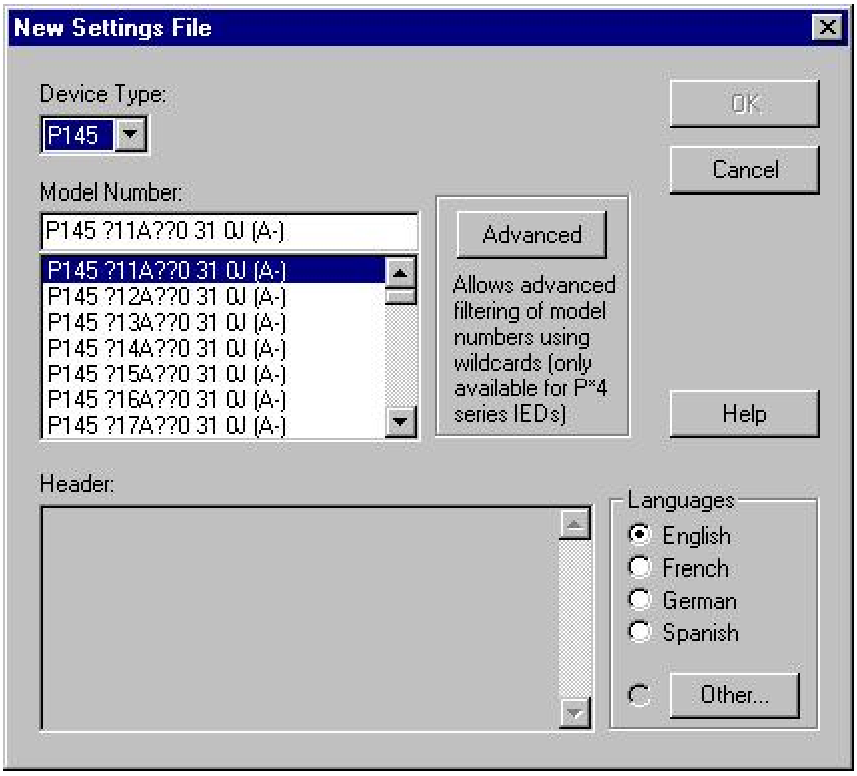
For further instruction on how to extract, download and modify settings files, please refer to the MiCOM S1 User Manual.

### 1.10.4 Off-line use of MiCOM S1

As well as being used for the on-line editing of settings, MiCOM S1 can also be used as an off-line tool to prepare settings without access to the relay. In order to open a default setting file for modification, in the “File” menu, select “New” and then “Settings File…”




This brings up a prompt for the relay model type where you can select the correct relay for your application:



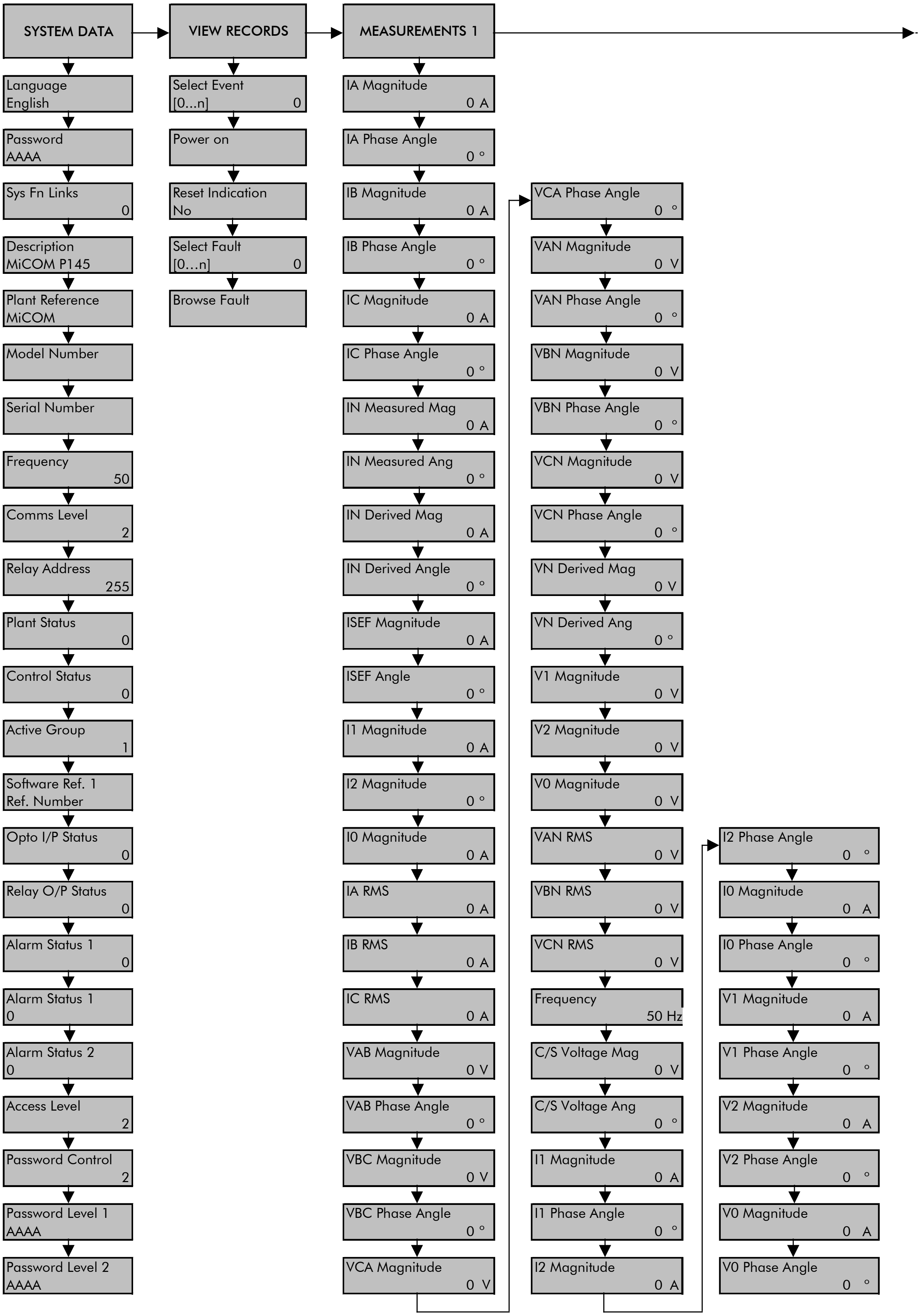

Clicking on OK will open the default file and you can start to edit settings. For further instruction on how to extract, download and modify settings files, please refer to the MiCOM S1 User Manual.

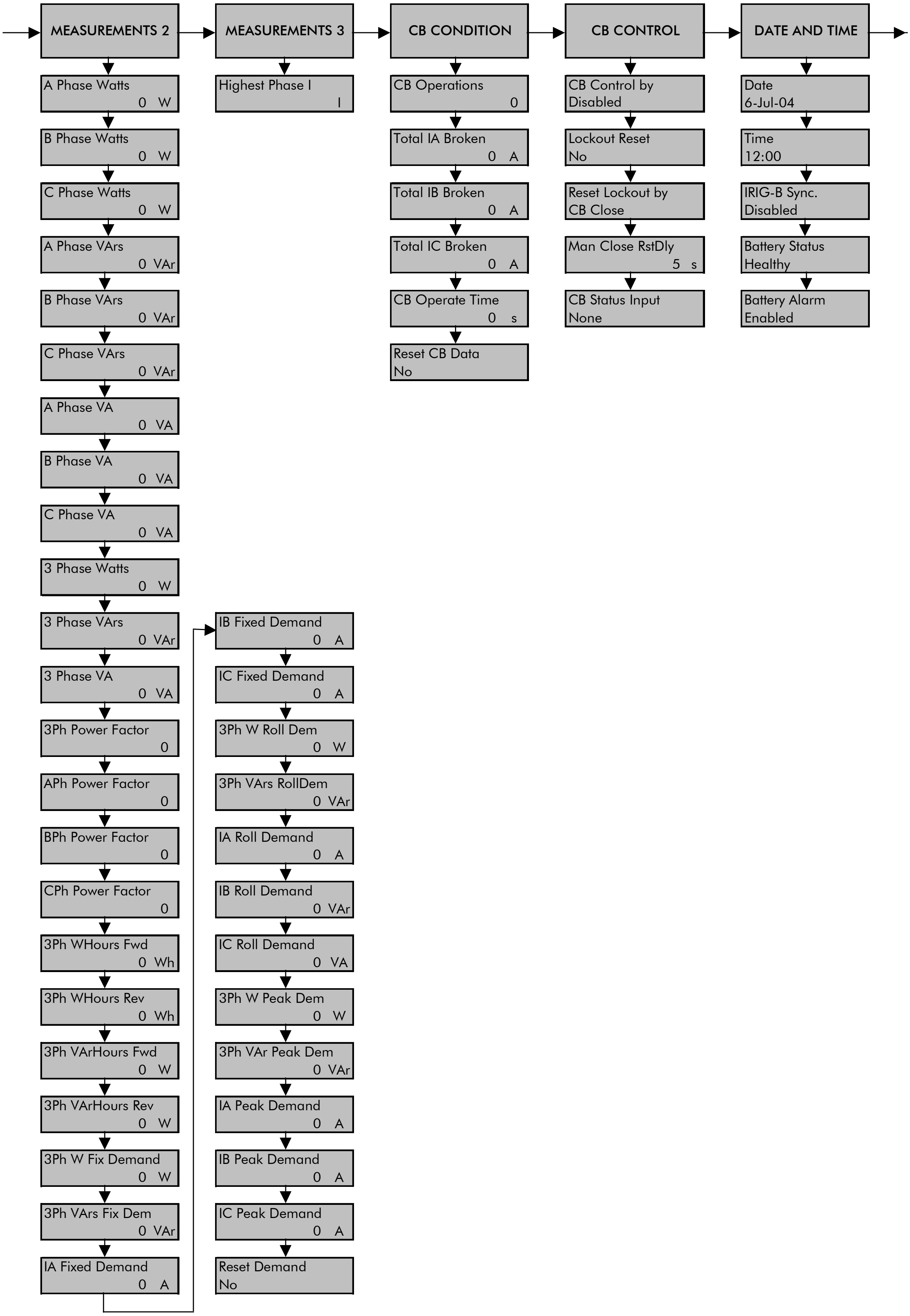
GS

GS

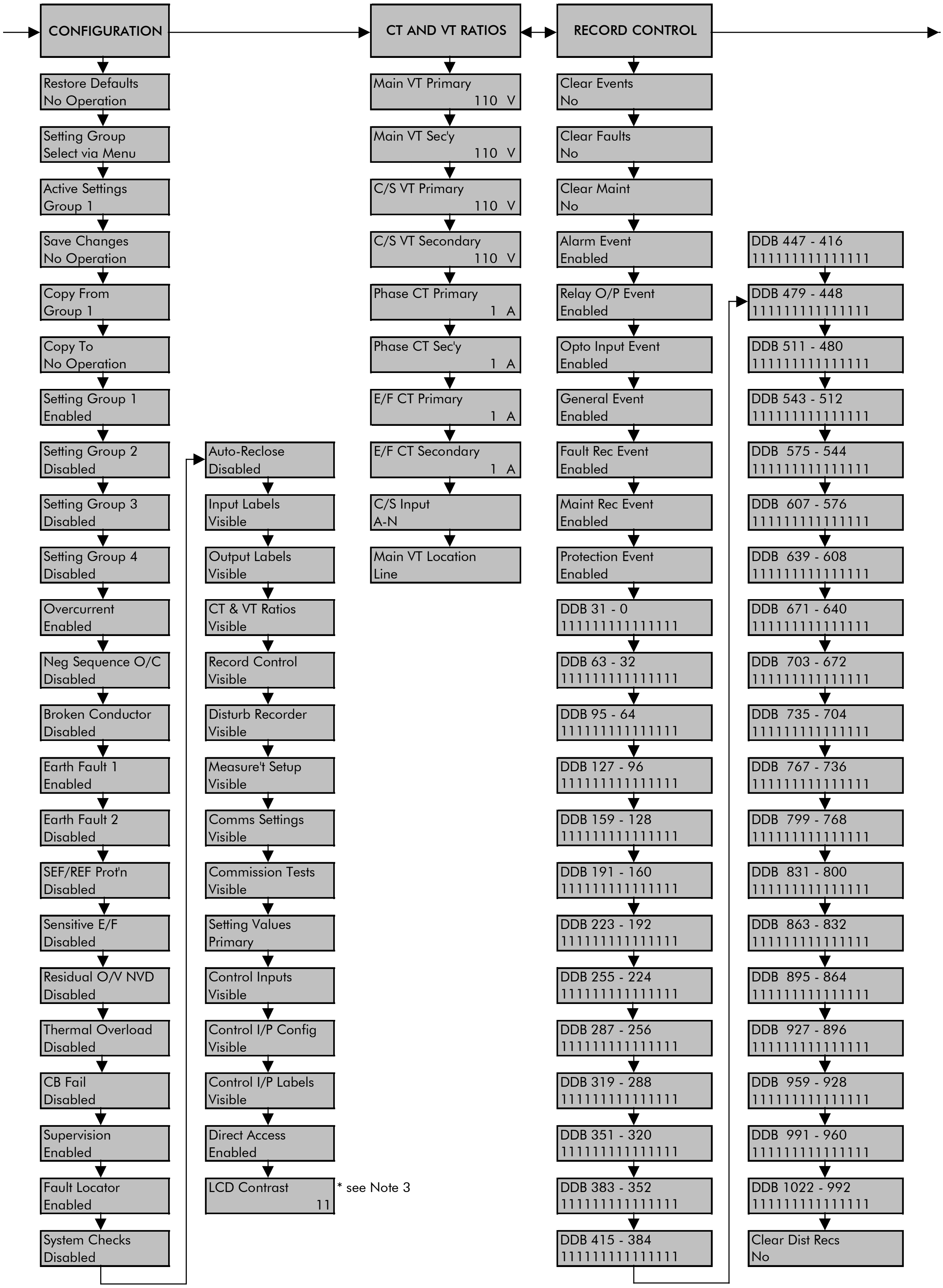
## Appendix - Relay Menu Map (Default)

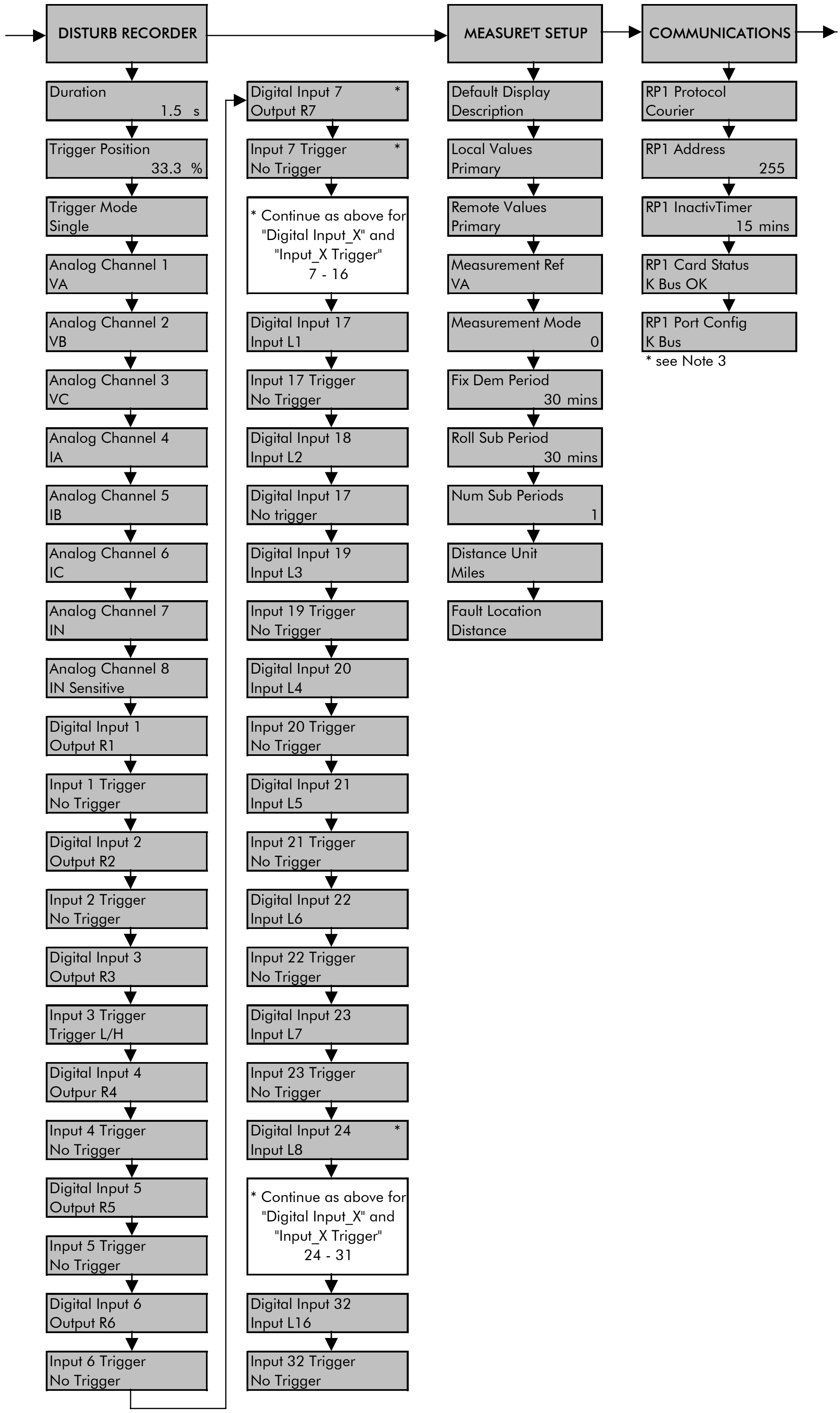
Note: This menu map is annotated with the factory default settings.



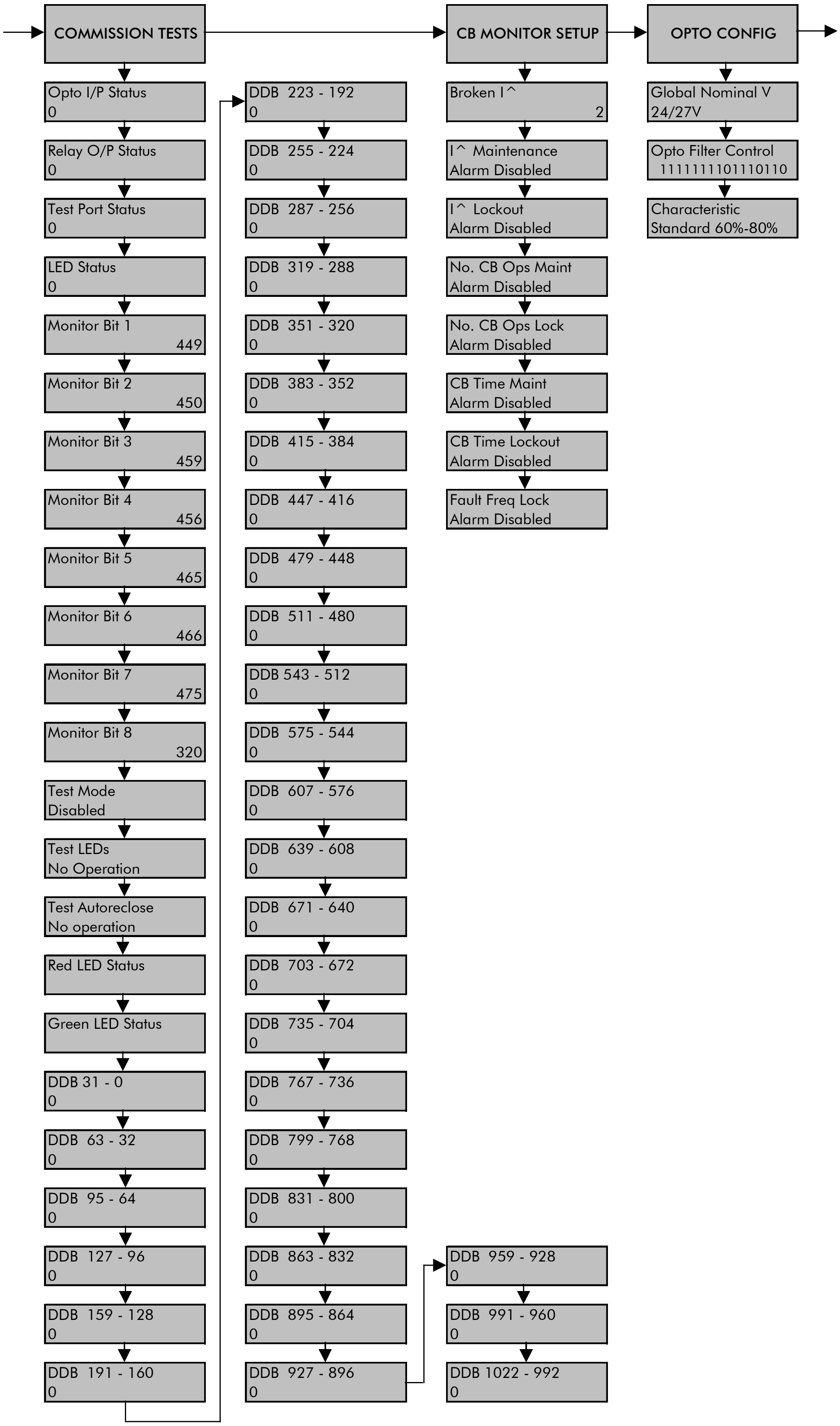

MEASUREMENTS 2
A Phase Watts
0 W
B Phase Watts
0 W
C Phase Watts
0 W
A Phase VArs
0 VAr
B Phase VArs
0 VAr
C Phase VArs
0 VAr
A Phase VA
0 VA
B Phase VA
0 VA
C Phase VA
0 VA
3 Phase Watts
0 W
3 Phase VArs
0 VAr
3 Phase VA
0 VA
3Ph Power Factor
0
APh Power Factor
0
BPh Power Factor
0
CPh Power Factor
0
3Ph WHours Fwd
0 Wh
3Ph WHours Rev
0 Wh
3Ph VArHours Fwd
0 W
3Ph VArHours Rev
0 W
3Ph W Fix Demand
0 W
3Ph VArs Fix Dem
0 VAr
IA Fixed Demand
0 A
IB Fixed Demand
0 A
IC Fixed Demand
0 A
3Ph W Roll Dem
0 W
3Ph VArs RollDem
0 VAr
IA Roll Demand
0 A
IB Roll Demand
0 VAr
IC Roll Demand
0 VA
3Ph W Peak Dem
0 W
3Ph VAr Peak Dem
0 VAr
IA Peak Demand
0 A
IB Peak Demand
0 A
IC Peak Demand
0 A
Reset Demand
No
MEASUREMENTS 3
Highest Phase I
I
CB CONDITION
CB Operations
0
Total IA Broken
0 A
Total IB Broken
0 A
Total IC Broken
0 A
CB Operate Time
0 s
Reset CB Data
No
CB CONTROL
CB Control by
Disabled
Lockout Reset
No
Reset Lockout by
CB Close
Man Close RstDly
5 s
CB Status Input
None
DATE AND TIME
Date
6-Jul-04
Time
12:00
IRIG-B Sync.
Disabled
Battery Status
Healthy
Battery Alarm
Enabled

GS

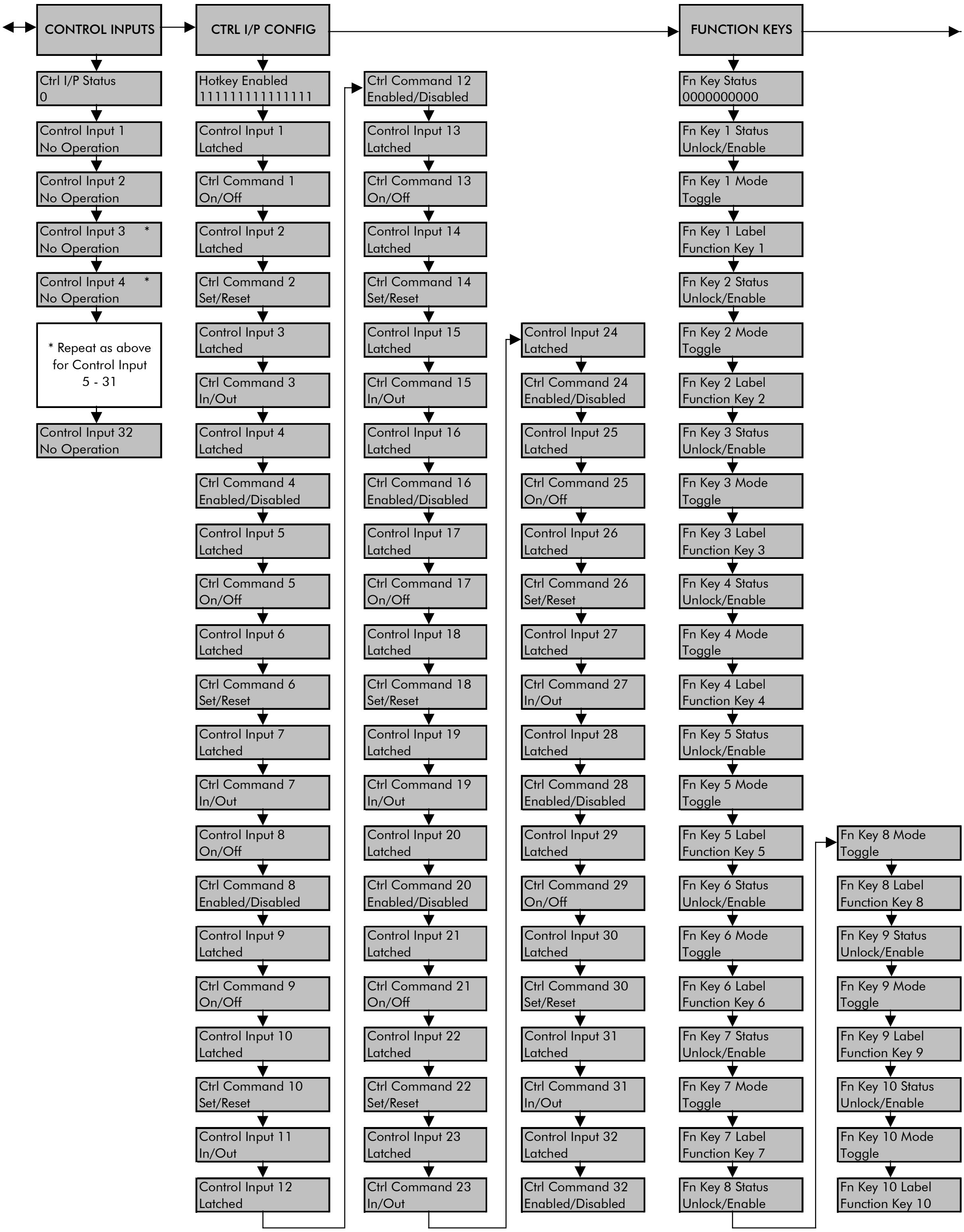

CONFIGURATION
Restore Defaults
No Operation
Setting Group
Select via Menu
Active Settings
Group 1
Save Changes
No Operation
Copy From
Group 1
Copy To
No Operation
Setting Group 1
Enabled
Setting Group 2
Disabled
Setting Group 3
Disabled
Setting Group 4
Disabled
Overcurrent
Enabled
Neg Sequence O/C
Disabled
Broken Conductor
Disabled
Earth Fault 1
Enabled
Earth Fault 2
Disabled
SEF/REF Prot'n
Disabled
Sensitive E/F
Disabled
Residual O/V NVD
Disabled
Thermal Overload
Disabled
CB Fail
Disabled
Supervision
Enabled
Fault Locator
Enabled
System Checks
Disabled
Auto-Reclose
Disabled
Input Labels
Visible
Output Labels
Visible
CT & VT Ratios
Visible
Record Control
Visible
Disturb Recorder
Visible
Measure't Setup
Visible
Comms Settings
Visible
Commission Tests
Visible
Setting Values
Primary
Control Inputs
Visible
Control I/P Config
Visible
Control I/P Labels
Visible
Direct Access
Enabled
LCD Contrast
11
* see Note 3
CT AND VT RATIOS
Main VT Primary
110 V
Main VT Sec'y
110 V
C/S VT Primary
110 V
C/S VT Secondary
110 V
Phase CT Primary
1 A
Phase CT Sec'y
1 A
E/F CT Primary
1 A
E/F CT Secondary
1 A
C/S Input
A-N
Main VT Location
Line
RECORD CONTROL
Clear Events
No
Clear Faults
No
Clear Maint
No
Alarm Event
Enabled
Relay O/P Event
Enabled
Opto Input Event
Enabled
General Event
Enabled
Fault Rec Event
Enabled
Maint Rec Event
Enabled
Protection Event
Enabled
DDB 31 - 0
111111111111111
DDB 63 - 32
111111111111111
DDB 95 - 64
111111111111111
DDB 127 - 96
111111111111111
DDB 159 - 128
111111111111111
DDB 191 - 160
111111111111111
DDB 223 - 192
111111111111111
DDB 255 - 224
111111111111111
DDB 287 - 256
111111111111111
DDB 319 - 288
111111111111111
DDB 351 - 320
111111111111111
DDB 383 - 352
111111111111111
DDB 415 - 384
111111111111111
DDB 447 - 416
111111111111111
DDB 479 - 448
111111111111111
DDB 511 - 480
111111111111111
DDB 543 - 512
111111111111111
DDB 575 - 544
111111111111111
DDB 607 - 576
111111111111111
DDB 639 - 608
111111111111111
DDB 671 - 640
111111111111111
DDB 703 - 672
111111111111111
DDB 735 - 704
111111111111111
DDB 767 - 736
111111111111111
DDB 799 - 768
111111111111111
DDB 831 - 800
111111111111111
DDB 863 - 832
111111111111111
DDB 895 - 864
111111111111111
DDB 927 - 896
111111111111111
DDB 959 - 928
111111111111111
DDB 991 - 960
111111111111111
DDB 1022 - 992
111111111111111
Clear Dist Recs
No


DISTURB RECORDER
Duration 1.5 s
Trigger Position 33.3 %
Trigger Mode Single
Analog Channel 1 VA
Analog Channel 2 VB
Analog Channel 3 VC
Analog Channel 4 IA
Analog Channel 5 IB
Analog Channel 6 IC
Analog Channel 7 IN
Analog Channel 8 IN Sensitive
Digital Input 1 Output R1
Input 1 Trigger No Trigger
Digital Input 2 Output R2
Input 2 Trigger No Trigger
Digital Input 3 Output R3
Input 3 Trigger Trigger L/H
Digital Input 4 Outpur R4
Input 4 Trigger No Trigger
Digital Input 5 Output R5
Input 5 Trigger No Trigger
Digital Input 6 Output R6
Input 6 Trigger No Trigger
Digital Input 7 * Output R7
Input 7 Trigger * No Trigger
* Continue as above for "Digital Input_X" and "Input_X Trigger" 7 - 16
Digital Input 17 Input L1
Input 17 Trigger No Trigger
Digital Input 18 Input L2
Digital Input 17 No trigger
Digital Input 19 Input L3
Input 19 Trigger No Trigger
Digital Input 20 Input L4
Input 20 Trigger No Trigger
Digital Input 21 Input L5
Input 21 Trigger No Trigger
Digital Input 22 Input L6
Input 22 Trigger No Trigger
Digital Input 23 Input L7
Input 23 Trigger No Trigger
Digital Input 24 * Input L8
* Continue as above for "Digital Input_X" and "Input_X Trigger" 24 - 31
Digital Input 32 Input L16
Input 32 Trigger No Trigger
MEASURE'T SETUP
Default Display Description
Local Values Primary
Remote Values Primary
Measurement Ref VA
Measurement Mode 0
Fix Dem Period 30 mins
Roll Sub Period 30 mins
Num Sub Periods 1
Distance Unit Miles
Fault Location Distance
COMMUNICATIONS
RP1 Protocol Courier
RP1 Address 255
RP1 InactivTimer 15 mins
RP1 Card Status K Bus OK
RP1 Port Config K Bus
* see Note 3

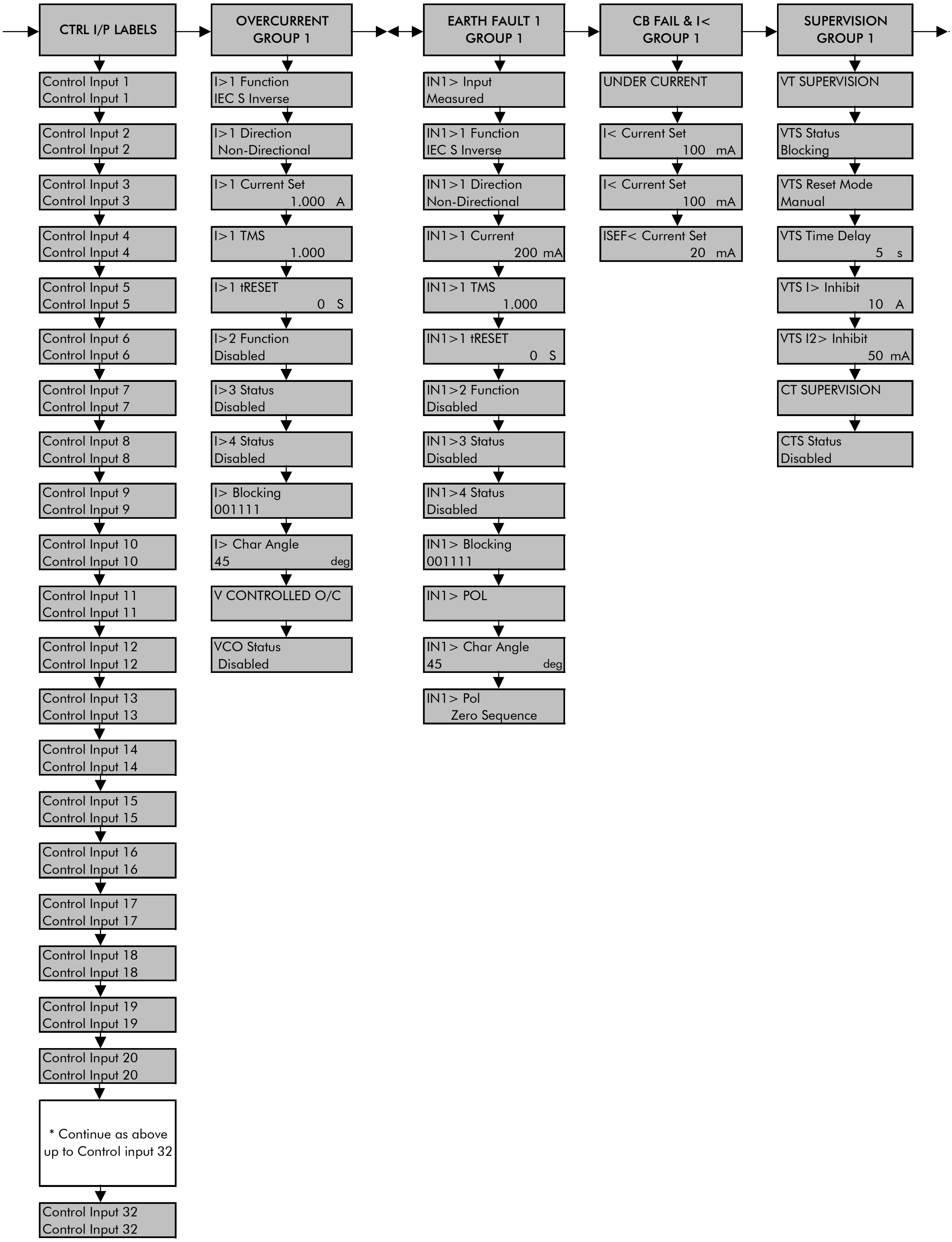
GS

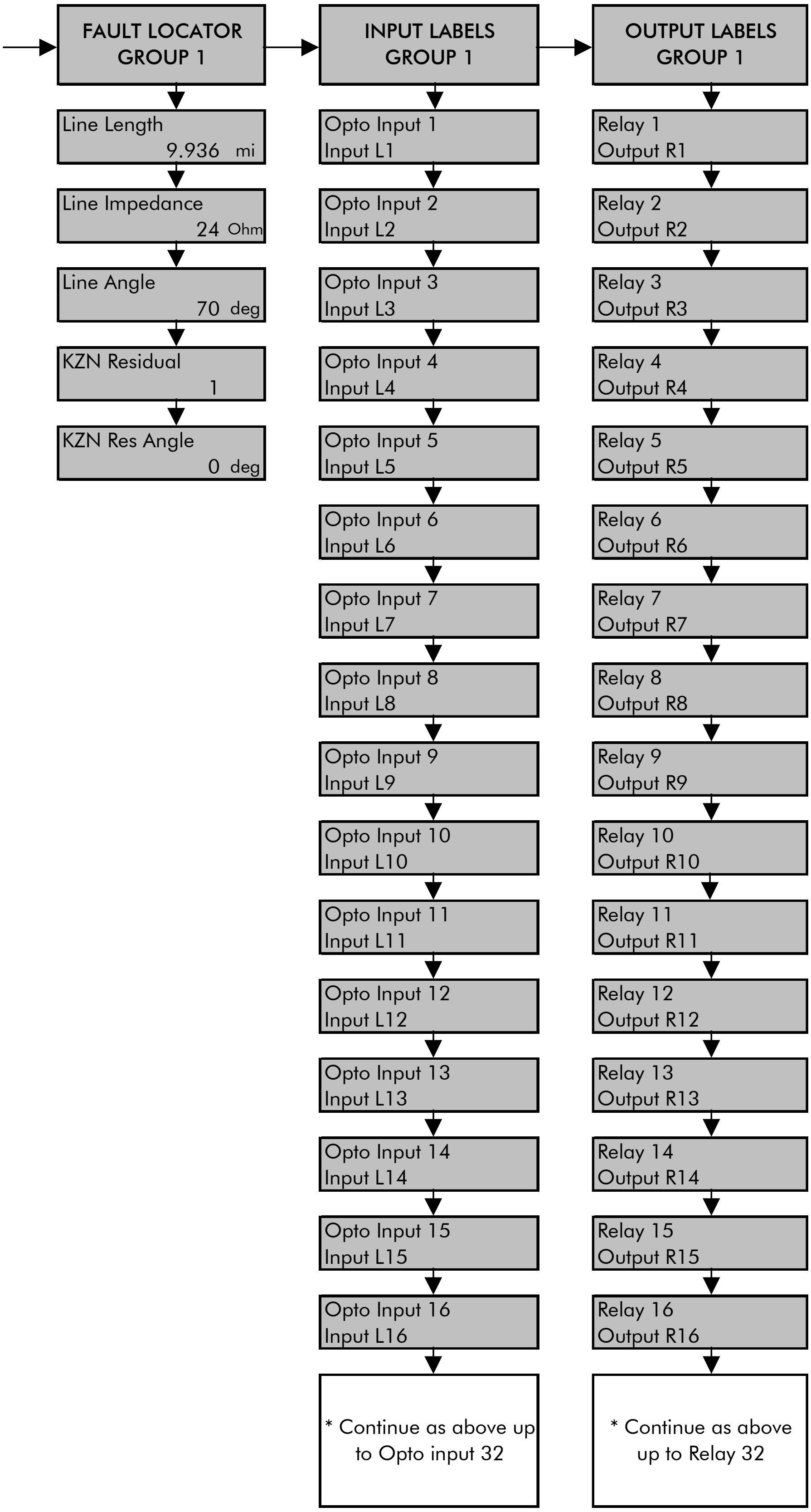

COMMISSION TESTS
Opto I/P Status 0
Relay O/P Status 0
Test Port Status 0
LED Status 0
Monitor Bit 1 449
Monitor Bit 2 450
Monitor Bit 3 459
Monitor Bit 4 456
Monitor Bit 5 465
Monitor Bit 6 466
Monitor Bit 7 475
Monitor Bit 8 320
Test Mode Disabled
Test LEDs No Operation
Test Autoreclose No operation
Red LED Status
Green LED Status
DDB 31 - 0 0
DDB 63 - 32 0
DDB 95 - 64 0
DDB 127 - 96 0
DDB 159 - 128 0
DDB 191 - 160 0
DDB 223 - 192 0
DDB 255 - 224 0
DDB 287 - 256 0
DDB 319 - 288 0
DDB 351 - 320 0
DDB 383 - 352 0
DDB 415 - 384 0
DDB 447 - 416 0
DDB 479 - 448 0
DDB 511 - 480 0
DDB 543 - 512 0
DDB 575 - 544 0
DDB 607 - 576 0
DDB 639 - 608 0
DDB 671 - 640 0
DDB 703 - 672 0
DDB 735 - 704 0
DDB 767 - 736 0
DDB 799 - 768 0
DDB 831 - 800 0
DDB 863 - 832 0
DDB 895 - 864 0
DDB 927 - 896 0
DDB 959 - 928 0
DDB 991 - 960 0
DDB 1022 - 992 0
CB MONITOR SETUP
Broken I^ 2
I^ Maintenance Alarm Disabled
I^ Lockout Alarm Disabled
No. CB Ops Maint Alarm Disabled
No. CB Ops Lock Alarm Disabled
CB Time Maint Alarm Disabled
CB Time Lockout Alarm Disabled
Fault Freq Lock Alarm Disabled
OPTO CONFIG
Global Nominal V 24/27V
Opto Filter Control 1111111101110110
Characteristic Standard 60%-80%

GS


CONTROL INPUTS
Ctrl I/P Status
0
Control Input 1
No Operation
Control Input 2
No Operation
Control Input 3 *
No Operation
Control Input 4 *
No Operation
* Repeat as above for Control Input 5 - 31
Control Input 32
No Operation
CTRL I/P CONFIG
Hotkey Enabled
11111111111111
Control Input 1
Latched
Ctrl Command 1
On/Off
Control Input 2
Latched
Ctrl Command 2
Set/Reset
Control Input 3
Latched
Ctrl Command 3
In/Out
Control Input 4
Latched
Ctrl Command 4
Enabled/Disabled
Control Input 5
Latched
Ctrl Command 5
On/Off
Control Input 6
Latched
Ctrl Command 6
Set/Reset
Control Input 7
Latched
Ctrl Command 7
In/Out
Control Input 8
On/Off
Ctrl Command 8
Enabled/Disabled
Control Input 9
Latched
Ctrl Command 9
On/Off
Control Input 10
Latched
Ctrl Command 10
Set/Reset
Control Input 11
In/Out
Control Input 12
Latched
Ctrl Command 12
Enabled/Disabled
Control Input 13
Latched
Ctrl Command 13
On/Off
Control Input 14
Latched
Ctrl Command 14
Set/Reset
Control Input 15
Latched
Ctrl Command 15
In/Out
Control Input 16
Latched
Ctrl Command 16
Enabled/Disabled
Control Input 17
Latched
Ctrl Command 17
On/Off
Control Input 18
Latched
Ctrl Command 18
Set/Reset
Control Input 19
Latched
Ctrl Command 19
In/Out
Control Input 20
Latched
Ctrl Command 20
Enabled/Disabled
Control Input 21
Latched
Ctrl Command 21
On/Off
Control Input 22
Latched
Ctrl Command 22
Set/Reset
Control Input 23
Latched
Ctrl Command 23
In/Out
Control Input 24
Latched
Ctrl Command 24
Enabled/Disabled
Control Input 25
Latched
Ctrl Command 25
On/Off
Control Input 26
Latched
Ctrl Command 26
Set/Reset
Control Input 27
Latched
Ctrl Command 27
In/Out
Control Input 28
Latched
Ctrl Command 28
Enabled/Disabled
Control Input 29
Latched
Ctrl Command 29
On/Off
Control Input 30
Latched
Ctrl Command 30
Set/Reset
Control Input 31
Latched
Ctrl Command 31
In/Out
Control Input 32
Latched
Ctrl Command 32
Enabled/Disabled
FUNCTION KEYS
Fn Key Status
0000000000
Fn Key 1 Status
Unlock/Enable
Fn Key 1 Mode
Toggle
Fn Key 1 Label
Function Key 1
Fn Key 2 Status
Unlock/Enable
Fn Key 2 Mode
Toggle
Fn Key 2 Label
Function Key 2
Fn Key 3 Status
Unlock/Enable
Fn Key 3 Mode
Toggle
Fn Key 3 Label
Function Key 3
Fn Key 4 Status
Unlock/Enable
Fn Key 4 Mode
Toggle
Fn Key 4 Label
Function Key 4
Fn Key 5 Status
Unlock/Enable
Fn Key 5 Mode
Toggle
Fn Key 5 Label
Function Key 5
Fn Key 6 Status
Unlock/Enable
Fn Key 6 Mode
Toggle
Fn Key 6 Label
Function Key 6
Fn Key 7 Status
Unlock/Enable
Fn Key 7 Mode
Toggle
Fn Key 7 Label
Function Key 7
Fn Key 8 Status
Unlock/Enable
Fn Key 8 Mode
Toggle
Fn Key 8 Label
Function Key 8
Fn Key 9 Status
Unlock/Enable
Fn Key 9 Mode
Toggle
Fn Key 9 Label
Function Key 9
Fn Key 10 Status
Unlock/Enable
Fn Key 10 Mode
Toggle
Fn Key 10 Label
Function Key 10

GS


CTRL I/P LABELS
Control Input 1 Control Input 1
Control Input 2 Control Input 2
Control Input 3 Control Input 3
Control Input 4 Control Input 4
Control Input 5 Control Input 5
Control Input 6 Control Input 6
Control Input 7 Control Input 7
Control Input 8 Control Input 8
Control Input 9 Control Input 9
Control Input 10 Control Input 10
Control Input 11 Control Input 11
Control Input 12 Control Input 12
Control Input 13 Control Input 13
Control Input 14 Control Input 14
Control Input 15 Control Input 15
Control Input 16 Control Input 16
Control Input 17 Control Input 17
Control Input 18 Control Input 18
Control Input 19 Control Input 19
Control Input 20 Control Input 20
* Continue as above up to Control input 32
Control Input 32 Control Input 32
OVERCURRENT GROUP 1
I>1 Function IEC S Inverse
I>1 Direction Non-Directional
I>1 Current Set 1.000 A
I>1 TMS 1.000
I>1 tRESET 0 S
I>2 Function Disabled
I>3 Status Disabled
I>4 Status Disabled
I> Blocking 001111
I> Char Angle 45 deg
V CONTROLLED O/C
VCO Status Disabled
EARTH FAULT 1 GROUP 1
IN1> Input Measured
IN1>1 Function IEC S Inverse
IN1>1 Direction Non-Directional
IN1>1 Current 200 mA
IN1>1 TMS 1.000
IN1>1 tRESET 0 S
IN1>2 Function Disabled
IN1>3 Status Disabled
IN1>4 Status Disabled
IN1> Blocking 001111
IN1> POL
IN1> Char Angle 45 deg
IN1> Pol Zero Sequence
CB FAIL & I< GROUP 1
UNDER CURRENT
I< Current Set 100 mA
I< Current Set 100 mA
ISEF< Current Set 20 mA
SUPERVISION GROUP 1
VT SUPERVISION
VTS Status Blocking
VTS Reset Mode Manual
VTS Time Delay 5 s
VTS I> Inhibit 10 A
VTS I2> Inhibit 50 mA
CT SUPERVISION
CTS Status Disabled


FAULT LOCATOR GROUP 1
Line Length 9.936 mi
Line Impedance 24 Ohm
Line Angle 70 deg
KZN Residual 1
KZN Res Angle 0 deg
INPUT LABELS GROUP 1
Opto Input 1 Input L1
Opto Input 2 Input L2
Opto Input 3 Input L3
Opto Input 4 Input L4
Opto Input 5 Input L5
Opto Input 6 Input L6
Opto Input 7 Input L7
Opto Input 8 Input L8
Opto Input 9 Input L9
Opto Input 10 Input L10
Opto Input 11 Input L11
Opto Input 12 Input L12
Opto Input 13 Input L13
Opto Input 14 Input L14
Opto Input 15 Input L15
Opto Input 16 Input L16
* Continue as above up to Opto input 32
OUTPUT LABELS GROUP 1
Relay 1 Output R1
Relay 2 Output R2
Relay 3 Output R3
Relay 4 Output R4
Relay 5 Output R5
Relay 6 Output R6
Relay 7 Output R7
Relay 8 Output R8
Relay 9 Output R9
Relay 10 Output R10
Relay 11 Output R11
Relay 12 Output R12
Relay 13 Output R13
Relay 14 Output R14
Relay 15 Output R15
Relay 16 Output R16
* Continue as above up to Relay 32

GS

ST

# SETTINGS

**Date:** **7th July 2005**
**Hardware Suffix:** **J**
**Software Version:** **31**
**Connection Diagrams:** **10P145xx (xx = 01 to 07)**

ST

# CONTENTS

# 1. SETTINGS

The P145 must be configured to the system and application by means of appropriate settings. The sequence in which the settings are listed and described in this chapter will be the protection setting, control and configuration settings and the disturbance recorder settings (see section P145/EN GS for the detailed relay menu map). 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. In order to simplify the setting of the relay, there is a configuration settings column which can be used to enable or disable many of the functions of the relay. The settings associated with any function that is disabled are made invisible; i.e. they are not shown 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 four 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.

The column also allows all of the setting values in one group of protection settings to be copied to another group.

To do this firstly 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 the temporary scratchpad, and will only be used by the relay following confirmation.

| Menu Text | Default Setting | Available Settings |
|---|---|---|
| Restore Defaults | No Operation | No Operation<br>All Settings<br>Setting Group 1<br>Setting Group 2<br>Setting Group 3<br>Setting Group 4 |
| Setting to restore a setting group to factory default settings. | | |
| Setting Group | Select via Menu | Select via Menu<br>Select via Optos |
| Allows setting group changes to be initiated via Opto Input or via Menu. | | |
| Active Settings | Group 1 | Group 1, Group 2, Group 3, Group 4 |
| Selects the active setting group. | | |
| Save Changes | No Operation | No Operation, Save, Abort |
| Saves all relay settings. | | |
| Copy from | Group 1 | Group 1, 2, 3 or 4 |
| Allows displayed settings to be copied from a selected setting group. | | |
| Copy to | No Operation | No Operation<br>Group 1, 2, 3 or 4 |
| Allows displayed settings to be copied to a selected setting group (ready to paste). | | |
| Setting Group 1 | Enabled | Enabled or Disabled |
| 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 |

ST

| Menu Text | Default Setting | Available Settings |
|---|---|---|
| Setting Group 3 (as above) | Disabled | Enabled or Disabled |
| Setting Group 4 (as above) | Disabled | Enabled or Disabled |
| Overcurrent | Enabled | Enabled or Disabled |
| To enable (activate) or disable (turn off) the Phase Overcurrent Protection function.<br>I> stages: ANSI 50/51/67P. | | |
| Neg. Sequence O/C | Disabled | Enabled or Disabled |
| To enable (activate) or disable (turn off) the Negative Sequence Overcurrent Protection function.<br>I2> stages: ANSI 46/67. | | |
| Broken Conductor | Disabled | Enabled or Disabled |
| To enable (activate) or disable (turn off) the Broken Conductor function.<br>I2/I1> stage: ANSI 46BC. | | |
| Earth Fault 1 | Enabled | Enabled or Disabled |
| To enable (activate) or disable (turn off) the Earth Fault 1 Protection function.<br>IN(measured)>stages: ANSI 50/51/67N. | | |
| Earth Fault 2 | Disabled | Enabled or Disabled |
| To enable (activate) or disable (turn off) the Earth Fault 2 Protection function.<br>IN(derived)>stages: ANSI 50/51/67N. | | |
| SEF/REF Prot. | Disabled | Enabled or Disabled |
| To enable (activate) or disable (turn off) the Sensitive Earth Fault/Restricted Earth Fault Protection function.<br>ISEF>stages: ANSI 50.51/67N, IREF>stage: ANSI 64. | | |
| Residual O/V NVD | Disabled | Enabled or Disabled |
| To enable (activate) or disable (turn off) the Residual Overvoltage Protection function.<br>VN>stages: ANSI 59N | | |
| Thermal Overload | Disabled | Enabled or Disabled |
| To enable (activate) or disable (turn off) the Thermal Overload Protection function.<br>ANSI 49. | | |
| Neg. Sequence O/V | Disabled | Enabled or Disabled |
| To enable (activate) or disable (turn off) the Negative Sequence Overvoltage Protection function.<br>V2>stages: ANSI 47. | | |
| Cold Load Pickup | Disabled | Enabled or Disabled |
| To enable (activate) or disable (turn off) the Cold Load Pick-up function. | | |
| Selective Logic | Disabled | Enabled or Disabled |
| To enable (activate) or disable (turn off) the Selective Logic function. | | |
| Admit. Protection | Disabled | Enabled or Disabled |
| To enable (activate) or disable (turn off) the Admittance Protection function.<br>YN, GN, BN>stages. | | |
| Volt Protection | Disabled | Enabled or Disabled |
| To enable (activate) or disable (turn off) the Voltage Protection (under/overvoltage) function.<br>V<, V> stages: ANSI 27/59. | | |

| Menu Text | Default Setting | Available Settings |
|---|---|---|
| Freq. Protection | Disabled | Enabled or Disabled |
| To enable (activate) or disable (turn off) the Frequency Protection (under/overfrequency) function.<br>F<, F> stages: ANSI 81O/U. | | |
| df/dt Protection | Disabled | Enabled or Disabled |
| To enable (activate) or disable (turn off) the Rate of Change of Frequency Protection function.<br>df/dt>stages: ANSI 81R. | | |
| CB Fail | Disabled | Enabled or Disabled |
| To enable (activate) or disable (turn off) the Circuit Breaker Fail Protection function.<br>ANSI 50BF. | | |
| Supervision | Enabled | Enabled or Disabled |
| To enable (activate) or disable(turn off) the Supervision (VTS&CTS) functions.<br>ANSI VTS/CTS. | | |
| Fault Locator | Enabled | Enabled or Disabled |
| To enable (activate) or disable (turn off) the Fault Locator function. | | |
| System Checks | Disabled | Enabled or Disabled |
| To enable (activate) or disable(turn off) the System Checks (Check Sync. and Voltage Monitor) function.<br>ANSI 25. | | |
| Auto-reclose | Disabled | Enabled or Disabled |
| To enable (activate) or disable(turn off) the Auto-reclose function.<br>ANSI 79. | | |
| Input Labels | Visible | Invisible or Visible |
| Sets the Input Labels menu visible further on in the relay settings menu. | | |
| Output Labels | Visible | Invisible or Visible |
| Sets the Output Labels menu visible further on in the relay settings menu. | | |
| CT & VT Ratios | Visible | Invisible or Visible |
| Sets the Current & Voltage Transformer Ratios menu visible further on in the relay settings menu. | | |
| Record Control | Invisible | Invisible or Visible |
| Sets the Record Control menu visible further on in the relay settings menu. | | |
| Disturb. Recorder | Invisible | Invisible or Visible |
| Sets the Disturbance Recorder menu visible further on in the relay settings menu. | | |
| Measure't. Set-up | Invisible | Invisible or Visible |
| Sets the Measurement Setup menu visible further on in the relay settings menu. | | |
| Comms. Settings | Visible | Invisible or Visible |
| Sets the Communications Settings menu visible further on in the relay settings menu. These are the settings associated with the $1^{st}$ and $2^{nd}$ rear communications ports. | | |
| Commission Tests | Visible | Invisible or Visible |
| Sets the Commissioning Tests menu visible further on in the relay settings menu. | | |
| Setting Values | Primary | Primary or Secondary |
| This affects all protection settings that are dependent upon CT and VT ratio’s. | | |

| Menu Text | Default Setting | Available Settings |
|---|---|---|
| Control Inputs | Visible | Invisible or Visible |
| Activates the Control Input status and operation menu further on in the relay setting menu. | | |
| Ctrl I/P Config. | Visible | Invisible or Visible |
| Sets the Control Input Configuration menu visible further on in the relay setting menu. | | |
| Ctrl I/P Labels | Visible | Invisible or Visible |
| Sets the Control Input Labels menu visible further on in the relay setting menu. | | |
| Direct Access | Enabled | Enabled/Disabled/Hotkey only/CB Cntrl. only |
| Defines what CB control direct access is allowed. Enabled implies control via menu, hotkeys etc. | | |
| Function Key | Visible | Invisible or Visible |
| Sets the Function Key menu visible further on in the relay setting menu. | | |
| LCD Contrast | 11 | 0…31 |
| Sets the LCD contrast. | | |



1.1.1 Default settings restore

To restore the default values to the settings in any protection settings group, set the ‘restore defaults’ cell to the relevant group number. Alternatively 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 will initially be placed in the scratchpad and will only be used by the relay after they have been confirmed. Note that restoring defaults to all settings includes the rear communication port settings, which may result in communication via the rear port being disrupted if the new (default) settings do not match those of the master station.

## 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.

– Auto-reclose and check synchronization settings.

– Fault locator settings.

There are four 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 is shown. The settings are discussed in the same order in which they are displayed in the menu.

1.2.1 Phase overcurrrent protection

The overcurrent protection included in the P145 relay provides four stage non-directional/directional three-phase overcurrent protection with independent time delay characteristics. All overcurrent and directional 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), or definite time (DT). The third and fourth stages have definite time characteristics only.

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| 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 | | |
| Setting for the tripping characteristic for the first stage overcurrent element. | | | | |
| I>1 Direction | Non-directional | Non-directional Directional Fwd Directional Rev | | |
| This setting determines the direction of measurement for first stage element. | | | | |
| I>1 Current Set | 1 x In | 0.08 x In | 4.0 x In | 0.01 x In |
| Pick-up setting for first stage overcurrent element. | | | | |
| I>1 Time Delay | 1 | 0 | 100 | 0.01 |
| Setting for the time-delay for the definite time setting if selected for first stage element. | | | | |
| I>1 TMS | 1 | 0.025 | 1.2 | 0.025 |
| Setting for the time multiplier setting to adjust the operating time of the IEC IDMT characteristic. | | | | |
| I>1 Time Dial | 1 | 0.01 | 100 | 0.01 |
| Setting for the time multiplier setting to adjust the operating time of the IEEE/US IDMT curves. | | | | |
| I>1 K (RI) | 1 | 0.1 | 10 | 0.05 |
| Setting for the time multiplier to adjust the operating time for the RI curve. | | | | |
| I>1 Reset Char. | DT | DT or Inverse | | N/A |
| Setting to determine the type of reset/release characteristic of the IEEE/US curves. | | | | |
| I>1 tRESET | 0 | 0s | 100s | 0.01s |
| Setting that determines the reset/release time for definite time reset characteristic. | | | | |
| I>2 Cells as for I>1 above | | | | |
| Setting the same as for the first stage overcurrent element. | | | | |
| I>3 Status | Disabled | Disabled or Enabled | | N/A |
| Setting to enable or disable the third stage overcurrent element. | | | | |
| I>3 Direction | Non-directional | Non-directional Directional Fwd Directional Rev | | N/A |
| This setting determines the direction of measurement for the overcurrent element. | | | | |
| I>3 Current Set | 20 x In | 0.08 x In | 32 x In | 0.01 x In |
| Pick-up setting for third stage overcurrent element. | | | | |
| I>3 Time Delay | 0 | 0s | 100s | 0.01s |
| Setting for the operating time-delay for third stage overcurrent element. | | | | |
| I>4 Cells as for I>3 Above | | | | |
| Settings the same as the third stage overcurrrent element. | | | | |

ST

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| I> Char. Angle | 45 | –95° | +95° | 1° |
| Setting for the relay characteristic angle used for the directional decision. | | | | |
| I> Blocking | 00001111 | Bit 0 = VTS Blocks I>1, Bit 1 = VTS Blocks I>2, Bit 2 = VTS Blocks I>3, Bit 3 = VTS Blocks I>4, Bit 4 = A/R Blocks I>3, Bit 5 = A/R Blocks I>4. Bits 6 & 7 are not used. | | |
| Logic Settings that determine whether blocking signals from VT supervision and auto-reclose affect certain overcurrent stages.<br>VTS Block – only affects directional overcurrent protection. With the relevant bit set to 1, operation of the Voltage Transformer Supervision (VTS), will block the stage. When set to 0, the stage will revert to Non-directional upon operation of the VTS.<br>A/R Block – the auto-reclose logic can be set to selectively block instantaneous overcurrent elements for each shot in an auto-reclose sequence. This is set in the auto-reclose column. When a block instantaneous signal is generated then only those overcurrent stages selected to '1' in the I> Function link will be blocked. | | | | |
| Voltage Controlled Overcurrent | | | | |
| VCO Status | Disabled | Disabled, I>1, I>2, Both I>1 & I>2 | | N/A |
| Allows selection of whether voltage control should be applied to each of the first or second stage overcurrent elements. | | | | |
| VCO V< Setting | 60 | 20/80V For 110/440V respectively | 120/480V For 110/440V respectively | 1/4V For 110/440V respectively |
| Sets the voltage threshold at which the current setting of the overcurrent stage/stages becomes reduced, noting that this occurs on a per phase basis. | | | | |
| VCO k Setting | 0.25 | 0.25 | 1 | 0.05 |
| Setting to determine the overcurrent multiplier factor used to reduce the pick-up overcurrent setting. | | | | |

ST

### 1.2.2 Negative sequence overcurrent

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| I2>1 Status | Disabled | Disabled or Enabled | | N/A |
| Setting to enable or disable the first stage negative sequence definite time element. | | | | |
| I2>1Direction | Non-directional | Non-directional<br>Directional Fwd<br>Directional Rev | | N/A |
| This setting determines the direction of measurement for this element. | | | | |
| I2>1 Current Set | 0.2 x In | 0.08In | 4In | 0.01In |
| Pick-up setting for the first stage negative sequence overcurrent element. | | | | |
| I2>1 Time Delay | 10 | 0s | 100s | 0.01s |
| Setting for the operating time-delay for the first stage negative sequence overcurrent element. | | | | |
| I2>2 Cells as for I>3 Above | | | | |

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| I2>3 Cells as for I>3 Above | | | | |
| I2>4 Cells as for I>3 Above | | | | |
| I2> VTS Blocking | 1111 | Bit 00 = VTS blocks I2>1<br>Bit 01 = VTS blocks I2>2<br>Bit 02 = VTS blocks I2>3<br>Bit 03 = VTS blocks I2>4 | | |
| Logic settings that determine whether VT supervision blocks selected negative sequence overcurrent stages. Setting ‘0’ will permit continued non-directional operation. | | | | |
| I2> Char. Angle | –60° | –95° | +95° | 1° |
| Setting for the relay characteristic angle used for the directional decision. | | | | |
| I2> V2pol Set | 5/20V For 110/440V respectively | 0.5/2V For 110/440V respectively | 25/100V For 110/440V respectively | 0.5/2V For 110/440V respectively |
| Setting determines the minimum negative sequence voltage threshold that must be present to determine directionality. | | | | |

1.2.3 Broken conductor

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| Broken Conductor | Disabled | Enabled/Disabled | | N/A |
| Enables or disables the broken conductor function. | | | | |
| I2/I1 | 0.2 | 0.2 | 1 | 0.01 |
| Setting to determine the pick- up level of the negative to positive sequence current ratio. | | | | |
| I2/I1 Time Delay | 60s | 0s | 100s | 1s |
| Setting for the function operating time delay. | | | | |

1.2.4 Earth fault

The standard earth fault protection elements are duplicated within the P145 relay and are referred to in the relay menu as “Earth Fault 1” (EF1) and “Earth Fault 2” (EF2). EF1 operates from earth fault current that is measured directly from the system; either by means of a separate CT located in a power system earth connection or via a residual connection of the three line CT's. The EF2 element operates from a residual current quantity that is derived internally from the summation of the three phase currents

EF1 and EF2 are identical elements, each having four stages. The first and second stages have selectable IDMT or DT characteristics, whilst the third and fourth stages are DT only. Each stage is selectable to be either non-directional, directional forward or directional reverse. The timer hold facility, previously described for the overcurrent elements, is available on each of the first two stages.

The following table shows the relay menu for "Earth Fault 1" protection, including the available setting ranges and factory defaults. The menu for "Earth Fault 2" is identical to that for EF1 and so is not shown here:

ST

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| IN1>1 Function | IEC S Inverse | Disabled, DT, IEC S Inverse, IEC V Inverse, IEC E Inverse, UK LT Inverse, RI, IEEE M Inverse, IEEE V Inverse, IEEE E Inverse, US Inverse, US ST Inverse, IDG | | |
| Setting for the tripping characteristic for the first stage earth fault element. | | | | |
| IN1>1 Direction | Non-directional | Non-directional<br>Directional Fwd<br>Directional Rev | | N/A |
| This setting determines the direction of measurement for the first stage earth fault element. | | | | |
| IN1>1 Current Set | 0.2 x In | 0.08 x In | 4.0 x In | 0.01 x In |
| Pick-up setting for the first stage earth fault element. | | | | |
| IN1>1 IDG Is | 1.5 | 1 | 4 | 0.1 |
| This setting is set as a multiple of "IN>" setting for the IDG curve (Scandinavian) and determines the actual relay current threshold at which the element starts. | | | | |
| IN1>1 Time Delay | 1 | 0s | 200s | 0.01s |
| Time-delay setting for the first stage definite time element. | | | | |
| IN1>1 TMS | 1 | 0.025 | 1.2 | 0.025 |
| Setting for the time multiplier setting to adjust the operating time of the IEC IDMT characteristic. | | | | |
| IN1>1 Time Dial | 1 | 0.01 | 100 | 0.1 |
| Setting for the time multiplier setting to adjust the operating time of the IEEE/US IDMT curves. | | | | |
| IN1>1 K (RI) | 1 | 0.1 | 10 | 0.05 |
| Setting for the time multiplier to adjust the operating time for the RI curve. | | | | |
| IN1>1 IDG Time | 1.2 | 1 | 2 | 0.01 |
| Setting for the IDG curve used to set the minimum operating time at high levels of fault current. | | | | |
| IN1>1 Reset Char. | DT | DT or Inverse N/A | | |
| Setting to determine the type of reset/release characteristic of the IEEE/US curves. | | | | |
| IN1>1 tRESET | 0 | 0s | 100s | 0.01s |
| Setting to determine the reset/release time for definite time reset characteristic. | | | | |
| IN1>2 Cells as for IN1>1 Above | | | | |
| IN1>3 Status | Disabled | Disabled or Enabled | | N/A |
| Setting to enable or disable the third stage definite time element. If the function is disabled, then all associated settings with the exception of this setting, are hidden. | | | | |
| IN1>3 Direction | Non-directional | Non-directional<br>Directional Fwd<br>Directional Rev | | N/A |
| This setting determines the direction of measurement for the third stage earth fault element. | | | | |

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| IN1>3 Current | 0.2 x In | 0.08 x In | 32 x In | 0.01 x In |
| Pick-up setting for third stage earth fault element. | | | | |
| IN1>3 Time Delay | 0 | 0s | 200s | 0.01s |
| Setting for the operating time delay for the third stage earth fault element. | | | | |
| IN1>4 Cells as for IN1>3 Above | | | | |
| IN1> Blocking | 00001111 | Bit 0 = VTS Blocks IN>1, Bit 1 = VTS Blocks IN>2, Bit 2 = VTS Blocks IN>3, Bit 3 = VTS Blocks IN>4, Bit 4 = A/R Blocks IN>3, Bit 5 = A/R Blocks IN>4. Bits 6 & 7 are not used. | | |
| Logic Settings that determine whether blocking signals from VT supervision and auto-reclose blocks selected earth fault overcurrent stages. | | | | |
| IN1> Char. Angle | –45° | –95° | +95° | 1° |
| Setting for the relay characteristic angle used for the directional decision. | | | | |
| IN1>Pol | Zero Sequence | Zero Sequence or Neg. Sequence | | N/A |
| Setting that determines whether the directional function uses zero sequence or negative sequence voltage polarizing. | | | | |
| IN1>VNpol Set | 5 | 0.5/2V | 80/320V | 0.5/2V |
| Setting for the minimum zero sequence voltage polarizing quantity for directional decision | | | | |
| IN1>V2pol Set | 5 | 0.5/2V | 25/100V | 0.5/2V |
| Setting for the minimum negative sequence voltage polarizing quantity for directional decision. | | | | |
| IN1>I2pol Set | 0.08 | 0.08 x In | 1 x In | 0.01In |
| Setting for the minimum negative sequence current polarizing quantity for directional decision. | | | | |

### 1.2.5 Sensitive earth fault/restricted earth fault

If a system is earthed through a high impedance, or is subject to high ground fault resistance, the earth fault level will be severely limited. Consequently, the applied earth fault protection requires both an appropriate characteristic and a suitably sensitive setting range in order to be effective. A separate four-stage sensitive earth fault element is provided within the P145 relay for this purpose, which has a dedicated input. This input may be configured to be used as a REF input. The REF protection in the P145 relay may be configured to operate as either a high impedance or biased element. Note that the high impedance REF element of the relay shares the same CT input as the SEF protection. Hence, only one of these elements may be selected. However, the low impedance REF element does not use the SEF input and so may be selected at the same time.

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| SEF/REF PROT'N. GROUP 1 | | | | |
| SEF/REF Options | SEF | SEF, SEF cos (PHI), SEF sin (PHI), Wattmetric, Hi Z REF, Lo Z REF, Lo Z REF + SEF, Lo Z REF + Wattmetric | | |
| Setting to select the type of sensitive earth fault protection function and the type of high-impedance function to be used. If the function is not selected, then all associated settings and signals are hidden, with the exception of this setting. | | | | |
| ISEF>1 Function | DT | 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 | | |
| Setting for the tripping characteristic for the first stage sensitive earth fault element. | | | | |
| ISEF>1 Direction | Non-directional | Non-directional<br>Direction Fwd<br>Direction Rev | | N/A |
| This setting determines the direction of measurement for the first stage sensitive earth fault element. | | | | |
| ISEF>1 Current | 0.05 x In | 0.005 x In | 0.1x In | 0.00025 x In |
| Pick-up setting for the first stage sensitive earth fault element. | | | | |
| ISEF>1 IDG Is | 1.5 | 1 | 4 | 0.1 |
| This setting is set as a multiple of "ISEF>" setting for the IDG curve (Scandinavian) and determines the actual relay current threshold at which the element starts. | | | | |
| ISEF>1 Delay | 1 | 0 | 200s | 0.01s |
| Setting for the time delay for the first stage definite time element. | | | | |
| ISEF>1 TMS | 1 | 0.025 | 1.2 | 0.025 |
| Setting for the time multiplier to adjust the operating time of the IEC IDMT characteristic. | | | | |
| ISEF>1 Time Dial | 7 | 0.1 | 100 | 0.1 |
| Setting for the time multiplier to adjust the operating time of the IEEE/US IDMT curves. | | | | |
| ISEF>1 IDG Time | 1.2 | 1 | 2 | 0.01 |
| Setting for the IDG curve used to set the minimum operating time at high levels of fault current. | | | | |
| ISEF>1 Reset Char. | DT | DT or Inverse | | N/A |
| Setting to determine the type of reset/release characteristic of the IEEE/US curves. | | | | |
| ISEF>1 tRESET | 0 | 0s | 100s | 0.01s |
| Setting to determine the reset/release time for definite time reset characteristic. | | | | |
| ISEF>2 Cells as for ISEF>1 Above | | | | |
| ISEF>3 Status | Disabled | Disabled or Enabled | | N/A |
| Setting to enable or disable the third stage definite time sensitive earth fault element. | | | | |
| ISEF>3 Direction | Non-directional | Non-directional<br>Directional Fwd<br>Directional Rev | | N/A |
| This setting determines the direction of measurement for the third stage element. | | | | |

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| ISEF>3 Current | 0.2 x In | 0.005 x In | 2.0 x In | 0.001 x In |
| Pick-up setting for the third stage sensitive earth fault element. | | | | |
| ISEF>3 Time Delay | 1 | 0s | 200s | 0.01s |
| Setting for the operating time delay for third stage sensitive earth fault element. | | | | |
| ISEF>4 Cells as for ISEF>3 Above | | | | |
| ISEF> Func. Link | 00001111 | Bit 0 = VTS Blocks ISEF>1, Bit 1 = VTS Blocks ISEF>2, Bit 2 = VTS Blocks ISEF>3, Bit 3 = VTS Blocks ISEF>4,<br>Bit 4 = A/R Blocks ISEF>3,<br>Bit 5 = A/R Blocks ISEF>4.<br>Bits 6 & 7 are not used. | | |
| Settings that determine whether VT supervision and auto-reclose logic signals blocks selected sensitive earth fault stages. | | | | |
| ISEF POL | Sub-heading in menu | | | |
| ISEF> Char. Angle | –45° | –95° | +95° | 1° |
| Setting for the relay characteristic angle used for the directional decision. | | | | |
| ISEF>VNpol Set | 5 | 0.5/2V | 80/320V | 0.5/2V |
| Setting for the minimum zero sequence voltage polarizing quantity required for directional decision. | | | | |
| WATTMETRIC SEF | Sub-heading in menu | | | |
| PN> Setting | 9In/36In W | 0 – 20In/80In W | | 0.05/<br>0.2In W |
| Setting for the threshold for the wattmetric component of zero sequence power. The power calculation is as follows:<br>The PN> setting corresponds to:<br>Vres x Ires x Cos (ϕ – ϕc) = 9 x Vo x Io x Cos (ϕ– ϕc)<br>Where; ϕ = Angle between the Polarizing Voltage (-Vres) and the Residual Current<br>ϕc = Relay Characteristic Angle (RCA) Setting (ISEF> Char Angle)<br>Vres = Residual Voltage<br>Ires = Residual Current<br>Vo = Zero Sequence Voltage<br>Io = Zero Sequence Current | | | | |
| RESTRICTED E/F | Sub-heading in menu | | | |
| IREF>k1 | 20% | 0.08x In | 1.0 x In | 0.01x In |
| Slope angle setting for the first slope of the low impedance biased characteristic. | | | | |
| IREF>k2 | 150% | 0% | 150% | 1% |
| Slope angle setting for the second slope of the low impedance biased characteristic. | | | | |
| IREF>Is1 | 0.2 | 0.08 x In | 1 x In | 0.01 x In |
| Setting that determines the minimum differential operating current for the low impedance characteristics. | | | | |

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| IREF>Is2 | 1 | 0.1 x In | 1.5 x In | 0.01 x In |
| Setting that determines the bias current operating threshold for the second slope low impedance characteristics. | | | | |

For the Hi Z REF option, the following settings are available:

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| RESTRICTED E/F | Sub-heading in menu | | | |
| IREF> Is | 20% | 0.05x In | 1.0 x In | 0.01x In |
| Setting that determines minimum differential operating current for the Hi-impedance element. | | | | |



### 1.2.6 Residual overvoltage (neutral voltage displacement)

The NVD element within the P145 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.

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| RESIDUAL O/V NVD GROUP 1 | | | | |
| VN>1 Function | DT | Disabled, DT, IDMT | | N/A |
| Setting for the tripping characteristic of the first stage residual overvoltage element. | | | | |
| VN>1 Voltage Set | 5/20V For 110/440V respectively | 1/4V For 110/440V respectively | 80/320V For 110/440V respectively | 1V |
| Pick-up setting for the first stage residual overvoltage characteristic. | | | | |
| VN>1 Time Delay | 5s | 0 | 100 | 0.01s |
| Operating time delay setting for the first stage definite time residual overvoltage element. | | | | |
| VN>1 TMS | 1 | 0.5 | 100 | 0.5 |
| Setting for the time multiplier setting to adjust the operating time of the IDMT characteristic.<br>The characteristic is defined as follows:<br>t = K / ( M – 1)<br>where: K = Time multiplier setting<br>t = Operating time in seconds<br>M = Derived residual voltage/relay setting voltage (VN> Voltage Set) | | | | |
| VN>1 Reset | 0 | 0 | 100 | 0.01 |
| Setting to determine the reset/release definite time for the first stage characteristic | | | | |
| VN>2 Status | Disabled | Disabled, Enabled | | N/A |
| Setting to enable or disable the second stage definite time residual overvoltage element. | | | | |
| VN>2 Voltage Set | 10 | 1/4V (110/440V) | 80/320V (110/440V) | 1V |
| Pick-up setting for the second stage residual overvoltage element. | | | | |

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| VN>2 Time Delay | 10s | 0 | 100 | 0.01s |
| Operating time delay for the second stage residual overvoltage element. | | | | |

### 1.2.7 Thermal overload

The thermal overload function within the P145 relay is capable of being selected as a single time constant or dual time constant characteristic, dependent on the type of plant to be protected.

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| THERMAL OVERLOAD GROUP 1 | | | | |
| Characteristic | Single | Disabled, Single, Dual | | |
| Setting for the operating characteristic of the thermal overload element. | | | | |
| Thermal Trip | 1In | 0.08In | 4In | 0.01In |
| Sets the maximum full load current allowed and the pick-up threshold of the thermal characteristic. | | | | |
| Thermal Alarm | 70% | 50% | 100% | 1% |
| Setting for the thermal state threshold corresponding to a percentage of the trip threshold at which an alarm will be generated. | | | | |
| Time Constant 1 | 10 minutes | 1 minute | 200 minutes | 1 minute |
| Setting for the thermal time constant for a single time constant characteristic or the first time constant for the dual time constant characteristic. | | | | |
| Time Constant 2 | 5 minutes | 1 minute | 200 minute | 1 minute |
| Setting for the second thermal time constant for the dual time constant characteristic. | | | | |

### 1.2.8 Negative sequence overvoltage

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| NEG. SEQUENCE O/V GROUP 1 | | | | |
| V2> status | Enabled | Enabled, Disabled | | N/A |
| Setting to enable or disable the definite time negative sequence overvoltage element. | | | | |
| V2> Voltage Set | 15/60V For 110/440V respectively | 1/4V For 110/440V respectively | 110/440V For 110/440V respectively | 1/4V For 110/440V respectively |
| Pick-up setting for the negative sequence overvoltage element. | | | | |
| V2> Time Delay | 5s | 0 | 100 | 0.01 |
| Operating time delay setting for the definite time stage element. | | | | |

### 1.2.9 Cold load pick-up

The CLP logic is included for each of the four overcurrent stages and the first stages of the measured (EF1) and derived (EF2) earth fault protection. Note that the CLP logic is enabled/disabled within the configuration column.

ST

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| COLD LOAD PICKUP GROUP 1 | | | | |
| tcold Time Delay | 7200s | 0 | 14,400s | 1s |
| This setting determines the time the load needs to be de-energized (dead time) before the new settings are applied. | | | | |
| tclp Time Delay | 7200s | 0 | 14,400s | 1s |
| This setting controls the period of time for which the relevant overcurrent and earth fault settings are altered or inhibited following circuit breaker closure. | | | | |
| OVERCURRENT | Sub-heading | | | |
| I>1 Status | Enable | Block, Enable | | N/A |
| As shown in the menu, the I>1 status cells have two setting options, "Enable" and "Block". Selection of "Enable" for a particular stage means that the current and time settings programmed in the following cells will be those that are adopted during the "tclp" time. Selection of "Block" simply blocks the relevant protection stage during the "tclp" time. It also removes the following current and time settings for that stage from the menu. | | | | |
| I>1 Current set | 1.5 x In | 0.08 x In | 4 x In | 0.01 x In |
| This setting determines the new pick-up setting for first stage overcurrent element during the tclp time delay. | | | | |
| I>1 Time Delay | 1s | 0 | 100s | 0.01s |
| Setting for the new operating time delay for the first stage definite time overcurrent element during the tclp time. | | | | |
| I>1 TMS | 1 | 0.025 | 1.2 | 0.025 |
| Setting for the new time multiplier setting for the first stage element to adjust the operating time of the IEC IDMT characteristic during the tclp time. | | | | |
| I>1 Time Dial | 7 | 0.5 | 15 | 0.1 |
| Setting for the new time multiplier setting to adjust the operating time of the IEEE/US IDMT curves during the tclp time. | | | | |
| I>2 Status as for I>1 Cells above | Enable | Block, Enable | | N/A |
| I>3 Status | Block | Block, Enable | | N/A |
| As shown in the menu the I>3 status cells have two setting options, "Enable" and "Block". Selection of "Enable" for a particular stage means that the current and time settings programmed in the following cells will be those that are adopted during the "tclp" time. Selection of "Block" simply blocks the relevant protection stage during the "tclp" time. It also removes the following current and time settings for that stage from the menu. | | | | |
| I>3 Current Set | 25 x In | 0.08 x In | 32 x In | 0.01 x In |
| This setting determines the new pick-up setting for the third stage overcurrent function during the tclp time delay. | | | | |
| I>3 Time Delay | 0 | 0 | 100s | 0.01s |
| Setting for the new operating time delay for the third stage definite time element during the tclp time. | | | | |
| I>4 Status as for I>3 Cells above | Block | Block, Enable | | N/A |
| STAGE 1 E/F 1 | Sub-heading | | | |

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| IN1>1 Status | Enable | Block, Enable | | N/A |
| As shown in the menu the IN1>1 status cells have two setting options, "Enable" and "Block". Selection of "Enable" for a particular stage means that the current and time settings programmed in the following cells will be those that are adopted during the "tclp" time. Selection of "Block" simply blocks the relevant protection stage during the "tclp" time. It also removes the following current and time settings for that stage from the menu. | | | | |
| IN1>1 Current | 0.2 x In | 0.08 x In | 4 x In | 0.01 x In |
| This setting determines the new pick-up setting for first stage earth fault element during the tclp time delay. | | | | |
| IN1> IDG Is | 1.5 | 1 | 4 | 0.1 x In |
| This setting is set as a multiple of “IN>” setting for the IDG curve (Scandinavian) and determines the new relay current threshold at which the element starts during the tclp time delay. | | | | |
| IN1>1 Time Delay | 1s | 0 | 200s | 0.01s |
| Setting for the new operating time delay for the first stage definite time element during the tclp time. | | | | |
| IN1>1 TMS | 1 | 0.025 | 1.2 | 0.025 |
| Setting for the new time multiplier setting to adjust the operating time of the IEC IDMT characteristic during the tclp time. | | | | |
| IN1>1 Time Dial | 7 | 0.5 | 15 | 0.1 |
| Setting for the new time multiplier setting to adjust the operating time of the IEEE/US IDMT curves during the tclp time. | | | | |
| IN1>1 k (RI) | 1.0 | 0.1 | 10 | 0.5 |
| Setting for the new time multiplier to adjust the operating time for the RI curve during the tclp time. | | | | |
| STAGE 1 E/F 2 | Sub-heading | | | |
| IN2>1 Status as for IN1> Cells above | Enable | Block, Enable | | N/A |

### 1.2.10 Selective overcurrent logic

The SOL function provides the ability to temporarily increase the time delay settings of the third and fourth stages of phase overcurrent, derived and measured earth fault and sensitive earth fault protection elements. This logic modifies the normal trip timer block functionality, to replace it with a second definite timer and is initiated by energization of the appropriate trip time opto-isolated input.

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| SELECTIVE LOGIC GROUP 1 | | | | |
| OVERCURRENT | Sub-heading | | | |
| I>3 Time Delay | 1s | 0 | 100s | 0.01s |
| Setting for the third stage definite time overcurrent element operating time when the selective logic is active. | | | | |
| I>4 Time Delay | 1s | 0 | 100s | 0.01s |
| Setting for the fourth stage definite time overcurrent element operating time when the selective logic is active. | | | | |
| EARTH FAULT 1 | Sub-heading | | | |
| IN1>3 Time Delay | 2s | 0 | 200s | 0.01s |
| Setting for the third stage definite time earth fault (measured) element operating time when the selective logic is active. | | | | |
| IN1>4 Time Delay | 2s | 0 | 200s | 0.01s |
| Setting for the fourth stage definite time earth fault (measured) element operating time when the selective logic is active. | | | | |
| EARTH FAULT 2 | Sub-heading | | | |
| IN2>3 Time Delay | 2s | 0 | 200s | 0.01s |
| Setting for the third stage definite time earth fault (derived) element operating time when the selective logic is active. | | | | |
| IN2>4 Time Delay | 2s | 0 | 200s | 0.01s |
| Setting for the fourth stage definite time earth fault (derived) element operating time when the selective logic is active. | | | | |
| SENSITIVE E/F | Sub-heading | | | |
| ISEF>3 Delay | 1s | 0 | 200s | 0.01s |
| Setting for the third stage definite time sensitive earth fault element operating time when the selective logic is active. | | | | |
| ISEF>4 Delay | 0.5s | 0 | 200s | 0.01s |
| Setting for the fourth stage definite time sensitive earth fault element operating time when the selective logic is active. | | | | |

### 1.2.11 Neutral admittance protection

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| ADMIT. PROTECTION GROUP 1 | | | | |
| VN Threshold | 10/40V For 110/440V respectively | 1/4V For 110/440V respectively | 40/160V For 110/440V respectively | 1/4V For 110/440V respectively |
| The overadmittance elements YN>, GN> and BN> will operate providing the neutral voltage remains above the set level for the set operating time of the element. They are blocked by operation of the fast VTS supervision output. | | | | |

ST

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| CT Input Type | SEF CT | SEF CT/E/F CT | | – |
| Setting determines which CT inputs are used for the admittance element calculations. | | | | |
| Correction Angle | 0 degree | –30 degree | 30 degree | 1 degree |
| This setting causes rotation of the directional boundary for conductance through the set correction angle. | | | | |
| OVER ADMITTANCE | | | | |
| YN> Status | Disabled | Disabled or Enabled | | – |
| Setting to enable or disable the overadmittance stage. If the function disabled, then all associated settings with the exception of this setting, are hidden. | | | | |
| YN> Set (SEF) | 5mS/1.25mS For 110/440V respectively | 0.1mS/ 0.025mS For 110/440V respectively | 10mS/ 2.5mS For 110/440V respectively | 0.1mS/ 0.025mS For 110/440V respectively |
| Sets the magnitude of the overadmittance threshold. If the measurement exceeds the set value and the magnitude of neutral voltage exceeds the set value threshold, the relay will operate. | | | | |
| YN> Set (EF) | 50mS/12.5mS For 110/440V respectively | 1mS/ 0.25mS For 110/440V respectively | 100mS/ 25mS For 110/440V respectively | 1mS/ 0.25mS For 110/440V respectively |
| Sets the magnitude of the overadmittance threshold. If the measurement exceeds the set value and the magnitude of neutral voltage exceeds the set value threshold, the relay will operate. | | | | |
| YN> Time Delay | 1 s | 0.05 s | 100 s | 0.01 s |
| Operating time delay setting for the overadmittance element. | | | | |
| YN> tRESET | 0 s | 0 s | 100 s | 0.01 s |
| Sets the reset/release time for the definite time reset characteristic. | | | | |

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| OVER CONDUCTANCE | | | | |
| GN> Status | Disabled | Disabled or Enabled | | |
| Setting to enable or disable the overconductance stage. If the function is disabled, then all associated settings with the exception of this setting, are hidden. | | | | |
| GN> Direction | Non-directional | Non-directional/ Directional Fwd/ Directional Rev | | |
| This setting determines the direction of measurement for this element. | | | | |

ST

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| GN> Set (SEF) | 0.8mS/0.2mS For 110/440V respectively | 0.1mS/ 0.025mS For 110/440V respectively | 5mS/ 1.25mS For 110/440V respectively | 0.1mS/ 0.025mS For 110/440V respectively |
| Sets the magnitude of the overconductance threshold. Provided the magnitude and the directional criteria are met for conductance and the magnitude of neutral voltage exceeds the set value VN Threshold, the relay will operate. | | | | |
| GN> Set (EF) | 2mS/0.5mS For 110/440V respectively | 1mS/ 0.25mS For 110/440V respectively | 50mS/ 2.5mS For 110/440V respectively | 1mS/ 0.25mS For 110/440V respectively |
| Sets the magnitude of the overconductance threshold. Provided the magnitude and the directional criteria are met for conductance and the magnitude of neutral voltage exceeds the set value VN Threshold, the relay will operate. | | | | |
| GN> Time Delay | 1 s | 0.05 s | 100 s | 0.01 s |
| Sets the operating time delay for the overadmittance element. | | | | |
| GN> tRESET | 0 s | 0 s | 100 s | 0.01 s |
| Sets the reset/release time for the definite time reset characteristic. | | | | |
| OVER SUSCEPTANCE | | | | |
| BN> Status | Disabled | Disabled or Enabled | | |
| Setting to enable or disable the oversusceptance stage. If the function is disabled, then all associated settings with the exception of this setting, are hidden. | | | | |
| BN> Direction | Non-directional | Non-directional/ Directional Fwd/ Directional Rev | | |
| This setting determines the direction of measurement for this element. | | | | |
| BN> Set (SEF) | 0.8mS/0.2mS For 110/440V respectively | 0.1mS/ 0.025mS For 110/440V respectively | 5mS/ 1.25mS For 110/440V respectively | 0.1mS/ 0.025mS For 110/440V respectively |
| Sets the magnitude of the oversusceptance threshold. Provided the magnitude and the directional criteria are met for conductance and the magnitude of neutral voltage exceeds the set value VN Threshold, the relay will operate. | | | | |
| BN> Set (EF) | 2mS/0.5mS For 110/440V respectively | 1mS/ 0.25mS For 110/440V respectively | 50mS/ 2.5mS For 110/440V respectively | 1mS/ 0.25mS For 110/440V respectively |
| Sets the magnitude of the oversusceptance threshold. Provided the magnitude and the directional criteria are met for conductance and the magnitude of neutral voltage exceeds the set value VN Threshold, the relay will operate. | | | | |
| BN> Time Delay | 1 s | 0.05 s | 100 s | 0.01 s |
| Setting for the operating time-delay for the oversusceptance element. | | | | |
| BN> tRESET | 0 s | 0 s | 100 s | 0.01 s |
| Sets the reset/release time for the definite time reset characteristic. | | | | |

ST

### 1.2.12 Voltage protection

The undervoltage protection included within the P145 relay consists of two independent stages. These are configurable as either phase to phase or phase to neutral measuring by means of the "V<Measur't mode" cell.

Stage 1 may be selected as IDMT, DT or Disabled, within the "V<1 function" cell. Stage 2 is DT only and is enabled/disabled in the "V<2 status" cell.

Two stages are included to provide both alarm and trip stages, where required.

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| VOLT PROTECTION GROUP 1 | | | | |
| UNDERVOLTAGE | Sub-heading | | | |
| V< Measur't. Mode | Phase-Phase | Phase to Phase<br>Phase to Neutral | | N/A |
| Sets the measured input voltage that will be used for the undervoltage elements. | | | | |
| V< Operate Mode | Any Phase | Any Phase<br>Three Phase | | N/A |
| Setting that determines whether any phase or all three phases has to satisfy the undervoltage criteria before a decision is made. | | | | |
| V<1 Function | DT | Disabled<br>DT<br>IDMT | | N/A |
| Tripping characteristic for the first stage undervoltage function.<br>The IDMT characteristic available on the first stage is defined by the following formula:<br>$t = K / (1 - M)$<br>Where:<br>K = Time multiplier setting<br>t = Operating time in seconds<br>M = Measured voltage/relay setting voltage (V< Voltage Set) | | | | |
| V<1 Voltage Set | 80/320V For 110/440V respectively | 10/40V For 110/440V respectively | 120/480V For 110/440V respectively | 1/4V For 110/440V respectively |
| Sets the pick-up setting for first stage undervoltage element. | | | | |
| V<1 Time Delay | 10s | 0 | 100 | 0.01s |
| Setting for the operating time-delay for the first stage definite time undervoltage element. | | | | |
| V<1 TMS | 1 | 0.5 | 100 | 0.5 |
| Setting for the time multiplier setting to adjust the operating time of the IEC IDMT characteristic. | | | | |
| V<1 Poledead Inh | Enabled | Enabled, Disabled | | N/A |
| If the cell is enabled, the relevant stage will become inhibited by the pole dead logic. This logic produces an output when it detects either an open circuit breaker via auxiliary contacts feeding the relay opto inputs or it detects a combination of both undercurrent and undervoltage on any one phase. It allows the undervoltage protection to reset when the circuit breaker opens to cater for line or bus side VT applications | | | | |
| V<2 Status | Disabled | Enabled, Disabled | | N/A |
| Setting to enable or disable the second stage undervoltage element. | | | | |

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| V<2 Voltage Set | 60/240V<br>For<br>110/440V<br>respectively | 10/40V<br>For<br>110/440V<br>respectively | 120/480V<br>For<br>110/440V<br>respectively | 1/4V<br>For<br>110/440V<br>respectively |
| This setting determines the pick-up setting for second stage undervoltage element. | | | | |
| V<2 Time Delay | 5s | 0 | 100 | 0.01s |
| Setting for the operating time-delay for the second stage definite time undervoltage element. | | | | |
| V<2 Poledead Inh | Enabled | Enabled<br>Disabled | | N/A |
| If the cell is enabled, the relevant stage will become inhibited by the pole dead logic. This logic produces an output when it detects either an open circuit breaker via auxiliary contacts feeding the relay opto inputs or it detects a combination of both undercurrent and undervoltage on any one phase. It allows the undervoltage protection to reset when the circuit breaker opens to cater for line or bus side VT applications | | | | |
| OVERVOLTAGE | Sub-heading | | | |
| V> Measur't. Mode | Phase-Phase | Phase to Phase<br>Phase to Neutral | | N/A |
| Sets the measured input voltage that will be used for the overvoltage elements. | | | | |
| V> Operate Mode | Any Phase | Any Phase<br>Three Phase | | N/A |
| Setting that determines whether any phase or all three phases has to satisfy the overvoltage criteria before a decision is made. | | | | |
| V>1 Function | DT | Disabled<br>DT<br>IDMT | | N/A |
| Tripping characteristic setting for the first stage overvoltage element.<br>The IDMT characteristic available on the first stage is defined by the following formula:<br>t = K / (M - 1)<br>Where:<br>K = Time multiplier setting<br>t = Operating time in seconds<br>M = Measured voltage/relay setting voltage (V<>Voltage Set) | | | | |
| V>1 Voltage Set | 130/520V<br>For<br>110/440V<br>respectively | 60/240V<br>For<br>110/440V<br>respectively | 185/740V<br>For<br>110/440V<br>respectively | 1/4V<br>For<br>110/440V<br>respectively |
| Sets the pick-up setting for first stage overvoltage element. | | | | |
| V>1 Time Delay | 10s | 0 | 100 | 0.01s |
| Setting for the operating time-delay for the first stage definite time overvoltage element. | | | | |
| V>1 TMS | 1 | 0.5 | 100 | 0.5 |
| Setting for the time multiplier setting to adjust the operating time of the IEC IDMT characteristic. | | | | |

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| V>2 Status | Disabled | Enabled, Disabled | | N/A |
| Setting to enable or disable the second stage overvoltage element. | | | | |
| V>2 Voltage Set | 150/600V For 110/440V respectively | 60/240V For 110/440V respectively | 185/740V For 110/440V respectively | 1/4V For 110/440V respectively |
| This setting determines the pick-up setting for the second stage overvoltage element. | | | | |
| V>2 Time Delay | 5s | 0 | 100 | 0.01s |
| Setting for the operating time-delay for the second stage definite time overvoltage element. | | | | |

### 1.2.13 Frequency protection

The Feeder relay includes 4 stages of underfrequency and 2 stages of overfrequency protection to facilitate load shedding and subsequent restoration. The underfrequency stages may be optionally blocked by a pole dead (CB Open) condition.

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| FREQ. PROTECTION GROUP 1 | | | | |
| UNDERFREQUENCY | | | | |
| F<1 Status | Enabled | Enabled or Disabled | | N/A |
| Setting to enable or disable the first stage underfrequency element. | | | | |
| F<1 Setting | 49.5 Hz | 45Hz | 65Hz | 0.01Hz |
| Setting that determines the pick-up threshold for the first stage underfrequency element. | | | | |
| F<1 Time Delay | 4s | 0s | 100s | 0.01s |
| Setting that determines the minimum operating time-delay for the first stage underfrequency element. | | | | |
| F<2 Status (same as stage 1) | Disabled | Enabled or Disabled | | N/A |
| F<3 Status (same as stage 1) | Disabled | Enabled or Disabled | | N/A |
| F<4 Status (same as stage1) | Disabled | Enabled or Disabled | | N/A |
| F< Function Link | 0000 | | | Bit 0 = F<1 Poledead Blk.<br>Bit 1 = F<2 Poledead Blk.<br>Bit 2 = F<3 Poledead Blk.<br>Bit 3 = F<4 Poledead Blk. |
| Settings that determines whether pole dead logic signals blocks the underfrequency elements. | | | | |

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| OVERFREQUENCY | | | | |
| F>1 Status | Enabled | Enabled or Disabled | | N/A |
| Setting to enable or disable the first stage overfrequency element. | | | | |
| F>1 Setting | 50.5 Hz | 45Hz | 65Hz | 0.01Hz |
| Setting that determines the pick-up threshold for the first stage overfrequency element. | | | | |
| F>1 Time Delay | 2s | 0s | 100s | 0.01s |
| Setting that determines the minimum operating time-delay for the first stage overfrequency element. | | | | |
| F>2 Status (same as stage1 above) | Disabled | Enabled or Disabled | | N/A |

ST

### 1.2.14 Independent rate of change of frequency protection

The P145 provides four independent stages of rate of change of frequency protection (df/dt+t). Depending upon whether the rate of change of frequency setting is set positive or negative, the element will react to rising or falling frequency conditions respectively, with an incorrect setting being indicated if the threshold is set to zero.

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| DF/DT PROTECTION GROUP 1 | | | | |
| df/dt Avg. Cycles | 6 | 6 | 12 | 6 |
| This setting is available for calculating the rate of change of frequency measurement over a fixed period of either 6 or 12 cycles. | | | | |
| df/dt>1 Status | Enabled | Enabled or Disabled | | N/A |
| Setting to enable or disable the first stage df/dt element. | | | | |
| df/dt>1 Setting | 2.000 Hz/s | 100.0mHz/s | 10Hz/s | 100mHz/s |
| Pick-up setting for the first stage df/dt element. | | | | |
| df/dt>1 Dir'n. | Positive | Negative/Positive/Both | | N/A |
| This setting determines whether the element will react to rising or falling frequency conditions respectively, with an incorrect setting being indicated if the threshold is set to zero. | | | | |
| df/dt>1 Time | 500.0ms | 0 | 100 | 10ms |
| Minimum operating time-delay setting for the first stage df/dt element. | | | | |
| df/dt>2 Status (same as stage1) | Enabled | Enabled or Disabled | | N/A |
| df/dt>3 Status (same as stage 1) | Enabled | Enabled or Disabled | | N/A |
| df/dt>4 Status (same as stage1) | Enabled | Enabled or Disabled | | N/A |

### 1.2.15 Circuit breaker fail and undercurrent function

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

- Current based protection elements
- Voltage 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. | |
| CB FAIL & I< GROUP 1 | | | | |
| BREAKER FAIL | Sub-heading | | | |
| CB Fail 1 Status | Enabled | Enabled or Disabled | | |
| Setting to enable or disable the first stage of the circuit breaker function. | | | | |
| CB Fail 1 Timer | 0.2s | 0s | 10s | 0.01s |
| Setting for the circuit breaker fail timer stage 1 for which the initiating condition must be valid. | | | | |
| CB Fail 2 Status | Disabled | Enabled or Disabled | | |
| Setting to enable or disable the second stage of the circuit breaker function. | | | | |
| CB Fail 2 Timer | 0.4s | 0s | 10s | 0.01s |
| Setting for the circuit breaker fail timer stage 2 for which the initiating condition must be valid. | | | | |
| Volt Prot. 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 voltage protection function initiated circuit breaker fail conditions. | | | | |
| Ext. Prot. 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 function initiated circuit breaker fail conditions. | | | | |
| UNDERCURRENT | Sub-heading | | | |
| I< Current Set | 0.1In | 0.02In | 3.2In | 0.01In |
| Setting that determines the circuit breaker fail timer reset current for overcurrent based protection circuit breaker fail initiation. | | | | |
| IN< Current Set | 0.1In | 0.02In | 3.2In | 0.01In |
| Setting that determines the circuit breaker fail timer reset current for earth fault current based protection circuit breaker fail initiation. | | | | |
| ISEF< Current | 0.02In | 0.001In | 0.8In | 0.0005In |
| Setting that determines the circuit breaker fail timer reset current for sensitive earth fault current based circuit breaker fail initiation. | | | | |

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| BLOCKED O/C | Sub-heading | | | |
| Remove I> Start | Disabled | Enabled or Disabled | | |
| The setting is used to remove starts issued from the overcurrent elements respectively following a breaker fail time out. The start is removed when the cell is set to enabled. | | | | |
| Remove IN> Start | Disabled | Enabled or Disabled | | |
| This setting is used to remove starts issued from the earth elements following a breaker fail time out. The start is removed when the cell is set to enabled. | | | | |

1.2.16 Supervision (VTS and CTS)

The VTS feature within the relay operates on detection of negative phase sequence (nps) voltage without the presence of negative phase sequence current.

ST

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.

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| SUPERVISION GROUP 1 | | | | |
| VT SUPERVISION | Sub-heading | | | |
| VTS Status | Blocking | Blocking, Indication | | |
| This setting determines whether the following operations will occur upon detection of VTS.<br>- VTS set to provide alarm indication only.<br>- Optional blocking of voltage dependent protection elements.<br>- Optional conversion of directional overcurrent elements to non-directional protection (available when set to blocking mode only). These settings are found in the function links cell of the relevant protection element columns in the menu. | | | | |
| VTS Reset Mode | Manual | Manual, Auto | | |
| The VTS block will be latched after a user settable time delay 'VTS Time Delay'. Once the signal has latched then two methods of resetting are available. The first is manually via the front panel interface (or remote communications) and secondly, when in 'Auto' mode, provided the VTS condition has been removed and the 3 phase voltages have been restored above the phase level detector settings for more than 240ms. | | | | |
| VTS Time Delay | 5s | 1s | 10s | 0.1s |
| Setting that determines the operating time-delay of the element upon detection of a voltage supervision condition. | | | | |
| VTS I> Inhibit | 10In | 0.08In | 32In | 0.01In |
| The setting is used to override a voltage supervision block in the event of a phase fault occurring on the system that could trigger the voltage supervision logic. | | | | |
| VTS I2> Inhibit | 0.05In | 0.05In | 0.5In | 0.01In |
| The setting is used to override a voltage supervision block in the event of a fault occurring on the system with negative sequence current above this setting which could trigger the voltage supervision logic. | | | | |
| CT SUPERVISION | Sub-heading | | | |
| CTS Status | Disabled | Enabled or Disabled | | N/A |
| Setting to enable or disable the current transformer supervision element. | | | | |

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| CTS VN< Inhibit | 5/20V For 110/440V respectively | 0.5/2V For 110/440V respectively | 22/88V For 110/440V respectively | 0.5/2V For 110/440V respectively |
| This setting is used to inhibit the current transformer supervision element should the zero sequence voltage exceed this setting. | | | | |
| CTS IN> Set | 0.1In | 0.08 x In | 4 x In | 0.01 x In |
| This setting determines the level of zero sequence current that must be present for a valid current transformer supervision condition. | | | | |
| CTS Time Delay | 5 | 0s | 10s | 1s |
| Setting that determines the operating time-delay of the element upon detection of a current transformer supervision condition. | | | | |

ST

### 1.2.17 Fault locator

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| FAULT LOCATOR GROUP 1 | | | | |
| Line Length (miles) | 10 | 0.005 | 621 | 0.005 |
| Setting for the line length. Distance to fault is available in metres, miles, impedance or percentage of line length. | | | | |
| Line Impedance | 6 | 0.1 | 250 | 0.01 |
| Setting for the positive sequence line impedance. | | | | |
| Line Angle | 70 | 20 | 85 | 1 |
| Setting for the positive sequence line impedance angle. | | | | |
| KZN Residual | 1 | 0 | 7 | 0.01 |
| Setting for the residual compensating factor. The residual impedance compensation magnitude and angle are calculated using the following formula: $KZn = \frac{ZL0 - ZL1}{3\ ZL1}$ | | | | |
| KZN Res. Angle | 0 | –90 | 90 | 1 |
| Setting for the residual compensating factor angle. | | | | |

ST

### 1.2.18 System checks (check sync. function)

The P145 has a two stage Check Synchronization function that can be set independently.

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| SYSTEM CHECKS GROUP 1 | | | | |
| VOLTAGE MONITORING | Sub-heading | | | |
| Live Voltage | 32V | 1/22V For 110/440V respectively | 132/528V For 110/440V respectively | 0.5/2V For 110/440V respectively |
| Sets the minimum voltage threshold above which a line or bus is to be recognized as being 'Live'. | | | | |
| Dead Voltage | 13V | 1/22V For 110/440V respectively | 132/528V For 110/440V respectively | 0.5/2V |
| Sets the voltage threshold below which a line or bus to be recognized as being 'Dead'. | | | | |
| CHECK SYNC. | Sub-heading | | | |
| Stage 1 | Enabled | Enabled or Disabled | | |
| Setting to enable or disable the first stage check sync. element. | | | | |
| CS1 Phase Angle | 20.00° | 5° | 90° | 1° |
| Sets the maximum phase angle difference between the line and bus voltage for the first stage check sync. element phase angle criteria to be satisfied. | | | | |
| CS1 Slip Control | Frequency | Frequency/Both/Timer/None | | |
| Setting that determines whether slip control is by slip frequency only, frequency + timer or timer only criteria to satisfy the first stage check sync. conditions.<br>If slip control by timer or frequency + timer is selected, the combination of phase angle and timer settings determines an effective maximum slip frequency, calculated as:<br>$\frac{2 \times A}{T \times 360}$ Hz. for Check Sync. 1, or<br>where<br>A = Phase angle setting (°)<br>T = Slip timer setting (seconds)<br>For example, with Check Sync. 1 Phase Angle setting 30° and Timer setting 3.3 sec, the "slipping" vector has to remain within ±30° of the reference vector for at least 3.3 seconds. Therefore a synchro check output will not be given if the slip is greater than 2 x 30° in 3.3 seconds. Using the formula: 2 x 30 ÷ (3.3 x 360) = 0.0505 Hz (50.5 mHz).<br>If Slip Control by Frequency + Timer is selected, for an output to be given, the slip frequency must be less than BOTH the set Slip Freq. value and the value determined by the Phase Angle and Timer settings.<br>If Slip Control by Frequency, for an output to be given, the slip frequency must be less than the set Slip Freq. value setting only. | | | | |

<table>
<tr><th rowspan="2">Menu Text</th><th rowspan="2">Default Setting</th><th colspan="2">Setting Range</th><th rowspan="2">Step Size</th></tr>
<tr><th>Min.</th><th>Max.</th></tr>
<tr><td>CS1 Slip Freq.</td><td>50mHz</td><td>10mHz</td><td>1Hz</td><td>10mHz</td></tr>
<tr><td colspan="5">Sets the maximum frequency difference between the line and bus voltage for the first stage check sync. element slip frequency to be satisfied.</td></tr>
<tr><td>CS1 Slip Timer</td><td>1s</td><td>0s</td><td>99s</td><td>0.01s</td></tr>
<tr><td colspan="5">Minimum operating time-delay setting for the first stage check sync. element.</td></tr>
<tr><td>Stage 2</td><td>Enabled</td><td colspan="3">Enabled or Disabled</td></tr>
<tr><td colspan="5">Setting to enable or disable the second stage check sync. element.</td></tr>
<tr><td>CS2 Phase Angle</td><td>20.00°</td><td>5°</td><td>90°</td><td>1°</td></tr>
<tr><td colspan="5">Sets the maximum phase angle difference between the line and bus voltage for the second stage check sync. element phase angle criteria to be satisfied.</td></tr>
<tr><td>CS2 Slip Control</td><td>Frequency</td><td colspan="3">Frequency/Freq. + Time/Freq. + Comp./ Timer/None</td></tr>
<tr><td colspan="5">Setting that determines whether slip control is by slip frequency only, frequency + timer or timer only criteria to satisfy the CS1 conditions.<br><br>If Slip Control by Timer or Frequency + Timer is selected, the combination of Phase Angle and Timer settings determines an effective maximum slip frequency, calculated as:<br><br>$\frac{A}{T \times 360}$ Hz. for Check Sync. 2, or<br><br>where<br><br>A = Phase angle setting (°)<br>T = Slip timer setting (seconds)<br><br>For Check Sync. 2, with Phase Angle setting 10° and Timer setting 0.1 sec, the slipping vector has to remain within 10° of the reference vector, with the angle decreasing, for 0.1 sec. When the angle passes through zero and starts to increase, the synchro check output is blocked. Therefore an output will not be given if slip is greater than 10° in 0.1 second. Using the formula: 10 ÷ (0.1 x 360) = 0.278 Hz (278 mHz).<br><br>If Slip Control by Frequency + Timer is selected, for an output to be given, the slip frequency must be less than BOTH the set Slip Freq. value and the value determined by the Phase Angle and Timer settings.<br><br>If Slip Control by Frequency, for an output to be given, the slip frequency must be less than the set Slip Freq. value setting only.<br><br>The “Freq. + Comp.” (Frequency + CB Time Compensation) setting modifies the Check Sync. 2 function to take account of the circuit breaker closing time. By measuring the slip frequency, and using the “CB Close Time” setting as a reference, the relay will issue the close command so that the circuit breaker closes at the instant the slip angle is equal to the “CS2 phase angle” setting. Unlike Check Sync. 1, Check Sync. 2 only permits closure for decreasing angles of slip, therefore the circuit breaker should always close within the limits defined by Check Sync. 2.</td></tr>
<tr><td>CS2 Slip Freq.</td><td>50mHz</td><td>10mHz</td><td>1Hz</td><td>10mHz</td></tr>
<tr><td colspan="5">Slip frequency setting for the second stage check sync. element.</td></tr>
<tr><td>CS2 Slip Timer</td><td>1s</td><td>0s</td><td>99s</td><td>0.01s</td></tr>
<tr><td colspan="5">Setting for the second stage Check Sync. slip timer.</td></tr>
</table>

ST

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| CS Undervoltage | 54/216V For 110/440V respectively | 10/40V For 110/440V respectively | 132/528V For 110/440V respectively | 0.5/2V For 110/440V respectively |
| Sets an undervoltage threshold above which the line and bus voltage must be to satisfy the Check Sync. condition if selected in the ‘CS Voltage Block’ cell. | | | | |
| CS Overvoltage | 130/520V For 110/440V respectively | 60/240V For 110/440V respectively | 185/740V For 110/440V respectively | 0.5/2V For 110/440V respectively |
| Sets an overvoltage threshold above below which the line and bus voltage must be to satisfy the Check Sync. condition if selected in the ‘CS Voltage Block’ cell. | | | | |
| CS Diff. Voltage | 6.5/26V For 110/440V respectively | 1/4V For 110/440V respectively | 132/528V For 110/440V respectively | 0.5/2V For 110/440V respectively |
| Sets the voltage magnitude threshold between the line and bus volts below that the line and bus voltage difference must be to satisfy the Check Sync. condition if selected in the ‘CS Voltage Block’ cell. | | | | |
| CS Voltage Block | V< | V< / V> / Vida.> / V< and V> / V< and Vida.> / V> and Vida.> / V< V> and Vida.> / None | | |
| Selects whether an undervoltage, overvoltage and voltage difference thresholds for the line and bus voltages must be satisfied in order for the Check Sync. conditions to be satisfied. | | | | |
| SYSTEM SPLIT | Sub-heading | | | |
| SS Status | Enabled | Enabled or Disabled | | |
| Setting to enable or disable the system split function. | | | | |
| SS Phase Angle | 120° | 90° | 175° | 1° |
| Sets the maximum phase angle difference between the line and bus voltage, which must be exceeded, for the System Split condition to be satisfied. | | | | |
| SS Under V Block | Enabled | Enabled or Disabled | | |
| Activates and undervoltage block criteria | | | | |
| SS Undervoltage | 54/216V For 110/440V respectively | 10/40V For 110/440V respectively | 132/528V For 110/440V respectively | 0.5/2V For 110/440V respectively |
| Sets an undervoltage threshold above which the line and bus voltage must be to satisfy the System Split condition. | | | | |
| SS Timer | 1s | 0s | 99s | 0.01s |
| The System Split output remains set for as long as the System Split criteria are true, or for a minimum period equal to the System Split Timer setting, whichever is longer. | | | | |
| CB Close Time | 50ms | 0s | 0.5s | 1ms |
| Setting for the circuit breaker closing time to be used in the second stage Check Sync. criteria to compensate for the breaker closing time if selected. | | | | |

### 1.2.19 Auto-reclose function

The P145 will initiate auto-reclose for fault clearances by the phase overcurrent, earth fault and SEF protections. It will block auto-reclose for fault clearances by other protections (voltage, frequency, thermal, etc.).

The following shows the relay settings for the auto-reclose function, which must be set in conjunction with the Circuit Breaker Control settings. The available setting ranges and factory defaults are shown:

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| AUTO-RECLOSE GROUP 1 | | | | |
| AR Mode Select | Command Mode | Command Mode/Opto Set Mode/User Set Mode/Pulse Set Mode | | |
| If the Live Line logic input is high, then auto-reclose is taken out of service and certain live-line specific settings applied as appropriate. Provided Live Line is low:<br>COMMAND MODE: Auto/Non-auto is selected by command cell "Auto-reclose Mode".<br>OPTO SET MODE: Selects the Auto-reclose in service or out of service via an opto input linked to the appropriate Auto Mode input signal.<br>USER SET MODE: Selects the mode of the AR via the telecontrol input signal. If Telecontrol input is high, the CB Control Auto-reclose Mode command cell is used to select Auto or Non-auto operating mode. If Telecontrol input is low, behaves as OPTO SET setting (follows the status of the Auto Input signal).<br>PULSE SET MODE: Selects the mode of the AR via the telecontrol input signals. If Telecontrol input is high, the operating mode is toggled between Auto and Non-auto Mode on the falling edge of Auto Mode input pulses. The pulses are produced by SCADA system.<br>If the Telecontrol input is low, behaves as OPTO SET setting setting (follows the status of the Auto Input signal).<br>Note: Auto Mode = AR in service and Non-auto = AR is out of service and instantaneous protection is blocked. | | | | |
| Number of Shots | 1 | 1 | 4 | 1 |
| Sets the number of auto-reclose shots/cycles for overcurrent and earth fault trips. | | | | |
| Number of SEF Shots | 0 | 0 | 4 | 1 |
| Sets the number of auto-reclose shots/cycles for sensitive earth fault trips. | | | | |
| Sequence Co-ord. | Disabled | Enabled/Disabled | | N/A |
| Enables the sequence co-ordination function to ensure the correct protection grading between an upstream and downstream re-closing device. The main protection start or sensitive earth fault protection start signals indicate to the relay when fault current is present, advance the sequence count by one and start the dead time whether the breaker is open or closed. When the dead time is complete and the protection start inputs are off the reclaim timer will be initiated. | | | | |

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| CS AR Immediate | Disabled | Enabled/Disabled | | N/A |
| Setting “CS AR Immediate” Enabled allows immediate re-closure of the circuit breaker provided both sides of the circuit breaker are live and in synchronism at any time after the dead time has started. This allows for quicker load restoration, as it is not necessary to wait for the full dead time.<br>If “CS AR Immediate” is disabled, or Line and Bus volts are not both live, the dead timer will continue to run, assuming the “DDB#457: Dead Time Enabled” (mapped in Programmable Scheme Logic) is asserted high. The “Dead Time Enabled” function could be mapped to an opto input to indicate that the circuit breaker is healthy i.e. spring charged etc. Mapping the “Dead Time Enabled” function in PSL increases the flexibility by allowing it, if necessary, to be triggered by other conditions such as “Live Line/Dead Bus” for example. If “Dead Time Enabled” is not mapped in PSL, it defaults to high, so the dead time can run. | | | | |
| Dead Time 1 | 10s | 0.01s | 300s | 0.01s |
| Sets the dead time for the first auto-reclose cycle. | | | | |
| Dead Time 2 | 60s | 0.01s | 300s | 0.01s |
| Sets the dead time for the second auto-reclose cycle. | | | | |
| Dead Time 3 | 180s | 0.01s | 9999s | 0.01s |
| Sets the dead time for the third auto-reclose cycle. | | | | |
| Dead Time 4 | 180s | 0.01s | 9999s | 0.01s |
| Sets the dead time for the fourth auto-reclose cycle. | | | | |
| CB Healthy Time | 5s | 0.01s | 9999s | 0.01s |
| If on completion of the dead time, the “CB Healthy" input is low, and remains low for a period given by the "CB Healthy Time" timer, lockout will result and the circuit breaker will remain open. | | | | |
| Start Dead t On | Protection Resets | Protection Resets/CB Trips | | N/A |
| Setting that determines whether the dead time is started when the circuit breaker trips or when the protection trip resets. | | | | |
| tReclaim Extend | No Operation | No Operation/On Prot Start | | |
| The setting allows the user to control whether the reclaim timer is suspended by the protection start contacts or not (i.e. whether the relay is permitted to reclaim if a fault condition is present and will be cleared in a long time-scale). When a setting of “No Operation” is used the Reclaim Timer will operate from the instant that the circuit breaker is closed and will continue until the timer expires. For certain applications it is advantageous to set “tReclaim Extend” to “On Prot. Start”. This facility allows the operation of the reclaim timer to be suspended after circuit breaker re-closure by a signal from the main protection start or sensitive earth fault protection start signals. The main protection start signal is initiated from the start of any protection which has been selected to "Initiate Main AR" (initiate auto-reclose) in the "AR Initiation" settings. | | | | |
| Reclaim Time | 180s | 1s | 600s | 0.01s |
| Sets the auto-reclose reclaim timer. | | | | |
| AR Inhibit Time | 5s | 0.01s | 600s | 0.01s |
| With this setting, auto-reclose initiation is inhibited for a period equal to setting “A/R Inhibit Time” following a manual circuit breaker closure. | | | | |
| AR Lockout | No Block | No Block/Block Inst. Prot. | | N/A |
| Instantaneous protection can be blocked when the relay is locked out, using this setting. | | | | |

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| EFF Maint. Lock | No Block | No Block/Block Inst. Prot. | | N/A |
| If this is set to "Block Inst. Prot." the instantaneous protection will be blocked for the last circuit breaker trip before lockout occurs. The instantaneous protection can be blocked to ensure that the last circuit breaker trip before lockout will be due to discriminative protection operation when the circuit breaker maintenance lockout counter or excessive fault frequency lockout has reached its penultimate value. | | | | |
| AR Deselected | No Block | No Block/Block Inst. Prot. | | N/A |
| This setting allows the instantaneous protection to be blocked when auto-reclose is in non-auto mode of operation. | | | | |
| Manual Close | No Block | No Block/Block Inst. Prot. | | N/A |
| This setting allows the instantaneous protection to be blocked when the circuit breaker is closed manually whilst there is no auto-reclose sequence in progress or auto-reclose is inhibited. | | | | |
| Trip 1 Main | No Block | No Block/Block Inst. Prot. | | N/A |
| These allow the instantaneous elements of phase, earth fault protection to be selectively blocked for a circuit breaker trip sequence. For example, if "Trip 1 Main" is set to "No Block" and "Trip 2 Main" is set to "Block Inst. Prot.", the instantaneous elements of the phase and earth fault protection will be available for the first trip but blocked afterwards for the second trip during the auto-reclose cycle. | | | | |
| Trip 2 Main (as above) | Block Inst. Prot. | No Block/Block Inst. Prot. | | N/A |
| Trip 3 Main (as above) | Block Inst. Prot. | No Block/Block Inst. Prot. | | N/A |
| Trip 4 Main (as above) | Block Inst. Prot. | No Block/Block Inst. Prot. | | N/A |
| Trip 5 Main (as above) | Block Inst. Prot. | No Block/Block Inst. Prot. | | N/A |
| Trip 1 SEF (as above) | Block Inst. Prot. | No Block/Block Inst. Prot. | | N/A |
| These allow the instantaneous elements of sensitive earth fault protection to be selectively blocked for a circuit breaker trip sequence. For example, if "Trip 1 SEF" is set to "No Block" and "Trip 2 SEF" is set to "Block Inst. Prot.", the instantaneous elements of the sensitive protection will be available for the first trip but blocked afterwards for the second trip during the auto-reclose cycle. | | | | |
| Trip 2 SEF (as above) | Block Inst. Prot. | No Block/Block Inst. Prot. | | N/A |
| Trip 3 SEF (as above) | Block Inst. Prot. | No Block/Block Inst. Prot. | | N/A |
| Trip 4 SEF (as above) | Block Inst. Prot. | No Block/Block Inst. Prot. | | N/A |
| Trip 5 SEF (as above) | Block Inst. Prot. | No Block/Block Inst. Prot. | | N/A |
| Man Close on Flt | Lockout | No Lockout/Lockout | | N/A |
| An auto-reclose lockout is caused by a protection operation after manual closing during the "AR Inhibit Time" when the "Manual Close on Flt" setting is set to “Lockout”. | | | | |
| Trip AR Inactive | No Lockout | No Lockout/Lockout | | N/A |
| An auto-reclose lockout is caused by a protection operation when the relay is in the Live Line or Non-auto modes when "Trip AR Inactive" is set to "Lockout". | | | | |

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| Reset Lockout by | User interface | User Interface/ Select Non-auto | | N/A |
| The setting is used to enable/disable the resetting of lockout when the relay is in the Non-auto operating mode. | | | | |
| AR on Man Close | Inhibited | Enabled/Inhibited | | N/A |
| If this is set to “Enabled”, auto-reclosing can be initiated immediately on circuit breaker closure, and settings “A/R Inhibit Time”, “Man Close on Flt” and “Manual Close” are irrelevant. | | | | |
| Sys. Check Time | 5 | 0.01 | 9999 | 0.01 |
| AR INITIATION | Sub-heading | | | |
| I>1<br>I>2 | Initiate Main AR | No Action/Initiate Main AR | | N/A |
| Setting that determines if the first and second stage overcurrent initiates auto-reclose. | | | | |
| I>3<br>I>4 | Initiate Main AR | No Action/Initiate Main AR/ Block AR | | N/A |
| Setting that determines if the third and fourth stage overcurrent initiates auto-reclose. | | | | |
| IN1>1<br>IN1>2 | Initiate Main AR | No Action/Initiate Main AR | | N/A |
| Setting that determines if the first and second stage Earth Fault 1 function initiates auto-reclose. | | | | |
| IN1>3<br>IN1>4 | No Action | No Action/Initiate Main AR/ Block AR | | N/A |
| Setting that determines if the third and fourth stage Earth Fault 1 function initiates auto-reclose. | | | | |
| IN2>1<br>IN2>2 | No Action | No Action/Initiate Main AR | | N/A |
| Setting that determines if the first and second stage Earth Fault 2 function initiates auto-reclose. | | | | |
| IN2>3<br>IN2>4 | No Action | No Action/Initiate Main AR/ Block AR | | N/A |
| Setting that determines if the third and fourth stage Earth Fault 2 function initiates auto-reclose. | | | | |
| ISEF>1<br>ISEF>2 | No Action | No Action/Initiate Main AR/ Initiate SEF AR/Block AR | | N/A |
| Setting that determines if the first and second stage sensitive earth fault initiates auto-reclose. | | | | |
| ISEF>3<br>ISEF>4 | No Action | No Action/Initiate Main AR/ Initiate SEF AR/Block AR | | N/A |
| Setting that determines if the third and fourth stage sensitive earth fault initiates auto-reclose. | | | | |
| YN><br>GN><br>BN> | No Action | No Action/Initiate Main AR | | N/A |
| Setting that determines if the admittance protection initiates auto-reclose. | | | | |

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| Ext. Prot. | No Action | No Action/Initiate Main AR | | N/A |
| Setting that determines if external protection inputs initiates auto-reclose. This must be mapped in programmable scheme logic. | | | | |
| SYSTEM CHECKS | | | | |
| AR with Chk. Sync. | Disabled | Enabled or Disabled | | N/A |
| Enables auto-reclose with check synchronization. Only allows auto-reclose when the system satisfies the "Check Sync. Stage 1" settings. | | | | |
| AR with Sys. Sync. | Disabled | Enabled or Disabled | | N/A |
| Enables auto-reclose with check synchronization. Only allows auto-reclose when the system satisfies the "Check Sync. Stage 2" settings | | | | |
| Live/Dead Ccts. | Disabled | Enabled or Disabled | | N/A |
| When enabled, this setting will give an "AR Check Ok" signal when the "DDB#461 Circuits OK" is asserted high. This logic input DDB would normally be mapped in programmable scheme logic to appropriate combinations of Line Live, Line Dead, Bus Live and Bus Dead DDB signals. Auto-reclose can be initiated once DDB#461 is asserted high | | | | |
| No System Checks | Disabled | Enabled or Disabled | | N/A |
| When enabled this setting completely disables system checks thus allowing auto-reclose initiation. | | | | |
| Sys. Chk. on Shot 1 | Enabled | Enabled or Disabled | | N/A |
| Can be used to disable system checks on first auto-reclose shot. | | | | |

### 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 and 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
- 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. | |
| Language | English | | | |
| The default language used by the device. Selectable as English, French, German, Russian, Spanish. | | | | |
| Password | **** | | | |
| Device default password. | | | | |
| Sys. Fn. Links | 0 | | | 1 |
| Setting to allow the fixed function trip LED to be self resetting. | | | | |
| Description | MiCOM P145 | | | |
| 16 character relay description. Can be edited. | | | | |
| Plant Reference | MiCOM | | | |
| Associated plant description and can be edited. | | | | |
| Model Number | P145?11???0310A | | | |
| Relay model number. This display cannot be altered. | | | | |
| Serial Number | 149188B | | | |
| Relay model number. This display cannot be altered. | | | | |
| Frequency | 50 Hz | | | 10Hz |
| Relay set frequency. Settable between 50 and 60Hz | | | | |
| Comms. Level 2 | | | | |
| Displays the conformance of the relay to the Courier Level 2 comms. | | | | |
| Relay Address 1 | | | | |
| Sets the first rear port relay address. | | | | |
| Plant Status | 0000000000000000 | | | |
| Displays the circuit breaker plant status for up to 8 circuit breakers. The P145 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 |
| Supports trip and close commands if enabled in the Circuit Breaker Control menu. | | | | |
| Software Ref. 1 | P145____1__310_A | | | |
| Software Ref. 2 | P145____1__310_A | | | |
| Displays the relay software version including protocol and relay model. Software Ref. 2 is displayed for relay with UCA2.0 protocol only and this will display the software version of the Ethernet card. | | | | |

ST

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| Opto I/P Status | 0000000000000000 | | | |
| Display the status of opto inputs fitted. | | | | |
| Relay O/P Status | 0000001000000000 | | | |
| Displays the status of all output relays fitted. | | | | |
| Alarm Status 1 | 00000000000000000000000000000000 | | | |
| 32 bit field gives status of first 32 alarms. Includes fixed and user settable alarms. | | | | |
| Opto I/P Status | 0000000000000000 | | | |
| Duplicate. Displays the status of opto inputs. | | | | |
| Relay O/P Status | 0000001000000000 | | | |
| Duplicate. Displays the status of output relays. | | | | |
| Alarm Status 1 | 00000000000000000000000000000000 | | | |
| Duplicate of Alarm Status 1 above. | | | | |
| Alarm Status 2 | 00000000000000000000000000000000 | | | |
| Next 32 alarm status defined. | | | | |
| Alarm Status 3 | 00000000000000000000000000000000 | | | |
| Next 32 alarm status defined. Assigned specifically for platform alarms. | | | | |
| Access Level | 2 | | | |
| Displays the current access level.<br>Level 0 - No password required - Read access to all settings, alarms, event records and fault records<br>Level 1 - Password 1 or 2 required - As level 0 plus: Control commands, e.g. circuit breaker open/close<br>Reset of fault and alarm conditions, Reset LEDs Clearing of event and fault records<br>Level 2 - Password 2 required - As level 1 plus: All other settings | | | | |
| 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 | **** | | | |
| Allows user to change password level 1. | | | | |
| Password Level 2 | **** | | | |
| Allows user to change password level 2. | | | | |

### 1.3.2 Circuit breaker control

The relay includes the following options for control of a single circuit breaker:

- Local tripping and closing, via the relay menu or hotkeys
- Local tripping and closing, via relay opto-isolated inputs
- Remote tripping and closing, using the relay communications

ST

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| CB control by | Disabled | Disabled, Local, Remote, Local + Remote, Opto, Opto + local, Opto + Remote, Opto + Remote + local | | |
| This Setting selects the type of circuit breaker control that be used in the logic | | | | |
| Close Pulse Time | 0.5s | 0.01s | 10s | 0.01s |
| Defines the duration of the close pulse. | | | | |
| Trip Pulse Time | 0.5s | 0.01s | 5s | 0.01s |
| Defines the duration of the trip pulse. | | | | |
| Man Close Delay | 10s | 0.01s | 600s | 0.01s |
| This defines the delay time before the close pulse is executed. | | | | |
| CB Healthy Time | 5s | 0.01s | 9999s | 0.01s |
| A settable time delay included for manual closure with this circuit breaker check. If the circuit breaker does not indicate a healthy condition in this time period following a close command then the relay will lockout and alarm. | | | | |
| Check Sync. Time | 5s | 0.01s | 9999s | 0.01s |
| A user settable time delay is included for manual closure with check synchronizing. If the check sync. criteria are not satisfied in this time period following a close command the relay will lockout and alarm. | | | | |
| Lockout Reset | No | No, Yes | | |
| Displays if the Lockout condition has been reset. | | | | |
| Reset Lockout By | CB Close | User Interface, CB Close | | |
| Setting that determines if a lockout condition will be reset by a manual circuit breaker close command or via the user interface. | | | | |
| Man Close RstDly | 5s | 0.01s | 600s | 0.01s |
| The manual close time, time delay, that is used to reset a lockout automatically from a manual close. | | | | |
| Auto-reclose Mode | No Operation | No operation, auto, non-auto (refer to auto-reclose notes for further information) | | |
| Visible if auto-reclose function is enabled. Works in conjunction with the auto-reclose mode selection and allows the auto-reclose to be switched in or out of service. | | | | |
| A/R Status (Indication of current mode only | Auto Mode | Auto mode, non-auto mode, live line (refer to auto-reclose notes for further information) | | |
| Displays the current status of the auto-reclose function. | | | | |
| Total Reclosures | Data | | | |
| Displays the number of successful reclosures. | | | | |
| Reset Total A/R | No | No, Yes | | |
| Allows user to reset the auto-reclose counters. | | | | |
| CB Status Input | None | None, 52A, 52B, Both 52A and 52B | | |
| Setting to define the type of circuit breaker contacts that will be used for the circuit breaker control logic. | | | | |
| 1 Shot Clearance | Data | | | |
| Displays the number of successful first shot fault clearances. | | | | |

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| 2 Shot Clearance | Data | | | |
| Displays the number of successful second shot fault clearances. | | | | |
| 3 Shot Clearance | Data | | | |
| Displays the number of successful third shot fault clearances. | | | | |
| 4 Shot Clearance | Data | | | |
| Displays the number of successful fourth shot fault clearances. | | | | |
| Persistent Fault | Data | | | |
| Displays the number of unsuccessful fault clearances (caused lockout) by the auto-recloser. | | | | |

### 1.3.3 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/Time | Data | | | |
| Displays the relay's current date and time. | | | | |
| IRIG-B Sync. | Disabled | Disabled or Enabled | | |
| Enable IRIG-B time synchronization. | | | | |
| IRIG-B Status | Data | Card not fitted/Card failed/ Signal healthy/No signal | | |
| Displays the status of IRIG-B. | | | | |
| Battery Status | Data | | | |
| Displays whether the battery is healthy or not. | | | | |
| Battery Alarm | Enabled | Disabled or Enabled | | |
| Setting that determines whether an unhealthy relay battery condition is alarmed or not. | | | | |

### 1.3.4 CT/VT ratios

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| Main VT Primary | 110.0 V | 100 | 1000 kV | 1 |
| Sets the main voltage transformer input primary voltage. | | | | |
| Main VT Sec'y | 110.0 V | 80 | 140 | 1 |
| Sets the main voltage transformer input secondary voltage. | | | | |
| C/S VT Primary | 110.0 V | 100 | 1000 kV | 1 |
| Sets the check sync. voltage transformer input primary voltage. | | | | |
| C/S VT Secondary | 110.0 V | 80 | 140 | 1 |
| Sets the check sync. voltage transformer input secondary voltage. | | | | |
| Phase CT Primary | 1.000A | 1 | 30k | 1 |
| Sets the phase current transformer input primary current rating. | | | | |

ST

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| Phase CT Sec'y | 1.000A | 1 | 5 | 4 |
| Sets the phase current transformer input secondary current rating. | | | | |
| E/F CT Primary | 1.000A | 1 | 30k | 1 |
| Sets the earth fault current transformer input primary current rating. | | | | |
| E/F CT Secondary | 1.000A | 1 | 5 | 4 |
| Sets the earth fault current transformer input secondary current rating. | | | | |
| SEF CT Primary | 1.000A | 1 | 30k | 1 |
| Sets the sensitive earth fault current transformer input primary current rating. | | | | |
| SEF CT Secondary | 1.000A | 1 | 5 | 4 |
| Sets the sensitive earth fault current transformer input secondary current rating. | | | | |
| C/S Input | A-N | A-N, B-N, C-N, A-B, B-C, C-A | | N/A |
| Selects the check sync. input voltage measurement . | | | | |
| Main VT Location | Line | Line, Bus | | N/A |
| Selects the main voltage transformer location. | | | | |

ST

### 1.3.5 Record control

It is possible to disable the reporting of events 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 |
|---|---|---|
| Clear Event | 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 Maint. | No | No or Yes |
| Selecting "Yes" will cause the existing maintenance records to be erased from the relay. | | |
| Alarm Event | Enabled | Enabled or Disabled |
| Disabling this setting means that all the occurrences that produce an alarm will result in no event being generated. | | |
| Relay O/P Event | Enabled | Enabled or Disabled |
| Disabling this setting means that no event will be generated for any change in logic input state. | | |
| Opto Input Event | Enabled | Enabled or Disabled |
| Disabling this setting means that no event will be generated for any change in logic input state. | | |
| General Event | Enabled | Enabled or Disabled |
| Disabling this setting means that no General Events will be generated | | |
| Fault Rec. Event | Enabled | Enabled or Disabled |
| Disabling this setting means that no event will be generated for any fault that produces a fault record | | |

| Menu Text | Default Setting | Available Settings |
|---|---|---|
| Maint. Rec. Event | Enabled | Enabled or Disabled |
| Disabling this setting means that no event will be generated for any occurrence that produces a maintenance record. | | |
| Protection Event | Enabled | Enabled or Disabled |
| Disabling this setting means that any operation of protection elements will not be logged as an event. | | |
| DDB 31 - 0 | 11111111111111111111111111111111 | |
| Displays the status of DDB signals 0 – 31. | | |
| DDB 1022 - 992 | 11111111111111111111111111111111 | |
| Displays the status of DDB signals 1022 – 992. | | |

### 1.3.6 Measurements

| Menu Text | Default Settings | Available settings |
|---|---|---|
| MEASUREMENT SETUP | | |
| Default Display | Description | Description/Plant Reference/ Frequency/Access Level/3Ph + N Current/3Ph Voltage/Power/Date and Time |
| This setting can be used to select the default display from a range of options, note that 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 via 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 via 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. | | |
| Measurement Mode | 0 | 0 to 3 step 1 |
| This setting is used to control the signing of the real and reactive power quantities; the signing convention used is defined in the Measurements and Recording section (P145/EN MR) | | |
| Fix Dem. Period | 30 minutes | 1 to 99 minutes step 1 minute |
| This setting defines the length of the fixed demand window. | | |
| Roll Sub Period | 30 minutes | 1 to 99 minutes step 1 minute |
| These two settings are used to set the length of the window used for the calculation of rolling demand quantities. | | |
| Num. Sub Periods | 1 | 1 to 15 step 1 |
| This setting is used to set the resolution of the rolling sub window. | | |

| Menu Text | Default Settings | Available settings |
|---|---|---|
| MEASUREMENT SETUP | | |
| Distance Unit* | km | km/miles |
| This setting is used to select the unit of distance for fault location purposes, note that the length of the line is preserved when converting from km to miles and vice versa. | | |
| Fault Location* | Distance | Distance/Ohms/% of Line |
| The calculated fault location can be displayed using one of several options selected using this setting | | |

### 1.3.7 Communications

The communications settings apply to the rear communications ports only and will depend upon the particular protocol being used. Further details are given in the SCADA communications section (P145/EN SC).

ST

These settings are available in the menu 'Communications' column and are displayed.

#### 1.3.7.1 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 Remote 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 | 15 mins. | 1 mins. | 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 Physical Link | Copper | Copper, Fiber Optic or KBus | | |
| 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 Port Config. | KBus | KBus or EIA(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 | IEC60870 FT1.2 Frame | IEC60870 FT1.2 Frame or 10-Bit No Parity | | |
| The choice is either IEC60870 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. | | | | |

1.3.7.2 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 Inactivity Timer | 15 mins. | 1 mins. | 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 | Copper | Copper 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 IEC60870-5-4 requirements such that byte 1 of the information is transmitted first, followed by bytes 2 through to 7. If 'Reverse' is selected the transmission of information is reversed. | | | | |

1.3.7.3 Communications settings for IEC60870-5-103 protocol

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| COMMUNICATIONS | | | | |
| RP1 Protocol | IEC60870-5-103 | | | |
| Indicates the communications protocol that will be used on the rear communications port. | | | | |
| RP1 Address | 1 | 0 | 247 | 1 |
| This cell sets the unique address for the relay such that only one relay is accessed by master station software. | | | | |
| RP1 Inactivity Timer | 15 mins. | 1 mins. | 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 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. | | | | |

ST

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| RP1 Measure't. Period | 15s | 1s | 60s | 1s |
| This cell controls the time interval that the relay will use between sending measurement data to the master station. | | | | |
| RP1 Physical Link | Copper | Copper 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:<br>Disabled - No blocking selected.<br>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.<br>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. | | | | |

1.3.7.4 Communications settings for DNP3.0 protocol

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| COMMUNICATIONS | | | | |
| RP1 Protocol | DNP 3.0 | | | |
| Indicates the communications protocol that will be used on the rear communications port. | | | | |
| RP1 Address | 3 | 0 | 65519 | 1 |
| This cell sets the unique address for the relay such that only one relay is accessed by master station software. | | | | |
| RP1 Baud Rate | 19200 bits/s | 1200 bits/s, 2400 bits/s, 4800 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 | Copper | Copper 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 'Fibre Optic' is selected, the optional fiber optic communications board will be required. | | | | |
| RP1 Time Sync. | Disabled | Disabled or Enabled | | |
| If set to 'Enabled' the DNP3.0 master station can be used to sychronize the time on the relay. If set to 'Disabled' either the internal free running clock, or IRIG-B input are used. | | | | |

### 1.3.7.5 UCA2.0 connection settings

The settings shown are those configurable to allow the UCA2.0 interface to operate.

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| COMMUNICATIONS | | | | |
| IP Address* | 000.000.000.000 | 000.000.000.000 to 255.255.255.255 | | |
| Unique network IP address that identifies the relay. | | | | |
| Subnet Mask* | 000.000.000.000 | 000.000.000.000 to 255.255.255.255 | | |
| Identifies the sub-network that the relay is connected to. | | | | |
| Number of Routes | 0 | 0 | 4 | 1 |
| The number of routers/target networks that the relay will recognize. | | | | |
| Router Address 1* | 000.000.000.000 | 000.000.000.000 to 255.255.255.255 | | |
| Address of a router on the same network as the relay. | | | | |
| Target Network 1* | 000.000.000.000 | 000.000.000.000 to 255.255.255.255 | | |
| Address of the network that router1 will connect. If IP address 000.000.000.000, the above router acts as the default router. | | | | |
| Router Address 2* | 000.000.000.000 | 000.000.000.000 to 255.255.255.255 | | |
| As Router Address 1. | | | | |
| Target Network 2* | 000.000.000.000 | 000.000.000.000 to 255.255.255.255 | | |
| As Target Network 1. | | | | |
| Router Address 3* | 000.000.000.000 | 000.000.000.000 to 255.255.255.255 | | |
| As Router Address 1. | | | | |
| Target Network 3* | 000.000.000.000 | 000.000.000.000 to 255.255.255.255 | | |
| As Target Network 1. | | | | |
| Router Address 4* | 000.000.000.000 | 000.000.000.000 to 255.255.255.255 | | |
| As Router Address 1. | | | | |
| Target Network 4* | 000.000.000.000 | 000.000.000.000 to 255.255.255.255 | | |
| As Target Network 1. | | | | |
| NIC Inactivity Timer | 15 | 1 | 30 | 1 |
| Minutes of inactivity before the relay releases a client's database lock. | | | | |
| Default Pass Lvl. | 2 | 0 | 2 | 1 |
| Default password level assigned to new client connections. The connected client can change password level at any time. | | | | |
| Goose Min. Cycle | 1 | 1msec. | 60msec. | 1 |
| The minimum cycle time is the time between the first event driven message being transmitted and the first retransmission. GOMFSE states that the minimum retransmission time will be in the order of 10ms. | | | | |
| Goose Max. Cycle | 1 | sec. | 60sec. | 1 |
| The maximum cycle time is the maximum time between message retransmissions. | | | | |
| Goose Increment | 900 | 0 | 999 | 1 |
| The Increment determines the rate at which the message 'steps-up' from min. cycle time to max. cycle time. | | | | |

ST

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| Goose Startup | Promiscuous | Promiscuous or Startup | | |
| When a MiCOM relay switches on, the UCA2.0 GOOSE processes will be initiated and two modes of Goose startup is supported:<br>Promiscuous - The Ethernet hardware will be set into a promiscuous mode of operation, whereby it will receive all Ethernet messages regardless of their target address. When in promiscuous mode, unwanted messages will be filtered by examining the destination MAC address. It will accept messages under the following conditions:<br>- Those addressed to the relay<br>- All multicast messages<br>- All broadcast messages<br>Startup - The starting relay will broadcast (rather than multicast) a set of messages as soon as the DNA and user status bit-pairs are in a valid state. Other MiCOM devices on the network will recognize this broadcast message. If subscribed to the starting device, its MAC address is recorded and a message is transmitted back to the device (addressed not broadcast or multicast). This allows the starting device to configure its own GOOSE management. If the starting relay has subscribed to the received message, the transmitting device's MAC address is (enrolled). This broadcast mechanism allows the starting device to construct a list of transmitting devices (from the returned messages), and allows other devices on the network to enroll the starting device. This approach achieves a known scheme state in a faster time when compared to the promiscuous start-up. | | | | |
| Ethernet Media* | Copper | Copper or Fiber | | |
| This cell defines whether a copper or fiber optic Ethernet connection is being used for communication between the master station and relay. | | | | |
| IED View Select | 0 | 0 | 32 | 1 |
| Selects one of the enrolled IEDs whose GOOSE statistics are to be displayed. | | | | |
| IED Stats. Reset | None | None, Enrolled + Local IED or Enrolled IED | | |
| Resets the GOOSE statistics for the select enrolled IED. | | | | |
| Report Link Test | Alarm | | | |
| Configures how a failed/unfitted network link (copper or fiber) is reported:<br>Alarm - an alarm is raised for a failed link<br>Event - an event is logged for a failed link<br>None - nothing reported for a failed link | | | | |
| Link Time-Out | 60s | 0.1 | 60 | 0.1 |
| Duration of time waited before a failed network link is reported. | | | | |

Note: * Changing Ethernet Media setting forces all client connections to close and the Ethernet card to reboot.

ST

### 1.3.7.6 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 rear communications port. | | | | |
| RP2 Port Config. | RS232 | EIA(RS)232, EIA(RS)485 or KBus | | |
| This cell defines whether an electrical EIA(RS)232, EIA(RS)485 or KBus is being used for communication. | | | | |
| RP2 Comms. Mode | IEC60870 FT1.2 Frame | IEC60870 FT1.2 Frame or 10-Bit No Parity | | |
| The choice is either IEC60870 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 Inactivity Timer | 15 mins. | 1 mins. | 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. | | | | |

### 1.3.8 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, user-programmable LEDs and, where available, the auto-reclose cycles.

| 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 | 0000000000000000 | |
| This menu cell displays the status of the digital data bus (DDB) signals that result in energization of the output relays as a binary string, a '1' indicating an operated state and '0' a non-operated state.<br><br>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 hence 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. | | |

ST

| Menu Text | Default Setting | Available Settings |
|---|---|---|
| Monitor Bit 1 | 64 (LED 1) | 0 to 511<br>See PSL section for details of digital data bus signals |
| 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. | | |
| Monitor Bit 8 | 71 (LED 8) | 0 to 511 |
| 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. | | |
| 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 operation of output contacts and 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 Circuit Breaker Condition column and in IEC60870-5-103 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<br>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.<br>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 hence 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<br>Apply Test |
| When the 'Apply Test' command in this cell is issued the eighteen user-programmable LEDs will illuminate for approximately 2 seconds before they extinguish and the command text on the LCD reverts to 'No Operation'. | | |

ST

| Menu Text | Default Setting | Available Settings |
|---|---|---|
| Test Auto-reclose | No Operation | No Operation<br>3 Pole Test |
| Where the relay provides an auto-reclose function, this cell will be available for testing the sequence of circuit breaker trip and auto-reclose cycles with the settings applied.<br><br>Issuing the command ‘3 Pole Trip’ will cause the relay to perform the first three phase trip/re-close cycle so that associated output contacts can be checked for operation at the correct times during the cycle. Once the trip output has operated the command text will revert to ‘No Operation’ whilst the rest of the auto-reclose cycle is performed. To test subsequent three phase auto-reclose cycles repeat the ‘3 Pole Trip’ command.<br><br>Note: The factory settings for the relay’s programmable scheme logic has the ‘AR Trip Test’ signal mapped to relay 3. If the programmable scheme logic has been changed, it is essential that this signal remains mapped to relay 3 for the ‘Test Auto-reclose’ facility to work. | | |
| Red LED Status | 000000000000000000 | |
| This cell is an eighteen 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. | | |
| Green LED Status | 000000000000000000 | |
| This cell is an eighteen 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. | | |
| DDB 31 - 0 | 00000000000000000000001000000000 | |
| Displays the status of DDB signals 0-31. | | |
| DDB 1022 - 992 | 00000000000000000000000000000000 | |
| Displays the status of DDB signals 1022 – 992. | | |

1.3.9 Circuit breaker condition monitor setup

The following table, detailing the options available for the Circuit Breaker condition monitoring, is taken from the relay menu. It includes the setup of the current broken facility and those features that can be set to raise an alarm or Circuit Breaker lockout.

| 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 | | |
| Setting which determines if an alarm will be raised or not when the cumulative I^ maintenance counter threshold is exceeded. | | | | |
| I^ Maintenance | 1000In^ | 1In^ | 25000In^ | 1In^ |
| Setting that determines the threshold for the cumulative I^ maintenance counter monitors. | | | | |
| I^ Lockout | Alarm Disabled | Alarm Disabled, Alarm Enabled | | |
| Setting which determines if an alarm will be raised or not when the cumulative I^lockout counter threshold is exceeded. | | | | |

ST

ST

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| I^ Lockout | 2000In^ | 1In^ | 25000In^ | 1In^ |
| Setting that determines the threshold for the cumulative I^ lockout counter monitor. Set that should maintenance not be carried out, the relay can be set to lockout the auto-reclose function on reaching a second operations threshold. | | | | |
| No CB Ops. Maint. | Alarm Disabled | Alarm Disabled, Alarm Enabled | | |
| Setting to activate the number of circuit breaker operations maintenance alarm. | | | | |
| No CB Ops. Maint. | 10 | 1 | 10000 | 1 |
| Sets the threshold for number of circuit breaker operations maintenance alarm, indicating when preventative maintenance is due. | | | | |
| No CB Ops. Lock | Alarm Disabled | Alarm Disabled, Alarm Enabled | | |
| Setting to activate the number of circuit breaker operations lockout alarm. | | | | |
| No CB Ops. Lock | 20 | 1 | 10000 | 1 |
| Sets the threshold for number of circuit breaker operations lockout. The relay can be set to lockout the auto-reclose function on reaching a second operations threshold. | | | | |
| CB Time Maint. | Alarm Disabled | Alarm Disabled, Alarm Enabled | | |
| Setting to activate the circuit breaker operating time maintenance alarm. | | | | |
| CB Time Maint. | 0.1s | 0.005s | 0.5s | 0.001s |
| Setting for the circuit operating time threshold which is set in relation to the specified interrupting time of the circuit breaker. | | | | |
| CB Time Lockout | Alarm Disabled | Alarm Disabled, Alarm Enabled | | |
| Setting to activate the circuit breaker operating time lockout alarm. | | | | |
| CB Time Lockout | 0.2s | 0.005s | 0.5s | 0.001s |
| Setting for the circuit breaker operating time threshold which is set in relation to the specified interrupting time of the circuit breaker. The relay can be set to lockout the auto-reclose function on reaching a second operations threshold. | | | | |
| Fault Freq. Lock | Alarm Disabled | Alarm Disabled, Alarm Enabled | | |
| Enables the fault frequency counter alarm. | | | | |
| Fault Freq. Count | 10 | 1 | 9999 | 1 |
| Sets a circuit breaker frequent operations counter that monitors the number of operations over a set time period. | | | | |
| Fault Freq. Time | 3600s | 0 | 9999s | 1s |
| Sets the time period over which the circuit breaker frequent operations are to be monitored. | | | | |

### 1.3.10 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 - 32 | 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. | 111111111111111 | | | |
| Selects each input with a pre-set filter of ½ cycle that renders the input immune to induced noise on the wiring. | | | | |
| 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. | | | | |

### 1.3.11 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 10ms 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. | | | |

ST

| Menu Text | Default Setting | Setting Range | Step Size |
|---|---|---|---|
| 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. | | | |

### 1.3.12 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 Status | Unlock/Enable | Disable, Lock, Unlock/Enable | | |
| Setting to activate function key. The ‘Lock’ setting allows a function key output that is set to toggle mode to be locked in its current active state. | | | | |
| Fn. Key 1 Mode | Toggle | Toggle, Normal | | |
| Sets the function key in toggle or normal mode. In ‘Toggle’ mode, a single key press will set/latch the function key output as ‘high’ or ‘low’ in programmable scheme logic. This feature can be used to enable/disable relay functions. In the ‘Normal’ mode the function key output will remain ‘high’ as long as 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 | Unlock/Enable | Disable, Lock, Unlock/Enable | | |
| Setting to activate function key. The ‘Lock’ 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 | Toggle | Toggle, Normal | | |
| Sets the function key in toggle or normal mode. In ‘Toggle’ mode, a single key press will set/latch the function key output as ‘high’ or ‘low’ in programmable scheme logic. This feature can be used to enable/disable relay functions. In the ‘Normal’ mode the function key output will remain ‘high’ as long as 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. | | | | |

### 1.3.13 Control input labels

| Menu Text | Default Setting | Setting Range | Step Size |
|---|---|---|---|
| CTRL I/P LABELS | | | |
| Control Input 1 | Control Input 1 | 16 Character Text | |
| Setting to change the text associated with each individual control input. This text will be displayed when a control input is accessed by the hotkey menu, or it can be displayed in the programmable scheme logic. | | | |
| Control Input 2 to 32 | Control Input 2 to 32 | 16 Character Text | |
| Setting to change the text associated with each individual control input. This text will be displayed when a control input is accessed by the hotkey menu, or it can be displayed in the programmable scheme logic. | | | |

## 1.4 Disturbance recorder settings

ST

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.

The "DISTURBANCE RECORDER" menu column is shown in the following table:

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| DISTURB. RECORDER | | | | |
| Duration | 1.5s | 0.1s | 10.5s | 0.01s |
| This sets the overall recording time. | | | | |
| Trigger Position | 33.3% | 0 | 100% | 0.1% |
| This sets the trigger point as a percentage of the duration. For example, the default settings show that the overall recording time is set to 1.5s with the trigger point being at 33.3% of this, giving 0.5s pre-fault and 1s post fault recording times. | | | | |
| 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 | VA | VA, VB, VC, VCHECKSYNC., IA, IB, IC, IN, IN Sensitive | | |
| Selects any available analog input to be assigned to this channel. | | | | |
| Analog. Channel 2 | VB | As above | | |
| Analog. Channel 3 | VC | 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 Sensitive | As above | | |
| Digital Inputs 1 to 32 | Relays 1 to 12 and Opto's 1 to 12 | Any of 12 O/P Contacts or Any of 12 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. | | | | |

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| Inputs 1 to 32 Trigger | No Trigger except Dedicated Trip Relay O/P's which are set to Trigger L/H | No Trigger, Trigger L/H, Trigger H/L | | |
| 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. | | | | |

# OPERATION

| | |
|---|---|
| **Date:** | **7th July 2005** |
| **Hardware Suffix:** | **J** |
| **Software Version:** | **31** |
| **Connection Diagrams:** | **10P145xx (xx = 01 to 07)** |

# CONTENTS



OP

OP

OP

# FIGURES

# 1. OPERATION OF INDIVIDUAL PROTECTION FUNCTIONS

The following sections detail the individual protection functions.

## 1.1 Overcurrent protection

The overcurrent protection included in the P145 relays provides four-stage non-directional/ directional three-phase overcurrent protection with independent time delay characteristics. All overcurrent and directional 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), or definite time (DT). The third and fourth stages have definite time characteristics only.

Various methods are available to achieve correct relay co-ordination on a system; by means of time alone, current alone or a combination of both time and current. Grading by means of current is only possible where there is an appreciable difference in fault level between the two 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 co-ordinating overcurrent relays is the IDMT type.

The inverse time delayed characteristics indicated above, comply with the following formula:

IEC curves

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

or

IEEE curves

$$t = TD \times \left( \frac{\beta}{(M^{\alpha} - 1)} + L \right)$$

where:

t = Operation time

$\beta$ = Constant

M = I/Is

K = Constant

I = Measured current

Is = Current threshold setting

$\alpha$ = Constant

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

T = Time multiplier setting for IEC curves

TD = Time dial setting for IEEE curves

OP

| 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 |



Note that 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. The menu is arranged such that if an IEC/UK curve is selected, the "I> Time Dial" cell is not visible and vice versa for the TMS setting.

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

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

where:

TD = Time dial setting for IEEE curves

S = Constant

M = I/Is

| Curve Description | Standard | S 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 |

### 1.1.1 RI curve

The RI curve (electromechanical) has been included in the first and second stage characteristic setting options for phase overcurrent and both earth fault 1 and earth fault 2 protections. The curve is represented by the following equation.

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

With K adjustable from 0.1 to 10 in steps of 0.05

### 1.1.2 Timer hold facility

The first two stages of overcurrent protection in the P145 relay are provided with a timer hold facility, which may either be set to zero or to a definite time value. Setting of the timer to zero means that the overcurrent timer for that stage will 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. When the reset time of the overcurrent relay is instantaneous, the relay will be repeatedly reset and not be able to trip until the fault becomes permanent. By using the Timer Hold facility the relay will integrate the fault current pulses, thereby reducing fault clearance time.

The timer hold facility can be found for the first and second overcurrent stages as settings "I>1 tRESET" and "I>2 tRESET", respectively. Note that 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 below. The overcurrent block is a level detector that detects that the current magnitude is above the threshold. It provides a start and also initiates the IDMT/DT characteristic depending on the setting.

OP

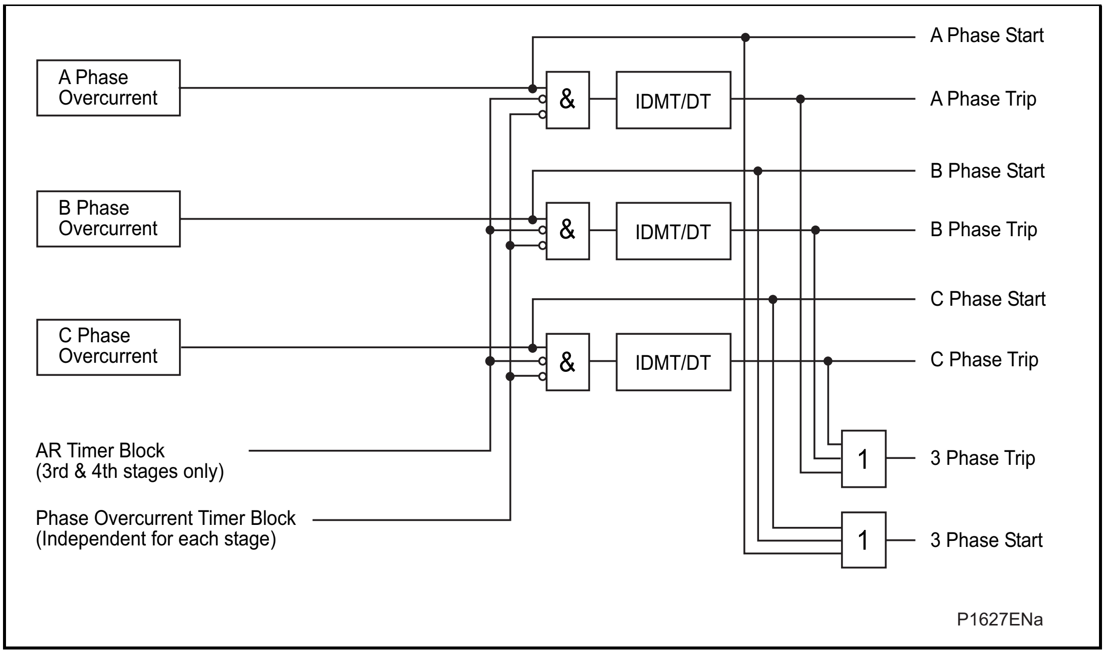



**Figure 1: Non-directional overcurrent logic diagram**

A timer block input is available for each stage which will reset 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.

The auto-reclose logic (A/R Block) can be set to block instantaneous overcurrent elements after a prescribed number of shots. This is set in the auto-reclose column. When a block instantaneous signal is generated then only those overcurrent stages i.e. “I>3” and “I>4” selected to '1' in the “I> Blocking” link will be blocked.

## 1.2 Directional overcurrent protection

The phase fault elements of the P145 relays are internally polarized by the quadrature phase-phase voltages, as shown in the table below:

| Phase of Protection | Operate Current | Polarizing Voltage |
|---|---|---|
| A Phase | IA | VBC |
| B Phase | IB | VCA |
| C Phase | IC | VAB |

Under system fault conditions, the fault current vector will lag its nominal phase voltage by an angle dependent upon the system X/R ratio. It is therefore a requirement that the relay operates with maximum sensitivity for currents lying in this region. This is achieved by means of the relay characteristic angle (RCA) setting; this defines the angle by which the current applied to the relay must be displaced from the voltage applied to the relay to obtain maximum relay sensitivity. This is set in cell "I>Char Angle" in the overcurrent menu. On the P145 relays, it is possible to set characteristic angles anywhere in the range –95° to +95°.

The functional logic block diagram for directional overcurrent is shown below.

The overcurrent block is a level detector that detects that the current magnitude is above the threshold and together with the respective polarizing voltage, a directional check is performed based on the following criteria:

**Directional forward**

-90° < (angle(I) - angle(V) - RCA) < 90°

**Directional reverse**

-90° > (angle(I) - angle(V) - RCA) > 90°

OP

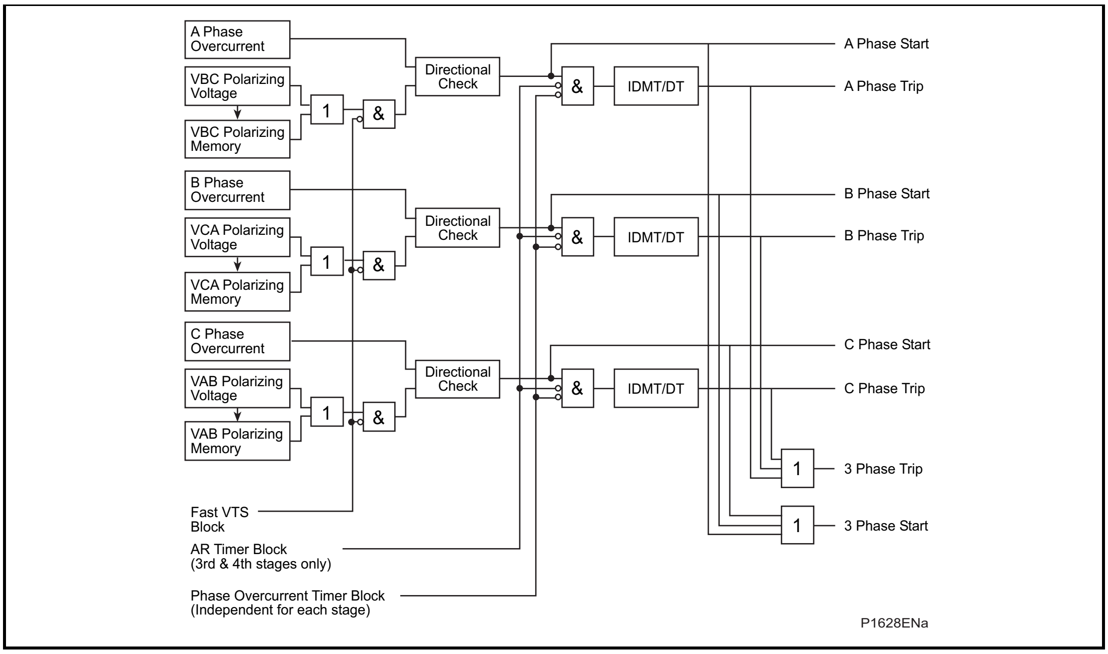



**Figure 2: Directional overcurrent logic**

Any of the four overcurrent stages may be configured to be directional noting that IDMT characteristics are only selectable on the first two stages. When the element is selected as directional, a VTS Block option is available. When the relevant bit is set to 1, operation of the Voltage Transformer Supervision (VTS), will block the stage if directionalized. When set to 0, the stage will revert to non-directional upon operation of the VTS.

### 1.2.1 Synchronous polarization

For a close up three-phase fault, all three voltages will collapse to zero and no healthy phase voltages will be present. For this reason, the P145 relays include a synchronous polarization feature that stores the pre-fault voltage information and continues to apply it to the directional overcurrent elements for a time period of 3.2 seconds. This ensures that either instantaneous or time delayed directional overcurrent elements will be allowed to operate, even with a three-phase voltage collapse.

## 1.3 Thermal overload protection

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

The heat generated within an item of plant, such as a cable or a transformer, is the resistive loss ($I^2R$ x t). Thus, heating is directly proportional to current squared. The thermal time characteristic used in the relay is therefore based on current squared, integrated over time. The relay automatically uses the largest phase current for input to the thermal model.

Equipment is designed to operate continuously at a temperature corresponding to its full load rating, where heat generated is balanced with heat dissipated by radiation etc.
Over-temperature conditions therefore occur when currents in excess of rating are allowed to flow for a period of time. It can be shown that temperatures during heating follow exponential time constants and a similar exponential decrease of temperature occurs during cooling.

The relay provides two characteristics that may be selected according to the application.

### 1.3.1 Single time constant characteristic

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

The thermal time characteristic is given by:

$$t = -\tau \log_e \left( \frac{I^2 - (K.I_{FLC})^2}{(I^2 - Ip^2)} \right)$$

Where:

$t$ = Time to trip, following application of the overload current, $I$;

$\tau$ = Heating and cooling time constant of the protected plant;

$I$ = Largest phase current;

$I_{FLC}$ = Full load current rating (relay setting ‘Thermal Trip’);

k = 1.05 constant, allows continuous operation up to <1.05 $I_{FLC}$;

$I_P$ = Steady state pre-loading before application of the overload.

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

The thermal time constant characteristic may be rewritten as:

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

Where:

$\theta = I^2/k^2 I_{FLC}^2$

and

$\theta p = Ip^2/k^2 I_{FLC}^2$

where $\theta$ is the thermal state and is $\theta_p$ the pre-fault thermal state.

> Note: A current of 105%Is ($kI_{FLC}$) has to be applied for several time constants to cause a thermal state measurement of 100%

### 1.3.2 Dual time constant characteristic

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

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

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

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

The thermal curve is defined as:

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



Where:

$\tau 1$ = Heating and cooling time constant of the transformer windings;

$\tau_2$ = Heating and cooling time constant for the insulating oil.

In practice, it is difficult to solve this equation to give the operating time (t), therefore a graphical solution, using a spreadsheet package, is recommended. The spreadsheet can be arranged to calculate the current that will give a chosen operating time. The equation to calculate the current is defined as:

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

Figure 3 shows how this equation can be used within a spreadsheet to calculate the relay operating time.

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| 1 | | | | | | |
| 2 | **Time constant 1 =** | | **300** | seconds | | |
| 3 | **Time constant 2 =** | | **7200** | seconds | | |
| 4 | **Pre-overload current Ip =** | | **0.9** | per unit | | |
| 5 | **Full load current =** | | **1** | Amps | | |
| 6 | | | | | Figures based | |
| 7 | **OP Time (t)** | **Overload current (I)** | | | upon Equation 1 | |
| 8 | 1 | 14.40852032 | | | | |
| 9 | 1.5 | 11.7805774 | | | | |
| 10 | 2 | 10.21617905 | | | | |
| 11 | 2.5 | 9.150045407 | | | | |
| 12 | 3 | 8.364131776 | | | | |
| 13 | 3.5 | 7.754150044 | | | | |
| 14 | 4 | 7.263123888 | | | | |
| 15 | 4.5 | 6.856949012 | | | | |

P2240ENa

**Figure 3: Spreadsheet calculation for dual time constant thermal characteristic**

The results from the spreadsheet can be plotted in a graph of current against time as shown in Figure 4.

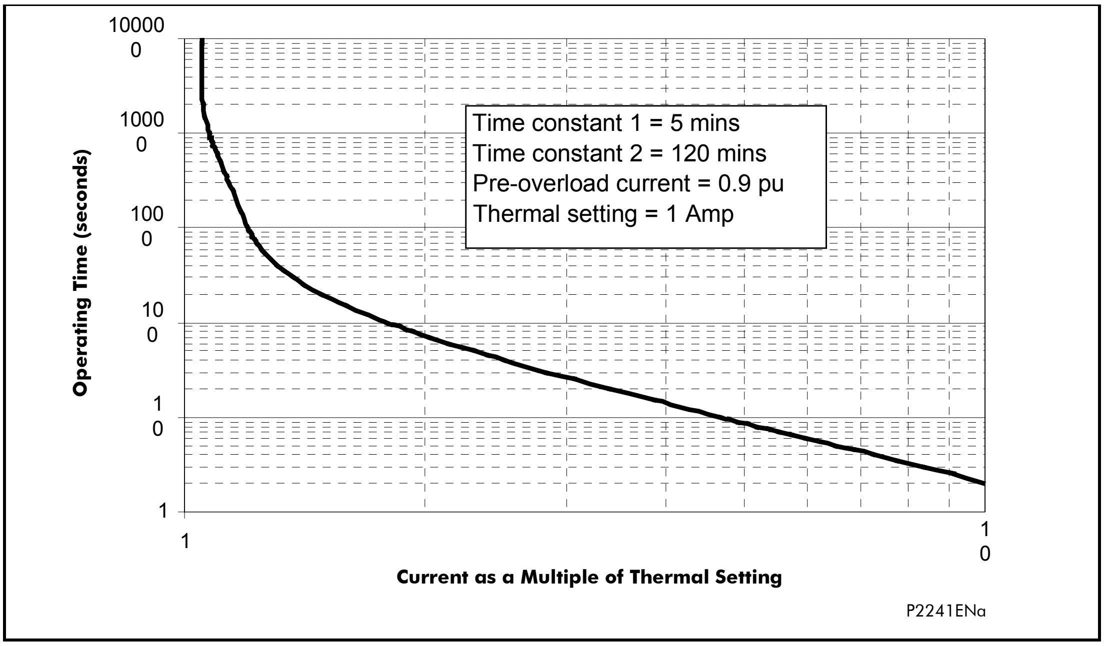



**Figure 4: Dual time constant thermal characteristic**

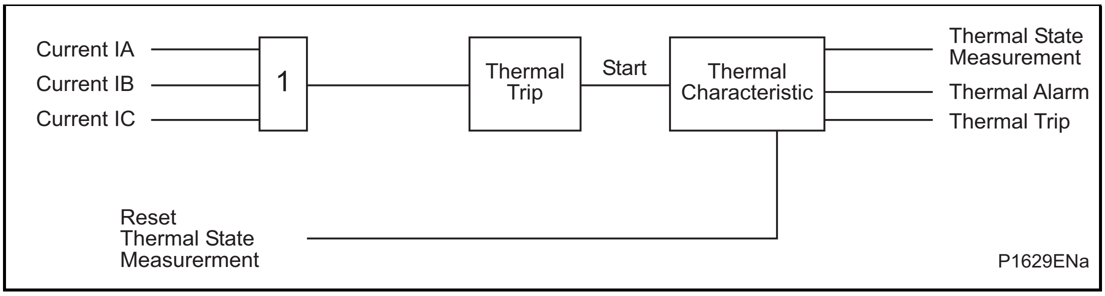



**Figure 5: Thermal overload protection logic diagram**

The functional block diagram for the thermal overload protection is shown in Figure 5.

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

The thermal protection also provides an indication of the thermal state in the 'MEASUREMENTS 3' column of the relay. The thermal state can be reset by either an opto input (if assigned to this function using the programmable scheme logic) or the relay menu. The reset function in the menu is also found in the 'MEASUREMENTS 3' column with the thermal state.

## 1.4 Earth fault protection

The P145 relays have a total of five input current transformers; one for each of the phase current inputs and two for supplying the earth fault protection elements. With this flexible input arrangement, various combinations of standard, sensitive (SEF) and restricted earth fault (REF) protection may be configured within the relay.

It should be noted that in order to achieve the sensitive setting range that is available in the P145 relays for SEF protection, the input CT is designed specifically to operate at low current magnitudes. This input is common to both the SEF and high impedance REF protection, so these features are treated as mutually exclusive within the relay menu.

### 1.4.1 Standard earth fault protection elements

**The standard earth fault protection elements are duplicated within the P145 relays and are referred to in the relay menu as "Earth Fault 1" (EF1) and "Earth Fault 2" (EF2). EF1 operates from earth fault current which is measured directly from the system; either by means of a separate CT located in a power system earth connection or via a residual connection of the three line CTs. The EF2 element operates from a residual current quantity which is derived internally from the summation of the three-phase currents.**

EF1 and EF2 are identical elements, each having four stages. The first and second stages have selectable IDMT or DT characteristics, whilst the third and fourth stages are DT only. Each stage is selectable to be either non-directional, directional forward or directional reverse. The Timer Hold facility, previously described for the overcurrent elements, is available on each of the first two stages.

The logic diagram for non-directional earth fault overcurrent is shown in Figure 6.

OP

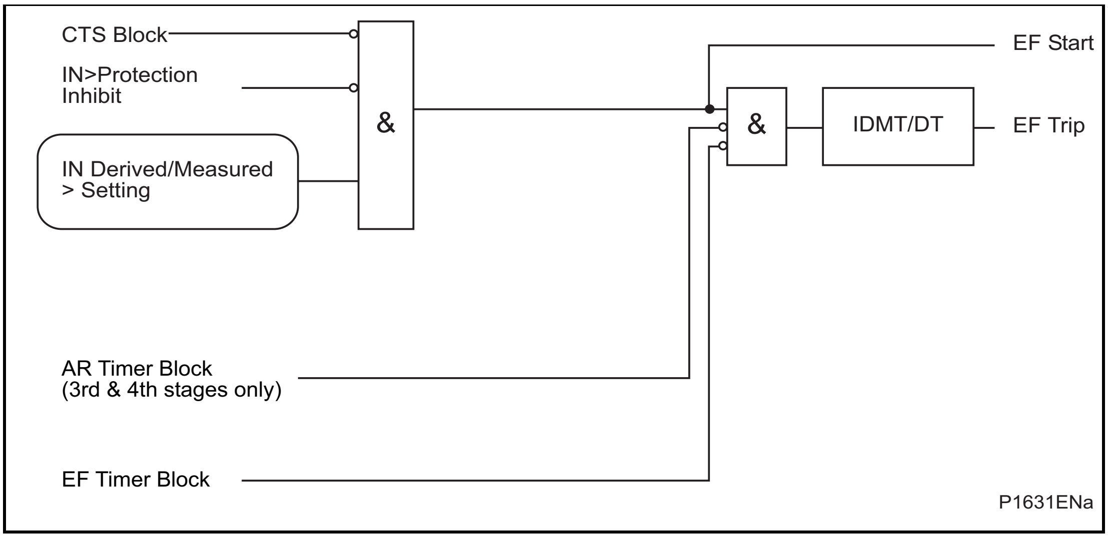



**Figure 6: Non-directional EF logic (single stage)**

The earth fault protection can be set IN/OUT of service using the appropriate DDB inhibit signal that can be operated from an opto input or control command.

The auto-reclose logic (A/R Block) can be set to block instantaneous earth fault elements after a prescribed number of shots. This is set in the auto-reclose column. When a block instantaneous signal is generated then only those earth fault stages selected to '1' in the "IN1> Function" or "IN2> Function" link will be blocked.

For inverse time delayed characteristics refer to the phase overcurrent elements, section 1.1.

#### 1.4.1.1 IDG curve

The IDG curve is commonly used for time delayed earth fault protection in the Swedish market. This curve is available in stages 1 and 2 of Earth Fault 1, Earth Fault 2 and Sensitive Earth Fault protections.

The IDG curve is represented by the following equation:

$$t = 5.8 - 1.35 \log_e \left( \frac{I}{IN > Setting} \right) \text{ in seconds}$$

Where:

I = Measured current

IN>Setting = An adjustable setting which defines the start point of the characteristic

Although the start point of the characteristic is defined by the “IN>” setting, the actual relay current threshold is a different setting called “IDG Is”. The “IDG Is” setting is set as a multiple of “IN>”.

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

Figure 7 – illustrates how the IDG characteristic is implemented.

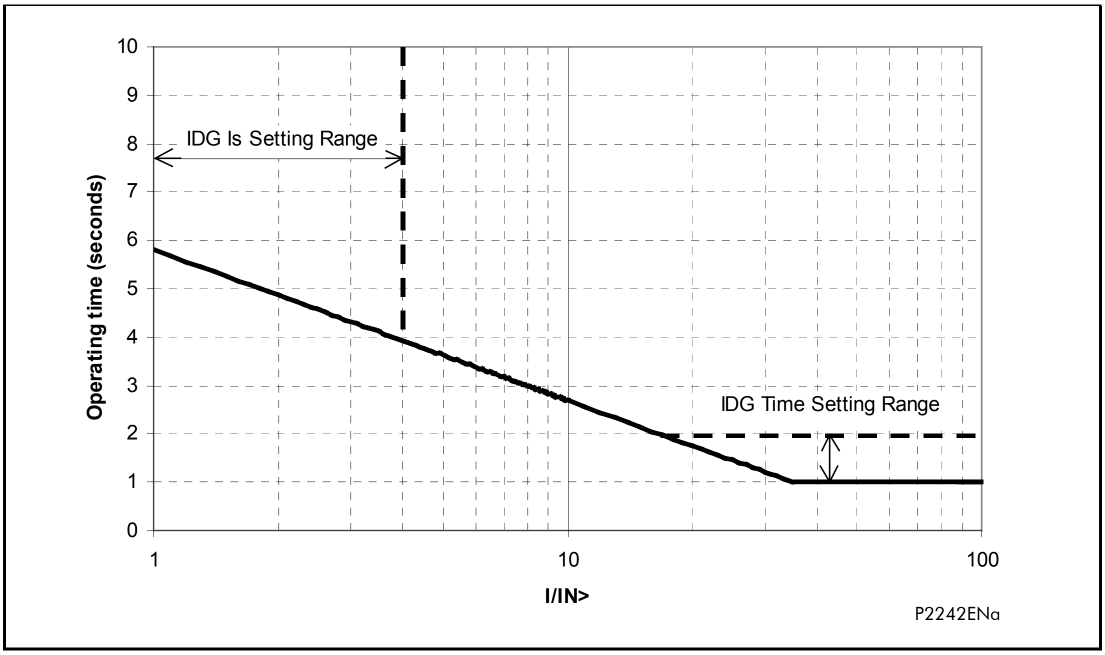



**Figure 7: IDG characteristic**

1.4.2 Sensitive earth fault protection element (SEF)

A separate four-stage sensitive earth fault element is provided within the P145 relay for this purpose, which has a dedicated input. The functionality of the SEF is the same as that illustrated in Figure 6 for EF1/2, bearing in mind that a separate input is used. The SEF protection can be set IN/OUT of service using the DDB 442 ‘Inhibit SEF’ input signal that can be operated from an opto input or control command. This DDB signal blocks the starts and trips of all four stages of SEF protection. DDBs 216 - 219 ‘ISEF>1/2/3/4 Timer Blk.’ can be used to block the four trip stages of SEF protection individually, however, these signals do not block the starts.

For the range of available inverse time delayed characteristics, refer to those of the phase overcurrent elements, section 1.1.

From the settings menu, the "SEF/REF options" cell has a number of setting options. To enable standard, four stage SEF protection, the SEF option should be selected, which is the default setting. However, if wattmetric, restricted earth fault or a combination of both protections are required, then one of the remaining options should be selected. These are described in more detail in sections 1.5 and 1.6. The "Wattmetric" and "Restricted E/F" cells will only appear in the menu if the functions have been selected in the option cell.

Each SEF stage is selectable to be either non-directional, directional forward or directional reverse in the "ISEF>Direction" cell. The timer hold facility, previously described for the overcurrent elements in section 1.1 is available on each of the first two stages and is set in the same manner.

## 1.5 Directional earth fault protection (DEF)

As stated in the previous sections, each of the four stages of EF1, EF2 and SEF protection may be set to be directional if required. Consequently, as with the application of directional overcurrent protection, a suitable voltage supply is required by the relay to provide the necessary polarization.

With the standard earth fault protection element in the P145 relay, two options are available for polarization; Residual Voltage or Negative Sequence. The sensitive earth fault protection element is available with only residual voltage polarization.

### 1.5.1 Residual voltage polarization

With earth fault protection, the polarizing signal requires to be representative of the earth fault condition. As residual voltage is generated during earth fault conditions, this quantity is commonly used to polarize DEF elements. The P145 relay internally derives this voltage from the 3-phase voltage input that must be supplied from either a 5-limb or three single-phase VTs. These types of VT design allow the passage of residual flux and consequently permit the relay to derive the required residual voltage. In addition, the primary star point of the VT must be earthed. A three limb VT has no path for residual flux and is therefore unsuitable to supply the relay.

It is possible that small levels of residual voltage will be present under normal system conditions due to system imbalances, VT inaccuracies, relay tolerances etc. Hence, the P145 relay includes a user settable threshold (IN>VNPol set) which must be exceeded in order for the DEF function to be operational. The residual voltage measurement provided in the “Measurements 1” column of the menu may assist in determining the required threshold setting during the commissioning stage, as this will indicate the level of standing residual voltage present.

Note that residual voltage is nominally 180° out of phase with residual current. Consequently, the DEF elements are polarized from the "-Vres" quantity. This 180° phase shift is automatically introduced within the P145 relay.

The logic diagram for directional earth fault overcurrent with neutral voltage polarization is shown below.

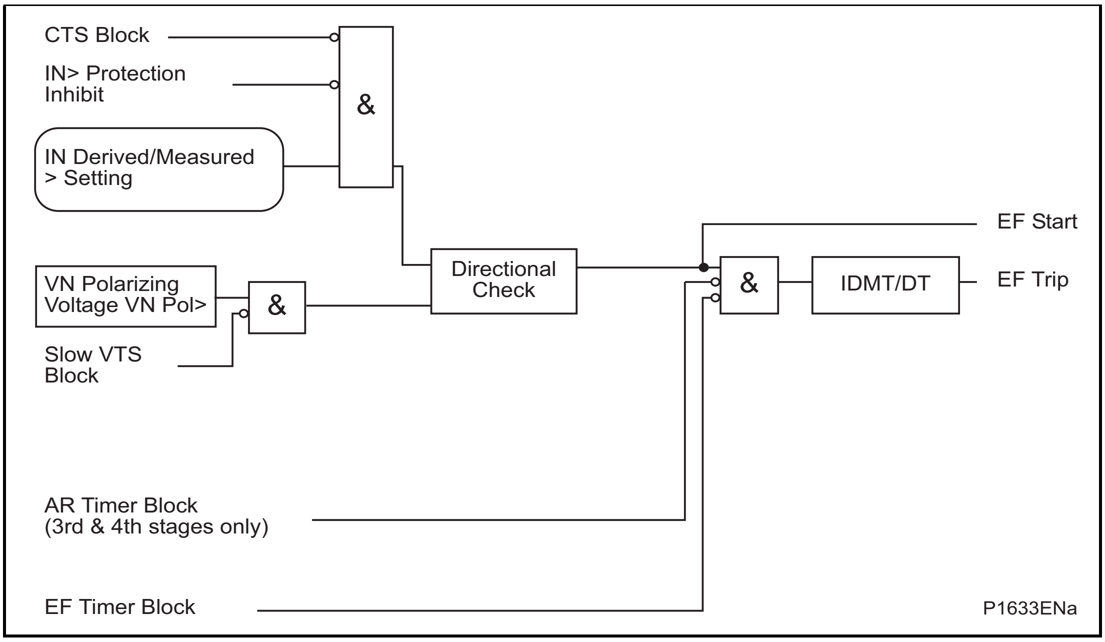



**Figure 8: Directional EF with neutral voltage polarization (single state)**

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

### 1.5.2 Negative sequence polarization

In certain applications, the use of residual voltage polarization of DEF may either be not possible to achieve, or problematic. An example of the former case would be where a suitable type of VT was unavailable, for example if only a three limb VT was fitted. An example of the latter case would be an HV/EHV parallel line application where problems with zero sequence mutual coupling may exist.

In either of these situations, the problem may be solved by the use of negative phase sequence (nps) quantities for polarization. This method determines the fault direction by comparison of nps voltage with nps current. The operate quantity, however, is still residual current.

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

Negative sequence polarizing is not recommended for impedance earthed systems regardless of the type of VT feeding the relay. This is due to the reduced earth fault current limiting the voltage drop across the negative sequence source impedance ($V_2$pol) to negligible levels. If this voltage is less than 0.5 volts the relay will cease to provide DEF.

The logic diagram for directional earth fault overcurrent with negative sequence polarization is shown below.

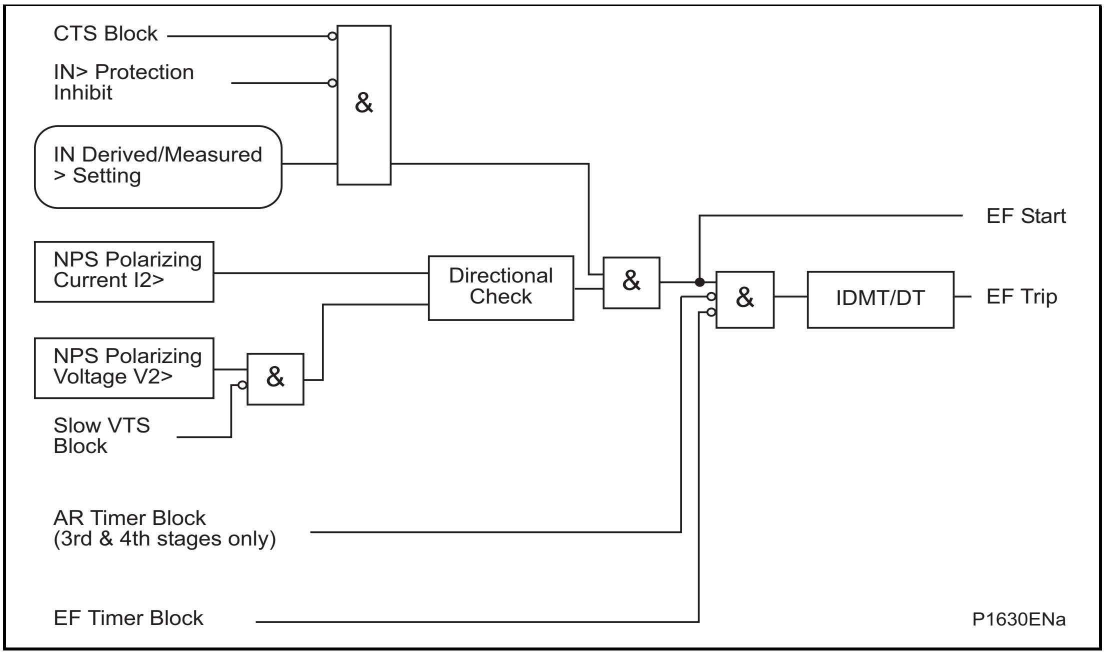



**Figure 9: Directional EF with negative sequence polarization (single stage)**

The directional criteria with negative sequence polarization is given below:

**Directional forward**

-90° < (angle(I2) - angle(V2 + 180°) - RCA) < 90°

**Directional reverse**

-90° > (angle(I2) - angle(V2 + 180°) - RCA) > 90°

1.5.3 Operation of sensitive earth fault element

The SEF element is designed to be applied to resistively earthed, insulated and compensated networks and have distinct functions to cater for these different requirements.

The logic diagram for sensitive directional earth fault overcurrent with neutral voltage polarization is shown in Figure 10.

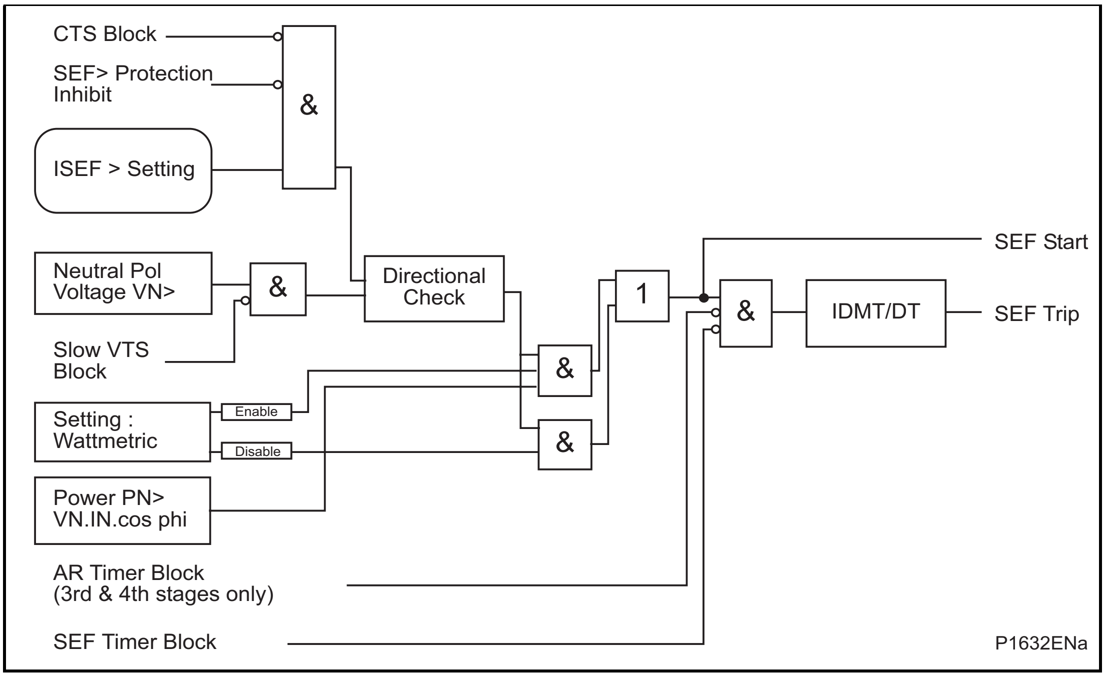



**Figure 10: Directional SEF with $V_N$ polarization (single stage)**

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

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

**Directional forward**

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

**Directional reverse**

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

Three possibilities exist for the type of protection element that may be applied for earth fault detection:

1. A suitably sensitive directional earth fault relay having a relay characteristic angle setting
2. (RCA) of zero degrees, with the possibility of fine adjustment about this threshold.
3. A sensitive directional zero sequence wattmetric relay having similar requirements to 1. Above with respect to the required RCA settings.
4. A sensitive directional earth fault relay having $I\cos\phi$ and $I\sin\phi$ characteristics.

All stages of the sensitive earth fault element of the P145 relay are settable down to 0.5% of rated current and would therefore fulfil 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.

### 1.5.4 Wattmetric characteristic

Analysis has shown (see Application Notes, section 2.5.4) that a small angular difference exists between the spill current on the healthy and faulted feeders for earth faults on compensated networks. Taking into account the efforts of coil and feeder resistance, it can be seen that this angular difference gives rise to active components of current which are in anti-phase to one another. This is shown in Figure 11 below:

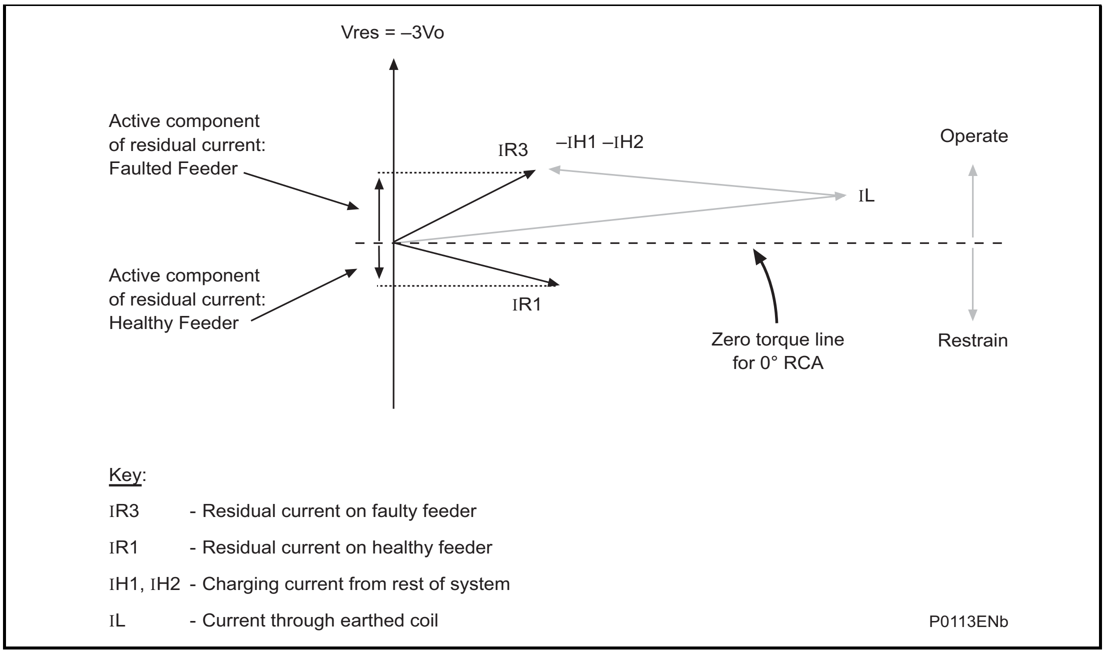



**Figure 11: Resistive components of spill current**

Consequently, the active components of zero sequence power will also lie in similar planes and so a relay capable of detecting active power would be able to make a discriminatory decision. i.e. if the wattmetric component of zero sequence power was detected in the forward direction, then this would be indicative of a fault on that feeder; if power was 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 within the P145 relays, all three of the settable thresholds on the relay must be exceeded; namely the current "ISEF>", the voltage "ISEF>VNpol Set" and the power "PN> Setting".

As can be seen from the following formula, the power setting within the relay menu is called PN> and is therefore calculated using residual rather than zero sequence quantities. Residual quantities are three times their respective zero sequence values and so the complete formula for operation is as shown below:

The PN> setting corresponds to:

$$Vres \times Ires \times \cos(\phi - \phi c) = 9 \times Vo \times Io \times \cos(\phi - \phi c)$$

Where:

| | | |
|---|---|---|
| $\phi$ | = | Angle between the Polarizing Voltage (-Vres) and the Residual Current |
| $\phi c$ | = | Relay Characteristic Angle (RCA) Setting (ISEF> Char. Angle) |
| Vres | = | Residual Voltage |
| Ires | = | Residual Current |
| Vo | = | Zero Sequence Voltage |
| Io | = | Zero Sequence Current |

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

Note that the residual power setting, PN>, is scaled by the programmed CT and VT ratios in the relay.

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

The directional check criteria is as follows:

**Directional forward**

$-85° < (\text{angle}(I_N) - \text{angle}(V_N + 180°) - \text{RCA}) < 85°$

**Directional reverse**

$-85° > (\text{angle}(I_N) - \text{angle}(V_N + 180°) - \text{RCA}) > 85°$



### 1.5.5 Icosϕ/Isinϕ characteristic

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

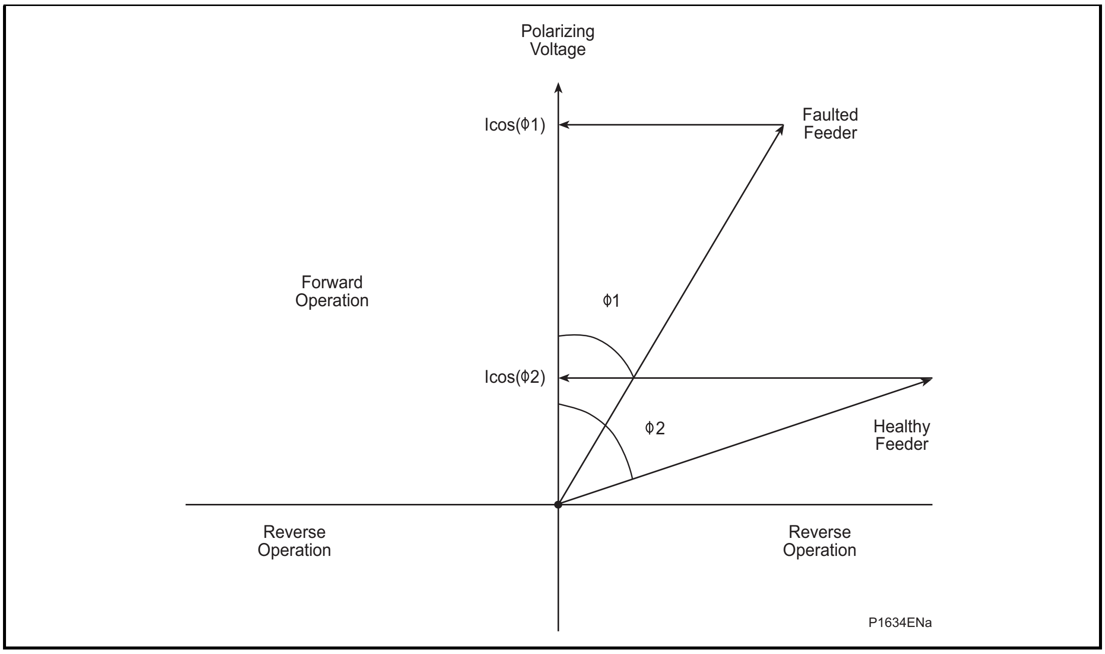



**Figure 12: Operating characteristic for Icosϕ**

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

**Active component Icosϕ**

The criterion for operation is: I (cosϕ) > Isef

**Reactive component Isinϕ**

The criterion for operation is: I (sinϕ) > Isef

Where Isef is the relay stage sensitive earth fault current setting.

If any stage is set non-directional, the element reverts back to normal operation based on current magnitude I with no directional decision.

In this case, correct discrimination is achieved by means of an Icosϕ characteristic as the faulted feeder will have a large active component of residual current, whilst the healthy feeder will have a small value.

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

**All of the relevant settings can be found under the SENSITIVE E/F column within the relay menu. Within the Sens. E/F Options cell, there are two possibilities for selecting wattmetric earth fault protection; either on its own or in conjunction with low impedance REF protection, which is described in section 1.6.1. The SEF cosϕ and SEF sinϕ options are not available with low impedance REF protection.**

## 1.6 Restricted earth fault protection

The REF protection in the P145 relays may be configured to operate as either a high impedance or low impedance element and the following sections describe the application of the relay in each mode.

The high impedance REF element of the relay shares the same CT input as the SEF protection hence, only one of these elements may be selected. However, the low impedance REF element does not use the SEF input and so may be selected at the same time.

### 1.6.1 Biased differential protection

In a biased differential relay, the through current is measured and used to increase the setting of the differential element. For heavy through faults, one CT in the scheme can be expected to become more saturated than the other and hence differential current can be produced. However, biasing will increase the relay setting such that the resulting differential current is insufficient to cause operation of the relay.

Figures 13 and 14 show the operating characteristic for the P145 relay applied for biased REF protection.

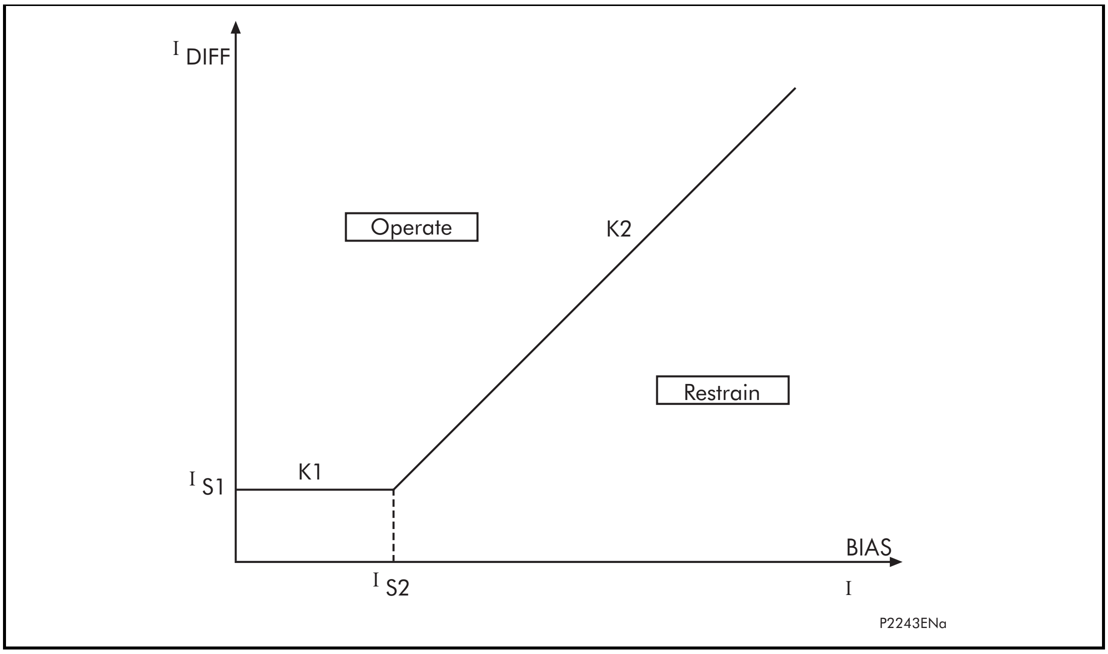



**Figure 13: REF bias characteristic**

The actual operating characteristic of the element is shown in Figure 13.

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

Ibias = {(Highest of Ia, Ib or Ic) + (Ineutral x Scaling Factor)}/2

The reason for the scaling factor included on the neutral current is explained by referring to Figure 14.

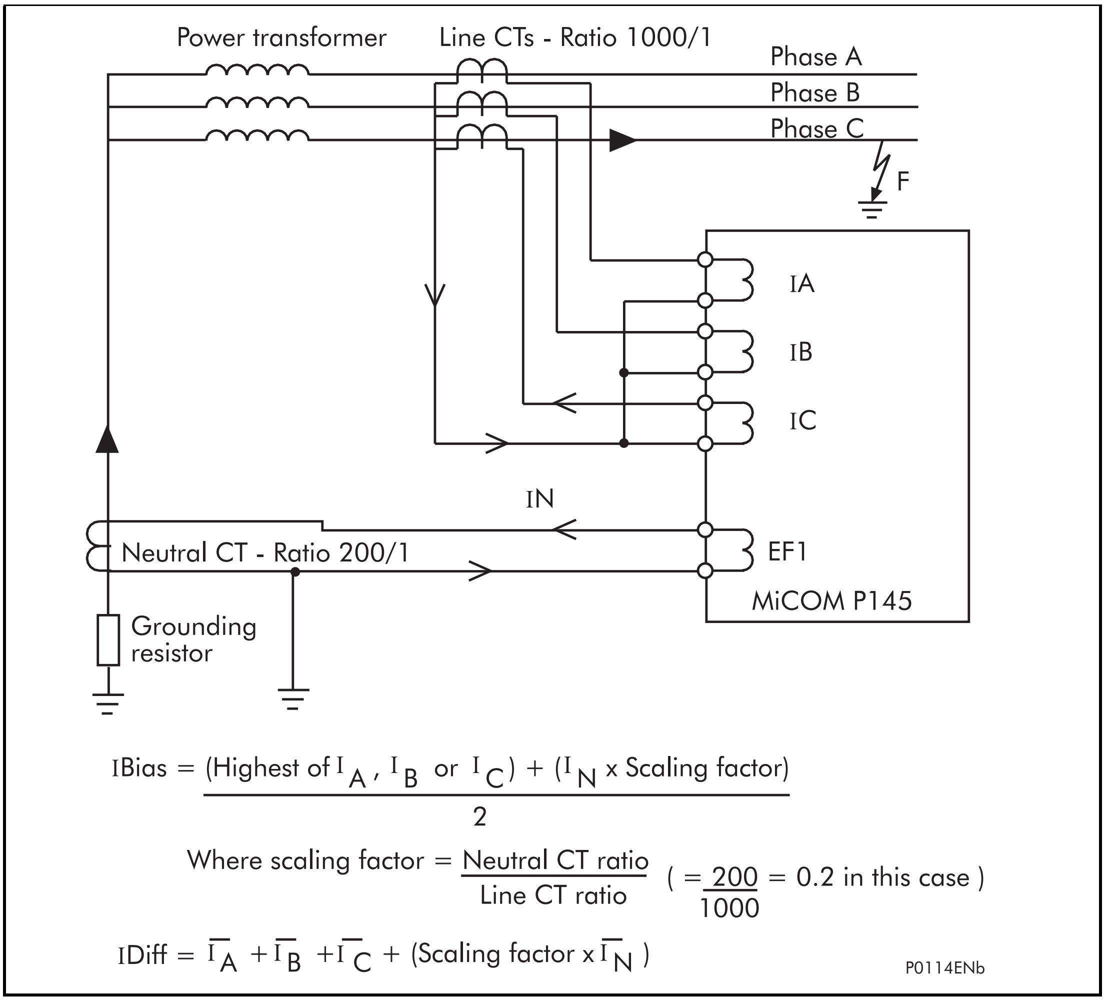



**Figure 14: REF bias principle**

Where it is required that the neutral CT also drives the EF1 protection element to provide standby earth fault protection, it may be a requirement that the neutral CT has a lower ratio than the line CTs in order to provide better earth fault sensitivity. If this were not accounted for in the REF protection, the neutral current value used would be incorrect. For this reason, the relay automatically scales the level of neutral current used in the bias calculation by a factor equal to the ratio of the neutral to line CT primary ratings. The use of this scaling factor is shown in Figure 14, where the formulae for bias and differential currents are given.

### 1.6.2 High Impedance restricted earth 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 15.

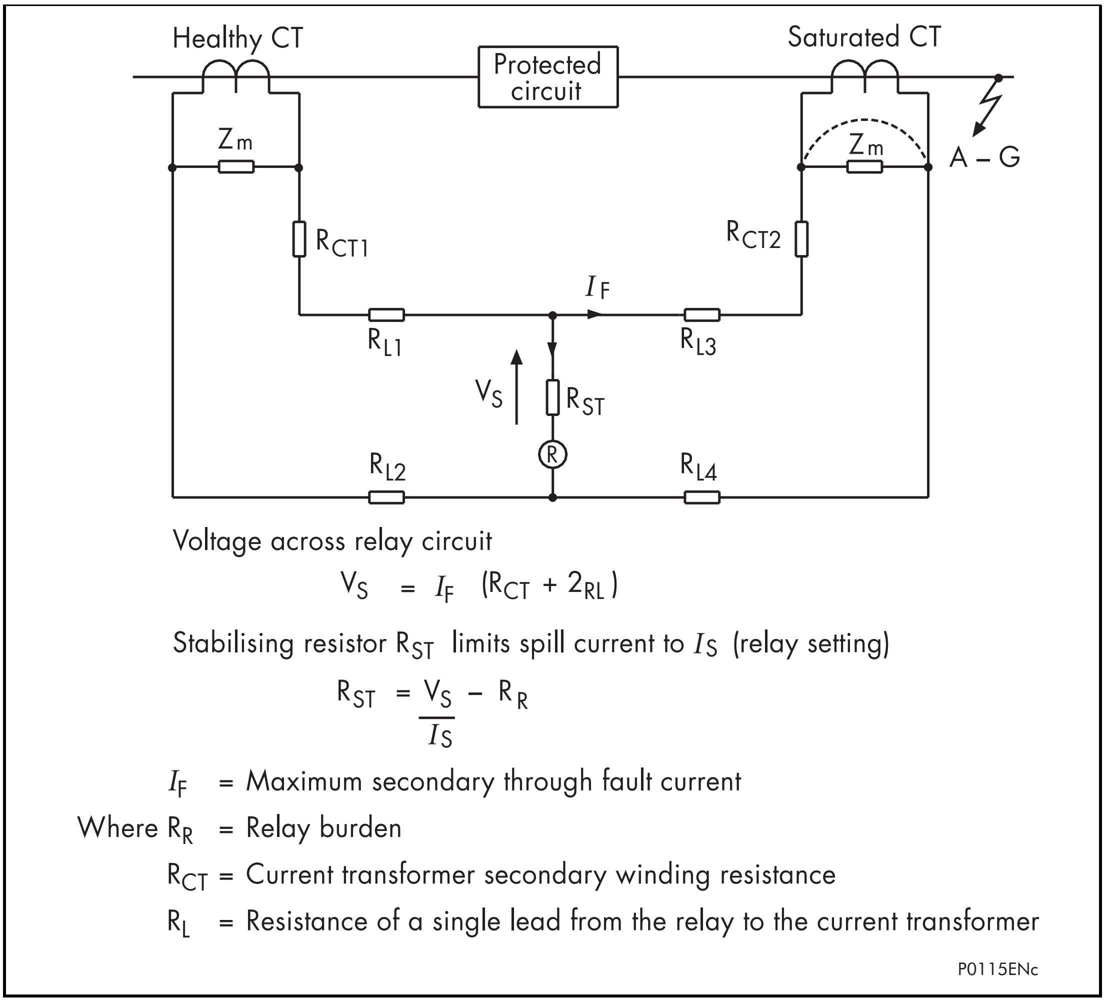



**Figure 15: High impedance principle**

If the relay circuit is considered to be a very high impedance, the secondary current produced by the healthy CT will flow through the saturated CT. If CT magnetizing impedance of the saturated CT is considered to be negligible, the maximum voltage across the relay circuit will be 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, such that 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 Figure15. An additional non-linear, metrosil, may be required to limit the peak secondary circuit voltage during internal fault conditions.

To ensure that the protection will operate quickly during an internal fault, the CT's used to operate the protection must have a kneepoint voltage of at least 4Vs.

The necessary relay connections for high impedance REF are shown in Figure 16.

OP

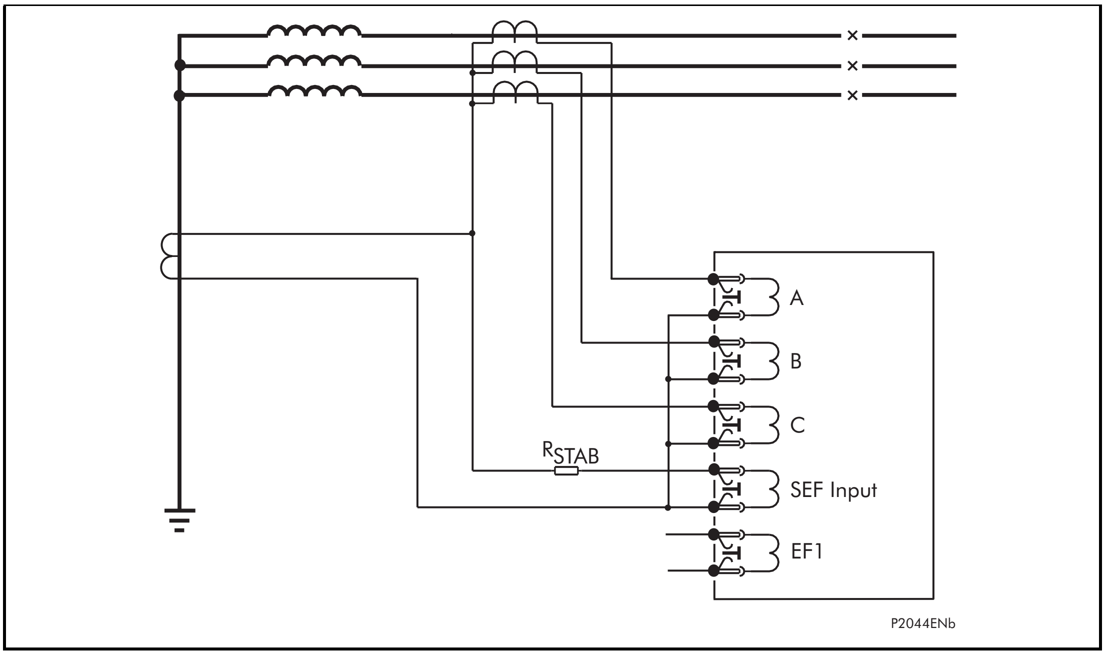



**Figure 16: High impedance REF relay/CT connections**

OP

### 1.7 Residual overvoltage (neutral displacement) protection

On a healthy three-phase power system, the addition of each of the three-phase to earth voltages is nominally zero, as it is the vector addition of three balanced vectors at 120° to one another. However, when an earth fault occurs on the primary system this balance is upset and a ‘residual’ voltage is produced. This could be measured, for example, at the secondary terminals of a voltage transformer having a “broken delta” secondary connection. Hence, a residual voltage-measuring relay can be used to offer earth fault protection on such a system. Note that this condition causes a rise in the neutral voltage with respect to earth that is commonly referred to as “neutral voltage displacement” or NVD.

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 or insulated systems, where the provision of core balance CT’s on each feeder may be either impractical, or uneconomic.

The P145 relay internally derives this residual voltage from the three-phase voltage input that must be supplied from either a 5-limb or three single-phase VT’s. The NVD element within the P145 relays 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:

$t = K / (M - 1)$

Where:

K = Time multiplier setting

t = Operating time in seconds

M = Derived residual voltage/relay setting voltage (VN> Voltage Set)

Two stages are included for the NVD protection to account for applications that require both alarm and trip stages, for example, an insulated system. It is common in such a case for the system to have been designed to withstand the associated healthy phase overvoltages for a number of hours following an earth fault. In such applications, an alarm is generated soon after the condition is detected, which serves to indicate the presence of an earth fault on the system. This gives time for system operators to locate and isolate the fault. The second stage of the protection can issue a trip signal if the fault condition persists.

The functional block diagram of the first stage residual overvoltage is shown below:

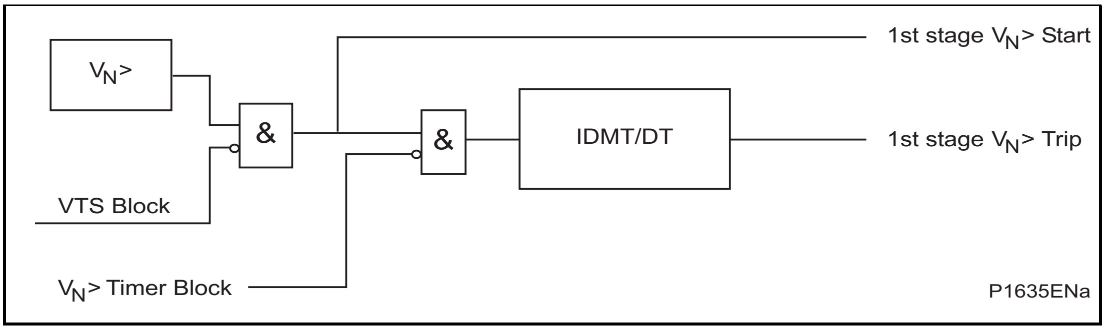



**Figure 17: Residual overvoltage logic (single stage)**

VTS blocking when asserted, effectively blocks the start outputs.

When enabled, the following signals are set by the residual overvoltage logic according to the status of the monitored function:

| | | |
|---|---|---|
| VN>1 Start | (DDB 327) | - 1st Stage Residual Overvoltage Start |
| VN>2 Start | (DDB 328) | - 2nd Stage Residual Overvoltage Start |
| VN>1 Timer Blk. | (DDB 220) | - Block Residual Overvoltage Stage 1 Time Delay |
| VN>2 Timer Blk. | (DDB 221) | - Block Residual Overvoltage Stage 2 Time Delay |
| VN>1 Trip | (DDB 274) | - 1st Stage Residual Overvoltage Trip |
| VN>2 Trip | (DDB 275) | - 2nd Stage Residual Overvoltage Trip |

## 1.8 Undervoltage protection

Both the under and overvoltage protection functions can be found in the relay menu "Volt Protection". The undervoltage protection included within the P145 relays consists of two independent stages. These are configurable as either phase to phase or phase to neutral measuring within the "V<Measur't mode" cell.

Stage 1 may be selected as IDMT, DT or Disabled, within the "V<1 Function" cell. Stage 2 is DT only and is enabled/disabled in the "V<2 status" cell.

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

$t = K / (M - 1)$

Where:

K = Time multiplier setting

t = Operating time in seconds

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

Two stages are included to provide both alarm and trip stages, where required. Alternatively, different time settings may be required depending upon the severity of the voltage dip, i.e. motor loads will be able to withstand a small voltage depression for a longer time than if a major voltage excursion were to occur.

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

The logic diagram of the first stage undervoltage function is shown in Figure 18.

OP

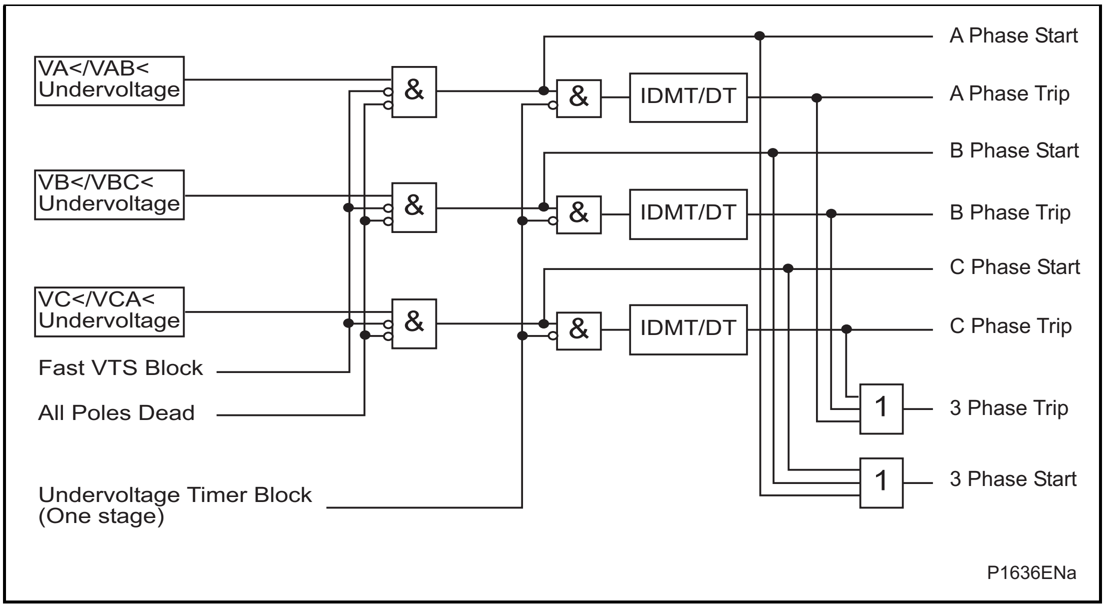





**Figure 18: Undervoltage - single and three phase tripping mode (single stage)**

When the protected feeder is de-energized, or the circuit breaker is opened, an undervoltage condition would be detected. Therefore, the "V<Poledead Inh" cell is included for each of the two stages to block the undervoltage protection from operating for this condition. If the cell is enabled, the relevant stage will become inhibited by the in-built pole dead logic within the relay. This logic produces an output when it detects either an open circuit breaker via auxiliary contacts feeding the relay opto inputs or it detects a combination of both undercurrent and undervoltage on any one phase.

## 1.9 Overvoltage protection

Both the under and overvoltage protection functions can be found in the relay menu "Volt Protection". The overvoltage protection included within the P145 relays consists of two independent stages. These are configurable as either phase to phase or phase to neutral measuring within the "V>Measur't mode" cell.

Stage 1 may be selected as IDMT, DT or Disabled, within the "V>1 Function" cell. Stage 2 is DT only and is enabled/disabled in the "V>2 status" cell.

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

$t = K / (M - 1)$

Where:

K = Time multiplier setting

t = Operating time in seconds

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

The logic diagram of the first stage overvoltage function is shown in Figure 19.

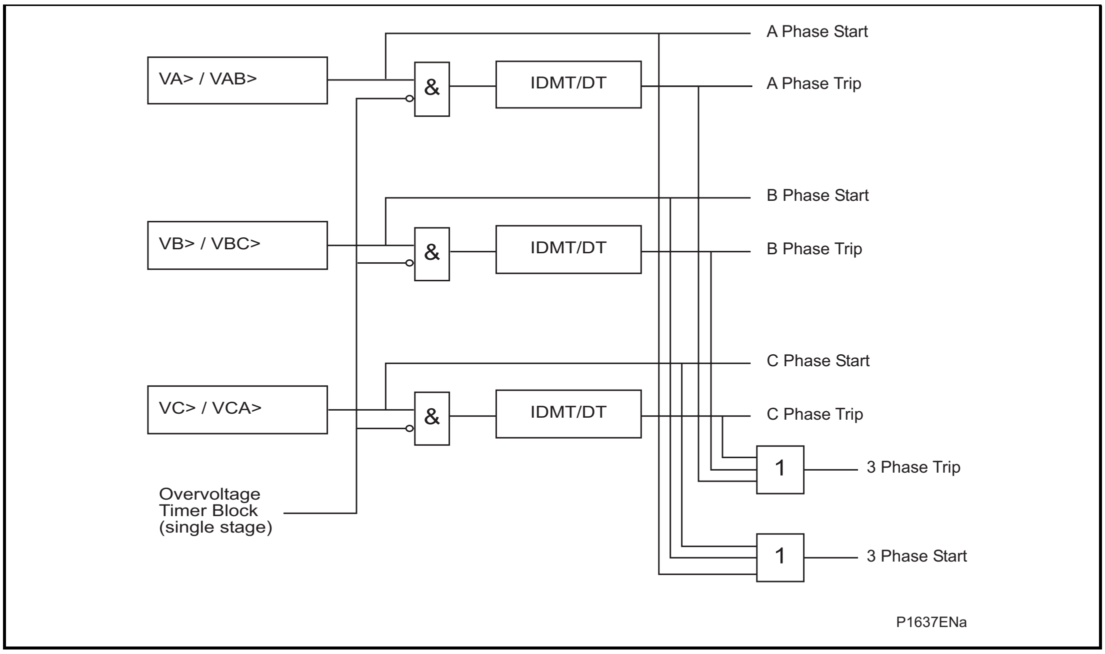



**Figure 19: Overvoltage - single and three phase tripping mode (single stage)**

## 1.10 Negative sequence overvoltage protection

The P145 relay includes a negative phase sequence overvoltage element. This element monitors the input voltage rotation and magnitude (normally from a bus connected voltage transformer) and may be interlocked with the motor contactor or circuit breaker to prevent the motor from being energized whilst incorrect phase rotation exists.

This single stage is selectable as definite time only and is enabled within the "V2>status" cell.

The logic diagram for the negative sequence overcurrent protection is shown below:

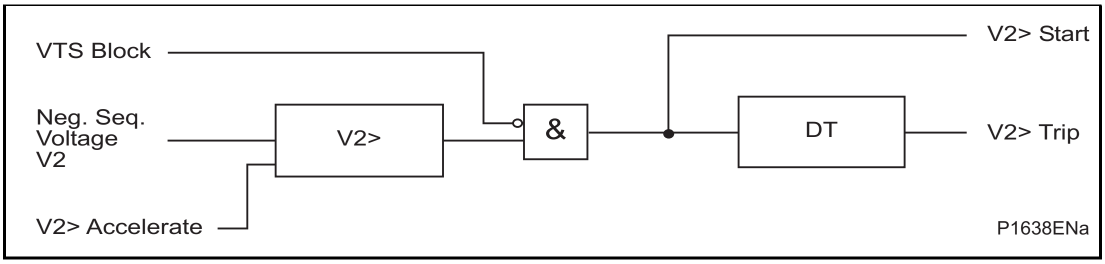



**Figure 20: Negative sequence overvoltage element logic**

When enabled, the following signals are set by the negative sequence overvoltage logic according to the status of the monitored function.

| | | | |
|---|---|---|---|
| V2> Accelerate | (DDB 517) | - | Accelerate the operating time of the function from typically 80msec. to 40msec. when set to instantaneous |
| V2> Start | (DDB 330) | - | Stage started when high |
| V2> Trip | (DDB 277) | - | Stage tripped when high |

## 1.11 Negative sequence overcurrent protection (NPS)

The relay provides four independent stages of negative phase sequence overcurrent protection. Each stage has a current pick up setting "I2>n Current Set", and is time delayed in operation by the adjustable timer "I2>n Time Delay". The user may choose to directionalize operation of the elements, for either forward or reverse fault protection for which a suitable relay characteristic angle may be set. Alternatively, the elements may be set as non-directional. For the negative phase sequence directional elements to operate, the relay must detect a polarizing voltage above a minimum threshold, "I2> V2pol Set".

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

When enabled, the following signals are set by the negative sequence O/C logic according to the status of the monitored function.

| | | |
|---|---|---|
| I2> Inhibit | (DDB 504) | - Inhibit all 4 stages when high |
| I2>1 Tmr. Block | (DDB 505) | - Block timer on 1st stage when high |
| I2>2 Tmr. Block | (DDB 506) | - Block timer on 1st stage when high |
| I2>3 Tmr. Block | (DDB 507) | - Block timer on 1st stage when high |
| I2>4 Tmr. Block | (DDB 508) | - Block timer on 1st stage when high |
| I2>1 Start | (DDB 509) | - 1st stage started when high |
| I2>2 Start | (DDB 510) | - 2nd stage started when high |
| I2>3 Start | (DDB 511) | - 3rd stage started when high |
| I2>4 Start | (DDB 512) | - 4th stage started when high |
| I2>1 Trip | (DDB 513) | - 1st stage tripped when high |
| I2>2 Trip | (DDB 514) | - 2nd stage tripped when high |
| I3>3 Trip | (DDB 515) | - 3rd stage tripped when high |
| I4>4 Trip | (DDB 516) | - 4th stage tripped when high |

All the above signals are available as DDB signals for mapping in Programmable Scheme Logic (PSL). In addition the negative sequence overcurrent protection trips 1/2/3/4 are mapped internally to the block auto-reclose logic.

Negative sequence overcurrent protection starts 1/2/3/4 are mapped internally to the ANY START DDB signal – DDB 294.

The non-directional and directional operation is shown in the following diagrams:

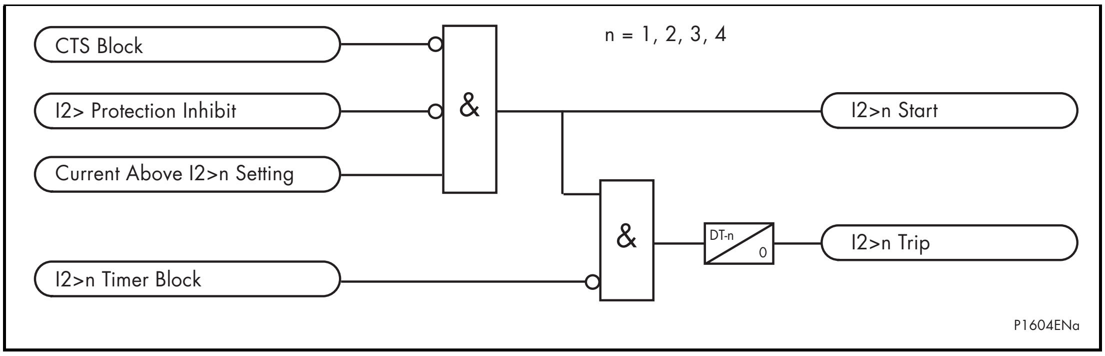



**Figure 21: Negative sequence overcurrent non-directional operation**

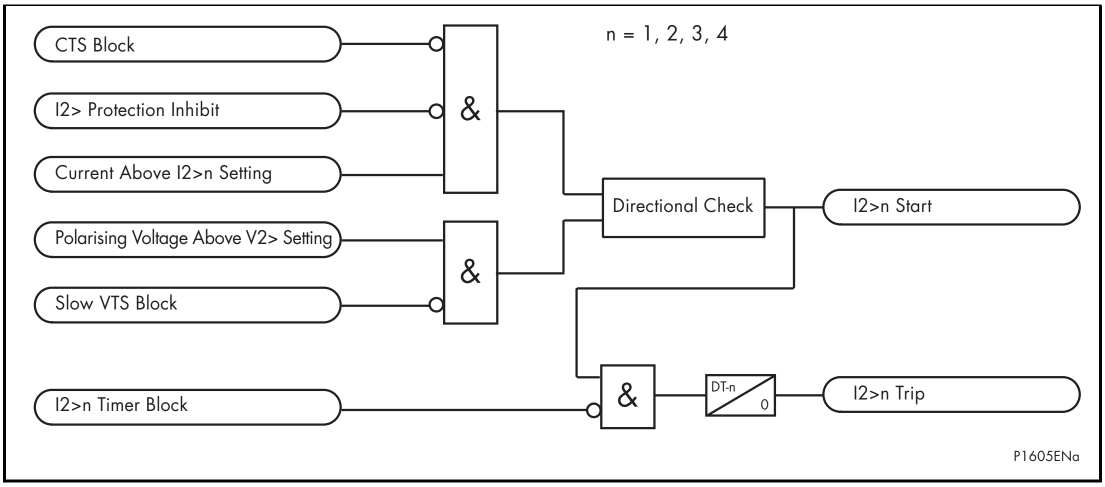



**Figure 22: Directionalizing the negative phase sequence overcurrent element**

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

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

## 1.12 Voltage controlled overcurrent protection (51V)

If the current seen by a local relay for a remote fault condition is below it's overcurrent setting, a voltage controlled overcurrent (VCO) element may be used to increase the relay sensitivity to such faults. In this case, a reduction in system voltage will occur; this may then be used to reduce the pick up level of the overcurrent protection.

The VCO function can be selectively enabled on the first two stages of the main overcurrent element, which was described in section 1.1. When VCO is enabled, the overcurrent setting is modified by the multiplier k when the voltage falls below a threshold as shown in the following table:

| Element | Phase to Phase Voltage for Control | Element Pick Up When Control Voltage > Setting | Element Pick Up When Control Voltage < Setting |
|---|---|---|---|
| Ia> | Vab | I>1, I>2 | k.I> |
| Ib> | Vbc | I>1, I>2 | k.I> |
| Ic> | Vca | I>1, I>2 | k.I> |

Note that voltage dependent overcurrent relays are more often applied in generator protection applications in order to give adequate overcurrent relay sensitivity for close up fault conditions. The fault characteristic of this protection must then co-ordinate with any of the downstream overcurrent relays that are responsive to the current decrement condition. It therefore follows that if the P145 relay is to be applied on an outgoing feeder from a generator station, the use of voltage controlled overcurrent protection in the feeder relay may allow better co-ordination with the VCO relay on the generator.

### 1.13 Circuit breaker fail protection (CBF)

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. The backtrip uses "CB Fail 2 Timer", which is also started at the instant of the initial protection element trip.



The complete breaker fail logic is illustrated in Figure 23.

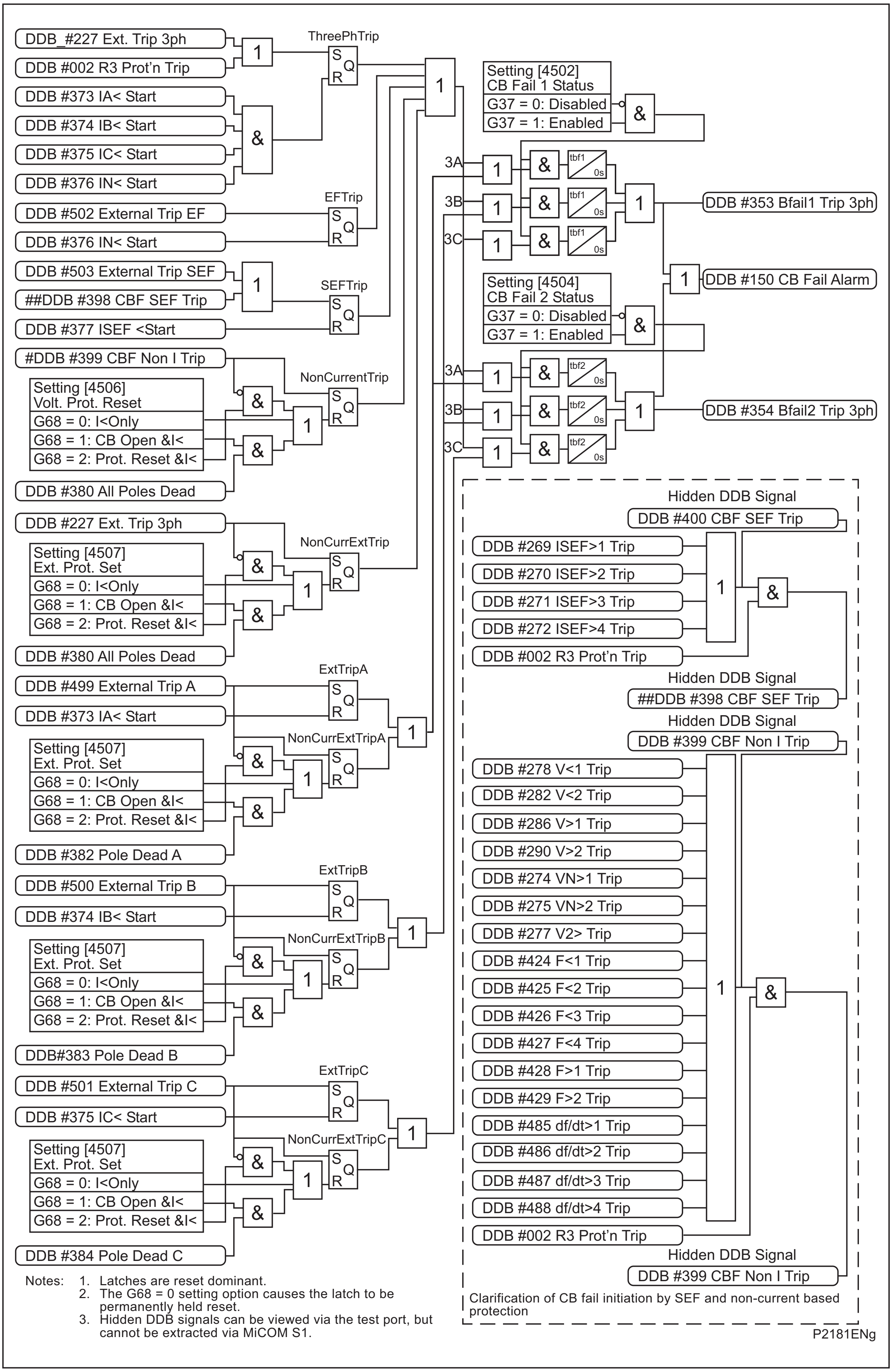



**Figure 23: CB fail logic**

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

Resetting of the CBF is possible from a breaker open indication (from the relay's pole dead logic) or from a protection reset. In these cases resetting is only allowed provided the undercurrent elements have also reset. The resetting options are summarized in the following table:

| Initiation (Menu Selectable) | CB Fail Timer Reset Mechanism |
|---|---|
| Current based protection | The resetting mechanism is fixed<br>(e.g. 50/51/46/21/87..)<br>[IA< operates] &<br>[IB< operates] &<br>[IC< operates] &<br>[IN< operates] |
| Sensitive earth fault element | The resetting mechanism is fixed. [ISEF< Operates] |
| Non-current based protection<br>(e.g. 27/59/81/32L..) | Three options are available. The user can Select from the following options.<br>[All I< and IN< elements operate]<br>[Protection element reset] AND [All I< and IN< elements operate]<br>CB open (all 3 poles) AND [All I< and IN< elements operate] |
| External protection | Three options are available.<br>The user can select any or all of the options.<br>[All I< and IN< elements operate]<br>[External trip reset] AND [All I< and IN< elements operate]<br>CB open (all 3 poles) AND [All I< and IN< elements operate] |

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

## 1.14 Broken conductor detection

The relay incorporates an element which measures the ratio of negative to positive phase sequence current ($I_2/I_1$). This will be affected to a lesser extent than the measurement of negative sequence current alone, since the ratio is approximately constant with variations in load current. Hence, a more sensitive setting may be achieved.

The logic diagram is as shown below. The ratio of I2/I1 is calculated and is compared with the threshold and if the threshold is exceeded then the delay timer is initiated. The CTS block signal is used to block the operation of the delay timer.

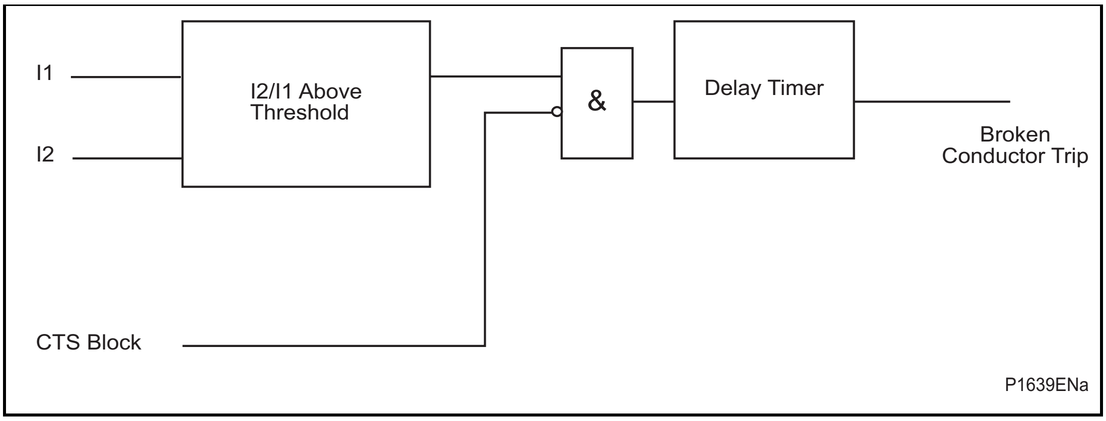



**Figure 24: Broken conductor logic**

### 1.15 Frequency protection



The Feeder relay includes 4 stages of underfrequency and 2 stages of overfrequency protection to facilitate load shedding and subsequent restoration. The underfrequency stages may be optionally blocked by a pole dead (CB Open) condition. All the stages may be enabled/disabled in the "F<n Status" or "F>n Status" cell depending on which element is selected.

The logic diagram for the underfrequency logic is as shown in Figure 25. Only a single stage is shown. The other 3 stages are identical in functionality.

If the frequency is below the setting and not blocked the DT timer is started. Blocking may come from the All_Poledead signal (selectively enabled for each stage) or the underfrequency timer block.

If the frequency cannot be determined, the function is also blocked.

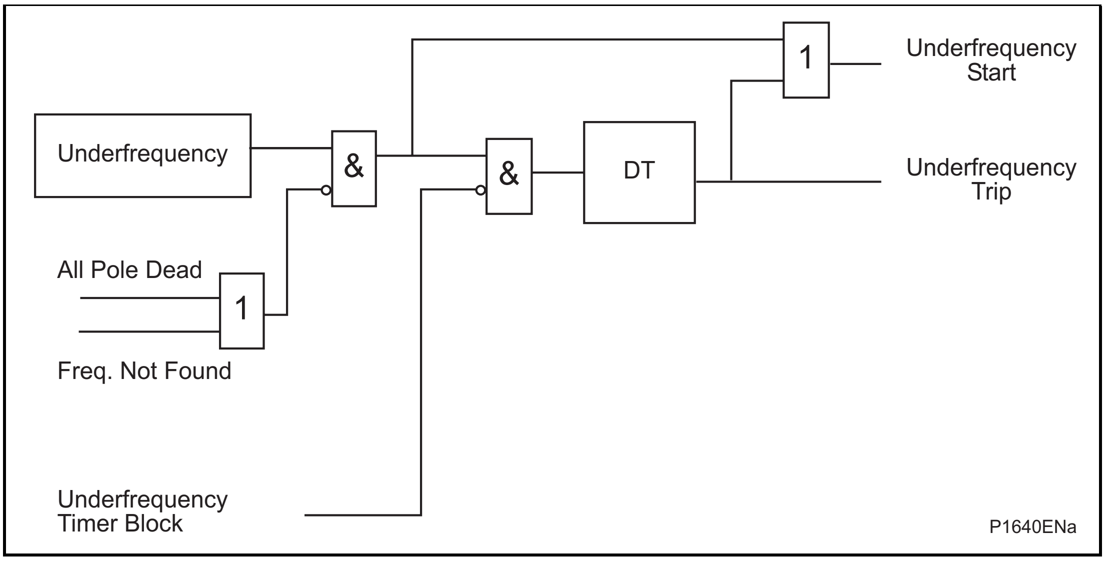



**Figure 25: Underfrequency logic (single stage)**

The functional logic diagram is for the overfrequency function as shown in Figure 26. Only a single stage is shown as the other stages are identical in functionality. If the frequency is above the setting and not blocked the DT timer is started and after this has timed out the trip is produced. Blocking may come from the All_Poledead signal (selectively enabled for each stage) or the overfrequency timer block.

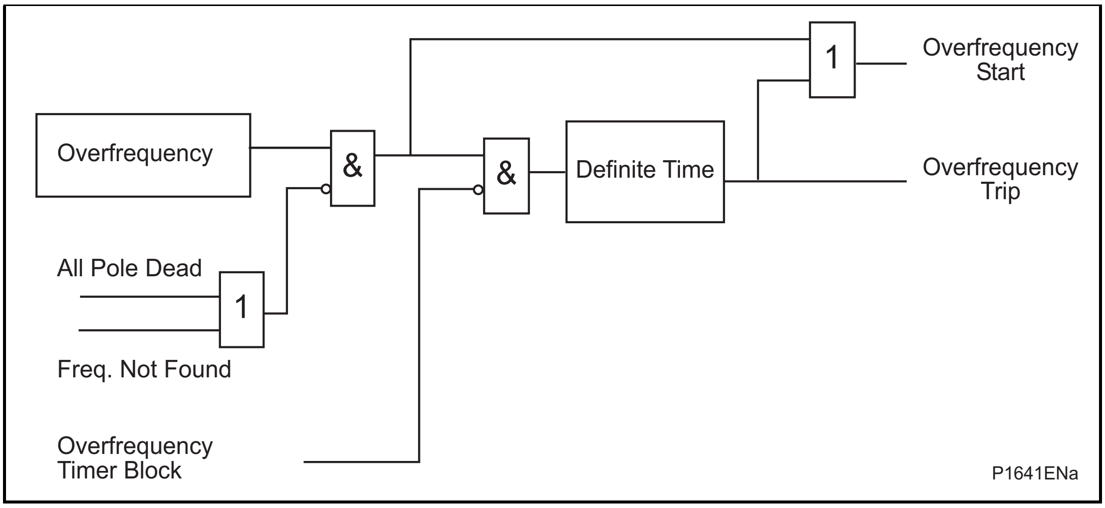





**Figure 26: Overfrequency logic (single stage)**

When enabled, the following signals are set by the under/overfrequency logic according to the status of the monitored functions.

Freq. Not Found (DDB 411) - Frequency Not Found by the frequency tracking

F<1 Timer Block (DDB 412) - Block Underfrequency Stage 1 Timer

F<2 Timer Block (DDB 413) - Block Underfrequency Stage 2 Timer

F<3 Timer Block (DDB 414) - Block Underfrequency Stage 3 Timer

F<4 Timer Block (DDB 415) - Block Underfrequency Stage 4 Timer

F>1 Timer Block (DDB 416) - Block Overfrequency Stage 1 Timer

F>2 Timer Block (DDB 417) - Block Overfrequency Stage 2 Timer

F<1 Start (DDB 418) - Underfrequency Stage 1 Start

F<2 Start (DDB 419) - Underfrequency Stage 2 Start

F<3 Start (DDB 420) - Underfrequency Stage 3 Start

F<4 Start (DDB 421) - Underfrequency Stage 4 Start

F>1 Start (DDB 422) - Overfrequency Stage 1 Start

F>2 Start (DDB 423) - Overfrequency Stage 2 Start

F<1 Trip (DDB 424) - Underfrequency Stage 1 Trip

F<2 Trip (DDB 425) - Underfrequency Stage 2 Trip

F<3 Trip (DDB 426) - Underfrequency Stage 3 Trip

F<4 Trip (DDB 427) - Underfrequency Stage 4 Trip

F>1 Trip (DDB 428) - Overfrequency Stage 1 Trip

F>2 Trip (DDB 429) - Overfrequency Stage 2 Trip

## 1.16 Independent rate of change of frequency protection [81R]

In the load shedding scheme below, it is assumed under falling frequency conditions that by shedding a stage of load, the system can be stabilized at frequency f2. For slow rates of decay, this can be achieved using the underfrequency protection element set at frequency f1 with a suitable time delay. However, if the generation deficit is substantial, the frequency will rapidly decrease and it is possible that the time delay imposed by the underfrequency protection will not allow for frequency stabilization. In this case, the chance of system recovery will be enhanced by disconnecting the load stage based upon a measurement of rate of change of frequency and bypassing the time delay.

This element is a rate of change of frequency monitoring element, and operates independently from the under and over frequency protection functions. A timer is included to provide a time delayed operation and the element can be utilized to provide extra flexibility to a load shedding scheme in dealing with severe load to generation imbalances.

Since the rate of change monitoring is independent of frequency, the element can identify frequency variations occurring close to nominal frequency and thus provide early warning to the operator on a developing frequency problem. Additionally, the element could also be used as an alarm to warn operators of unusually high system frequency variations.

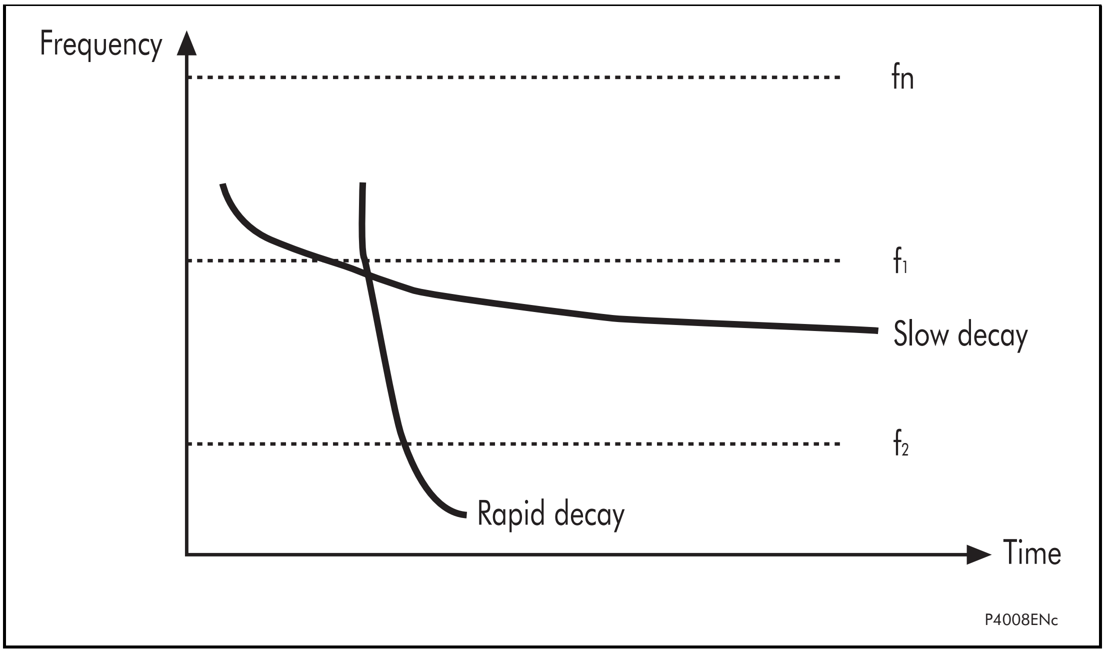



**Figure 27: Rate of change of frequency protection**

1.16.1 Basic functionality

The P145 provides four independent stages of rate of change of frequency protection (df/dt+t). Depending upon whether the rate of change of frequency setting is set positive or negative, the element will react to rising or falling frequency conditions respectively, with an incorrect setting being indicated if the threshold is set to zero. The output of the element would normally be given a user-selectable time delay, although it is possible to set this to zero and create an instantaneous element.

An Independent setting is available for calculating the rate of change of frequency measurement, “df/dt Avg. Cycles” over a fixed period of either 6 or 12 cycles. This provides the ability to de-sensitize the frequency based protection element against oscillations in the power system frequency. The 12-cycle averaging window setting improves measurement accuracy, but slows down the protection start time following fault inception. The maximum fault detection start time following fault inception can be approximated as follows:

Fault Detection Delay Time (cycles) = 2 X M + 1

Where M = No. of frequency averaging cycles “df/dt.Av. Cycles”

When enabled, the following signals are set by the df/dt logic according to the status of the monitored function.

df/dt> Inhibit (DDB 476) - Inhibit all 4 stages when high

df/dt>1 Tmr. Block (DDB 477) - Block timer on 1st stage when high

df/dt>2 Tmr. Block (DDB 478) - Block timer on 2nd stage when high

df/dt>3 Tmr. Block (DDB 479) - Block timer on 3rd stage when high

df/dt>4 Tmr. Block (DDB 480) - Block timer on 4th stage when high df/dt>1 Start (DDB 481) - 1st stage started when high

df/dt>2 Start (DDB 482) - 2nd stage started when high

df/dt>3 Start (DDB 483) - 3rd stage started when high

df/dt>4 Start (DDB 484) - 4th stage started when high

df/dt>1 Trip (DDB 485) - 1st stage tripped when high

df/dt>2 Trip (DDB 486) - 2nd stage tripped when high

df/dt>3 Trip (DDB 487) - 3rd stage tripped when high

df/dt>4 Trip (DDB 488) - 4th stage tripped when high

All the above signals are available as DDB signals for mapping in Programmable Scheme Logic (PSL). In addition the df/dt protection trips 1/2/3/4 are mapped internally to the following:



- CB Fail (non-current based protection)
- Block auto-reclose

DF/DT protection starts 1/2/3/4 are mapped internally to the ANY START ddb signal – DDB 294

### 1.17 Cold load pick-up logic

The Cold Load Pick-Up (CLP) logic included within the P145 relays serves to either inhibit one or more stages of the overcurrent protection for a set duration or, alternatively, to raise the settings of selected stages. This, therefore, allows the protection settings to be set closer to the load profile by automatically increasing them following circuit energization. The CLP logic thus provides stability, whilst maintaining protection during starting. Note that any of the overcurrent stages that have been disabled in the main relay menu will not appear in the CLP menu.

This function acts upon the following protection functions:

- Non-Directional/Directional phase overcurrent ($1^{st}$, $2^{nd}$, 3rd and 4th stages)
- Non-Directional/Directional earth fault - 1 (1st stage)
- Non-Directional/Directional earth fault - 2 (1st stage)

The functional logic diagram for the cold load pick-up function is shown in Figure 28, together with the example of its effect on phase A of the first stage overcurrent function. The principle of operation is identical for the 3-phase overcurrent function stages 1, 2, 3 and 4 and EF-1 stage 1 and directional EF-2 stage 1.

Cold load pick up operation occurs when the circuit breaker remains open for a time greater than tcold and is subsequently closed. CLP operation is applied after tcold and remains for a set time delay of tclp following closure of the circuit breaker. The status of the circuit breaker is provided either by means of the CB auxiliary contacts or by means of an external device via logic inputs. Whilst CLP operation is in force, the CLP settings are enabled for all the 3- phase overcurrent function stages 1, 2, 3 and 4 and associated time delayed elements, EF-1 function stage 1 and EF-2 stage 1. (Note that one setting option is the ability to disable (or block) a given overcurrent stage). After the time delay tclp has elapsed, the normal overcurrent settings are applied.

The impact of VCO is considered in the diagram since this function can also affect the 3 individual phase overcurrent settings for stages 1 and 2.

In the quiescent state, the protection operates from the normal phase overcurrent and time delay settings. However, if a VCO undervoltage condition arises, the relay will operate from the normal settings multiplied by the VCO “K” factor. Where there is a simultaneous VCO undervoltage and CLP condition, the relay will operate from the normal settings multiplied by the VCO “K” factor. If the CLP condition prevails and the VCO function resets, the relay will operate using the CLP settings.

Time delayed elements are reset to zero if they are disabled during the transitions between normal settings and CLP settings.

It should be noted that in the event of a conflict between Selective Logic and CLP on the 3rd and 4th stages of the 3-phase directional overcurrent, EF and SEF protection functions, Selective Logic has greater priority.

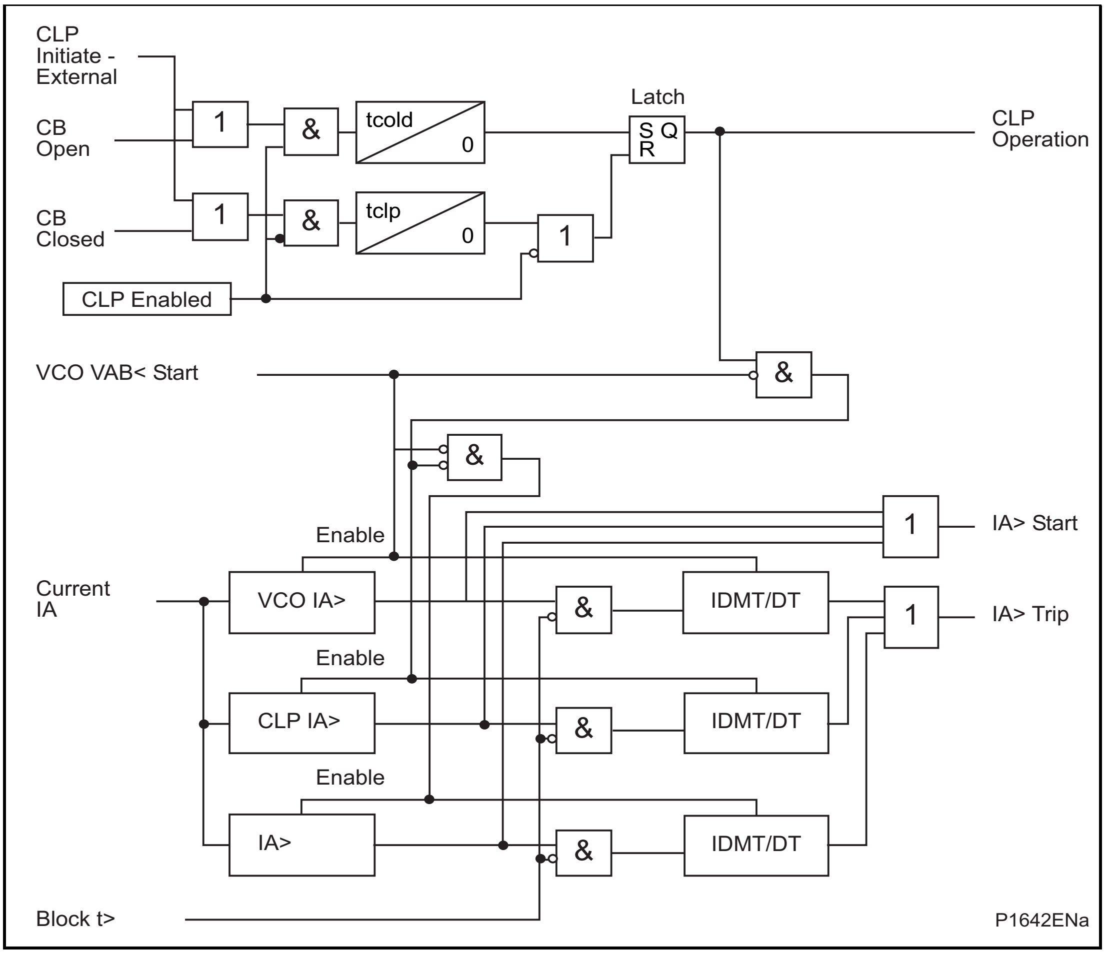



**Figure 28: Cold load pick-up logic**

The normal settings will be applied to the directional phase overcurrent, standby earth fault and sensitive earth fault protection functions when the CLP element resets.

When enabled, the following signals are set by the CLP logic according to the status of the monitored function.

CLP Initiate (DDB 226) - Initiate Cold load pick-up

CLP Operation (DDB 347) - Indicates the Cold load pick-up logic is in operation

"tcold" and "tclp" are initiated via the CB open and CB closed signals generated within the relay. Connecting auxiliary contacts from the circuit breaker or starting device to the relay opto-inputs produces these signals. It is important to note that if both an open and closed contact are unavailable, the relay can be configured to be driven from either a single 52a, or 52b contact, as the relay will simply invert one signal to provide the other. This option is available in the "CB control column" in the "CB status input" cell and can be programmed as either "None", 52a, 52b or both 52a and 52b.

## 1.18 Selective overcurrent logic

Section 1.19 describes the use of non-cascade protection schemes that make use of start contacts from downstream relays connected to block operation of upstream relays. In the case of Selective Overcurrent Logic (SOL), the start contacts are used to raise the time delays of upstream relays, instead of blocking. This provides an alternative approach to achieving non-cascade types of overcurrent scheme. This may be more familiar to some utilities than the blocked overcurrent arrangement.

The SOL function provides the ability to temporarily increase the time delay settings of the third and fourth stages of phase overcurrent, derived and measured earth fault and sensitive earth fault protection elements. This logic is initiated by energization of the appropriate opto-isolated input.

To allow time for a start contact to initiate a change of setting, the time settings of the third and fourth stages should include a nominal delay.

This function acts upon the following protection functions:

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



The logic diagram for the selective overcurrent function is shown for phase A of the third stage overcurrent function. The principle of operation is identical for the 3-phase phase overcurrent function stages 3 and 4, earth fault function -1 stages 3 and 4, earth fault function -2 stages 3 and 4 and the sensitive earth fault function stages 3 and 4.

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

1. No block applied

   In the event of a fault condition that continuously asserts the start output, the function will assert a trip signal after the normal time delay t>3 has elapsed.

2. Logic input block applied

   In the event of a fault condition that continuously asserts the start output, the function will assert a trip signal after the selective logic time delay t>3 sel has elapsed.

3. Auto-reclose input block applied

   In the event of a fault condition that continuously asserts the start output, when an auto-reclose block is applied the function will not trip. The auto-reclose block also overrides the logic input block and will block the t>3 sel timer.

   It is noted that the Auto-reclose function outputs two signals that block protection, namely; AR Block Maint. Protection and AR Block SEF Protection.

   a) AR Block Maint. Protection is common to the 3-phase overcurrent function stages 3 & 4, earth fault function -1 stages 3 & 4, and earth fault function -2 stages 3 & 4.

   b) AR Block SEF Protection is common to the sensitive earth fault function stages 3 & 4.

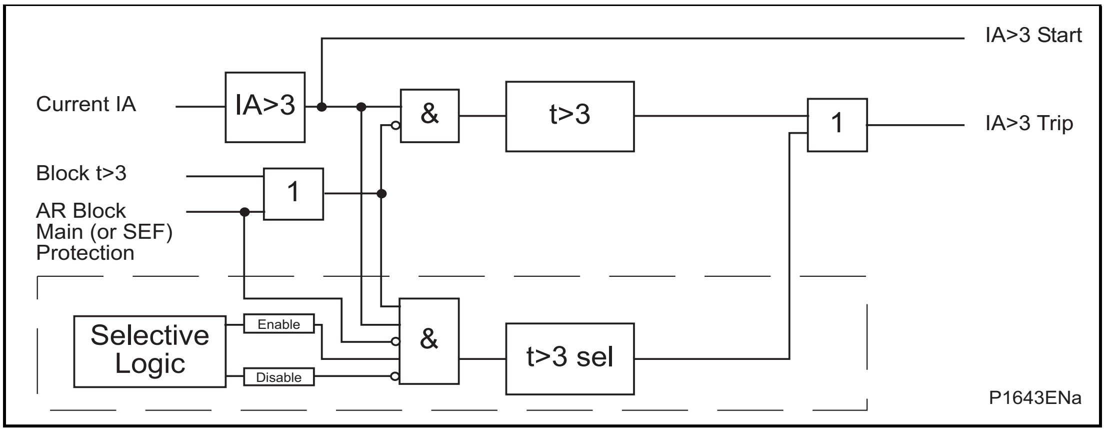



**Figure 29: Selective overcurrent logic**

## 1.19 Blocked overcurrent scheme logic

The P145 relay has start outputs available from each stage of the overcurrent and earth fault elements, including the sensitive earth fault element. These start signals may then be routed to output contacts by programming accordingly. Each stage is also capable of being blocked by being programmed to the relevant opto-isolated input.

To facilitate the implementation of a blocked overcurrent scheme the following logic is implemented to provide the “I> Blocked O/C Start (DDB 348)” signal.

The I> Blocked O/C Start is derived from the logical “OR” of the phase overcurrent start outputs.

The logical “OR” output is then gated with the signal BF Alarm (Block AR) and the setting {I> Start Blocked By CB Fail} as shown in the diagram below:

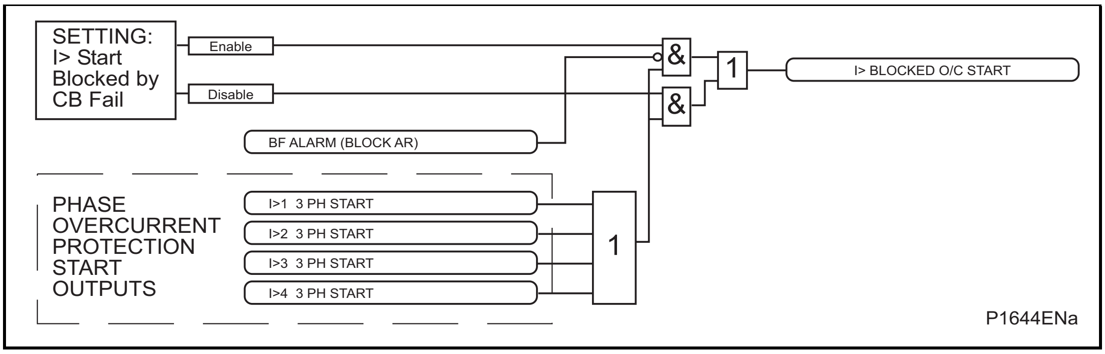



**Figure 30: Overcurrent blocked operation**

For the earth fault and sensitive earth fault element, the following logic is implemented to provide the “IN>/ISEF> Blocked O/C Start (DDB 349)” signal.

The IN>/ISEF> Blocked O/C Start is derived from the logical “OR” of the earth fault and sensitive earth fault signals protection start outputs.

The logical “OR” output is then gated with the signal BF Alarm (Block AR) and the setting {IN>/ISEF> Start Blocked By CB Fail} as shown in Figure 31.

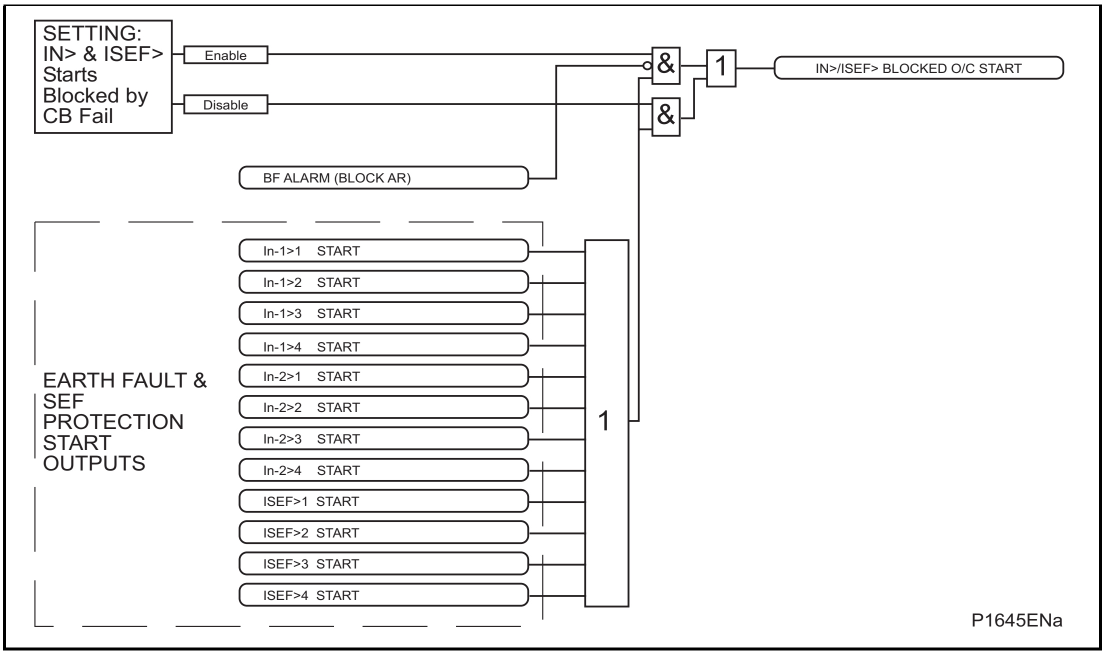



**Figure 31: Earth fault blocked operation**

## 1.20 Neutral admittance protection

Neutral admittance protection is mandatory for the Polish market, deriving its neutral current input from either the E/F CT or the SEF CT by means of a setting. The neutral voltage is based on the internally derived quantity VN.

Three single stage elements are provided:

- Overadmittance YN> that is non-directional, providing both start and time delayed trip outputs. The trip may be blocked by a logic input
- Overconductance GN> that is non-directional/directional, providing both start and time delayed trip outputs. The trip may be blocked by a logic input
- Oversusceptance BN> that is non-directional/directional, providing both start and time delayed trip outputs. The trip may be blocked by a logic input

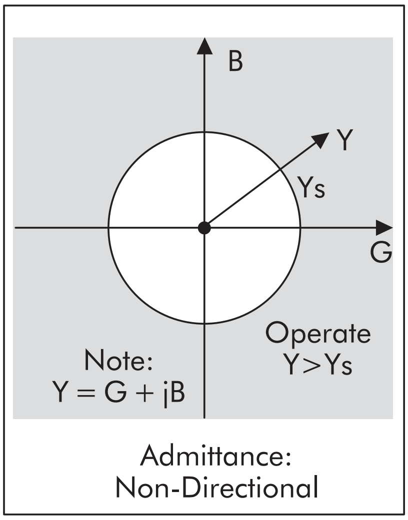
The overadmittance elements YN>, GN> and BN> will operate providing the neutral voltage remains above the set level for the set operating time of the element. They are blocked by operation of the fast VTS supervision output.

The overadmittance elements provide measurements of admittance, conductance and susceptance that also appear in the fault record, providing the protection is enabled.

The overadmittance elements are capable of initiating auto-reclose, similarly to the earth fault protection, by means of YN>, GN> and BN> settings in the AUTO-RECLOSE menu column.

### 1.20.1 Operation of admittance protection

The admittance protection is non-directional. Hence, provided the magnitude of admittance exceeds the set value YN> Set and the magnitude of neutral voltage exceeds the set value VN Threshold, the relay will operate.

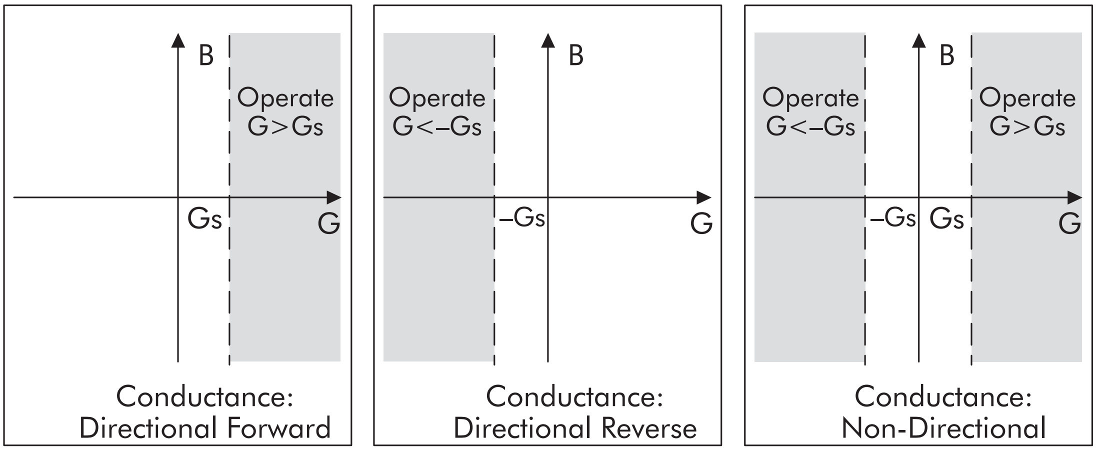



P0153ENa

OP

### 1.20.2 Operation of conductance protection

The conductance protection may be set non-directional, directional forward or directional reverse. Hence, provided the magnitude and the directional criteria are met for conductance and the magnitude of neutral voltage exceeds the set value VN Threshold, the relay will operate. The correction angle causes rotation of the directional boundary for conductance through the set correction angle.




P0154ENa

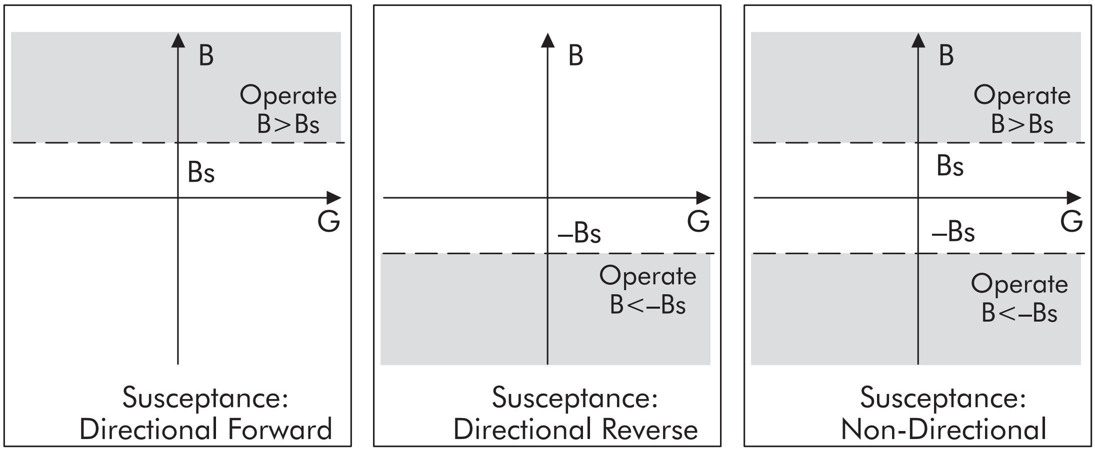
Note the following:

1. Forward operation: Center of characteristic occurs when IN is in phase with VN.

2. If the correction angle is set to +30°, this rotates the boundary from 90° – 270° to 60° – 240°. It is assumed that the direction of the G axis indicates 0°.

### 1.20.3 Operation of susceptance protection

The susceptance protection may be set non-directional, directional forward or directional reverse. Hence, provided the magnitude and the directional criteria are met for susceptance and the magnitude of neutral voltage exceeds the set value VN Threshold, the relay will operate. The correction angle causes rotation of the directional boundary for susceptance through the set correction angle.




P0155ENa

OP

Note the following:

1. Forward operation: Center of characteristic occurs when IN leads VN by 90°.

2. If the correction angle is set to +30°, this rotates the boundary from 0° – 180° to 330° – 150°. It is assumed that the direction of the G axis indicates 0°.

# 2. OPERATION OF NON PROTECTION FUNCTIONS

## 2.1 Three-phase auto-reclosing

The P145 will initiate auto-reclose for fault clearances by the phase overcurrent, earth fault and SEF protections.

In addition to these settings, function links in the "OVERCURRENT", "EARTH FAULT1", "EARTH FAULT2" and "SEF/REF PROT'N" columns are also required to fully integrate the auto-reclose logic in the relay.

The auto-reclose function provides multi-shot three-phase auto-reclose control. It can be adjusted to perform a single shot, two shot, three shot or four shot cycle, selectable via "Number of Shots". There is also the option to initiate a separate auto-reclose cycle with a different number of shots, "Number of SEF Shots", for the SEF protection. Dead times for all shots (reclose attempts) are independently adjustable.

An auto-reclose cycle can be internally initiated by operation of a protection element or externally by a separate protection device, provided the circuit breaker is closed until the instant of protection operation. The dead time "Dead Time 1", "Dead Time 2", "Dead Time 3", "Dead Time 4" starts when the circuit breaker has tripped and optionally when the protection has reset, selectable via "Start Dead t On". At the end of the relevant dead time, a CB close signal is given, provided system conditions are suitable. The system conditions to be met for closing are that the system voltages are in synchronism or dead line/live bus or live line/dead bus conditions exist, indicated by the internal check synchronizing element and that the circuit breaker closing spring, or other energy source, is fully charged indicated from the "DDB 230: CB Healthy" input. The CB close signal is cut-off when the circuit breaker closes.

OP

When the CB has closed the reclaim time "Reclaim Time" starts. If the circuit breaker does not trip again, the auto-reclose function resets at the end of the reclaim time. If the protection operates during the reclaim time the relay either advances to the next shot in the programmed auto-reclose cycle, or, if all programmed reclose attempts have been made, goes to lockout.

CB Status signals must also be available within the relay, i.e. the default setting for "CB Status Input" should be modified accordingly for the application. The default PSL requires 52A, 52B and CB Healthy logic inputs, so a setting of "Both 52A and 52B" is required for the CB Status Input.

### 2.1.1 Logic functions

#### 2.1.1.1 Logic inputs

The auto-reclose function has several Digital Data Bus (DDB) logic inputs, which can be mapped in PSL to any of the opto-isolated inputs on the relay or to one or more of the DDB signals generated by the relay logic. The function of these inputs is described below, identified by their signal text.

##### 2.1.1.1.1 CB healthy

The majority of circuit breakers are only capable of providing one trip-close-trip cycle. Following this, it is necessary to re-establish if there is sufficient energy in the circuit breaker (spring charged, gas pressure healthy, etc.) before the CB can be re-closed. The "DDB 230: CB Healthy" input is used to ensure that there is sufficient energy available to close and trip the CB before initiating a CB close command. If on completion of the dead time, the "DDB 230: CB Healthy" input is low, and remains low for a period given by the "CB Healthy Time" timer, lockout will result and the CB will remain open

This check can be disabled by not allocating an opto input for "DDB 230: CB Healthy". The signal defaults to high if no logic is mapped to DDB 230 within the PSL in the relay

2.1.1.1.2 BAR

The "DDB 239: Block AR" input will block auto-reclose and cause a lockout if auto-reclose is in progress. It can be used when protection operation without auto-reclose is required. A typical example is on a transformer feeder, where auto-reclosing may be initiated from the feeder protection but blocked from the transformer protection.

2.1.1.1.3 Reset lockout

The "DDB 237: Reset Lockout" input can be used to reset the auto-reclose function following lockout and reset any auto-reclose alarms, provided that the signals which initiated the lockout have been removed.

2.1.1.1.4 Auto mode

The "DDB 241: Auto Mode" input is used to select the Auto operating mode; auto-reclose in service. When the "DDB 241: Auto Mode", "DDB 240: Live Line Mode" and "DDB 242: Telecontrol" inputs are off the "Non Auto Mode" of operation is selected; auto-reclose out of service.



2.1.1.1.5 Live line mode

The "DDB 240: Live Line Mode" input is used to select the Live Line operating mode where auto-reclose is out of service and all blocking of instantaneous protection by auto-reclose is disabled. This operating mode takes precedence over all other operating modes for safety reasons, as it indicates that utility personnel are working near live equipment.

2.1.1.1.6 Telecontrol mode

The "DDB 242: Telecontrol" input is used to select the Telecontrol operating mode whereby the Auto and Non Auto modes of operation can be selected remotely.

2.1.1.1.7 Live/Dead Ccts OK

DDB 461: “Live/Dead Ccts OK” is an input to the auto-reclose logic. When AR is enabled with one or both sides of the CB dead (AUTO-RECLOSE GROUP 1 – SYSTEM CHECKS setting [49 43] – Live/Dead Ccts: Enabled), DDB 461 should be mapped in PSL to appropriate combinations of Live Line, Dead Line, Live Bus and Dead Bus signals from the system check logic (DDB 443, 444, 445 & 446), as required for the specific application. If setting 49 43 is Disabled, DDB 461 mapping is irrelevant.

2.1.1.1.8 AR SysChecks OK

DDB 403: “AR Sys. Checks OK” can be mapped in PSL from system checks output DDB 449: “Sys. Chks. Inactive”, to enable auto-reclosing without any system checks, if the system check function is disabled (CONFIGURATION setting 09 23 – System Checks: Disabled). This mapping is not essential, because AUTO-RECLOSE GROUP 1 – SYSTEM CHECKS setting [49 44] – No System Checks can be set to Enabled to achieve the same effect.

DDB 403 can also be mapped to an opto input, to enable the P145 to receive a signal from an external system monitoring relay to indicate that system conditions are suitable for CB closing. This should not normally be necessary, since the P145 has comprehensive built in system check functionality.

2.1.1.1.9 Ext. AR Prot. trip/start

DDB 439: “Ext. AR Prot. Trip” and/or DDB 440: “Ext. AR Prot. Start” allow initiation of auto-reclosing by a separate protection relay. Please refer to section 2.1.2.2 – Auto-reclose Initiation.

2.1.1.1.10 DAR complete

At least one major utility, which uses delayed auto-reclosing (DAR) on most of its transmission network, requires a “DAR in Progress” signal from AR initiation up to the application of the CB Close command, but not during the reclaim time following CB reclosure. DDB 453: “DAR Complete” can, if required, be mapped in PSL to be activated for a short pulse when a CB Close command is given at the end of the dead time. If DDB 453: “DAR Complete” is activated during an auto-reclose cycle, output DDB 456: “AR in Progress 1” resets, even though the reclaim time may still be running and DDB 360: “AR in Progress” remains set until the end of the reclaim time. For most applications, DDB 453 can be ignored, i.e. not mapped in PSL; in such cases, output DDB 456: AR in Progress 1 operates and resets in parallel with DDB 360: AR in Progress.

#### 2.1.1.1.11 CB in service

One of the interlocks in the auto-reclose initiation logic is DDB 454: "CB in Service". This input must be high until the instant of protection operation for an auto-reclose cycle to be initiated. For most applications, this DDB can be mapped simply from the "CB Closed" DDB 379. More complex PSL mapping can be programmed if required, e.g. where it is necessary to confirm not only that the CB is closed but also that the line and/or bus VT is actually live up to the instant of protection operation.

#### 2.1.1.1.12 AR restart

In a very small number of applications, it is sometimes necessary to initiate an auto-reclose cycle via an external signal to an opto input when the normal interlock conditions are not all satisfied, i.e. the CB is open and the associated feeder is dead. If input DDB 455: "AR Restart" is mapped to an opto input, activation of that opto input will initiate an auto-reclose cycle irrespective of the status of the "CB in Service" input, provided the other interlock conditions, such as AR enabled, are still satisfied.



#### 2.1.1.1.13 DT OK to start

This is an optional extra interlock in the dead time initiation logic. In addition to the CB being open and the protection reset, DDB 458: "DT OK to Start" has to be high to enable the dead time function to be "primed" after an AR cycle has started. Once the dead time function is primed, DDB 458 has no further effect – the dead time function stays primed even if DDB 458 subsequently goes low. A typical PSL mapping for this input is from a "Dead Line" signal (DDB 444) from the system check logic, to enable dead time priming only when the feeder has gone dead after CB tripping. If this extra dead time priming interlock is not required, DDB 458 can be left unmapped, and will then default to high.

#### 2.1.1.1.14 Dead time enabled

This is another optional interlock in the dead time logic. In addition to the CB open, protection reset and "dead time primed" signals, DDB 457: "Dead Time Enabled" has to be high to allow the dead time to run. If DDB 457 goes low, the dead time stops and resets, but stays primed, and will restart from zero when DDB 457 goes high again. A typical PSL mapping for DDB 457 is from the CB Healthy input DDB 230, or from selected Live Bus, Dead Line etc. signals from the system check logic. It could also be mapped to an opto input to provide a "hold off" function for the follower CB in a "master/follower" application with 2 CBs. If this optional interlock is not required, DDB 457 can be left unmapped, and will then default to high.

#### 2.1.1.1.15 AR init. trip test

If DDB 464: "AR Init. Trip Test" is mapped to an opto input, and that input is activated momentarily, the relay logic generates a CB trip output via DDB 372, mapped in default PSL to output R3, and initiates an auto-reclose cycle.

#### 2.1.1.1.16 AR skip shot 1

If DDB 530: "AR Skip Shot 1" is mapped to an opto input, and that input is activated momentarily, the relay logic will cause the auto-reclose sequence counter to increment by 1. This will therefore decrease the available reclose shots and will lockout the recloser should the recloser be on its maximum reclose attempt e.g. if the recloser is set to two reclose shots, initiation of the DDB 530 will cause the reclose counter to 1, thus the recloser only has one reclose cycle before it locks out.

### 2.1.1.2 Auto-reclose logic outputs

The following DDB signals can be assigned to a relay contact in the PSL or assigned to a Monitor Bit in "Commissioning Tests", to provide information about the status of the auto-reclose cycle. They can also be applied to other PSL logic as required. The logic output DDBs are described below, identified by their DDB signal text.

2.1.1.2.1 AR in progress

The "DDB 360: AR in Progress" signal is present during the complete reclose cycle from protection initiation to the end of the reclaim time or lockout. DDB 456: “AR in Progress 1” operates with DDB 360 at auto-reclose initiation, and, if DDB 453: “DAR Complete” does not operate, remains operated until DDB 360 resets at the end of the cycle. If DDB 453 goes high during the auto-reclose cycle, DDB 456 resets (see notes on logic input “DAR Complete” above).

2.1.1.2.2 Sequence counter status

During each auto-reclose cycle, a “Sequence Counter” increments by 1 after each fault trip, and resets to zero at the end of the cycle.

DDB 362: “Seq. Counter = 0” is set when the counter is at zero;

DDB 363: “Seq. Counter = 1” is set when the counter is at 1;

DDB 364: “Seq. Counter = 2” is set when the counter is at 2;



DDB 365: “Seq. Counter = 3” is set when the counter is at 3;

and

DDB 366: “Seq. Counter = 4” is set when the counter is at 4.

2.1.1.2.3 Successful close

The "DDB 367: Successful Close" output indicates that an auto-reclose cycle has been successfully completed. A successful auto-reclose signal is given after the CB has tripped from the protection and reclosed whereupon the fault has been cleared and the reclaim time has expired resetting the auto-reclose cycle. The successful auto-reclose output is reset at the next CB trip or from one of the reset lockout methods; see section 2.1.2.8.1. ’Reset from lockout’.

2.1.1.2.4 AR in service

The "DDB 361: AR in service" output indicates whether the auto-reclose is in or out of service. Auto-reclose is in service when the relay is in Auto mode and out of service when in the Non Auto and Live Line modes.

2.1.1.2.5 Block main prot.

The "DDB 358: Block Main Prot." output indicates that the instantaneous protection "I>3", "I>4", "IN1>3", "IN1>4", "IN2>3", "IN2>4" is being blocked by the auto-reclose logic during the auto-reclose cycle. Blocking of the instantaneous stages for each trip of the auto-reclose cycle is programmed using the Overcurrent and Earth Fault 1/2 function link settings, "I> Function Link", "IN1> Func. Link", "IN2> Func. Link", and the "Trip 1/2/3/4/5 Main" settings; see section 2.1.2.3 ‘Blocking instantaneous protection during an auto-reclose cycle’.

2.1.1.2.6 Block SEF prot.

The "DDB 359: Block SEF Prot." output indicates that the instantaneous SEF protection "ISEF>3, ISEF>4" is being blocked by the auto-reclose logic during the auto-reclose cycle. Blocking of the instantaneous SEF stages for each trip of the auto-reclose cycle is programmed using the SEF/REF Prot’n. function link setting, "ISEF> Func. Link", and the "Trip 1/2/3/4/5 SEF" settings; see section 2.1.2.3 ‘Blocking instantaneous protection during an auto-reclose cycle’.

2.1.1.2.7 Reclose checks

DDB 460: “Re-close Checks” operates when the dead time function is “primed” (see notes on logic input “DT OK to Start”, above).

2.1.1.2.8 Dead T in prog.

The "DDB 368: Dead T in Prog." output indicates that the dead time is in progress. This signal is set when DDB 460: “Re-close Checks” is set AND input DDB 457: “Dead Time Enabled” is high, and may be useful during relay commissioning to check the operation of the auto-reclose cycle.

2.1.1.2.9 DT complete

DDB 459: "DT Complete" operates at the end of the set dead time, and remains operated until either the scheme resets at the end of the reclaim time or a further protection operation/AR initiation occurs. It can be applied purely as an indication, or included in PSL mapping to logic input DDB 453: "DAR Complete" if required (see logic input notes).

2.1.1.2.10 System checks indication

DDB 462: "AR Sync. Check" operates when either of the synchro check modules, if selected for auto-reclosing, confirms an "in synchronism" condition.

DDB 463: "AR Sys. Checks OK" operates when any selected system check condition (synchro check, live bus/dead line etc.) is confirmed.

2.1.1.2.11 Auto close

The "DDB 371: Auto Close" output indicates that the auto-reclose logic has issued a close signal to the CB. This output feeds a signal to the control close pulse timer and remains on until the CB has closed. This signal may be useful during relay commissioning to check the operation of the auto-reclose cycle.



2.1.1.2.12 "Trip when AR blocked" indication

DDB 369: "Protection Lockt." operates if AR lockout is triggered by protection operation either during the inhibit period following a manual CB close (see section 2.1.2.7 – "Auto-reclose inhibit following manual close"), or when the relay is in Non Auto or Live Line mode (see section 2.1.2.8 – "AR lockout").

2.1.1.2.13 Reset lockout indication

DDB 370: "Reset Lckout Alm." operates when the relay is in Non Auto mode, if setting 49 22 – "Reset Lockout by" – is set to "Select Non Auto". See section 2.1.2.8.1 – 'Reset from lockout'.

2.1.1.3 Auto-reclose alarms

The following DDB signals will produce a relay alarm. These are described below, identified by their DDB signal text.

2.1.1.3.1 AR no checksync. (latched)

The "DDB 165: AR No Check Sync." alarm indicates that the system voltages were not suitable for auto-reclosing at the end of the check sync. window time (Sys. Check Time), leading to a lockout condition. This alarm can be reset using one of the reset lockout methods; see section 2.1.2.8.1 'Reset from lockout'.

2.1.1.3.2 AR CB unhealthy (latched)

The "DDB 164: AR CB Unhealthy" alarm indicates that the "DDB 230: CB Healthy" input was not energized at the end of the "CB Healthy Time", leading to a lockout condition. The "DDB 230: CB Healthy" input is used to indicate that there is sufficient energy in the CB operating mechanism to close and trip the CB at the end of the dead time. This alarm can be reset using one of the reset lockout methods; see section 2.1.2.8.1 'Reset from lockout'.

2.1.1.3.3 AR lockout (self reset)

The "DDB 163: AR Lockout" alarm indicates that the relay is in a lockout status and that further reclose attempts will not be made; see section 2.1.2.8 'AR Lockout' for more details. This alarm can be reset using one of the reset lockout methods; see section 2.1.2.8.1 'Reset from lockout'.

## 2.1.2 Main operating features

### 2.1.2.1 Operation modes

The auto-reclosing function has three operating modes:

1. AUTO MODE — Auto-reclose in service
2. NON AUTO MODE — Auto-reclose out of service – selected protection functions are blocked if setting "AR Deselected" [4914] = Block Inst. Prot.
3. LIVE LINE MODE — Auto-reclose out of service – protection functions are NOT blocked, even if setting "AR Deselected" [4914] = Block Inst. Prot. LIVE LINE MODE is a functional requirement by some utilities, for maximum safety during live line working on the protected feeder.



For any operating mode to be selected, CONFIGURATION menu setting "Auto-reclose" [0924] must first be set to "Enabled". The required operating mode can then be selected by different methods, to suit specific application requirements. The basic method of mode selection is determined by AUTO-RECLOSE Group n menu setting "AR Mode Select" [4091], as summarized in the following table:

| A/R Mode Select Setting | Description |
|---|---|
| COMMAND MODE | Auto/Non Auto is selected by command cell "Auto-reclose Mode". |
| OPTO SET MODE | If DDB 241: Auto Mode input is high Auto operating mode is selected (Auto-reclose is in service).<br>If DDB 241: Auto Mode input is low Non Auto operating mode is selected (Auto-reclose is out of service and instantaneous protection is blocked). |
| USER SET MODE | If DDB 242: Telecontrol input is high, the CB Control Auto-reclose Mode is used to select Auto or Non Auto operating mode.<br>If DDB 242: Telecontrol input is low, behaves as OPTO SET setting. |
| PULSE SET MODE | If DDB 242: Telecontrol input is high, the operating mode is toggled between Auto and Non Auto Mode on the falling edge of DDB 241: Auto Mode input pulses. The pulses are produced by SCADA system.<br>If DDB 242: Telecontrol input is low, behaves as OPTO SET setting. |

Note: If "Live Line Mode" input DDB 240 is active, the scheme is forced into LIVE LINE MODE, irrespective of the AR Mode Select setting and Auto Mode and Telecontrol input DDBs.

Live Line Mode input DDB 240 and Telecontrol input DDB 242 are provided to meet the requirements of some utilities who apply a four position selector switch to select AUTO, NON AUTO or LIVE Line operating modes, as shown in Figure 32.

OP

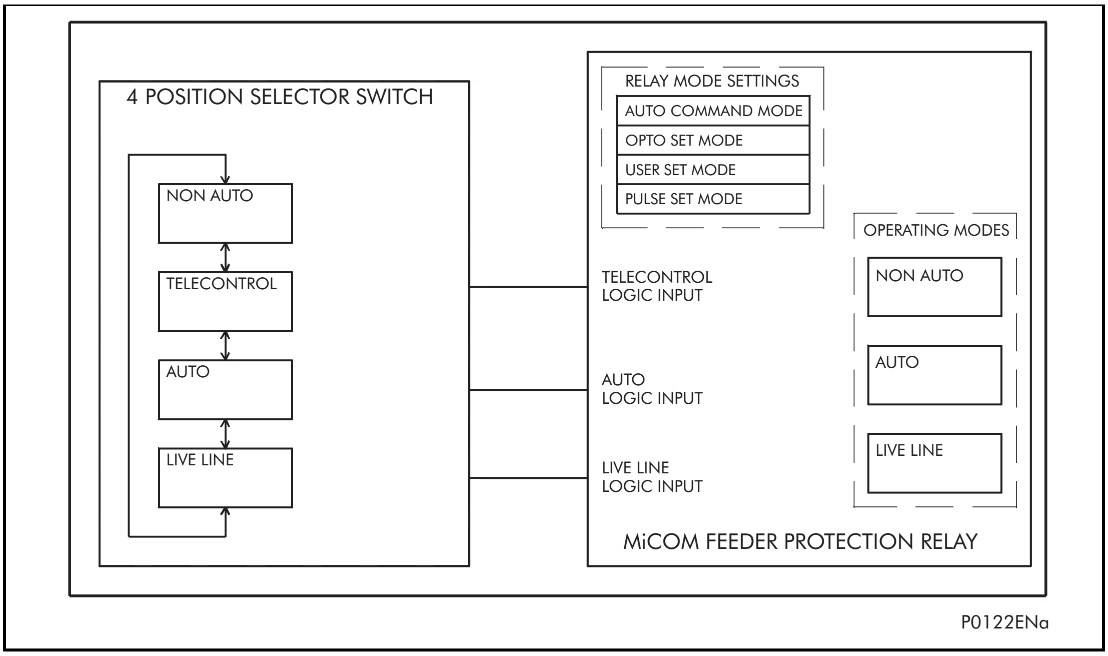



**Figure 32: Operating modes**

For this application, the four position switch is arranged to activate relay inputs as shown in the table below:

| Switch | Input Logic Signals | | |
|---|---|---|---|
| Position | Auto | Telecontrol | Live Line |
| Non Auto | 0 | 0 | 0 |
| Telecontrol | 0 or SCADA Pulse | 1 | 0 |
| Auto | 1 | 0 | 0 |
| Live Line | 0 | 0 | 1 |

Operating mode selection logic is shown in Figure 33.

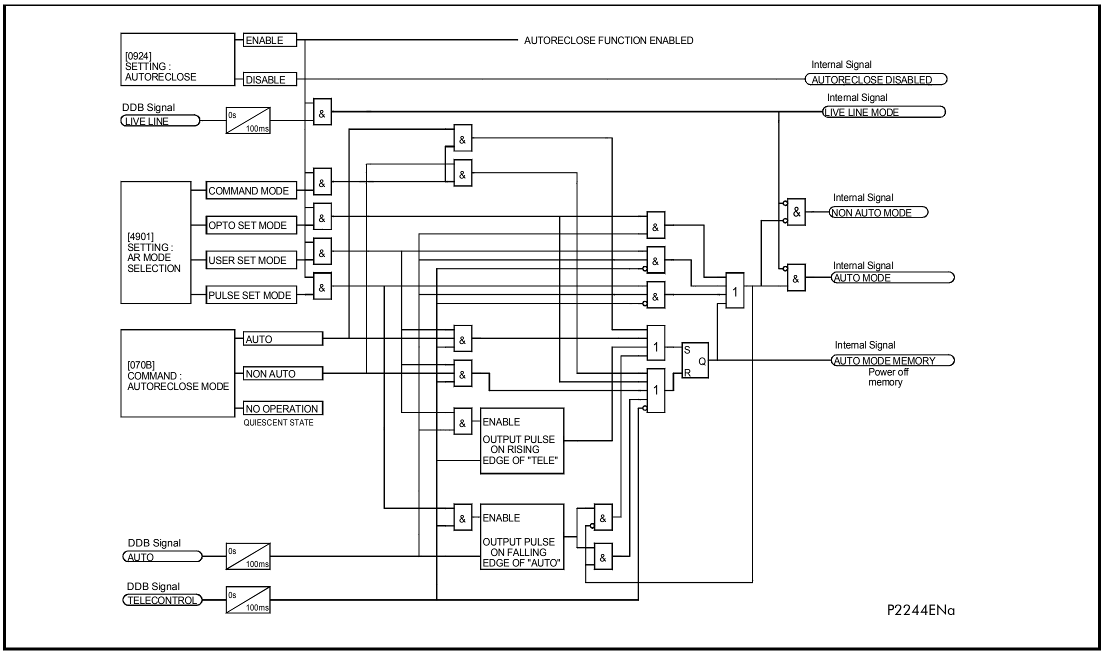



**Figure 33: Mode select functional diagram**

The mode selection logic includes a 100ms delayed drop off on Auto Mode, Telecontrol and Live Line Mode logic inputs, to ensure a predictable change of operating modes even if the four position switch does not have make-before-break contacts. The logic also ensures that when the switch is moved from Auto or Non Auto position to Telecontrol, the scheme remains in the previously selected mode (Auto or Non Auto) until a different mode is selected by remote control.

The status of the AUTO MODE MEMORY signal is stored in non volatile memory to ensure that the selected operating mode is restored following an auxiliary power interruption.

For applications where live line operating mode and remote selection of Auto/Non-auto modes are not required, a simple two position switch can be arranged to activate Auto Mode input DDB 241, with DDB 240 and DDB 242 being unused.

### 2.1.2.2 Auto-reclose initiation



Auto-reclose is usually initiated from the internal protection of the relay. The stages of overcurrent and earth fault protection can be programmed to initiate auto-reclose, "Initiate Main AR", not initiate auto-reclose, "No Action", or block auto-reclose, "Block AR". High set instantaneous protection may be used to indicate a transformer fault on a transformer feeder and so be set to "Block AR". The stages of sensitive earth fault protection can be programmed to initiate auto-reclose, "Initiate Main AR", initiate SEF auto-reclose, "Initiate SEF AR", not initiate auto-reclose, "No Action", or block auto-reclose, "Block AR". Normally, SEF protection operation is due to a permanent fault and is set for "No Action". These settings are found under the "AR INITIATION" settings. For example if "I>1" is set to "Initiate Main AR", operation of the "I>1" protection stage will initiate auto-reclose; if ISEF>1 is set to "No Action", operation of the ISEF>1 protection stage will lead to a CB trip but no reclose.

A selection must be made for each protection stage that is enabled.

A separate protection device may also externally initiate auto-reclose. In this case, the following DDB signals should be mapped to logic inputs:

DDB 439: Ext. AR Prot. Trip

DDB 440: Ext. AR Prot. Start (if appropriate)

The setting EXT. PROT. should be set to "Initiate Main AR".

The auto-reclose can be initiated from a protection start, when sequence co-ordination is required, and from a protection trip.

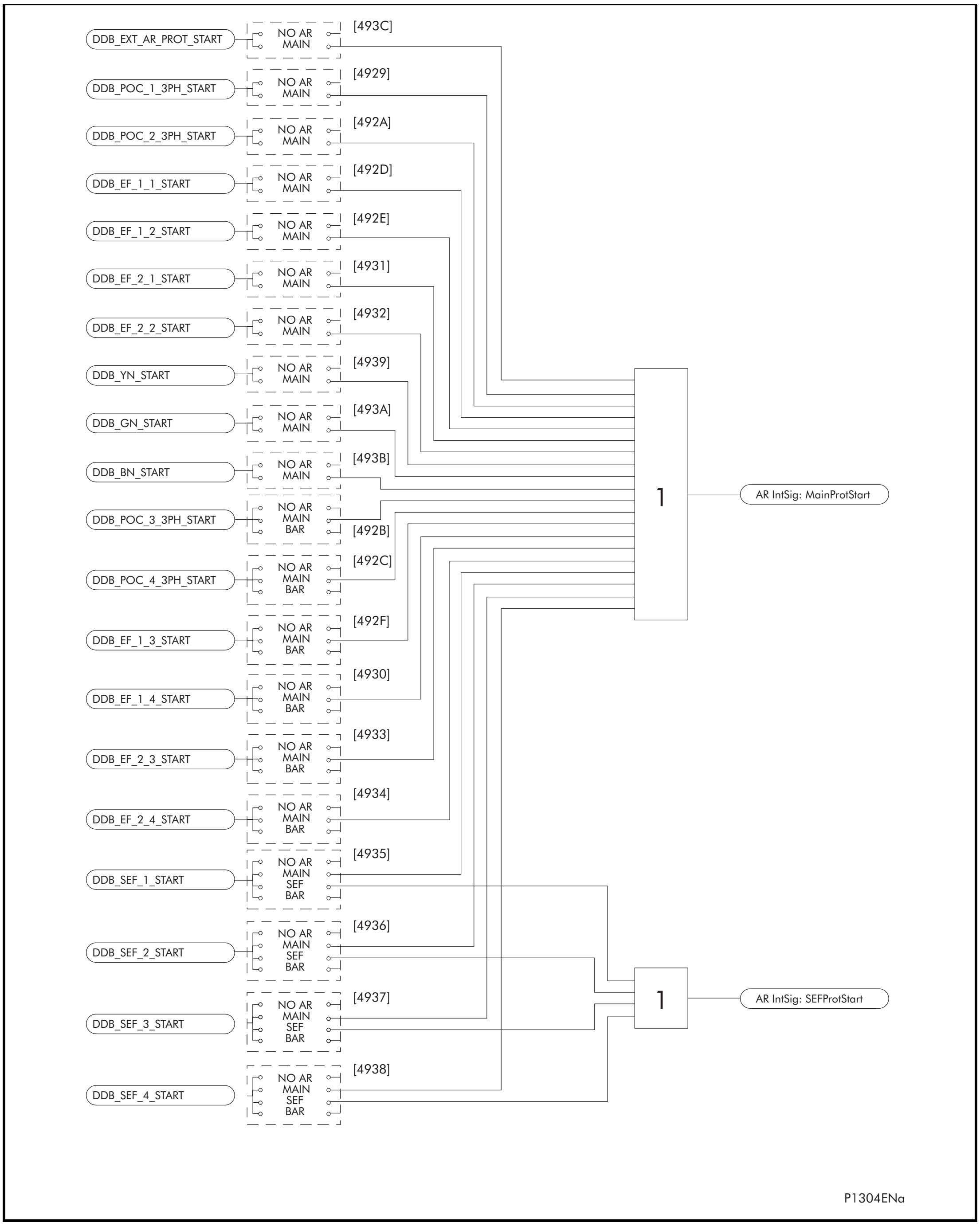



**Figure 34: "Protection start" signals**

Figure 34 illustrates how the start signal is generated and Figure 35, demonstrates how the protection trip signal is produced. Figure 35 also shows how the block auto-reclose is performed together with external AR initiation. Auto-reclose blocking is discussed in detail in section 2.1.2.8.

OP

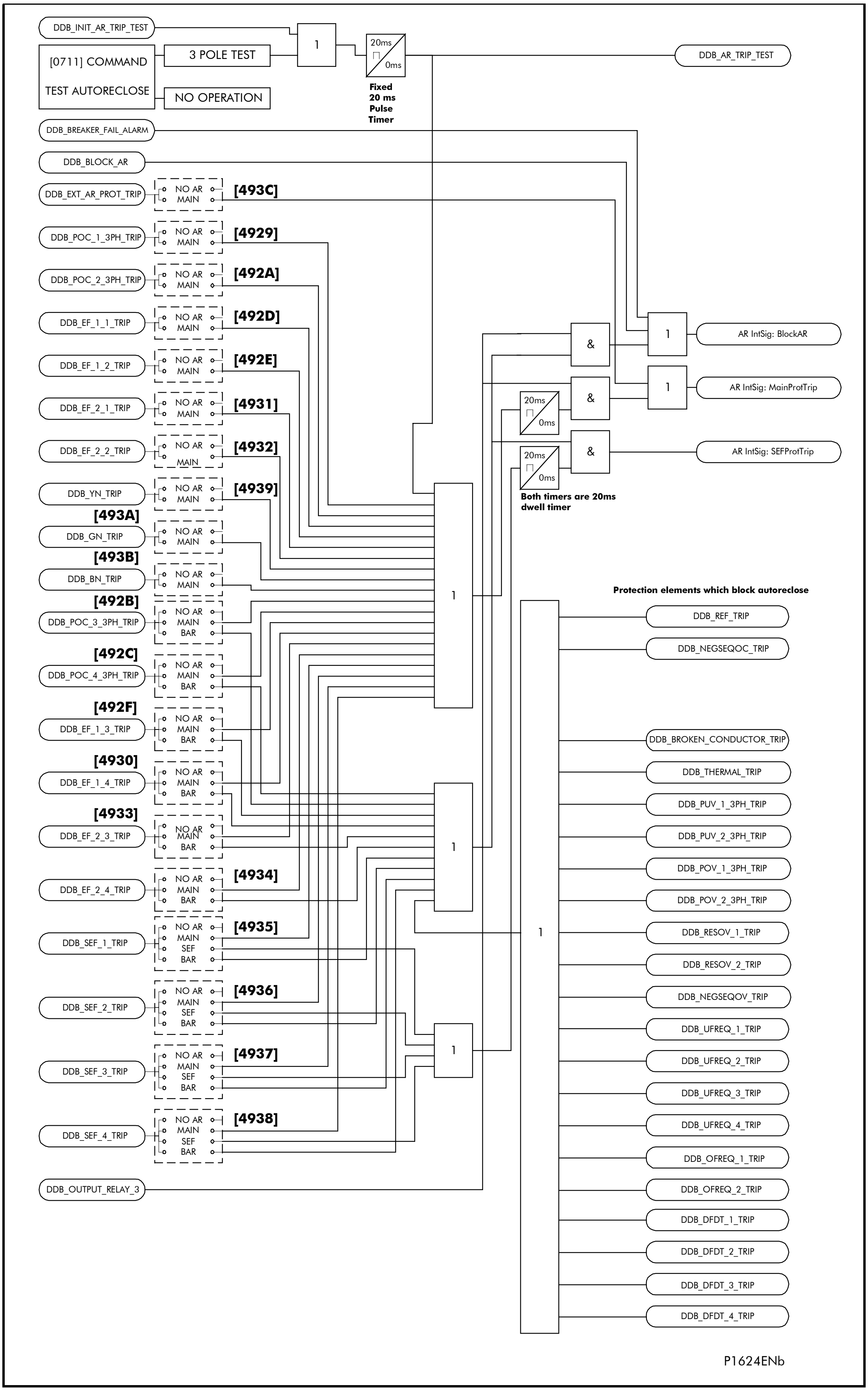



**Figure 35: Auto-reclose blocking logic**

Although a protection start and a protection trip can initiate an AR cycle, several checks still have to be performed before the initiate signal is given. Some of the checks are listed below:

- Auto mode has been selected (AR in service)
- Live line mode is disabled
- The number of main protection and SEF shots have not been reached (“Man High Shots” and SEF “High Shots” Signals see Figure 18).
- Sequence co-ordination enabled (required only for protection start to initiate AR; not necessary for protection trip)
- CB lockout not set
- CB “In Service” (DDB 454 is high)

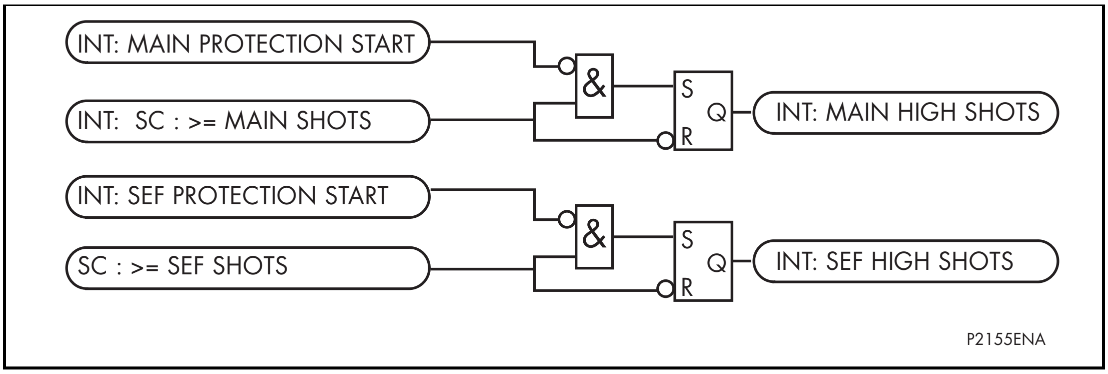



**Figure 36: Shots exceeded logic**

OP

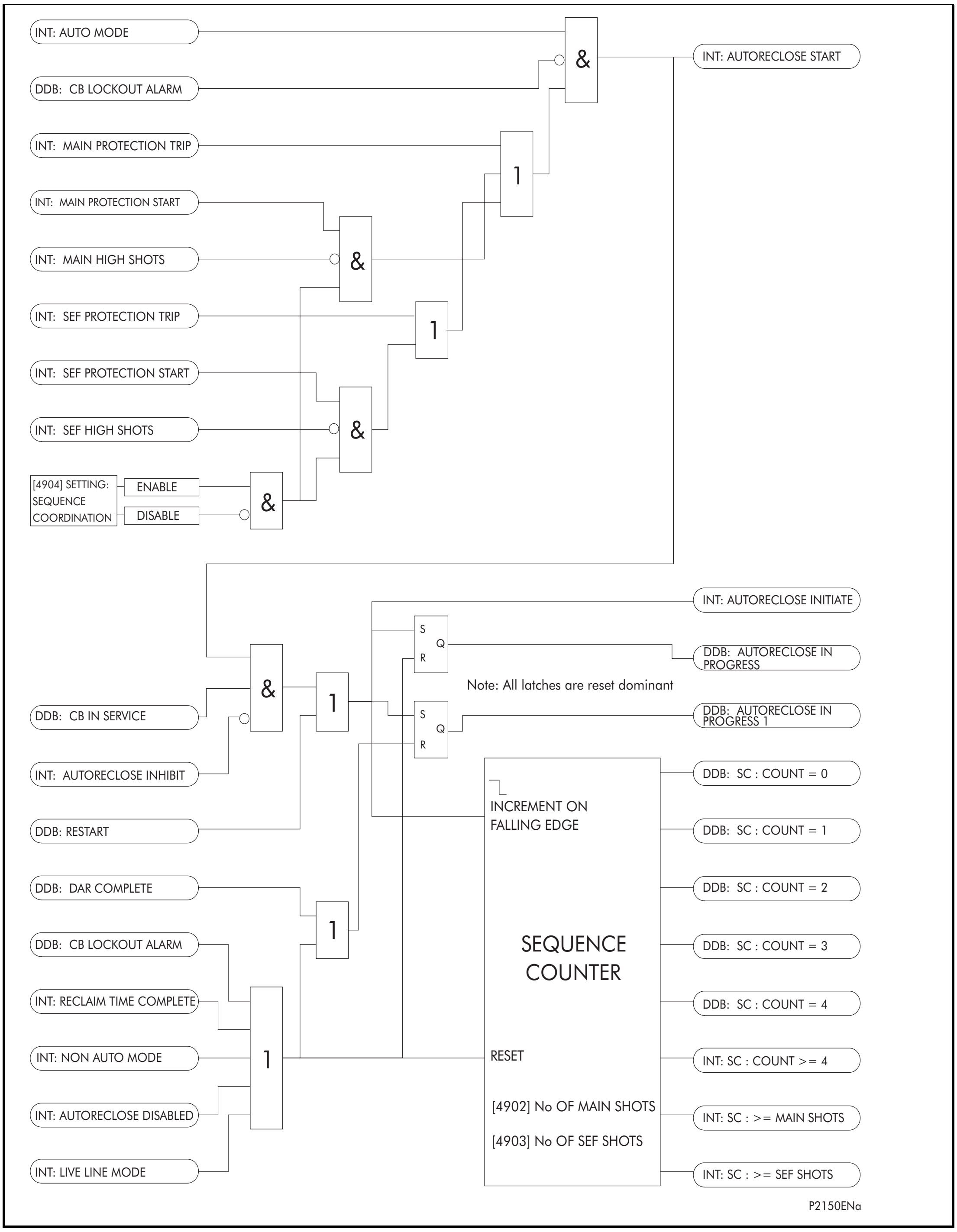



**Figure 37: AR initiation and sequence counter**

Figure 37 illustrates how the auto-reclose is initiated.

### 2.1.2.3 Blocking instantaneous protection during an AR cycle

Instantaneous protection may be blocked or not blocked for each trip in an auto-reclose cycle. This is selected using the "Trip 1/2/3/4/5 Main" and "Trip 1/2/3/4/5 SEF" settings. These allow the instantaneous elements of phase, earth fault and SEF protection to be selectively blocked for a CB trip sequence. For example, if "Trip 1 Main" is set to "No Block" and "Trip 2 Main" is set to "Block Inst. Prot.", the instantaneous elements of the phase and earth fault protection will be available for the first trip but blocked afterwards for the second trip during the auto-reclose cycle. This is clearly illustrated in Figure 38.

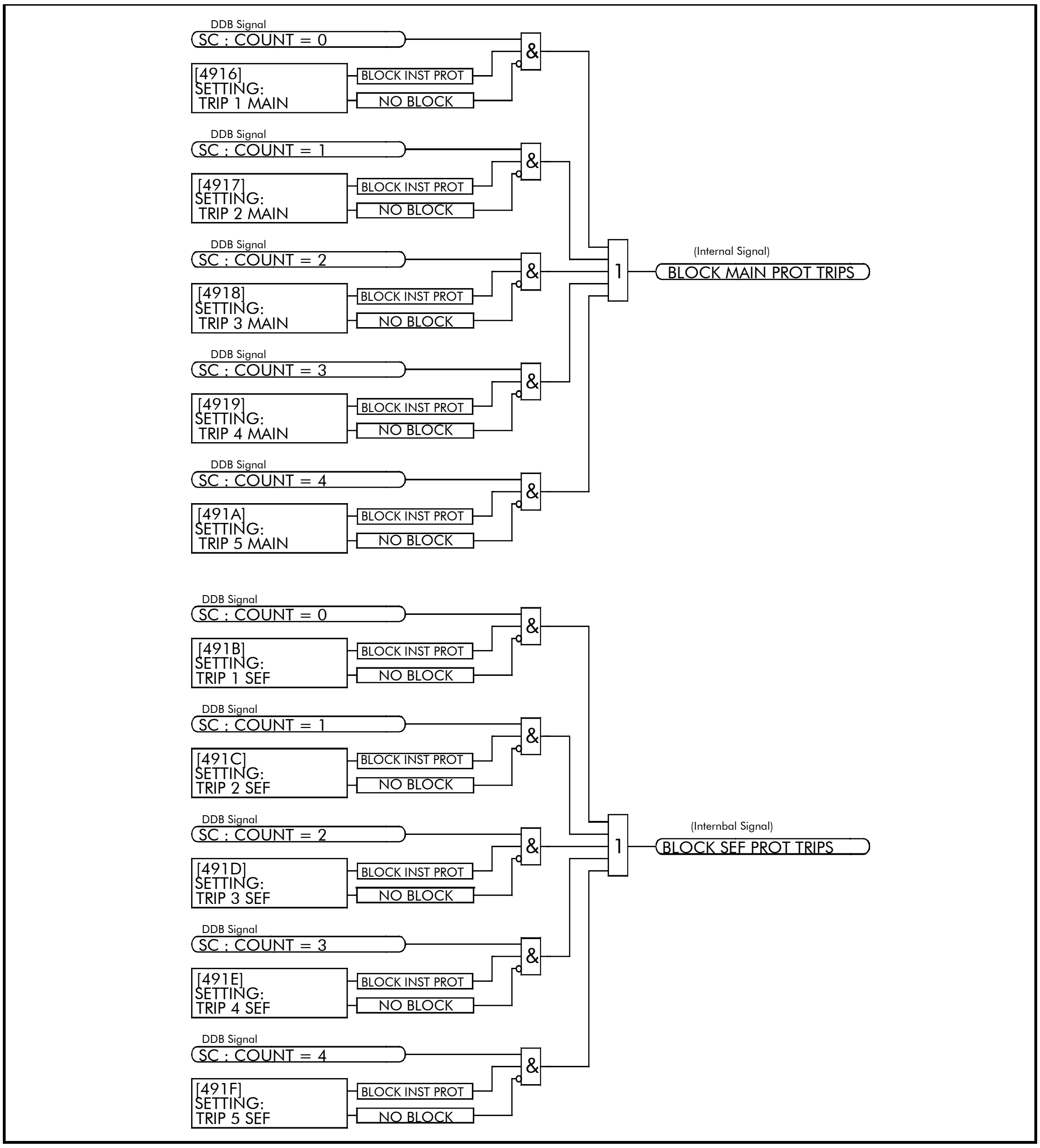



**Figure 38: "Block instantaneous protection" for selected trips**

Instantaneous protection can also be blocked when the CB maintenance lockout counter or excessive fault frequency lockout has reached its penultimate value. For example, if "No CB Ops. Lock" is set to 100 and the "CB Operations = 99", the instantaneous protection can be blocked to ensure that the last CB trip before lockout will be due to discriminative protection operation.

This is controlled using the "EFF Maint. Lock" setting, if this is set to "Block Inst. Prot." the instantaneous protection will be blocked for the last CB Trip before lockout occurs.

Instantaneous protection can also be blocked when the relay is locked out, using the "A/R Lockout" setting, "No Block/Block Inst. Prot.". It can also be blocked after a manual close using the "Manual Close" setting, "No Block/Block Inst. Prot." or when the relay is in the Non Auto mode using the "A/R Deselected" setting "No Block/Block Inst. Prot.". The logic for these features is shown in Figure 39.

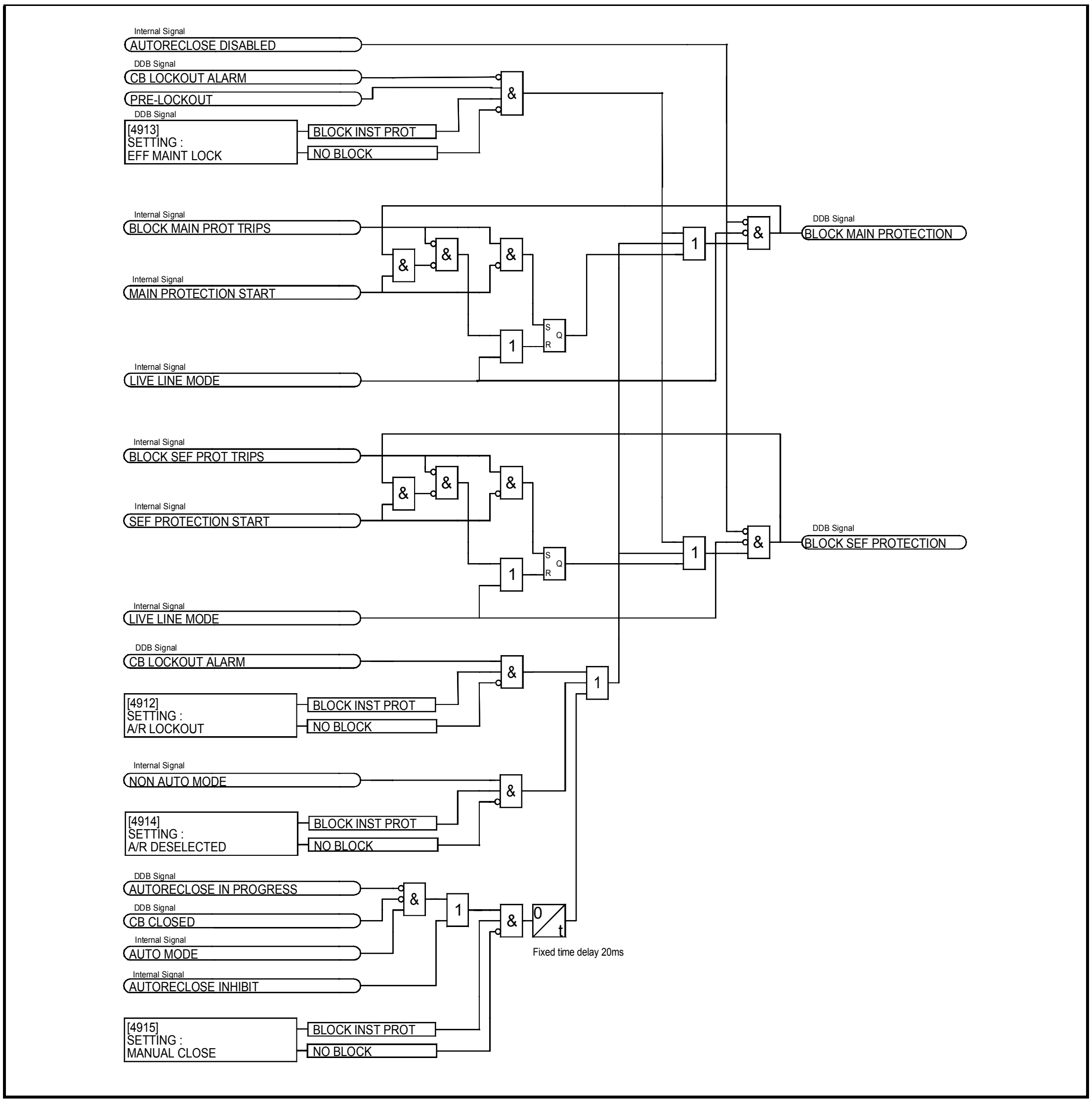



**Figure 39: "Block instantaneous protection" for AR unavailable or maintenance/EFF lockout**

Note: The instantaneous protection stages must be identified in the Overcurrent, Earth Fault1, Earth Fault2 and SEF/REF Prot'n. function link settings, "I> Blocking", "IN1> Blocking", "IN2> Blocking" and "ISEF> Blocking" respectively.

External protection may be blocked by mapping DDB 358 "Block Main Prot." Or DDB 359 "Block SEF Prot." to appropriate output relay contacts.

### 2.1.2.4 Dead time control

Dead time is "primed" (DDB 460 – Reclose Checks – set) when:

- the CB has tripped, and
- (optionally via setting "Start Dead t On"), the protection has reset, and
- DDB 458 - DT OK to Start - goes high

Dead time remains "primed" until the protection re-operates, or the scheme resets at the end of the auto-reclose cycle.

Once primed, the dead timer starts to run when DDB 457 – Dead Time Enabled is high.

Setting “CS AR Immediate” Enabled allows immediate re-closure of the circuit breaker provided both sides of the circuit breaker are live and in synchronism at any time after the dead time has started. This allows for quicker load restoration, as it is not necessary to wait for the full dead time.

If “CS AR Immediate” is disabled, or Line and Bus volts are not both live, the dead timer will continue to run, assuming the “DDB 457: Dead Time Enabled” (mapped in PSL) is asserted high. The “Dead Time Enabled” function could be mapped to an opto input to indicate that the circuit breaker is healthy i.e. spring charged etc. Mapping the “Dead Time Enabled” function in PSL increases the flexibility by allowing it, if necessary, to be triggered by other conditions such as “Live Line/Dead Bus” for example. If “Dead Time Enabled” is not mapped in PSL, it defaults to high, so the dead time can run.

The dead time control logic is illustrated in Figure 40.

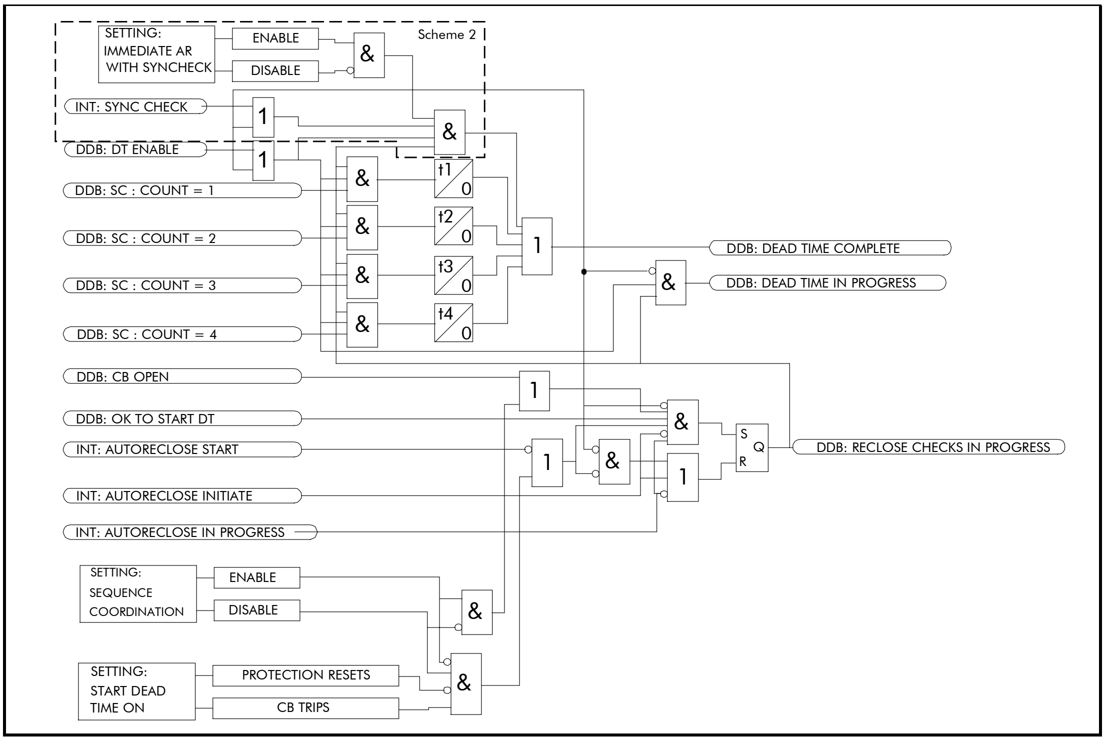



**Figure 40: Dead time control**

Once the dead time is completed or a synchronism check is confirmed, the “Auto-close” signal is given, provided both the “CB Healthy” and the “System Checks” are satisfied. (See Figure 41: “System Checks”). The “Auto-close” signal triggers a “CB Close” command via the CB Control functionality (see section 2.10).

The “AR CB Close Control” Logic is illustrated in Figure 41.

OP

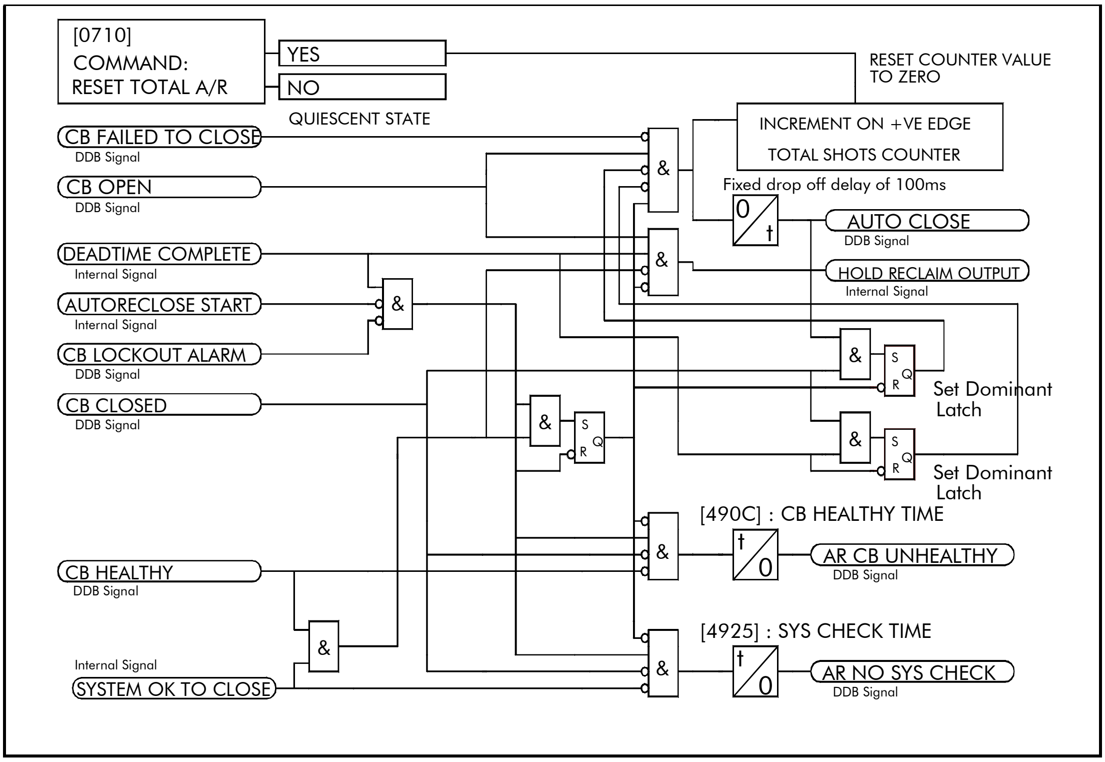



**Figure 41: AR CB close control**

### 2.1.2.5 System checks

The permission to initiate an auto-reclose depends upon the following System Check settings:

- **Live/Dead Ccts** - When enabled this setting will give an "AR Check Ok" signal when the "DDB 461 Circuits OK" is asserted high. This logic input DDB would normally be mapped in PSL to appropriate combinations of Line Live, Line Dead, Bus Live and Bus Dead DDB signals. Auto-reclose can be initiated once DDB 461 is asserted high
- **No System Checks** - When enabled this setting completely disables system checks thus allowing auto-reclose initiation
- **Sys. Chk. on Shot 1** - Can be used to disable system checks on first AR shot
- **AR with Chk. Sync.** - Only allows auto-reclose when the system satisfies the "Check Sync. Stage 1" settings (SYSTEM CHECKS menu)
- **AR with Sys. Sync.** - Only allows auto-reclose when the system satisfies the "Check Sync. Stage 2" settings (SYSTEM CHECKS menu)

The "SYSTEM CHECKS" logic can be found in Figure 42.

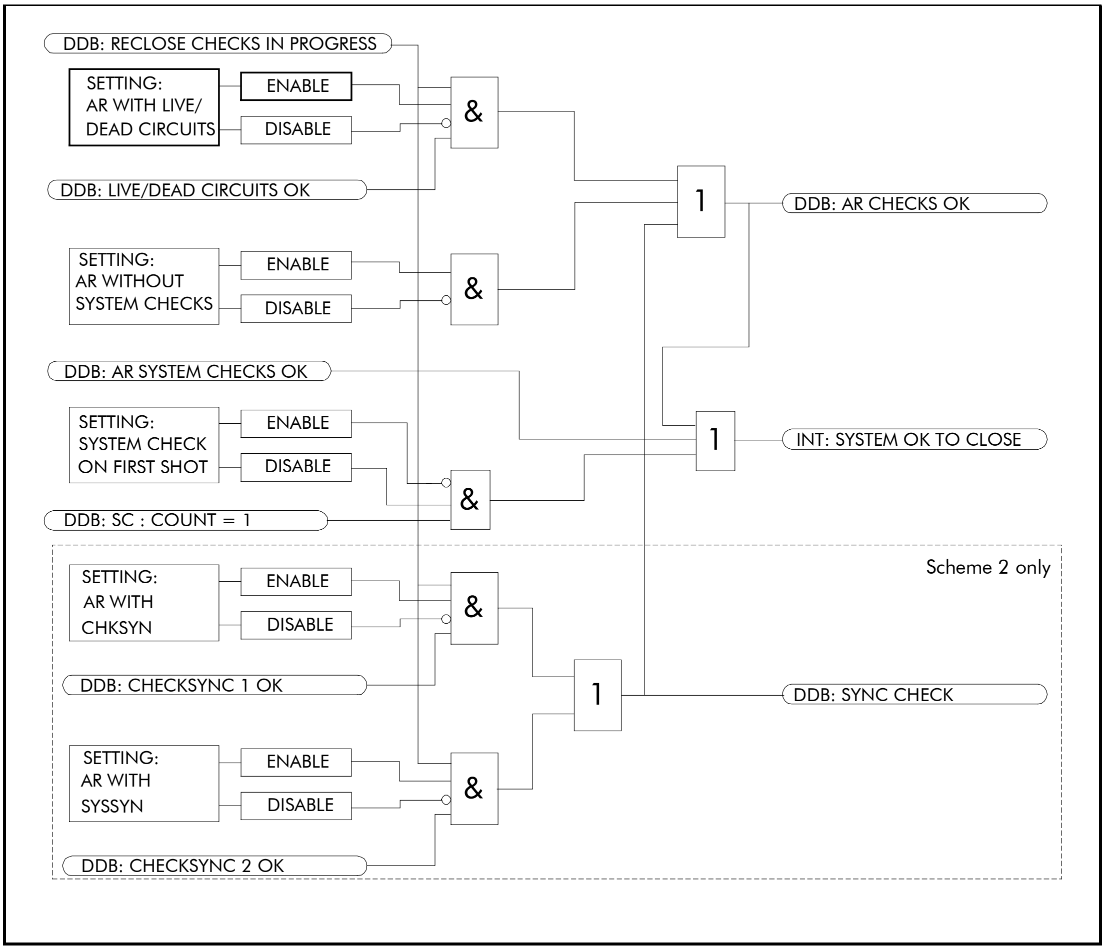



**Figure 42: System checks**

### 2.1.2.6 Reclaim timer initiation

The “tReclaim Extend” setting allows the user to control whether the timer is suspended from the protection start contacts or not. When a setting of “No Operation” is used the Reclaim Timer will operate from the instant that the CB is closed and will continue until the timer expires. The "Reclaim Time" must, therefore, be set in excess of the time delayed protection operating time to ensure that the protection can operate before the auto-reclose function is reset. If the auto-reclose function resets before the time delayed protection has operated instantaneous protection could be re-enabled and discriminating tripping lost.

For certain applications it is advantageous to set “tReclaim Extend” to “On Prot. Start”. This facility allows the operation of the reclaim timer to be suspended after CB re-closure by a signal from the main protection start or SEF protection start signals. The main protection start signal is initiated from the start of any protection which has been selected to "Initiate Main AR" (initiate auto-reclose) in the "AR Initiation" settings. The SEF protection start signal is initiated from the start of any SEF protection that has been selected to "Initiate SEF AR" (initiate SEF auto-reclose) in the "AR Initiation" settings. This feature ensures that the reclaim time cannot time out and reset the auto-reclose before the time delayed protection has operated. Since the Reclaim Timer will be suspended, it is unnecessary to use a timer setting in excess of the protection operating time, therefore a short reclaim time can be used. Short reclaim time settings can help to prevent unnecessary lockout for a succession of transient faults in a short period, for example during a thunderstorm. For more information, please refer to the Reclaim Timer logic in Figure 43.

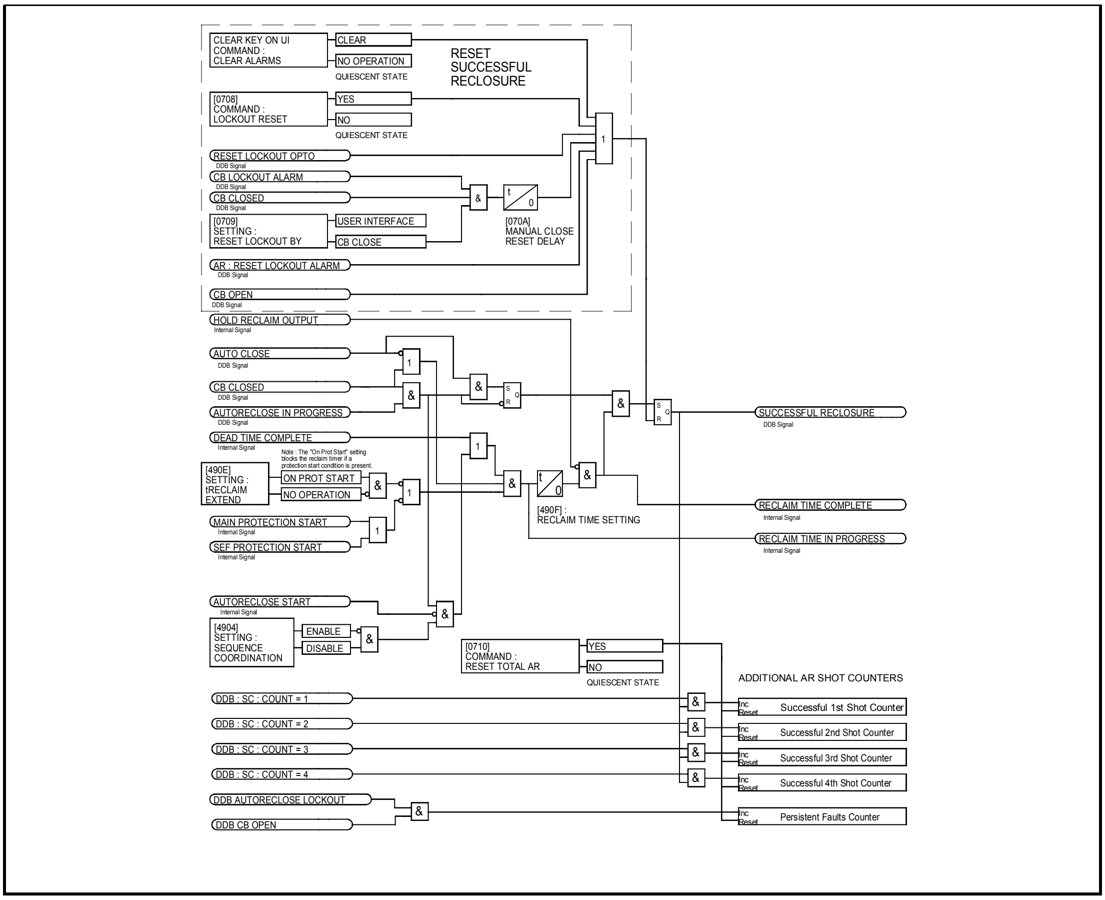



**Figure 43: Reclaim time/AR successful logic**

2.1.2.7 Auto-reclose inhibit following manual close

To ensure that auto-reclosing is not initiated for a manual CB closure on to a pre-existing fault (switch on to fault), AUTO-RECLOSE menu setting "A/R on Man Close" can be set to "Inhibited". With this setting, auto-reclose initiation is inhibited for a period equal to setting "A/R Inhibit Time" following a manual CB closure. The logic for A/R Inhibit is shown in Figure 44.

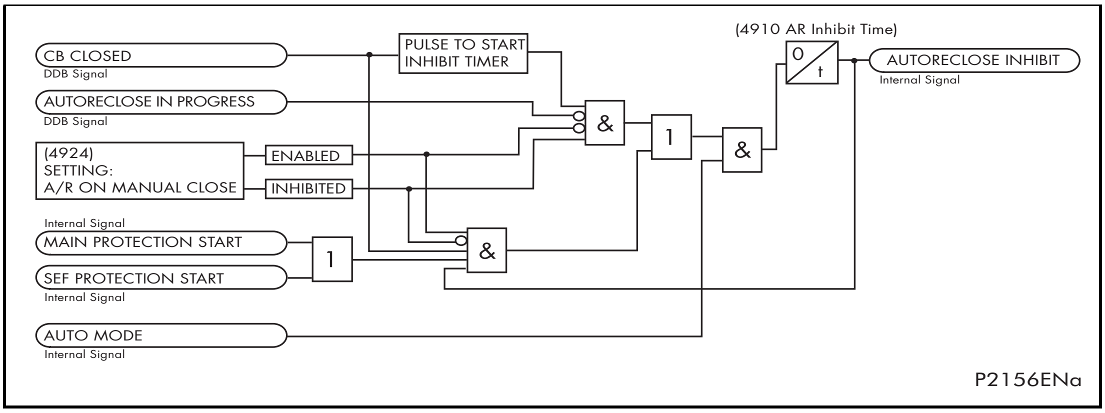



**Figure 44: AR initiation inhibit**

If a protection operation occurs during the inhibit period, auto-reclosing is not initiated. A further option is provided by setting "Man Close on Flt"; if this is set to "Lockout", auto-reclose is locked out (DDB 163: AR Lockout – see section 2.1.1.3.3) for a fault during the inhibit period following manual CB closure. If "Man Close on Flt" is set to "No Lockout", the CB trips without re-closure, but auto-reclose is not locked out.

If it is required to block selected fast non-discriminating protection to obtain fully discriminative tripping during the AR initiation inhibit period following CB manual close, setting “Manual Close” can be set to “Block Inst. Prot.”. A “No Block” setting will enable all protection elements immediately on CB closure. (See also section 2.1.1.3.3).

If setting “A/R on Man Close” is set to “Enabled”, auto-reclosing can be initiated immediately on CB closure, and settings “A/R Inhibit Time”, “Man Close on Flt” and “Manual Close” are irrelevant.

Settings “A/R on Man Close”, “A/R Inhibit Time”, “Man Close on Flt” and “Manual Close” are all in the AUTO-RECLOSE menu.

### 2.1.2.8 AR lockout

If protection operates during the reclaim time, following the final reclose attempt, the relay will be driven to lockout and the auto-reclose function will be disabled until the lockout condition is reset. This will produce an alarm, "DDB 163: AR Lockout". The "DDB 239: Block AR" input will block auto-reclose and cause a lockout if auto-reclose is in progress.

Auto-reclose lockout can also be caused by the CB failing to close because the CB springs are not charged/low gas pressure or there is no synchronism between the system voltages indicated by the "DDB 164: AR CB Unhealthy" and "DDB 165: AR No Check Sync." alarms. The functionality, described above, is illustrated in the AR Lockout logic diagram in Figure 45.

OP

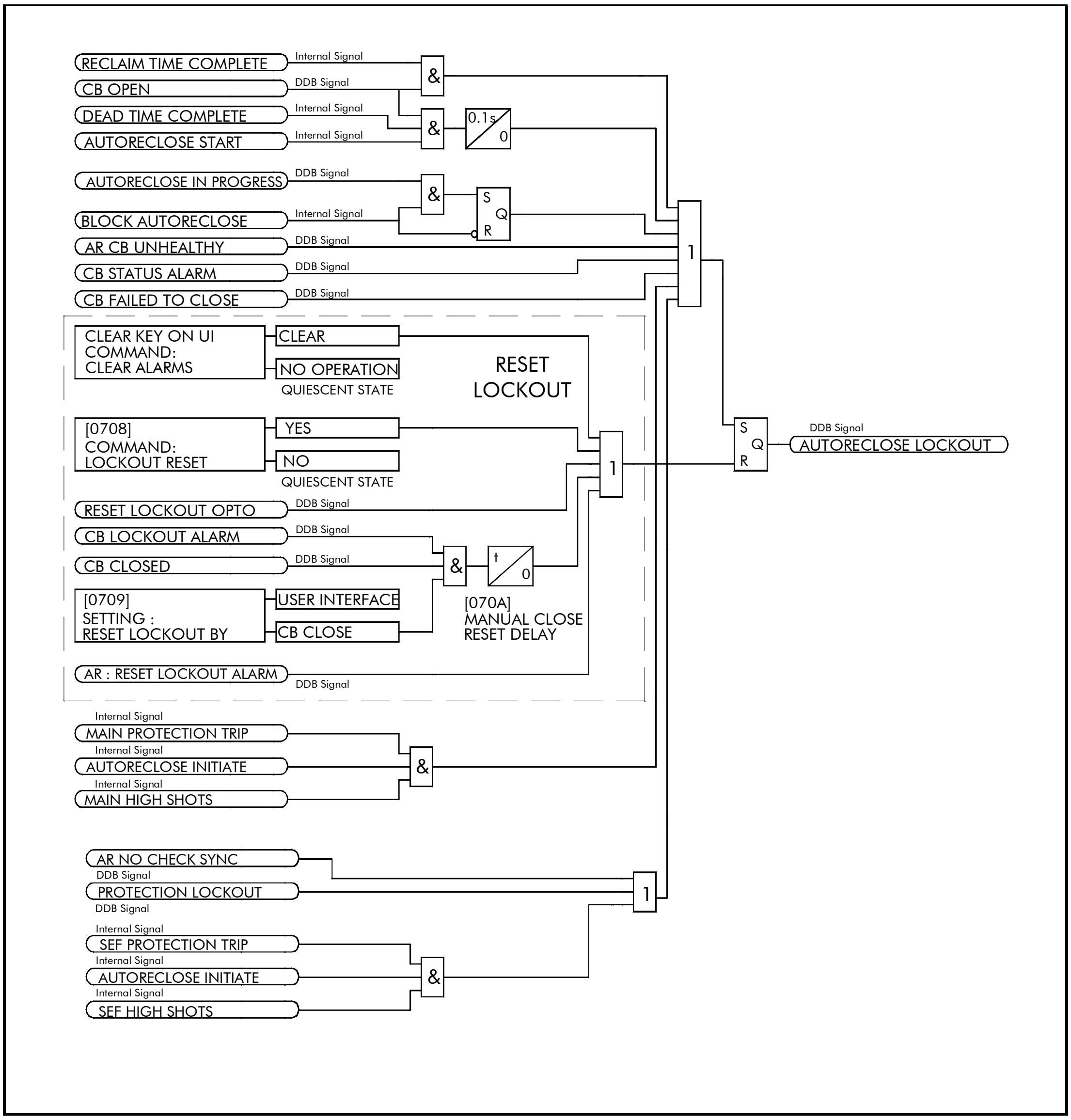



**Figure 45: Overall AR lockout logic**

AR lockout may also be due to a protection operation when the relay is in the Live Line or Non Auto modes when "Trip AR Inactive" is set to "Lockout". Auto-reclose lockout can also be caused by a protection operation after manual closing during the "AR Inhibit Time" when the "Manual Close on Flt." setting is set to Lockout.

Figure 46 shows the logic associated with these functions.

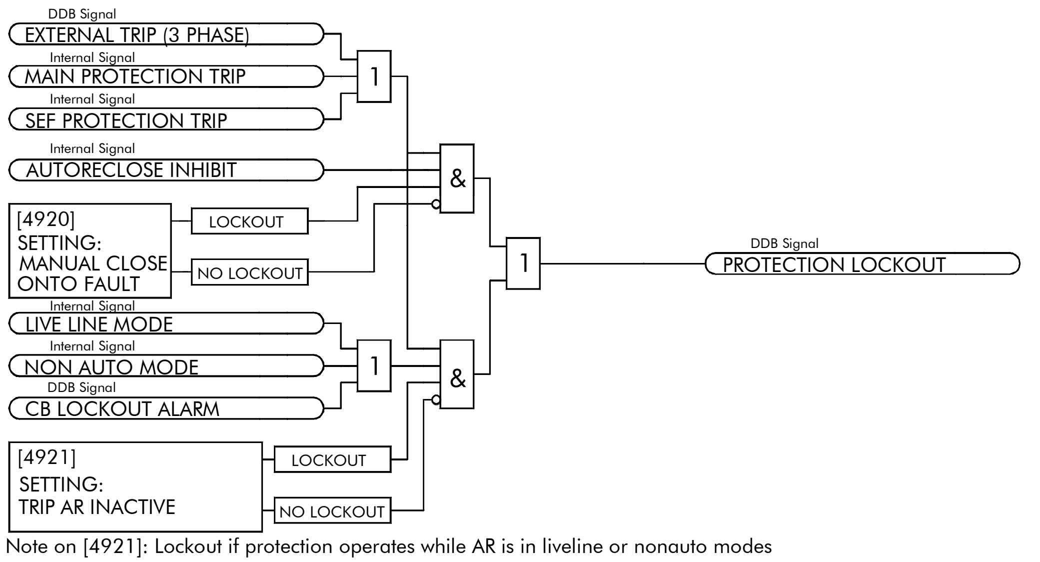



**Figure 46: Lockout for protection trip when AR not available**

Note: Lockout can also be caused by the CB condition monitoring functions, maintenance lockout, excessive fault frequency lockout, broken current lockout, CB failed to trip, CB failed to close, manual close no check synchronism and CB unhealthy.

2.1.2.8.1 Reset from lockout

The "DDB 237: Reset Lockout" input can be used to reset the auto-reclose function following lockout and reset any auto-reclose alarms, provided that the signals which initiated the lockout have been removed. Lockout can also be reset from the clear key or the "CB CONTROL" command "Lockout Reset".

The "Reset Lockout by" setting, "CB Close/User interface" in "CB CONTROL" (0709) is used to enable/disable reset of lockout automatically from a manual close after the manual close time "Man. Close Rst. Dly.". The "Reset Lockout by" setting, "Select Non Auto/User interface" in "AUTO-RECLOSE" (4922) is used to enable/disable the resetting of lockout when the relay is in the Non Auto operating mode. The reset lockout methods are summarized in the following table:

| Reset Lockout Method | When Available? |
|---|---|
| User Interface via the “Clear” key. Note - this will also reset all other protection flags | Always |
| User interface via “CB Control” Command “Lockout Reset | Always |
| Via opto input “Reset lockout” | Always |
| Following a successful manual close if “Reset Lockout by” (CB CONTROL menu) is set to “CB Close” after “Man. Close Rst. Dly.” time | Only when set |
| By selecting “Non Auto” mode, provided “Reset Lockout by” (AUTO-RECLOSE menu) is set to “Select Non Auto” | Only when set |



2.1.2.9 Sequence co-ordination

The auto-reclose setting "Sequence Co-ord." can be used to enable the selection of sequence co-ordination with other protection devices, such as downstream pole mounted reclosers. The main protection start or SEF protection start signals indicate to the relay when fault current is present, advance the sequence count by one and start the dead time whether the breaker is open or closed. When the dead time is complete and the protection start inputs are off the reclaim timer will be initiated. This is illustrated in Figure 40.

Both the upstream and downstream auto-reclose relay should be programmed with the same number of shots to lockout and number of instantaneous trips before instantaneous protection is blocked. Thus, for a persistent downstream fault using sequence co-ordination both auto-reclose relays will be on the same sequence count and will be blocking instantaneous protection at the same time and so correct discrimination can be obtained. When sequence co-ordination is disabled, the breaker has to be tripped to start the dead time and advance the sequence count by one.

For some applications with downstream pole mounted reclosers when using sequence co-ordination it may be desirable to re-enable instantaneous protection when the recloser has locked out. When the downstream recloser has locked out there is no need for discrimination. This allows the user to have instantaneous then IDMT and then instantaneous trips again during an auto-reclose cycle. Instantaneous protection may be blocked or not blocked for each trip in an auto-reclose cycle using the "Trip 1/2/3/4/5 Main" and "Trip 1/2/3/4/5 SEF" settings, "Block Inst. Prot./No Block".

2.1.2.10 Check synchronizing for first reclose

The “Sys. Chk. on Shot 1”, (within SYSTEM CHECKS sub menu of AUTO-RECLOSE) setting is used to "Enable/Disable" system checks for the first reclose in an auto-reclose cycle. This may be preferred when high speed auto-reclose is applied to avoid the extra time for a synchronism check. Subsequent reclose attempts in a multi-shot cycle will still require a synchronism check.

## 2.2 Trip LED logic

The trip LED can be reset when the flags for the last fault are displayed. The flags are displayed automatically after a trip occurs, or can be selected in the fault record menu. The reset of trip LED and the fault records is performed by pressing the ⓒ key once the fault record has been read.

Setting “Sys. Fn. Links” (SYSTEM DATA Column) to logic “1” sets the trip LED to automatic reset. Resetting will occur when the circuit is reclosed and the “Any Pole Dead” signal (DDB 380) has been reset for three seconds. Resetting, however, will be prevented if the “Any start” signal is active after the breaker closes. This function is particularly useful when used in conjunction with the auto-reclose logic, as it will prevent unwanted trip flags being displayed after a successful reclosure of the breaker.

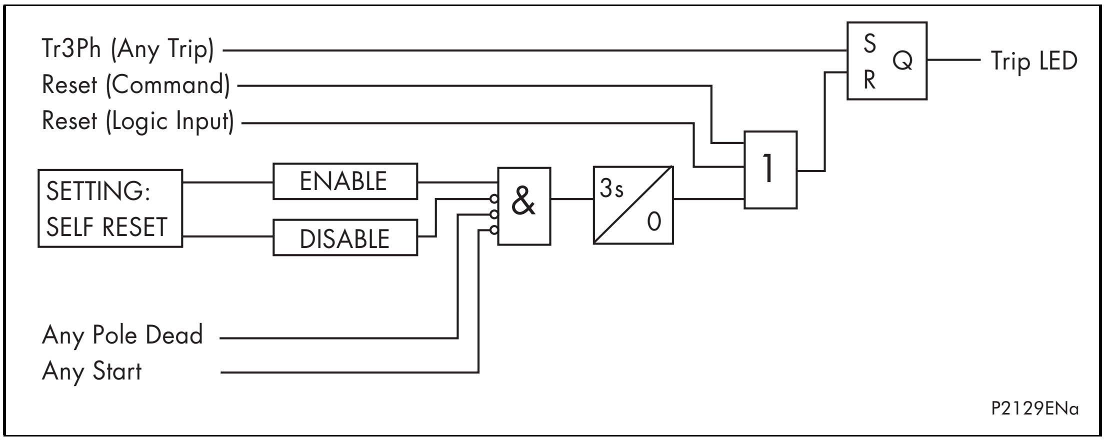



**Figure 47: Trip LED logic diagram**

OP

## 2.3 Check synchronism

### 2.3.1 Overview

In some situations it is possible for both "bus" and "line" sides of a circuit breaker to be live when the circuit breaker is open, for example at the ends of a feeder which has a power source at each end. Therefore, when closing the circuit breaker, it is normally necessary to check that the network conditions on both sides are suitable, before giving a CB Close command. This applies to both manual circuit breaker closing and auto-reclosure. If a circuit breaker is closed when the line and bus voltages are both live, with a large phase angle, frequency or magnitude difference between them, the system could be subjected to an unacceptable shock, resulting in loss of stability, and possible damage to connected machines.

System checks involve monitoring the voltages on both sides of a circuit breaker, and, if both sides are live, performing a synchronism check to determine whether the phase angle, frequency and voltage magnitude differences between the voltage vectors, are within permitted limits.

The pre-closing system conditions for a given circuit breaker depend on the system configuration and, for auto-reclosing, on the selected auto-reclose program. For example, on a feeder with delayed auto-reclosing, the circuit breakers at the two line ends are normally arranged to close at different times. The first line end to close usually has a live bus and a dead line immediately before reclosing, and charges the line (dead line charge) when the circuit breaker closes. The second line end circuit breaker sees live bus and live line after the first circuit breaker has reclosed. If there is a parallel connection between the ends of the tripped feeder, they are unlikely to go out of synchronism, i.e. the frequencies will be the same, but the increased impedance could cause the phase angle between the two voltages to increase. Therefore the second circuit breaker to close might need a synchronism check, to ensure that the phase angle has not increased to a level that would cause unacceptable shock to the system when the circuit breaker closes.

If there are no parallel interconnections between the ends of the tripped feeder, the two systems could lose synchronism, and the frequency at one end could "slip" relative to the other end. In this situation, the second line end would require a synchronism check comprising both phase angle and slip frequency checks.

If the second line end busbar has no power source other than the feeder that has tripped; the circuit breaker will see a live line and dead bus assuming the first circuit breaker has reclosed. When the second line end circuit breaker closes the bus will charge from the live line (dead bus charge).

2.3.2 VT selection

The P145 has a three-phase “Main VT” input and a single-phase “Check Sync. VT” input. Depending on the primary system arrangement, the main three-phase VT for the relay may be located on either the busbar side or the line side of the circuit breaker, with the check sync. VT being located on the other side. Hence, the relay has to be programmed with the location of the main VT. This is done via the “Main VT Location” setting in the CT & VT RATIOS menu.

The Check Sync. VT may be connected to either a phase to phase or phase to neutral voltage, and for correct synchronism check operation, the relay has to be programmed with the required connection. The “C/S Input” setting in the CT & VT RATIOS menu should be set to A-N, B-N, C-N, A-B, B-C or C-A as appropriate.

2.3.3 Basic functionality

System check logic is collectively enabled or disabled as required, by setting “System Checks” in the CONFIGURATION menu. The associated settings are available in SYSTEM CHECKS, sub-menus VOLTAGE MONITORS, CHECK SYNC. and SYSTEM SPLIT. If “System Checks” is selected to Disabled, the associated SYSTEM CHECKS menu becomes invisible, and a **Sys. checks inactive** DDB signal is set.



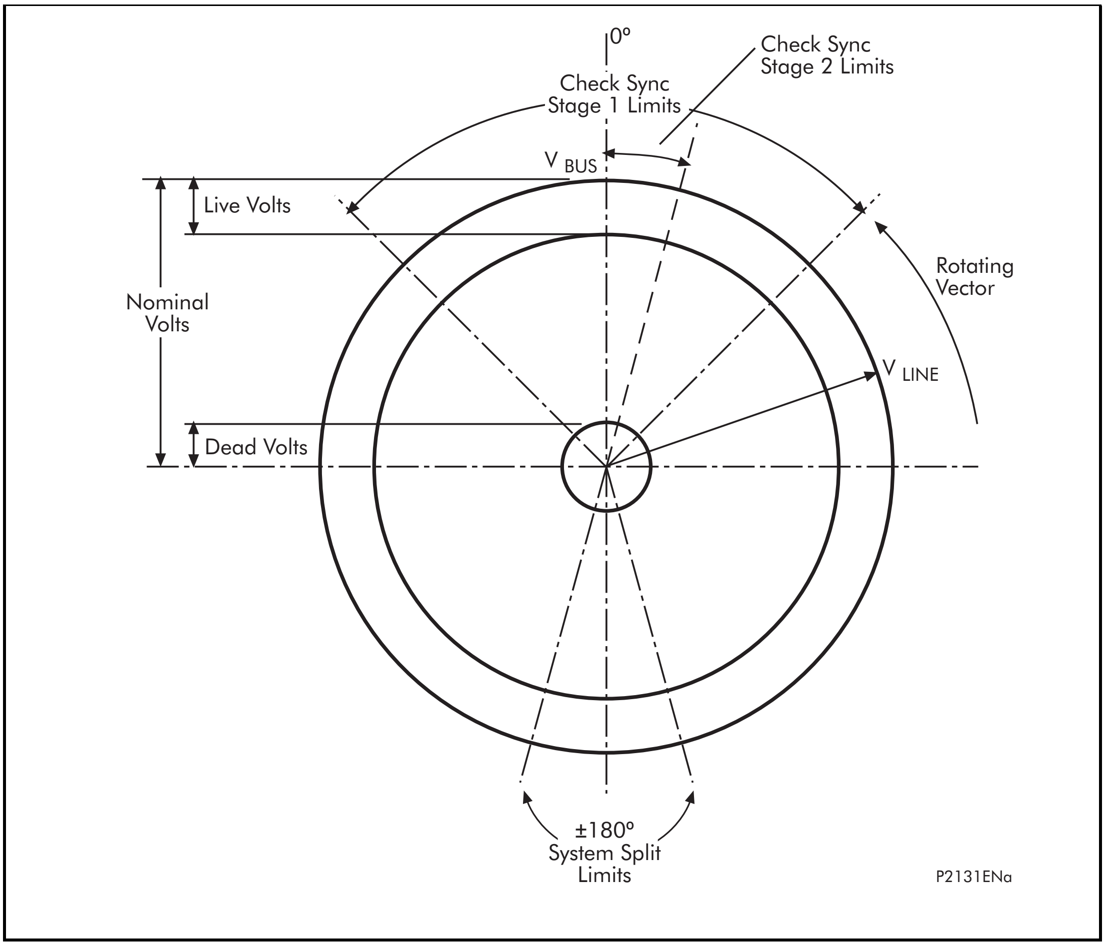



**Figure 48: Synchro check and synchro split functionality**

The overall “Check Sync.” and “System Split” functionality is illustrated in Figure 48.

In most situations where synchronism check is required, the Check Sync. 1 function alone will provide the necessary functionality, and the Check Sync. 2 and System Split signals can be ignored.

### 2.3.3.1 Synchronism check

Check Sync. 1 and Check Sync. 2 are two synchro check logic modules with similar functionality, but independent settings (see Figure 49).

For either module to function:

the System Checks setting must be Enabled

AND

the individual Check Sync. 1(2) Status setting must be Enabled

AND

the module must be individually "enabled", by activation of DDB signal Check Sync. 1(2) Enabled, mapped in PSL.

When enabled, each logic module sets its output signal when:



Line volts and bus volts are both live (Line Live and Bus Live signals both set)

AND

measured phase angle is < Check Sync. 1(2) Phase Angle setting

AND

(for Check Sync. 2 only), the phase angle magnitude is decreasing (Check Sync. 1 can operate with increasing or decreasing phase angle provided other conditions are satisfied)

AND

if Check Sync. 1(2) Slip Control is set to Frequency or Frequency + Timer, the measured slip frequency is < Check Sync. 1(2) Slip Freq. Setting

AND

if Check Sync. Voltage Blocking is set to OV, UV + OV, OV + DiffV or UV + OV + DiffV, both line volts and bus volts magnitudes are < Check Sync. Overvoltage setting

AND

if Check Sync. Voltage Blocking is set to UV, UV + OV, UV + DiffV or UV + OV + DiffV, both line volts and bus volts magnitudes are > Check Sync. Undervoltage setting

AND

if Check Sync. Voltage Blocking is set to DiffV, UV + DiffV, OV + DiffV or UV + OV + DiffV, the voltage magnitude difference between line volts and bus volts is < Check Sync. Diff. Voltage setting

AND

if Check Sync. 1(2) Slip Control is set to Timer or Frequency + Timer, the above conditions have been true for a time > or = Check Sync. 1(2) Slip Timer setting

Note: Live Line/Dead Bus and Dead Bus/Line functionality is provided as part of the default PSL (see Figure 50).

### 2.3.3.2 Slip control by timer

If Slip Control by Timer or Frequency + Timer is selected, the combination of Phase Angle and Timer settings determines an effective maximum slip frequency, calculated as:

$$\frac{2 \times A}{T \times 360} \text{ Hz. for Check Sync. 1, or}$$

$$\frac{A}{T \times 360} \text{ Hz. for Check Sync. 2}$$

A = Phase Angle setting (°)
T = Slip Timer setting (seconds)

For example, with Check Sync. 1 Phase Angle setting 30° and Timer setting 3.3 sec., the "slipping" vector has to remain within ±30° of the reference vector for at least 3.3 seconds. Therefore a synchro check output will not be given if the slip is greater than 2 x 30° in 3.3 seconds. Using the formula: 2 x 30 ÷ (3.3 x 360) = 0.0505 Hz (50.5 mHz).

For Check Sync. 2, with Phase Angle setting 10° and Timer setting 0.1 sec., the slipping vector has to remain within 10° of the reference vector, with the angle decreasing, for 0.1 sec. When the angle passes through zero and starts to increase, the synchro check output is blocked. Therefore an output will not be given if slip is greater than 10° in 0.1 second. Using the formula: 10 ÷ (0.1 x 360) = 0.278 Hz (278 mHz).

Slip control by Timer is not practical for "large slip/small phase angle" applications, because the timer settings required are very small, sometimes < 0.1s. For these situations, slip control by frequency is recommended.

If Slip Control by Frequency + Timer is selected, for an output to be given, the slip frequency must be less than BOTH the set Slip Freq. value and the value determined by the Phase Angle and Timer settings.



### 2.3.4 Check sync. 2 and system split

Check sync. 2 and system split functions are included for situations where the maximum permitted slip frequency and phase angle for synchro check can change according to actual system conditions. A typical application is on a closely interconnected system, where synchronism is normally retained when a given feeder is tripped, but under some circumstances, with parallel interconnections out of service, the feeder ends can drift out of synchronism when the feeder is tripped. Depending on the system and machine characteristics, the conditions for safe circuit breaker closing could be, for example:

Condition 1: For synchronized systems, with zero or very small slip:

Slip ≦50 mHz; phase angle <30°

Condition 2: For unsynchronized systems, with significant slip:

Slip ≦250 mHz; phase angle <10° and decreasing

By enabling both Check Sync. 1, set for condition 1, and Check Sync. 2, set for condition 2, the P145 can be configured to allow CB closure if either of the two conditions is detected.

For manual circuit breaker closing with synchro check, some utilities might prefer to arrange the logic to check initially for condition 1 only. However, if a System Split is detected before the condition 1 parameters are satisfied, the relay will switch to checking for condition 2 parameters instead, based upon the assumption that a significant degree of slip must be present when system split conditions are detected. This can be arranged by suitable PSL logic, using the system check DDB signals.

#### 2.3.4.1 Predictive closure of circuit breaker

The "Freq.+Comp. " (Frequency + CB Time Compensation) setting modifies the Check Sync. 2 function to take account of the circuit breaker closing time. By measuring the slip frequency, and using the "CB Close Time" setting as a reference, the relay will issue the close command so that the circuit breaker closes at the instant the slip angle is equal to the "CS2 phase angle" setting. Unlike Check Sync. 1, Check Sync. 2 only permits closure for decreasing angles of slip, therefore the circuit breaker should always close within the limits defined by Check Sync. 2 (see Figure 48).

### 2.3.4.2 System split

For the System Split module to function (see Figure 49):

The System Checks setting must be Enabled

AND

the SS Status setting must be Enabled

AND

the module must be individually “enabled”, by activation of DDB signal System Split Enabled, mapped in PSL.

When enabled, the System Split module sets its output signal when:

Line volts and bus volts are both live (Line Live and Bus Live signals both set)

AND

measured phase angle is > SS Phase Angle setting

AND

if SS Volt Blocking is set to Undervoltage, both line volts and bus volts magnitudes are > SS Undervoltage setting

The System Split output remains set for as long as the above conditions are true, or for a minimum period equal to the SS Timer setting, whichever is longer.

The overall system checks functionality and default PSL for the function is shown in Figures 49 and 50 respectively.

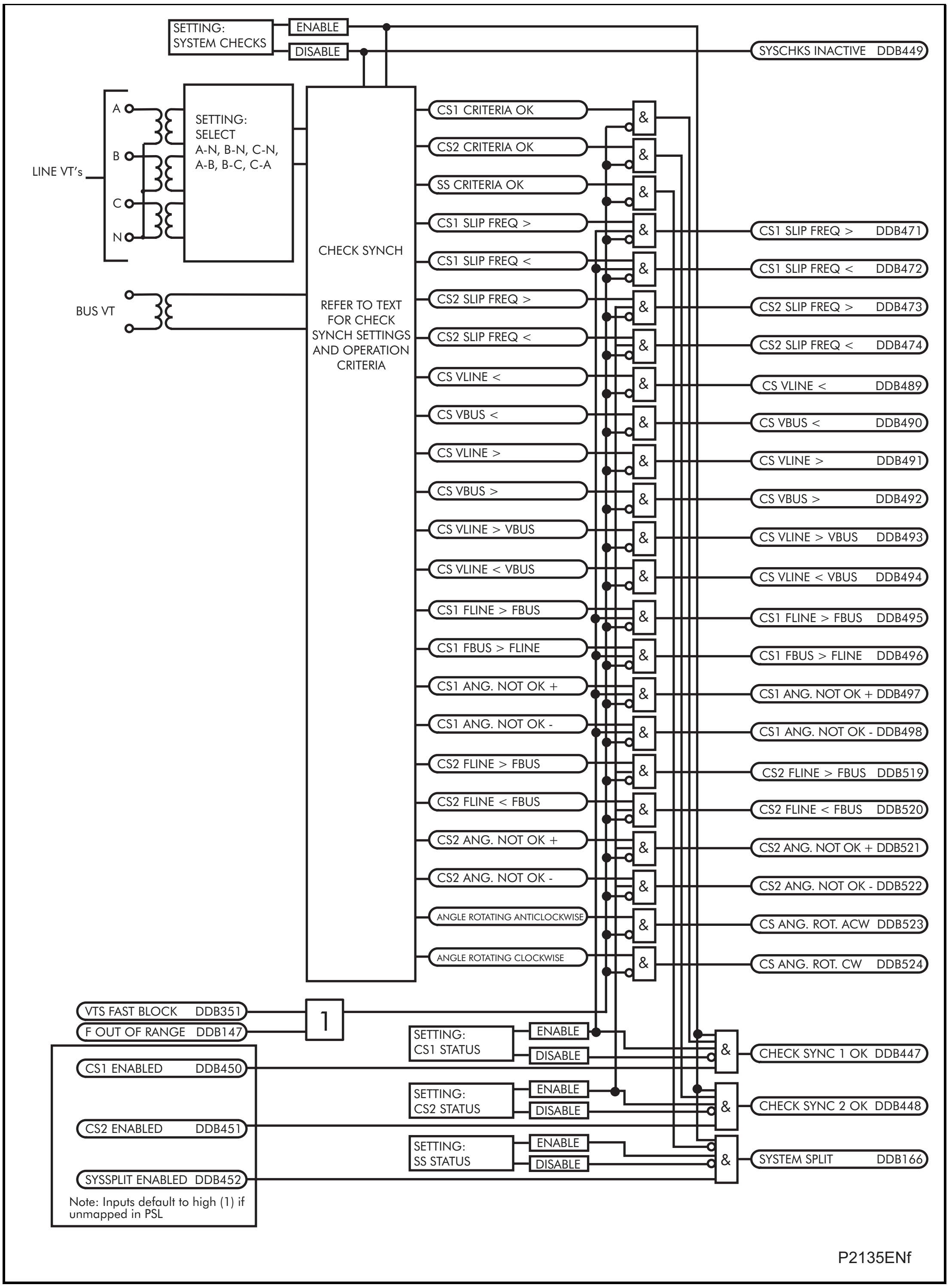



**Figure 49: System checks functional logic diagram**

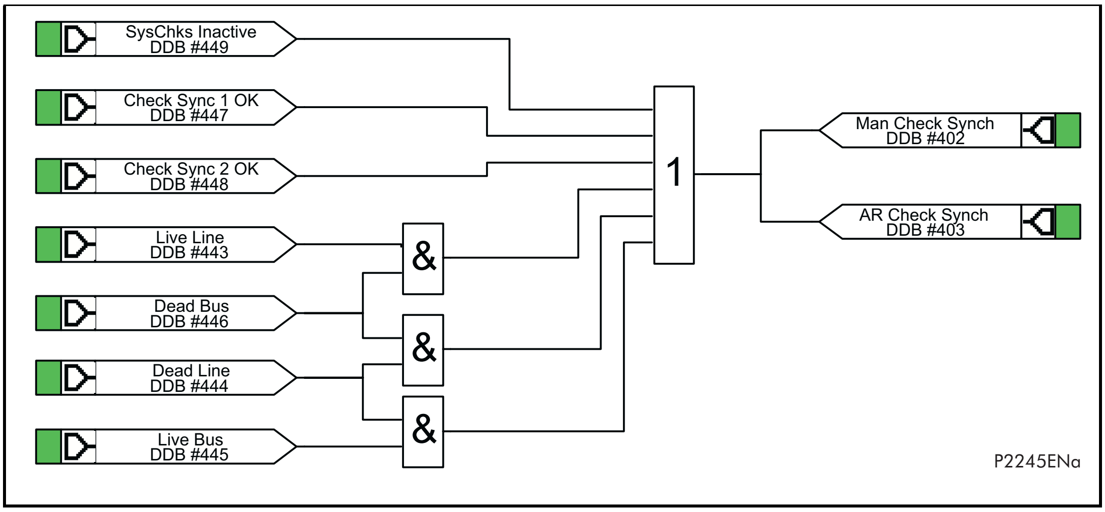



**Figure 50: Check sync. default PSL**



## 2.4 Function keys

The P145 relay offers users 10 function keys for programming any operator control functionality such as auto-reclose ON/OFF, earth fault1 ON/OFF etc. via PSL. Each function key has an associated programmable tri-color 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 can be found in the ‘Function Keys’ menu (see Settings section, P145/EN ST). In the ‘Fn. Key Status’ menu cell there is a 10 bit word which represent the 10 function key commands and their status can be read from this 10 bit word.

In the programmable scheme logic editor 10 function key signals, DDB 712 - 721, which can be set to a logic 1 or On state, as described above, are available to perform control functions defined by the user.

The “Function Keys” column has ‘Fn. Key n Mode’ cell which allows the user to configure the function key as either ‘Toggled’ or ‘Normal’. In the ‘Toggle’ mode the function key DDB signal output will remain 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 will remain energized for as long as the function key is pressed and will then reset automatically. A minimum pulse duration can be programmed for a function key by adding a minimum pulse timer to the function key DDB output signal.

The “Fn. Key n Status” cell is used to enable/unlock or disable the function key signals in PSL. The ‘Lock’ setting has been specifically provided to allow the locking of a function key thus preventing further activation of the key on consequent key presses. This allows function keys that are set to ‘Toggled’ mode and their DDB signal active ‘high’, to be locked in their active state thus preventing any further key presses from deactivating the associated function. Locking a function key that is set to the “Normal” mode causes the associated DDB signals to be permanently off. This safety feature prevents any inadvertent function key presses from activating or deactivating critical relay functions.

The “Fn. Key Labels” cell makes it possible to change the text associated with each individual function key. This text will be displayed when a function key is accessed in the function key menu, or it can be displayed in the PSL.

The status of the function keys is stored in battery backed memory. In the event that the auxiliary supply is interrupted the status of all the function keys will be recorded. Following the restoration of the auxiliary supply the status of the function keys, prior to supply failure, will be reinstated. If the battery is missing or flat the function key DDB signals will set to logic 0 once the auxiliary supply is restored. Please also note the relay will only recognize a single function key press at a time and that a minimum key press duration of approximately 200msec. is required before the key press is recognized in PSL. This deglitching feature avoids accidental double presses.

## 2.5 Voltage transformer supervision (VTS)

The voltage transformer supervision (VTS) feature is used to detect failure of the ac voltage inputs to the relay. This may be caused by internal voltage transformer faults, overloading, or faults on the interconnecting wiring to relays. This usually results in one or more VT fuses blowing. Following a failure of the ac voltage input there would be a misrepresentation of the phase voltages on the power system, as measured by the relay, which may result in

mal-operation.

The VTS logic in the relay is designed to detect the voltage failure, and automatically adjust the configuration of protection elements whose stability would otherwise be compromised. A time-delayed alarm output is also available.

There are three main aspects to consider regarding the failure of the VT supply. These are defined below:

1. Loss of one or two-phase voltages

2. Loss of all three-phase voltages under load conditions

3. Absence of three-phase voltages upon line energization



The VTS feature within 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.

Negative Sequence VTS Element:

The negative sequence thresholds used by the element are $V_2$ = 10V (or 40V on a 380/440V rated relay), and $I_2$ = 0.05 to 0.5In settable (defaulted to 0.05In).

### 2.5.1 Loss of all three-phase voltages under load conditions

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. These signals are generated by comparison of the present value of the current with that exactly one cycle previously. Under normal load conditions, the value of superimposed current should therefore be zero. Under a fault condition a superimposed current signal will be generated which will prevent operation of the VTS.

The phase voltage level detectors are fixed and will drop off at 10V (40V on 380/440V relays) and pickup at 30V (120V on 380/440V relays).

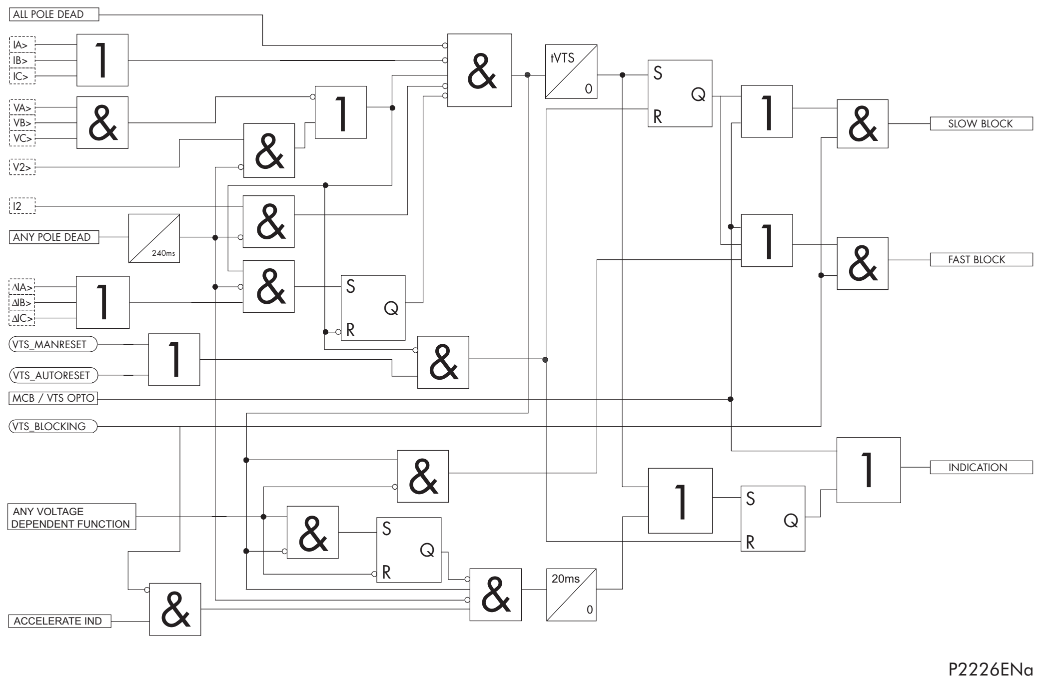
The sensitivity of the superimposed current elements is fixed at 0.1In.

### 2.5.2 Absence of three-phase voltages upon line energization

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 3-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.

This logic will only be enabled during a live line condition (as indicated by the relays pole dead logic) to prevent operation under dead system conditions i.e. where no voltage will be present and the VTS I> Inhibit overcurrent element will not be picked up.




Note: The Accelerated Ind. input is not used in the Feeder Protection.

**Figure 51: VTS Logic**

Required to drive the VTS logic are a number of dedicated level detectors as follows:

- IA>, IB>, IC> these level detectors operate in less than 20ms and their settings should be greater than load current. This setting is specified as VTS current threshold
- I2> this level detector operates on negative sequence current and has a user setting
- ΔIIA>, ΔIB>, ΔIC> these are level detectors operating on superimposed phase currents and have a fixed setting of 10% of nominal
- VA>, VB>, VC> these are level detectors operating on phase voltages and have a fixed setting Pickup level 30V (Vn 100/120V), 120V (Vn 380/440V), Drop Off level 10V (Vn 100/120V), 40V (Vn 380/440V)
- V2> this level detector operates on negative sequence voltage, it has a fixed setting of 10V/40V depending on VT ratio (100/120 or 380/440)

2.5.2.1 Outputs

| Signal Name | Description |
|---|---|
| VTS Fast Block | Used to block voltage dependent functions. |
| VTS Slow block | Used to block the Any Pole dead signal. |
| VTS Indication | Signal used to indicate a VTS operation. |

## 2.6 Current transformer supervision

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 CTS logic is shown in Figure 52.

The voltage transformer connection used must be able to refer zero sequence voltages from the primary to the secondary side. Thus, this element should only be enabled where the VT is of five limb construction, or comprises three single-phase units, and has the primary star point earthed.

Operation of the element will produce a time-delayed alarm visible on the LCD and event record (plus DDB 149: CT Fail Alarm), with an instantaneous block (DDB 352: CTS Block) for inhibition of protection elements. Protection elements operating from derived quantities (Broken Conductor, Earth Fault2, Neg. Seq. O/C) are always blocked on operation of the CT supervision element; other protections can be selectively blocked by customizing the PSL, integrating DDB 352: CTS Block with the protection function logic.



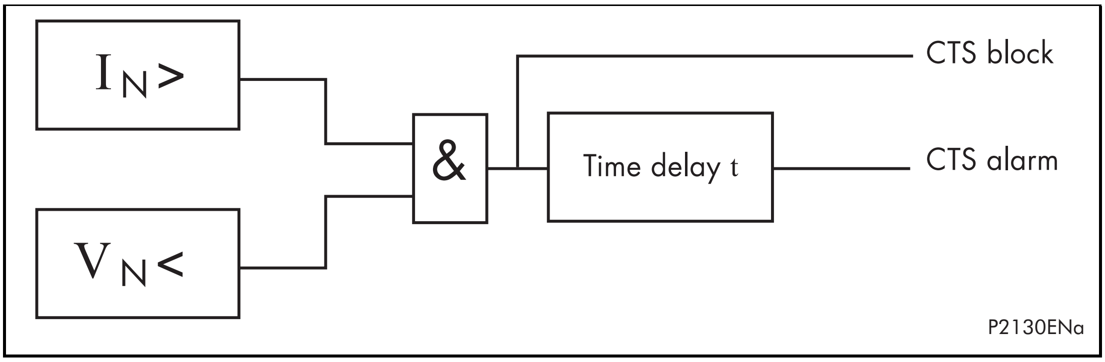



**Figure 52: CT supervision logic diagram**

## 2.7 Circuit breaker state monitoring

The relay incorporates circuit breaker state monitoring, giving an indication of the position of the circuit breaker, or, if the state is unknown, an alarm is raised.

### 2.7.1 Circuit breaker state monitoring features

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 will be in opposite states. Should both sets of contacts be open, this would indicate one of the following conditions:

- Auxiliary contacts/wiring defective
- Circuit Breaker (CB) is defective
- CB is in isolated position

Should both sets of contacts be closed, only one of the following two conditions would apply:

- Auxiliary contacts/wiring defective
- Circuit Breaker (CB) is defective

If any of the above conditions exist, an alarm will be issued after a 5s time delay. A normally open / normally closed output contact can be assigned to this function via the programmable scheme logic (PSL). The time delay is set to avoid unwanted operation during normal switching duties.

In the CB CONTROL column of the relay menu there is a setting called 'CB Status Input'. This cell can be set at one of the following four options:

None

52A

52B

Both 52A and 52B

Where 'None' is selected no CB status will be available. This will directly affect any function within the relay that requires this signal, for example CB control, auto-reclose, etc. Where only 52A is used on its own then the relay will assume a 52B signal from the absence of the 52A signal. Circuit breaker status information will be available in this case but no discrepancy alarm will be available. The above is also true where only a 52B is used. If both 52A and 52B are used then status information will be available and in addition a discrepancy alarm will be possible, according to the following table. 52A and 52B inputs are assigned to relay opto-isolated inputs via the PSL. The CB State Monitoring logic is shown in Figure 53.



| Auxiliary Contact Position | | CB State Detected | Action |
|---|---|---|---|
| 52A | 52B | | |
| Open | Closed | Breaker open | Circuit breaker healthy |
| Closed | Open | Breaker closed | Circuit breaker healthy |
| Closed | Closed | CB failure | Alarm raised if the condition persists for greater than 5s |
| Open | Open | State unknown | Alarm raised if the condition persists for greater than 5s |

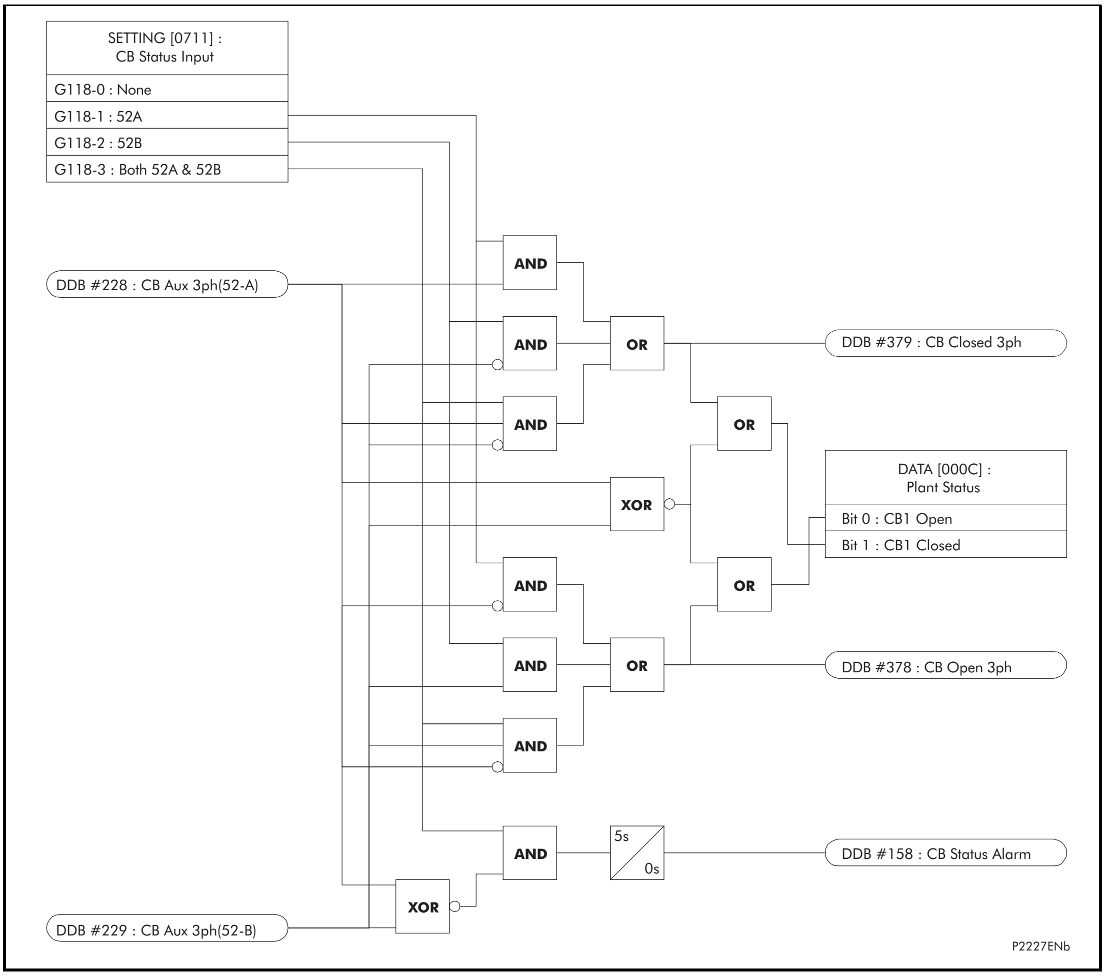



**Figure 53: CB state monitoring**

## 2.8 Pole dead logic

The Pole Dead Logic can be used to give an indication if one or more phases of the line are dead. It can also be used to selectively block operation of both the under frequency and under voltage elements. The under voltage protection will be blocked by a pole dead condition provided the “Pole Dead Inhibit” setting is enabled. Any of the four under frequency elements can be blocked by setting the relevant “F< function links”.

A pole dead condition is determined by either monitoring the status of the circuit breaker auxiliary contacts or by measuring the line currents and voltages. The status of the circuit breaker is provided by the “CB State Monitoring” logic. If a “CB Open” signal (DDB 378) is given the relay will automatically initiate a pole dead condition regardless of the current and voltage measurement. Similarly if both the line current and voltage fall below a pre-set threshold the relay will also initiate a pole dead condition. This is necessary so that a pole dead indication is still given even when an upstream breaker is opened. The under voltage (V<) and under current (I<) thresholds have the following, fixed, pickup and drop-off levels:

| Settings | Range | Step Size |
|---|---|---|
| V< Pick-up and drop off | 10V and 30V (100/120V)<br>40V and 120V (380/440V) | Fixed |
| I< Pick-up and drop off | 0.05 In and 0.055In | Fixed |

If one or more poles are dead the relay will indicate which phase is dead and will also assert the ANY POLE DEAD DDB signal (DDB 384). If all phases were dead the ANY POLE DEAD signal would be accompanied by the ALL POLE DEAD DDB signal (DDB 380).

OP

In the event that the VT fails a signal is taken from the VTS logic (DDB 351 - Slow Block) to block the pole dead indications that would be generated by the under voltage and undercurrent thresholds. However, the VTS logic will not block the pole dead indications if they are initiated by a “CB Open” signal (DDB 378).

The pole dead logic diagram is shown in Figure 54.

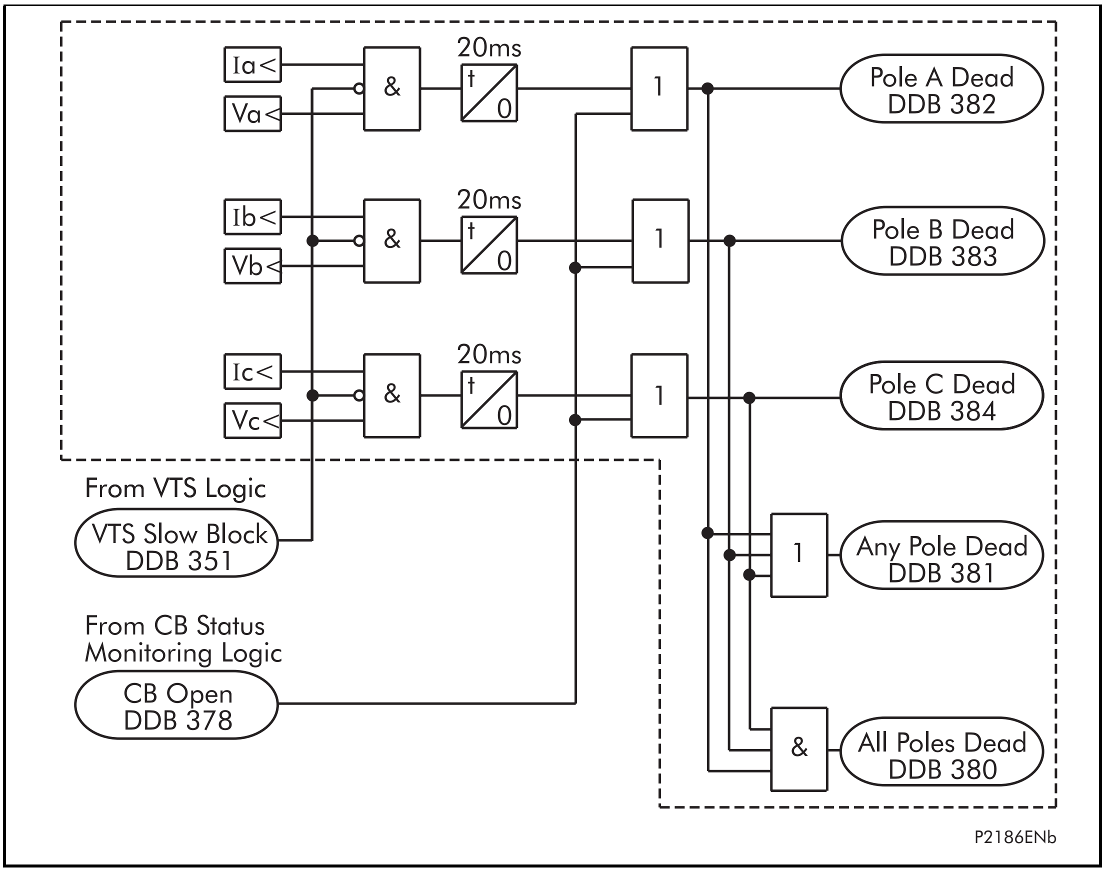



**Figure 54: Pole dead logic**

## 2.9 Circuit breaker condition monitoring

The P145 relays record various statistics related to each circuit breaker trip operation, allowing a more accurate assessment of the circuit breaker condition to be determined. These monitoring features are discussed in the following section.

### 2.9.1 Circuit breaker condition monitoring 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 in this case 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 {3 pole tripping} | 0 | 0 | 10000 | 1 |
| Displays the total number of 3 pole trips issued by the relay. | | | | |
| Total IA Broken | 0 | 0 | 25000In^ | 1 |
| Displays the total fault current interrupted by the relay for the A phase. | | | | |
| Total IB Broken | 0 | 0 | 25000In^ | 1 |
| Displays the total fault current interrupted by the relay for the A phase. | | | | |
| Total IC Broken | 0 | 0 | 25000In^ | 1In^ |
| Displays the total fault current interrupted by the relay for the A phase. | | | | |
| CB Operate Time | 0 | 0 | 0.5s | 0.001 |
| Displays the calculated CB operating time. | | | | |
| Reset CB Data | No | | Yes, No | |
| Setting to reset the CB condition counters. | | | | |

OP

The above counters may be reset to zero, for example, following a maintenance inspection and overhaul. The circuit breaker condition monitoring counters will be updated every time the relay issues a trip command. In cases where the breaker is tripped by an external protection device it is also possible to update the CB condition monitoring. This is achieved by allocating one of the relays opto-isolated inputs (via the programmable scheme logic) to accept a trigger from an external device. The signal that is mapped to the opto is called 'External Trip'.

Note that when in Commissioning test mode the CB condition monitoring counters will not be updated.

## 2.10 Circuit breaker control

The relay includes the following options for control of a single circuit breaker:

- Local tripping and closing, via the relay menu, hotkeys or function keys
- Local tripping and closing, via relay opto-isolated inputs
- Remote tripping and closing, using the relay communications

It is recommended that separate relay output contacts are allocated for remote circuit breaker control and protection tripping. This enables the control outputs to be selected via a local/remote selector switch as shown in Figure 55. Where this feature is not required the same output contact(s) can be used for both protection and remote tripping.

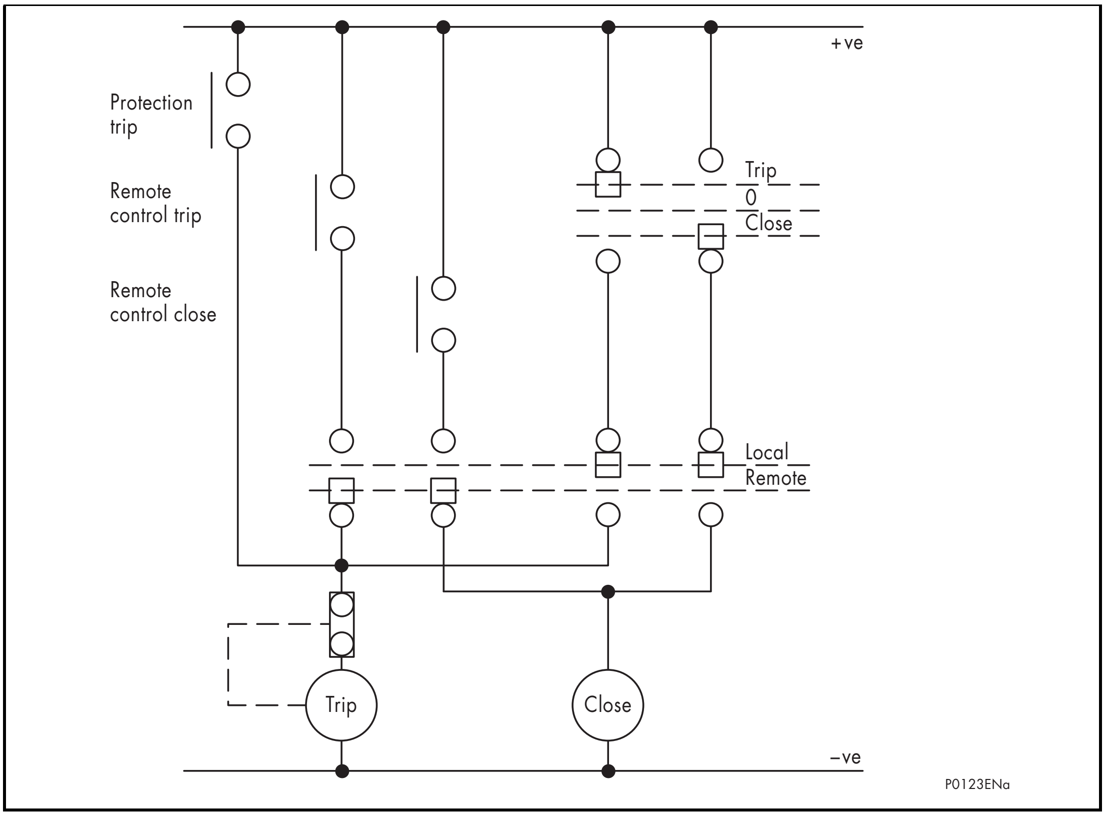



**Figure 55: Remote control of circuit breaker**

A manual trip will be permitted provided that 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 will be necessary to use the breaker 52A and/or 52B contacts (the different selection options are given from the ‘CB Status Input’). If no CB auxiliary contacts are available then this cell should be set to None. Under these circumstances no CB control (manual or auto) will be possible.

Once a CB Close command is initiated the output contact can be set to operate following a user defined time delay (‘Man. Close Delay’). This would give personnel time to move safely away from the circuit breaker following the close command. This time delay will apply to all manual CB Close commands.

The length of the trip or close control pulse can be set via the ‘Trip Pulse Time’ and ‘Close Pulse Time’ settings respectively. These should be set long enough to ensure the breaker has completed its open or close cycle before the pulse has elapsed.

**Note that the manual trip and 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.

Where the check synchronism function is set, this can be enabled to supervise manual circuit breaker close commands. A circuit breaker close output will only be issued if the check synchronism criteria are satisfied. A user settable time delay is included (‘C/S Window’) for manual closure with check synchronizing. If the check sync. criteria are not satisfied in this time period following a close command the relay will lockout and alarm.

In addition to a synchronism check before manual reclosure there is also a CB Healthy check if required. This facility accepts an input to one of the relays opto-isolators to indicate that the breaker is capable of closing (circuit breaker energy for example). A user settable time delay is included "CB Healthy Time" for manual closure with this check. If the CB does not indicate a healthy condition in this time period following a close command then the relay will lockout and alarm.

The "Reset Lockout by" setting, "CB Close/User interface" in "CB CONTROL" (0709) is used to enable/disable reset of lockout automatically from a manual close after the manual close time "Man. Close Rst. Dly.".

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 will be generated after the relevant trip or close pulses have expired. These alarms can be viewed on the relay LCD display, remotely via the relay communications, or can be assigned to operate output contacts for annunciation using the relays programmable scheme logic (PSL).

Note that the "CB Healthy Time" timer and "Check Sync. Time" timer set under this menu section are applicable to manual circuit breaker operations only. These settings are duplicated in the auto-reclose menu for auto-reclose applications.

The "Lockout Reset" and "Reset Lockout by" setting cells in the menu are applicable to CB Lockouts associated with manual circuit breaker closure, CB Condition monitoring (Number of circuit breaker operations, for example) and auto-reclose lockouts.

The CB Control logic is illustrated in Figure 56.

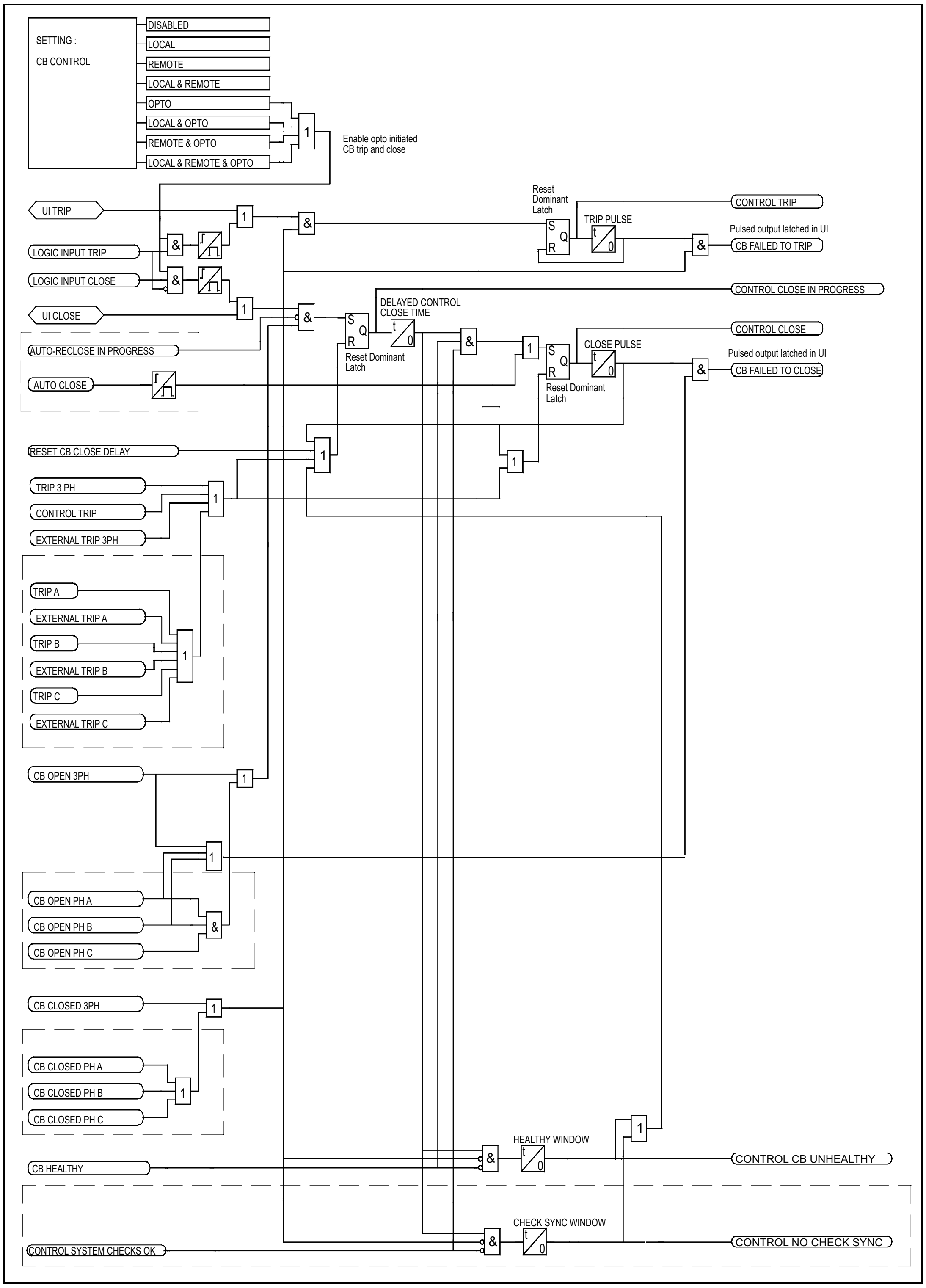



**Figure 56: Circuit breaker control**

## 2.10.1 CB control using hotkeys

The hotkeys allow direct access to the manual trip and close commands without the need to enter the SYSTEM DATA column. Hotkeys supplement the direct access possible via the function keys described in section 2.4. Red or green color coding can be applied when used in CB control applications.

IF <<TRIP>> or <<CLOSE>> is selected the user is prompted to confirm the execution of the relevant command. If a trip is executed a screen with the CB status will be displayed once the command has been completed. If a close is executed a screen with a timing bar will appear while the command is being executed. This screen has the option to cancel or restart the close procedure. The timer used is taken from the manual close delay timer setting in the CB Control menu. When the command has been executed, a screen confirming the present status of the circuit breaker is displayed. The user is then prompted to select the next appropriate command or exit – this will return to the default relay screen.

If no keys are pressed for a period of 25 seconds while waiting for the command confirmation, the relay will revert to showing the CB Status. If no key presses are made for a period of 25 seconds while displaying the CB status screen, the relay will revert to the default relay screen. Figure 57 shows the hotkey menu associated with CB control functionality.

To avoid accidental operation of the trip and close functionality, the hotkey CB control commands will be disabled for 10 seconds after exiting the hotkey menu.

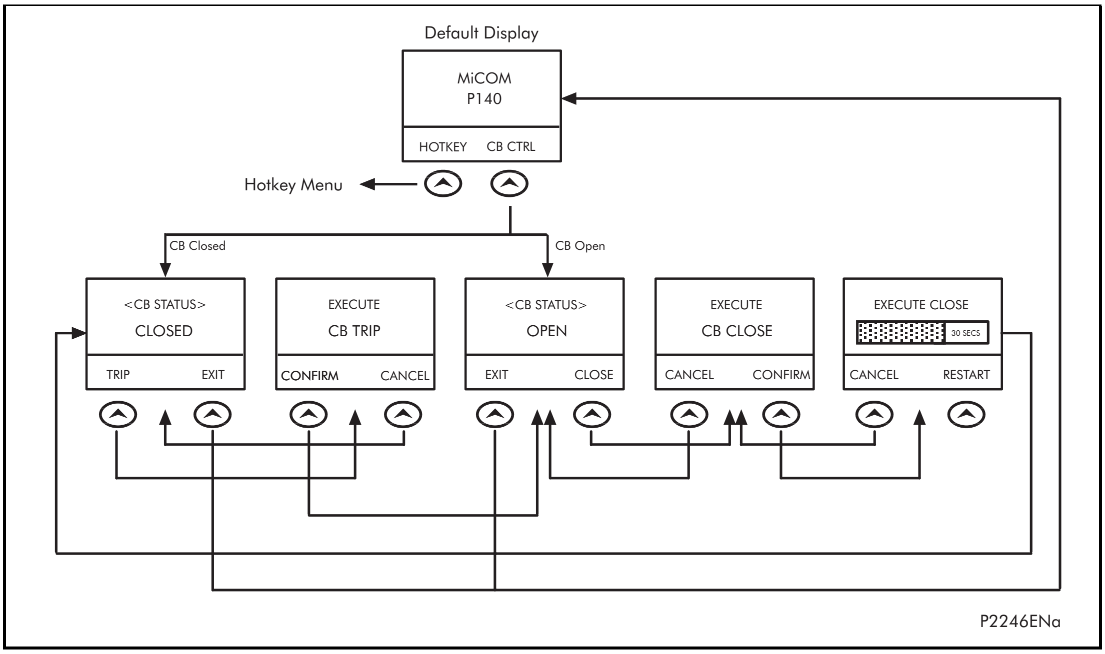



**Figure 57: CB control hotkey menu**

2.10.2 CB control using function keys

The function keys allow direct control of the circuit breaker if programmed to do this in PSL. local tripping and closing, via relay opto-isolated inputs must be set in the “CB Control” menu ‘CB control by’ cell to enable this functionality. All CB manual control settings and conditions will apply for manual tripping and closing via function keys.

The following default logic can be programmed to activate this feature:

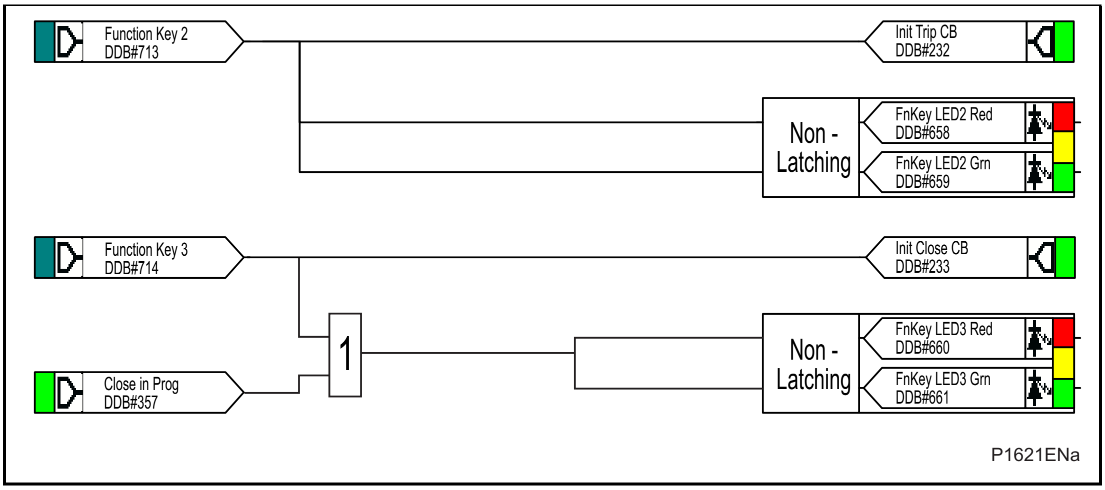



**Figure 58: CB control via function keys default PSL**

Function key 2 and function key 3 are both enabled and set to ‘Normal’ Mode and the associated DDB signals ‘DDB 713’ and ‘DDB 714’ will be active high ‘1’ on key press.

The following DDB signal must be mapped to the relevant function key:

**Init. Trip CB** (DDB 232) – Initiate manual circuit breaker trip

**Init. Close CB** (DDB 233) – Initiate manual circuit breaker close

The programmable function key LED’s have been mapped such that the LED’s will indicate yellow whilst the keys are activated.

### 2.11 Setting groups selection

The setting groups can be changed either via opto inputs, via a menu selection, via the hotkey menu or via function keys. In the Configuration column if 'Setting Group - select via optos' is selected then any opto input or function key can be programmed in PSL to select the setting group as shown in the table below. If 'Setting Group - select via menu' is selected then in the Configuration column the 'Active Settings - Group1/2/3/4' can be used to select the setting group.

OP

The setting group can be changed via the hotkey menu providing ‘Setting Group select via menu’ is chosen.

Two DDB signals are available in PSL for selecting a setting group via an opto input or function key selection (see default PSL in the Programmable Scheme Logic section, P145/EN PL). The following table illustrates the setting group that is active on activation of the relevant DDB signals.

| DDB 527<br>SG Select 1X | DDB 526<br>SG Select X1 | Selected Setting Group |
|---|---|---|
| 0 | 0 | 1 |
| 1 | 0 | 2 |
| 0 | 1 | 3 |
| 1 | 1 | 4 |

Note: Each setting group has its own PSL. Once a PSL has been designed it can be sent to any one of 4 setting groups within the relay. When downloading a PSL to the relay the user will be prompted to enter the desired setting group to which it will be sent. This is also the case when extracting a PSL from the relay.

### 2.12 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. There are three setting columns associated with the control inputs that are: “CONTROL INPUTS”, “CTRL. I/P CONFIG.” and “CTRL. I/P LABELS”. The function of these columns is described below:

| Menu Text | Default Setting | Setting Range | Step Size |
|---|---|---|---|
| CONTROL INPUTS | | | |
| Ctrl I/P Status | 00000000000000000000000000000000 | | |
| Control Input 1 | No Operation | No Operation, Set, Reset | |
| Control Input 2 to 32 | No Operation | No Operation, Set, Reset | |

The Control Input commands can be found in the ‘Control Input’ menu. In the ‘Ctrl. I/P status’ menu cell there is a 32 bit word which represent the 32 control input commands. The status of the 32 control inputs can be read from this 32-bit word. The 32 control inputs can also be set and reset from this cell by setting a 1 to set or 0 to reset a particular control input. Alternatively, each of the 32 Control Inputs can be set and reset using the individual menu setting cells ‘Control Input 1, 2, 3’ etc. The Control Inputs are available through the relay menu as described above and also via the rear communications.

In the programmable scheme logic editor 32 Control Input signals, DDB 800 – 831, which can be set to a logic 1 or On state, as described above, are available to perform control functions defined by the user.

| Menu Text | Default Setting | Setting Range | Step Size |
|---|---|---|---|
| CTRL. I/P CONFIG. | | | |
| Hotkey Enabled | 11111111111111111111111111111111 | | |
| Control Input 1 | Latched | Latched, Pulsed | |
| Ctrl Command 1 | SET/RESET | SET/RESET, IN/OUT, ENABLED/DISABLED, ON/OFF | |
| Control Input 2 to 32 | Latched | Latched, Pulsed | |
| Ctrl Command 2 to 32 | SET/RESET | SET/RESET, IN/OUT, ENABLED/DISABLED, ON/OFF | |



| Menu Text | Default Setting | Setting Range | Step Size |
|---|---|---|---|
| CTRL. I/P LABELS | | | |
| Control Input 1 | Control Input 1 | 16 character text | |
| Control Input 2 to 32 | Control Input 2 to 32 | 16 character text | |

The “CTRL. I/P CONFIG.” column has several functions one of which allows the user to configure 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 10ms after the set command is given and will then reset automatically (i.e. no reset command required).

In addition to the latched/pulsed option this column also allows 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. The “Ctrl. Command” cell also 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.

The “CTRL. I/P LABELS” column makes it possible to change the text associated with each individual control input. This text will be displayed when a control input is accessed by the hotkey menu, or it can be displayed in the PSL.

Note: With the exception of pulsed operation, the status of the control inputs is stored in battery backed memory. In the event that the auxiliary supply is interrupted the status of all the inputs will be recorded. Following the restoration of the auxiliary supply the status of the control inputs, prior to supply failure, will be reinstated. If the battery is missing or flat the control inputs will set to logic 0 once the auxiliary supply is restored.

### 2.13 Real time clock synchronization via opto-inputs

In modern protective schemes it is often desirable to synchronize the relays real time clock so that events from different relays can be placed in chronological order. This can be done using the IRIG-B input, if fitted, or via the communication interface connected to the substation control system. In addition to these methods the P145 range offers the facility to synchronize via an opto-input by routing it in PSL to DDB 475 (Time Sync.). Pulsing this input will result in the real time clock snapping to the nearest minute. The recommended pulse duration is 20ms to be repeated no more than once per minute. An example of the time sync. function is shown.

| Time of “Sync. Pulse” | Corrected Time |
|---|---|
| 19:47:00 to 19:47:29 | 19:47:00 |
| 19:47:30 to 19:47:59 | 19:48:00 |

Note: The above assumes a time format of hh:mm:ss

To avoid the event buffer from being filled with unnecessary time sync. events, it is possible to ignore any event that is generated by the time sync. opto input. This can be done by applying the following settings:

| Menu Text | Value |
|---|---|
| RECORD CONTROL | |
| Opto Input Event | Enabled |
| Protection Event | Enabled |
| DDB 63 – 32 (Opto Inputs) | Set “Time Sync.” associated opto to 0 |



To improve the recognition time of the time sync. opto input by approximately 10ms, the opto input filtering could be disabled. This is achieved by setting the appropriate bit to 0 in the “Opto Filter Cntl.” cell (OPTO CONFIG. column). Disabling the filtering may make the opto input more susceptible to induced noise. Fortunately the effects of induced noise can be minimized by using the methods described in section 1.2.3.3 of Firmware Design (P145/EN FD) section.

AP

# APPLICATION NOTES

| | |
|---|---|
| **Date:** | **7th July 2005** |
| **Hardware Suffix:** | **J** |
| **Software Version:** | **31** |
| **Connection Diagrams:** | **10P145xx (xx = 01 to 07)** |

# CONTENTS

AP

AP

# FIGURES

# 1. INTRODUCTION

## 1.1 Protection of feeders

The secure and reliable transmission and distribution of power within a network is heavily dependent upon the integrity of the overhead lines and underground cables which link the various sections of the network together. As such, the associated protection system must also provide both secure and reliable operation.

The most common fault conditions, on both overhead lines and cables, are short circuit faults. Such faults may occur between phases but will most often involve one or more phases becoming short circuit to earth. Faults of this nature require the fastest possible fault clearance times but at the same time allowing suitable co-ordination with other downstream protection devices.

The effect of fault resistance is more pronounced on lower voltage systems, resulting in potentially lower fault currents, which in turn increases the difficulty in the detection of high resistance faults. In addition, many distribution systems use earthing arrangements designed to limit the passage of earth fault current. Methods such as resistance earthing, Petersen Coil earthing or insulated systems makes the detection of earth faults difficult. Special protection requirements are often used to overcome these problems.

For distribution systems, continuity of supply is of paramount importance. The majority of faults on overhead lines are transient or semi-permanent in nature. Multi-shot auto-reclose cycles are therefore commonly used in conjunction with instantaneous tripping elements to increase system availability.

Damage to items of plant such as transformers, cables and lines may also be incurred by excessive loading conditions, which leads directly to overheating of the equipment and subsequent degradation of the insulation. To protect against conditions of this nature, protective devices require characteristics, which closely match the thermal, withstand capability of the item of plant in question.

Uncleared faults, arising from either failure of the associated protection system or of the switchgear itself, must also be given due consideration. As such, the protection devices concerned may well be fitted with logic to deal with breaker failure conditions, in addition to the relays located upstream being required to provide adequate back-up protection for the condition.

Other situations may arise on overhead lines, such as broken phase conductors. Being a series fault condition, it has traditionally been very difficult to detect. However, with numerical technology, it is now possible to design elements that are responsive to such unbalanced system conditions and to subsequently issue alarm/trip signals.

# 2. APPLICATION OF INDIVIDUAL PROTECTION FUNCTIONS

The following sections detail individual protection functions in addition to where and how they may be applied. Each section provides some worked examples on how the settings are applied to the relay

## 2.1 Overcurrent protection

Overcurrent relays are the most commonly used protective devices in any industrial or distribution power system. They provide main protection to both feeders and busbars when unit protection is not used. They are also commonly applied to provide back-up protection when unit systems, such as pilot wire schemes, are used.

There are a few application considerations to make when applying overcurrent relays.

### 2.1.1 Transformer magnetizing inrush

When applying overcurrent protection to the HV side of a power transformer it is usual to apply a high set instantaneous overcurrent element in addition to the time delayed low-set, to reduce fault clearance times for HV fault conditions. Typically, this will be set to approximately 1.3 times the LV fault level, such that it will only operate for HV faults. A 30% safety margin is sufficient due to the low transient overreach of the third and fourth overcurrent stages. Transient overreach defines the response of a relay to DC components of fault current and is quoted as a percentage.



The second requirement for this element is that it should remain inoperative during transformer energization, when a large primary current flows for a transient period. In most applications, the requirement to set the relay above the LV fault level will automatically result in settings that will be above the level of magnetizing inrush current.

All four overcurrent stages operate on the fourier fundamental component. Hence, for the third and fourth overcurrent stages in P145 relays, it is possible to apply settings corresponding to 35% of the peak inrush current, whilst maintaining stability for the condition.

This is important where low-set instantaneous stages are used to initiate auto-reclose equipment. In such applications, the instantaneous stage should not operate for inrush conditions, which may arise from small teed-off transformer loads for example.

Where an instantaneous element is required to accompany the time delayed protection, as described above, the third or fourth overcurrent stage of the P145 relay should be used, as they have wider setting ranges.

### 2.1.2 Application of timer hold facility

This feaure may be useful in certain applications, for example when grading with upstream electromechanical overcurrent relays, which have inherent reset time delays. Setting of the hold timer to a value other than zero, delays the resetting of the protection element timers for this period thus allowing the element to behave similar to an electromechanical relay.

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

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

### 2.1.3 Setting guidelines

When applying the overcurrent protection provided in the P145 relays, standard principles should be applied in calculating the necessary current and time settings for co-ordination The Network Protection and Automation Guide (NPAG) textbook offers further assistance.

The example detailed below shows a typical setting calculation and describes how the settings are applied to the relay.

Assume the following parameters for a relay feeding an LV switchboard:

CT Ratio = 500/1

Full load current of circuit = 450A

Slowest downstream protection = 100A Fuse

The current setting employed on the P145 relay must account for both the maximum load current and the reset ratio of the relay itself:

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

The P145 relay allows the current settings to be applied to the relay in either primary or secondary quantities. This is done by programming the "Setting Values" cell of the "CONFIGURATION" column to either primary or secondary. When this cell is set to primary, all phase overcurrent setting values are scaled by the programmed CT ratio. This is found in the "VT & CT Ratios" column of the relay menu, where cells "Phase CT Primary" and "Phase CT Secondary" can be programmed with the primary and secondary CT ratings, respectively.

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

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

AP

A suitable time delayed characteristic will now need to be chosen. When co-ordinating with downstream fuses, the applied relay characteristic should be closely matched to the fuse characteristic. Therefore, assuming IDMT co-ordination is to be used, an Extremely Inverse (EI) characteristic would normally be chosen. As previously described, this is found under "I>1 Function" and should therefore be programmed as "IEC E Inverse".

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

Also note that the final 4 cells in the overcurrent menu refer to the voltage controlled overcurrent (VCO) protection which is separately described in section 2.12.

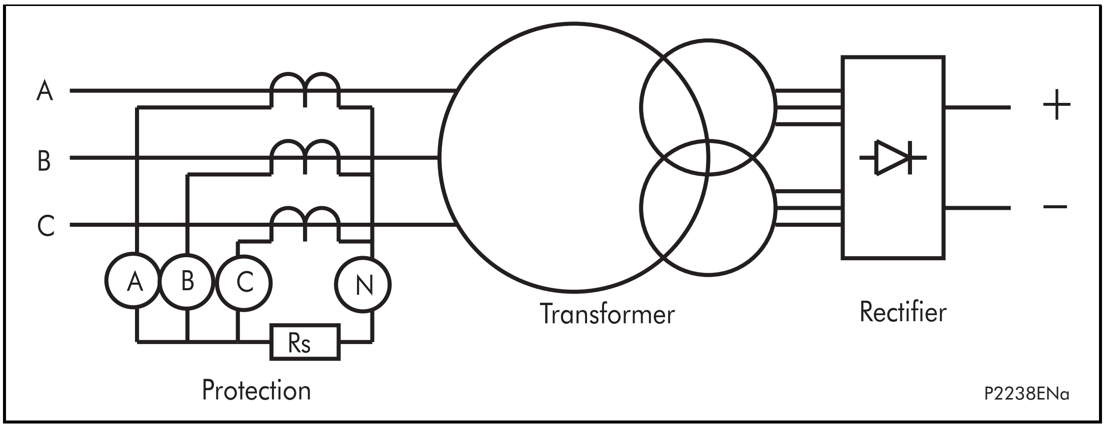



**Figure 1: Protection for silicon rectifiers**

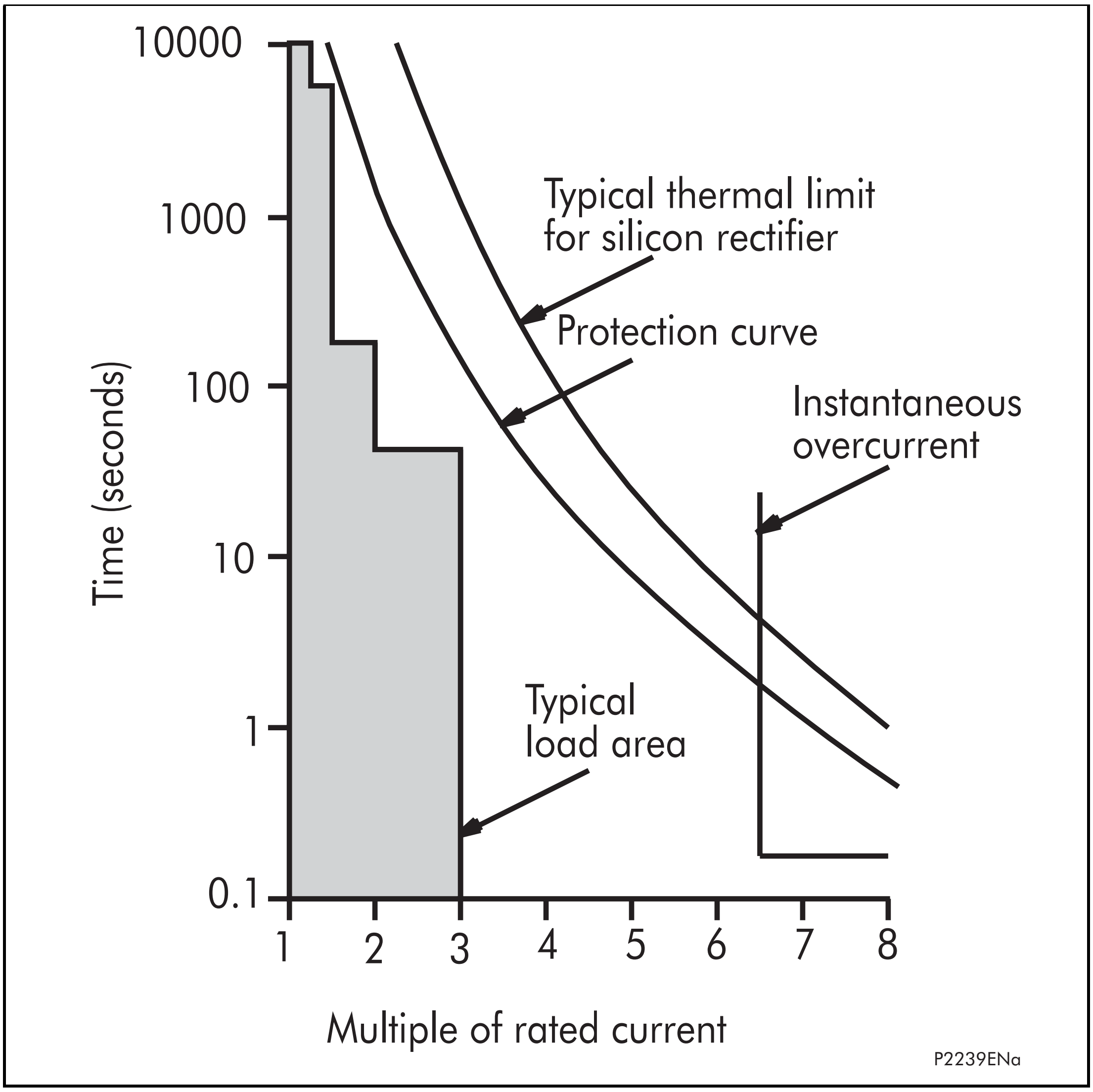



**Figure 2: Matching curve to load and thermal limit of rectifier**

The rectifier protection feature has been based upon the inverse time/current characteristic as used in the MCTD 01 (Silicon Rectifier Protection Relay) and the above diagram show a typical application.

The protection of a rectifier differs from the more traditional overcurrent applications in that many rectifiers can withstand relatively long overload periods without damage, typically 150% for 2 hours and 300% for 1 min.

The I> setting should be set to typically 110% of the maximum allowable continuous load of the rectifier. The relay gives start indications when the I> setting has been exceeded, but this is of no consequence, as this function is not used in this application. The rectifier curve should be chosen for the inverse curve as it allows for relatively long overloads even with a 110% I> setting.

Typical settings for the TMS are:

Light industrial service TMS = 0.025

Medium duty service TMS = 0.1

Heavy duty traction TMS = 0.8

The high set is typically set at 8 times rated current as this ensures HV AC protection will discriminate with faults covered by the LV protection. However, it has been known for the high set to be set to 4, or 5 times where there is more confidence in the AC protection.

AP

Use of the thermal element to provide protection between 70% and 160% of rated current could enhance the protection. It is also common practice to provide restricted earth fault protection for the transformer feeding the rectifier. See the appropriate section dealing with restricted earth fault protection.

## 2.2 Directional overcurrent protection

If fault current can flow in both directions through a relay location, it is necessary to add directionality to the overcurrent relays in order to obtain correct co-ordination. Typical systems that require such protection are parallel feeders (both plain and transformer) and ring main systems, each of which are relatively common in distribution networks.

Two common applications, which require the use of directional relays, are considered in the following sections.

### 2.2.1 Parallel feeders

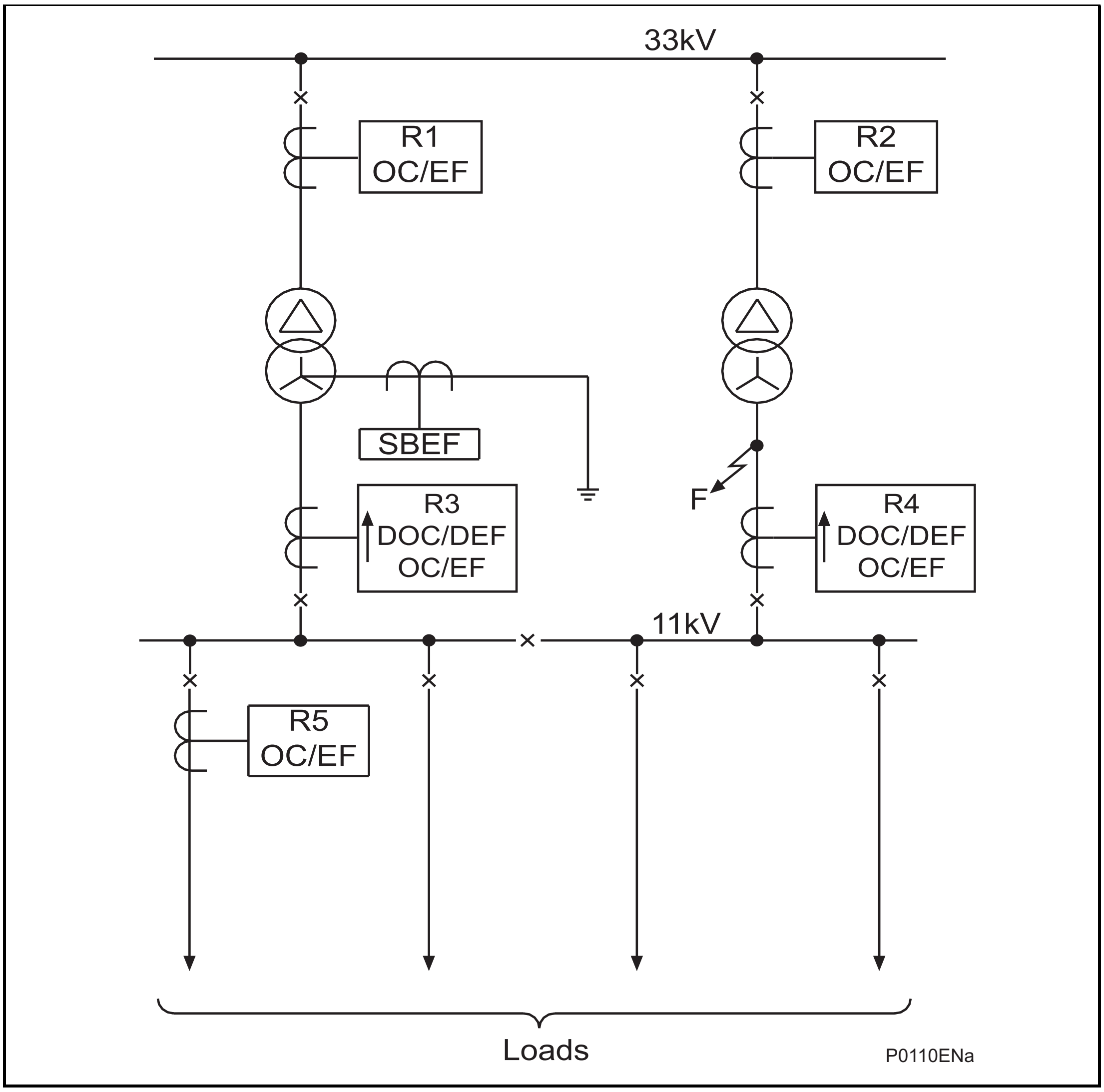



**Figure 3: Typical distribution system using parallel transformers**

Figure 3 shows a typical distribution system utilizing parallel power transformers. In such an application, a fault at 'F' could result in the operation of both R3 and R4 relays and the subsequent loss of supply to the 11kV busbar. Hence, with this system configuration, it is necessary to apply directional relays at these locations set to 'look into' their respective transformers. These relays should co-ordinate with the non-directional relays, R1 and R2; hence ensuring discriminative relay operation during such fault conditions.

AP

AP

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

When applying the P145 relays in the above application, stage 1 of the overcurrent protection of relays R3 and R4 would be set non-directional and time graded with R5, using an appropriate time delay characteristic. Stage 2 could then be set directional, looking back into the transformer, also having a characteristic which provided correct co-ordination with R1 and R2 IDMT or DT characteristics are selectable for both stages 1 and 2 and directionality of each of the overcurrent stages is set in cell "I> Direction".

Note that the principles previously outlined for the parallel transformer application are equally applicable for plain feeders that are operating in parallel.

### 2.2.2 Ring main arrangements

A typical ring main with associated overcurrent protection is shown in Figure 4.

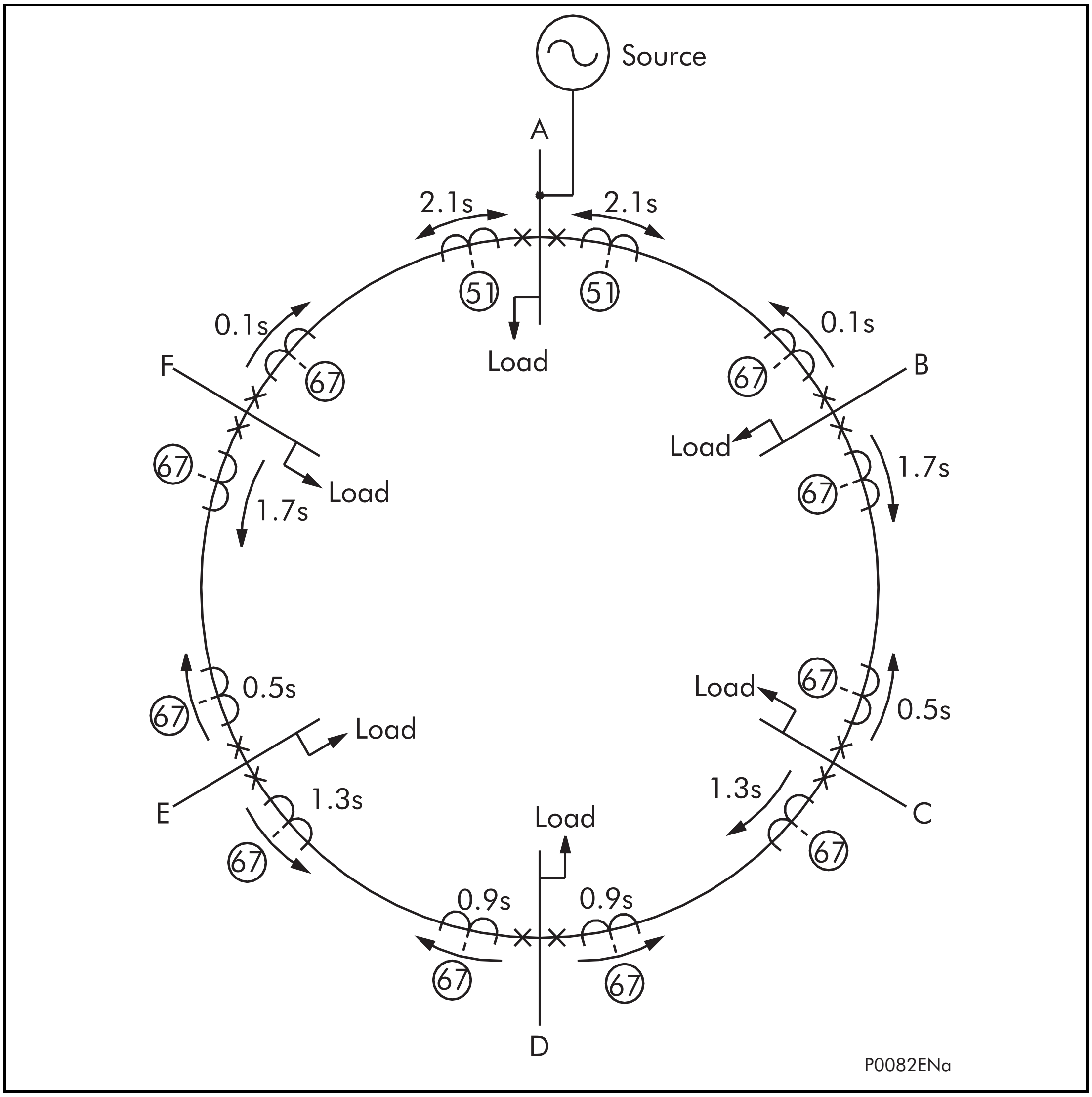



**Figure 4: Typical ring main with associated overcurrent protection**

As with the previously described parallel feeder arrangement, it can be seen that current may flow in either direction through the various relay locations. Therefore, directional overcurrent relays are again required in order to provide a discriminative protection system.

The normal grading procedure for overcurrent relays protecting a ring main circuit is to open the ring at the supply point and to grade the relays first clockwise and then anti-clockwise. The arrows shown at the various relay locations in Figure 4 depict the direction for forward operation of the respective relays, i.e. in the same way as for parallel feeders, the directional relays are set to look into the feeder that they are protecting. Figure 4 shows typical relay time settings (if definite time co-ordination was employed), from which it can be seen that any faults on the inter-connectors between stations are cleared discriminatively by the relays at each end of the feeder.

Again, any of the four overcurrent stages may be configured to be directional and co-ordinated as per the previously outlined grading procedure, noting that IDMT characteristics are only selectable on the first two stages.

2.2.3 Setting guidelines

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

Note that the minimum setting that may be applied has to take into account the thermal rating of the relay. Some electro-mechanical directional overcurrent relays have continuous withstand ratings of only twice the applied current setting and hence 50% of rating was the minimum setting that could be applied. With the P145, the continuous current rating is 4 x rated current and so it is possible to apply much more sensitive settings if required. However, there are minimum safe current setting constraints to be observed when applying directional overcurrent protection at the receiving-ends of parallel feeders. The minimum safe settings to ensure that there is no possibility of an unwanted trip during clearance of a source fault are as follows for linear system load:



Parallel plain feeders:

Set>50% Prefault load current

Parallel transformer feeders:

Set>87% Prefault load current

When the above setting constraints are infringed, independent-time protection is more likely to issue an unwanted trip during clearance of a source fault than dependent-time protection.

Where the above setting constraints are unavoidably infringed, secure phase fault protection can be provided with relays which have 2-out-of-3 directional protection tripping logic.

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

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

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

Whilst it is possible to set the RCA to exactly match the system fault angle, it is recommended that the above guidelines are adhered to, as these settings have been shown to provide satisfactory performance and stability under a wide range of system conditions.

## 2.3 Thermal overload protection

Thermal overload protection can be used to prevent electrical plant from operating at temperatures in excess of the designed maximum withstand. Prolonged overloading causes excessive heating, which may result in premature ageing of the insulation, or in extreme cases, insulation failure.

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

The heat generated within an item of plant, such as a cable or a transformer, is the resistive loss ($I^2R \times t$). Thus, heating is directly proportional to current squared. The thermal time characteristic used in the relay is therefore based on current squared, integrated over time. The relay automatically uses the largest phase current for input to the thermal model.

Equipment is designed to operate continuously at a temperature corresponding to its full load rating, where heat generated is balanced with heat dissipated by radiation etc.
Over-temperature conditions therefore occur when currents in excess of rating are allowed to flow for a period of time. It can be shown that temperatures during heating follow exponential time constants and a similar exponential decrease of temperature occurs during cooling.

### 2.3.1 Setting guidelines

#### 2.3.1.1 Single time constant characteristic

The current setting is calculated as:

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

Typical time constant values are given in the following tables. The relay setting, "Time Constant 1", is in minutes.

Paper insulated lead sheathed cables or polyethylene insulated cables, laid above ground or in conduits. The table shows it in minutes, for different cable rated voltages and conductor cross-sectional areas:



| CSA $mm^2$ | 6 – 11 kV | 22 kV | 33 kV | 66 kV |
|---|---|---|---|---|
| 25 – 50 | 10 | 15 | 40 | – |
| 70 – 120 | 15 | 25 | 40 | 60 |
| 150 | 25 | 40 | 40 | 60 |
| 185 | 25 | 40 | 60 | 60 |
| 240 | 40 | 40 | 60 | 60 |
| 300 | 40 | 60 | 60 | 90 |

Other plant items:

| | Time Constant $\tau$ (Minutes) | Limits |
|---|---|---|
| Dry-type Transformers | 40<br>60 – 90 | Rating <400 kVA<br>Rating 400 – 800 kVA |
| Air-core Reactors | 40 | |
| Capacitor Banks | 10 | |
| Overhead Lines | 10 | Cross section ≥100 mm2 Cu or 150mm2 Al |
| Busbars | 60 | |

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

#### 2.3.1.2 Dual time constant characteristic

The current setting is calculated as:

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

Typical time constants:

| | $\tau_1$ (Minutes) | $\tau_2$ (Minutes) | Limits |
|---|---|---|---|
| Oil-filled Transformer | 5 | 120 | Rating 400 – 1600 kVA |

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

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

## 2.4 Earth fault protection

The fact that both EF1 and EF2 elements may be enabled in the relay at the same time leads to a number of applications advantages. For example, the parallel transformer application previously shown in Figure 3 requires directional earth fault protection at locations R3 and R4, to provide discriminative protection. However, in order to provide back-up protection for the transformer, busbar and other downstream earth fault devices, Standby Earth Fault (SBEF) protection is also commonly applied. This function has traditionally been fulfilled by a separate earth fault relay, fed from a single CT in the transformer earth connection. The EF1 and EF2 elements of the P145 relay may be used to provide both the directional earth fault (DEF) and SBEF functions, respectively.

Where a Neutral Earthing Resistor (NER) is used to limit the earth fault level to a particular value, it is possible that an earth fault condition could cause a flashover of the NER and hence a dramatic increase in the earth fault current. For this reason, it may be appropriate to apply two stage SBEF protection. The first stage should have suitable current and time characteristics which co-ordinate with downstream earth fault protection. The second stage may then be set with a higher current setting but with zero time delay; hence providing fast clearance of an earth fault which gives rise to an NER flashover.

The remaining two stages are available for customer specific applications.

The previous examples relating to transformer feeders utilize both EF1 and EF2 elements. In a standard feeder application requiring three-phase overcurrent and earth fault protection, only one of the earth fault elements would need to be applied. If EF1 were to be used, the connection would be a standard arrangement of the three-phase currents feeding into the phase inputs, with the EF1 input connected into the residual path. This is shown in Figure 5. In this application, EF2 should be disabled in the menu. Alternatively, where the EF2 element is used, no residual connection of the CT's will be required.

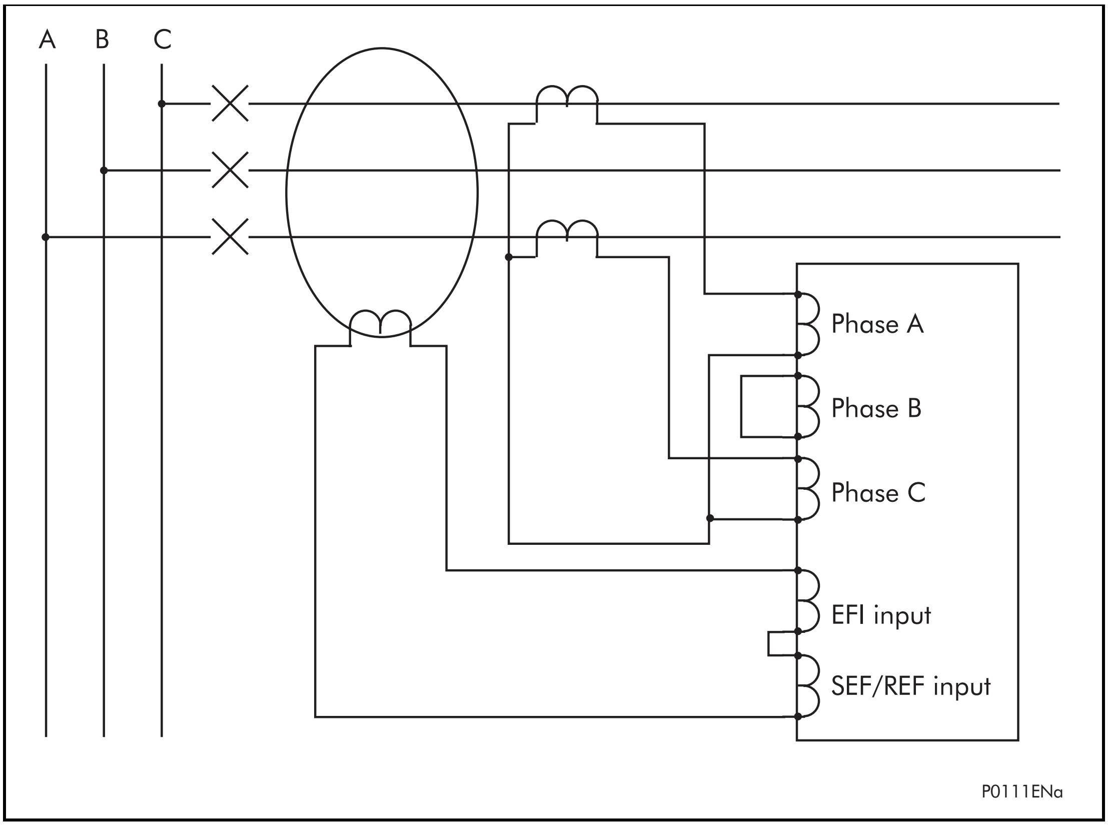





**Figure 5: Three-phase overcurrent & residually connected earth fault protection**

2.4.1 Sensitive earth fault protection element (SEF)

SEF would normally be fed from a core balance current transformer (CBCT) mounted around the three phases of the feeder cable. However, care must be taken in the positioning of the CT with respect to the earthing of the cable sheath. See Figure 6 below.

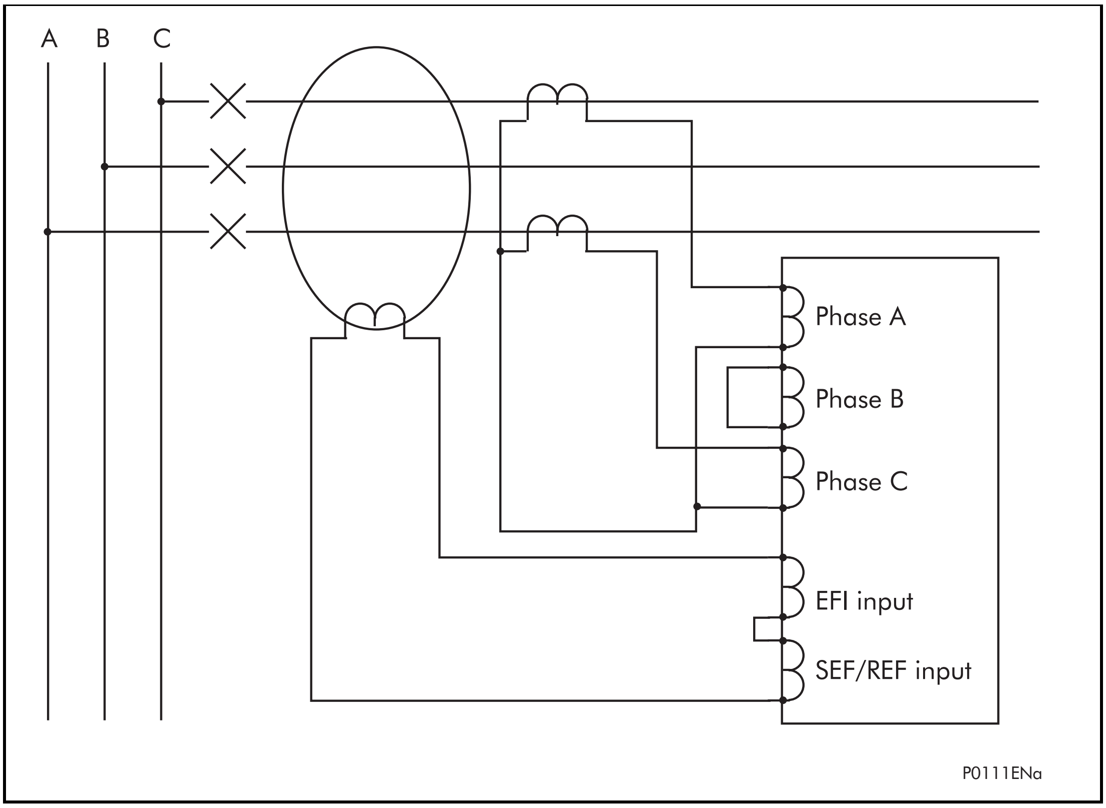



**Figure 6: Positioning of core balance current transformers**

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

## 2.5 Directional earth fault protection (DEF)

As stated in the previous sections, each of the four stages of EF1, EF2 and SEF protection may be set to be directional if required. Consequently, as with the application of directional overcurrent protection, a suitable voltage supply is required by the relay to provide the necessary polarization.

### 2.5.1 General setting guidelines for DEF applied to earthed systems

When setting the Relay Characteristic Angle (RCA) for the directional overcurrent element, a positive angle setting was specified. With DEF, the residual current under fault conditions lies at an angle lagging the polarizing voltage. Hence, negative RCA settings are required for DEF applications. This is set in cell "I>Char Angle" in the relevant earth fault menu.

The following angle settings are recommended for a residual voltage polarized relay:

| | | |
|---|---|---|
| Resistance earthed systems | = | 0° |
| Distribution systems (solidly earthed) | = | –45° |
| Transmission systems (solidly earthed) | = | –60° |

For negative sequence polarization, the RCA settings must be based on the angle of the nps source impedance, much the same as for residual polarizing. Typical settings would be:

| | |
|---|---|
| Distribution systems | –45° |
| Transmission systems | –60° |

### 2.5.2 Application to insulated systems

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 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 P145 relays and is detailed in section 2.7. However, fully discriminative earth fault protection on this type of system can only 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 be used for this application.

This eliminates the possibility of spill current that may arise from slight mismatches between residually connected line CTs. It also enables a much lower CT ratio to be applied, thereby allowing the required protection sensitivity to be more easily achieved.

When considering the fault distribution on an insulated system for a C phase fault, from Figure 7, it can be seen that the relays on the healthy feeders see the unbalance in the charging currents for their own feeder. The relay on the faulted feeder, however, sees the charging current from the rest of the system (IH1 and IH2 in this case), with it's own feeders charging current (IH3) becoming cancelled out. The phasor diagrams shown in Figure 8 further illustrate this.

Referring to the phasor diagram, it can be seen that the C phase to earth fault causes the voltages on the healthy phases to rise by a factor of √3. The A phase charging current (Ia1), 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°.

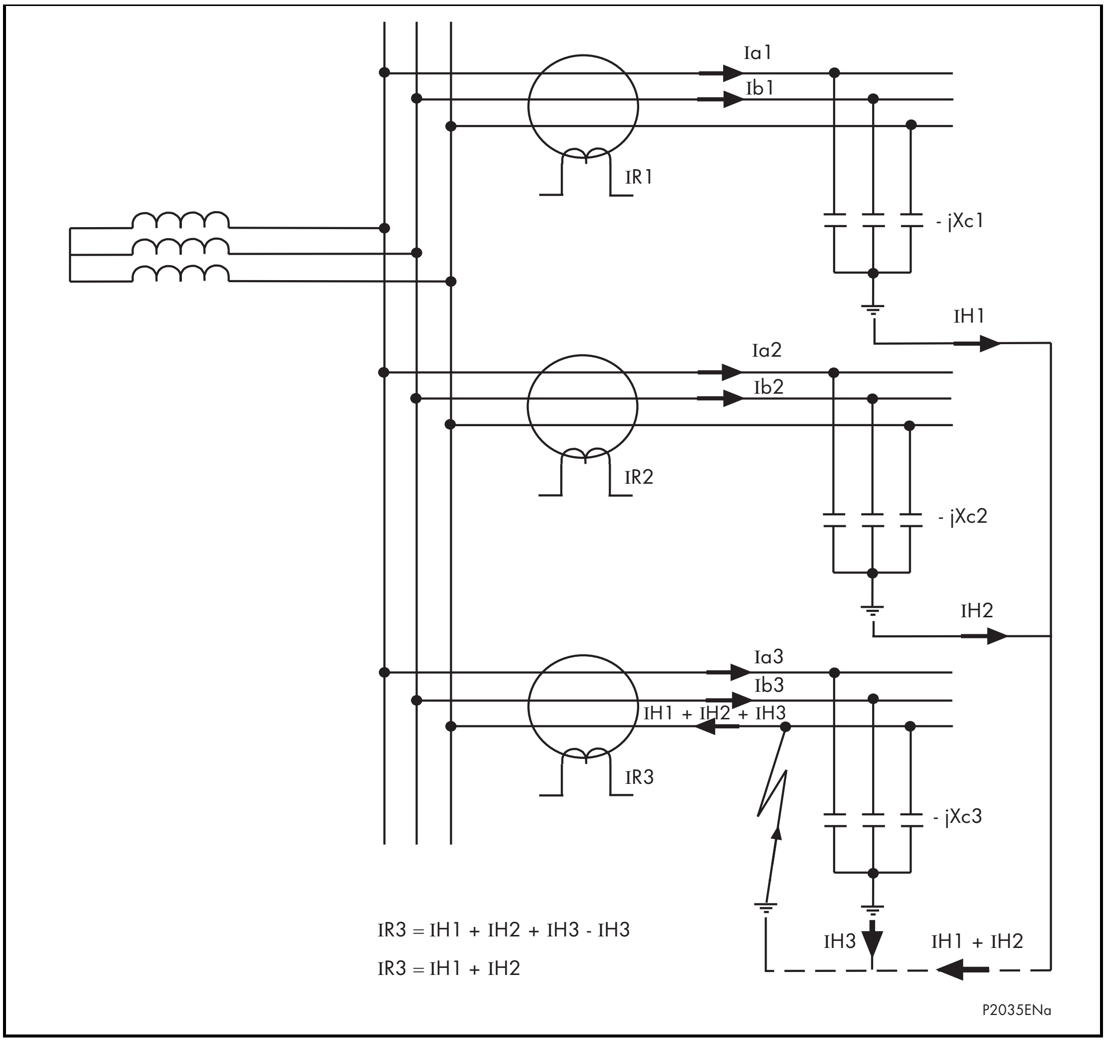



**Figure 7: Current distribution in an insulated system with C phase fault**

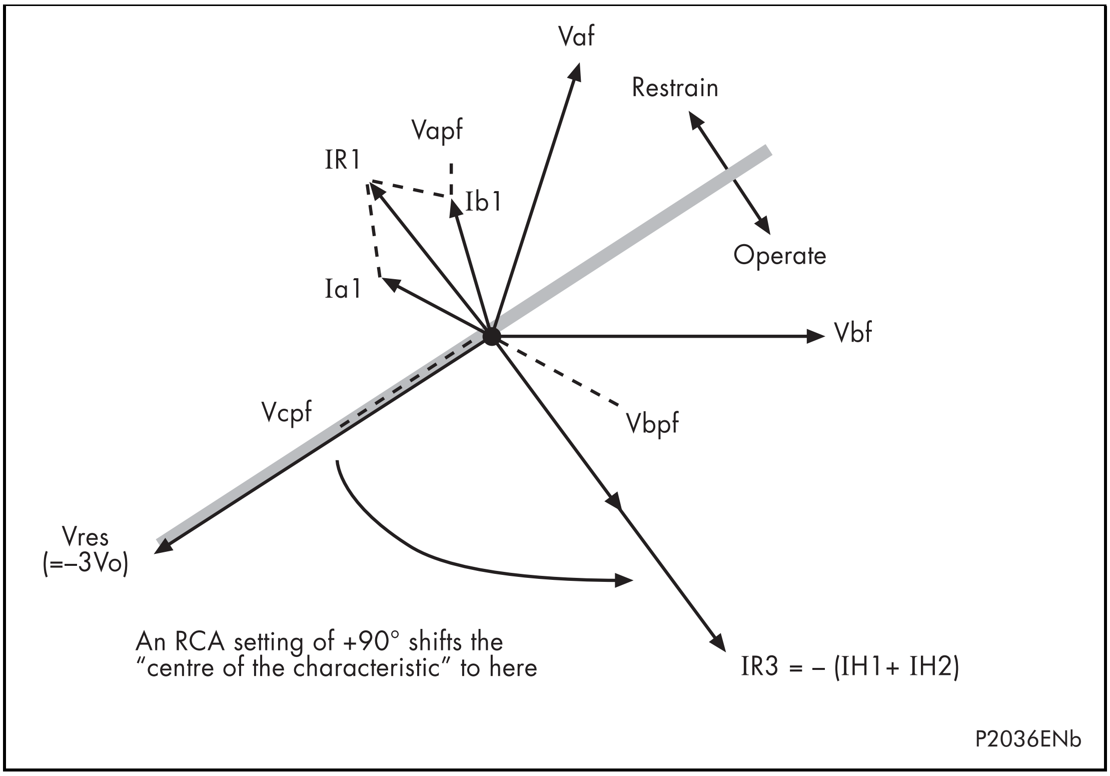



**Figure 8: Phasor diagrams for insulated system with C phase fault**

The unbalance current detected by a core balance current transformer on the healthy feeders can be seen to be the vector addition of Ia1 and Ib1, giving a residual current which lies at exactly 90° lagging the polarizing voltage (–3Vo). As the healthy phase voltages have risen by a factor of √3, the charging currents on these phases will also be √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.

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

If the polarizing voltage of this element, equal to –3Vo, 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.

As previously stated, the required characteristic angle setting for the SEF element when applied to insulated systems, is +90°. It should be noted though, that this recommended setting corresponds to the relay being connected such that it's direction of current flow for operation is from the source busbar towards the feeder, as would be the convention for a relay on an earthed system. However, if the forward direction for operation were set as being from the feeder into the busbar, (which some utilities may standardize on), then a –90° RCA would be required. The correct relay connections to give a defined direction for operation are shown on the relay connection diagram.

Note that 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.



### 2.5.3 Setting guidelines - insulated systems

As has been previously shown, the residual current detected by the relay on the faulted feeder is equal to the sum of the charging currents flowing from the rest of the system. 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 unbalance current detected by the relay is equal to three times the per phase charging current of the rest of the system. A typical relay setting 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 upon practically obtained results. The use of the P145 relays' comprehensive measurement and fault recording facilities may prove useful in this respect.

### 2.5.4 Application to Petersen Coil earthed systems

Power systems are usually earthed in order 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 will be reduced but the steady state and transient overvoltages on the sound phases can be very high. Consequently, it is generally the case that high impedance earthing will only be used in low/medium voltage networks in which it does not prove too costly to provide the necessary insulation against such overvoltages. Higher system voltages would normally be solidly earthed or earthed via a low impedance.

A special case of high impedance earthing via a reactor occurs when the inductive earthing reactance is made equal to the total system capacitive reactance to earth at system frequency. This practice is widely referred to as Petersen (or resonant) Coil Earthing. With a correctly tuned system, the steady state earthfault current will be zero, so that arcing earth faults become self-extinguishing. Such a system can, if designed to do so, be run with one phase earthed for a long period until the cause of the fault is identified and rectified.

Figure 9 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. Consequently, the calculations show that if the reactance of the earthing coil is set correctly, the resulting steady state earth fault current will be zero.

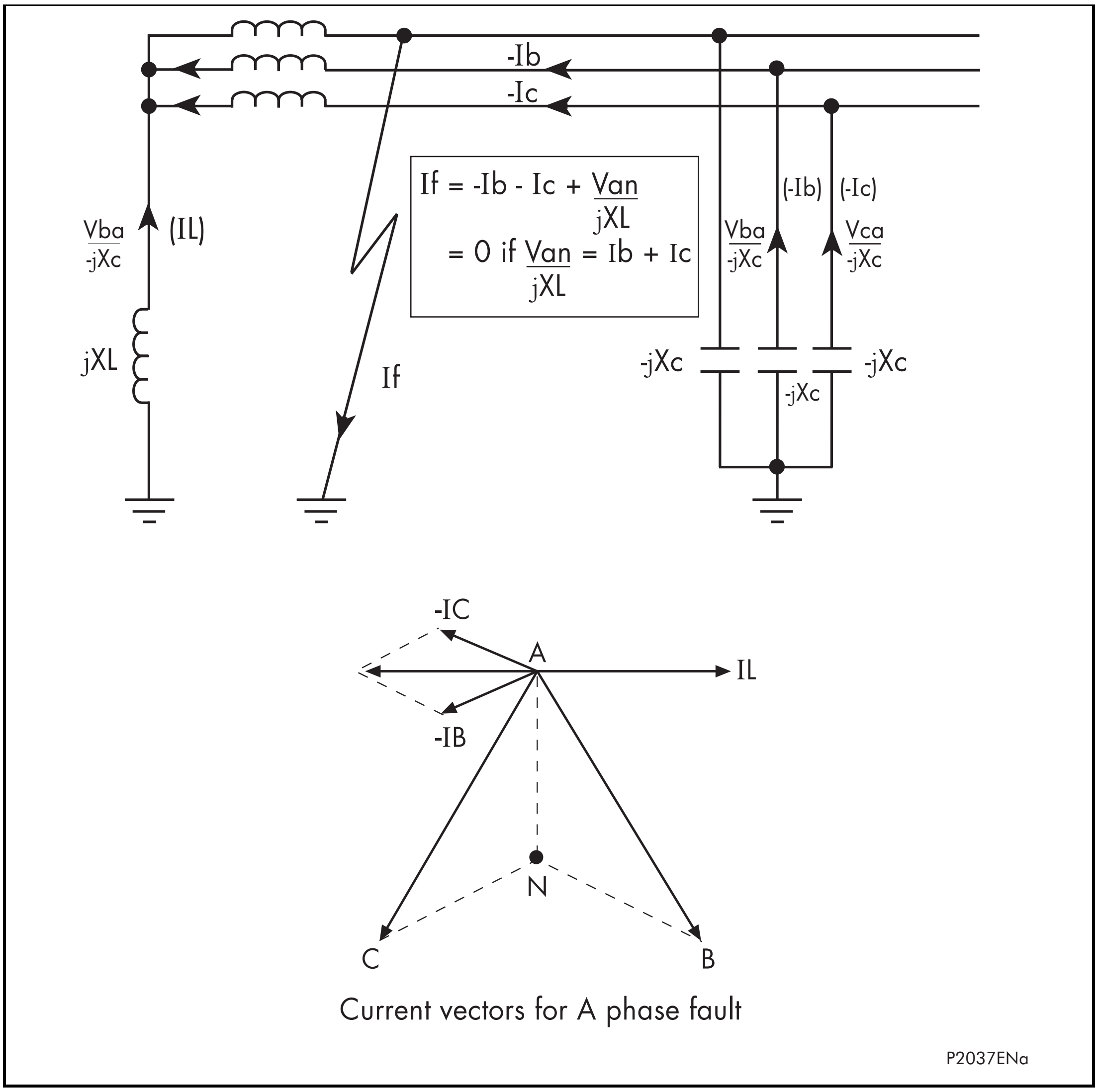



**Figure 9: Current distribution in Petersen Coil earthed system**

Figure 10 shows a radial distribution system having a source that is earthed via a Petersen Coil. Three outgoing feeders are present, the lower of which has a phase to earth fault applied on the C phase.

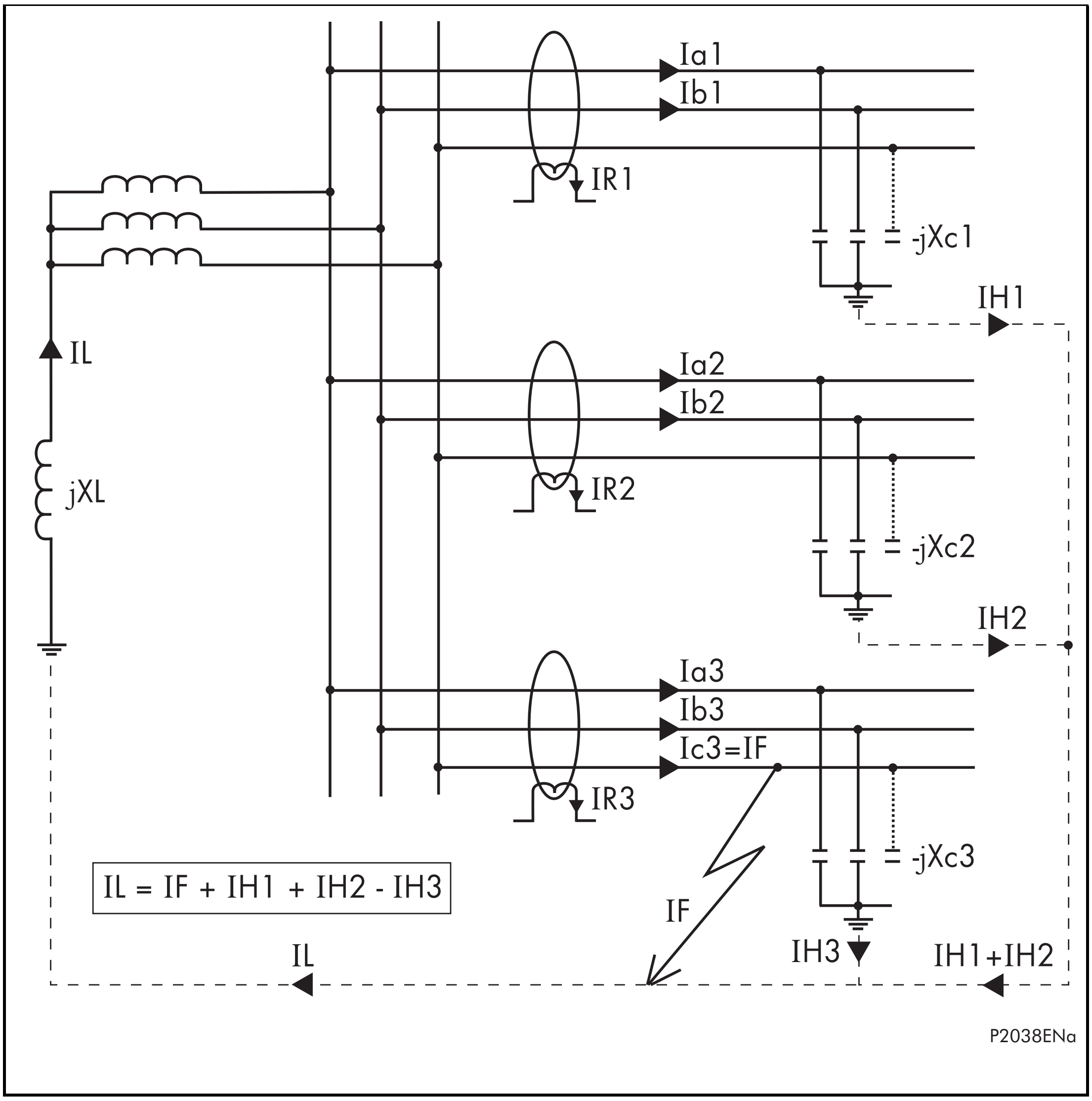



**Figure 10: Distribution of currents during a C phase to earth fault**

Figures 11 (a, b and c) show vector diagrams for the previous system, assuming that it is fully compensated (i.e. 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.

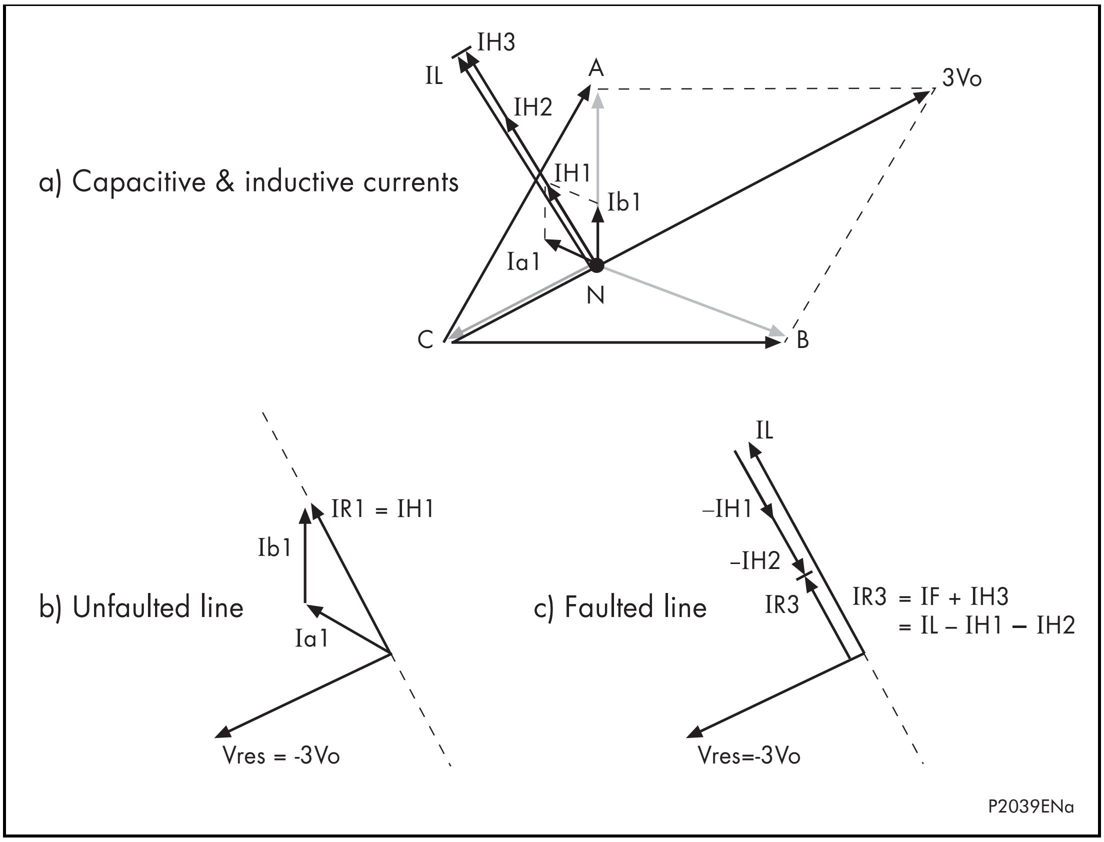



**Figure 11: Theoretical case - no resistance present in XL or XC**

Referring to the vector diagram illustrated in Figure 11a, it can be seen that the C phase to earth fault causes the voltages on the healthy phases to rise by a factor of √3. The A phase charging currents (Ia1, Ia2 and Ia3), are then shown to be leading the resultant A phase voltage by 90° and likewise for the B phase charging currents with respect to the resultant Vb.

The unbalance current detected by a core balance current transformer on the healthy feeders can be seen to be a simple vector addition of Ia1 and Ib1, giving a residual current which lies at exactly 90° lagging the residual voltage (Figure 11b). Clearly, as the healthy phase voltages have risen by a factor of √3, the charging currents on these phases will also be √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 –3Vo in the vector diagrams. This phase shift is automatically introduced within the P145 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 11c.

This situation may be more readily observed by considering the zero sequence network for this fault condition. This is depicted in Figure 12.

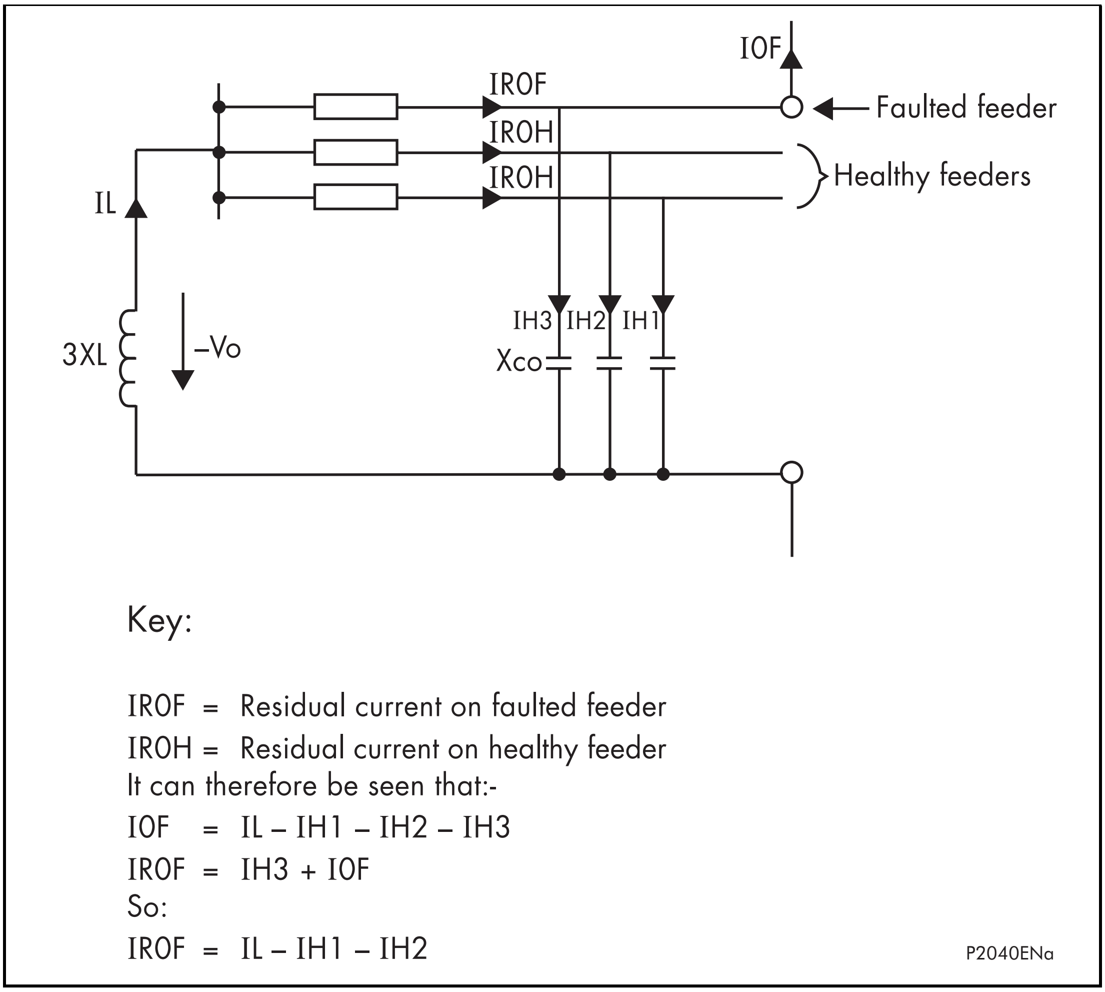



**Figure 12: Zero sequence network showing residual currents**

In comparing the residual currents occurring on the healthy and on the faulted feeders (Figures 11b & 11c), it can be seen that the currents would be similar in both magnitude and phase; hence it would not be possible to apply a relay which could provide discrimination.

However, as previously stated, 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 – consider Figure 13.

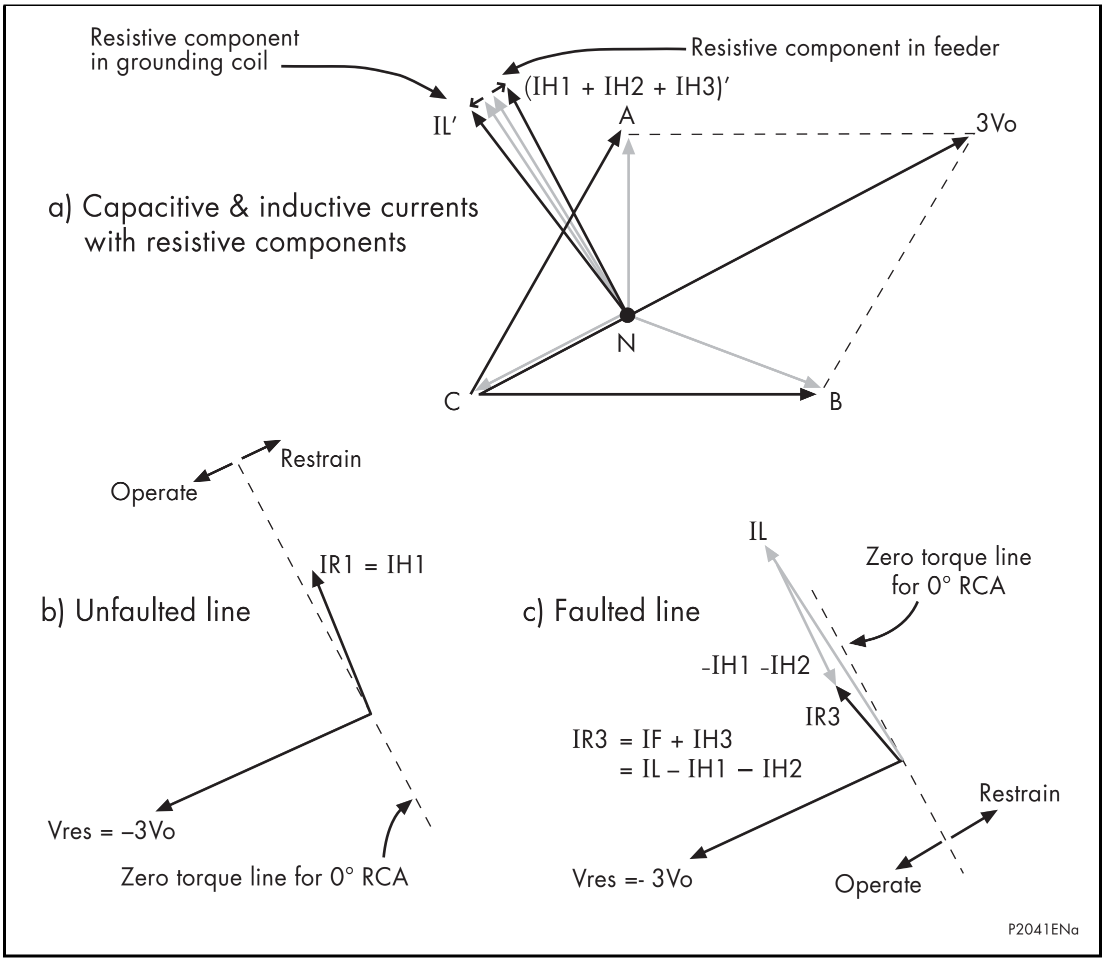



**Figure 13: Practical case - resistance present in XL and Xc**

Figure 13a 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 Figures 13b and 13c.

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. Hence, a directional relay having a characteristic angle setting of 0° (with respect to the polarizing signal of -3Vo) could be applied to provide discrimination. i.e. the healthy feeder residual current would appear within the restrain section of the characteristic but the residual current on the faulted feeder would lie within the operate region - as shown in diagrams 13b and 13c.

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

### 2.5.5 Applications to compensated networks

#### 2.5.5.1 Required relay current and voltage connections

Referring to the relevant application diagram for the P145 Relay, it should be applied such that it's direction for forward operation is looking down into the protected feeder (away from the busbar), with a 0° RCA setting.

AP

#### 2.5.5.2 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 upon practically obtained results.

It should be noted that in most situations, the system will not be fully compensated and consequently a small level of steady state fault current will be allowed to flow. The residual current seen by the relay on the faulted feeder may thus be a larger value, which further emphasizes the fact that relay settings should be based upon 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 0º is required. However, fine-tuning of this setting will require to be carried out on site in order to obtain the optimum setting in accordance with the levels of coil and feeder resistances present. The loading and performance of the CT will also have an effect in this regard. The effect of CT magnetizing current will be to create phase lead of current. Whilst this would assist with operation of faulted feeder relays it would reduce 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 P145 relays.



## 2.6 Restricted earth fault protection

Earth faults occurring on a transformer winding or terminal may be of limited magnitude, either due to the impedance present in the earth path or by the percentage of transformer winding that is involved in the fault. As stated in section 2.4, it is common to apply standby earth fault protection fed from a single CT in the transformer earth connection - this provides time-delayed protection for a transformer winding or terminal fault. In general, particularly as the size of the transformer increases, it becomes unacceptable to rely on time delayed protection to clear winding or terminal faults as this would lead to an increased amount of damage to the transformer. A common requirement is therefore to provide instantaneous phase and earth fault protection. Applying differential protection across the transformer may fulfil these requirements. However, an earth fault occurring on the LV winding, particularly if it is of a limited level, may not be detected by the differential relay, as it is only measuring the corresponding HV current. Therefore, instantaneous protection that is restricted to operating for transformer earth faults only, is applied. This is referred to as restricted, or balanced, earthfault protection (REF or BEF). The BEF terminology is usually used when the protection is applied to a delta winding.

When applying differential protection such as REF, some suitable means must be employed to give the protection stability under external fault conditions, thus ensuring that relay operation only occurs for faults on the transformer winding / connections.

Two methods are commonly used; bias or high impedance. The biasing technique operates by measuring the level of through current flowing and altering the relay sensitivity accordingly. The high impedance technique ensures that the relay circuit is of sufficiently high impedance such that the differential voltage that may occur under external fault conditions is less than that required to drive setting current through the relay.

The REF protection in the P145 relays may be configured to operate as either a high impedance or biased element and the following sections describe the application of the relay in each mode.

Note that the high impedance REF element of the relay shares the same CT input as the SEF protection. Hence, only one of these elements may be selected. However, the low impedance REF element does not use the SEF input and so may be selected at the same time.

Note that CT requirements for REF protection are included in section 4.

2.6.1 Biased differential protection

Figures 14 show the appropriate relay connections for the P145 relay applied for biased REF protection.

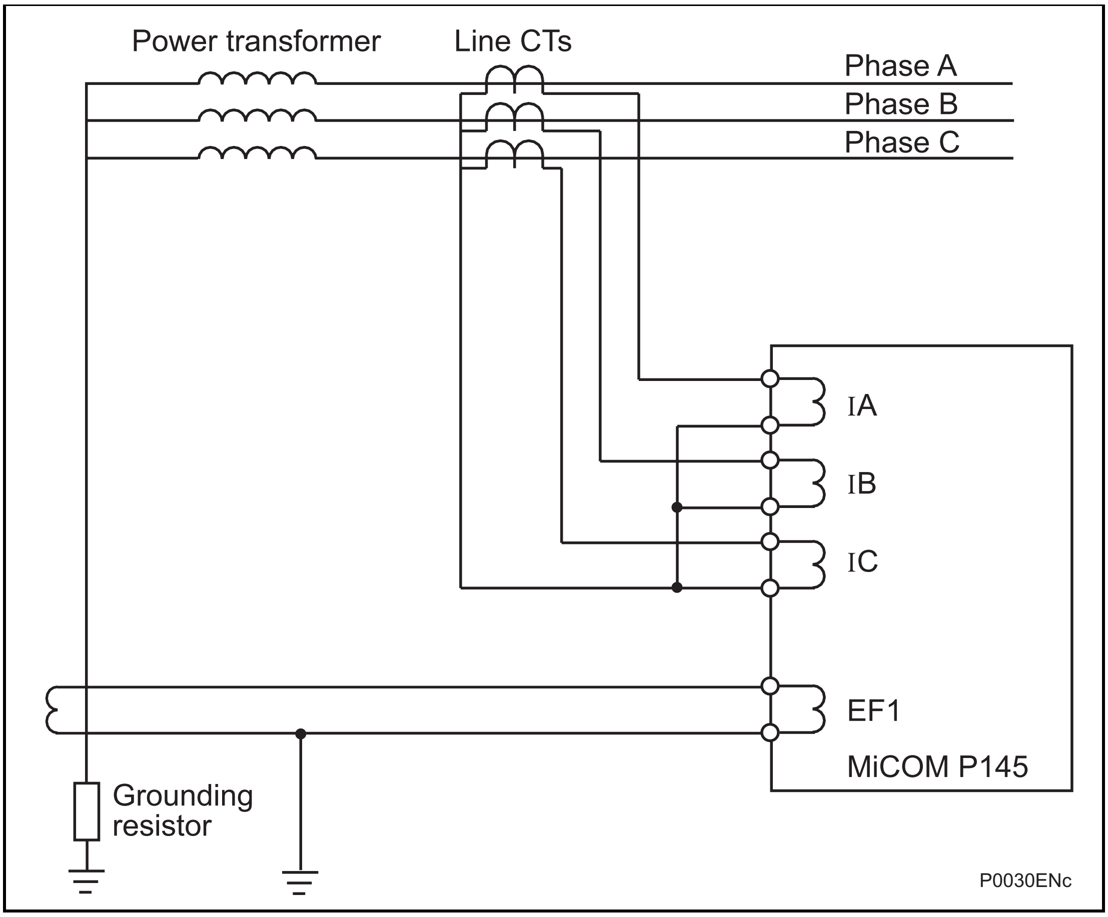



**Figure 14: Relay connections for biased REF protection**

As can be seen in Figure 14, the three line CTs are connected to the three-phase CTs in the normal manner. The neutral CT is then connected to the EF1 CT input. These currents are then used internally to derive both a bias and a differential current quantity for use by the low impedance REF protection. The advantage of this mode of connection is that the line and neutral CT's are not differentially connected and so the neutral CT can also be used to drive the EF1 protection to provide Standby Earth Fault Protection. Also, no external equipment such as stabilizing resistors or metrosils is required, as is the case with high impedance protection.

2.6.2 Setting guidelines for biased REF protection

As can be seen from Figure 13 in the Operation section (P145/EN OP), two bias settings are provided in the REF characteristic of the P145. The k1 level of bias is applied up to through currents of Is2, which is normally set to the rated current of the transformer. k1 should normally be set to 0% to give optimum sensitivity for internal faults. However, if any CT mismatch is present under normal conditions, then k1 may be increased accordingly, to compensate.

k2 bias is applied for through currents above Is2 and would typically be set to 150%.

AP

### 2.6.3 Setting guidelines for high impedance REF

From the "Sens. E/F option" cell, "Hi Z REF" must be selected to enable this protection. The only setting cell then visible is "IREF>Is", which may be programmed with the required differential current setting. This would typically be set to give a primary operating current of either 30% of the minimum earth fault level for a resistance earthed system or between 10 and 60% of rated current for a solidly earthed system.

The primary operating current (Iop) will be a function of the current transformer ratio, the relay operating current (IREF>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:

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

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

2. To determine the minimum relay current setting to achieve a specific primary operating current with a given current transformer magnetizing current.

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

3. To express the protection primary operating current for a particular relay operating current and with a particular level of magnetizing current.

$$I_{op} = (\text{CT ratio}) \times (\text{IREF} > \text{Is} + nI_c)$$

In order to achieve the required primary operating current with the current transformers that are used, a current setting (IREF>Is) must be selected for the high impedance element, as detailed in expression (ii) above. The setting of the 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 (IREF>Is).

$$\frac{Vs}{\text{IREF>Is}} = \frac{I_F\,(R_{CT} + 2_{RL})}{I_{REF} > I_s}$$

Note: The above formula assumes negligible relay burden.

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

### 2.6.4 Use of METROSIL non-linear resistors

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 3000V peak.

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

$$Vp = 2\sqrt{2V_k\,(V_f - V_k)}$$

$$Vf = I'f\,(Rct + 2RL + RST)$$

Where Vp = Peak voltage developed by the CT under internal fault conditions

Vk = Current transformer kneepoint voltage

AP

Vf = Maximum voltage that would be produced if CT saturation did not occur

I'f = Maximum internal secondary fault current

Rct = Current transformer secondary winding resistance

RL = Maximum lead burden from current transformer to relay

RST = Relay stabilizing resistor

When the value given by the formulae is greater than 3000V peak, metrosils should be applied. They are connected across the relay circuit and serve the purpose of shunting the secondary current output of the current transformer from the relay in order 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 non-linear resistor (metrosil)

C = Constant of the non-linear resistor (metrosil)

I = Instantaneous current through the non-linear resistor (metrosil)

AP

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

$$I(rms) = 0.52 \left( \frac{Vs\ (rms) \times \sqrt{2}}{C} \right)^4$$

where Vs(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.

For satisfactory application of a non-linear resistor (metrosil), it's characteristic should be such that it complies with the following requirements:

1. At the relay voltage setting, the non-linear resistor (metrosil) current should be as low as possible, but no greater than approximately 30mA rms for 1A current transformers and approximately 100mA rms for 5A current transformers.

2. At the maximum secondary current, the non-linear resistor (metrosil) should limit the voltage to 1500V rms or 2120V peak for 0.25 second. At higher relay voltage settings, it is not always possible to limit the fault voltage to 1500V 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 Relays with a 1 Amp CT

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

1. At the relay voltage setting, the Metrosil current should be less than 30mA rms.

2. At the maximum secondary internal fault current the Metrosil unit should limit the voltage to 1500V rms if possible.

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

| Relay Voltage Setting | Nominal Characteristic | | Recommended Metrosil Type | |
|---|---|---|---|---|
| | C | β | Single Pole Relay | Triple Pole Relay |
| Up to 125V rms<br>125 to 300V rms | 450<br>900 | 0.25<br>0.25 | 600A/S1/S256<br>600A/S1/S1088 | 600A/S3/1/S802<br>600A/S3/1/S1195 |

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

Metrosil units for relays with a 5 amp CT

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

1. At the relay voltage setting, the Metrosil current should be less than 100mA rms (the actual maximum currents passed by the units shown below their type description.

2. At the maximum secondary internal fault current the Metrosil unit should limit the voltage to 1500V rms for 0.25secs. At the higher relay settings, it is not possible to limit the fault voltage to 1500V rms hence higher fault voltages have to be tolerated (indicated by *, **, ***).

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

| Secondary Internal Fault Current | Recommended Metrosil Type | | | |
|---|---|---|---|---|
| | Relay Voltage Setting | | | |
| Amps rms | Up to 200V rms | 250V rms | 275V rms | 300V rms |
| 50A | 600A/S1/S1213<br>C = 540/640<br>35mA rms | 600A/S1/S1214<br>C = 670/800<br>40mA rms | 600A/S1/S1214<br>C =670/800<br>50mA rms | 600A/S1/S1223<br>C = 740/870*<br>50mA rms |
| 100A | 600A/S2/P/S1217<br>C = 470/540<br>70mA rms | 600A/S2/P/S1215<br>C = 570/670<br>75mA rms | 600A/S2/P/S1215<br>C =570/670<br>100mA rms | 600A/S2/P/S1196<br>C =620/740*<br>100mA rms |
| 150A | 600A/S3/P/S1219<br>C = 430/500<br>100mA rms | 600A/S3/P/S1220<br>C = 520/620<br>100mA rms | 600A/S3/P/S1221<br>C = 570/670**<br>100mA rms | 600A/S3/P/S1222<br>C =620/740***<br>100mA rm |
| | Note: | *2400V peak | **2200V peak | ***2600V peak |

In some situations single disc assemblies may be acceptable, contact AREVA T&D for detailed applications.

Note:

1. 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 from each other. To order these units please specify "Triple pole Metrosil type", followed by the single pole type reference.

2. Metrosil units for higher relay voltage settings and fault currents can be supplied if required.

## 2.7 Residual overvoltage (neutral displacement) protection

On a healthy three-phase power system, the addition of each of the three-phase to earth voltages is nominally zero, as it is the vector addition of three balanced vectors at 120° to one another. However, when an earth fault occurs on the primary system this balance is upset and a ‘residual’ voltage is produced. This could be measured, for example, at the secondary terminals of a voltage transformer having a “broken delta” secondary connection.

AP

Hence, a residual voltage-measuring relay can be used to offer earth fault protection on such a system. Note that this condition causes a rise in the neutral voltage with respect to earth that is commonly referred to as “neutral voltage displacement” or NVD.

Figures 15 and 16 show the residual voltages that are produced during earth fault conditions occurring on a solid and impedance earthed power system respectively.

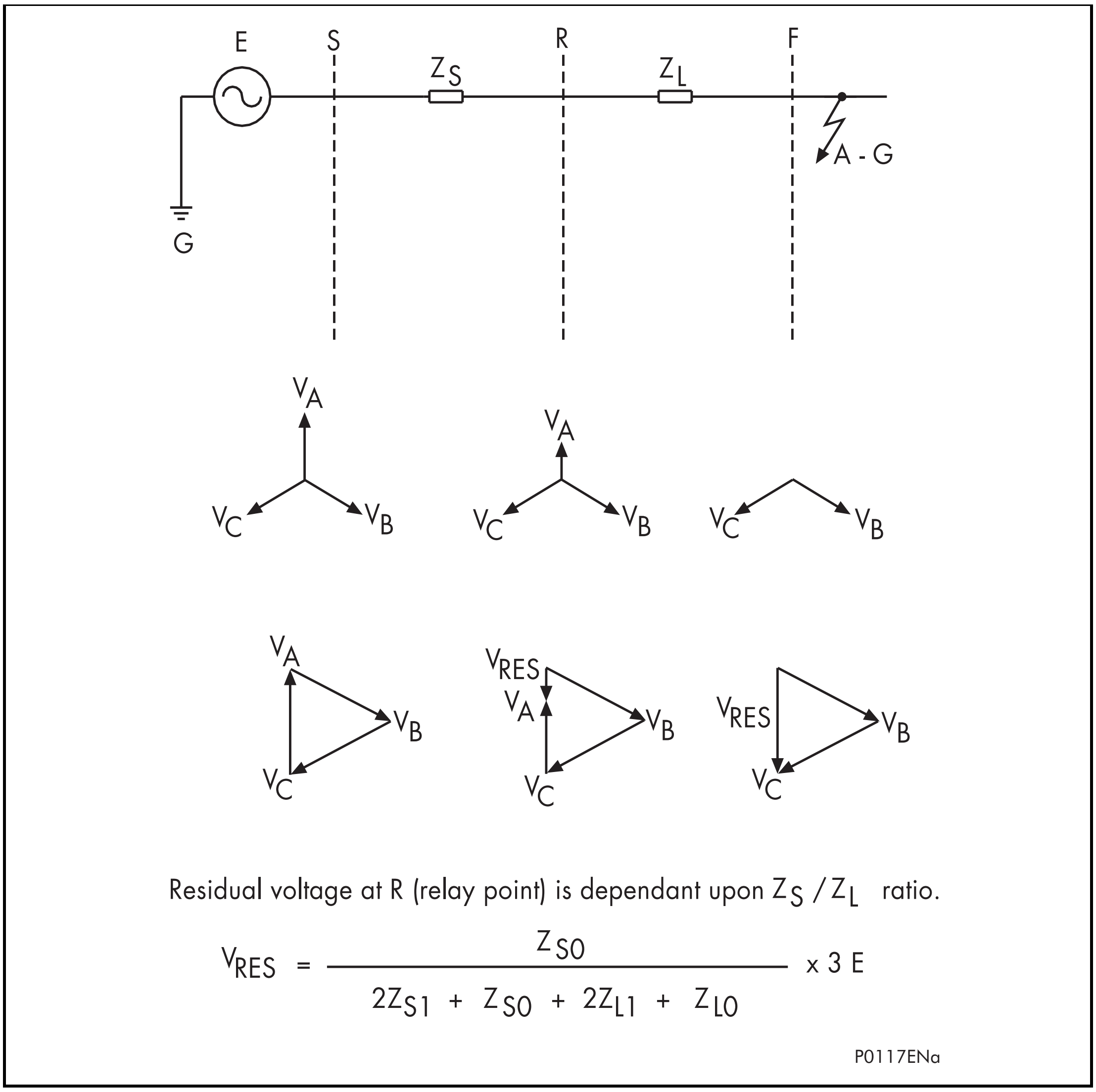



**Figure 15: Residual voltage, solidly earthed system**

As can be seen in Figure 15, the residual voltage measured by a relay for an earth fault on a solidly earthed system is solely dependent upon the ratio of source impedance behind the relay to line impedance in front of the relay, up to the point of fault. For a remote fault, the Zs/Zl ratio will be small, resulting in a correspondingly small residual voltage. As such, depending upon the relay setting, such a relay would only operate for faults up to a certain distance along the system. The value of residual voltage generated for an earth fault condition is given by the general formula shown in Figure 15.

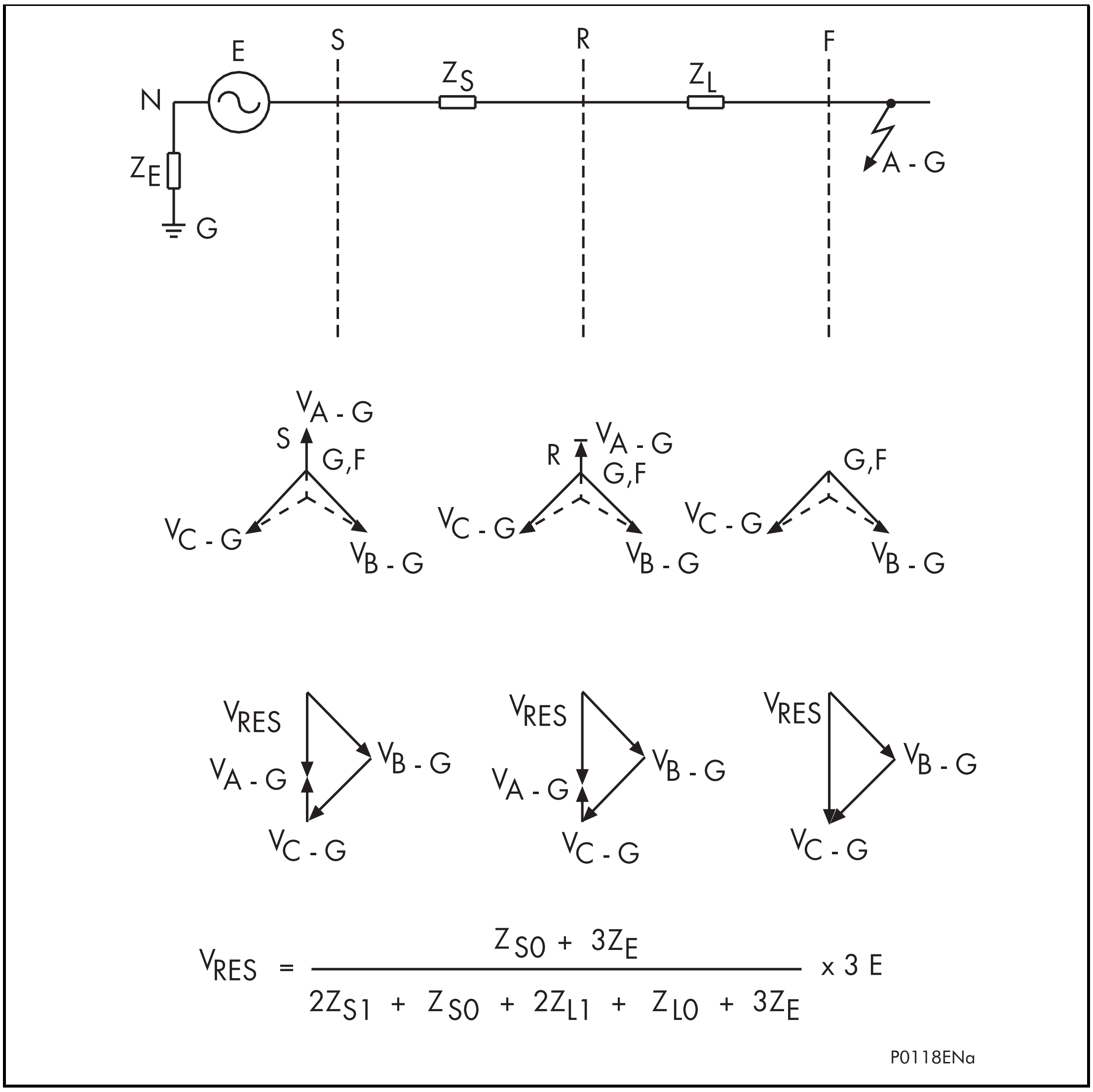



**Figure 16: Residual voltage, resistance earthed system**

Figure 16 shows that a resistance earthed system will always generate a relatively large degree of residual voltage, as the zero sequence source impedance now includes the earthing impedance. It follows then, that the residual voltage generated by an earth fault on an insulated system will be the highest possible value (3 x phase-neutral voltage), as the zero sequence source impedance is infinite.

From the previous information 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 or insulated systems, where the provision of core balance CT's on each feeder may be either impractical, or uneconomic.

It must be noted that where residual overvoltage protection is applied, such a voltage will be generated for a fault occurring anywhere on that section of the system and hence the NVD protection must co-ordinate with other earth fault protections.

AP

The P145 relay internally derives this voltage from the three-phase voltage input that must be supplied from either a 5-limb or three single-phase VT's. These types of VT design allow the passage of residual flux and consequently permit the relay to derive the required residual voltage. In addition, the primary star point of the VT must be earthed. A three limb VT has no path for residual flux and is therefore unsuitable to supply the relay.

2.7.1 Setting guidelines

The voltage setting applied to the elements is dependent upon the magnitude of residual voltage that is expected to occur during the earth fault condition. This in turn is dependent upon the method of system earthing employed and may be calculated by using the formulae previously given in Figures 15 and 16. It must also be ensured that the relay is set above any standing level of residual voltage that is present on the system.

Note that IDMT characteristics are selectable on the first stage of NVD in order that elements located at various points on the system may be time graded with one another.

## 2.8 Undervoltage protection

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

- Increased system loading. Generally, some corrective action would be taken by voltage regulating equipment such as AVR's or On Load Tap Changers, in order to bring the system voltage back to it's nominal value. If the regulating equipment is unsuccessful in restoring healthy system voltage, then tripping by means of an undervoltage relay will be required following a suitable time delay.

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

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

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

Both the under and overvoltage protection functions can be found in the relay menu "Volt Protection". The following table shows the undervoltage section of this menu along with the available setting ranges and factory defaults.

2.8.1 Setting guidelines

In the majority of applications, undervoltage protection is not required to operate during system earth fault conditions. If this is the case, the element should be selected in the menu to operate from a phase to phase voltage measurement, as this quantity is less affected by single-phase voltage depressions due to earth faults.

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

Similar comments apply with regard to a time setting for this element, i.e. the required time delay is dependent upon the time for which the system is able to withstand a depressed voltage. As mentioned earlier, if motor loads are connected, then a typical time setting may be in the order of 0.5 seconds.

## 2.9 Overvoltage protection

As previously discussed, undervoltage conditions are relatively common, as they are related to fault conditions etc. However, overvoltage conditions are also a possibility and are generally related to loss of load conditions as described below:

Under conditions of load rejection, the supply voltage will increase in magnitude. This situation would normally be rectified by voltage regulating equipment such as AVR's or on-load tap changers. However, failure of this equipment to bring the system voltage back within prescribed limits leaves the system with an overvoltage condition which must be cleared in order to preserve the life of the system insulation. Hence, overvoltage protection that is suitably time-delayed to allow for normal regulator action, may be applied.

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

### 2.9.1 Setting guidelines

The inclusion of the two stages and their respective operating characteristics allows for a number of possible applications:

- Use of the IDMT characteristic gives the option of a longer time delay if the overvoltage condition is only slight but results in a fast trip for a severe overvoltage. As the voltage settings for both of the stages are independent, the second stage could then be set lower than the first to provide a time delayed alarm stage if required
- Alternatively, if preferred, both stages could be set to definite time and configured to provide the required alarm and trip stages
- If only one stage of overvoltage protection is required, or if the element is required to provide an alarm only, the remaining stage may be disabled within the relay menu

This type of protection must be co-ordinated with any other overvoltage relays at other locations on the system. This should be carried out in a similar manner to that used for grading current operated devices.

AP

## 2.10 Negative sequence overvoltage protection

Where an incoming feeder is supplying a switchboard which is feeding rotating plant (e.g. induction motors), correct phasing and balance of the ac supply is essential. Incorrect phase rotation will result in any connected motors rotating in the wrong direction. For directionally sensitive applications, such as elevators and conveyor belts, it may be unacceptable to allow this to happen.

Any unbalanced condition occurring on the incoming supply will result in the presence of negative phase sequence (nps) components of voltage. In the event of incorrect phase rotation, the supply voltage would effectively consist of 100% negative phase sequence voltage only.

### 2.10.1 Setting guidelines

As the primary concern is normally the detection of incorrect phase rotation (rather than small unbalances), a sensitive setting is not required. In addition, it must be ensured that the setting is above any standing nps voltage that may be present due to imbalances in the measuring VT, relay tolerances etc. A setting of approximately 15% of rated voltage may be typical.

Note that standing levels of nps voltage (V2) will be displayed in the "Measurements 1" column of the relay menu, labeled "V2 Magnitude". Hence, if more sensitive settings are required, they may be determined during the commissioning stage by viewing the actual level that is present.

The operation time of the element will be highly dependent on the application. A typical setting would be in the region of 5s.

## 2.11 Negative sequence overcurrent protection (NPS)

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

Any unbalanced fault condition will produce negative sequence current of some magnitude. Thus, a negative phase sequence overcurrent element can operate for both phase to phase and phase to earth faults.

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

AP

### 2.11.1 Setting guidelines

#### 2.11.1.1 Negative phase sequence current threshold, 'I2> Current Set'

The 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.

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

#### 2.11.1.2 Time delay for the negative phase sequence overcurrent element, 'I2> Time Delay'

As stated above, correct setting of the time delay for this function is vital. It should also be noted that this element is applied primarily to provide back-up protection to other protective devices or to provide an alarm. Hence, in practice, it would be associated with a long time delay.

It must be ensured that the time delay is set greater than the operating time of any other protective device (at minimum fault level) on the system which may respond to unbalanced faults, such as:

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

2.11.1.3 Directionalizing the negative phase sequence overcurrent element

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

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

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

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

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



## 2.12 Voltage controlled overcurrent protection (51V)

As described in section 2.1, overcurrent relays are co-ordinated throughout a system such that cascade operation is achieved. This means that the failure of a downstream circuit breaker to trip for a fault condition, whether due to the failure of a protective device, or of the breaker itself, should result in time graded tripping of the next upstream circuit breaker.

However, where long feeders are protected by overcurrent relays, the detection of remote phase to phase faults may prove difficult. This is due to the fact that the current pick up of phase overcurrent elements must be set above the maximum load current, thereby limiting the elements minimum sensitivity. If the current seen by a local relay for a remote fault condition is below it's overcurrent setting, a voltage controlled overcurrent (VCO) element may be used to increase the relay sensitivity to such faults. In this case, a reduction in system voltage will occur; this may then be used to reduce the pick up level of the overcurrent protection.

Note that voltage dependent overcurrent relays are more often applied in generator protection applications in order to give adequate overcurrent relay sensitivity for close up fault conditions. The fault characteristic of this protection must then co-ordinate with any of the downstream overcurrent relays that are responsive to the current decrement condition. It therefore follows that if the P145 relay is to be applied on an outgoing feeder from a generator station, the use of voltage controlled overcurrent protection in the feeder relay may allow better co-ordination with the VCO relay on the generator. The settings in such an application will be directly dependent upon those employed for the generator relay.

2.12.1 Setting guidelines

The "VCO k Setting" should be set low enough to allow operation for remote phase to phase faults, typically:

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

where:

If = Minimum fault current expected for the remote fault

I> = Phase current setting for the element to have VCO control e.g. If the overcurrent relay has a setting of 160% In, but the minimum fault current for the remote fault condition is only 80% In, then the required k factor is given by:

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

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

## 2.13 Circuit breaker fail protection (CBF)

Following inception of a fault one or more main protection devices will operate and issue a trip output to the circuit breaker(s) associated with the faulted circuit. Operation of the circuit breaker is essential to isolate the fault, and prevent damage / further damage to the power system. For transmission/sub-transmission systems, slow fault clearance can also threaten system stability. It is therefore common practice to install circuit breaker failure protection, which monitors that the circuit breaker has opened within a reasonable time. If the fault current has not been interrupted following a set time delay from circuit breaker trip initiation, breaker failure protection (CBF) will operate.

CBF operation can be used to backtrip upstream circuit breakers to ensure that the fault is isolated correctly. CBF operation can also reset all start output contacts, ensuring that any blocks asserted on upstream protection are removed.



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

Resetting of the CBF is possible from a breaker open indication (from the relay’s pole dead logic) or from a protection reset. In these cases resetting is only allowed provided the undercurrent elements have also reset.

2.13.2 Typical settings

2.13.2.1 Breaker fail timer settings

Typical timer settings to use are as follows:

| CB fail reset mechanism | tBF time delay | Typical delay for 2 cycle circuit breaker |
|---|---|---|
| Initiating element reset | CB interrupting time + element reset time (max.) + error in tBF timer + safety margin | 50 + 50 + 10 + 50 = 160 ms |
| CB open | CB auxiliary contacts opening/ closing time (max.) + error in tBF timer + safety margin | 50 + 10 + 50 = 110 ms |
| Undercurrent elements | CB interrupting time + undercurrent element (max.) + safety margin operating time | 50 + 25 + 50 = 125 ms |

Note that 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 2-cycle circuit breaker. Note that where auxiliary tripping relays are used, an additional 10-15ms must be added to allow for trip relay operation.



2.13.2.2 Breaker fail undercurrent settings

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

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

ISEF< = (ISEF> trip) / 2

IN< = (IN> trip) / 2

## 2.14 Broken conductor detection

The majority of faults on a power system occur between one phase and ground or two phases and ground. These are known as shunt faults and arise from lightning discharges and other overvoltages that initiate flashovers. Alternatively, they may arise from other causes such as birds on overhead lines or mechanical damage to cables etc.

Another type of unbalanced fault that can occur on the system is the series or open circuit fault. These can arise from broken conductors, mal-operation of single-phase switchgear, or the operation of fuses. Series faults will not cause an increase in phase current on the system and hence are not readily detectable by standard overcurrent relays. However, they will produce an unbalance and a resultant level of negative phase sequence current, which can be detected.

It is possible to apply a negative phase sequence overcurrent relay to detect the above condition. However, on a lightly loaded line, the negative sequence current resulting from a series fault condition may be very close to, or less than, the full load steady state unbalance arising from CT errors, load unbalance etc. A negative sequence element therefore would not operate at low load levels.

2.14.1 Setting guidelines

For a broken conductor affecting a single point earthed power system, there will be little zero sequence current flow and the ratio of I2/I1 that flows in the protected circuit will approach 100%. In the case of a multiple earthed power system (assuming equal impedance's in each sequence network), the ratio I2/I1 will be 50%.

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

Note that a minimum value of 8% negative phase sequence current is required for successful relay operation.

Since sensitive settings have been employed, it can be expected that the element will operate for any unbalance condition occurring on the system (for example, during a single pole auto-reclose cycle). Hence, a long time delay is necessary to ensure co-ordination with other protective devices. A 60 second time delay setting may be typical.

The example following information was recorded by the relay during commissioning;

$I_{full\ load}$ = 500A

$I_2$ = 50A

AP

therefore the quiescent I2/I1 ratio is given by;

$I_2/I_1$ = 50/500 = 0.1

To allow for tolerances and load variations a setting of 20% of this value may be typical: Therefore set I2/I1 = 0.2

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

Set I2/I1 Time Delay = 60s to allow adequate time for short circuit fault clearance by time delayed protections.

## 2.15 Cold-load pick-up logic

When a feeder circuit breaker is closed in order to energize a load, the current levels that flow for a period of time following energization may differ greatly from the normal load levels. Consequently, overcurrent settings that have been applied to give short circuit protection may not be suitable during the period of energization, as they may give incorrect operation.

The Cold Load Pick-Up (CLP) logic included within the P145 relays serves to either inhibit one or more stages of the overcurrent protection for a set duration or, alternatively, to raise the settings of selected stages. This, therefore, allows the protection settings to be set closer to the load profile by automatically increasing them following circuit energization. The CLP logic thus provides stability, whilst maintaining protection during starting.

2.15.1 Air conditioning/resistive heating loads

Where a feeder is being used to supply air conditioning or resistive heating loads there may be a conflict between the 'steady state' overcurrent settings and those required following energization. This is due to the temporary increase in load current that may arise during this period. The CLP logic can be used to alter the applied settings during this time.

In this situation, "Enable" should be selected (from the "I> status" option) and the temporary current and time settings can then be programmed. These settings would be chosen in accordance with the expected load profile. Where it is not necessary to alter the setting of a particular stage, the CLP settings should be set to the required overcurrent settings.

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

It should be noted that it is not possible to alter any of the directional settings in the CLP logic.

### 2.15.2 Motor feeders

In general, a dedicated motor protection device from the MiCOM range would protect feeders supplying motor loads. However, if no specific protection has been applied (possibly due to economic reasons) then the CLP logic in the P145 may be used to modify the overcurrent settings accordingly during starting.

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

As previously described, the CLP logic includes the option of either blocking or raising the settings of the first stage of the standard earth fault protection. This may be useful where instantaneous earth fault protection is required to be applied to the motor. During conditions of motor starting, it is likely that incorrect operation of the earth fault element would occur due to asymmetric CT saturation. This is a result of the high level of starting current causing saturation of one or more of the line CT's feeding the overcurrent/earth fault protection. The resultant transient imbalance in the secondary line current quantities is thus detected by the residually connected earth fault element. For this reason, it is normal to either apply a nominal time delay to the element, or to utilize a series stabilizing resistor.



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

### 2.15.3 Switch onto fault protection (SOTF)

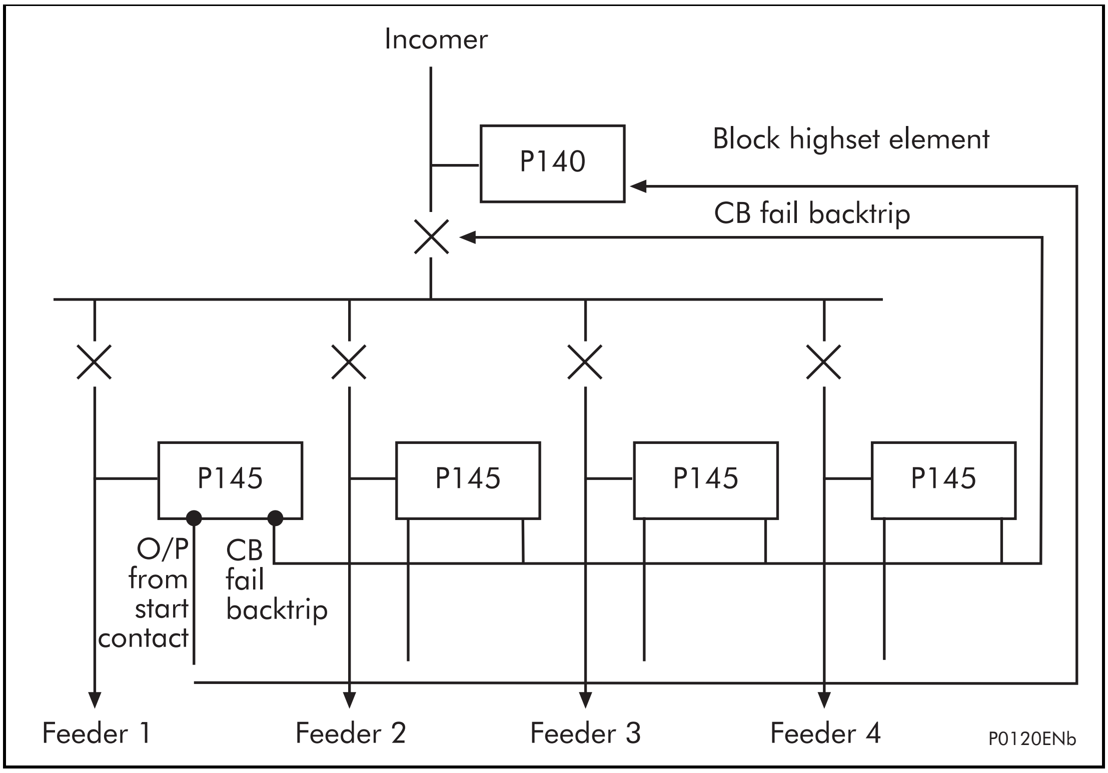
In some feeder applications, fast tripping may be required if a fault is present on the feeder when it is energized. Such faults may be due to a fault condition not having been removed from the feeder, or due to earthing clamps having been left on following maintenance. In either case, it may be desirable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

The above situation may be catered for by the CLP logic. Selected overcurrent/earth fault stages could be set to instantaneous operation for a defined period following circuit breaker closure (typically 200ms). Hence, instantaneous fault clearance would be achieved for a switch onto fault (SOTF) condition.

## 2.16 Blocked overcurrent protection

Blocked overcurrent protection involves the use of start contacts from downstream relays wired onto blocking inputs of upstream relays. This allows identical current and time settings to be employed on each of the relays involved in the scheme, as the relay nearest to the fault does not receive a blocking signal and hence trips discriminatively. This type of scheme therefore reduces the amount of required grading stages and consequently fault clearance times.

The principle of blocked overcurrent protection may be extended by setting fast acting overcurrent elements on the incoming feeders to a substation which are then arranged to be blocked by start contacts from the relays protecting the outgoing feeders. The fast acting element is thus allowed to trip for a fault condition on the busbar but is stable for external feeder faults by means of the blocking signal. This type of scheme therefore provides much reduced fault clearance times for busbar faults than would be the case with conventional time graded overcurrent protection. The availability of multiple overcurrent and earth fault stages means that back-up time graded overcurrent protection is also provided. This is shown in Figures 17 and 18.




AP

**Figure 17: Simple busbar blocking scheme (single incomer**

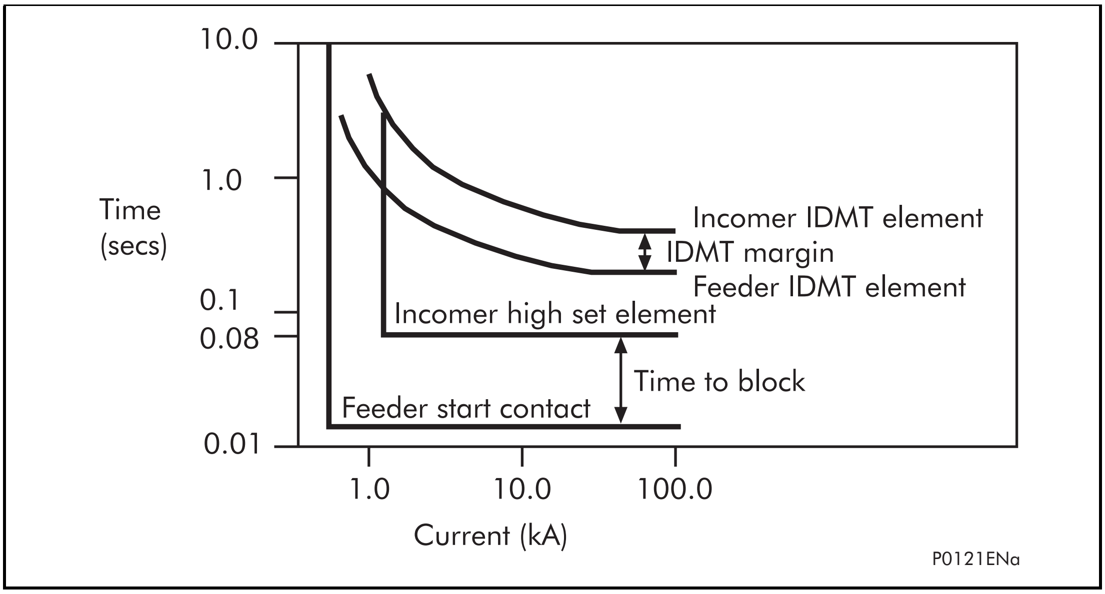



**Figure 18: Simple busbar blocking scheme (single incomer**

For further guidance on the use of blocked overcurrent schemes refer to AREVA T&D.

# 3. APPLICATION OF NON PROTECTION FUNCTIONS

## 3.1 Three-phase auto-reclosing

An analysis of faults on any overhead line network has shown that 80 – 90% are transient in nature.

A transient fault, such as an insulator flashover, is a self-clearing 'non-damage' fault. This type of fault can be cleared by the immediate tripping of one or more circuit breakers to isolate the fault, and does not recur when the line is re-energized. Lightning is the most common cause of transient faults, other possible causes being clashing conductors and wind blown debris. The remaining 10 – 20% of faults are either semi-permanent or permanent.

A small tree branch falling on the line could cause a semi-permanent fault. Here the cause of the fault would not be removed by the immediate tripping of the circuit, but could be burnt away during a time-delayed trip.

Permanent faults could be broken conductors, transformer faults, cable faults or machine faults that must be located and repaired before the supply can be restored.

In the majority of fault incidents, if the faulty line is immediately tripped out, and time is allowed for the fault arc to de-ionize, re-closure of the circuit breakers will result in the line being successfully re-energized. Auto-reclose schemes are employed to automatically reclose a switching device a set time after it has been opened due to operation of protection where transient and semi-permanent faults are prevalent.



On HV/MV distribution networks, auto-reclosing is applied mainly to radial feeders where system stability problems do not generally arise. The main advantages to be derived from using auto-reclose can be summarized as follows:

- Minimizes interruptions in supply to the consumer
- Reduces operating costs - less man-hours in repairing fault damage and the possibility of running substations unattended. With auto-reclose instantaneous protection can be used which means shorter fault duration's which gives rise to less fault damage and fewer permanent faults

The introduction of auto-reclosing gives an important benefit on circuits using time graded protection, in that it allows the use of instantaneous protection to give a high speed first trip. With fast tripping, the duration of the power arc resulting from an overhead line fault is reduced to a minimum, thus lessening the chance of damage to the line, which might otherwise cause a transient fault to develop into a permanent fault. Using instantaneous protection also prevents blowing of fuses in teed circuits and reduces circuit breaker maintenance by eliminating pre-arc heating when clearing transient faults.

It should be noted that when instantaneous protection is used with auto-reclosing, the scheme is normally arranged to block the instantaneous protection after the first trip. Therefore, if the fault persists after re-closure, the time graded protection will give discriminative tripping with fuses or other protection devices, resulting in the isolation of the faulted section. However, for certain applications, where the majority of the faults are likely to be transient, it is not uncommon to allow more than one instantaneous trip before the instantaneous protection is blocked.

Some schemes allow a number of reclosures and time graded trips after the first instantaneous trip, which may result in the burning out and clearance of semi-permanent faults. Such a scheme may also be used to allow fuses to operate in teed feeders where the fault current is low.

When considering feeders that are partly overhead line and partly underground cable, any decision to install auto-reclosing would be influenced by any data known on the frequency of transient faults. When a significant proportion of the faults are permanent, the advantages of auto-reclosing are small, particularly since re-closing on to a faulty cable is likely to aggravate the damage.

### 3.1.1 Setting guidelines

#### 3.1.1.1 Number of shots

There are no clear-cut rules for defining the number of shots for a particular application. Generally medium voltage systems utilize only two or three shot auto-reclose schemes. However, in certain countries, for specific applications, four shots is not uncommon. Four shots have the advantage that the final dead time can be set sufficiently long to allow any thunderstorms to pass before reclosing for the final time. This arrangement will prevent unnecessary lockout for consecutive transient faults.

Typically, the first trip, and sometimes the second, will result from instantaneous protection - since 80% of faults are transient, the subsequent trips will be time delayed, all with increasing dead times to clear semi-permanent faults.

In order to determine the required number of shots the following factors must be taken into account:

An important consideration is the ability of the circuit breaker to perform several trip-close operations in quick succession and the effect of these operations on the maintenance period.

On EHV transmission circuits with high fault levels, only one reclosure is normally applied, because of the damage that could be caused by multiple reclosures if the fault is permanent.

#### 3.1.1.2 Dead timer setting



The choice of dead time is, very much, system dependent. The main factors that can influence the choice of dead time are:

- Stability and synchronism requirements
- Operational convenience
- Load
- The type of circuit breaker
- Fault de-ionizing time
- The protection reset time

#### 3.1.1.3 Stability and synchronism requirements

If the power transfer level on a specific feeder is such that the systems at either end of the feeder could quickly fall out of synchronism if the feeder is opened, it is usually required to reclose the feeder as quickly as possible, to prevent loss of synchronism. This is called high speed auto-reclosing (HSAR). In this situation, the dead time setting should be adjusted to the minimum time necessary to allow complete de-ionization of the fault path and restoration of the full voltage withstand level, and comply with the “minimum dead time” limitations imposed by the circuit breaker and protection (see below). Typical HSAR dead time values are between 0.3 and 0.5 seconds.

On a closely interconnected transmission system, where alternative power transfer paths usually hold the overall system in synchronism even when a specific feeder opens, or on a radial supply system where there are no stability implications, it is often preferred to leave a feeder open for a few seconds after fault clearance. This allows the system to stabilize, and reduces the shock to the system on reclosure. This is called slow or delayed auto-reclosing (DAR). The dead time setting for DAR is usually selected for operational convenience (see below).

##### 3.1.1.3.1 Operational convenience

When HSAR is not required, the dead time chosen for the first reclosure (shot) following a fault trip is not critical. It should be long enough to allow any transients resulting from the fault and trip to decay, but not so long as to cause major inconvenience to consumers who are affected by the loss of the feeder. The setting chosen often depends on service experience with the specific feeder.

Typical first shot dead time settings on 11 kV distribution systems are 5 to 10 seconds. In situations where two parallel circuits from one substation are carried on the same towers, it is often arranged for the dead times on the two circuits to be staggered, e.g. one at 5 seconds and the other at 10 seconds, so that the two circuit breakers do not reclose simultaneously following a fault affecting both circuits.

For multi-shot auto-reclose cycles, the second and subsequent shot dead times are usually longer than the first shot, to allow time for “semi-permanent” faults to burn clear, and to allow for the CB rated duty cycle and spring charging time. Typical second and third shot dead time settings are 30 seconds and 60 seconds respectively.

3.1.1.3.2 Load requirements

Some types of electrical load might have specific requirements for minimum and/or maximum dead time, to prevent damage and ensure minimum disruption. For example, synchronous motors are only capable of tolerating extremely short interruptions of supply without loss of synchronism. In practice it is desirable to disconnect the motor from the supply in the event of a fault; the dead time would normally be sufficient to allow the motor no-volt device to operate. Induction motors, on the other hand, can withstand supply interruptions up to typically 0.5 seconds and re-accelerate successfully.

3.1.1.3.3 Circuit breaker

For high speed auto-reclose the minimum dead time of the power system will depend on the minimum time delays imposed by the circuit breaker during a tripping and reclosing operation.

After tripping, time must be allowed for the mechanism to reset before applying a closing pulse; otherwise, the circuit breaker might fail to close correctly. This resetting time will vary depending on the circuit breaker, but is typically 0.1 seconds.

Once the mechanism has reset, a CB Close signal can be applied. The time interval between the energization of the closing mechanism and the making of the contacts is termed the closing time. Owing to the time constant of a solenoid closing mechanism and the inertia of the plunger, a solenoid closing mechanism may take 0.3s. A spring operated breaker, on the other hand, can close in less than 0.1 seconds.

Where high speed reclosing is required, for the majority of medium voltage applications, the circuit breaker mechanism reset time itself dictates the minimum dead time. The minimum system dead time only considering the CB is the mechanism reset time plus the CB closing time. Thus, a solenoid mechanism will not be suitable for high speed auto-reclose as the closing time is generally too long.

For most circuit breakers, after one reclosure, it is necessary to recharge the closing mechanism energy source, (spring, gas pressure etc.) before a further reclosure can take place. Therefore the dead time for second and subsequent shots in a multi-shot sequence must be set longer than the spring or gas pressure recharge time.

3.1.1.3.4 Fault de-ionizing time

For high speed auto-reclose the fault de-ionizing time may be the most important factor when considering the dead time. This is the time required for ionized air to disperse around the fault position so that the insulation level of the air is restored. It cannot be accurately predicted. However, it can be approximated from the following formula, based on extensive experience on many transmission and distribution systems throughout the world:

De-ionizing time = (10.5 + ((system voltage in kV)/34.5))/frequency

For 66 kV = 0.25s (50Hz)

For 132 kV = 0.29s (50 Hz)

3.1.1.3.5 Protection reset

It is essential that any time graded protection fully resets during the dead time, so that correct time discrimination will be maintained after reclosure on to a fault. For high speed auto-reclose, instantaneous reset of protection is required. However at distribution level, where the protection is predominantly made up of overcurrent and earthfault relays, the protection reset time may not be instantaneous (e.g. induction disk relays). In the event that the circuit breaker recloses on to a fault and the protection has not fully reset, discrimination may be lost with the downstream protection. To avoid this condition the dead time must be set in excess of the slowest reset time of either the local relay or any downstream protection.

Typical 11/33kV dead time settings in the UK are as follows:

1st dead time = 5 - 10 seconds

2nd dead time = 30 seconds

3rd dead time = 60 - 180 seconds

4th dead time (uncommon in the UK, however used in South Africa) = 1 - 30 minutes

#### 3.1.1.4 Reclaim timer setting

A number of factors influence the choice of the reclaim timer, such as:

- Supply continuity – Large reclaim times can result in unnecessary lockout for transient faults
- Fault incidence/Past experience – Small reclaim times may be required where there is a high incidence of lightning strikes to prevent unnecessary lockout for transient faults
- Spring charging time – For high speed auto-reclose the reclaim time may be set longer than the spring charging time to ensure there is sufficient energy in the circuit breaker to perform a trip-close-trip cycle. For delayed auto-reclose there is no need as the dead time can be extended by an extra CB healthy check window time if there is insufficient energy in the CB. If there is insufficient energy after the check window time the relay will lockout
- Switchgear Maintenance – Excessive operation resulting from short reclaim times can mean shorter maintenance periods. A minimum reclaim time of >5s may be needed to allow the CB time to recover after a trip and close before it can perform another trip-close-trip cycle. This time will depend on the duty (rating) of the CB

AP

The reclaim time must be long enough to allow any time delayed protection initiating auto-reclose to operate. Failure to do so would result in premature resetting of the auto-reclose scheme and re-enabling of instantaneous protection. If this condition arose, a permanent fault would effectively look like a number of transient faults, resulting in continuous auto-reclosing unless additional measures were taken to overcome this such as excessive fault frequency lockout protection

Sensitive earth fault protection is applied to detect high resistance earth faults and usually has a long time delay, typically 10 - 15s. This longer time may have to be taken into consideration, if auto-reclosing from SEF protection, when deciding on a reclaim time, if the reclaim time is not blocked by an SEF protection start signal. High resistance earth faults, for example, a broken overhead conductor in contact with dry ground or a wood fence, is rarely transient and may be a danger to the public. It is therefore common practice to block auto-reclose by operation of sensitive earth fault protection and lockout the circuit breaker.

A typical 11/33kV reclaim time in the UK is 5 - 10 seconds, this prevents unnecessary lockout during thunderstorms. However, times up to 60 - 180 seconds may be used elsewhere in the world.

### 3.2 Function keys

The following default PSL logic illustrates the programming of function keys to enable/disable the auto-reclose functionality. Please note the auto-reclose functionality should be enabled in the Configuration column for this feature to work.

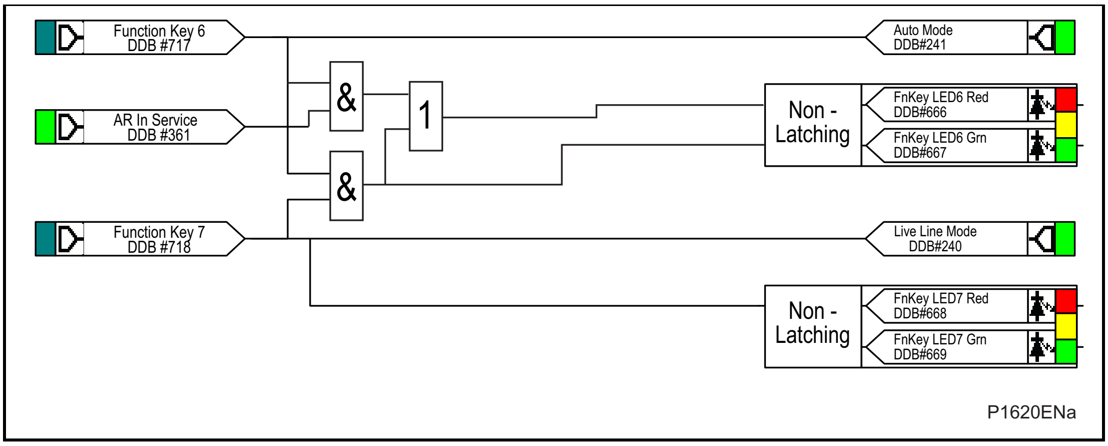



**Figure 19: Auto-reclose default PSL**

Note: Energizing two inputs to an LED conditioner creates a YELLOW illumination.

Function Key 6 is set to 'Toggle' mode and on activation of the key, the auto-reclose function will be in service as long as the auto-reclose function has been enabled in the "Configuration" menu. The associated LED will indicate the state of the ARC function in service as RED. The LED indication will show YELLOW should the 'Live Line mode' be activated whilst the ARC in service function key is active.

Function Key 7 is set to 'Toggle' mode and on activation of the key, the auto-reclose function will be set to the 'Live Line Mode' with the auto-reclose enabled in the "Configuration" menu. The associated LED will indicate the state of the ARC function in 'Live Line' as RED.

AP

## 3.3 Current transformer supervision

The current transformer supervision feature is used to detect failure of one or more of the ac phase current inputs to the relay. Failure of a phase CT or an open circuit of the interconnecting wiring can result in incorrect operation of any current operated element. Additionally, interruption in the ac current circuits risks dangerous CT secondary voltages being generated.

### 3.3.1 Setting the CT supervision element

The residual voltage setting, "CTS Vn< Inhibit" and the residual current setting, "CTS In> set", should be set to avoid unwanted operation during healthy system conditions. For example "CTS Vn< Inhibit" should be set to 120% of the maximum steady state residual voltage. The "CTS In> set" will typically be set below minimum load current. The time-delayed alarm, "CTS Time Delay", is generally set to 5 seconds.

Where the magnitude of residual voltage during an earth fault is unpredictable, the element can be disabled to prevent protection elements being blocked during fault conditions.

## 3.4 Circuit breaker condition monitoring

Periodic maintenance of circuit breakers is necessary to ensure that the trip circuit and mechanism operate correctly, and also that the interrupting capability has not been compromised due to previous fault interruptions. Generally, such maintenance is based on a fixed time interval, or a fixed number of fault current interruptions. These methods of monitoring circuit breaker condition give a rough guide only and can lead to excessive maintenance.

### 3.4.1 Setting guidelines

#### 3.4.1.1 Setting the $\Sigma$ I^ thresholds

Where overhead lines are prone to frequent faults and are protected by oil circuit breakers (OCB's), oil changes account for a large proportion of the life cycle cost of the switchgear.

Generally, oil changes are performed at a fixed interval of circuit breaker fault operations. However, this may result in premature maintenance where fault currents tend to be low, and hence oil degradation is slower than expected. The $\Sigma$ I^ counter monitors the cumulative severity of the duty placed on the interrupter allowing a more accurate assessment of the circuit breaker condition to be made.

For OCB's, the dielectric withstand of the oil generally decreases as a function of $\Sigma I^2t$. This is where 'I' is the fault current broken, and 't' is the arcing time within the interrupter tank (not the interrupting time). As the arcing time cannot be determined accurately, the relay would normally be set to monitor the sum of the broken current squared, by setting 'Broken I^' = 2.

For other types of circuit breaker, especially those operating on higher voltage systems, practical evidence suggests that the value of 'Broken I^' = 2 may be inappropriate. In such applications 'Broken I^' may be set lower, typically 1.4 or 1.5. An alarm in this instance may be indicative of the need for gas/vacuum interrupter HV pressure testing, for example.

The setting range for 'Broken I^' is variable between 1.0 and 2.0 in 0.1 steps. It is imperative that any maintenance program must be fully compliant with the switchgear manufacturer's instructions.

#### 3.4.1.2 Setting the number of operations thresholds

AP

Every operation of a circuit breaker results in some degree of wear for its components. Thus, routine maintenance, such as oiling of mechanisms, may be based upon the number of operations. Suitable setting of the maintenance threshold will allow an alarm to be raised, indicating when preventative maintenance is due. Should maintenance not be carried out, the relay can be set to lockout the auto-reclose function on reaching a second operations threshold. This prevents further reclosure when the circuit breaker has not been maintained to the standard demanded by the switchgear manufacturer's maintenance instructions.

Certain circuit breakers, such as oil circuit breakers (OCB's) can only perform a certain number of fault interruptions before requiring maintenance attention. This is because each fault interruption causes carbonizing of the oil, degrading its dielectric properties. The maintenance alarm threshold "No CB Ops. Maint." may be set to indicate the requirement for oil sampling for dielectric testing, or for more comprehensive maintenance. Again, the lockout threshold "No CB Ops. Lock" may be set to disable auto-reclosure when repeated further fault interruptions could not be guaranteed. This minimizes the risk of oil fires or explosion.

#### 3.4.1.3 Setting the operating time thresholds

Slow CB operation is also indicative of the need for mechanism maintenance. Therefore, alarm and lockout thresholds (CB Time Maint./CB Time Lockout) are provided and are settable in the range of 5 to 500ms. This time is set in relation to the specified interrupting time of the circuit breaker.

#### 3.4.1.4 Setting the excessive fault frequency thresholds

Persistent faults will generally cause auto-reclose lockout, with subsequent maintenance attention. Intermittent faults such as clashing vegetation may repeat outside of any reclaim time, and the common cause might never be investigated. For this reason it is possible to set a frequent operations counter on the relay which allows the number of operations "Fault Freq. Count" over a set time period "Fault Freq. Time" to be monitored. A separate alarm and lockout threshold can be set.

### 3.5 Trip circuit supervision (TCS)

The trip circuit, in most protective schemes, extends beyond the relay enclosure and passes through components such as fuses, links, relay contacts, auxiliary switches and other terminal boards. This complex arrangement, coupled with the importance of the trip circuit, has led to dedicated schemes for its supervision.

Several trip circuit supervision schemes with various features can be produced with the P145 range. Although there are no dedicated settings for TCS, in the P145, 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 re-named using the menu text editor to indicate that there is a fault with the trip circuit.

### 3.5.1 TCS scheme 1

#### 3.5.1.1 Scheme description

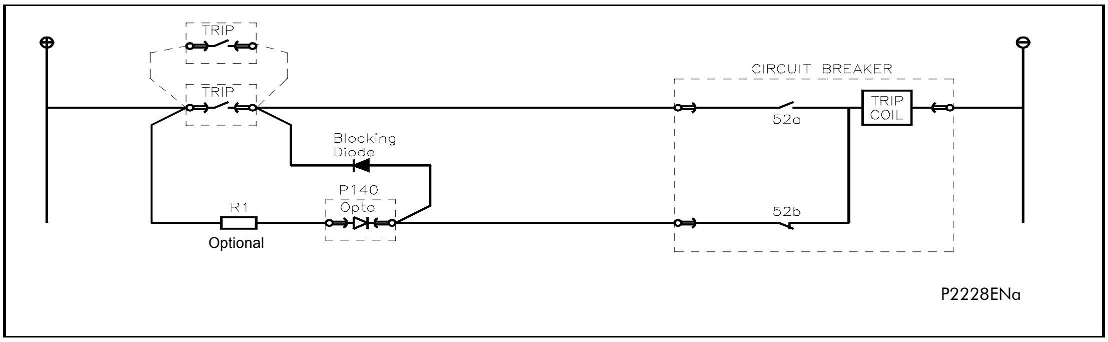



**Figure 20: TCS scheme 1**



This scheme provides supervision of the trip coil with the breaker open or closed, however, pre-closing supervision is not provided. This scheme is also incompatible with latched trip contacts, as a latched contact will short out the opto for greater than the recommended DDO timer setting of 400ms. If breaker status monitoring is required a further 1 or 2 opto inputs must be used. Note: a 52a CB auxiliary contact follows the CB position and a 52b contact is the opposite.

When the breaker is closed, supervision current passes through the opto input, blocking diode and trip coil. When the breaker is open current still flows through the opto input and into the trip coil via the 52b auxiliary contact. Hence, 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 400ms delay.

Resistor R1 is an optional resistor that can be fitted to prevent maloperation of the circuit breaker if the opto input is inadvertently shorted, by limiting the current to <60mA. 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 will function correctly even without resistor R1, since the opto input automatically limits the supervision current to less that 10mA. However, if the opto is accidentally shorted the circuit breaker may trip.

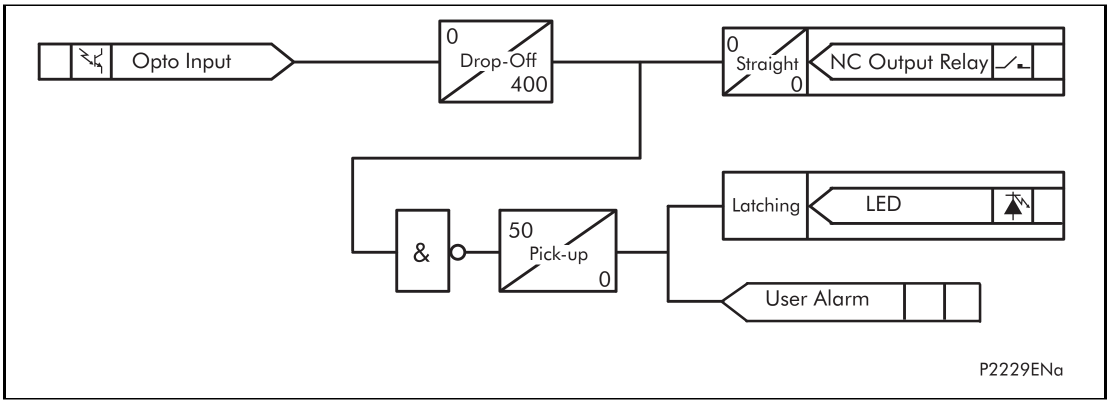
| Auxiliary Voltage (Vx) | Resistor R1 (ohms) | Opto Voltage Setting with R1 Fitted |
|---|---|---|
| 24/27 | - | - |
| 30/34 | - | - |
| 48/54 | 1.2k | 24/27 |
| 110/250 | 2.5k | 48/54 |
| 220/250 | 5.0k | 110/125 |

Note: When R1 is not fitted the opto voltage setting must be set equal to supply voltage of the supervision circuit.

### 3.5.2 Scheme 1 PSL

Figure 21 shows the scheme logic diagram for the TCS scheme 1. Any of the available opto inputs can be used to indicate whether or not the trip circuit is healthy. The delay on drop off timer operates as soon as the opto is energized, but will take 400ms to drop off/reset in the event of a trip circuit failure. The 400ms 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 50ms delay on pick-up timer prevents false LED and user alarm indications during the relay power up time, following an auxiliary supply interruption.




AP

**Figure 21: PSL for TCS schemes 1 and 3**

### 3.5.3 TCS scheme 2

#### 3.5.3.1 Scheme description

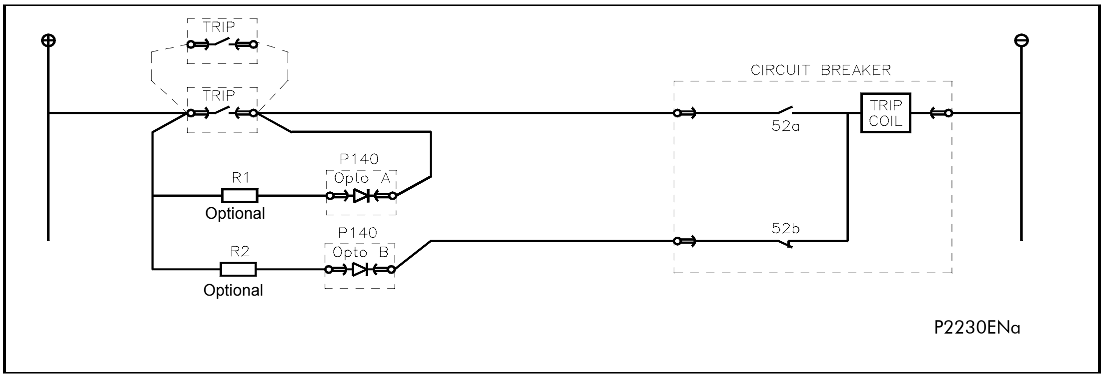



**Figure 22: TCS scheme 2**

Much like scheme 1, this scheme provides supervision of the trip coil with the breaker open or closed and also does not provide pre-closing supervision. However, using two opto inputs allows the relay to correctly monitor the circuit breaker status since they are connected in series with the CB auxiliary contacts. This is achieved by assigning Opto A to the 52a contact and Opto B to the 52b contact. Provided the “Circuit Breaker Status” is set to “52a and 52b” (CB CONTROL column) the relay will correctly monitor the status of the breaker. This scheme is also fully compatible with latched contacts as the supervision current will be maintained through the 52b contact when the trip contact is closed.

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. As with scheme 1, no supervision of the trip path is provided whilst the breaker is open. Any fault in the trip path will only be detected on CB closing, after a 400ms delay.

As with scheme 1, 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.

### 3.5.4 Scheme 2 PSL

The PSL for this scheme (Figure 23) is practically the same as that of scheme 1. The main difference being that both opto inputs must be off before a trip circuit fail alarm is given.

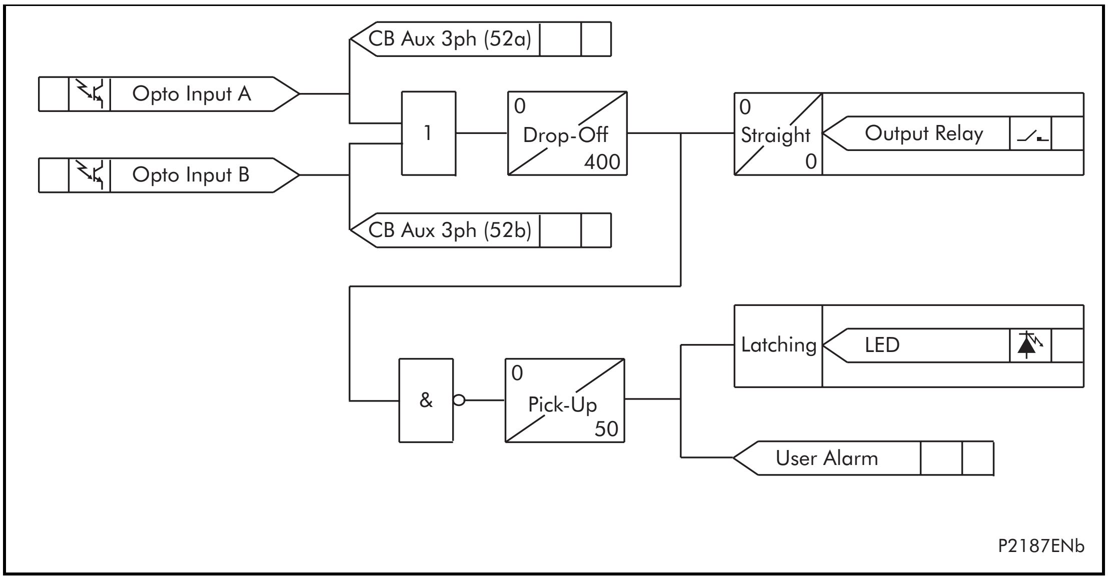



**Figure 23: PSL for TCS scheme 2**

### 3.5.5 TCS scheme 3

#### 3.5.5.1 Scheme description

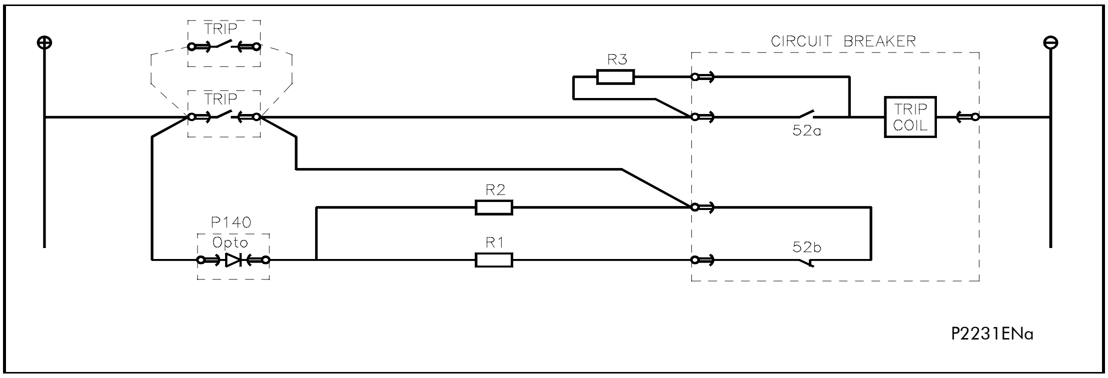



**Figure 24: TCS scheme 3**

Scheme 3 is designed to provide supervision of the trip coil with the breaker open or closed, but unlike schemes 1 and 2, it also provides pre-closing supervision. Since only one opto input is used, this scheme is not compatible with latched trip contacts. If circuit breaker status monitoring is required a further 1 or 2 opto inputs must be used.

When the breaker is closed, supervision current passes through the opto input, resistor R1 and the trip coil. When the breaker is open current flows through the opto input, resistors R1 and R2 (in parallel), resistor R3 and the trip coil. Unlike schemes 1 and 2, supervision current is maintained through the trip path with the breaker in either state, thus giving pre-closing supervision.

As with schemes 1 and 2, resistors R1 and R2 are used to prevent false tripping, if the opto-input is accidentally shorted. However, unlike the other two schemes, this scheme is dependent upon the position and value of these resistors. Removing them would result in

AP

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 | 1.2k | 0.6k | 24/27 |
| 110/250 | 2.5k | 1.2k | 48/54 |
| 220/250 | 5.0k | 2.5k | 110/125 |

Note: Scheme 3 is not compatible with auxiliary supply voltages of 30/34 volts and below.

3.5.6 Scheme 3 PSL

The PSL for scheme 3 is identical to that of scheme 1 (see Figure 21).

### 3.6 Fault locator

AP

Fault location is part of the data included within the relay fault record and therefore the fault locator is triggered whenever a fault record is generated. This is controlled by DDB 144: Fault REC TRIG; in the default PSL this signal is energized from operation of any protection trip.

3.6.1 Setting example

Assuming the following data for the protected line:

230kV transmission line

CT ratio = 1200/5

VT ratio = 230,000/115

Line length = 10km

Positive sequence line impedance ZL1 = 0.089+j0.476 Ohms/km

Zero sequence line impedance ZL0 = 0.34+j1.03 ohms/km

Zero sequence mutual impedance ZM0 = 0.1068+j0.5712 Ohms/km

The line length can be set in either meters or miles.

Therefore for this example set line length = 10km.

The line impedance magnitude and angle settings are calculated as follows:

Ratio of secondary to primary impedance = CT ratio/VT ratio = 0.12

Positive sequence line impedance ZL1 = $0.12 \times 10(0.484\angle 79.4°) = 0.58 \angle 79.4°$

Therefore set line length = 0.58

Line angle = 79°

The residual impedance compensation magnitude and angle are calculated using the following formula:

$$KZn = \frac{ZL0 - ZL1}{3\ ZL1}$$

$$= \frac{(0.34 + j1.03) - (0.089 + j0.476)}{3 \times (0.484 \angle 79.4°)}$$

$$= \frac{0.6 \angle 65.2^\circ}{1.45 \angle 79.4^\circ}$$

$$= 0.41 \angle -14.2^\circ$$

Therefore set kZn Residual = 0.41

kZn Res. Angle = $\angle$-14°

## 3.7 VT connections

### 3.7.1 Open delta (vee connected) VT's

The P145 can be used with vee connected VTs by connecting the VT secondaries to C19, C20 and C21 input terminals, with the C22 input left unconnected.

This type of VT arrangement cannot pass zero-sequence (residual) voltage to the relay, or provide any phase to neutral voltage quantities. Therefore any protection that is dependent upon phase to neutral voltage measurements should be disabled.

The under and over voltage protection can be set as phase to phase measurement with vee connected VTs. The voltage dependent overcurrent use phase-phase voltages anyway, therefore the accuracy should not be affected. Directional earth fault and sensitive directional earth fault protection should be disabled as the neutral voltage will always be zero, even in the event of an earth fault. CT supervision should also be disabled, as this is also dependent upon the measurement of zero sequence voltage.

AP

The accuracy of the single-phase voltage measurements can be impaired when using vee connected VT's. The relay attempts to derive the phase to neutral voltages from the phase to phase voltage vectors. If the impedance of the voltage inputs were perfectly matched the phase to neutral voltage measurements would be correct, provided the phase to phase voltage vectors were balanced. However, in practice there are small differences in the impedance of the voltage inputs, which can cause small errors in the phase to neutral voltage measurements. This may give rise to an apparent residual voltage. This problem also extends to single-phase power measurements that are also dependent upon their respective single-phase voltages.

The phase to neutral voltage measurement accuracy can be improved by connecting 3, well matched, load resistors between the phase voltage inputs (C19, C20, C21) and neutral C22, thus creating a 'virtual' neutral point. The load resistor values must be chosen so that their power consumption is within the limits of the VT. It is recommended that 10kΩ ±1% (6W) resistors be used for the 110V (Vn) rated relay, assuming the VT can supply this burden.

### 3.7.2 VT single point earthing

The P145 range will function correctly with conventional three-phase VT's earthed at any one point on the VT secondary circuit. Typical earthing examples being neutral earthing and yellow phase earthing.

# 4. CT REQUIREMENTS

The 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.

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 the following sections:

| Nominal Rating | Nominal Output | Accuracy Class | Accuracy Limited Factor | Limiting Lead Resistance |
|---|---|---|---|---|
| 1A | 2.5VA | 10P | 20 | 1.3 ohms |
| 5A | 7.5VA | 10P | 20 | 0.11 ohms |

Separate requirements for Restricted Earth Fault are given in section 4.6 and 4.7.

## 4.1 Non-directional definite time/IDMT overcurrent & earth fault protection

### 4.1.1 Time-delayed phase overcurrent elements

$$V_K \geq I_{cp}/2 * (R_{CT} + R_L + R_{rp})$$

### 4.1.2 Time-delayed earth fault overcurrent elements

$$V_K \geq I_{cn}/2 * (R_{CT} + 2R_L + R_{rp} + R_{rn})$$

## 4.2 Non-directional instantaneous overcurrent & earth fault protection

### 4.2.1 CT requirements for instantaneous phase overcurrent elements

$$V_K \geq I_{sp} \text{ x } (R_{CT} + R_L + R_{rp})$$

### 4.2.2 CT requirements for instantaneous earth fault overcurrent elements

$$V_K \geq I_{sn} \text{ x } (R_{CT} + 2R_L + R_{rp} + R_{rn})$$

## 4.3 Directional definite time/IDMT overcurrent & earth fault protection

### 4.3.1 Time-delayed phase overcurrent elements

$$VK \geq Icp/2 * (RCT + RL + Rrp)$$

### 4.3.2 Time-delayed earth fault overcurrent elements

$$V_K \geq I_{cn}/2 * (R_{CT} + 2R_L + R_{rp} + R_{rn})$$

## 4.4 Directional instantaneous overcurrent & earth fault protection

### 4.4.1 CT requirements for instantaneous phase overcurrent elements

$$V_K \geq I_{fp}/2 * (R_{CT} + R_L + R_{rp})$$

### 4.4.2 CT requirements for instantaneous earth fault overcurrent elements

$$V_K \geq I_{fn}/2 * (R_{CT} + 2R_L + R_{rp} + R_{rn})$$

AP

## 4.5 Non-directional/directional definite time/IDMT sensitive earth fault (SEF) protection

### 4.5.1 Non-directional time delayed SEF protection (residually connected)

$V_K \geq I_{cn}/2 * (R_{CT} + 2R_L + R_{rp} + R_{rn})$

### 4.5.2 Non-directional instantaneous SEF protection (residually connected)

$V_K \geq I_{sn} \times (R_{CT} + 2R_L + R_{rp} + R_{rn})$

### 4.5.3 Directional time delayed SEF protection (residually connected)

$V_K \geq I_{cn}/2 \times (R_{CT} + 2R_L + R_{rp} + R_{rn})$

### 4.5.4 Directional instantaneous SEF protection (residually connected)

$V_K \geq I_{fn}/2 * (R_{CT} + 2R_L + R_{rp} + R_{rn})$

### 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:

$V_K \geq I_{cn}/2 * (R_{CT} + 2R_L + R_{rn})$

Directional instantaneous element:

$V_K \geq I_{fn}/2 * (R_{CT} + 2R_L + R_{rn})$

Non-directional element:

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

Note that, 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) |
| $I_{fn}$ | = | Maximum prospective secondary earth fault current (amps) |
| $I_{fp}$ | = | Maximum prospective secondary phase fault current (amps) |
| $I_{cn}$ | = | Maximum prospective secondary earth fault current or 31 times I> setting (whichever is lower) (amps) |
| $I_{cp}$ | = | Maximum prospective secondary phase fault current or 31 times I> setting (whichever is lower) (amps) |
| $I_{sn}$ | = | Stage 2 & 3 earth fault setting (amps) |
| $I_{sp}$ | = | Stage 2 and 3 setting (amps) |
| $R_{CT}$ | = | Resistance of current transformer secondary winding (ohms) |
| $R_L$ | = | Resistance of a single lead from relay to current transformer (ohms) |
| $R_{rp}$ | = | Impedance of relay phase current input at 30In (ohms) |
| $R_{rn}$ | = | Impedance of the relay neutral current input at 30In (ohms) |

AP

### 4.6 Low impedance restricted earth fault protection

$V_K \geq$ 24 * In * ($R_{CT}$ + 2$R_L$) for X/R < 40 and if < 15In

$V_K \geq$ 48 * In * ($R_{CT}$ + 2$R_L$) for X/R < 40, 15In < If < 40In and 40 <X/R < 120, If < 15In

Where:

$V_K$ = Required CT knee point voltage (volts)

$I_n$ = rated secondary current (amps)

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

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

If = Maximum through fault current level (amps)

Note: Class x or Class 5P CT's should be used for low impedance restricted earth fault applications.

### 4.7 High impedance restricted earth fault protection

The high impedance restricted earth fault element shall maintain stability for through faults and operate in less than 40ms for internal faults provided the following equations are met:

$$R_{st} = \frac{I_F (R_{CT} + 2_{RL})}{I_S}$$

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

Where:

$V_K$ = Required CT knee-point voltage (volts)

$R_{st}$ = Value of stabilizing resistor (ohms)

If = Maximum secondary through fault current level (amps)

$V_K$ = CT knee point voltage (volts)

$I_S$ = Current setting of REF element (amps), (IREF>$I_s$)

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

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

Note: Class x CT's should be used for high impedance restricted earth fault applications.

### 4.8 Use of ANSI/IEEE "C" class CTs

Where American/IEEE standards are used to specify CTs, the C class voltage rating can be checked to determine the equivalent Vk (knee point voltage according to IEC). The equivalence formula is

$$V_K = [\text{ (C rating in volts) x 1.05 }] + [\text{ 100 x } R_{CT}\text{ }]$$

AP

# 5. AUXILIARY SUPPLY FUSE RATING

In the Safety section of this manual, the maximum allowable fuse rating of 16A is quoted. To allow time grading with fuses upstream, a lower fuselink current rating is often preferable. Use of standard ratings of between 6A and 16A is recommended. Low voltage fuselinks, rated at 250V minimum and compliant with IEC60269-2 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 | 6A | 10A Fuse | 15 or 16A Fuse | Fuse Rating > 16A |
| 24 to 54V | 2 | 4 | 6 | Not permitted |
| 60 to 125V | 4 | 8 | 12 | Not permitted |
| 138 to 250V | 6 | 10 | 16 | Not permitted |

Alternatively, miniature circuit breakers (MCB) may be used to protect the auxiliary supply circuits.

PL

# PROGRAMMABLE LOGIC

**Date:** **7th July 2005**
**Hardware Suffix:** **J**
**Software Version:** **31**
**Connection Diagrams:** **10P145xx (xx = 01 to 07)**

# CONTENTS

# 1. PROGRAMMABLE LOGIC

## 1.1 Overview

The purpose of the programmable scheme logic (PSL) is to allow the relay user to configure an individual protection scheme to suit their own particular application. This is achieved through the use of programmable logic gates and delay timers.

The input to the PSL is any combination of the status of opto inputs. It is also used to assign the mapping of functions to the opto inputs and output contacts, the outputs of the protection elements, e.g. protection starts and trips, and the outputs of the fixed protection scheme logic. The fixed scheme logic provides the relay's standard protection schemes. The PSL itself 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, e.g. 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; even with large, complex PSL schemes the relay trip time will not lengthen.

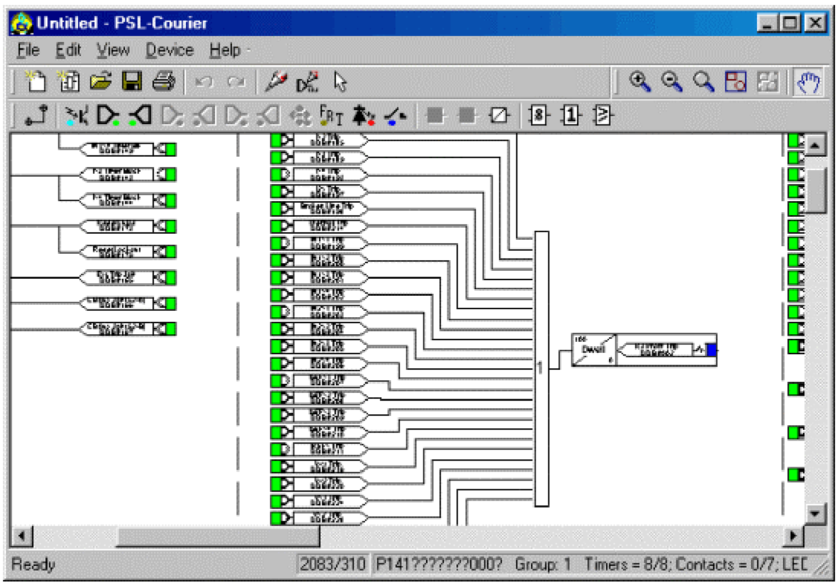
This system provides flexibility for the user to create their own scheme logic design. However, it also means that the PSL can be configured into a very complex system, hence setting of the PSL is implemented through the PC support package MiCOM S1.



## 1.2 MiCOM S1 Px40 PSL editor

To access the Px40 PSL Editor menu click on 

The PSL Editor module enables you to connect to any MiCOM device front port, retrieve and edit its Programmable Scheme Logic files and send the modified file back to a MiCOM Px40 device.




S0059ENa

### 1.3 How to use MiCOM Px40 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

For a detailed discussion on how to use these functions, please refer to MiCOM S1 Users Manual.



### 1.4 Warnings

Before the scheme is sent to the relay checks are done. Various warning messages may be displayed as a result of these checks.

The Editor first reads in the model number of the connected relay, and then compares it with the stored model number. A "wildcard" comparison is employed. If a model mismatch occurs then a warning will be generated before sending commences. Both the stored model number and that read-in from the relay are displayed along with the warning; the onus is on you to decide if the settings to be sent are compatible with the connected relay. Wrongly ignoring the warning could lead to undesired behavior in the relay.

If there are any potential problems of an obvious nature then a list will be generated. The types of potential problems that the program attempts to detect are:

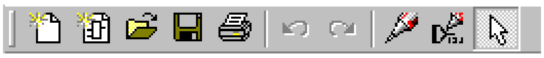
- One or more gates, LED signals, contact signals, and/or timers have their outputs linked directly back to their inputs. An erroneous link of this sort could lock up the relay, or cause other more subtle problems to arise.
- Inputs To Trigger (ITT) exceeds the number of inputs. A programmable gate has its ITT value set to greater than the number of actual inputs; the gate can never activate. Note that there is no lower ITT value check. 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.

### 1.5 Toolbar and commands

There are a number of toolbars available for easy navigation and editing of PSL.

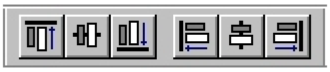
### 1.5.1 Standard tools

- For file management and printing.



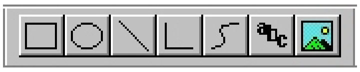
### 1.5.2 Alignment tools

- To snap logic elements into horizontally or vertically aligned groupings.



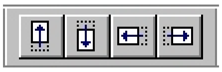
### 1.5.3 Drawing Tools

- To add text comments and other annotations, for easier reading of PSL schemes.



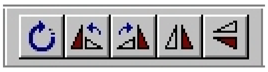
### 1.5.4 Nudge tools

- To move logic elements.



### 1.5.5 Rotation tools

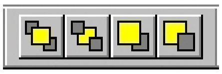
- Tools to spin, mirror and flip.





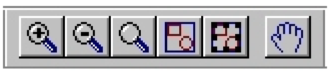
### 1.5.6 Structure tools

- To change the stacking order of logic components.

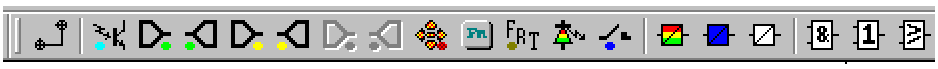


### 1.5.7 Zoom and pan tools

- For scaling the displayed screen size, viewing the entire PSL, or zooming to a selection.

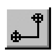


### 1.5.8 Logic symbols



This 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.

**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 UCA2.0 GOOSE message transmitted from another IED.

**GOOSE Out**

Create an output signal from logic to transmit a UCA2.0 GOOSE message to another IED.

**Control In**

Create an input signal to logic that can be operated from an external command.

**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.

**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.

## 1.6 PSL logic signals properties

The logic signal toolbar is used for the selection of logic signals.

Performing a right-mouse click on any logic signal will open a context sensitive menu and one of the options for certain logic elements is the **Properties…** command. Selecting the Properties option will open a Component Properties window, the format of which will vary according to the logic signal selected.

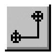
Properties of each logic signal, including the Component Properties windows, are shown in the following sub-sections:

**Signal properties menu**

The **Signals List** tab is used for the selection of logic signals.

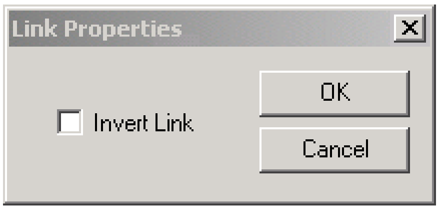
The signals listed will be appropriate to the type of logic symbol being added to the diagram. They will be of one of the following types:

1.6.1 Link properties



Links form the logical link between the output of a signal, gate or condition and the input to any element.

Any link that is connected to the input of a gate can be inverted via its properties window. An inverted link is indicated with a "bubble" on the input to the gate. It is not possible to invert a link that is not connected to the input of a gate.




Links can only be started from the output of a signal, gate, or conditioner, and can only be ended on an input to any element.

Since signals can only be either an input or an output then the concept is somewhat different. In order to follow the convention adopted for gates and conditioners, input signals are connected from the left and output signals to the right. The Editor will automatically enforce this convention.

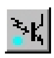
PL

A link attempt will be refused where one or more rules would otherwise be broken. A link will be refused for the following reasons:

- An attempt to connect to a signal that is already driven. The cause of the refusal may not be obvious, since the signal symbol may appear elsewhere in the diagram. Use "Highlight a Path" to find the other signal.
- An attempt is made to repeat a link between two symbols. The cause of the refusal may not be obvious, since the existing link may be represented elsewhere in the diagram.

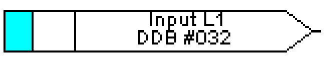
1.6.2 Opto signal properties

**Opto Signal**



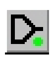
Each opto input can be selected and used for programming in PSL. Activation of the opto input will drive an associated DDB signal.

For example activating opto input L1 will assert DDB 032 in the PSL.




1.6.3 Input signal properties

**Input Signal**



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 261 will be asserted in the PSL should the active earth fault 1, stage 1 protection operate/trip.


1.6.4 Output signal properties

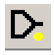
**Output Signal**

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 216 is asserted in the PSL, it will block the sensitive earth function stage 1 timer.


1.6.5 GOOSE input signal properties

**GOOSE In**



The Programmable Scheme Logic interfaces with the GOOSE Scheme Logic (see S1 users manual) by means of 32 Virtual inputs. The Virtual Inputs can be used in much the same way as the Opto Input signals.

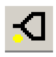
The logic that drives each of the Virtual Inputs is contained within the relay's GOOSE Scheme Logic file. It is possible to map any number of bit-pairs, from any enrolled device, using logic gates onto a Virtual Input (see S1 Users manual for more details).

PL

For example DDB 832 will be asserted in PSL should virtual input 1 and its associated bit pair operate.


1.6.6 GOOSE output signal properties

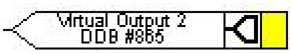
**GOOSE Out**



The Programmable Scheme Logic interfaces with the GOOSE Scheme Logic by means of 32 Virtual outputs.

It is possible to map virtual outputs to bit-pairs for transmitting to any enrolled devices (see S1 Users manual for more details).

For example if DDB 865 is asserted in PSL, Virtual Output 32 and its associated bit-pair mappings will operate.




1.6.7 Control in signal properties

**Control In**

There are 32 control inputs which can be activated via the relay menu, 'hotkeys' or via rear communications. Depending on the programmed setting i.e. latched or pulsed, an associated DDB signal will be activated in PSL when a control input is operated.

For example operate control input 1 to assert DDB 800 in the PSL.

### 1.6.8 Function key properties

**Function Key** 

Each function key can be selected and used for programming in PSL. Activation of the function key will drive an associated DDB signal and the DDB signal will remain active depending on the programmed setting i.e. 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 712 in the PSL.

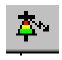

### 1.6.9 Fault recorder trigger properties

**Fault Record Trigger** 

The fault recording facility can be activated, by driving the fault recorder trigger DDB signal.

For example assert DDB 144 to activate the fault recording in the PSL.


### 1.6.10 LED signal properties

**LED** 

All programmable LEDs will drive associated DDB signal when the LED is activated.

For example DDB 652 will be asserted when LED 7 is activated.

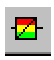

### 1.6.11 Contact signal properties

**Contact Signal** 

All relay output contacts will drive associated DDB signal when the output contact is activated.

For example DDB 009 will be asserted when output R10 is activated.


### 1.6.12 LED conditioner properties

**LED Conditioner** 

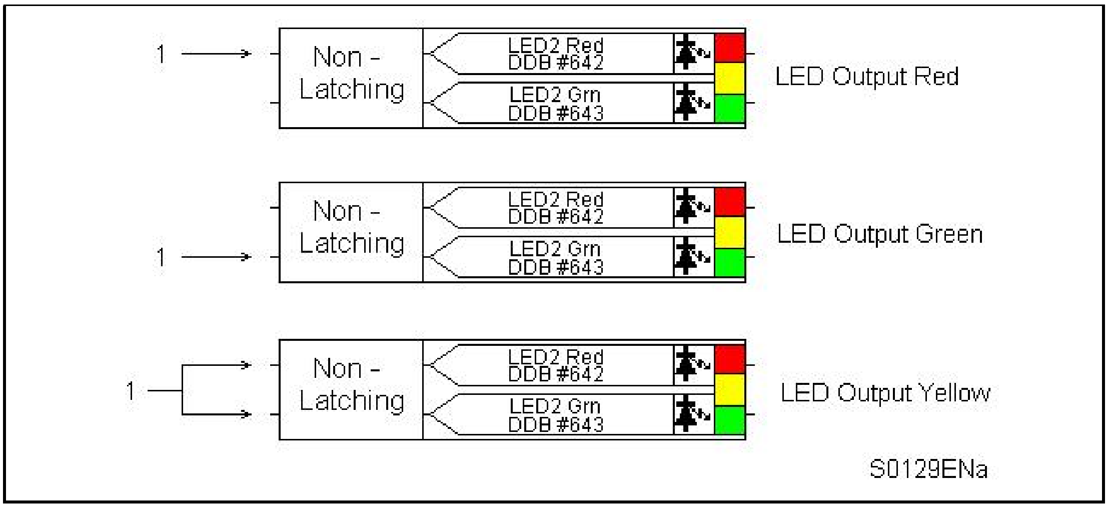
1. Select the **LED name** from the list (only shown when inserting a new symbol).

2. Configure the LED output to be Red, Yellow or Green.

   Configure a Green LED by driving the Green DDB input.

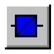
   Configure a RED LED by driving the RED DDB input.

   Configure a Yellow LED by driving the RED and GREEN DDB inputs simultaneously.



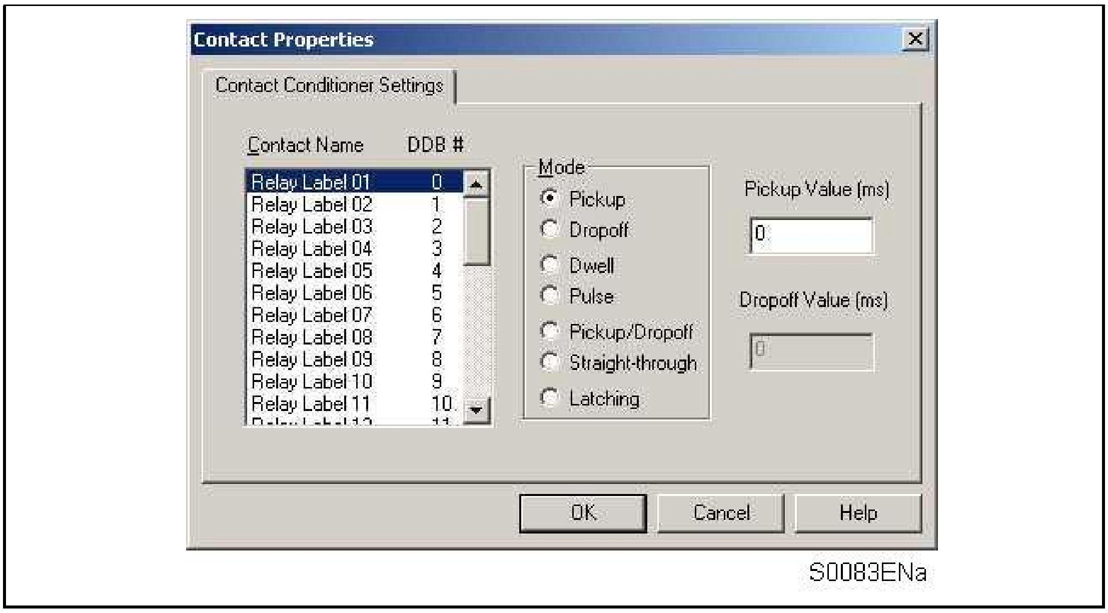

3. Configure the LED output to be latching or non-latching.

### 1.6.13 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 in any way whereas "latching" is used to create a sealed-in or lockout type function.

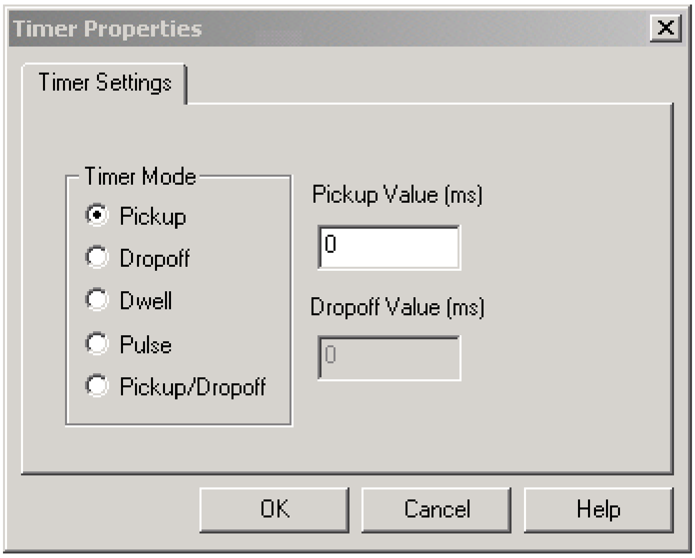
PL




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** Time (in milliseconds), if required.
4. Set the **Drop-off** Time (in milliseconds), if required.

### 1.6.14 Timer properties

Each timer can be selected for pick up, drop off, dwell, pulse or pick-up/drop-off operation.




1. Choose the operation mode from the **Timer Mode** tick list.
2. Set the Pick-up Time (in milliseconds), if required.
3. Set the Drop-off Time (in milliseconds), if required.

### 1.6.15 Gate properties

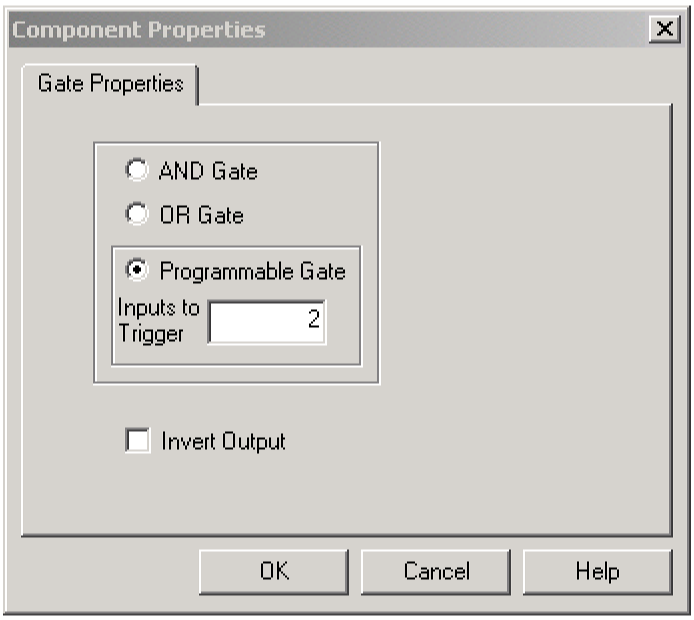


A Gate may be an AND, OR, or programmable gate.

An **AND** gate requires that all inputs are TRUE for the output to be TRUE.

An **OR** gate requires that one or more input is TRUE for the output to be TRUE.

A **Programmable** gate requires that the number of inputs that are TRUE is equal to or greater than its ‘Inputs to Trigger’ setting for the output to be TRUE.



1. Select the Gate type AND, OR, or Programmable.
2. Set the number of inputs to trigger when Programmable is selected.
3. Select if the output of the gate should be inverted using the Invert Output check box. An inverted output is indicated with a "bubble" on the gate output.

## 1.7 Description of logic nodes

| DDB No. | English Text | Source | Description |
|---|---|---|---|
| 0 | Output Label 1 (Setting) | Output Conditioner | Output signal from output Relay 1 when activated |
| 31 | Output Label 32 (Setting) | Output Conditioner | Output signal from output Relay 32 when activated |
| 32 | Opto Label 1 (Setting) | Opto Input | From opto input 1 - when opto energized |
| 63 | Opto Label 32 (Setting) | Opto Input | From opto input 32 - when opto energized |
| 64 - 71 | | | Unused |
| 72 | Relay Cond. 1 | PSL | Input to Relay Output Conditioner |
| 73 | Relay Cond. 2 | PSL | Input to Relay Output Conditioner |
| 74 | Any Trip | PSL | Input to Relay Output Conditioner |
| 75 | Relay Cond. 4 | PSL | Input to Relay Output Conditioner |
| 103 | Relay Cond. 4 | PSL | Input to Relay Output Conditioner |
| 104 - 111 | | | Unused |
| 112 | Timer in 1 | PSL | Input to Auxiliary Timer 1 |
| 127 | Timer in 16 | PSL | Input to Auxiliary Timer 16 |
| 128 | Timer out 1 | Auxiliary Timer | Output from Auxiliary Timer 1 |
| 129 - 242 | Timer out 2 …15 | Auxiliary Timer | Output from Auxiliary Timer 2 …15 |
| 143 | Timer out 16 | Auxiliary Timer | Output from Auxiliary Timer 16 |
| 144 | Fault REC TRIG | PSL | Input Trigger for Fault Recorder |
| 145 | SG-opto Invalid | Group Selection | Setting group selection opto inputs have detected an invalid (disabled) settings group |
| 146 | Prot'n. Disabled | Commissioning Test | Protection disabled - typically out of service due to test mode |
| 147 | F out of Range | Frequency Tracking | Frequency Out of Range Alarm |
| 148 | VT Fail Alarm | VT Supervision | VTS Indication alarm- failed VT (fuse blow) detected by VT supervision |
| 149 | CT Fail Alarm | CT Supervision | CTS Indication Alarm (CT supervision alarm) |
| 150 | CB Fail Alarm | CB Fail | Circuit Breaker Fail Alarm |
| 151 | I^ Maint. Alarm | CB Monitoring | Broken Current Maintenance Alarm - circuit breaker cumulative duty alarm set-point |
| 152 | I^ Lockout Alarm | CB Monitoring | Broken Current Lockout Alarm - circuit breaker cumulative duty has been exceeded |
| 153 | CB Ops Maint. | CB Monitoring | No of Circuit Breaker Operations Maintenance Alarm - indicated due to circuit breaker trip operations threshold |
| 154 | CB Ops Lockout | CB Monitoring | No of Circuit Breaker Operations Maintenance Lockout - excessive number of circuit breaker trip operations, safety lockout |
| 155 | CB Op Time Maint. | CB Monitoring | Excessive Circuit Breaker Operating Time Maintenance Alarm - excessive operation time alarm for the circuit breaker (slow interruption time) |
| 156 | CB Op Time Lock | CB Monitoring | Excessive Circuit Breaker Operating Time Lockout Alarm - excessive operation time alarm for the circuit breaker (too slow interruption) |
| 157 | Fault Freq. Lock | CB Monitoring | Excessive fault frequency Lockout Alarm |

| DDB No. | English Text | Source | Description |
|---|---|---|---|
| 158 | CB Status Alarm | CB Status | Indication of problems by Circuit Breaker state monitoring - example defective auxiliary contacts |
| 159 | Man CB Trip Fail | CB Control | Circuit Breaker Failed to Trip (after a manual/operator trip command) |
| 160 | Man CB Cls. Fail | CB Control | Circuit Breaker Failed to Close (after a manual/operator or auto-reclose close command) |
| 161 | Man CB Unhealthy | CB Control | Manual Circuit Breaker Unhealthy Output signal indicating that the circuit breaker has not closed successfully after a manual close command. (A successful close also requires The Circuit Breaker Healthy signal to reappear within the "healthy window" timeout) |
| 162 | Man No Check Sync. | CB Control | Indicates that the check synchronism signal has failed to appear for a manual close |
| 163 | AR Lockout | Auto-reclose | Indicates an Auto-reclose Lockout condition - no further auto-reclosures possible until resetting |
| 164 | AR CB Unhealthy | Auto-reclose | Auto-reclose Circuit Breaker unhealthy signal, output from auto-reclose logic. Indicates during auto-reclose in progress, if the Circuit Breaker has not become healthy within the Circuit Breaker Healthy time window |
| 165 | AR No Sys. Checks | Auto-reclose | Indicates during auto-reclose in progress, if system checks have not been satisfied within the Check Synchronizing time window |
| 166 | System Split | Check Sync. | System Split Alarm – will be raised if the system is split (remains permanently out of synchronism) for the duration of the system split timer |
| 167 | SR User Alarm 1 | PSL | Triggers User Alarm 1 message to be alarmed on LCD display (self-resetting) |
| 199 | SR User Alarm 32 | PSL | Triggers User Alarm 32 message to be alarmed on LCD display (self-resetting) |
| 200 | MR User Alarm 34 | PSL | Triggers User Alarm 34 message to be alarmed on LCD display (manual-resetting) |
| 202 | MR User Alarm 36 | PSL | Triggers User Alarm 36 message to be alarmed on LCD display (manual-resetting)) |
| 203 | I>1 Timer Block | PSL | Block Phase Overcurrent Stage 1 Time Delay |
| 204 | I>2 Timer Block | PSL | Block Phase Overcurrent Stage 2 Time Delay |
| 205 | I>3 Timer Block | PSL | Block Phase Overcurrent Stage 3 Time Delay |
| 206 | I>4 Timer Block | PSL | Block Phase Overcurrent Stage 4 Time Delay |
| 207 | | | Unused |
| 208 | IN1>1 Timer Blk. | PSL | Block Earth Fault Measured Stage 1 Time Delay |
| 209 | IN1>2 Timer Blk. | PSL | Block Earth Fault Measured Stage 2 Time Delay |
| 210 | IN1>3 Timer Blk. | PSL | Block Earth Fault Measured Stage 3 Time Delay |
| 211 | IN1>4 Timer Blk. | PSL | Block Earth Fault Measured Stage 4 Time Delay |
| 212 | IN2>1 Timer Blk. | PSL | Block Earth Fault Derived Stage 1 Time Delay |
| 213 | IN2>2 Timer Blk. | PSL | Block Earth Fault Derived Stage 2 Time Delay |
| 214 | IN2>3 Timer Blk. | PSL | Block Earth Fault Derived Stage 3 Time Delay |
| 215 | IN2>4 Timer Blk. | PSL | Block Earth Fault Derived Stage 4 Time Delay |
| 216 | ISEF>1 Timer Blk. | PSL | Block Sensitive Earth Fault Stage 1 Time Delay |
| 217 | ISEF>2 Timer Blk. | PSL | Block Sensitive Earth Fault Stage 2 Time Delay |

| DDB No. | English Text | Source | Description |
|---|---|---|---|
| 218 | ISEF>3 Timer Blk. | PSL | Block Sensitive Earth Fault Stage 3 Time Delay |
| 219 | ISEF>4 Timer Blk. | PSL | Block Sensitive Earth Fault Stage 4 Time Delay |
| 220 | VN>1 Timer Blk. | PSL | Block Residual Overvoltage Stage 1 Time Delay |
| 221 | VN>2 Timer Blk. | PSL | Block Residual Overvoltage Stage 2 Time Delay |
| 222 | V<1 Timer Block | PSL | Block Phase Undervoltage Stage 1 Time Delay |
| 223 | V<2 Timer Block | PSL | Block Phase Undervoltage Stage 2 Time Delay |
| 224 | V>1 Timer Block | PSL | Block Phase Overvoltage Stage 1 Time Delay |
| 225 | V>2 Timer Block | PSL | Block Phase Overvoltage Stage 2 Time Delay |
| 226 | CLP Initiate | PSL | Initiate Cold Load Pickup |
| 227 | Ext. Trip 3ph | PSL | External Trip 3 phase - allows external protection to initiate breaker fail, circuit breaker condition monitoring statistics, and internal auto-reclose (if enabled) |
| 228 | CB Aux. 3ph(52-A) | PSL | 52-A (CB closed)CB Auxiliary Input (3 phase) |
| 229 | CB Aux. 3ph(52-B) | PSL | 52-B (CB open)CB Auxiliary Input (3 phase) |
| 230 | CB Healthy | PSL | Circuit Breaker Healthy (input to auto-recloser - that the CB has enough energy to allow re.closing) |
| 231 | MCB/VTS | PSL | VT supervision input - signal from external miniature Circuit Breaker showing MCB tripped |
| 232 | Init. Trip CB | PSL | Initiate tripping of circuit breaker from a manual command |
| 233 | Init. Close CB | PSL | Initiate closing of Circuit Breaker from a manual command |
| 234 | Reset Close Dly. | PSL | Reset Manual Circuit Breaker Close Time Delay |
| 235 | Reset Relays/LED | PSL | Reset Latched Relays & LEDs (manual reset of any lockout trip contacts, auto-reclose lockout, and LEDs) |
| 236 | Reset Thermal | PSL | Reset Thermal State to 0% |
| 237 | Reset Lockout | PSL | Manual control to reset auto-recloser from lockout |
| 238 | Reset CB Data | PSL | Reset Circuit Breaker Maintenance Values |
| 239 | Block A/R | PSL | Block the Auto-reclose function from an external input |
| 240 | Live Line Mode | PSL | Auto-reclose Live Line Mode Operation-switches the auto-reclose out of service and protection functions are not blocked. If DDB is active, the scheme is forced to Live Line Mode, irrespective of the Auto-reclose Mode Select setting and Auto Mode and Telecontrol input DDBs |
| 241 | Auto Mode | PSL | Auto-recloser Auto Mode Operation-switches the auto-reclose in service |
| 242 | Telecontrol Mode | PSL | Telecontrol Mode Operation selection-whereby the Auto and Non-Auto modes of auto-reclose can be selected remotely |
| 243 | I>1 Trip | Phase Overcurrent | 1st Stage Overcurrent Trip 3ph |
| 244 | I>1 Trip A | Phase Overcurrent | 1st Stage Overcurrent Trip A |
| 245 | I>1 Trip B | Phase Overcurrent | 1st Stage Overcurrent Trip B |
| 246 | I>1 Trip C | Phase Overcurrent | 1st Stage Overcurrent Trip C |
| 247 | I>2 Trip | Phase Overcurrent | 2nd Stage Overcurrent Trip 3ph |

PL

| DDB No. | English Text | Source | Description |
|---|---|---|---|
| 248 | I>2 Trip A | Phase Overcurrent | 2nd Stage Overcurrent Trip A |
| 249 | I>2 Trip B | Phase Overcurrent | 2nd Stage Overcurrent Trip B |
| 250 | I>2 Trip C | Phase Overcurrent | 2nd Stage Overcurrent Trip C |
| 251 | I>3 Trip | Phase Overcurrent | 3rd Stage Overcurrent Trip 3ph |
| 252 | I>3 Trip A | Phase Overcurrent | 3rd Stage Overcurrent Trip A |
| 253 | I>3 Trip B | Phase Overcurrent | 3rd Stage Overcurrent Trip B |
| 254 | I>3 Trip C | Phase Overcurrent | 3rd Stage Overcurrent Trip C |
| 255 | I>4 Trip | Phase Overcurrent | 4th Stage Overcurrent Trip 3ph |
| 256 | I>4 Trip A | Phase Overcurrent | 4th Stage Overcurrent Trip A |
| 257 | I>4 Trip B | Phase Overcurrent | 4th Stage Overcurrent Trip B |
| 258 | I>4 Trip C | Phase Overcurrent | 4th Stage Overcurrent Trip C |
| 259 | | | Unused |
| 260 | Broken Line Trip | Broken Conductor | Broken Conductor Trip |
| 261 | IN1>1 Trip | Earth Fault 1 | 1st Stage Measured Earth Fault Trip |
| 262 | IN1>2 Trip | Earth Fault 1 | 2nd Stage Measured Earth Fault Trip |
| 263 | IN1>3 Trip | Earth Fault 1 | 3rd Stage Measured Earth Fault Trip |
| 264 | IN1>4 Trip | Earth Fault 1 | 4th Stage Measured Earth Fault Trip |
| 265 | IN2>1 Trip | Earth Fault 2 | 1st Stage Derived Earth Fault Trip |
| 266 | IN2>2 Trip | Earth Fault 2 | 2nd Stage Derived Earth Fault Trip |
| 267 | IN2>3 Trip | Earth Fault 2 | 3rd Stage Derived Earth Fault Trip |
| 268 | IN2>4 Trip | Earth Fault 2 | 4th Stage Derived Earth Fault Trip |
| 269 | ISEF>1 Trip | Sensitive Earth Fault | 1st Stage Sensitive Earth Fault Trip |
| 270 | ISEF>2 Trip | Sensitive Earth Fault | 2nd Stage Sensitive Earth Fault Trip |
| 271 | ISEF>3 Trip | Sensitive Earth Fault | 3rd Stage Sensitive Earth Fault Trip |
| 272 | ISEF>4 Trip | Sensitive Earth Fault | 4th Stage Sensitive Earth Fault Trip |
| 273 | IREF> Trip | Restricted Earth Fault | Restricted Earth Fault Trip |
| 274 | VN>1 Trip | Residual Overvoltage | 1st Stage Residual Overvoltage Trip |
| 275 | VN>2 Trip | Residual Overvoltage | 2nd Stage Residual Overvoltage Trip |
| 276 | Thermal Trip | Thermal Overload | Thermal Overload Trip |
| 277 | V2> Trip | Neg. Sequence O/V | Negative Sequence Overvoltage Trip |
| 278 | V<1 Trip | Undervoltage | 1st Stage Phase Undervoltage Trip 3ph |
| 279 | V<1 Trip A/AB | Undervoltage | 1st Stage Phase Undervoltage Trip A/AB |
| 280 | V<1 Trip B/BC | Undervoltage | 1st Stage Phase Undervoltage Trip B/BC |
| 281 | V<1 Trip C/CA | Undervoltage | 1st Stage Phase Undervoltage Trip C/CA |
| 282 | V<2 Trip | Undervoltage | 2nd Stage Phase Undervoltage Trip 3ph |

| DDB No. | English Text | Source | Description |
|---|---|---|---|
| 283 | V<2 Trip A/AB | Undervoltage | 2nd Stage Phase Undervoltage Trip A/AB |
| 284 | V<2 Trip B/BC | Undervoltage | 2nd Stage Phase Undervoltage Trip B/BC |
| 285 | V<2 Trip C/CA | Undervoltage | 2nd Stage Phase Undervoltage Trip C/CA |
| 286 | V>1 Trip | Overvoltage | 1st Stage Phase Overvoltage Trip 3ph |
| 287 | V>1 Trip A/AB | Overvoltage | 1st Stage Phase Overvoltage Trip A/AB |
| 288 | V>1 Trip B/BC | Overvoltage | 1st Stage Phase Overvoltage Trip B/BC |
| 289 | V>1 Trip C/CA | Overvoltage | 1st Stage Phase Overvoltage Trip C/CA |
| 290 | V>2 Trip | Overvoltage | 2nd Stage Phase Overvoltage Trip 3ph |
| 291 | V>2 Trip A/AB | Overvoltage | 2nd Stage Phase Overvoltage Trip A/AB |
| 292 | V>2 Trip B/BC | Overvoltage | 2nd Stage Phase Overvoltage Trip B/BC |
| 293 | V>2 Trip C/CA | Overvoltage | 2nd Stage Phase Overvoltage Trip C/CA |
| 294 | Any Start | All protection | Any Start |
| 295 | I>1 Start | Phase Overcurrent | 1st Stage Overcurrent Start 3ph |
| 296 | I>1 Start A | Phase Overcurrent | 1st Stage Overcurrent Start A |
| 297 | I>1 Start B | Phase Overcurrent | 1st Stage Overcurrent Start B |
| 298 | I>1 Start C | Phase Overcurrent | 1st Stage Overcurrent Start C |
| 299 | I>2 Start | Phase Overcurrent | 2nd Stage Overcurrent Start 3ph |
| 300 | I>2 Start A | Phase Overcurrent | 2nd Stage Overcurrent Start A |
| 301 | I>2 Start B | Phase Overcurrent | 2nd Stage Overcurrent Start B |
| 302 | I>2 Start C | Phase Overcurrent | 2nd Stage Overcurrent Start C |
| 303 | I>3 Start | Phase Overcurrent | 3rd Stage Overcurrent Start 3ph |
| 304 | I>3 Start A | Phase Overcurrent | 3rd Stage Overcurrent Start A |
| 305 | I>3 Start B | Phase Overcurrent | 3rd Stage Overcurrent Start B |
| 306 | I>3 Start C | Phase Overcurrent | 3rd Stage Overcurrent Start C |
| 307 | I>4 Start | Phase Overcurrent | 4th Stage Overcurrent Start 3ph |
| 308 | I>4 Start A | Phase Overcurrent | 4th Stage Overcurrent Start A |
| 309 | I>4 Start B | Phase Overcurrent | 4th Stage Overcurrent Start B |
| 310 | I>4 Start C | Phase Overcurrent | 4th Stage Overcurrent Start C |
| 311 | VCO Start AB | Voltage Controlled O/C | Voltage Controlled Overcurrent Start AB |
| 312 | VCO Start BC | Voltage Controlled O/C | Voltage Controlled Overcurrent Start BC |
| 313 | VCO Start CA | Voltage Controlled O/C | Voltage Controlled Overcurrent Start CA |
| 314 | | | Unused |
| 315 | IN1>1 Start | Earth Fault 1 | 1st Stage Measured Earth Fault Start |
| 316 | IN1>2 Start | Earth Fault 1 | 2nd Stage Measured Earth Fault Start |
| 317 | IN1>3 Start | Earth Fault 1 | 3rd Stage Measured Earth Fault Start |

| DDB No. | English Text | Source | Description |
|---|---|---|---|
| 318 | IN1>4 Start | Earth Fault 1 | 4th Stage Measured Earth Fault Start |
| 319 | IN2>1 Start | Earth Fault 2 | 1st Stage Derived Earth Fault Start |
| 320 | IN2>2 Start | Earth Fault 2 | 2nd Stage Derived Earth Fault Start |
| 321 | IN2>3 Start | Earth Fault 2 | 3rd Stage Derived Earth Fault Start |
| 322 | IN2>4 Start | Earth Fault 2 | 4th Stage Derived Earth Fault Start |
| 323 | ISEF>1 Start | Sensitive Earth Fault | 1st Stage Sensitive Earth Fault Start |
| 324 | ISEF>2 Start | Sensitive Earth Fault | 2nd Stage Sensitive Earth Fault Start |
| 325 | ISEF>3 Start | Sensitive Earth Fault | 3rd Stage Sensitive Earth Fault Start |
| 326 | ISEF>4 Start | Sensitive Earth Fault | 4th Stage Sensitive Earth Fault Start |
| 327 | VN>1 Start | Residual Overvoltage | 1st Stage Residual Overvoltage Start |
| 328 | VN>2 Start | Residual Overvoltage | 2nd Stage Residual Overvoltage Start |
| 329 | Thermal Alarm | Thermal Overload | Thermal Overload Alarm |
| 330 | V2> Start | Neg. Sequence O/V | Negative Sequence Overvoltage Start |
| 331 | V<1 Start | Undervoltage | 1st Stage Phase Undervoltage Start 3ph |
| 332 | V<1 Start A/AB | Undervoltage | 1st Stage Phase Undervoltage Start A/AB |
| 333 | V<1 Start B/BC | Undervoltage | 1st Stage Phase Undervoltage Start B/BC |
| 334 | V<1 Start C/CA | Undervoltage | 1st Stage Phase Undervoltage Start C/CA |
| 335 | V<2 Start | Undervoltage | 2nd Stage Phase Undervoltage Start 3ph |
| 336 | V<2 Start A/AB | Undervoltage | 2nd Stage Phase Undervoltage Start A/AB |
| 337 | V<2 Start B/BC | Undervoltage | 2nd Stage Phase Undervoltage Start B/BC |
| 338 | V<2 Start C/CA | Undervoltage | 2nd Stage Phase Undervoltage Start C/CA |
| 339 | V>1 Start | Overvoltage | 1st Stage Phase Overvoltage Start 3ph |
| 340 | V>1 Start A/AB | Overvoltage | 1st Stage Phase Overvoltage Start A/AB |
| 341 | V>1 Start B/BC | Overvoltage | 1st Stage Phase Overvoltage Start B/BC |
| 342 | V>1 Start C/CA | Overvoltage | 1st Stage Phase Overvoltage Start C/CA |
| 343 | V>2 Start | Overvoltage | 2nd Stage Phase Overvoltage Start 3ph |
| 344 | V>2 Start A/AB | Overvoltage | 2nd Stage Phase Overvoltage Start A/AB |
| 345 | V>2 Start B/BC | Overvoltage | 2nd Stage Phase Overvoltage Start B/BC |
| 346 | V>2 Start C/CA | Overvoltage | 2nd Stage Phase Overvoltage Start C/CA |
| 347 | CLP Operation | Cold Load Pickup | Indicates the Cold Load Pickup logic is in operation |
| 348 | I> BlockStart | CBF & POC | I> Blocked Overcurrent Start |
| 349 | IN/SEF>Blk Start | CBF & IN1/IN2/SEF | IN/ISEF> Blocked Overcurrent Start |
| 350 | VTS Fast Block | VT Supervision | VT Supervision Fast Block - blocks elements which would otherwise mal-operate immediately a fuse failure event occurs |
| 351 | VTS Slow Block | VT Supervision | VT Supervision Slow Block - blocks elements which would otherwise mal-operate some time after a fuse failure event occurs |

| DDB No. | English Text | Source | Description |
|---|---|---|---|
| 352 | CTS Block | CT Supervision | CT Supervision Block (current transformer supervision) |
| 353 | Bfail1 Trip 3ph | CB Fail | tBF1 Trip 3Ph - three phase output from circuit breaker failure logic, stage 1 timer |
| 354 | Bfail2 Trip 3ph | CB Fail | tBF2 Trip 3Ph - three phase output from circuit breaker failure logic, stage 2 timer |
| 355 | Control Trip | CB Control | Control Trip - operator trip instruction to the circuit breaker, via menu, or SCADA. (Does not operate for protection element trips) |
| 356 | Control Close | CB Control | Control Close command to the circuit breaker. Operates for a manual close command (menu, SCADA), and additionally is driven by the auto-reclose close command |
| 357 | Close in Prog. | CB Control | Control Close in Progress - the relay has been given an instruction to close the circuit breaker, but the Manual Close timer Delay has not yet finished timing out |
| 358 | Block Main Prot. | Auto-reclose | Auto-reclose block Main Protection during auto-reclose cycle. Can be used to block external protection via relay output contacts |
| 359 | Block SEF Prot. | Auto-reclose | Auto-reclose block Sensitive Earth Fault Protection during auto-reclose cycle. Can be used to block external protection via relay output contacts |
| 360 | AR In Progress | Auto-reclose | Auto-reclose In Progress |
| 361 | AR In Service | Auto-reclose | Auto-reclose In/Out of service - the auto-reclose function has been enabled either in the relay menu, or by an opto input |
| 362 | Seq. Counter = 0 | Auto-reclose | Auto-reclose sequence counter is at zero - no previous faults have been cleared within recent history. The sequence count is at zero because no reclaim times are timing out, and the auto-recloser is not locked out. The recloser is awaiting the first protection trip, and all programmed cycles are free to follow |
| 363 | Seq. Counter = 1 | Auto-reclose | The first fault trip has happened in a new auto-reclose sequence. Dead time 1, or reclaim time 1 are in the process of timing out |
| 366 | Seq. Counter = 4 | Auto-reclose | Auto-reclose sequence counter is at 4. This means that the initial fault trip happened, and then 3 trips followed, moving the counter on to 4 |
| 367 | Successful Close | Auto-reclose | Successful Re-closure indication. The circuit breaker was re-closed by the auto-reclose function, and stayed closed. This indication is raised at the expiry of the reclaim time |
| 368 | Dead T in Prog. | Auto-reclose | Indicates Dead Time in Progress |
| 369 | Protection Lockt. | Auto-reclose | Indicates a Protection Lockout of auto-reclose when the AR is set to Live Line or Non Auto modes |
| 370 | Reset Lckout Alm. | Auto-reclose | Auto-reclose Reset Lockout Alarm indication |
| 371 | Auto Close | Auto-reclose | Auto-reclose command to the circuit breaker |
| 372 | A/R Trip Test | Auto-reclose | Auto-reclose trip test which initiates an auto-reclose cycle |
| 373 | IA< Start | Undercurrent | A phase Undercurrent Start |
| 374 | IB< Start | Undercurrent | B phase Undercurrent Start |
| 375 | IC< Start | Undercurrent | C phase Undercurrent Start |
| 376 | IN< Start | Undercurrent | Earth Fault Undercurrent Start |
| 377 | ISEF< Start | Undercurrent | Sensitive Earth Fault Undercurrent Start |
| 378 | CB Open 3 ph | CB Status | Three phase Circuit breaker Open Status |

PL

| DDB No. | English Text | Source | Description |
|---|---|---|---|
| 379 | CB Closed 3 ph | CB Status | Three phase Circuit breaker Closed Status |
| 380 | All Poles Dead | Poledead | Pole dead logic detects 3 phase breaker open condition |
| 381 | Any Pole Dead | Poledead | Pole dead logic detects at least one breaker pole open |
| 382 | Pole Dead A | Poledead | Phase A Pole Dead |
| 383 | Pole Dead B | Poledead | Phase B Pole Dead |
| 384 | Pole Dead C | Poledead | Phase C Pole Dead |
| 385 | VTS Acc. Ind. | VT Supervision | Voltage Transformer Supervision Accelerate Indication signal form a fast tripping voltage dependent function used to accelerate indications when the indicate only option is selected |
| 386 | VTS Volt Dep. | VT Supervision input | Outputs from any function that utilizes the system voltage, if any of these elements operate before a VTS is detected, the VTS is blocked from operation. The outputs include starts and trips |
| 387 | VTS Ia> | VT Supervision | VTS A phase current level detector is over threshold |
| 388 | VTS Ib> | VT Supervision | VTS B phase current level detector is over threshold |
| 389 | VTS Ic> | VT Supervision | VTS C phase current level detector is over threshold |
| 390 | VTS Va> | VT Supervision | VTS A phase voltage level detector is over threshold |
| 391 | VTS Vb> | VT Supervision | VTS B phase voltage level detector is over threshold |
| 392 | VTS Vc> | VT Supervision | VTS C phase voltage level detector is over threshold |
| 393 | VTS I2> | VT Supervision | VTS negative sequence current level detector is over threshold |
| 394 | VTS V2> | VT Supervision | VTS negative sequence voltage level detector is over threshold |
| 395 | VTS Ia delta> | VT Supervision | Superimposed A phase current over threshold |
| 396 | VTS Ib delta> | VT Supervision | Superimposed B phase current over threshold |
| 397 | VTS Ic delta > | VT Supervision | Superimposed C phase current over threshold |
| 398 | CBF SEF Trip | Breaker Fail (Fixed Logic) | Internal signal for the Circuit Breaker Fail logic to indicate general Sensitive Earth Fault Trip condition |
| 399 | CBF Non I Trip | Breaker Fail (Fixed Logic) | Internal signal for the Circuit Breaker Fail logic to indicate general Non Current based Protection Trip |
| 400 | CBF SEF Trip-1 | Breaker Fail (Fixed Logic) | Internal signal for the Circuit Breaker Fail logic to indicate a Sensitive Earth Fault Stage Trip condition |
| 401 | CBF Non I Trip-1 | Breaker Fail (Fixed Logic) | Internal signal for the Circuit Breaker Fail logic to indicate Non Current Protection Stage Trip |
| 402 | Man Check Sync. | PSL | Input to the Circuit Breaker Control Logic to indicate manual check synchronization conditions are satisfied |
| 403 | AR SysChecks OK | PSL | Input to the auto-reclose logic to indicate auto-reclose check synchronization conditions are satisfied |
| 404 | Lockout Alarm | CB Monitoring | Composite Lockout Alarm |
| 405 | Pre-Lockout | CB Monitoring | Pre-Lockout Alarm indicates the auto-reclose will lockout on the next shot |
| 406 | Freq. High | Frequency Tracking | Frequency tracking detects frequency above the allowed range |
| 407 | Freq. Low | Frequency Tracking | Frequency tracking detects frequency below the allowed range |

| DDB No. | English Text | Source | Description |
|---|---|---|---|
| 408 | Stop Freq. Track | Fixed Logic | Stop Frequency Tracking signal - indicates under legitimate conditions when the relay suspends frequency tracking on the instruction of the protection elements |
| 409 | Start N | EF1/EF2/SEF/VN/YN | Composite Earth Fault Start |
| 410 | Field Volts Fail | Field Voltage Monitor | 48V Field Voltage Failure |
| 411 | Freq. Not Found | Frequency Tracking | Frequency Not Found by the frequency tracking |
| 412 | F<1 Timer Block | PSL | Block Underfrequency Stage 1 Timer |
| 413 | F<2 Timer Block | PSL | Block Underfrequency Stage 2 Timer |
| 414 | F<3 Timer Block | PSL | Block Underfrequency Stage 3 Timer |
| 415 | F<4 Timer Block | PSL | Block Underfrequency Stage 4 Timer |
| 416 | F>1 Timer Block | PSL | Block Overfrequency Stage 1 Timer |
| 417 | F>2 Timer Block | PSL | Block Overfrequency Stage 2 Timer |
| 418 | F<1 Start | Frequency Protection | Under frequency Stage 1 Start |
| 419 | F<2 Start | Frequency Protection | Under frequency Stage 2 Start |
| 420 | F<3 Start | Frequency Protection | Under frequency Stage 3 Start |
| 421 | F<4 Start | Frequency Protection | Under frequency Stage 4 Start |
| 422 | F>1 Start | Frequency Protection | Over frequency Stage 1 Start |
| 423 | F>2 Start | Frequency Protection | Over frequency Stage 2 Start |
| 424 | F<1 Trip | Frequency Protection | Under frequency Stage 1 Trip |
| 425 | F<2 Trip | Frequency Protection | Under frequency Stage 2 Trip |
| 426 | F<3 Trip | Frequency Protection | Under frequency Stage 3 Trip |
| 427 | F<4 Trip | Frequency Protection | Under frequency Stage 4 Trip |
| 428 | F>1 Trip | Frequency Protection | Over frequency Stage 1 Trip |
| 429 | F>2 Trip | Frequency Protection | Over frequency Stage 2 Trip |
| 430 | YN> Timer Block | PSL | Block Overadmittance Timer |
| 431 | GN> Timer Block | PSL | Block Overconductance Timer |
| 432 | BN> Timer Block | PSL | Block Oversusceptance Timer |
| 433 | YN> Start | Admittance Protection | Overadmittance Start |
| 434 | GN> Start | Admittance Protection | Overconductance Start |
| 435 | BN> Start | Admittance Protection | Oversusceptance Start |
| 436 | YN> Trip | Admittance Protection | Overadmittance Trip |
| 437 | GN> Trip | Admittance Protection | Overconductance Trip |
| 438 | BN> Trip | Admittance Protection | Oversusceptance Trip |
| 439 | Ext. AR Prot. Trip | PSL | Initiate Auto-reclose from an external protection device trip |
| 440 | Ext. AR Prot. Strt. | PSL | Initiate Auto-reclose from an external protection device start |

| DDB No. | English Text | Source | Description |
|---|---|---|---|
| 441 | Test Mode | PSL | Initiate Test Mode which takes the relay out of service and allows secondary injection testing of the relay |
| 442 | Inhibit SEF | PSL | Inhibit Sensitive Earth Fault Protection - All Stages |
| 443 | Live Line | Voltage Monitors | Indicates Live Line condition is detected |
| 444 | Dead Line | Voltage Monitors | Indicates Dead Line condition is detected |
| 445 | Live Bus | Voltage Monitors | Indicates Live Bus condition is detected |
| 446 | Dead Bus | Voltage Monitors | Indicates Dead Bus condition is detected |
| 447 | Check Sync. 1 OK | Check Synchronization | Check Sync. Stage 1 OK |
| 448 | Check Sync. 2 OK | Check Synchronization | Check Sync. Stage 2 OK |
| 449 | SysChks Inactive | Check Synchronization | System Checks Inactive (output from the check synchronism, and other voltage checks) |
| 450 | CS1 Enabled | PSL | Check Sync. Stage 1 Enabled |
| 451 | CS2 Enabled | PSL | Check Sync. Stage 2 Enabled |
| 452 | SysSplit Enabled | PSL | System Split function Enabled |
| 453 | DAR Complete | PSL | Delayed Auto-reclose Complete |
| 454 | CB In Service | PSL | Circuit breaker is In Service |
| 455 | AR Restart | PSL | Auto-reclose Restart input to initiate an auto-reclose cycle irrespective of the normal AR interlock conditions |
| 456 | AR In Progress 1 | Auto-reclose | Auto-reclose In Progress indication which is active during AR cycle and is reset by the 'DAR Complete' DDB if mapped or otherwise by the 'AR in Progress' DDB |
| 457 | DeadTime Enabled | PSL | Dead Time Enabled |
| 458 | DT OK To Start | PSL | Dead Time OK To Start input to the dead time initiation logic. Allows an interlock condition besides CB open and protection reset to 'prime' the dead time logic |
| 459 | DT Complete | Auto-reclose | Dead Time Complete indication and operates at the end of the set dead time period |
| 460 | Reclose Checks | Auto-reclose | Re-close Checks indicates the dead time logic is 'primed' |
| 461 | Circuits OK | PSL | Input to the auto-reclose logic to indicate Live/Dead Circuit conditions are satisfied when AR with 'Live/Dead Ccts' is enabled |
| 462 | AR Sync. Check | Auto-reclose | Auto-reclose Check Synchronism OK (system checks passed) |
| 463 | AR SysChecksOK | Auto-reclose | Auto-reclose System Check OK conditions are confirmed by the system checks function |
| 464 | AR Init. TripTest | PSL | Initiates a trip and auto-reclose cycle and is usually mapped to an opto input |
| 465 | Monitor Block | PSL | For IEC-870-5-103 protocol only, used for "Monitor Blocking" (relay is quiet - issues no messages via SCADA port) |
| 466 | Command Block | PSL | For IEC-870-5-103 protocol only, used for "Command Blocking" (relay ignores SCADA commands) |
| 467 | ISEF>1 Start 2 | Sensitive Earth Fault | 1st Stage Sensitive Earth Fault second Start indication |
| 468 | ISEF>2 Start 2 | Sensitive Earth Fault | 2nd Stage Sensitive Earth Fault second Start indication |
| 469 | ISEF>3 Start 2 | Sensitive Earth Fault | 3rd Stage Sensitive Earth Fault second Start indication |

| DDB No. | English Text | Source | Description |
|---|---|---|---|
| 470 | ISEF>4 Start 2 | Sensitive Earth Fault | 4th Stage Sensitive Earth Fault second Start indication |
| 471 | CS1 Slipfreq.> | Check Synchronization | Operates when 1st Stage Check Sync. slip frequency is above the Check Sync. 1 Slip Frequency setting |
| 472 | CS1 Slipfreq.< | Check Synchronization | Operates when 1st Stage Check Sync. slip frequency is below the Check Sync. 1 Slip Frequency setting |
| 473 | CS2 Slipfreq.> | Check Synchronization | Operates when 2nd Stage Check Sync. slip frequency is above the Check Sync. 2 Slip Frequency setting |
| 474 | CS2 Slipfreq.< | Check Synchronization | Operates when 2nd Stage Check Sync. slip frequency is below the Check Sync. 2 Slip Frequency setting |
| 475 | Time Sync. | PSL | Time Synchronism by Opto pulse |
| 476 | df/dt> Inhibit | PSL | Inhibit input for the Rate of change of Frequency function |
| 477 | df/dt>1 Tmr. Blk. | PSL | Block Rate of change of Frequency Stage 1Timer |
| 478 | df/dt>2 Tmr. Blk. | PSL | Block Rate of change of Frequency Stage 2 Timer |
| 479 | df/dt>3 Tmr. Blk. | PSL | Block Rate of change of Frequency Stage 3 Timer |
| 480 | df/dt>4 Tmr. Blk. | PSL | Block Rate of change of Frequency Stage 4 Timer |
| 481 | df/dt>1 Start | df/dt Protection | 1st Stage Rate of change of Frequency Start indication |
| 482 | df/dt>2 Start | df/dt Protection | 2nd Stage Rate of change of Frequency Start indication |
| 483 | df/dt>3 Start | df/dt Protection | 3rd Stage Rate of change of Frequency Start indication |
| 484 | df/dt>4 Start | df/dt Protection | 4th Stage Rate of change of Frequency Start indication |
| 485 | df/dt>1 Trip | df/dt Protection | 1st Stage Rate of change of Frequency Trip |
| 486 | df/dt>2 Trip | df/dt Protection | 2nd Stage Rate of change of Frequency Trip |
| 487 | df/dt>3 Trip | df/dt Protection | 3rd Stage Rate of change of Frequency Trip |
| 488 | df/dt>4 Trip | df/dt Protection | 4th Stage Rate of change of Frequency Trip |
| 489 | CS Vline< | Check Synchronization | Indicates the Line voltage is less than the Check Sync. undervoltage setting |
| 490 | CS Vbus< | Check Synchronization | Indicates the Bus voltage is less than the Check Sync. undervoltage setting |
| 491 | CS Vline> | Check Synchronization | Indicates the Line voltage is greater than the Check Sync. overvoltage setting |
| 492 | CS Vbus> | Check Synchronization | Indicates the Bus voltage is greater than the Check Sync. overvoltage setting |
| 493 | CS Vline>Vbus | Check Synchronization | Indicates that the Line voltage is greater than Bus voltage + Check Sync. differential voltage setting |
| 494 | CS Vline<Vbus | Check Synchronization | Indicates the Bus voltage is greater than Line voltage + Check Sync. differential voltage setting |
| 495 | CS1 Fline>Fbus | Check Synchronization | Indicates the Line frequency is greater than the Bus frequency + Check Sync. 1 Slip Frequency setting where Check Sync. 1 Slip Control is set to Frequency |
| 496 | CS1 Fline<Fbus | Check Synchronization | Indicates the Bus frequency is greater than Line frequency + Check Sync. 1 Slip Frequency setting where Check Sync. 1 Slip Control is set to Frequency |
| 497 | CS1 Ang. Not OK + | Check Synchronization | Indicates the Line angle leads the bus angle and falls in range + CS1 Phase Angle (deg.) to 180° |
| 498 | CS1 Ang. Not OK - | Check Synchronization | Indicates if the Line angle lags the bus angle and falls in range - CS1 Phase Angle (deg.) to -180° |
| 499 | External Trip A | PSL | External Trip A input |

| DDB No. | English Text | Source | Description |
|---|---|---|---|
| 500 | External Trip B | PSL | External Trip B input |
| 501 | External Trip C | PSL | External Trip C input |
| 502 | External Trip EF | PSL | External Trip Earth Fault input |
| 503 | External TripSEF | PSL | External Trip Sensitive Earth Fault input |
| 504 | I2> Inhibit | PSL | Inhibit all Negative Sequence Overcurrent stages |
| 505 | I2>1 Tmr. Blk. | PSL | Block Negative Sequence Overcurrent Stage 1Timer |
| 506 | I2>2 Tmr. Blk. | PSL | Block Negative Sequence Overcurrent Stage 2 Timer |
| 507 | I2>3 Tmr. Blk. | PSL | Block Negative Sequence Overcurrent Stage 3 Timer |
| 508 | I2>4 Tmr. Blk. | PSL | Block Negative Sequence Overcurrent Stage 4 Timer |
| 509 | I2>1 Start | Neg. Sequence O/C | 1st Stage Negative Sequence Overcurrent Start |
| 510 | I2>2 Start | Neg. Sequence O/C | 2nd Stage Negative Sequence Overcurrent Start |
| 511 | I2>3 Start | Neg. Sequence O/C | 3rd Stage Negative Sequence Overcurrent Start |
| 512 | I2>4 Start | Neg. Sequence O/C | 4th Stage Negative Sequence Overcurrent Start |
| 513 | I2>1 Trip | Neg. Sequence O/C | 1st Stage Negative Sequence Overcurrent Trip |
| 514 | I2>2 Trip | Neg. Sequence O/C | 2nd Stage Negative Sequence Overcurrent Trip |
| 515 | I2>3 Trip | Neg. Sequence O/C | 3rd Stage Negative Sequence Overcurrent Trip |
| 516 | I2>4 Trip | Neg. Sequence O/C | 4th Stage Negative Sequence Overcurrent Trip |
| 517 | V2> Accelerate | PSL | Input to Accelerate Negative Sequence Overvoltage (V2> Protection) instantaneous operating time |
| 518 | Trip LED | PSL | Input to Trigger Trip LED (other than Relay 3) |
| 519 | CS2 Fline>Fbus | Check Synchronization | Indicates the Line frequency is greater than the Bus Frequency + Check Sync. 2 Slip Frequency setting where Check Sync. 2 Slip Control is set to Frequency |
| 520 | CS2 Fline<Fbus | Check Synchronization | Indicates the Bus frequency is greater than Line Frequency + Check Sync. 2 Slip Frequency setting where Check Sync. 2 Slip Control is set to Frequency |
| 521 | CS2 Ang. Not OK + | Check Synchronization | Indicates the Line angle leads the bus angle and falls in range + Check Sync. 2 Phase Angle (deg.) to 180° |
| 522 | CS2 Ang. Not OK - | Check Synchronization | Indicates the Line angle lags the bus angle and falls in range - Check Sync. 2 Phase Angle (deg.) to -180° |
| 523 | CS Ang. Rot ACW | Check Synchronization | The direction of rotation of line angle, using bus as a reference, is anti-clockwise (ACW) |
| 524 | CS Ang. Rot CW | Check Synchronization | The direction of rotation of line angle, using bus as a reference, is clockwise (CW) |
| 525 | Blk. Rmt. CB Ops | PSL | Block Remote CB Trip/Close Commands |
| 526 | SG Select x1 | PSL | Setting Group Selector X1 (low bit)-selects SG2 if only DDB 526 signal is active.<br>SG1 is active if both DDB 526 & DDB 527=0<br>SG4 is active if both DDB 526 & DDB 527=1 |
| 527 | SG Select 1x | PSL | Setting Group Selector 1X (high bit)-selects SG3 if only DDB 527 is active.<br>SG1 is active if both DDB 526 & DDB 527=0<br>SG4 is active if both DDB 526 & DDB 527=1 |
| 528 | IN1> Inhibit | PSL | Inhibit Earth Fault 1 Protection |
| 529 | IN2> Inhibit | PSL | Inhibit Earth Fault 2 Protection |

| DDB No. | English Text | Source | Description |
|---|---|---|---|
| 530 | AR Skip Shot 1 | PSL | When active skips the first auto-reclose shot in an auto-reclose cycle |
| 531 | Logic 0 Ref. | Reference DDB Signal | Logic zero reference DDB signal |
| 532 - 639 | Unused | | |
| 640 | LED1 Red | Output Conditioner | Programmable LED 1 Red is energized |
| 641 | LED1 Grn. | Output Conditioner | Programmable LED 1 Green is energized |
| 654 | LED8 Red | Output Conditioner | Programmable LED 8 Red is energized |
| 655 | LED8 Grn. | Output Conditioner | Programmable LED 8 Green is energized |
| 656 | FnKey LED1 Red | Output Conditioner | Programmable Function Key LED 1 Red is energized |
| 657 | FnKey LED1 Grn. | Output Conditioner | Programmable Function Key LED 1 Green is energized |
| 674 | FnKey LED10 Red | Output Conditioner | Programmable Function Key LED 10 Red is energized |
| 675 | FnKey LED10 Grn. | Output Conditioner | Programmable Function Key LED 10 Green is energized |
| 676 | LED1 Con R | PSL | Assignment of input  signal to drive output LED 1Red |
| 677 | LED1 Con G | PSL | Assignment of signal to drive output LED 1Green.To drive LED1 Yellow DDB 676 and DDB 677 must be driven at the same time |
| 690 | LED8 Con R | PSL | Assignment of signal to drive output LED 8Red |
| 691 | LED8 Con G | PSL | Assignment of signal to drive output LED 8 Green.  To drive LED8 Yellow DDB 690 and DDB 691 must be active at the same time |
| 692 | FnKey LED1 ConR | PSL | Assignment of signal to drive output Function Key LED 1 Red.  This LED is associated with Function Key 1 |
| 693 | FnKey LED1 ConG | PSL | Assignment of signal to drive output Function Key LED 1 Green.  This LED is associated with Function Key 1. To drive function key LED, yellow DDB 692 and DDB 693 must be active at the same time |
| 710 | FnKey LED10 ConR | PSL | Assignment of signal to drive output Function Key LED 10 Red.  This LED is associated with Function Key 10 |
| 711 | FnKey LED10 ConG | PSL | Assignment of signal to drive output Function Key LED 10 Green.  This LED is associated with Function Key 10.  To drive function key LED1 yellow, DDB 710 and DDB 711 must be active at the same time |
| 712 | Function Key 1 | Function Key | Function Key 1 is activated.  In ‘Normal’ mode it is high on keypress and in ‘Toggle’ mode remains high/low on single keypress |
| 721 | Function Key 10 | Function Key | Function Key 10 is activated.  In ‘Normal’ mode it is high on keypress and in ‘Toggle’ mode remains high/low on single keypress |
| 722 - 768 | | | Unused |
| 800 | Control Input 1 | Control Input Command | Control Input 1 - for SCADA and menu commands into PSL |
| 831 | Control Input 32 | Control Input Command | Control Input 32 - for SCADA and menu commands into PSL |
| 832 | Virtual Input 1 | GOOSE Input Command | GOOSE Input 1 (reserved for future use when IEC61850 implemented) |
| 833 - 862 | Virtual Input 2-31 | GOOSE Input Command | GOOSE Input 1 - allows binary signals that are mapped  to virtual inputs to interface into PSL (reserved for future use when IEC61850 implemented) |
| 863 | Virtual Input 32 | GOOSE Input Command | GOOSE Input 2-31 - allows binary signals that are mapped  to virtual inputs to interface into PSL (reserved for future use when IEC61850 implemented) |

PL

| DDB No. | English Text | Source | Description |
|---|---|---|---|
| 864 | Virtual Output 1 | PSL | GOOSE Input 32 - allows binary signals that are mapped to virtual inputs to interface into PSL (reserved for future use when IEC61850 implemented) |
| 865 - 894 | Virtual Output 2 - 31 | PSL | GOOSE Output 2 - 31 - output allows user to control a binary signal which can be mapped via SCADA protocol output to other devices |
| 895 | Virtual Output 32 | PSL | GOOSE Output 32 - output allows user to control a binary signal which can be mapped via SCADA protocol output to other devices |

## 1.8 Factory default programmable scheme logic

The following section details the default settings of the PSL. Note that the default PSL has been implemented for the P145 B variant with 12 inputs and 12 outputs available.

The P145 model options are as follows:

| Model | Logic Inputs | Relay Outputs |
|---|---|---|
| P145xxxAxxxxxxJ | 16 | 16 |
| P145xxxBxxxxxxJ | 12 | 12 |
| P145xxxCxxxxxxJ | 24 | 16 |
| P145xxxDxxxxxxJ | 16 | 24 |
| P145xxxExxxxxxJ | 24 | 24 |
| P145xxxFxxxxxxJ | 32 | 16 |
| P145xxxGxxxxxxJ | 16 | 32 |

PL

## 1.9 Logic input mapping

The default mappings for each of the opto-isolated inputs are as shown in the following table:

| Opto-Input Number | P145 Relay Text | Function |
|---|---|---|
| 1 | Input L1 | Setting Group selection |
| 2 | Input L2 | Setting Group selection |
| 3 | Input L3 | Block earth fault stages IN1>3 & 4 |
| 4 | Input L4 | Block overcurrent stages I>3 & 4 |
| 5 | Input L5 | L5 Not Mapped |
| 6 | Input L6 | External 3-phase Trip input |
| 7 | Input L7 | Circuit Breaker 52-A auxiliary contact input |
| 8 | Input L8 | Circuit Breaker 52-B auxiliary contact input |
| 9 | Input L9 | L9 Not Mapped |
| 10 | Input L10 | Activates Telecontrol Mode for AR |
| 11 | Input L11 | External Auto-reclose Block |
| 12 | Input L12 | Circuit Breaker Healthy input |
| 13 | L13 Not Mapped | L13 Not Mapped |
| 14 | L14 Not Mapped | L14 Not Mapped |
| 15 | L15 Not Mapped | L15 Not Mapped |
| 16 | L16 Not Mapped | L16 Not Mapped |
| 17 | L17 Not Mapped | L17 Not Mapped |

| Opto-Input Number | P145 Relay Text | Function |
|---|---|---|
| 18 | L18 Not Mapped | L18 Not Mapped |
| 19 | L19 Not Mapped | L19 Not Mapped |
| 20 | L20 Not Mapped | L20 Not Mapped |
| 21 | L21 Not Mapped | L21 Not Mapped |
| 22 | L22 Not Mapped | L22 Not Mapped |
| 23 | L23 Not Mapped | L23 Not Mapped |
| 24 | L24 Not Mapped | L24 Not Mapped |
| 25 | L25 Not Mapped | L25 Not Mapped |
| 26 | L26 Not Mapped | L26 Not Mapped |
| 27 | L27 Not Mapped | L27 Not Mapped |
| 28 | L28 Not Mapped | L28 Not Mapped |
| 29 | L29 Not Mapped | L29 Not Mapped |
| 30 | L30 Not Mapped | L30 Not Mapped |
| 31 | L31 Not Mapped | L31 Not Mapped |
| 32 | L32 Not Mapped | L32 Not Mapped |

Note: If the "Setting Group" cell in the "CONFIGURATION" column is set to "Select via Opto", the opto's that are used for changing setting groups are always opto's 1 and 2. This mapping is effectively hardwired and does not therefore need to be mapped within the PSL.



## 1.10 Relay output contact mapping

The default mappings for each of the relay output contacts are as shown in the following table:

| Relay Contact Number | P145 Relay Text | P145 Relay Conditioner | Function |
|---|---|---|---|
| 1 | Output R1 | Straight | Earth fault /Sensitive earth fault started IN>/ISEF> Start |
| 2 | Output R2 | Straight | Overcurrent I> Start |
| 3 | Output R3 | Dwell 100ms | Protection Trip output |
| 4 | Output R4 | Dwell 100ms | General Alarm output |
| 5 | Output R5 | Dwell 100ms | Circuit Breaker Fail Tmr. 1 trip |
| 6 | Output R6 | Straight | Circuit Breaker Control Close |
| 7 | Output R7 | Straight | Circuit Breaker Control Trip |
| 8 | Output R8 | Straight | Any Protection Start output |
| 9 | Output R9 | Straight | Auto-reclose Successful Close indication |
| 10 | Output R10 | Straight | Auto-reclose In Service Indication |
| 11 | Output R11 | Straight | Auto-reclose In Progress Indication |
| 12 | Output R12 | Straight | Auto-reclose Lockout indication |
| 13 | R13 Not Mapped | Not Mapped | Not Mapped |

| Relay Contact Number | P145 Relay Text | P145 Relay Conditioner | Function |
|---|---|---|---|
| 14 | R14 Not Mapped | Not Mapped | R14 Liveline |
| 15 | R15 Not Mapped | Not Mapped | R15 Not Mapped |
| 16 | R16 Not Mapped | Not Mapped | R16 Not Mapped |
| 17 | R17 Not Mapped | Not Mapped | R17 Not Mapped |
| 18 | R18 Not Mapped | Not Mapped | R18 Not Mapped |
| 19 | R19 Not Mapped | Not Mapped | R19 Not Mapped |
| 20 | R20 Not Mapped | Not Mapped | R20 Not Mapped |
| 21 | R21 Not Mapped | Not Mapped | R21 Not Mapped |
| 22 | R22 Not Mapped | Not Mapped | R22 Not Mapped |
| 23 | R23 Not Mapped | Not Mapped | R23 Not Mapped |
| 24 | R24 Not Mapped | Not Mapped | R24 Not Mapped |
| 25 | R25 Not Mapped | Not Mapped | R25 Not Mapped |
| 26 | R26 Not Mapped | Not Mapped | R26 Not Mapped |
| 27 | R27 Not Mapped | Not Mapped | R27 Not Mapped |
| 28 | R28 Not Mapped | Not Mapped | R28 Not Mapped |
| 29 | R29 Not Mapped | Not Mapped | R29 Not Mapped |
| 30 | R30 Not Mapped | Not Mapped | R30 Not Mapped |
| 31 | R31 Not Mapped | Not Mapped | R31 Not Mapped |
| 32 | R32 Not Mapped | Not Mapped | R32 Not Mapped |



Note: It is essential that Relay 3 is used for tripping purposes as this output drives the trip LED on the frontplate. It also feeds into other logic sections that require CB trip information such as the CB fail, auto-reclose, condition monitoring etc.

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.

### 1.11 Programmable LED output mapping

The default mappings for each of the programmable LEDs are as shown in the following table:

| LED Number | LED Input Connection/Text | Latched | P145 LED Function Indication |
|---|---|---|---|
| 1 | LED 1 Red | Yes | E/F Trip Indication |
| 2 | LED 2 Red | Yes | Overcurrent Stage I>1/2 Trip |
| 3 | LED 3 Red | Yes | Overcurrent Stage I>3/4 Trip |
| 4 | LED 4 Red | No | Auto-reclose In Progress |
| 5 | LED 5 Red | No | Auto-reclose Lockout |
| 6 | LED 6 Red | No | Any Start |
| 7 | LED 7 Grn. | No | Circuit Breaker Open |
| 8 | LED 8 Red | No | Circuit Breaker Closed |

| LED Number | LED Input Connection/Text | Latched | P145 LED Function Indication |
|---|---|---|---|
| 9 | FnKey LED1 Red | No | Remote SCADA Comms. CB operation enabled |
| 10 | FnKey LED2 Red/ FnKey LED2 Grn. (Yellow) | No | Circuit Breaker Trip |
| 11 | FnKey LED3 Red/ FnKey LED3 Grn. (Yellow) | No | Circuit Breaker Close |
| 12 | FnKey LED4 Red | No | Sensitive Earth Fault Protection Enable |
| 13 | FnKey LED5 Red | No | Enable Setting Group 2 |
| 14 | FnKey LED6 Red | No | Enable Auto-reclose |
| 15 | FnKey LED7 Red | No | Enable Live Line Mode |
| 16 | FnKey LED8 Red | No | Not Mapped |
| 17 | FnKey LED9 Red/ FnKey LED9 Grn. | No | Reset Alarms/LEDs |
| 18 | FnKey LED10 Red | No | Reset Auto-reclose Lockout |



### 1.12 Fault recorder start mapping

The default mapping for the signal which initiates a fault record is as shown in the following table:

| Initiating Signal | Fault Trigger |
|---|---|
| Output R3 | Initiate fault recording from main protection trip |

### 1.13 PSL DATA column

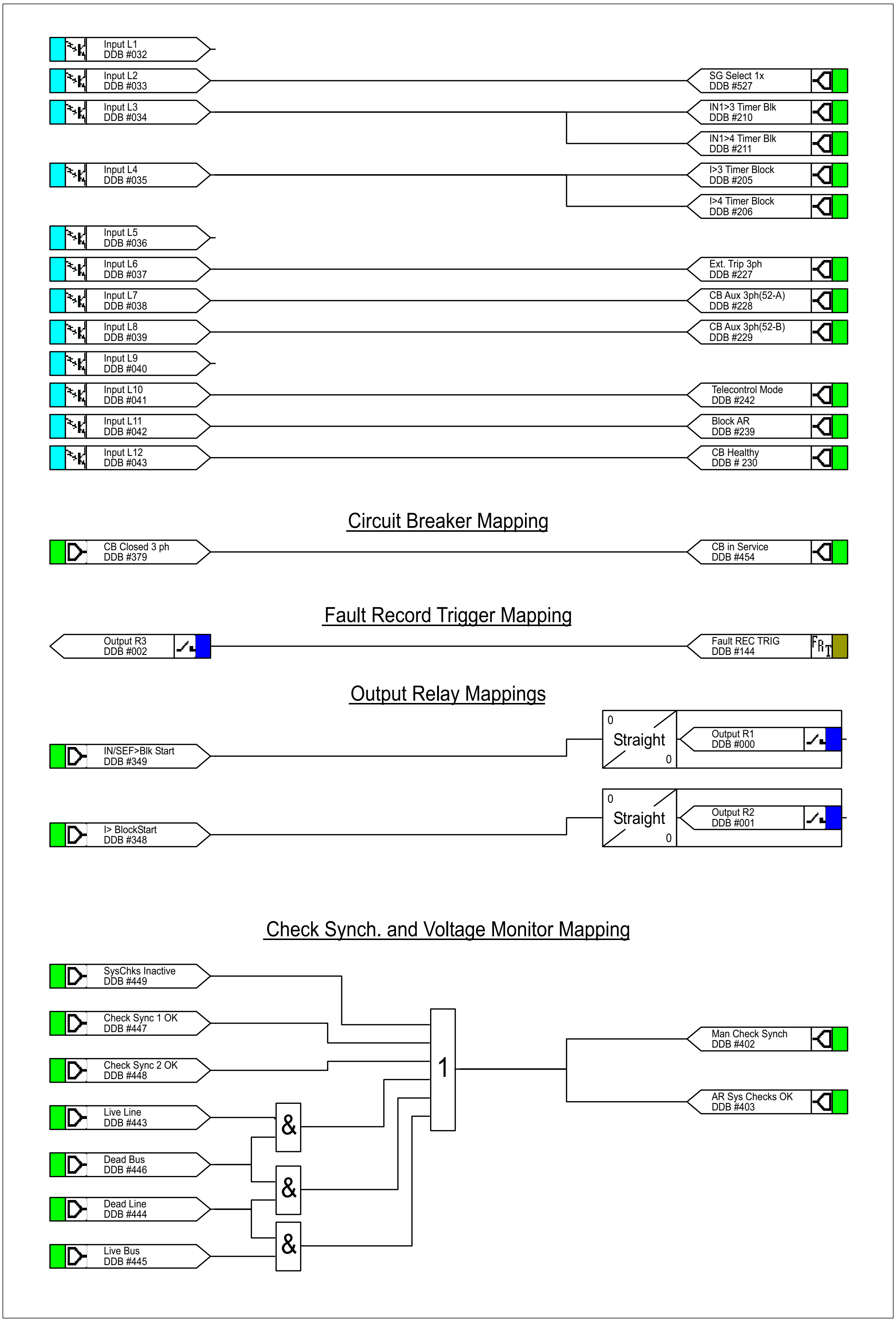
The MiCOM P145 relay contains a PSL DATA column that can be used to track PSL modifications. A total of 12 cells are contained in the PSL DATA column, 3 for each setting group. The function for each cell is shown below:

| | |
|---|---|
| Grp. PSL Ref. | When downloading a PSL to the relay, the user will be prompted to enter which group the PSL is for and a reference identifier. The first 32 characters of the reference ID will be displayed in this cell. The ◁ and ▷ keys can be used to scroll through 32 characters as only 16 can be displayed at any one time. |
| 18 Nov 2002<br>08:59:32.047 | This cell displays the date and time when the PSL was down loaded to the relay. |
| Grp. 1 PSL<br>ID - 2062813232 | This is a unique number for the PSL that has been entered. Any change in the PSL will result in a different number being displayed. |

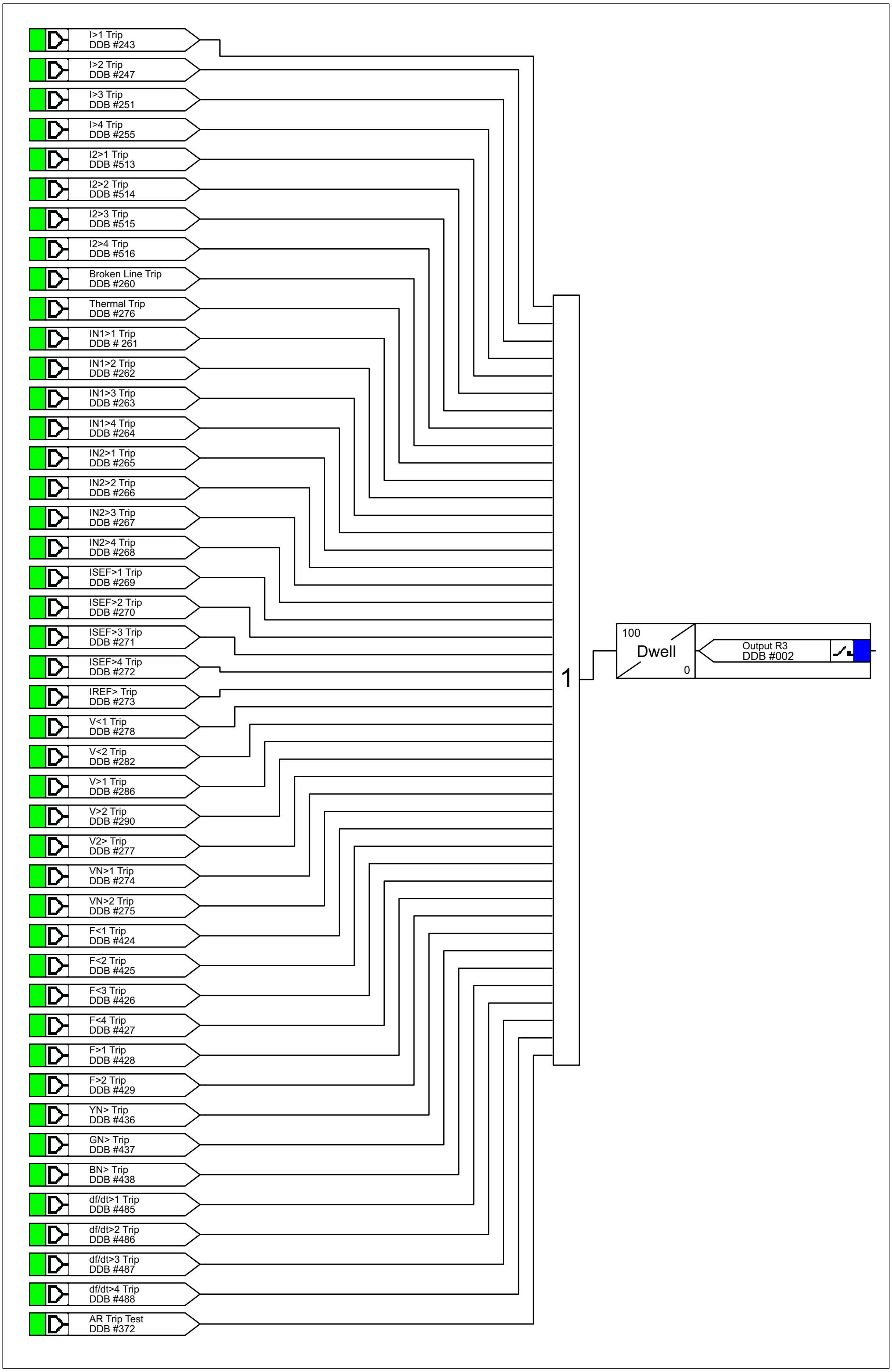
Note: The above cells are repeated for each setting group.

# MiCOM P145 PROGRAMMABLE SCHEME LOGIC

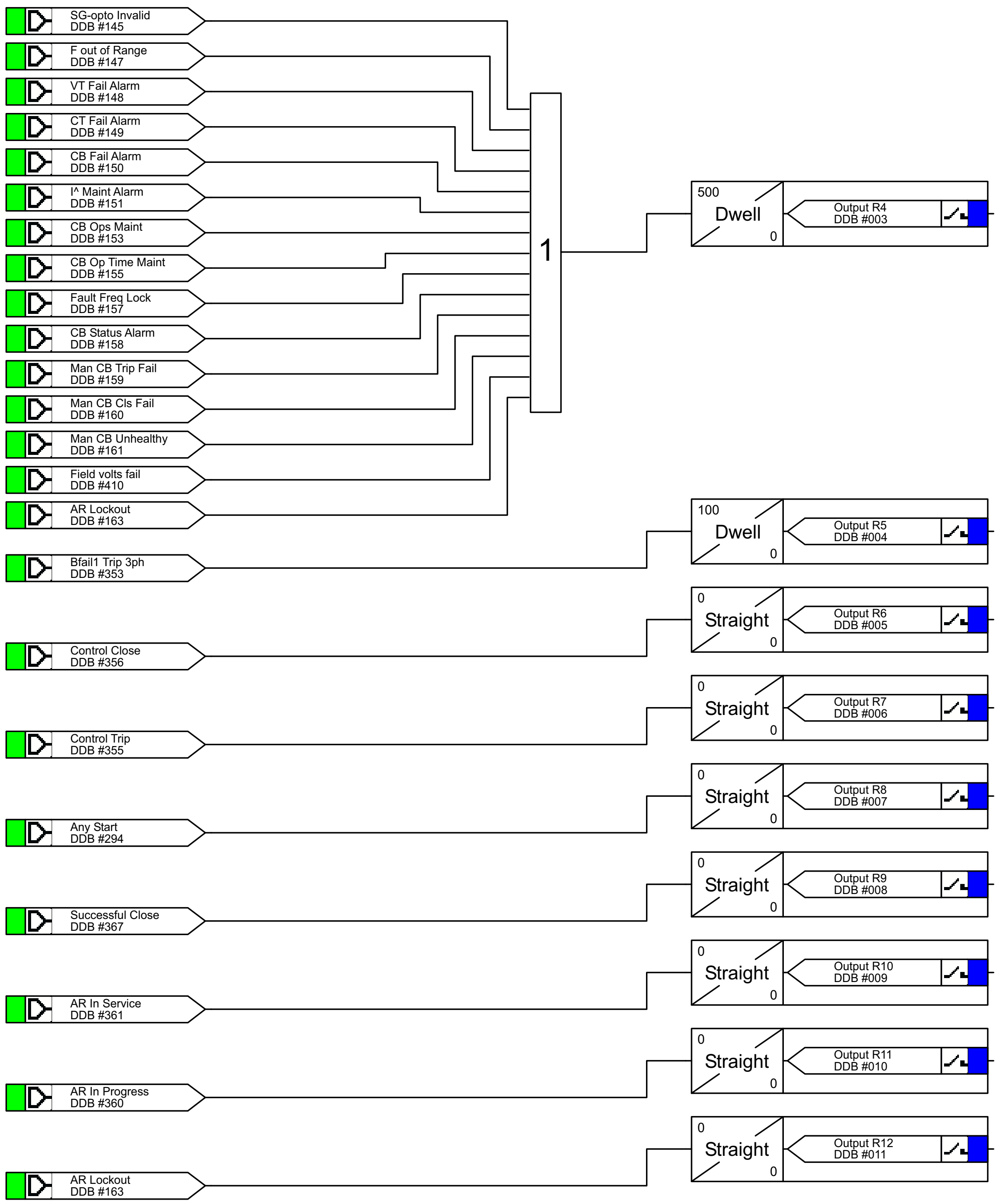
## Opto Input Mappings



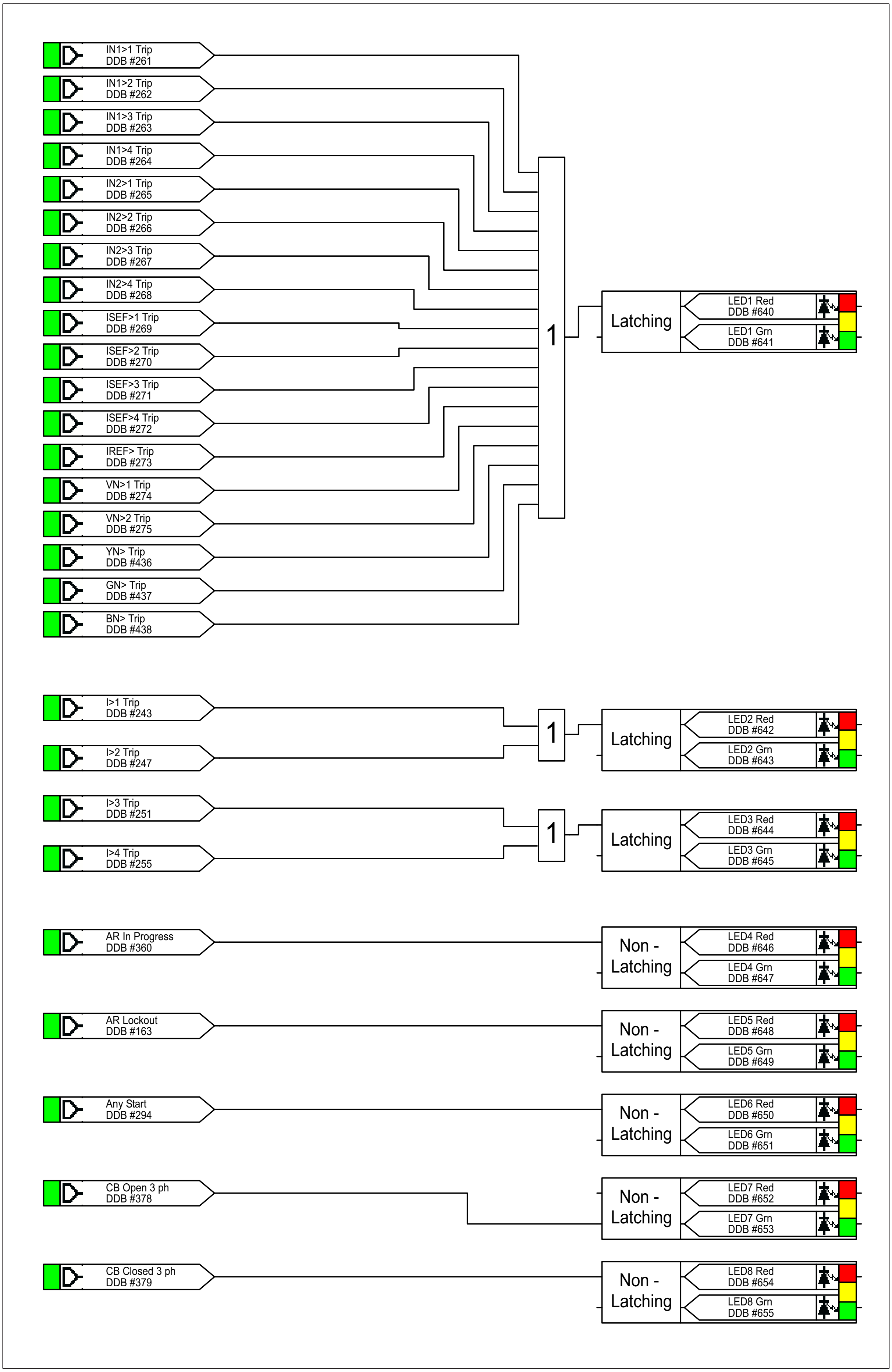
### Output Relay Mappings



## Output Relay Mappings

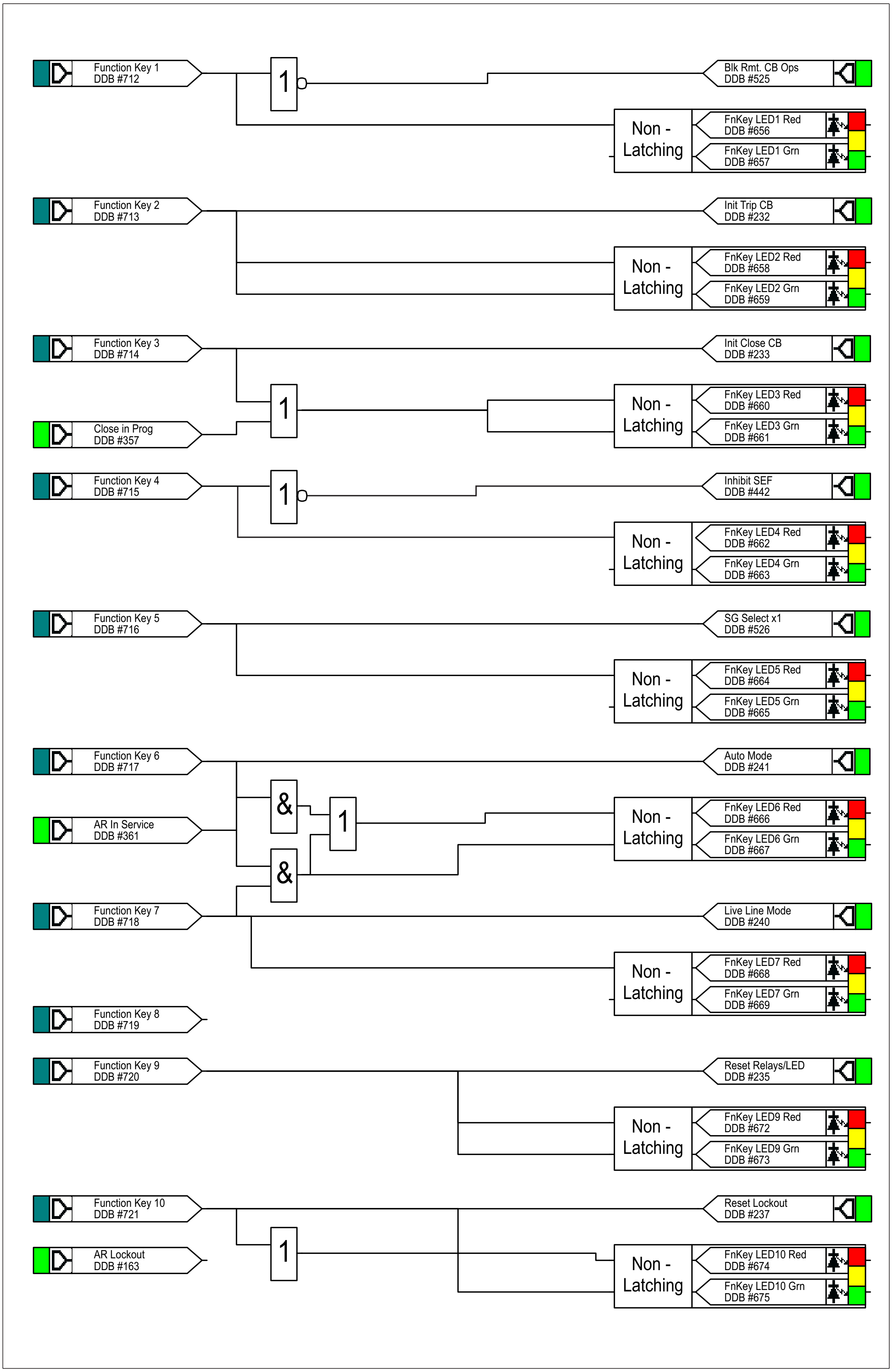


## LED Mappings




PL

**Function Key Mappings**




**PL**

# MEASUREMENTS AND RECORDING

MR

**Date:** **7th July 2005**

**Hardware Suffix:** **J**

**Software Version:** **31**

**Connection Diagrams:** **10P145xx (xx = 01 to 07)**

MR

# CONTENTS

# 1. MEASUREMENTS AND RECORDING

## 1.1 Introduction

The P145 is equipped with integral measurements, event, fault and disturbance recording facilities suitable for analysis of complex system disturbances.

The relay is flexible enough to allow for the programming of these facilities to specific user application requirements and are discussed below.

## 1.2 Event & fault records

The relay records and time tags up to 512 events and stores them in non-volatile (battery backed up) memory. This enables the system operator to establish the sequence of events that occurred within the relay following a particular power system condition, switching sequence etc. When the available space is exhausted, the oldest event is automatically overwritten by the new one.

The real time clock within the relay provides the time tag to each event, to a resolution of 1ms.

The event records are available for viewing either via the frontplate LCD or remotely, via the communications ports (courier and MODBUS versions only).

Local viewing on the LCD is achieved in the menu column entitled "VIEW RECORDS". This column allows viewing of event, fault and maintenance records and is shown in the following table:

| VIEW RECORDS | |
|---|---|
| LCD Reference | Description |
| Select Event | Setting range from 0 to 511. This selects the required event record from the possible 512 that may be stored. A value of 0 corresponds to the latest event and so on. |
| Time & Date | Time & Date Stamp for the event given by the internal Real Time Clock. |
| Event Text | Up to 16 Character description of the Event refer to following sections). |
| Event Value | Up to 32 Bit Binary Flag or integer representative of the Event (refer to following sections). |
| Select Fault | Setting range from 0 to 9. This selects the required fault record from the possible 10 that may be stored. A value of 0 corresponds to the latest fault and so on. |
| | The following cells show all the fault flags, protection starts, protection trips, fault location, measurements etc. associated with the fault, i.e. the complete fault record. |
| Select Maint. | Setting range from 0 to 9. This selects the required maintenance report from the possible 10 that may be stored. A value of 0 corresponds to the latest report and so on. |
| Maint. Text | Up to 16 Character description of the occurrence (refer to following sections). |
| Maint. Type/Main Data | These 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 | Either Yes or No. This serves to reset the trip LED indications provided that the relevant protection element has reset. |

For extraction from a remote source via communications, refer to the SCADA Communications section (P145/EN CT), where the procedure is fully explained.

### 1.2.1 Types of event

An event may be a change of state of a control input or output relay, an alarm condition, setting change etc. The following sections show the various items that constitute an event:

#### 1.2.1.1 Change of state of opto-isolated inputs

If one or more of the opto (logic) inputs has changed state since the last time that the protection algorithm ran, the new status is logged as an event. When this event is selected to be viewed on the LCD, three applicable cells will become visible as shown below:

| |
|---|
| Time & date of event |
| “LOGIC INPUTS #” |
| “Event Value 0101010101010101” |

Where # = 1 or 2 depending upon which group of 32 opto inputs is selected. In the case of P145 relay, however, the value will always be “1” as it is impossible to have more than 32 opto inputs.

The Event Value is a 12, 16, 24 or 32-bit word showing the status of the opto inputs, where the least significant bit (extreme right) corresponds to opto input 1 etc. The same information is present if the event is extracted and viewed via PC.

#### 1.2.1.2 Change of state of one or more output relay contacts

If one or more of the output relay contacts have changed state since the last time that the protection algorithm ran, then the new status is logged as an event. When this event is selected to be viewed on the LCD, three applicable cells will become visible as shown below:

MR

| |
|---|
| Time & date of event |
| “OUTPUT CONTACTS #” |
| “Event Value 010101010101010101010” |

Where # = 1 or 2 depending upon which group of 32 output relays is selected. In the case of P145 relay, however, the value will always be “1” as it is impossible to have more than 32 output relays.

The Event Value is a 12, 16, 24 or 32 bit word showing the status of the output contacts, where the least significant bit (extreme right) corresponds to output contact 1 etc. The same information is present if the event is extracted and viewed via PC.

#### 1.2.1.3 Relay alarm conditions

Any alarm conditions generated by the relays will also be logged as individual events. The following table shows examples of some of the alarm conditions and how they appear in the event list:

| Alarm Condition | Event Text | Event Value |
|---|---|---|
| Battery Fail | Battery Fail ON/OFF | Bit position 0 in 32 bit field |
| Field Voltage Fail | Field Volt Fail ON/OFF | Bit position 1 in 32 bit field |
| Setting Group via Opto Invalid | Setting Grp. Invalid ON/OFF | Bit position 2 in 32 bit field |
| Protection Disabled | Prot’n. Disabled ON/OFF | Bit position 3 in 32 bit field |
| Frequency out of Range | Freq. out of Range ON/OFF | Bit position 4 in 32 bit field |
| VTS Alarm | VT Fail Alarm ON/OFF | Bit position 5 in 32 bit field |
| CB Trip Fail Protection | CB Fail ON/OFF | Bit position 7 in 32 bit field |

The previous table shows the abbreviated description that is given to the various alarm conditions and also a corresponding value between 0 and 31. This value is appended to each alarm event in a similar way as for the input and output events previously described. It is used by the event extraction software, such as MiCOM S1, to identify the alarm and is therefore invisible if the event is viewed on the LCD. Either ON or OFF is shown after the description to signify whether the particular condition has become operated or has reset.

#### 1.2.1.4 Protection element starts and trips

Any operation of protection elements, (either a start or a trip condition) will be logged as an event record, consisting of a text string indicating the operated element and an event value. Again, this value is intended for use by the event extraction software, such as MiCOM S1, rather than for the user, and is therefore invisible when the event is viewed on the LCD.

#### 1.2.1.5 General events

A number of events come under the heading of ‘General Events’ - an example is shown below:

| Nature of Event | Displayed Text in Event Record | Displayed Value |
|---|---|---|
| Level 1 password modified, either from user interface, front or rear port. | PW1 modified UI, F, R or R2 | 0 UI=6, F=11, R=16, R2=38 |

A complete list of the ‘General Events’ is given in the Relay Menu Database (P145/EN MD), which is a separate document, available for downloaded from our website.

#### 1.2.1.6 Fault records

Each time a fault record is generated, an event is also created. The event simply states that a fault record was generated, with a corresponding time stamp.

Note that viewing of the actual fault record is carried out in the "Select Fault’" cell further down the "VIEW RECORDS" column, which is selectable from up to 5 records. These records consist of fault flags, fault location, fault measurements etc. Also note that the time stamp given in the fault record itself will be more accurate than the corresponding stamp given in the event record as the event is logged some time after the actual fault record is generated.

The fault record is triggered from the ‘Fault REC. TRIG.’ signal assigned in the default programmable scheme logic to relay 3, protection trip. Note the fault measurements in the fault record are given at the time of the protection start. Also, the fault recorder does not stop recording until any start or relay 3 (protection trip) resets in order to record all the protection flags during the fault.

It is recommended that the triggering contact (relay 3 for example) be ‘self reset’ and not latching. If a latching contact were chosen the fault record would not be generated until the contact had fully reset.

#### 1.2.1.7 Maintenance reports

Internal failures detected by the self-monitoring circuitry, such as watchdog failure, field voltage failure etc. are logged into a maintenance report. The maintenance report holds up to 10 such ‘events’ and is accessed from the "Select Report" cell at the bottom of the "VIEW RECORDS" column.

Each entry consists of a self explanatory text string and a ‘Type’ and ‘Data’ cell, which are explained in the menu extract at the beginning of this section.

Each time a Maintenance Report is generated, an event is also created. The event simply states that a report was generated, with a corresponding time stamp.

1.2.1.8 Setting changes

Changes to any setting within 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 4

Note: Control/Support settings are communications, measurement, CT/VT ratio settings etc, which are not duplicated within the four 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’.

1.2.2 Resetting of event/fault records

If it is required to delete either the event, fault or maintenance reports, this may be done from within the "RECORD CONTROL" column.

1.2.3 Viewing event records via MiCOM S1 support software

When the event records are extracted and viewed on a PC they look slightly different than when viewed on the LCD. The following shows an example of how various events appear when displayed using MiCOM S1:



- Monday 03 January 2005 15:32:49 GMT I>1 Start ON

MiCOM : MiCOM P145

Model Number: P145318B4M0310J

Address: 001 Column: 00 Row: 23

Event Type: Protection operation

- Monday 03 January 2005 15:32:52 GMT Fault Recorded

MiCOM : MiCOM P145

Model Number: P145318B4M0310J

Address: 001 Column: 01 Row: 00

Event Type: Fault record

- Monday 03 January 2005 15:33:11 GMT Logic Inputs

MiCOM : MiCOM P145

Model Number: P145318B4M0310J

Address: 001 Column: 00 Row: 20

Event Type: Logic input changed state

- Monday 03 January 2005 15:34:54 GMT Output Contacts

MiCOM : MiCOM P145

Model Number: P145318B4M0310J

Address: 001 Column: 00 Row: 21

Event Type: Relay output changed state

- Monday 03 January 2005 15:35:55 GMT A/R Lockout ON

  MiCOM : MiCOM P145

  Model Number: P145318B4M0310J

  Address: 001 Column: 00 Row: 22

  Event Type: Alarm event

- Tuesday 04 January 2005 20:18:22.988 GMT V<1 Trip ON

  MiCOM : MiCOM P145

  Model Number: P145318B4M0310J

  Address: 001 Column: 0F Row: 28

  Event Type: Setting event

  As can be seen, the first line gives the description and time stamp for the event, whilst the additional information that is displayed below may be collapsed via the +/– symbol.

For further information regarding events and their specific meaning, refer to relay menu database document (P145/EN MD). This is a standalone document not included in this manual.

### 1.2.4 Event filtering

It is possible to disable the reporting of events 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 |
|---|---|---|
| Clear Event | 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 Maint. | No | No or Yes |
| Selecting "Yes" will cause the existing maintenance records to be erased from the relay. | | |
| Alarm Event | Enabled | Enabled or Disabled |
| Disabling this setting means that all the occurrences that produce an alarm will result in no event being generated. | | |
| Relay O/P Event | Enabled | Enabled or Disabled |
| Disabling this setting means that no event will be generated for any change in logic input state. | | |
| Opto Input Event | Enabled | Enabled or Disabled |
| Disabling this setting means that no event will be generated for any change in logic input state. | | |
| General Event | Enabled | Enabled or Disabled |
| Disabling this setting means that no General Events will be generated | | |
| Fault Rec. Event | Enabled | Enabled or Disabled |
| Disabling this setting means that no event will be generated for any fault that produces a fault record | | |

MR

| Menu Text | Default Setting | Available Settings |
|---|---|---|
| Maint. Rec. Event | Enabled | Enabled or Disabled |
| Disabling this setting means that no event will be generated for any occurrence that produces a maintenance record. | | |
| Protection Event | Enabled | Enabled or Disabled |
| Disabling this setting means that any operation of protection elements will not be logged as an event. | | |
| DDB 31 - 0 | 11111111111111111111111111111111 | |
| Displays the status of DDB signals 0 – 31. | | |
| DDB 1022 - 992 | 11111111111111111111111111111111 | |
| Displays the status of DDB signals 1022 – 992. | | |

Note that some occurrences will result in more than one type of event, e.g. 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.

For further information regarding events and their specific meaning, refer to relay menu database document (P145/EN MD).

### 1.3 Disturbance recorder

The integral disturbance recorder has an area of memory specifically set aside for record storage. The number of records that may be stored by the relay is dependent upon the selected recording duration. The relay can typically store a minimum of 50 records, each of 1.5 seconds duration. VDEW relays, however, have the same total record length but the VDEW protocol dictates that only 8 records (of 3 seconds duration) can be extracted via the rear port. Disturbance records continue to be recorded until the available memory is exhausted, at which time the oldest record(s) are overwritten to make space for the newest one.

MR

The recorder stores actual samples that are taken at a rate of 24 samples per cycle.

Each disturbance record consists of eight analog data channels and thirty-two digital data channels. The relevant CT and VT ratios for the analog channels are also extracted to enable scaling to primary quantities. Note that if a CT ratio is set less than unity, the relay will choose a scaling factor of zero for the appropriate channel.

The "DISTURBANCE RECORDER" menu column is shown in the following table:

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| DISTURB. RECORDER | | | | |
| Duration | 1.5s | 0.1s | 10.5s | 0.01s |
| This sets the overall recording time. | | | | |
| Trigger Position | 33.3% | 0 | 100% | 0.1% |
| This sets the trigger point as a percentage of the duration. For example, the default settings show that the overall recording time is set to 1.5s with the trigger point being at 33.3% of this, giving 0.5s pre-fault and 1s post fault recording times. | | | | |
| 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. | | | | |

| Menu Text | Default Setting | Setting Range | | Step Size |
|---|---|---|---|---|
| | | Min. | Max. | |
| Analog. Channel 1 | VA | VA, VB, VC, VCHECKSYNC., IA, IB, IC, IN, IN Sensitive | | |
| Selects any available analog input to be assigned to this channel. | | | | |
| Analog. Channel 2 | VB | As above | | |
| Analog. Channel 3 | VC | 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 Sensitive | As above | | |
| Digital Inputs 1 to 32 | Relays 1 to 12 and Opto's 1 to 12 | Any of 12 O/P Contacts or Any of 12 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. | | | | |
| Inputs 1 to 32 Trigger | No Trigger except Dedicated Trip Relay O/P's which are set to Trigger L/H | No Trigger, Trigger L/H, Trigger H/L | | |
| 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. | | | | |

MR

The pre and post fault recording times are set by a combination of the "Duration" and "Trigger Position" cells. "Duration" sets the overall recording time and the "Trigger Position" sets the trigger point as a percentage of the duration. For example, the default settings show that the overall recording time is set to 1.5s with the trigger point being at 33.3% of this, giving 0.5s pre-fault and 1s post fault recording times.

If a further trigger occurs whilst a recording is taking place, the recorder will ignore the trigger if the "Trigger Mode" has been set to "Single". However, if this has been set to "Extended", the post trigger timer will be reset to zero, thereby extending the recording time.

As can be seen from the menu, each of the analog channels is selectable from the available analog inputs to the relay. 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. The complete list of these signals may be found by viewing the available settings in the relay menu or via a setting file in MiCOM S1. 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, via the "Input Trigger" cell. The default trigger settings are that any dedicated trip output contacts (e.g. relay 3) will trigger the recorder.

It is not possible to view the disturbance records locally via the LCD; they must be extracted using suitable software such as MiCOM S1. This process is fully explained in the SCADA Communications section (P145/EN SC).

## 1.4 Measurements

The relay produces a variety of both directly measured and calculated power system quantities. These measurement values are updated on a per second basis and can be viewed in the “Measurements” columns (up to three) of the relay or via MiCOM S1 Measurement viewer. The P145 relay is able to measure and display the following quantities as summarized.

– Phase Voltages and Currents
– Phase to Phase Voltage and Currents
– Sequence Voltages and Currents
– Slip Frequency
– Power and Energy Quantities
– Rms. Voltages and Currents
– Peak, Fixed and Rolling Demand Values

There are also measured values from the protection functions, which are also displayed under the measurement columns of the menu; these are described in the section on the relevant protection function.

### 1.4.1 Measured voltages and currents

The relay produces both phase to ground and phase to phase voltage and current values. They are produced directly from the DFT (Discrete Fourier Transform) used by the relay protection functions and present both magnitude and phase angle measurement.

### 1.4.2 Sequence voltages and currents

Sequence quantities are produced by the relay from the measured Fourier values; these are displayed as magnitude and phase angle values.

### 1.4.3 Slip frequency

The relay produces a slip frequency measurement by measuring the rate of change of phase angle, between the bus and line voltages, over a one-cycle period. The slip frequency measurement assumes the bus voltage to be the reference phasor.



### 1.4.4 Power and energy quantities

Using the measured voltages and currents the relay calculates the apparent, real and reactive power quantities. These are produced on a phase by phase basis together with three-phase values based on the sum of the three individual phase values. The signing of the real and reactive power measurements can be controlled using the measurement mode setting. The four options are defined in the table below:

| Measurement Mode | Parameter | Signing |
|---|---|---|
| 0 (Default) | Export Power | + |
| | Import Power | – |
| | Lagging Vars | + |
| | Leading VArs | – |
| 1 | Export Power | – |
| | Import Power | + |
| | Lagging Vars | + |
| | Leading VArs | – |
| 2 | Export Power | + |
| | Import Power | – |
| | Lagging Vars | – |
| | Leading VArs | + |

| Measurement Mode | Parameter | Signing |
|---|---|---|
| 3 | Export Power | – |
| | Import Power | + |
| | Lagging Vars | – |
| | Leading VArs | + |

In addition to the measured power quantities the relay calculates the power factor on a phase by phase basis in addition to a three-phase power factor.

These power values are also used to increment the total real and reactive energy measurements. Separate energy measurements are maintained for the total exported and imported energy. The energy measurements are incremented up to maximum values of 1000GWhr or 1000GVARhr at which point they will reset to zero, it is also possible to reset these values using the menu or remote interfaces using the reset demand cell.

### 1.4.5 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.

### 1.4.6 Demand values

The relay produces fixed, rolling and peak demand values, using the reset demand menu cell it is possible to reset these quantities via the user interface or the remote communications.

Fixed demand values

The fixed demand value is the average value of a quantity over the specified interval; values are produced for each phase current and for three phase real and reactive power. The fixed demand values displayed by the relay are those for the previous interval, the values are updated at the end of the fixed demand period.



Rolling demand values

The rolling demand values are similar to the fixed demand values, the difference being that a sliding window is used. The rolling demand window consists of a number of smaller sub-periods. The resolution of the sliding window is the sub-period length, with the displayed values being updated at the end of each of the sub-periods.

Peak demand values

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.

### 1.4.7 Settings

The following settings under the heading measurement set-up can be used to configure the relay measurement function.

| Menu Text | Default Settings | Available settings |
|---|---|---|
| MEASUREMENT SETUP | | |
| Default Display | Description | Description/Plant Reference/ Frequency/Access Level/3Ph + N Current/3Ph Voltage/Power/Date and Time |
| This setting can be used to select the default display from a range of options, note that 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. | | |

| Menu Text | Default Settings | Available settings |
|---|---|---|
| MEASUREMENT SETUP | | |
| Local Values | Primary | Primary/Secondary |
| This setting controls whether measured values via 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 via 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. | | |
| Measurement Mode | 0 | 0 to 3 step 1 |
| This setting is used to control the signing of the real and reactive power quantities; the signing convention used is defined in section 1.4.4. | | |
| Fix Dem. Period | 30 minutes | 1 to 99 minutes step 1 minute |
| This setting defines the length of the fixed demand window. | | |
| Roll Sub Period | 30 minutes | 1 to 99 minutes step 1 minute |
| These two settings are used to set the length of the window used for the calculation of rolling demand quantities. | | |
| Num. Sub Periods | 1 | 1 to 15 step 1 |
| This setting is used to set the resolution of the rolling sub window. | | |
| Distance Unit* | km | km/miles |
| This setting is used to select the unit of distance for fault location purposes, note that the length of the line is preserved when converting from km to miles and vice versa. | | |
| Fault Location* | Distance | Distance/Ohms/% of Line |
| The calculated fault location can be displayed using one of several options selected using this setting | | |

MR

### 1.4.8 Measurement display quantities

There are three “Measurement” columns available in the relay for viewing of measurement quantities. These can also be viewed with MiCOM S1 (see MiCOM Px40 – Monitoring section of the MiCOM S1 User Manual) and are shown below:

| MEASUREMENTS 1 | | MEASUREMENTS 2 | | MEASUREMENTS 3 | |
|---|---|---|---|---|---|
| IA Magnitude | 0 A | A Phase Watts | 0 W | Highest Phase I | 0 A |
| IA Phase Angle | 0 deg. | B Phase Watts | 0 W | Thermal State | 0% |
| IB Magnitude | 0 A | C Phase Watts | 0 W | Reset Thermal | No |
| IB Phase Angle | 0 deg. | A Phase VArs | 0 Var | IREF Diff. | 1.000 A |
| IC Magnitude | 0 A | B Phase VArs | 0 Var | IREF Bias | 1.000 A |
| IC Phase Angle | 0 deg. | C Phase VArs | 0 Var | Admittance | 0 S |
| IN Measured Mag. | 0 A | A Phase VA | 0 VA | Conductance | 0 S |
| IN Measured Ang. | 0 deg. | B Phase VA | 0 VA | Susceptance | 0 S |

| MEASUREMENTS 1 | | MEASUREMENTS 2 | | MEASUREMENTS 3 | |
|---|---|---|---|---|---|
| IN Derived Mag. | 0 A | C Phase VA | 0 VA | Admittance | 0 S |
| IN Derived Angle | 0 deg. | 3 Phase Watts | 0 W | Conductance | 0 S |
| ISEF Magnitude | 0 A | 3 Phase VArs | 0 VAr | Susceptance | 0 S |
| ISEF Angle | 0 deg. | 3 Phase VA | 0 VA | I2/I1 Ratio | 0 |
| I1 Magnitude | 0 A | 3Ph Power Factor | 0 | SEF Power | 0 W |
| I2 Magnitude | 0 A | APh Power Factor | 0 | df/dt | |
| I0 Magnitude | 0 A | BPh Power Factor | 0 | | |
| IA RMS | 0 A | CPh Power Factor | 0 | | |
| IB RMS | 0 A | 3Ph WHours Fwd | 0 Wh | | |
| IC RMS | 0 A | 3Ph WHours Rev | 0 Wh | | |
| VAB Magnitude | 0 V | 3Ph VArHours Fwd | 0 VArh | | |
| VAB Phase Angle | 0 deg. | 3Ph VArHours Rev | 0 VArh | | |
| VBC Magnitude | 0 V | 3Ph W Fix Demand | 0 W | | |
| VBC Phase Angle | 0 deg. | 3Ph VArs Fix Dem. | 0 VAr | | |
| VCA Magnitude | 0 V | IA Fixed Demand | 0 A | | |
| VCA Phase Angle | 0 deg. | IB Fixed Demand | 0 A | | |
| VAN Magnitude | 0 V | IC Fixed Demand | 0 A | | |
| VAN Phase Angle | 0 deg. | 3 Ph W Roll Dem. | 0 W | | |
| VBN Magnitude | 0 V | 3Ph VArs Roll Dem. | 0 VAr | | |
| VBN Phase Angle | 0 deg. | IA Roll Demand | 0 A | | |
| VCN Magnitude | 0 V | IB Roll Demand | 0 A | | |
| VCN Phase Angle | 0 deg. | IC Roll Demand | 0 A | | |
| VN Derived Mag. | 0 V | 3Ph W Peak Dem. | 0 W | | |
| VN Derived Ang. | 0 deg. | 3Ph VAr Peak Dem. | 0 VAr | | |
| V1 Magnitude | 0 V | IA Peak Demand | 0 A | | |
| V2 Magnitude | 0 V | IB Peak Demand | 0 A | | |
| V0 Magnitude | 0 V | IC Peak Demand | 0 A | | |
| VAN RMS | 0 V | Reset Demand | No | | |
| VBN RMS | 0 V | | | | |
| VCN RMS | 0 V | | | | |
| Frequency | | | | | |

MR

| MEASUREMENTS 1 | | MEASUREMENTS 2 | MEASUREMENTS 3 |
|---|---|---|---|
| C/S Voltage Mag. | 0 V | | |
| C/S Voltage Ang. | 0 deg. | | |
| C/S Bus-Line Ang. | 0 deg. | | |
| Slip Frequency | | | |
| I1 Magnitude | 0 A | | |
| I1 Phase Angle | 0 deg. | | |
| I2 Magnitude | 0 A | | |
| I2 Phase Angle | 0 deg. | | |
| I0 Magnitude | 0 A | | |
| I0 Phase Angle | 0 deg. | | |
| V1 Magnitude | 0 V | | |
| V1 Phase Angle | 0 deg. | | |
| V2 Magnitude | 0 V | | |
| V2 Phase Angle | 0 deg. | | |
| V0 Magnitude | 0 V | | |
| V0 Phase Angle | 0 deg. | | |

# FIRMWARE DESIGN

FD

| | |
|---|---|
| **Date:** | **7th July 2005** |
| **Hardware Suffix:** | **J** |
| **Software Version:** | **31** |
| **Connection Diagrams:** | **10P145xx (xx = 01 to 07)** |

# CONTENTS



FD

# FIGURES

# 1. FIRMWARE DESIGN

## 1.1 Relay system overview

### 1.1.1 Hardware overview

The relay hardware is based on a modular design whereby the relay is made up of an assemblage of several modules that are drawn from a standard range. Some modules are essential while others are optional depending on the user's requirements.

The different modules that can be present in the relay are as follows:

#### 1.1.1.1 Processor board

The processor board performs all calculations for the relay and controls the operation of all other modules within the relay. The processor board also contains and controls the user interfaces (LCD, LEDs, keypad, function keys and communication interfaces).

#### 1.1.1.2 Input module

The input module converts the information contained in the analog and digital input signals into a format suitable for processing by the processor board. The standard input module consists of two boards; a transformer board to provide electrical isolation and a main input board which provides analog to digital conversion and the isolated digital inputs.

#### 1.1.1.3 Power supply module

The power supply module provides a power supply to all of the other modules in the relay, at three different voltage levels. The power supply board also provides the EIA(RS)485 electrical connection for the rear communication port. On a second board the power supply module contains the relays that provide the output contacts.

The power supply module also provides a 48V external field supply output to drive the opto isolated digital inputs (or the substation battery may be used to drive the optos).



#### 1.1.1.4 IRIG-B board

This board, which is optional, can be used where an IRIG-B signal is available to provide an accurate time reference for the relay. There is also an option on this board to specify a fiber optic rear communication port, for use with Courier, MODBUS, DNP3.0 and IEC60870-5-103 communication.

#### 1.1.1.5 Second rear comms. board

The optional second rear port is designed typically for dial-up modem access by protection engineers/operators, when the main port is reserved for SCADA traffic. Communication is via one of three physical links; K-Bus, EIA(RS)485 or EIA(RS)232. The port supports full local or remote protection and control access by MiCOM S1 software. The second rear port is also available with an on board IRIG-B input.

#### 1.1.1.6 Ethernet board

This is a mandatory board for UCA2.0 enabled relays. It provides network connectivity through either copper or fiber media at rates of 10Mb/s or 100Mb/s. This board, the IRIG-B board and second rear comms. board are mutually exclusive as they both utilize slot A within the relay case.

All modules are connected by a parallel data and address bus that allows the processor board to send and receive information to and from the other modules as required. There is also a separate serial data bus for conveying sample data from the input module to the processor. Figure 1 shows the modules of the relay and the flow of information between them.

### 1.1.2 Software overview

The software for the relay can be conceptually split into four elements; the real-time operating system, the system services software, the platform software and the protection and control software. These four elements are not distinguishable to the user, and are all processed by the same processor board. The distinction between the four parts of the software is made purely for the purpose of explanation here:

#### 1.1.2.1 Real-time operating system

The real time operating system is used to provide a framework for the different parts of the relay's software to operate within. To this end the software is split into tasks.

The real-time operating system is responsible for scheduling the processing of these tasks such that they are carried out in the time available and in the desired order of priority. The operating system is also responsible for the exchange of information between tasks, in the form of messages.

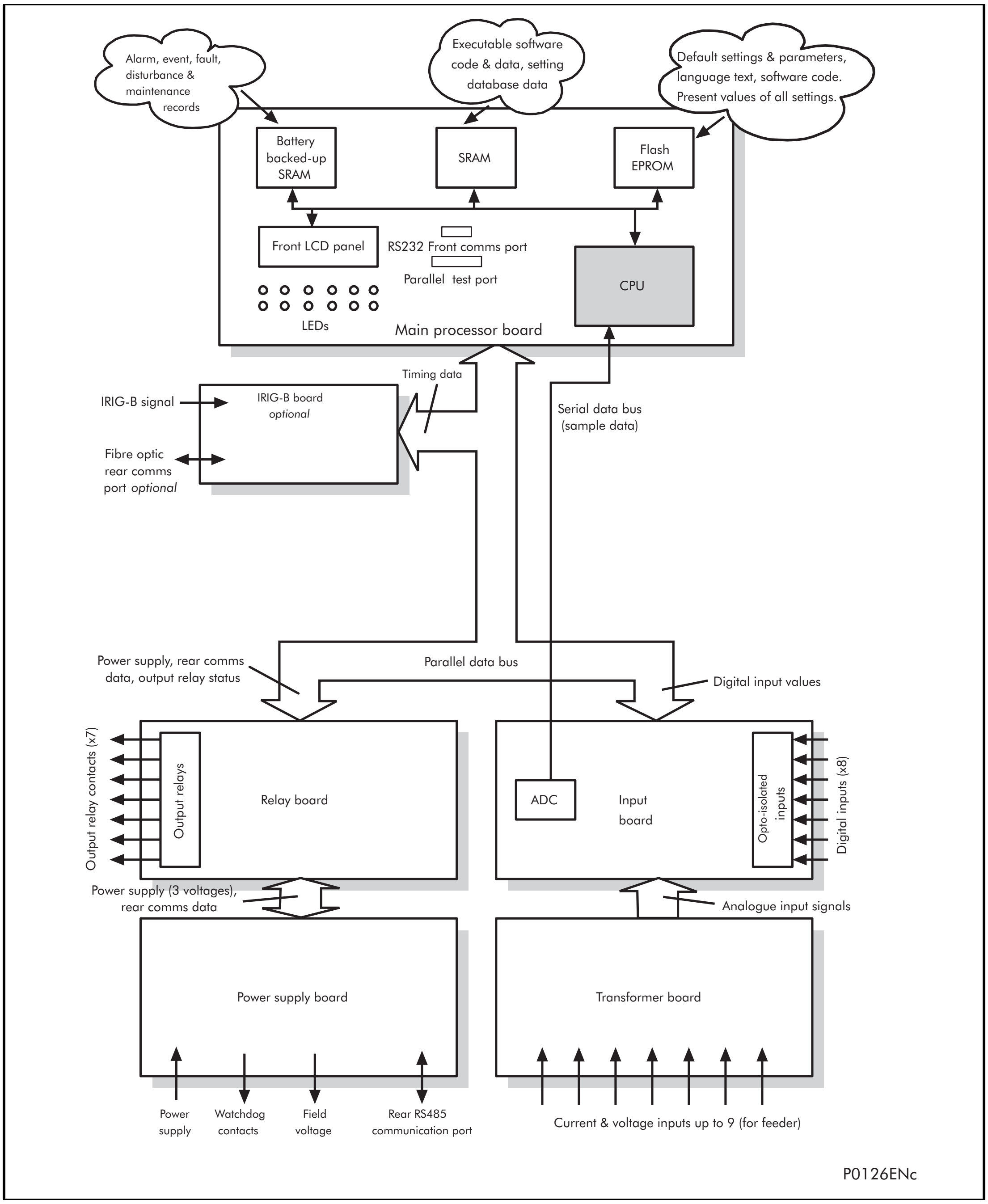



**Figure 1: Relay modules and information flow**

FD

#### 1.1.2.2 System services software

The system services software provides the low-level control of the relay hardware. For example, the system services software controls the boot of the relay's software from the non-volatile flash EPROM memory at power-on, and provides driver software for the user interface via the LCD and keypad, and via the serial communication ports. The system services software provides an interface layer between the control of the relay's hardware and the rest of the relay software.

#### 1.1.2.3 Platform software

The platform software deals with the management of the relay settings, the user interfaces and logging of event, alarm, fault and maintenance records. All of the relay settings are stored in a database within the relay that provides direct compatibility with Courier communications. For all other interfaces (i.e. the front panel keypad and LCD interface, MODBUS, IEC60870-5-103, DNP3.0 and UCA2.0) the platform software converts the information from the database into the format required. The platform software notifies the protection & control software of all settings changes and logs data as specified by the protection & control software.

#### 1.1.2.4 Protection & control software

The protection and control software performs the calculations for all of the protection algorithms of the relay. This includes digital signal processing such as Fourier filtering and ancillary tasks such as the measurements. The protection & control software interfaces with the platform software for settings changes and logging of records, and with the system services software for acquisition of sample data and access to output relays and digital opto-isolated inputs.

#### 1.1.2.5 Disturbance recorder

The analog values and logic signals are routed from the protection and control software to the disturbance recorder software. The platform software interfaces to the disturbance recorder to allow extraction of the stored records.



## 1.2 Hardware modules

The relay is based on a modular hardware design where each module performs a separate function within the relay operation. This section describes the functional operation of the various hardware modules.

### 1.2.1 Processor board

The relay is based around a TMS320VC33 floating point, 32-bit digital signal processor (DSP) operating at a clock frequency of 75MHz. This processor performs all of the calculations for the relay, including the protection functions, control of the data communication and user interfaces including the operation of the LCD, keypad and LEDs.

The processor board is located directly behind the relay's front panel which allows the LCD, function keys and LEDs to be mounted on the processor board along with the front panel communication ports. These comprise the 9-pin D-connector for EIA(RS)232 serial communications (e.g. using MiCOM S1 and Courier communications) and the 25-pin D-connector relay test port for parallel communication. All serial communication is handled using a field programmable gate array (FPGA).

The memory provided on the main processor board is split into two categories, volatile and non-volatile; the volatile memory is fast access SRAM which is used for the storage and execution of the processor software, and data storage as required during the processor's calculations. The non-volatile memory is sub-divided into 2 groups; 4MB of flash memory for non-volatile storage of software code, present setting values, text, configuration data, latched data signals (from control inputs, function keys, LEDs, relay outputs) and 4MB of battery backed-up SRAM for the storage of disturbance, event, fault and maintenance record data.

### 1.2.2 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.

### 1.2.3 Input module

The input module provides the interface between the relay processor board and the analog and digital signals coming into the relay. The input module consists of two PCBs; the main input board and a transformer board. The relay provides an additional voltage input for the check sync. function.

#### 1.2.3.1 Transformer board

The transformer board holds up to four voltage transformers (VTs) and up to five current transformers (CTs). The current inputs will accept either 1A or 5A nominal current (menu and wiring options) and the voltage inputs can be specified for either 110V or 440V nominal voltage (order option). The transformers are used both to step-down the currents and voltages to levels appropriate to the relay’s electronic circuitry and to provide effective isolation between the relay and the power system. The connection arrangements of both the current and voltage transformer secondaries provide differential input signals to the main input board to reduce noise.

#### 1.2.3.2 Input board

The main input board is shown as a block diagram in Figure 2. It provides the circuitry for the digital input signals and the analog-to-digital conversion for the analog signals. Hence it takes the differential analog signals from the CTs and VTs on the transformer board(s), converts these to digital samples and transmits the samples to the processor board via the serial data bus. On the input board the analog signals are passed through an anti-alias filter before being multiplexed into a single analog to digital converter chip. The A - D converter provides 16-bit resolution and a serial data stream output. The digital input signals are opto isolated on this board to prevent excessive voltages on these inputs causing damage to the relay's internal circuitry.

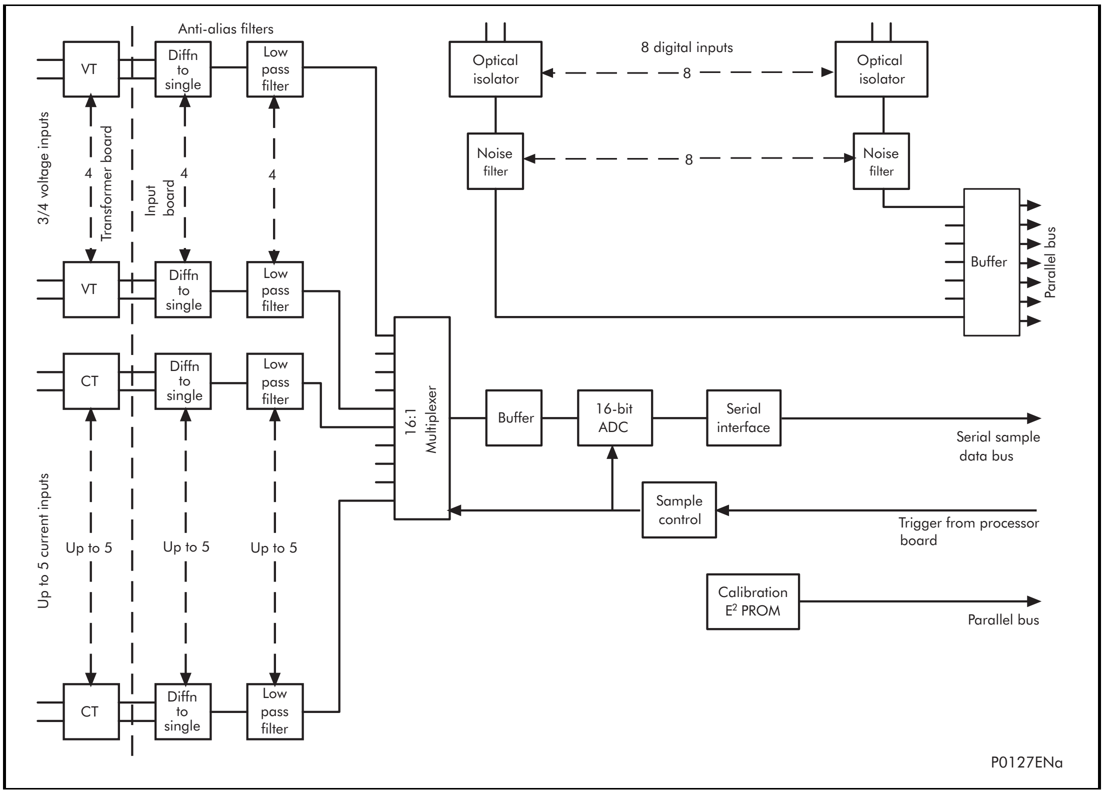



**Figure 2: Main input board**

The signal multiplexing arrangement provides for 16 analog channels to be sampled. The P145 relay provides 5 current inputs and 4 voltage inputs. 3 spare channels are used to sample 3 different reference voltages for the purpose of continually checking the operation of the multiplexer and the accuracy of the A - D converter. The sample rate is maintained at 24 samples per cycle of the power waveform by a logic control circuit that is driven by the frequency tracking function on the main processor board. The calibration $E^2$PROM holds the calibration coefficients that are used by the processor board to correct for any amplitude or phase errors introduced by the transformers and analog circuitry.

The other function of the input board is to read the state of the signals present on the digital inputs and present this to the parallel data bus for processing. The input board holds 8 optical isolators for the connection of up to eight digital input signals. The opto-isolators are used with the digital signals for the same reason as the transformers with the analog signals; to isolate the relay's electronics from the power system environment. The input board provides some hardware filtering of the digital signals to remove unwanted noise before buffering the signals for reading on the parallel data bus.

FD

### 1.2.3.3 Universal opto isolated logic inputs

The P145 relay is fitted with universal opto isolated logic inputs that can be programmed for the nominal battery voltage of the circuit of which they are a part. The inputs can be programmed with a pick-up/drop-off characteristic selectable as the standard 60% - 80% value or an optional characteristic of 50% - 70%. This implies, that they nominally provide a Logic 1 or On value for Voltages ≥80% or 70% of the set lower nominal voltage and a Logic 0 or Off value for the voltages ≤60% or 50% of the set higher nominal voltage. This lower value eliminates fleeting pickups that may occur during a battery earth fault, when stray capacitance may present up to 50% of battery voltage across an input. Each input also has a selectable filter of ½ cycle which renders the input immune to induced noise on the wiring; although this method is secure it can be slow, particularly for intertripping and back-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. The first method is to use double pole switching on the input, the second is to use screened twisted cable on the input circuit.

In the Opto Config. menu the nominal battery voltage can be selected 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.

Depending on the model, the P145 can have up to three opto-input cards that will increase the total number of opto inputs to 32.

| 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 | | |
| Opto Input 1 | 24-27 | 24 - 27, 30 - 34, 48 - 54, 110 - 125, 220 - 250 | | |
| Opto Input 2-32 | 24-27 | 24 - 27, 30 - 34, 48 - 54, 110 - 125, 220 - 250 | | |
| Opto Filter Cntrl. | 111111111111 | | | |
| Characteristic | Standard 60% - 80% | Standard 60% - 80%, 50% - 70% | | |

Each opto input also has a pre-set filter of ½ cycle which renders the input immune to induced noise on the wiring; although this method is secure it can be slow, particularly for intertripping.

For the P145 feeder protection relay, the protection task is executed twice per cycle, i.e. after every 12 samples for the sample rate of 24 samples per power cycle used by the relay. Therefore, the time taken to register a change in the state of an opto input can vary between a half to one cycle. The time to register the change of state will depend on if the opto input changes state at the start or end of a protection task cycle with the additional half cycle filtering time.



### 1.2.4 Power supply module (including output relays)

The power supply module contains two PCBs, one for the power supply unit itself and the other for the output relays. The power supply board also contains the input and output hardware for the rear communication port which provides an EIA(RS)485 communication interface.

#### 1.2.4.1 Power supply board (including EIA(RS)485 communication interface)

One of three different configurations of the power supply board can be fitted to the relay. This will be specified at the time of order and depends on the nature of the supply voltage that will be connected to the relay. The three options are shown in table 1 below:

| Nominal dc Range | Nominal ac Range |
|---|---|
| 24/54 V | DC only |
| 48/125 V | 30/100 Vrms |
| 110/250 V | 100/240 Vrms |

Table 1: Power supply options

The output from all versions of the power supply module are used to provide isolated power supply rails to all of the other modules within the relay. Three voltage levels are used within the relay, 5.1V for all of the digital circuits, ±16V for the analog electronics, e.g. on the input board, and 22V for driving the output relay coils. All power supply voltages including the 0V earth line are distributed around the relay via the 64-way ribbon cable. The power supply board provides one further voltage level that is the field voltage of 48V. This is brought out to terminals on the back of the relay so that it can be used to drive the optically isolated digital inputs.

The two other functions provided by the power supply board are the EIA(RS)485 communications interface and the watchdog contacts for the relay. The EIA(RS)485 interface is used with the relay's rear communication port to provide communication using one of either Courier, MODBUS, IEC60870-5-103 or DNP3.0 protocols. The EIA(RS)485 hardware supports half-duplex communication and provides optical isolation of the serial data being transmitted and received. All internal communication of data from the power supply board is conducted via the output relay board that is connected to the parallel bus.

The watchdog facility provides two output relay contacts, one normally open and one normally closed that are driven by the processor board. These are provided to give an indication that the relay is in a healthy state.

The power supply board incorporates inrush current limiting. This limits the peak inrush current, during energization, to approximately 10A.

#### 1.2.4.2 Output relay board

The output relay board holds eight relays, six with normally open contacts and two with changeover contacts. The relays are driven from the 22V power supply line. The relays' state is written to or read from using the parallel data bus.

Depending on the relay model, up to three output relay boards may be fitted to the P145 relay to provide a total number of 32 relay outputs.

#### 1.2.4.3 Input/output (4 + 4) relay board

The input/output relay board holds four isolated digital inputs and four output relays, two with normally open contacts and two with changeover contacts. The output relays are driven from the 22V power supply line. The relays' state is written to or read from using the parallel data bus.

This is used with the B model variant of the P145 relay that has 12 opto inputs and 12 output contacts.

#### 1.2.4.4 IRIG-B board

The IRIG-B board is an order option that can be fitted to provide an accurate timing reference for the relay. This can be used wherever an IRIG-B signal is available. The IRIG-B signal is connected to the board via a BNC connector on the back of the relay. The timing information is used to synchronize the relay's internal real-time clock to an accuracy of 1ms. The internal clock is then used for the time tagging of the event, fault maintenance and disturbance records.

The IRIG-B board can also be specified with a fiber optic transmitter/receiver that can be used for the rear communication port instead of the EIA(RS)485 electrical connection (Courier, MODBUS, DNP3.0 and IEC60870-5-103).

#### 1.2.4.5 Second rear communications board

For relays with Courier, MODBUS, IEC60870-5-103 or DNP3.0 protocol on the first rear communications port there is the hardware option of a second rear communications port, which will run the Courier language. This can be used over one of three physical links: twisted pair K-Bus (non-polarity sensitive), twisted pair EIA(RS)485 (connection polarity sensitive) or EIA(RS)232.

The second rear comms. board and IRIG-B board are mutually exclusive since they use the same hardware slot. For this reason two versions of second rear comms. board are available; one with an IRIG-B input and one without. The physical layout of the second rear comms. board is shown in Figure 3.

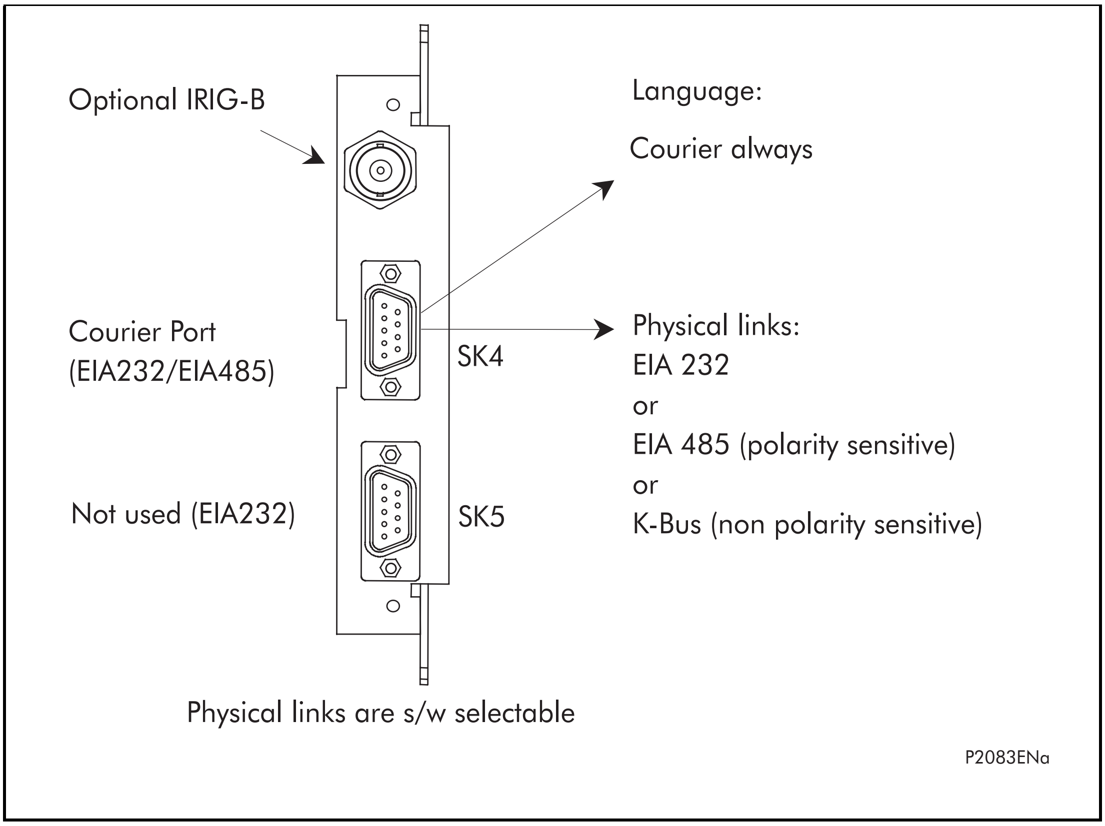



**Figure 3: Rear comms. port**

1.2.5 Ethernet board

The Ethernet board, presently only available for UCA2.0 communication variant relays, supports network connections of the following type:

- 10BASE-T
- 10BASE-FL
- 100BASE-TX
- 100BASE-FX

For all copper based network connections an RJ45 style connector is supported. 10Mb fiber network connections use an ST style connector while 100Mb connections use the SC style fiber connection.

An extra processor, a Motorola PPC, and memory block is fitted to the Ethernet card that is responsible for running all the network related functions such as TCP/IP/OSI as supplied by VxWorks and the UCA2.0/MMS server as supplied by Sisco inc. The extra memory block also holds the UCA2.0 data model supported by the relay.

1.2.6 Mechanical layout

The case materials of the relay are constructed from pre-finished steel that has a conductive covering of aluminum and zinc. This provides good earthing at all joints giving a low impedance path to earth that is essential for performance in the presence of external noise. The boards and modules use a multi-point earthing strategy to improve the immunity to external noise and minimize the effect of circuit noise. Ground planes are used on boards to reduce impedance paths and spring clips are used to ground the module metalwork.

Heavy duty terminal blocks are used at the rear of the relay for the current and voltage signal connections. Medium duty terminal blocks are used for the digital logic input signals, the output relay contacts, the power supply and the rear communication port. A BNC connector is used for the optional IRIG-B signal. 9-pin and 25-pin female D-connectors are used at the front of the relay for data communication.

Inside the relay the PCBs plug into the connector blocks at the rear, and can be removed from the front of the relay only. The connector blocks to the relay's CT inputs are provided with internal shorting links inside the relay which will automatically short the current transformer circuits before they are broken when the board is removed.

The front panel consists of a membrane keypad with tactile dome keys, an LCD and 12 LEDs mounted on an aluminum backing plate.

## 1.3 Relay software

The relay software was introduced in the overview of the relay at the start of this manual (P145/EN FD). The software can be considered to be made up of four sections:

- The real-time operating system
- The system services software
- The platform software
- The protection & control software

This section describes in detail the latter two of these, the platform software and the protection & control software, which between them control the functional behavior of the relay. Figure 4 shows the structure of the relay software.

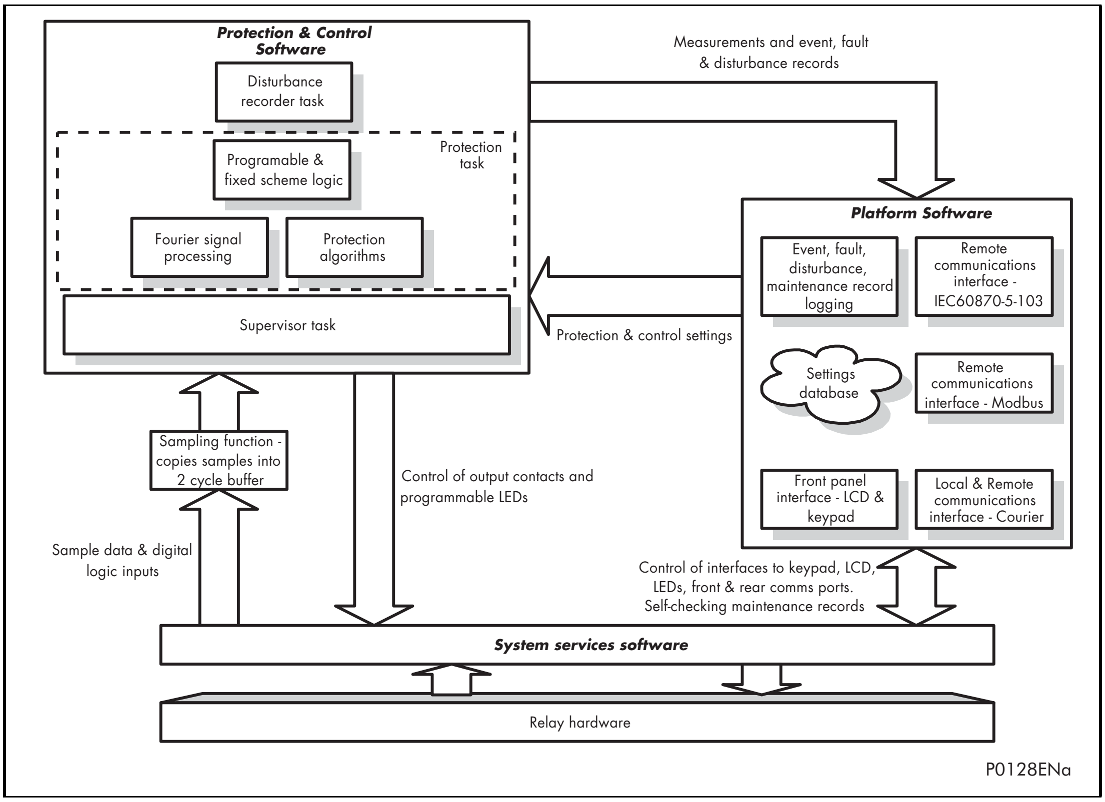



**Figure 4: Relay software structure**

### 1.3.1 Real-time operating system

The software is split into tasks; the real-time operating system is used to schedule the processing of the tasks to ensure that they are processed in the time available and in the desired order of priority. The operating system is also responsible in part for controlling the communication between the software tasks through the use of operating system messages.

FD

### 1.3.2 System services software

As shown in Figure 4, the system services software provides the interface between the relay's hardware and the higher-level functionality of the platform software and the protection & control software. For example, the system services software provides drivers for items such as the LCD display, the keypad and the remote communication ports, and controls the boot of the processor and downloading of the processor code into SRAM from flash EPROM at power up.

### 1.3.3 Platform software

The platform software has three main functions:

- To control the logging of records that are generated by the protection software, including alarms and event, fault, and maintenance records.
- To store and maintain a database of all of the relay's settings in non-volatile memory.
- To provide the internal interface between the settings database and each of the relay's user interfaces, i.e. the front panel interface and the front and rear communication ports, using whichever communication protocol has been specified (Courier, MODBUS, IEC 60870-5-103, DNP3.0 or UCA2.0).

#### 1.3.3.1 Record logging

The logging function is provided to store all alarms, events, faults and maintenance records. The records for all of these incidents are logged in battery backed-up SRAM in order to provide a non-volatile log of what has happened. The relay maintains four logs: one each for up to 32 alarms, 512 event records, 5 fault records and 5 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 or the platform software is responsible for logging of a maintenance record in the event of a relay failure. This includes errors that have been detected by the platform software itself or error that are detected by either the system services or the protection software function. See also the section on supervision and diagnostics later in this document (P145/EN FD).



#### 1.3.3.2 Settings database

The settings database contains all of the settings and data for the relay, including the protection, disturbance recorder and control & support settings. The settings are maintained in non-volatile memory. The platform software's management of the settings database includes the responsibility of ensuring that only one user interface modifies the settings of the database at any one time. This feature is employed to avoid conflict between different parts of the software during a setting change. For changes to protection settings and disturbance recorder settings, the platform software operates a 'scratchpad' in SRAM memory. This allows a number of setting changes to be applied to the protection elements, disturbance recorder and saved in the database in non-volatile memory. (See also the Introduction to this manual (P145/EN IT) on the user interface). If a setting change affects the protection & control task, the database advises it of the new values.

#### 1.3.3.3 Database interface

The other function of the platform software is to implement the relay's internal interface between the database and each of the relay's user interfaces. The database of settings and measurements must be accessible from all of the relay's user interfaces to allow read and modify operations. The platform software presents the data in the appropriate format for each user interface.

## 1.3.4 Protection and control software

The protection and control software task is responsible for processing all of the protection elements and measurement functions of the relay. To achieve this it has to communicate with both the system services software and the platform software as well as organize its own operations. The protection software has the highest priority of any of the software tasks in the relay in order to provide the fastest possible protection response. The protection & control software has a supervisor task that controls the start-up of the task and deals with the exchange of messages between the task and the platform software.

### 1.3.4.1 Overview - protection and control scheduling

After initialization at start-up, the protection and control task is suspended until there are sufficient samples available for it to process. The acquisition of samples is controlled by a 'sampling function' which is called by the system services software and takes each set of new samples from the input module and stores them in a two-cycle buffer. The protection and control software resumes execution when the number of unprocessed samples in the buffer reaches a certain number. For the P145 feeder protection relay, the protection task is executed twice per cycle, i.e. after every 12 samples for the sample rate of 24 samples per power cycle used by the relay. The protection and control software is suspended again when all of its processing on a set of samples is complete. This allows operations by other software tasks to take place.

### 1.3.4.2 Signal processing

The sampling function provides filtering of the digital input signals from the opto-isolators and frequency tracking of the analog signals. The digital inputs are checked against their previous value over a period of half a cycle. Hence a change in the state of one of the inputs must be maintained over at least half a cycle before it is registered with the protection and control software.

The frequency tracking of the analog input signals is achieved by a recursive Fourier algorithm which is applied to one of the input signals, and works by detecting a change in the measured signal's phase angle. The calculated value of the frequency is used to modify the sample rate being used by the input module so as to achieve a constant sample rate of 24 samples per cycle of the power waveform. The value of the frequency is also stored for use by the protection and control task.



### 1.3.4.3 Fourier filtering

When the protection and control task is re-started by the sampling function, it calculates the Fourier components for the analog signals. With the exception of the RMS measurements all other measurements and protection functions are based on the Fourier derived fundamental component. The Fourier components are calculated using a one-cycle, 24-sample Discrete Fourier Transform (DFT). The DFT is always calculated using the last cycle of samples from the 2-cycle buffer, i.e. the most recent data is used. The DFT used in this way extracts the power frequency fundamental component from the signal and produces the magnitude and phase angle of the fundamental in rectangular component format. This gives good harmonic rejection for frequencies up to the 23$^{rd}$ harmonic. The 23$^{rd}$ is the first predominant harmonic that is not attenuated by the Fourier filter and this is known as 'Alias'. However, the Alias is attenuated by approximately 85% by an additional, analog, 'anti-aliasing' filter (low pass filter). The combined affect of the anti-aliasing and Fourier filters is shown below:

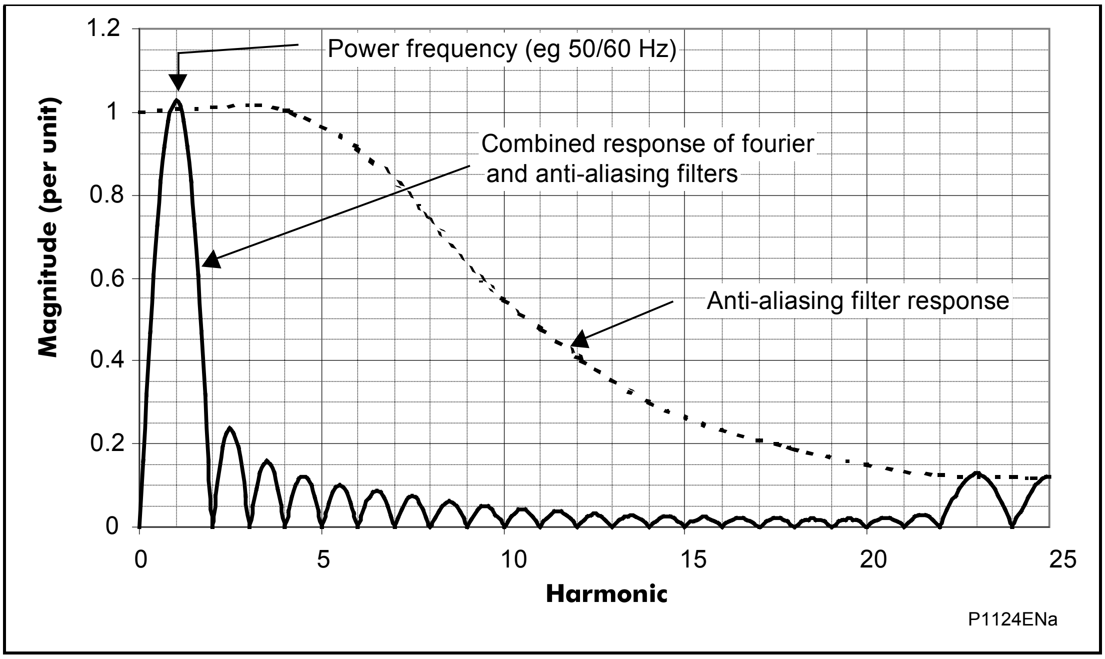



**Figure 5: Frequency response**

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 samples from the input module are also used in an unprocessed form by the disturbance recorder for waveform recording and to calculate true rms. values of current, voltage and power for metering purposes.

### 1.3.4.4 Programmable scheme logic

The purpose of the programmable scheme logic (PSL) is to allow the relay user to configure an individual protection scheme to suit their own particular application. This is achieved through the use of programmable logic gates and delay timers.

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, e.g. protection starts and trips, control inputs, function keys and the outputs of the fixed protection scheme logic. The fixed scheme logic provides the relay's standard protection schemes. The PSL itself 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, e.g. 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 and control software updates the logic delay timers and checks for a change in the PSL input signals every time it runs.

This system provides flexibility for the user to create their own scheme logic design. However, it also means that the PSL can be configured into a very complex system, and because of this setting of the PSL is implemented through the PC support package MiCOM S1.

### 1.3.4.5 Function key interface

The ten function keys interface directly into the PSL as digital input signals and are processed based on the PSL's event driven execution. However, a change of state is only recognized when a keypress 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 and can be configured to individual protection scheme requirements. The latched state signal for each function key is written to non-volatile memory and read from non-volatile memory during relay power up thus allowing the function Key state to be reinstated after power-up should relay power be inadvertently lost.

1.3.4.6 Event and fault recording

A change in any digital input signal or protection element output signal causes an event record to be created. 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 in SRAM which is controlled by the supervisor task. When the supervisor task receives either an event or fault record message, it instructs the platform software to create the appropriate log in battery backed-up SRAM. The operation of the record logging to battery backed-up SRAM is slower than the supervisor's 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's buffer is full before the platform software is able to create a new log in battery backed-up SRAM. If this occurs then an event is logged to indicate this loss of information.

1.3.4.7 Disturbance recorder

The disturbance recorder operates as a separate task from the protection and control task. It can record the waveforms for up to 8 analog channels and the values of up to 32 digital signals. The recording time is user selectable up to a maximum of 10 seconds. The disturbance recorder is supplied with data by the protection and control task once per cycle. The disturbance recorder collates the data that it receives into the required length disturbance record. The disturbance records can be extracted by MiCOM S1 that can also store the data in COMTRADE format, thus allowing the use of other packages to view the recorded data.

1.3.4.8 Fault locator

FD

The fault locator task is also separate from the protection and control task. The fault locator is invoked by the protection and control task when a fault is detected. The fault locator uses a 12-cycle buffer of the analog input signals and returns the calculated location of the fault to the protection and control task which includes it in the fault record for the fault. When the fault record is complete (i.e. includes the fault location), the protection and control task can send a message to the supervisor task to log the fault record.

## 1.4 Fault locator

The relay has an integral fault locator that uses information from the current and voltage inputs to provide a distance to fault location feature. The sampled data from the analog input circuits is written to a cyclic buffer until a fault condition is detected. The data in the input buffer is then held to allow the fault calculation to be made. When the fault calculation is complete the fault location information is available in the relay fault record.

1.4.1 Basic theory for ground faults

A two-machine equivalent circuit of a faulted power system is shown in Figure 6.

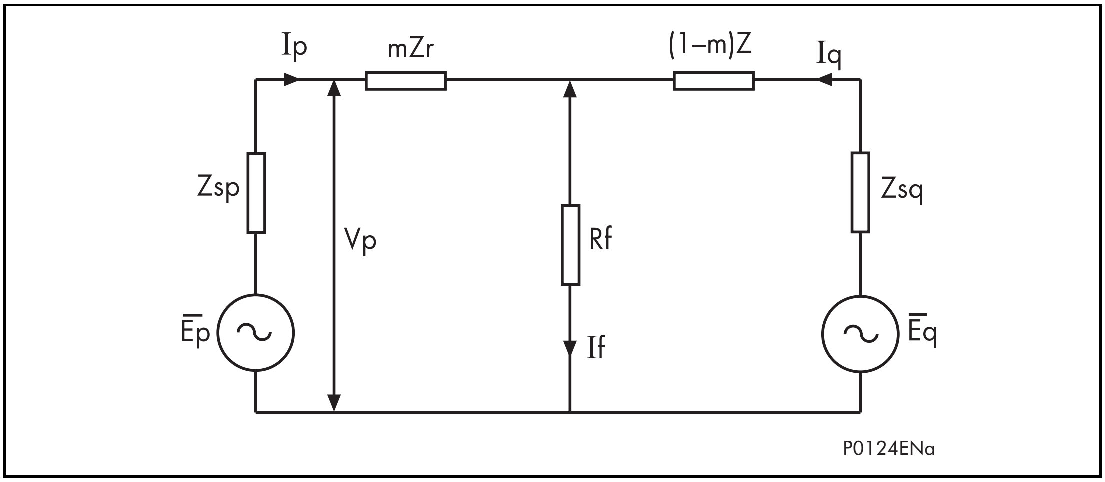



**Figure 6: Two machine equivalent circuit**

From this diagram:

$Vp = mIpZr + IfRf$ …(equation 1)

The fault location, m, can be found if If can be estimated allowing equation 1 to be solved.

### 1.4.2 Data acquisition and buffer processing

The fault locator stores the sampled data within a 12 cycle cyclic buffer at a resolution of 24 samples per cycle. When the fault recorder is triggered the data in the buffer is frozen such that the buffer contains 6 cycles of pre-trigger data and 6 cycles of post-trigger data. Fault calculation commences shortly after this trigger point.

The trigger for the fault locator is user selectable via the programmable scheme logic.

The fault locator can store data for up to four faults. This ensures that fault location can be calculated for all shots on a typical multiple re-close sequence.



### 1.4.3 Faulted phase selection

Selection of the faulted phase(s) is performed by comparing the magnitude of the pre fault and post fault values of the three phase-to-phase currents. A single phase-to-ground fault produces the same change on two of these signals and zero on the third. A phase-to-phase or double phase-to-ground fault produces one signal that is larger than the other two. A three-phase fault produces the same change on all 3 currents.

Current changes are considered to be the same if they are within 20% of each other. Phase selection and fault location calculation can only be made if the current change exceeds 5%In.

### 1.4.4 The fault location calculation

This works by:

a) First obtaining the vectors

b) Selecting the faulted phase(s)

c) Estimating the phase of the fault current, If, for the faulted phase(s)

d) Solving equation 1 for the fault location m at the instant of time where If = 0

1.4.4.1 Obtaining the vectors

Different sets of vectors are chosen depending on the type of fault identified by the phase selection algorithm. The calculation using equation 1 is applied for either a phase to ground fault or a phase to phase fault.

Thus for an A phase to ground fault:

IpZr = Ia (Zline /THETA line) + In (Zresidual /THETA residual) ….. (equation 2)

and Vp = VA

and for an A phase to B phase fault:

IpZr = Ia (Zline /THETA line) – Ib (Zresidual /THETA residual) ….. (equation 3)

and Vp = VA – VB

1.4.4.2 Solving the equation for the fault location

As the sine wave of If passes through zero, the instantaneous values of the sine waves Vp and Ip can be used to solve equation (1) for the fault location m. (The term IfRf being zero.)

This is determined by shifting the calculated vectors of Vp and IpZr by the angle (90° - angle of fault current) and then dividing the real component of Vp by the real component of IpZr. See Figure 7 below.

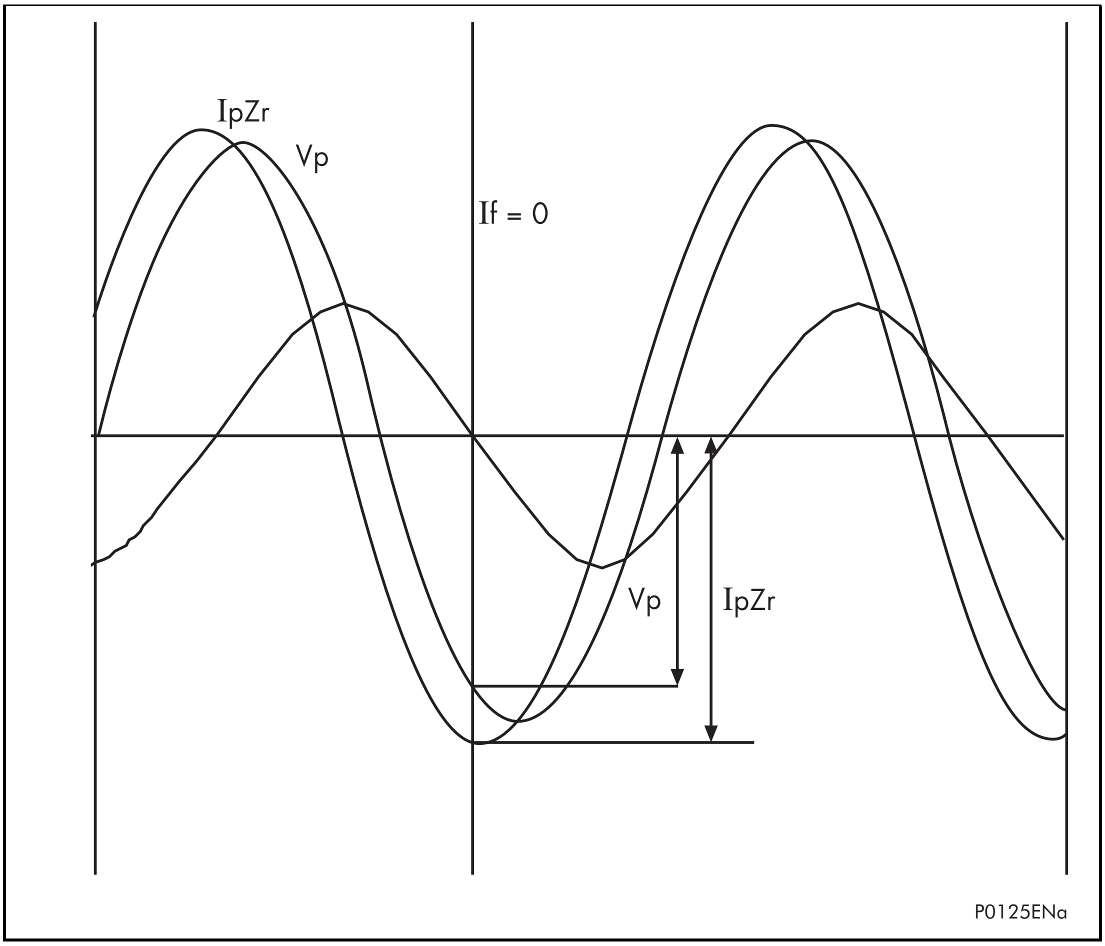



**Figure 7: Fault locator selection of fault current zero**

FD

i.e.:

Phase advanced vector Vp

= | Vp | (cos(s) + jsin(s)) * (sin(d) + jcos(d))

= | Vp | [- sin(s-d) + jcos(s-d)]

Phase advanced vector IpZr

= | IpZr | (cos (e) + jsin (e)) * (sin (d) + jcos (d))

= | IpZr | [- sin(e-d) + jcos(e-d)]

therefore from equation 1

m = Vp ÷ (Ip * Zr) at If = 0

= Vpsin(s-d) / (IpZr * sin(e-d))

where

d = angle of fault current If

s = angle of Vp

e = angle of IpZr

Thus the relay evaluates m which is the fault location as a percentage of the fault locator line impedance setting and then calculates the output fault location by multiplying this by the line length setting. When calculated, the fault location can be found in the fault record under the "VIEW RECORDS" column in the Fault Location cells. Distance to fault is available in kilometers, miles, impedance or percentage of line length.

1.4.4.3 Data acquisition and buffer processing

The fault locator stores the sampled data within a 12 cycle cyclic buffer at a resolution of 24 samples per cycle. When the fault recorder is triggered the data in the buffer is frozen such that the buffer contains 6 cycles of pre-trigger data and 6 cycles of post-trigger data. Fault calculation commences shortly after this trigger point.

FD

The trigger for the fault locator is user selectable via the programmable scheme logic.

The fault locator can store data for up to four faults. This ensures that fault location can be calculated for all shots on a typical multiple re-close sequence.

## 1.5 Self testing & diagnostics

The relay includes a number of self-monitoring functions to check the operation of its hardware and software when it is in service. These are included so that if an error or fault occurs within the relay’s hardware or software, the relay is able to detect and report the problem and attempt to resolve it by performing a re-boot. This involves the relay being out of service for a short period of time which is indicated by the ‘Healthy’ LED on the front of the relay being extinguished and the watchdog contact at the rear operating. If the restart fails to resolve the problem, then the relay will take itself permanently out of service. Again this will be indicated by the LED and watchdog contact.

If a problem is detected by the self-monitoring functions, the relay attempts to store a maintenance record in battery backed-up SRAM to allow the nature of the problem to be notified to the user.

The self-monitoring is implemented in two stages: firstly a thorough diagnostic check which is performed when the relay is booted-up, e.g. at power-on, and secondly a continuous self-checking operation which checks the operation of the relay’s critical functions whilst it is in service.

### 1.5.1 Start-up self-testing

The self-testing which is carried out when the relay is started takes a few seconds to complete, during which time the relay's protection is unavailable. This is signaled by the 'Healthy' LED on the front of the relay which will illuminate when the relay has passed all of the tests and entered operation. If the testing detects a problem, the relay will remain out of service until it is manually restored to working order.

The operations that are performed at start-up are as follows:

#### 1.5.1.1 System boot

The integrity of the flash memory is verified using a checksum before the program code and data stored in it is copied into SRAM to be used for execution by the processor. When the copy has been completed the data then held in SRAM is compared to that in the flash to ensure that the two are the same and that no errors have occurred in the transfer of data from flash to SRAM. The entry point of the software code in SRAM is then called which is the relay initialization code.

#### 1.5.1.2 Initialization software

The initialization process includes the operations of initializing the processor registers and interrupts, starting the watchdog timers (used by the hardware to determine whether the software is still running), starting the real-time operating system and creating and starting the supervisor task. In the course of the initialization process the relay checks:

- The status of the battery
- The integrity of the battery backed-up SRAM that is used to store event, fault and disturbance records
- The voltage level of the field voltage supply which is used to drive the opto-isolated inputs
- The operation of the LCD controller
- The watchdog operation

FD

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

#### 1.5.1.3 Platform software initialization & monitoring

In starting the platform software, the relay checks the integrity of the data held in non-volatile memory with a checksum, the operation of the real-time clock, and the IRIG-B board if fitted. The final test that is made concerns the input and output of data; the presence and healthy condition of the input board is checked and the analog data acquisition system is checked through sampling the reference voltage.

At the successful conclusion of all of these tests the relay is entered into service and the protection started-up.

### 1.5.2 Continuous self-testing

When the relay 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 (see section on relay software earlier in this document (P145/EN FD)) and the results reported to the platform software. The functions that are checked are as follows:

- The flash containing all program code setting values and language text is verified by a checksum
- The code and constant data held in SRAM is checked against the corresponding data in flash to check for data corruption
- The SRAM containing all data other than the code and constant data is verified with a checksum

- The battery status
- The level of the field voltage
- The integrity of the digital signal I/O data from the opto-isolated inputs and the relay contacts 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, by means of sampling the reference voltages
- The operation of the IRIG-B board is checked, where it is fitted, by the software that reads the time and date from the board
- The operation of the Ethernet board is checked, where it is fitted, 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

In the unlikely event that one of the checks detects an error within the relay's subsystems, the platform software is notified and it will attempt to log a maintenance record in battery backed-up SRAM. If the problem is with the battery status or the IRIG-B board, the relay will continue in operation. However, for problems detected in any other area the relay will initiate a shutdown and re-boot. This will result in a period of up to 5 seconds when the protection is unavailable, but the complete restart of the relay including all initializations should clear most problems that could occur. As described above, an integral part of the start-up procedure is a thorough diagnostic self-check. If this detects the same problem that caused the relay to restart, i.e. the restart has not cleared the problem, then the relay will take itself permanently out of service. This is indicated by the 'Healthy' LED on the front of the relay, which will extinguish, and the watchdog contact that will operate.

# COMMISSIONING



| | |
|---|---|
| **Date:** | **7th July 2005** |
| **Hardware Suffix:** | **J** |
| **Software Version:** | **31** |
| **Connection Diagrams:** | **10P145xx (xx = 01 to 07)** |

# CONTENTS

# FIGURES



CM

CM

# 1. INTRODUCTION

The MiCOM P145 feeder protection relays are fully numerical in their design, implementing all protection and non-protection functions in software. The relays employ a high degree of self-checking and, in the unlikely event of a failure, will give an alarm. As a result of this, the commissioning tests do not need to be as extensive as with non-numeric electronic or electro-mechanical relays.

To commission numeric relays, it is only necessary to verify that the hardware is functioning correctly and the application-specific software settings have been applied to the relay. It is considered unnecessary to test every function of the relay if the settings have been verified by one of the following methods:

- Extracting the settings applied to the relay using appropriate setting software (preferred method)
- Via the operator interface

Unless previously agreed to the contrary, the customer will be responsible for determining the application-specific settings to be applied to the relay and for testing of any scheme logic applied by external wiring and/or configuration of the relay's internal programmable scheme logic.

Blank commissioning test and setting records are provided at the end of this chapter for completion as required.

As the relay's menu language is user-selectable, it is acceptable for the Commissioning Engineer to change it to allow accurate testing as long as the menu is restored to the customer's preferred language on completion.

To simplify the specifying of menu cell locations in these Commissioning Instructions, they will be given in the form [courier reference: COLUMN HEADING, Cell Text]. For example, the cell for selecting the menu language (first cell under the column heading) is located in the System Data column (column 00) so it would be given as [0001: SYSTEM DATA, Language].

**Before carrying out any work on the equipment, the user should be familiar with the contents of the Safety and Technical Data sections and the ratings on the equipment's rating label.**

# 2. RELAY COMMISSIONING TOOLS

To help minimize the time required to test MiCOM relays the relay provides several test facilities under the 'COMMISSION TESTS' menu heading. 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, user-programmable LEDs and, where available, the auto-reclose cycles.

The following table shows the relay menu of commissioning tests, including the available setting ranges and factory defaults:

| Menu Text | Default Setting | Settings |
|---|---|---|
| COMMISSION TESTS | | |
| Opto I/P Status | – | – |
| Relay O/P Status | – | – |
| Test Port Status | – | – |
| LED Status | – | – |
| Monitor Bit 1 | 64 (LED 1) | 0 to 1022<br>See section P145/EN PL for details of Digital Data Bus signals |
| Monitor Bit 2 | 65 (LED 2) | 0 to 1022 |
| Monitor Bit 3 | 66 (LED 3) | 0 to 1022 |
| Monitor Bit 4 | 67 (LED 4) | 0 to 1022 |
| Monitor Bit 5 | 68 (LED 5) | 0 to 1022 |
| Monitor Bit 6 | 69 (LED 6) | 0 to 1022 |
| Monitor Bit 7 | 70 (LED 7) | 0 to 1022 |
| Monitor Bit 8 | 71 (LED 8) | 0 to 1022 |
| Test Mode | Disabled | Disabled<br>Test Mode<br>Contacts Blocked |
| Test Pattern | All bits set to 0 | 0 = Not Operated<br>1 = Operated |
| Contact Test | No Operation | No Operation<br>Apply Test<br>Remove Test |
| Test LEDs | No Operation | No Operation<br>Apply Test |
| Test Auto-reclose | No Operation | No Operation<br>3 Pole Test |
| Red LED Status | – | – |
| Green LED Status | – | – |

CM

## 2.1 Opto I/P status

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. If the cursor is moved along the binary numbers the corresponding label text will be displayed for each logic input.

It can be used during commissioning or routine testing to monitor the status of the opto-isolated inputs whilst they are sequentially energized with a suitable dc voltage.

## 2.2 Relay O/P status

This menu cell displays the status of the digital data bus (DDB) signals that result in energization of the output relays as a binary string, a '1' indicating an operated state and '0' a non-operated state. If the cursor is moved along the binary numbers the corresponding label text will be displayed for each relay output.

The information displayed can be used during commissioning or routine testing to indicate the status of the output relays when the relay is 'in service'. Additionally fault finding for output relay damage can be performed by comparing the status of the output contact under investigation with it's associated bit.

Note: When the 'Test Mode' cell is set to 'Enabled' this cell will continue to indicate which contacts would operate if the relay was in-service, it does not show the actual status of the output relays.

## 2.3 Test port status

This menu cell displays the status of the eight digital data bus (DDB) signals that have been allocated in the 'Monitor Bit' cells. If the cursor is moved along the binary numbers the corresponding DDB signal text string will be 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. Thus the programmable scheme logic can be tested.

As an alternative to using this cell, the optional monitor/download port test box can be plugged into the monitor/download port located behind the bottom access cover. Details of the monitor/download port test box can be found in section 2.11 of this section (P145/EN CM).

## 2.4 Monitor bits 1 to 8

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.

Each 'Monitor Bit' is set by entering the required digital data bus (DDB) signal number (0 - 1022) from the list of available DDB signals in section P145/EN PL. The pins of the monitor/download port used for monitor bits are given in the table below. The signal ground is available on pins 18, 19, 22 and 25.

CM

| Monitor bit | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Monitor/download port pin | 11 | 12 | 15 | 13 | 20 | 21 | 23 | 24 |

**THE MONITOR/DOWNLOAD PORT DOES NOT HAVE ELECTRICAL ISOLATED AGAINST INDUCED VOLTAGES ON THE COMMUNICATIONS CHANNEL. IT SHOULD THEREFORE ONLY BE USED FOR LOCAL COMMUNICATIONS.**

## 2.5 Test mode

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' that takes the relay out of service and blocks operation of output contacts and 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 IEC60870-5-103 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.

### 2.6 Test pattern

The 'Test Pattern' cell is used to select the output relay contacts that will 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 under test conditions and '0' to not operate it.

### 2.7 Contact 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 hence 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.

### 2.8 Test LEDs

When the 'Apply Test' command in this cell is issued the eight user-programmable LEDs will illuminate for approximately 2 seconds before they extinguish and the command text on the LCD reverts to 'No Operation'.

### 2.9 Test auto-reclose

Where the relay provides an auto-reclose function, this cell will be available for testing the sequence of circuit breaker trip and auto-reclose cycles with the settings applied.

Issuing the command '3 Pole Trip' will cause the relay to perform the first three-phase trip/reclose cycle so that associated output contacts can be checked for operation at the correct times during the cycle. Once the trip output has operated the command text will revert to 'No Operation' whilst the rest of the auto-reclose cycle is performed. To test subsequent three-phase auto-reclose cycles repeat the '3 Pole Trip' command.

Note: The factory settings for the relay's programmable scheme logic has the 'AR Trip Test' signal mapped to relay 3. If the programmable scheme logic has been changed, it is essential that this signal remains mapped to relay 3 for the 'Test Auto-reclose' facility to work.



### 2.10 Red LED status and green LED status

The 'Red LED Status' and 'Green LED Status' cells are eighteen bit binary strings that indicate which of the user-programmable LEDs on the relay are illuminated when accessing the relay from a remote location, a '1' indicating a particular LED is lit and a '0' not lit. When the status of a particular LED in both cells are '1', this indicates the LEDs illumination is yellow.

### 2.11 Using a monitor/download port test box

A monitor/download port test box containing 8 LEDs and a switchable audible indicator is available from AREVA T&D, or one of their regional sales offices. It is housed in a small plastic box with a 25-pin male D-connector that plugs directly into the relay's monitor/download port. There is also a 25-pin female D-connector which allows other connections to be made to the monitor/download port whilst the monitor/download port test box is in place.

Each LED corresponds to one of the monitor bit pins on the monitor/download port with 'Monitor Bit 1' being on the left hand side when viewing from the front of the relay. The audible indicator can either be selected to sound if a voltage appears on any of the eight monitor pins or remain silent so that indication of state is by LED alone.

# 3. SETTING FAMILIARIZATION

When commissioning a MiCOM P145 relay for the first time, sufficient time should be allowed to become familiar with the method by which the settings are applied.

The Getting Started section (P145/EN GS) contains a detailed description of the menu structure of P145 relays.

With the secondary front cover in place all keys except the ↵ 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 will require the appropriate password to be entered before changes can be made.

Alternatively, if a portable PC is available together with suitable setting software (such as MiCOM S1), the menu can be viewed a page at a time to display a full column of data and text. This PC software also allows settings to be entered more easily, saved to a file on disk for future reference or printed to produce a setting record. Refer to the PC software user manual for details. If the software is being used for the first time, allow sufficient time to become familiar with its operation.

# 4. EQUIPMENT REQUIRED FOR COMMISSIONING

## 4.1 Minimum equipment required

Multifunctional dynamic current and voltage injection test set.

Multimeter with suitable ac current range, and ac and dc voltage ranges of 0 – 440V and 0 – 250V respectively.

Continuity tester (if not included in multimeter).

Phase angle meter.

Phase rotation meter.

Note: Modern test equipment may contain many of the above features in one unit.

CM

## 4.2 Optional equipment

Multi-finger test plug type P992 (if test block type P991 installed) or MMLB (if using MMLG blocks).

An electronic or brushless insulation tester with a dc output not exceeding 500V (for insulation resistance testing when required).

A portable PC, with appropriate software (this enables the rear communications port to be tested, if this is to be used, and will also save considerable time during commissioning).

KITZ K-Bus to EIA(RS)232 protocol converter (if EIA(RS)485 K-Bus port is being tested and one is not already installed).

EIA(RS)485 to EIA(RS)232 converter (if EIA(RS)485 MODBUS/IEC60870/DNP3.0 port is being tested).

A printer (for printing a setting record from the portable PC).

# 5. PRODUCT CHECKS

These product checks cover all aspects of the relay which should be checked to ensure that it has not been physically damaged prior to commissioning, is functioning correctly and all input quantity measurements are within the stated tolerances.

If the application-specific settings have been applied to the relay prior to commissioning, it is advisable to make a copy of the settings so as to allow their restoration later. This could be done by:

- Obtaining a setting file on a diskette from the customer (this requires a portable PC with appropriate setting software for transferring the settings from the PC to the relay)
- Extracting the settings from the relay itself (this again requires a portable PC with appropriate setting software)
- Manually creating a setting record. This could be done using a copy of the setting record located at the end of this chapter to record the settings as the relay's menu is sequentially stepped through via the front panel user interface

If password protection is enabled and the customer has changed password 2 that prevents unauthorized changes to some of the settings, either the revised password 2 should be provided, or the customer should restore the original password prior to commencement of testing.

Note: In the event that the password has been lost, a recovery password can be obtained from AREVA T&D by quoting the serial number of the relay. The recovery password is unique to that relay and is unlikely to work on any other relay.

## 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 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 easily be achieved by inserting test plug type P992 that effectively open-circuits all wiring routed through the test block.



Before inserting the test plug, reference should be made to the scheme (wiring) diagram to ensure that this will not potentially cause damage or a safety hazard. For example, the test block may be associated with protection current transformer circuits. It is essential that the sockets in the test plug, which correspond to the current transformer secondary windings, are 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.**

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 (e.g. isolation links, fuses, MCB, etc.) are provided, these should be used. If this is not possible, the wiring to these circuits will have to be disconnected and the exposed ends suitably terminated to prevent them from being a safety hazard.

### 5.1.1 Visual inspection

**The rating information given under the top access cover on the front of the relay should be checked. Check that the relay being tested is correct for the protected line/circuit. Ensure that the circuit reference and system details are entered onto the setting record sheet. Double-check the CT secondary current rating, and be sure to record the actual 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 (optional check)

If required, the current transformer shorting contacts can be checked to ensure that they close when the heavy duty terminal block (block reference C in Figure 1) is disconnected from the current input PCB.

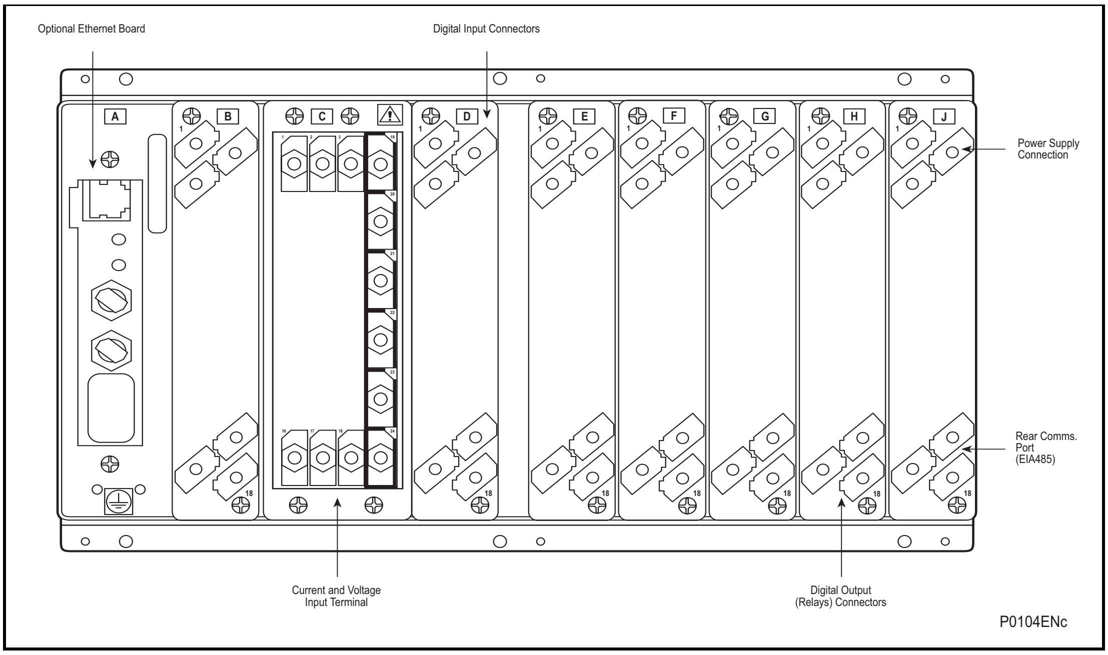



**Figure 1: Rear terminal blocks on size 60TE case (G variant)**

The heavy duty terminal block is fastened to the rear panel using four crosshead screws. These are located top and bottom between the first and second, and third and fourth, columns of terminals (see Figure 2).

Note: The use of a magnetic bladed screwdriver is recommended 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. Table 1 shows the terminals between which shorting contacts are fitted.

| Current Input | Shorting Contact Between Terminals | |
|---|---|---|
| | | |
| IA | 1A CT’s | 5A CT’s |
| IB | C3 - C2 | C1 - C2 |
| IC | C6 - C5 | C4 - C5 |
| IN | C9 - C8 | C7 - C8 |
| IN SENSITIVE | C12 - C11 | C10 - C11 |
| | C15 - C14 | C13 - C14 |

Table 1: Current transformer shorting contact locations

CM

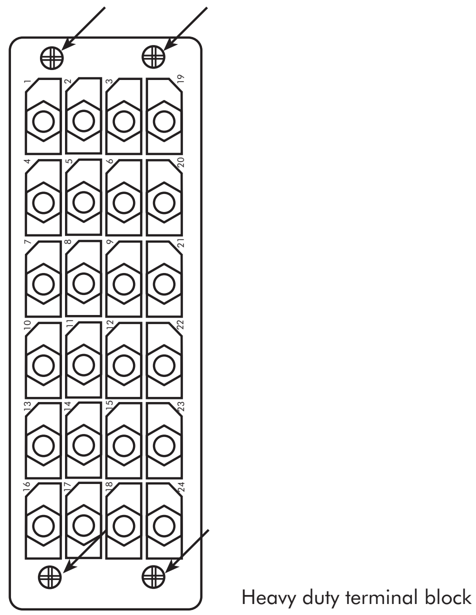



**Figure 2: Location of securing screws for heavy duty terminal blocks**

5.1.3 Insulation

Insulation resistance tests are only necessary during commissioning if it is required for them to be done and they have not been performed during installation.

Isolate all wiring from the earth and test the insulation with an electronic or brushless insulation tester at a dc voltage not exceeding 500V. Terminals of the same circuits should be temporarily connected together.

The main groups of relay terminals are:

a) Voltage transformer circuits

b) Current transformer circuits

c) Auxiliary voltage supply

d) Field voltage output and opto-isolated control inputs

e) Relay contacts

f) EIA(RS)485 communication port

g) Case earth

The insulation resistance should be greater than 100MΩ at 500V.

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 to the relevant relay diagram and scheme diagram. Ensure as far as practical that phasing/phase rotation appears to be as expected. The relay diagram number appears on the rating label under the top access cover on the front of the relay.**

If a P991 test block is provided, the connections should be checked against the scheme (wiring) diagram. It is recommended that the supply connections are to the live side of the test block colored orange with the odd numbered terminals (1, 3, 5, 7 etc.). The auxiliary supply is normally routed via terminals 13 (supply positive) and 15 (supply negative), with terminals 14 and 16 connected to the relay's positive and negative auxiliary supply terminals respectively. However, check the wiring against the schematic diagram for the installation to ensure compliance with the customer's normal practice.

### 5.1.5 Watchdog contacts

Using a continuity tester, check that the watchdog contacts are in the states given in Table 2 for a de-energized relay.

| Terminals | | Contact State | |
|---|---|---|---|
| | | Relay De-energized | Relay Energized |
| J11 - J12 | (P145) | Closed | Open |
| J13 - J14 | (P145) | Open | Closed |

Table 2: Watchdog contact status

### 5.1.6 Auxiliary supply

The relay can be operated from either a dc only or AC/DC auxiliary supply depending on the relay's nominal supply rating. The incoming voltage must be within the operating range specified in Table 3.

Without energizing the relay measure the auxiliary supply to ensure it is within the operating range.

| Nominal Supply Rating DC [AC rms] | | DC Operating Range | AC Operating Range |
|---|---|---|---|
| 24 - 48V | [-] | 19 to 65V | - |
| 48 - 110V | [30 - 100V] | 37 to 150V | 24 - 110V |
| 125 - 250V | [100 - 240V] | 87 to 300V | 80 to 265V |

Table 3: Operational range of auxiliary supply Vx

It should be noted that 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 unit using the battery charger with the battery disconnected as this can irreparably damage the relay's power supply circuitry.**

Energize the relay only if the auxiliary supply is within the specified operating ranges. If a test block is provided, it may be necessary to link across the front of the test plug to connect the auxiliary supply to the relay.



## 5.2 With the relay energized

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.

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.

### 5.2.1 Watchdog contacts

Using a continuity tester, check the watchdog contacts are in the states given in Table 2 for an energized relay.

### 5.2.2 LCD front panel display

The liquid crystal display is designed to operate in a wide range of substation ambient temperatures. For this purpose, the Px40 relays have an "*LCD Contrast"* setting. This allows the user to adjust how light or dark the characters displayed will be. The contrast is factory pre-set to account for a standard room temperature, however it may be necessary to adjust the contrast to give the best in-service display. To change the contrast, cell [09FF: LCD Contrast] at the bottom of the CONFIGURATION column can be incremented (darker) or de-cremented (lighter), as required.

Care: Before applying a contrast setting, ensure that it will not render the display too light or dark such that menu text becomes unreadable. Should such a mistake be made, it is possible to restore a visible display by downloading a MiCOM S1 setting file, with the LCD Contrast set within the typical range of 7 - 11.

### 5.2.3 Date and time

Before setting the date and time, ensure that the factory-fitted battery isolation strip, that prevents battery drain during transportation and storage, has been removed. With the lower access cover open, presence of the battery isolation strip can be checked by a red tab protruding from the positive side of the battery compartment. Whilst lightly pressing the battery, to prevent it from falling out of the battery compartment, pull the red tab to remove the isolation strip.

The date and time should now be set to the correct values. The method of setting will depend on whether accuracy is being maintained via the optional Inter-Range Instrumentation Group standard B (IRIG-B) port on the rear of the relay.

#### 5.2.3.1 With an IRIG-B signal

If a satellite time clock signal conforming to IRIG-B is provided and the relay has the optional IRIG-B port fitted, the satellite clock equipment should be energized.

To allow the relay's time and date to be maintained from an external IRIG-B source cell [0804: DATE and TIME, IRIG-B Sync.] must be set to 'Enabled'.

Ensure the relay is receiving the IRIG-B signal by checking that cell [0805: DATE and TIME, IRIG-B Status] reads 'Active'.

Once the IRIG-B signal is active, adjust the time offset of the universal co-ordinated time (satellite clock time) on the satellite clock equipment so that local time is displayed.

Check the time, date and month are correct in cell [0801: DATE and TIME, Date/Time]. The IRIG-B signal does not contain the current year so it will need to be set manually in this cell.

In the event of the auxiliary supply failing, with a battery fitted in the compartment behind the bottom access cover, the time and date will be maintained. Therefore, when the auxiliary supply is restored, the time and date will be correct and not need to be set again.



To test this, remove the IRIG-B signal, and then remove the auxiliary supply from the relay. Leave the relay de-energized for approximately 30 seconds. On re-energization, the time in cell [0801: DATE and TIME, Date/Time] should be correct.

Reconnect the IRIG-B signal.

#### 5.2.3.2 Without an IRIG-B signal

If the time and date is not being maintained by an IRIG-B signal, ensure that cell [0804: DATE and TIME, IRIG-B Sync.] is set to 'Disabled'.

Set the date and time to the correct local time and date using cell [0801: DATE and TIME, Date/Time].

In the event of the auxiliary supply failing, with a battery fitted in the compartment behind the bottom access cover, the time and date will be maintained. Therefore when the auxiliary supply is restored the time and date will be correct and not need to be set again.

To test this, remove the auxiliary supply from the relay for approximately 30 seconds. On re-energization, the time in cell [0801: DATE and TIME, Date/Time] should be correct.

### 5.2.4 Light emitting diodes (LEDs)

On power up the green LED should have illuminated and stayed on indicating that the relay is healthy. The relay has non-volatile memory which remembers the state (on or off) of the alarm, trip and, if configured to latch, user-programmable LED indicators when the relay was last energized from an auxiliary supply. Therefore 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 out), there is no testing required for that LED because it is known to be operational.

Note: It is likely that alarms related to the communications channels will not reset at this stage.

#### 5.2.4.1 Testing the alarm and out of service LEDs

The alarm and out of service LEDs can be tested using the COMMISSION TESTS menu column. Set cell [0F0D: COMMISSION TESTS, Test Mode] to ‘Contacts Blocked’. Check that the out of service LED illuminates continuously and the alarm LED flashes.

It is not necessary to return cell [0F0D: COMMISSION TESTS, Test Mode] to ‘Disabled’ at this stage because the test mode will be required for later tests.

#### 5.2.4.2 Testing the trip LED

The trip LED can be tested by initiating a manual circuit breaker trip from the relay. 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 Testing the user-programmable LEDs

To test the user-programmable LEDs set cell [0F10: COMMISSION TESTS, Test LEDs] to ‘Apply Test’. Check that all 18 programmable LEDs on the relay illuminate.

### 5.2.5 Field voltage supply

The relay generates a field voltage of nominally 48V that can be used to energize the opto-isolated inputs (alternatively the substation battery may be used).

Measure the field voltage across the terminals 1 and 2 on the terminal block given in Table 4. Check that the field voltage is within the range 40V to 60V when no load is connected and that the polarity is correct.

Repeat for terminals 8 and 10.

| Supply Rail | Terminals |
|---|---|
| | MiCOM P145 |
| +ve | J2 |
| –ve | J1 |

Table 4: Field voltage terminals

CM

### 5.2.6 Input opto-isolators

This test checks that all the opto-isolated inputs on the relay are functioning correctly.

- The P145 with I/O option “A” (model no. begins: P145xxxA..) has 16 opto inputs
- The P145 with I/O option “B” (model no. begins: P145xxxB..) has 12 opto inputs
- The P145 with I/O option “C” (model no. begins: P145xxxC..) has 24 opto inputs
- The P145 with I/O option “D” (model no. begins: P145xxxD..) has 16 opto inputs
- The P145 with I/O option “E” (model no. begins: P145xxxE..) has 24 opto inputs
- The P145 with I/O option “F” (model no. begins: P145xxxF..) has 32 opto inputs
- The P145 with I/O option “G” (model no. begins: P145xxxG..) has 16 opto inputs

The opto-isolated inputs should be energized one at a time, see external connection diagrams (P145/EN IN) for terminal numbers.

Ensuring that the correct opto input nominal voltage is set in the 'Opto Config.' menu and correct polarity, connect the field supply voltage to the appropriate terminals for the input being tested. Each opto input also has selectable filtering. This allows use of a pre-set filter of ½ a cycle that renders the input immune to induced noise on the wiring.

Note: The opto-isolated inputs may be energized from an eternal dc auxiliary supply (e.g. the station battery) in some installations. Check that this is not the case before connecting the field voltage otherwise damage to the relay may result. If an external 24/27V, 30/34V, 48/54V, 110/125V, 220/250V supply is being used it will be connected to the relays optically isolated inputs directly. If an external supply is being used than it must be energized for this test but only if it has been confirmed that it is suitably rated with less than 12% ac ripple.

The status of each opto-isolated input can be viewed using either cell [0020: SYSTEM DATA, Opto I/P Status] or [0F01: COMMISSION TESTS, Opto I/P Status], a '1' indicating an energized input and a '0' indicating a de-energized input. When each opto-isolated input is energized one of the characters on the bottom line of the display will change to indicate the new state of the inputs.

### 5.2.7 Output relays

– This test checks that all the output relays are functioning correctly.

– The P145 with I/O option "A" (model no. begins: P145xxxA..) has 16 relay outputs

– The P145 with I/O option "B" (model no. begins: P145xxxB..) has 12 relay outputs

– The P145 with I/O option "C" (model no. begins: P145xxxC..) has 16 opto outputs

– The P145 with I/O option "D" (model no. begins: P145xxxD..) has 24 opto outputs

– The P145 with I/O option "E" (model no. begins: P145xxxE..) has 24 opto outputs

– The P145 with I/O option "F" (model no. begins: P145xxxF..) has 16 opto outputs

– The P145 with I/O option "G" (model no. begins: P145xxxG..) has 32 opto outputs



Ensure that the relay is still in test mode by viewing cell [0F0D: COMMISSION TESTS, Test Mode] to ensure that it is set to 'Blocked'.

The output relays should be energized one at a time. To select output relay 1 for testing, set cell [0F0E: COMMISSION TESTS, Test Pattern] as appropriate.

Connect a continuity tester across the terminals corresponding to output relay 1 as given in external connection diagram (P145/EN IN).

To operate the output relay set cell [0F0F: COMMISSION TESTS, Contact Test] to 'Apply Test'. Operation will be confirmed by the continuity tester operating for a normally open contact and ceasing to operate for a normally closed contact. Measure the resistance of the contacts in the closed state.

Reset the output relay by setting cell [0F0F: COMMISSION TESTS, Contact Test] to 'Remove Test'.

Note: It should be ensured that thermal ratings of anything connected to the output relays during the contact test procedure are not exceeded by the associated output relay being operated for too long. It is therefore advised that the time between application and removal of the contact test is kept to the minimum.

Repeat the test for all the relay outputs of the particular hardware model.

Return the relay to service by setting cell [0F0D: COMMISSION TESTS, Test Mode] to 'Disabled'.

### 5.2.8 Rear communications port

This test should only be performed where the relay is to be accessed from a remote location and will vary depending on the communications standard being adopted.

It is not the intention of the test to verify the operation of the complete system from the relay to the remote location, just the relay's rear communications port and any protocol converter necessary.

#### 5.2.8.1 Courier communications

If a K-Bus to EIA(RS)232 KITZ protocol converter is installed, connect a portable PC running the appropriate software to the incoming (remote from relay) side of the protocol converter. The terminal numbers for the relay's K-Bus port are given in Table 5.

| Connection | | Terminal |
|---|---|---|
| K-Bus | IEC60870-5-103 or DNP3.0 | P145 |
| Screen | Screen | J16 |
| 1 | +ve | J18 |
| 2 | –ve | J17 |

Table 5: EIA(RS)485 terminals

Ensure that the communications baud rate and parity settings in the application software are set the same as those on the protocol converter (usually a KITZ but could be a SCADA RTU). The relays courier address in cell [0E02: COMMUNICATIONS, Remote Access] must be set to a value between 1 and 254.

Check that communications can be established with this relay using the portable PC.

If the relay has the optional fiber optic communications port fitted, the port to be used should be selected by setting cell [0E07: COMMUNICATIONS, Physical Link] to 'Fiber Optic'. Ensure that the relay address and baud rate settings in the application software are set the same as those in cell [0E04 COMMUNICATIONS, Baud Rate] of the relay. Check that, using the Master Station, communications with the relay can be established.

CM

#### 5.2.8.2 IEC60870-5-103 (VDEW) communications

If the relay has the optional fiber optic communications port fitted, the port to be used should be selected by setting cell [0E07: COMMUNICATIONS, Physical Link] to 'Fiber Optic'.

IEC60870-5-103/VDEW communication systems are designed to have a local Master Station and this should be used to verify that the relay's fiber optic or EIA(RS)485 port, as appropriate, is working.

Ensure that the relay address and baud rate settings in the application software are set the same as those in cell [0E04: COMMUNICATIONS, Baud Rate] of the relay.

Check that, using the Master Station, communications with the relay can be established.

#### 5.2.8.3 DNP 3.0 interface

Connect a portable PC running the appropriate DNP 3.0 software to the relay's EIA(RS)485 port via an EIA(RS)232 interface converter. The terminal numbers for the relay's EIA(RS)485 port are given in Table 5. Ensure that the relay address, baud rate and parity are set the same as those in cells [0E04: COMMUNICATIONS, Baud Rate] and [0E05: COMMUNICATIONS, Parity] of the relay.

Check that communications with this relay can be established.

If the relay has the optional fiber optic communications port fitted, the port to be used should be selected by setting cell [0E07: COMMUNICATIONS, Physical Link] to 'Fiber Optic'. Ensure that the relay address and baud rate settings in the application software are set the same as those in cell [0E04: COMMUNICATIONS, Baud Rate] of the relay.

Check that, using the Master Station, communications with the relay can be established.

5.2.8.4 MODBUS communications

Connect a portable PC running the appropriate MODBUS Master Station software to the relays first rear EIA(RS)485 port via an EIA(RS)485 to EIA(RS)232 interface converter. The terminal numbers for the relays EIA(RS)485 port are given in Table 8.

Ensure that the relay address, baud rate and parity settings in the application software are set the same as those in cells [0E02: COMMUNICATIONS, Remote Address], [0E04: COMMUNICATIONS, Baud Rate] and [0E05: COMMUNICATIONS, Parity] of the relay.

Check that communications with this relay can be established.

5.2.9 Second rear communications port

This test should only be performed where the relay is to be accessed from a remote location and will vary depending on the communications standard being adopted.

It is not the intention of the test to verify the operation of the complete system from the relay to the remote location, just the relays rear communications port and any protocol converter necessary.

5.2.9.1 K-Bus configuration

If a K-Bus to EIA(RS)232 KITZ protocol converter is installed, connect a portable PC running the appropriate software (e.g. MiCOM S1 or PAS&T) to the incoming (remote from relay) side of the protocol converter.

If a KITZ protocol converter is not installed, it may not be possible to connect the PC to the relay installed. In this case a KITZ protocol converter and portable PC running appropriate software should be temporarily connected to the relays second rear communications port configured for K-Bus. The terminal numbers for the relays K-Bus port are given in Table 9. However, as the installed protocol converter is not being used in the test, only the correct operation of the relays K-Bus port will be confirmed.

| Pin* | Connection |
|---|---|
| 4 | EIA(RS)485 - 1 (+ ve) |
| 7 | EIA(RS)485 - 2 (- ve) |

Table 9: 2nd rear communications port K-Bus terminals

* - All other pins unconnected.

Ensure that the communications baud rate and parity settings in the application software are set the same as those on the protocol converter (usually a KITZ but could be a SCADA RTU). The relays courier address in cell [0E90: COMMUNICATIONS, RP2 Address] must be set to a value between 1 and 254. The second rear communications port configuration [0E88: COMMUNICATIONS RP2 Port Config.] must be set to K-Bus.

Check that communications can be established with this relay using the portable PC.

5.2.9.2 EIA(RS)485 configuration

If an EIA(RS)485 to EIA(RS)232 converter (AREVA T&D CK222) is installed, connect a portable PC running the appropriate software (e.g. MiCOM S1) to the EIA(RS)232 side of the converter and the second rear communications port of the relay to the EIA(RS)485 side of the converter.

The terminal numbers for the relays EIA(RS)485 port are given in Table 9.

Ensure that the communications baud rate and parity settings in the application software are set the same as those in the relay. The relays courier address in cell [0E90: COMMUNICATIONS, RP2 Address] must be set to a value between 1 and 254. The second rear communications port configuration [0E88: COMMUNICATIONS RP2 Port Config.] must be set to EIA(RS)485.

Check that communications can be established with this relay using the portable PC.

### 5.2.9.3 EIA(RS)232 configuration

Connect a portable PC running the appropriate software (e.g. MiCOM S1) to the rear EIA(RS)232[1] port of the relay.

The second rear communications port connects via the 9-way female D-type connector (SK4). The connection is compliant to EIA(RS)574.

| Pin | Connection |
|---|---|
| 1 | No Connection |
| 2 | RxD |
| 3 | TxD |
| 4 | DTR# |
| 5 | Ground |
| 6 | No Connection |
| 7 | RTS# |
| 8 | CTS# |
| 9 | No Connection |

Table 10: Second rear communications port EIA(RS)232 terminals

# - These pins are control lines for use with a modem.

Connections to the second rear port configured for EIA(RS)232 operation can be made using a screened multi-core communication cable up to 15m long, or a total capacitance of 2500pF. The cable should be terminated at the relay end with a 9-way, metal shelled, D-type male plug. The terminal numbers for the relays EIA(RS)232 port are given in Table 10.

Ensure that the communications baud rate and parity settings in the application software are set the same as those in the relay. The relays courier address in cell [0E90: COMMUNICATIONS, RP2 Address] must be set to a value between 1 and 254. The second rear communications port configuration [0E88: COMMUNICATIONS RP2 Port Config.] must be set to EIA(RS)232.

Check that communications can be established with this relay using the portable PC.

CM

### 5.2.10 Current inputs

This test verifies that the accuracy of current measurement is within the acceptable tolerances.

All relays will leave the factory set for operation at a system frequency of 50Hz. If operation at 60Hz is required then this must be set in cell [0009: SYSTEM DATA, Frequency].

Apply current equal to the line current transformer secondary winding rating to each current transformer input of the corresponding rating in turn, see Table 1 or external connection diagram (P145/EN IN) for appropriate terminal numbers, checking its magnitude using a multimeter/test set readout. The corresponding reading can then be checked in the relay's MEASUREMENTS 1 column and value displayed recorded.

The measured current values displayed on the relay LCD or a portable PC connected to the front communication port will either be in primary or secondary Amperes. If cell [0D02: MEASURE'T SETUP, Local Values] 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' menu column (see Table 6). If cell [0D02: MEASURE'T SETUP, Local Values] is set to 'Secondary', the value displayed should be equal to the applied current.

[1] This port is actually compliant to EIA(RS)574; the 9-pin version of EIA(RS)232, see www.tiaonline.org.

Note: If a PC connected to the relay via the rear communications port is being used to display the measured current, the process will be similar. However, the setting of cell [0D03: MEASURE'T SETUP, Remote Values] 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.

| Cell in MEASUREMENTS 1 column (02) | Corresponding CT Ratio (in 'CT and VT RATIOS' column(0A) of menu) |
|---|---|
| [0201: IA Magnitude]<br>[0203: IB Magnitude]<br>[0205: IC Magnitude] | [0A07 : Phase CT Primary] / [0A08 : Phase CT Secondary] |
| [0232: IN Measured Magnitude] | [0A07 : E/F CT Primary] / [0A08 : E/F CT Secondary] |
| [0232: ISEF Magnitude] | [0A07 : SEF CT Primary] / [0A08 : SEF CT Secondary] |

Table 6: CT ratio settings

### 5.2.11 Voltage inputs

This test verifies that the accuracy of voltage measurement is within the acceptable tolerances.

Apply rated voltage to each voltage transformer input in turn, checking its magnitude using a multimeter/test set readout. Refer to Table 7 for the corresponding reading in the relay's MEASUREMENTS 1 column and record the value displayed.

| | Voltage Applied To |
|---|---|
| Cell in MEASUREMENTS 1 column | MiCOM P145 |
| [021A: VAN Magnitude] | C19 - C22 |
| [021C: VBN Magnitude] | C20 - C22 |
| [021E: VCN Magnitude] | C21 - C22 |
| [022E: C/S Voltage Mag.] | C23 - C24 |

Table 7: Voltage input terminals

The measured voltage values on the relay LCD or a portable PC connected to the front communication port will either be in primary or secondary volts. If cell [0D02: MEASURE'T SETUP, Local Values] is set to 'Primary', the values displayed should be equal to the applied voltage multiplied by the corresponding voltage transformer ratio set in the 'VT and CT RATIOS' menu column (see Table 8). If cell [0D02: MEASURE'T SETUP, Local Values] is set to 'Secondary', the value displayed should be equal to the applied voltage.

Note: If a PC connected to the relay via the rear communications port is being used to display the measured voltage, the process will be similar. However, the setting of cell [0D03: MEASURE'T SETUP, Remote Values] will determine whether the displayed values are in primary or secondary Volts.

The measurement accuracy of the relay is ±1%. However, an additional allowance must be made for the accuracy of the test equipment being used.

| Cell in MEASUREMENTS 1 column (02) | Corresponding CT Ratio (in 'CT and VT RATIO' column(0A) of menu) |
|---|---|
| [021A: VAN Magnitude]<br>[021C: VBN Magnitude]<br>[021E: VCN Magnitude] | $\frac{\text{[0A01 : Main VT Primary]}}{\text{[0A02 : Main VT Secondary]}}$ |
| [022E: C/S Voltage Mag.] | $\frac{\text{[0A03 : C/S VT Primary]}}{\text{[0A04 : C/S VT Secondary]}}$ |

Table 8: VT ratio settings

# 6. SETTING CHECKS

The setting checks ensure that all of the application-specific relay settings (i.e. both the relay's function and programmable scheme logic settings), for the particular installation, have been correctly applied to the relay.

If the application-specific settings are not available, ignore sections 6.1 and 6.2.

Note: 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 methods of applying the settings to the relay:

Transferring them from a pre-prepared setting file to the relay using a portable PC running the appropriate software via the relay's front EIA(RS)232 port, located under the bottom access cover, or rear communications port (with a KITZ protocol converter connected). This method is preferred for transferring function settings as it is much faster and there is less margin for error. If programmable scheme logic other than the default settings with which the relay is supplied are to be used then this is the only way of changing the settings.

If a setting file has been created for the particular application and provided on a diskette, this will further reduce the commissioning time and should always be the case where application-specific programmable scheme logic is to be applied to the relay.

Enter them manually via the relay's operator interface. This method is not suitable for changing the programmable scheme logic.

Note: It is essential that where the installation needs application-specific Programmable Scheme Logic, that the appropriate .psl file is downloaded (sent) to the relay, for each and every setting group that will be used. If the user fails to download the required .psl file to any setting group that may be brought into service, then factory default PSL will still be resident. This may have severe operational and safety consequences.



## 6.2 Demonstrate correct relay operation

Tests 5.2.9 and 5.2.10 have already demonstrated that the relay is within calibration, thus the purpose of these tests is as follows:

- To determine that the primary protection functions of the relay, overcurrent, earth-fault etc. can trip according to the correct application settings.
- To verify correct assignment of the trip contacts, by monitoring the response to a selection of fault injections.

### 6.2.1 Overcurrent protection testing

This test, performed on stage 1 of the overcurrent 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 [3502: GROUP 1 OVERCURRENT, I>1 Direction] is set to 'Directional Fwd' or 'Directional Rev.' as tests detailed already confirm the correct functionality between current and voltage inputs, processor and outputs and earlier checks confirmed the measurement accuracy is within the stated tolerance.

#### 6.2.1.1 Connection and preliminaries

Determine which output relay has been selected to operate when an I>1 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 has not been available then the default output relay allocations will still be applicable.

If the trip outputs are phase-segregated (i.e. a different output relay allocated for each phase), the relay assigned for tripping on 'A' phase faults should be used.

If stage 1 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.

The associated terminal numbers can be found from the external connection diagram (P145/EN IN).

Connect the output relay so that its operation will trip the test set and stop the timer.

Connect the current output of the test set to the 'A' phase current transformer input of the relay (terminals C3 and C2 where 1A current transformers are being used and terminals C1 and C2 for 5A current transformers).

If [3502: GROUP 1 OVERCURRENT, I>1 Direction] is set to 'Directional Fwd', the current should flow out of terminal C2 but into C2 if set to 'Directional Rev'.

If cell [351D: GROUP 1 OVERCURRENT, VCO Status] is set to 'Enabled' (overcurrent function configured for voltage controlled overcurrent operation) or [3502: GROUP 1 OVERCURRENT, I>1 Direction] has been set to 'Directional Fwd' or 'Directional Rev' then rated voltage should be applied to terminals C20 and C21.

Ensure that the timer will start when the current is applied to the relay.

Note: If the timer does not start 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.

6.2.1.2 Perform the test

Ensure that the timer is reset.

Apply a current of twice the setting in cell [3503: GROUP 1 OVERCURRENT, I>1 Current Set] to the relay and note the time displayed when the timer stops.

Check that the red trip LED has illuminated. The display will show Alarms/Faults present and the Alarm and Trip LEDs will illuminate. To view the alarm message press the read key, repeat presses of this key should be used to verify that phase A was the "Start Element". Keep pressing the key until the yellow alarm LED changes from flashing to being steadily on. At the prompt 'Press clear to reset alarms', press the 'C' key. This will clear the fault record from the display.

6.2.1.3 Check the operating time

Check that the operating time recorded by the timer is within the range shown in Table 9.

Note: Except for the definite time characteristic, the operating times given in Table 12 are for a time multiplier or time dial setting of 1. Therefore, to obtain the operating time at other time multiplier or time dial settings, the time given in Table 12 must be multiplied by the setting of cell [3505: GROUP 1 OVERCURRENT, I>1 TMS] for IEC and UK characteristics or cell [3506: GROUP 1 OVERCURRENT, Time Dial] for IEEE and US characteristics.

In addition, for definite time and inverse characteristics there is an additional delay of up to 0.02 second and 0.08 second respectively that may need to be added to the relay's acceptable range of operating times.

For all characteristics, allowance must be made for the accuracy of the test equipment being used.

| Characteristic | Operating Time at Twice Current Setting and Time Multiplier/Time Dial Setting of 1.0 | |
|---|---|---|
| | Nominal (Seconds) | Range (Seconds) |
| DT | [3504: I>1 Time Delay] Setting | Setting ±5% |
| IEC S Inverse | 10.03 | 9.53 - 0.53 |
| IEC V Inverse | 13.50 | 12.83 - 14.18 |
| IEC E Inverse | 26.67 | 24.67 - 28.67 |
| UK LT Inverse | 120.00 | 114.00 - 126.00 |
| IEEE M Inverse | 3.8 | 3.61 - 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 |

Table 9: Characteristic operating times for I>1

Reconfigure to test a B phase fault. Repeat the test in section 6.2.1.2, this time ensuring that the breaker trip contacts relative to B phase operation close correctly. Record the phase B trip time. Repeat for C phase fault. Switch OFF the ac supply and reset the alarms.

## 6.3 Check trip and auto-reclose cycle



If the auto-reclose function is being used, the circuit breaker trip and auto-reclose cycle can be tested automatically at the application-specific settings.

To test the first three-phase auto-reclose cycle, set cell [0F11: COMMISSION TESTS, Test Auto-reclose] to '3 Pole Test'. The relay will perform a trip/reclose cycle. Repeat this operation to test the subsequent three-phase auto-reclose cycles.

Check all output relays used for circuit breaker tripping and closing, blocking other devices, etc. operate at the correct times during the trip/close cycle.

## 6.4 Disable all commissioning testing options

Ensure that all Test Mode, and Static Test options have been **disabled**. Clear, then re-read any alarms present to be certain that no alarms relating to these test options remain.

## 6.5 Check application settings

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 the injection test.

There are two methods of checking the settings:

- Extract the settings from the relay using a portable PC running the appropriate software via the front EIA(RS)232 port, located under the bottom access cover, or rear communications port (with a KITZ protocol converter connected). Compare the settings transferred from the relay with the original written application-specific setting record. (For cases where the customer has only provided a printed copy of the required settings but a portable PC is available).
- Step through the settings using the relay's operator interface and compare them with the original application-specific setting record. Ensure that all protection elements required have been ENABLED in the CONFIGURATION column.

Unless previously agreed to the contrary, the application-specific programmable scheme logic will not be checked as part of the commissioning tests.

# 7. ON-LOAD CHECKS

The objectives of the on-load checks are to:

- Confirm the external wiring to the current and voltage inputs is correct.
- Check the polarity of the line current transformers at each end is consistent.
- Directionality check for directional elements.

However, these checks can only be carried out if there are no restrictions preventing the energization of the plant being protected and the other P145 relays in the group have been commissioned.

Remove all test leads, temporary shorting leads, etc. and replace any external wiring that has been removed to allow testing.

If it has been necessary to disconnect any of the external wiring from the relay in order to perform any of the foregoing tests, it should be ensured that all connections are replaced in accordance with the relevant external connection or scheme diagram.

## 7.1 Confirm current and voltage transformer wiring

### 7.1.1 Voltage connections

Using a multimeter measure the voltage transformer secondary voltages to ensure they are correctly rated. Check that the system phase rotation is correct using a phase rotation meter.

Compare the values of the secondary phase voltages with the relay's measured values, which can be found in the MEASUREMENTS 1 menu column.

| Voltage | Cell in MEASUREMENTS 1 column (02) | Corresponding VT Ratio in 'VT and CT RATIO' column (0A) of menu) |
|---|---|---|
| VAB | [0214: VAB Magnitude] | [0A01 : Main VT Primary] / [0A02 : Main VT Secondary] |
| VBC | [0216: VBC Magnitude] | |
| VCA | [0218: VCA Magnitude] | |
| VAN | [021A: VAN Magnitude] | |
| VBN | [021C: VBN Magnitude] | |
| VCN | [021E: VCN Magnitude] | |
| VCHECKSYNC. | [022E: C/S Voltage Mag.] | [0A03 : C/S VT Primary] / [0A04 : C/S VT Secondary] |

Table 10: Measured voltages and VT ratio settings

If cell [0D02: MEASURE'T. SETUP, Local Values] is set to 'Secondary', the values displayed on the relay LCD or a portable PC connected to the front EIA(RS)232 communication port 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 cell [0D02: MEASURE'T. SETUP, Local Values] 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' menu column (see Table 10). Again the values should be within 1% of the expected value, plus an additional allowance for the accuracy of the test equipment being used.

7.1.2 Current connections

Measure the current transformer secondary values for each input using a multimeter connected in series with the corresponding relay current input.

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 center.

Ensure the current flowing in the neutral circuit of the current transformers is negligible.

Compare the values of the secondary phase currents and phase angle with the relay's measured values, which can be found in the MEASUREMENTS 1 menu column.

If cell [0D02: MEASURE'T. SETUP, Local Values] is set to 'Secondary', the currents displayed on the LCD or a portable PC connected to the front EIA(RS)232 communication port of the relay should be equal to the applied secondary current. The values should be within 1% of the applied secondary currents. However, an additional allowance must be made for the accuracy of the test equipment being used.

If cell [0D02: MEASURE'T. SETUP, Local Values] is set to 'Primary', the currents displayed on the relay should be equal to the applied secondary current multiplied by the corresponding current transformer ratio set in 'CT & VT RATIOS' menu column (see Table 9). Again the values should be within 1% of the expected value, plus an additional allowance for the accuracy of the test equipment being used.

## 7.2 On load directional test

This test is important to ensure that directionalized overcurrent and fault locator functions have the correct forward/reverse response to fault and load conditions.

Firstly the actual direction of power flow on the system must be ascertained, using adjacent instrumentation or protection already in-service, or a knowledge of the prevailing network operation conditions.

– For load current flowing in the Forward direction - i.e. power export to the remote line end, cell [0301: MEASUREMENTS 2, A Phase Watts] should show **positive** power signing.

– For load current flowing in the Reverse direction - i.e. power import from the remote line end, cell [0301: MEASUREMENTS 2, A Phase Watts] should show **negative** power signing.

Note: The check above applies only for Measurement Modes 0 (default), and 2. This should be checked in [0D05: MEASURE'T. SETUP, Measurement Mode = 0 or 2]. If measurement modes 1 or 3 are used, the expected power flow signing would be opposite to that shown in the bullets above.

In the event of any uncertainty, check the phase angle of the phase currents with respect to the their phase voltage.

# 8. FINAL CHECKS

The tests are now complete.

**Remove all test or temporary shorting leads, etc. If it has been necessary to disconnect any of the external wiring from the relay in order to perform the wiring verification tests, it should be ensured that all connections (wiring, fuses and links) are replaced in accordance with the relevant external connection or scheme diagram.**

Ensure that the relay has been restored to service by checking that cell
[0F0D: COMMISSION TESTS, Test Mode] is set to 'Disabled'.

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 cell [0609: CB CONDITION, Reset All Values]. If the required access level is not active, the relay will prompt for a password to be entered so that the setting change can be made.

If the menu language has been changed to allow accurate testing it should be restored to the customer's preferred language.

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.

Ensure that all event records, fault records, disturbance records, alarms and LEDs have been reset before leaving the relay.

If applicable, replace the secondary front cover on the relay.

# 9. COMMISSIONING TEST RECORD

| | | | |
|---|---|---|---|
| Date: | | Engineer: | |
| Station: | | Circuit: | |
| | | System Frequency: | Hz |
| VT Ratio: | / V | CT Ratio (tap in use): | / A |

**Front Plate Information**

| | |
|---|---|
| Feeder protection relay | **MiCOM P145** |
| Model number | |
| Serial number | |
| Rated current In | 1A ☐ 5A ☐ |
| Rated voltage Vn | |
| Auxiliary voltage Vx | |

**Test Equipment Used**

This section should be completed to allow future identification of protective devices that have been commissioned using equipment that is later found to be defective or incompatible but may not be detected during the commissioning procedure.

| | | |
|---|---|---|
| Injection test set | Model:<br>Serial No: | |
| Phase angle meter | Model:<br>Serial No: | |
| Phase rotation meter | Model:<br>Serial No: | |
| Insulation tester | Model:<br>Serial No: | |
| Setting software: | Type:<br>Version: | |

*Delete as appropriate

| | | |
|---|---|---|
| | Have all relevant safety instructions been followed? | Yes* ☐ No* ☐ |
| 5. | **Product Checks** | |
| 5.1 | **With the relay de-energized** | |
| 5.1.1 | Visual inspection | |
| | Relay damaged? | Yes* ☐ No* ☐ |
| | Rating information correct for installation? | Yes* ☐ No* ☐ |
| | Case earth installed? | Yes* ☐ No* ☐ |
| 5.1.2 | Current transformer shorting contacts close? | Yes* ☐ No* ☐<br>Not checked* ☐ |
| 5.1.3 | Insulation resistance >100MΩ at 500V dc | Yes* ☐ No* ☐<br>Not Tested* ☐ |
| 5.1.4 | External wiring | |
| | Wiring checked against diagram? | Yes* ☐ No* ☐ |
| | Test block connections checked? | Yes* ☐ No* ☐<br>N/A* ☐ |
| 5.1.5 | Watchdog contacts (auxiliary supply off) | |
| | Terminals 11 and 12 Contact closed? | Yes* ☐ No* ☐ |
| | Terminals 13 and 14 Contact open? | Yes* ☐ No* ☐ |
| 5.1.6 | Measured auxiliary supply | _____ V ac/dc* |
| 5.2 | **With the relay energized** | |
| 5.2.1 | Watchdog contacts (auxiliary supply on) | |
| | Terminals 11 and 12 Contact open? | Yes* ☐ No* ☐ |
| | Terminals 13 and 14 Contact closed? | Yes* ☐ No* ☐ |
| 5.2.2 | LCD front panel display | |
| | LCD contrast setting used | _____ |
| 5.2.3 | Date and time | |
| | Clock set to local time? | Yes* ☐ No* ☐ |
| | Time maintained when auxiliary supply removed? | Yes* ☐ No* ☐ |

CM

5.2.4 Light emitting diodes

| | |
|---|---|
| Alarm (yellow) LED working? | Yes* ☐ No* ☐ |
| Out of service (yellow) LED working? | Yes* ☐ No* ☐ |

5.2.4.3 All 18 programmable LEDs working? Yes* ☐ No* ☐

5.2.5 Field supply voltage

Value measured between terminals 8 and 9 ______ V dc

5.2.6 Input opto-isolators

| | | |
|---|---|---|
| Opto input 1 | working? | Yes* ☐ No* ☐ |
| Opto input 2 | working? | Yes* ☐ No* ☐ |
| Opto input 3 | working? | Yes* ☐ No* ☐ |
| Opto input 4 | working? | Yes* ☐ No* ☐ |
| Opto input 5 | working? | Yes* ☐ No* ☐ |
| Opto input 6 | working? | Yes* ☐ No* ☐ |
| Opto input 7 | working? | Yes* ☐ No* ☐ |
| Opto input 8 | working? | Yes* ☐ No* ☐ |
| Opto input 9 | working? | Yes* ☐ No* ☐ |
| Opto input 10 | working? | Yes* ☐ No* ☐ |
| Opto input 11 | working? | Yes* ☐ No* ☐ |
| Opto input 12 | working? | Yes* ☐ No* ☐ |
| Opto input 13 | working? | Yes* ☐ No* ☐ N/A* ☐ |
| Opto input 14 | working? | Yes* ☐ No* ☐ N/A* ☐ |
| Opto input 15 | working? | Yes* ☐ No* ☐ N/A* ☐ |
| Opto input 16 | working? | Yes* ☐ No* ☐ N/A* ☐ |
| Opto input 17 | working? | Yes* ☐ No* ☐ N/A* ☐ |
| Opto input 18 | working? | Yes* ☐ No* ☐ N/A* ☐ |
| Opto input 19 | working? | Yes* ☐ No* ☐ N/A* ☐ |
| Opto input 20 | working? | Yes* ☐ No* ☐ N/A* ☐ |
| Opto input 21 | working? | Yes* ☐ No* ☐ N/A* ☐ |

| | | |
|---|---|---|
| Opto input 22 | working? | Yes* ☐ No* ☐ N/A* ☐ |
| Opto input 23 | working? | Yes* ☐ No* ☐ N/A* ☐ |
| Opto input 24 | working? | Yes* ☐ No* ☐ N/A* ☐ |
| Opto input 25 | working? | Yes* ☐ No* ☐ |
| Opto input 26 | working? | Yes* ☐ No* ☐ N/A* ☐ |
| Opto input 27 | working? | Yes* ☐ No* ☐ N/A* ☐ |
| Opto input 28 | working? | Yes* ☐ No* ☐ N/A* ☐ |
| Opto input 29 | working? | Yes* ☐ No* ☐ N/A* ☐ |
| Opto input 30 | working? | Yes* ☐ No* ☐ N/A* ☐ |
| Opto input 31 | working? | Yes* ☐ No* ☐ N/A* ☐ |
| Opto input 32 | working? | Yes* ☐ No* ☐ N/A* ☐ |

5.2.7 Output relays

| | | |
|---|---|---|
| Relay 1 | working? | Yes* ☐ No* ☐ |
| Relay 2 | working? | Yes* ☐ No* ☐ |
| Relay 3 | working? | Yes* ☐ No* ☐ |
| Relay 4 | working? | Yes* ☐ No* ☐ |
| Relay 5 | working? | Yes* ☐ No* ☐ |
| Relay 6 | working? | Yes* ☐ No* ☐ |
| Relay 7 | working? | Yes* ☐ No* ☐ |
| Relay 8 | working? | Yes* ☐ No* ☐ |
| Relay 9 | working? | Yes* ☐ No* ☐ |
| Relay 10 | working? | Yes* ☐ No* ☐ |
| Relay 11 | working? | Yes* ☐ No* ☐ |
| Relay 12 | working? | Yes* ☐ No* ☐ |
| Relay 13 | working? | Yes* ☐ No* ☐ N/A* ☐ |
| Relay 14 | working? | Yes* ☐ No* ☐ N/A* ☐ |
| Relay 15 | working? | Yes* ☐ No* ☐ N/A* ☐ |

| | | |
|---|---|---|
| Relay 16 | working? | Yes* ☐ No* ☐ N/A* ☐ |
| Relay 17 | working? | Yes* ☐ No* ☐ N/A* ☐ |
| Relay 18 | working? | Yes* ☐ No* ☐ N/A* ☐ |
| Relay 19 | working? | Yes* ☐ No* ☐ N/A* ☐ |
| Relay 20 | working? | Yes* ☐ No* ☐ N/A* ☐ |
| Relay 21 | working? | Yes* ☐ No* ☐ N/A* ☐ |
| Relay 22 | working? | Yes* ☐ No* ☐ N/A* ☐ |
| Relay 23 | working? | Yes* ☐ No* ☐ N/A* ☐ |
| Relay 24 | working? | Yes* ☐ No* ☐ N/A* ☐ |
| Relay 25 | working? | Yes* ☐ No* ☐ N/A* ☐ |
| Relay 26 | working? | Yes* ☐ No* ☐ N/A* ☐ |
| Relay 27 | working? | Yes* ☐ No* ☐ N/A* ☐ |
| Relay 28 | working? | Yes* ☐ No* ☐ N/A* ☐ |
| Relay 29 | working? | Yes* ☐ No* ☐ N/A* ☐ |
| Relay 30 | working? | Yes* ☐ No* ☐ N/A* ☐ |
| Relay 31 | working? | Yes* ☐ No* ☐ N/A* ☐ |
| Relay 32 | working? | Yes* ☐ No* ☐ N/A* ☐ |

| | | |
|---|---|---|
| 5.2.8 | Communication standard | Courier/MODBUS/ IEC60870-5-103/DNP3.0*/ UCA2.0 |
| | Communications established? | Yes* ☐ No* ☐ |
| | Protocol converter tested? | Yes* ☐ No* ☐ N/A* ☐ |

CM

5.2.9 Current inputs

| | | |
|---|---|---|
| Displayed current | | Primary* ☐ Secondary* ☐ |
| Phase CT ratio | | _____ N/A* ☐ |
| Earth fault CT ratio | | _____ N/A* ☐ |
| SEF CT ratio | | _____ N/A* ☐ |
| Input CT | Applied Value | Displayed Value |
| IA | _____ A | _____ A |
| IB | _____ A | _____ A |
| IC | _____ A | _____ A |
| IN | _____ A N/A* ☐ | _____ A N/A* ☐ |
| IN Sensitive/ISEF | _____ A | _____ A |

5.2.10 Voltage inputs

| | | |
|---|---|---|
| Displayed voltage | | Primary* ☐ Secondary* ☐ |
| Main VT ratio | | _____ N/A* ☐ |
| C/S VT ratio | | _____ N/A* ☐ |
| Input VT | Applied Value | Displayed value |
| VAN | _____ V | _____ V |
| VBN | _____ V | _____ V |
| VCN | _____ V | _____ V |
| C/S voltage | _____ V N/A* ☐ | _____ V |

6. Setting Checks

| | | |
|---|---|---|
| 6.1 | Application-specific function settings applied? | Yes* ☐ No* ☐ |
| | Application-specific programmable scheme logic settings applied? | Yes* ☐ No* ☐ N/A* ☐ |

| | | |
|---|---|---|
| 6.2 | Protection function timing tested? | Yes* ☐ No* ☐ |
| | Overcurrent type (set in cell [I>1 Direction]) | Directional* ☐ Non-Directional* ☐ |
| | Applied voltage | _____ V / N/A* |
| | Applied current | _____ A |
| | Expected operating time | _____ s |
| | Measured operating time | _____ s |

| | | |
|---|---|---|
| 6.3 | Trip and auto-reclose cycle checked | Yes* ☐ No* ☐ N/A* ☐ |

CM

| | | |
|---|---|---|
| 6.4 | All commissioning test options disabled? | Yes* ☐ No* ☐ |
| 6.5 | Application-specific function settings verified? | Yes* ☐ No* ☐ N/A* ☐ |
| | Application-specific programmable scheme logic tested? | Yes* ☐ No* ☐ N/A* ☐ |

| | | |
|---|---|---|
| 7. | On-load checks | |
| | Test wiring removed? | Yes* ☐ No* ☐ |
| 7.1.1 | Voltage inputs and phase rotation OK? | Yes* ☐ No* ☐ |
| 7.1.2 | Current inputs and polarities OK? | Yes* ☐ No* ☐ |
| 7.2 | On-load test performed? | Yes* ☐ No* ☐ |
| | (If “No”, give reason why) … | |
| | Relay is correctly directionalized? | Yes* ☐ No* ☐ N/A* ☐ |

| | | |
|---|---|---|
| 8. | Final Checks | |
| | All test equipment, leads, shorts and test blocks removed safely? | Yes* ☐ No* ☐ |
| | Disturbed customer wiring re-checked? | Yes* ☐ No* ☐ N/A* ☐ |
| | All commissioning tests disabled? | Yes* ☐ No* ☐ |
| | Circuit breaker operations counter reset? | Yes* ☐ No* ☐ N/A* ☐ |
| | Current counters reset? | Yes* ☐ No* ☐ N/A* ☐ |
| | Event records reset? | Yes* ☐ No* ☐ |
| | Fault records reset? | Yes* ☐ No* ☐ |
| | Disturbance records reset? | Yes* ☐ No* ☐ |
| | Alarms reset? | Yes* ☐ No* ☐ |
| | LEDs reset? | Yes* ☐ No* ☐ |
| | Secondary front cover replaced? | Yes* ☐ No* ☐ N/A* ☐ |

| COMMENTS # |
|---|
| |
| (# Optional, for site observations or utility-specific notes). |

CM

| Commissioning Engineer | Customer Witness |
|---|---|
| Date: | Date: |

# 10. SETTING RECORD

| | | | |
|---|---|---|---|
| Date: | | Engineer: | |
| Station: | | Circuit: | |
| | | System Frequency: | Hz |
| VT Ratio: | / V | CT Ratio (tap in use): | / A |

**Front Plate Information**

| | |
|---|---|
| Feeder protection relay | **MiCOM P145** |
| Model number | |
| Serial number | |
| Rated current In | 1A ☐ 5A ☐ |
| Rated voltage Vn | |
| Auxiliary voltage Vx | |

**Setting Groups Used**

*Delete as appropriate

| | |
|---|---|
| Group 1 | Yes* ☐ No* ☐ |
| Group 2 | Yes* ☐ No* ☐ |
| Group 3 | Yes* ☐ No* ☐ |
| Group 4 | Yes* ☐ No* ☐ |

**0000 SYSTEM DATA**

| | | |
|---|---|---|
| 0001 | Language | English* ☐ Francais* ☐ Deutsche* ☐ Espanol* ☐ |
| 0002 | Password | |
| 0003 | Sync. Fn. Links | |
| 0004 | Description | |
| 0005 | Plant Reference | |
| 0006 | Model Number | |
| 0008 | Serial Number | |
| 0009 | Frequency | |
| 000B | Relay Address | |
| 0011 | Software Ref. 1 | |
| 00D1 | Password Control | Level 0* ☐ Level 1* ☐ Level 2* ☐ |
| 00D2 | Password Level 1 | |
| 00D3 | Password Level 2 | |

CM

**0700 CB CONTROL**

| | | |
|---|---|---|
| 0701 | CB Control by | Disabled* ☐ Local* ☐ Remote* ☐<br>Local + Remote* ☐ Opto* ☐<br>Opto + Remote* ☐ Opto + Rem. + Local ☐ |
| 0702 | Close Pulse Time | |
| 0703 | Trip Pulse Time | |
| 0704 | Man Close t Max. | |
| 0705 | Man Close Delay | |
| 0706 | CB Healthy Time | |
| 0707 | Check Sync. Time | |
| 0709 | Reset Lockout by | User Interface* ☐ CB Close* ☐ |
| 070A | Man Close RstDly. | |
| 070B | AR TeleControl | No Operation* ☐ Auto* ☐ Non-Auto ☐ |
| 070C | Single Pole A/R | Disabled* ☐ Enabled* ☐ |
| 070D | Three Pole A/R | Disabled* ☐ Enabled* ☐ |
| 0711 | CB Status Input | |

**0800 DATE AND TIME**

| | | |
|---|---|---|
| 0804 | IRIG-B Sync. | Disabled* ☐ Enabled* ☐ |
| 0807 | Battery Alarm | Disabled* ☐ Enabled* ☐ |

**0900 CONFIGURATION**

| | | |
|---|---|---|
| 0902 | Setting Group | Select via Menu* ☐ Select via Optos* ☐ |
| 0903 | Active Settings | Group 1* ☐ Group 2* ☐ Group 3* ☐<br>Group 4* ☐ |
| 0907 | Setting Group 1 | Disabled* ☐ Enabled* ☐ |
| 0908 | Setting Group 2 | Disabled* ☐ Enabled* ☐ |
| 0909 | Setting Group 3 | Disabled* ☐ Enabled* ☐ |
| 090A | Setting Group 4 | Disabled* ☐ Enabled* ☐ |
| 0910 | Overcurrent | Disabled* ☐ Enabled* ☐ |
| 0911 | Neg. Sequence O/C | Disabled* ☐ Enabled* ☐ |
| 0912 | Broken Conductor | Disabled* ☐ Enabled* ☐ |
| 0913 | Earth Fault 1 | Disabled* ☐ Enabled* ☐ |
| 0914 | Earth Fault 2 | Disabled* ☐ Enabled* ☐ |
| 0915 | SEF/REF Prot'n. | Disabled* ☐ Enabled* ☐ |
| 0916 | Residual O/V NVD | Disabled* ☐ Enabled* ☐ |
| 0917 | Thermal Overload | Disabled* ☐ Enabled* ☐ |
| 0918 | Neg. Sequence O/V | Disabled* ☐ Enabled* ☐ |
| 0919 | Cold Load Pickup | Disabled* ☐ Enabled* ☐ |
| 091A | Selective Logic | Disabled* ☐ Enabled* ☐ |
| 091D | Volt Protection | Disabled* ☐ Enabled* ☐ |

CM

**0900 CONFIGURATION**

| | | | | | |
|---|---|---|---|---|---|
| 0920 | CB Fail | Disabled* | ☐ | Enabled* | ☐ |
| 0921 | Supervision | Disabled* | ☐ | Enabled* | ☐ |
| 0922 | Fault Locator | Disabled* | ☐ | Enabled* | ☐ |
| 0923 | System Checks | Disabled* | ☐ | Enabled* | ☐ |
| 0924 | Auto-Reclose | Disabled* | ☐ | Enabled* | ☐ |
| 0925 | Input Labels | Invisible* | ☐ | Visible* | ☐ |
| 0926 | Output Labels | Invisible* | ☐ | Visible* | ☐ |
| 0928 | CT & VT Ratios | Invisible* | ☐ | Visible* | ☐ |
| 0929 | Event Recorder | Invisible* | ☐ | Visible* | ☐ |
| 092A | Disturb Recorder | Invisible* | ☐ | Visible* | ☐ |
| 092B | Measure’t. Setup | Invisible* | ☐ | Visible* | ☐ |
| 092C | Comms. Settings | Invisible* | ☐ | Visible* | ☐ |
| 092D | Commissioning Tests | Invisible* | ☐ | Visible* | ☐ |
| 092E | Setting Values | Primary* | ☐ | Secondary* | ☐ |

**0A00 CT AND VT RATIOS**

| | | |
|---|---|---|
| 0A01 | Main VT Primary | |
| 0A02 | Main VT Sec'y. | |
| 0A03 | C/S VT Primary | |
| 0A04 | C/S VT Secondary | |
| 0A07 | Phase CT Primary | |
| 0A08 | Phase CT Sec'y. | |
| 0A09 | E/F CT Primary | |
| 0A0A | E/F CT Sec'y. | |
| 0A0B | E/F CT Primary | |
| 0A0C | E/F CT Sec'y. | |
| 0A0F | C/S Input | A – N* ☐ B – N* ☐ C – N* ☐<br>A – B* ☐ B – C* ☐ C – A* ☐ |
| 0A10 | Main VT Location | Line* ☐ Bus* ☐ |

**0B00 RECORD CONTROL**

| | | | | | |
|---|---|---|---|---|---|
| 0B04 | Alarm Event | Disabled* | ☐ | Enabled* | ☐ |
| 0B05 | Relay O/P Event | Disabled* | ☐ | Enabled* | ☐ |
| 0B06 | Opto Input Event | Disabled* | ☐ | Enabled* | ☐ |
| 0B07 | General Event | Disabled* | ☐ | Enabled* | ☐ |
| 0B08 | Fault Rec. Event | Disabled* | ☐ | Enabled* | ☐ |
| 0B09 | Maint. Rec. Event | Disabled* | ☐ | Enabled* | ☐ |
| 0B0A | Protection Event | Disabled* | ☐ | Enabled* | ☐ |

**0C00 DISTURB. RECORDER**

| | | | | | |
|---|---|---|---|---|---|
| 0C01 | Duration | | | | |
| 0C02 | Trigger Position | Single* | ☐ | Extended* | ☐ |
| 0C04 | Analog Channel 1 | | | | |
| 0C05 | Analog Channel 2 | | | | |
| 0C06 | Analog Channel 3 | | | | |
| 0C07 | Analog Channel 4 | | | | |
| 0C08 | Analog Channel 5 | | | | |
| 0C09 | Analog Channel 6 | | | | |
| 0C0A | Analog Channel 7 | | | | |
| 0C0B | Analog Channel 8 | | | | |
| 0C0C | Digital Input 1 | | | | |
| 0C0D | Input 1 Trigger | No Trigger*<br>Trigger H – L* | ☐<br>☐ | Trigger L – H* | ☐ |
| 0C0E | Digital Input 2 | | | | |
| 0C0F | Input 2 Trigger | No Trigger*<br>Trigger H – L* | ☐<br>☐ | Trigger L – H* | ☐ |
| 0C10 | Digital Input 3 | | | | |
| 0C11 | Input 3 Trigger | No Trigger*<br>Trigger H – L* | ☐<br>☐ | Trigger L – H* | ☐ |
| 0C12 | Digital Input 4 | | | | |
| 0C13 | Input 4 Trigger | No Trigger*<br>Trigger H – L* | ☐<br>☐ | Trigger L – H* | ☐ |
| 0C14 | Digital Input 5 | | | | |
| 0C15 | Input 5 Trigger | No Trigger*<br>Trigger H – L* | ☐<br>☐ | Trigger L – H* | ☐ |
| 0C16 | Digital Input 6 | | | | |
| 0C17 | Input 6 Trigger | No Trigger*<br>Trigger H – L* | ☐<br>☐ | Trigger L – H* | ☐ |
| 0C18 | Digital Input 7 | | | | |
| 0C19 | Input 7 Trigger | No Trigger*<br>Trigger H – L* | ☐<br>☐ | Trigger L – H* | ☐ |
| 0C1A | Digital Input 8 | | | | |
| 0C1B | Input 8 Trigger | No Trigger*<br>Trigger H – L* | ☐<br>☐ | Trigger L – H* | ☐ |
| 0C1C | Digital Input 9 | | | | |
| 0C1D | Input 9 Trigger | No Trigger*<br>Trigger H – L* | ☐<br>☐ | Trigger L – H* | ☐ |
| 0C1E | Digital Input 10 | | | | |
| 0C1F | Input 10 Trigger | No Trigger*<br>Trigger H – L* | ☐<br>☐ | Trigger L – H* | ☐ |

| 0C00 | DISTURB. RECORDER | | | | |
|---|---|---|---|---|---|
| 0C20 | Digital Input 11 | | | | |
| 0C21 | Input 11 Trigger | No Trigger*<br>Trigger H – L* | ☐<br>☐ | Trigger L – H* | ☐ |
| 0C22 | Digital Input 12 | | | | |
| 0C23 | Input 12 Trigger | No Trigger*<br>Trigger H – L* | ☐<br>☐ | Trigger L – H* | ☐ |
| 0C24 | Digital Input 13 | | | | |
| 0C25 | Input 13 Trigger | No Trigger*<br>Trigger H – L* | ☐<br>☐ | Trigger L – H* | ☐ |
| 0C26 | Digital Input 14 | | | | |
| 0C27 | Input 14 Trigger | No Trigger*<br>Trigger H – L* | ☐<br>☐ | Trigger L – H* | ☐ |
| 0C28 | Digital Input 15 | | | | |
| 0C29 | Input 15 Trigger | No Trigger*<br>Trigger H – L* | ☐<br>☐ | Trigger L – H* | ☐ |
| 0C2A | Digital Input 16 | | | | |
| 0C2B | Input 16 Trigger | No Trigger*<br>Trigger H – L* | ☐<br>☐ | Trigger L – H* | ☐ |
| 0C2C | Digital Input 17 | | | | |
| 0C2D | Input 17 Trigger | No Trigger*<br>Trigger H – L* | ☐<br>☐ | Trigger L – H* | ☐ |
| 0C2E | Digital Input 18 | | | | |
| 0C2F | Input 18 Trigger | No Trigger*<br>Trigger H – L* | ☐<br>☐ | Trigger L – H* | ☐ |
| 0C30 | Digital Input 19 | | | | |
| 0C31 | Input 19 Trigger | No Trigger*<br>Trigger H – L* | ☐<br>☐ | Trigger L – H* | ☐ |
| 0C32 | Digital Input 20 | | | | |
| 0C33 | Input 20 Trigger | No Trigger*<br>Trigger H – L* | ☐<br>☐ | Trigger L – H* | ☐ |
| 0C34 | Digital Input 21 | | | | |
| 0C35 | Input 21 Trigger | No Trigger*<br>Trigger H – L* | ☐<br>☐ | Trigger L – H* | ☐ |
| 0C36 | Digital Input 22 | | | | |
| 0C37 | Input 22 Trigger | No Trigger*<br>Trigger H – L* | ☐<br>☐ | Trigger L – H* | ☐ |
| 0C38 | Digital Input 23 | | | | |
| 0C39 | Input 23 Trigger | No Trigger*<br>Trigger H – L* | ☐<br>☐ | Trigger L – H* | ☐ |
| 0C3A | Digital Input 24 | | | | |

**0C00 DISTURB. RECORDER**

| | | |
|---|---|---|
| 0C3B | Input 24 Trigger | No Trigger* ☐ Trigger L – H* ☐ Trigger H – L* ☐ |
| 0C3C | Digital Input 25 | |
| 0C3D | Input 25 Trigger | No Trigger* ☐ Trigger L – H* ☐ Trigger H – L* ☐ |
| 0C3E | Digital Input 26 | |
| 0C3F | Input 26 Trigger | No Trigger* ☐ Trigger L – H* ☐ Trigger H – L* ☐ |
| 0C40 | Digital Input 27 | |
| 0C41 | Input 27 Trigger | No Trigger* ☐ Trigger L – H* ☐ Trigger H – L* ☐ |
| 0C42 | Digital Input 28 | |
| 0C43 | Input 28 Trigger | No Trigger* ☐ Trigger L – H* ☐ Trigger H – L* ☐ |
| 0C44 | Digital Input 29 | |
| 0C45 | Input 29 Trigger | No Trigger* ☐ Trigger L – H* ☐ Trigger H – L* ☐ |
| 0C46 | Digital Input 30 | |
| 0C47 | Input 30 Trigger | No Trigger* ☐ Trigger L – H* ☐ Trigger H – L* ☐ |
| 0C48 | Digital Input 31 | |
| 0C49 | Input 31 Trigger | No Trigger* ☐ Trigger L – H* ☐ Trigger H – L* ☐ |
| 0C4A | Digital Input 32 | |
| 0C4B | Input 32 Trigger | No Trigger* ☐ Trigger L – H* ☐ Trigger H – L* ☐ |

CM

**0D00 MEASURE'T. SETUP**

| | | |
|---|---|---|
| 0D01 | Default Display | 3Ph + N Current* ☐ 3h Voltage* ☐ Power* ☐ Date & Time* ☐ Description* ☐ Plant Reference* ☐ Frequency* ☐ Access Level* ☐ |
| 0D02 | Local Values | Primary* ☐ Secondary* ☐ |
| 0D03 | Remote Values | Primary* ☐ Secondary* ☐ |
| 0D04 | Measurement Ref. | VA* ☐ VB* ☐ VC* ☐ IA* ☐ IB* ☐ IC* ☐ |
| 0D05 | Measurement Mode | |
| 0D06 | Fix Dem. Period | |
| 0D07 | Roll Sub Period | |
| 0D08 | Num. Sub Periods | |

**0D00 MEASURE'T. SETUP**

| | | |
|---|---|---|
| 0D09 | Distance Unit | Kilometres* ☐ Miles* ☐ |
| 0D0A | Fault Location | Distance* ☐ Ohms* ☐ % of Line* ☐ |

**0E00 COMMUNICATIONS**

| | | |
|---|---|---|
| 0E01 | RP1 Protocol | Courier* ☐ IEC870-5-103* ☐<br>MODBUS* ☐ DNP3.0* ☐ |
| 0E02 | RP1 Address | |
| 0E03 | RP1 InactivTimer | |
| 0E04 | RP1 Baud Rate | 1200* ☐ 2400* ☐ 4800* ☐<br>9600* ☐ 19200* ☐ 38400* ☐ |
| 0E05 | RP1 Parity | Odd* ☐ Even* ☐ None* ☐ |
| 0E06 | RP1 Meas. Period | |
| 0E07 | RP1 PhysicalLink | EIA(RS)485* ☐ Fiber Optic* ☐ |
| 0E08 | RP1 Time Sync. | Disabled* ☐ Enabled* ☐ |
| 0E0A | RP1 CS103Blocking | Disabled* ☐ Monitor Blocking* ☐<br>Command Blocking* ☐ |
| 0E88 | RP2 Port Config. | K Bus* ☐ EIA(RS)485* ☐ |
| 0E8A | RP2 Comms. Mode | IEC60870 FT1.2* ☐ 10-Bit Frame* ☐ |
| 0E90 | RP2 Address | |
| 0E92 | RP2 InactivTimer | |
| 0E94 | RP2 Baud Rate | 9600* ☐ 19200* ☐ 38400* ☐ |
| 0E1F | Ethernet Comms. | UCA2.0 ☐ |
| 0E20 | IP Address | |
| 0E21 | Subnet Mask | |
| 0E24 | Number of Routes | |
| 0E25 | Router Address 1 | |
| 0E26 | Target Network 1 | |
| 0E27 | Router Address 2 | |
| 0E28 | Target Network 2 | |
| 0E29 | Router Address 3 | |
| 0E2A | Target Network 3 | |
| 0E2B | Router Address 4 | |
| 0E2C | Target Address 4 | |
| 0E2D | Inactivity Timer | |
| 0E2E | Default Pass Level | |
| 0E2F | GOOSE Min. Cycle | |
| 0E30 | GOOSE Max. Cycle | |
| 0E31 | GOOSE Increment | |
| 0E32 | GOOSE Start-up | Promiscuous ☐ Broadcast ☐ |
| 0E3D | Ethernet Media | Copper ☐ Fiber ☐ |

**0F00 COMMISSION TESTS**

| | | |
|---|---|---|
| 0F05 | Monitor Bit 1 | |
| 0F06 | Monitor Bit 2 | |
| 0F07 | Monitor Bit 3 | |
| 0F08 | Monitor Bit 4 | |
| 0F09 | Monitor Bit 5 | |
| 0F0A | Monitor Bit 6 | |
| 0F0B | Monitor Bit 7 | |
| 0F0C | Monitor Bit 8 | |
| 0F0D | Test Mode | Disabled* ☐ Test Mode* ☐<br>Contacts Blocked* ☐ |

**1000 CB MONITOR SETUP**

| | | |
|---|---|---|
| 1001 | Broken I^ | |
| 1002 | I^ Maintenance | Alarm Disabled* ☐ Alarm Enabled* ☐ |
| 1003 | I^ Maintenance | |
| 1004 | I^ Lockout | Alarm Disabled* ☐ Alarm Enabled* ☐ |
| 1005 | I^ Lockout | |
| 1006 | No. CB Ops. Maint. | Alarm Disabled* ☐ Alarm Enabled* ☐ |
| 1007 | No. CB Ops. Maint. | |
| 1008 | No. CB Ops. Lock | Alarm Disabled* ☐ Alarm Enabled* ☐ |
| 1009 | No. CB Ops. Lock | |
| 100A | CB Time Maint. | Alarm Disabled* ☐ Alarm Enabled* ☐ |
| 100B | CB Time Maint. | |
| 100C | CB Time Lockout | Alarm Disabled* ☐ Alarm Enabled* ☐ |
| 100D | CB Time Lockout | |
| 100E | Fault Freq. Lock | Alarm Disabled* ☐ Alarm Enabled* ☐ |
| 100F | Fault Freq. Count | |
| 1010 | Fault Freq. Time | |



**1100 OPTO CONFIG.**

| | | |
|---|---|---|
| 1101 | Global Nominal V | |
| 1102 | Opto Input 1 | |
| 1103 | Opto Input 2 | |
| 1104 | Opto Input 3 | |
| 1105 | Opto Input 4 | |
| 1106 | Opto Input 5 | |
| 1107 | Opto Input 6 | |
| 1108 | Opto Input 7 | |
| 1109 | Opto Input 8 | |
| 110A | Opto Input 9 | |

**1100 OPTO CONFIG.**

| | | |
|---|---|---|
| 110B | Opto Input 10 | |
| 110C | Opto Input 11 | |
| 110D | Opto Input 12 | |
| 110E | Opto Input 13 | |
| 110F | Opto Input 14 | |
| 1110 | Opto Input 15 | |
| 1111 | Opto Input 16 | |
| 1112 | Opto Input 17 | |
| 1113 | Opto Input 18 | |
| 1114 | Opto Input 19 | |
| 1115 | Opto Input 20 | |
| 1116 | Opto Input 21 | |
| 1117 | Opto Input 22 | |
| 1118 | Opto Input 23 | |
| 1119 | Opto Input 24 | |
| 111A | Opto Input 25 | |
| 111B | Opto Input 26 | |
| 111C | Opto Input 27 | |
| 111D | Opto Input 28 | |
| 111E | Opto Input 29 | |
| 111F | Opto Input 30 | |
| 1120 | Opto Input 31 | |
| 1121 | Opto Input 32 | |
| 1150 | Filter Control | |
| 1180 | Characteristic | Standard 60% - 80%* ☐ 50% - 70%* ☐ |

**1300 CTRL. I/P CONFIG.**

| | | |
|---|---|---|
| 1301 | Hotkey Enabled | |
| 1310 | Control Input 1 | Latched* ☐ Pulsed* ☐ |
| 1311 | Ctrl Command 1 | |
| 1314 | Control Input 2 | Latched* ☐ Pulsed* ☐ |
| 1315 | Ctrl Command 2 | |
| 1318 | Control Input 3 | Latched* ☐ Pulsed* ☐ |
| 1319 | Ctrl Command 3 | |
| 131C | Control Input 4 | Latched* ☐ Pulsed* ☐ |
| 131D | Ctrl Command 4 | |
| 1320 | Control Input 5 | Latched* ☐ Pulsed* ☐ |
| 1321 | Ctrl Command 5 | |
| 1324 | Control Input 6 | Latched* ☐ Pulsed* ☐ |
| 1325 | Ctrl Command 6 | |

**1300 CTRL. I/P CONFIG.**

| | | | | | |
|---|---|---|---|---|---|
| 1328 | Control Input 7 | Latched* | ☐ | Pulsed* | ☐ |
| 1329 | Ctrl Command 7 | | | | |
| 132C | Control Input 8 | Latched* | ☐ | Pulsed* | ☐ |
| 132D | Ctrl Command 8 | | | | |
| 1330 | Control Input 9 | Latched* | ☐ | Pulsed* | ☐ |
| 1331 | Ctrl Command 9 | | | | |
| 1334 | Control Input 10 | Latched* | ☐ | Pulsed* | ☐ |
| 1335 | Ctrl Command 10 | | | | |
| 1338 | Control Input 11 | Latched* | ☐ | Pulsed* | ☐ |
| 1339 | Ctrl Command 11 | | | | |
| 133C | Control Input 12 | Latched* | ☐ | Pulsed* | ☐ |
| 133C | Ctrl Command 12 | | | | |
| 1340 | Control Input 13 | Latched* | ☐ | Pulsed* | ☐ |
| 1341 | Ctrl Command 13 | | | | |
| 1344 | Control Input 14 | Latched* | ☐ | Pulsed* | ☐ |
| 1345 | Ctrl Command 14 | | | | |
| 1348 | Control Input 15 | Latched* | ☐ | Pulsed* | ☐ |
| 1349 | Ctrl Command 15 | | | | |
| 134C | Control Input 16 | Latched* | ☐ | Pulsed* | ☐ |
| 134D | Ctrl Command 16 | | | | |
| 1350 | Control Input 17 | Latched* | ☐ | Pulsed* | ☐ |
| 1351 | Ctrl Command 17 | | | | |
| 1354 | Control Input 18 | Latched* | ☐ | Pulsed* | ☐ |
| 1355 | Ctrl Command 18 | | | | |
| 1358 | Control Input 19 | Latched* | ☐ | Pulsed* | ☐ |
| 1359 | Ctrl Command 19 | | | | |
| 135C | Control Input 20 | Latched* | ☐ | Pulsed* | ☐ |
| 135D | Ctrl Command 20 | | | | |
| 1360 | Control Input 21 | Latched* | ☐ | Pulsed* | ☐ |
| 1361 | Ctrl Command 21 | | | | |
| 1364 | Control Input 22 | Latched* | ☐ | Pulsed* | ☐ |
| 1365 | Ctrl Command 22 | | | | |
| 1368 | Control Input 23 | Latched* | ☐ | Pulsed* | ☐ |
| 1369 | Ctrl Command 23 | | | | |
| 136C | Control Input 24 | Latched* | ☐ | Pulsed* | ☐ |
| 136D | Ctrl Command 24 | | | | |
| 1370 | Control Input 25 | Latched* | ☐ | Pulsed* | ☐ |
| 1371 | Ctrl Command 25 | | | | |
| 1374 | Control Input 26 | Latched* | ☐ | Pulsed* | ☐ |
| 1375 | Ctrl Command 26 | | | | |

CM

**1300 CTRL. I/P CONFIG.**

| | | | | | |
|---|---|---|---|---|---|
| 1378 | Control Input 27 | Latched* | ☐ | Pulsed* | ☐ |
| 1379 | Ctrl Command 27 | | | | |
| 137C | Control Input 28 | Latched* | ☐ | Pulsed* | ☐ |
| 137D | Ctrl Command 28 | | | | |
| 1380 | Control Input 29 | Latched* | ☐ | Pulsed* | ☐ |
| 1381 | Ctrl Command 29 | | | | |
| 1384 | Control Input 30 | Latched* | ☐ | Pulsed* | ☐ |
| 1385 | Ctrl Command 30 | | | | |
| 1388 | Control Input 31 | Latched* | ☐ | Pulsed* | ☐ |
| 1389 | Ctrl Command 31 | | | | |
| 138C | Control Input 32 | Latched* | ☐ | Pulsed* | ☐ |
| 138D | Ctrl Command 32 | | | | |

**1700 FUNCTION KEYS**

| | | | | | |
|---|---|---|---|---|---|
| 1702 | Fn. Key 1 Status | Unlock* | ☐ | Enable* | ☐ |
| 1703 | Fn. Key 1 Mode | Normal* | ☐ | Toggle* | ☐ |
| 1704 | Fn. Key 1 Label | | | | |
| 1705 | Fn. Key 2 Status | Unlock* | ☐ | Enable* | ☐ |
| 1706 | Fn. Key 2 Mode | Normal* | ☐ | Toggle* | ☐ |
| 1707 | Fn. Key 2 Label | | | | |
| 1708 | Fn. Key 3 Status | Unlock* | ☐ | Enable* | ☐ |
| 1709 | Fn. Key 3 Mode | Normal* | ☐ | Toggle* | ☐ |
| 170A | Fn. Key 3 Label | | | | |
| 170B | Fn. Key 4 Status | Unlock* | ☐ | Enable* | ☐ |
| 170C | Fn. Key 4 Mode | Normal* | ☐ | Toggle* | ☐ |
| 170D | Fn. Key 4 Label | | | | |
| 170E | Fn. Key 5 Status | Unlock* | ☐ | Enable* | ☐ |
| 170F | Fn. Key 5 Mode | Normal* | ☐ | Toggle* | ☐ |
| 1710 | Fn. Key 5 Label | | | | |
| 1711 | Fn. Key 6 Status | Unlock* | ☐ | Enable* | ☐ |
| 1712 | Fn. Key 6 Mode | Normal* | ☐ | Toggle* | ☐ |
| 1713 | Fn. Key 6 Label | | | | |
| 1714 | Fn. Key 7 Status | Unlock* | ☐ | Enable* | ☐ |
| 1715 | Fn. Key 7 Mode | Normal* | ☐ | Toggle* | ☐ |
| 1716 | Fn. Key 7 Label | | | | |
| 1717 | Fn. Key 8 Status | Unlock* | ☐ | Enable* | ☐ |
| 1718 | Fn. Key 8 Mode | Normal* | ☐ | Toggle* | ☐ |
| 1719 | Fn. Key 8 Label | | | | |
| 171A | Fn. Key 9 Status | Unlock* | ☐ | Enable* | ☐ |
| 171B | Fn. Key 9 Mode | Normal* | ☐ | Toggle* | ☐ |

**1700 FUNCTION KEYS**

| | | | | | |
|---|---|---|---|---|---|
| 171C | Fn. Key 9 Label | | | | |
| 171D | Fn. Key 10 Status | Unlock* | ☐ | Enable* | ☐ |
| 171E | Fn. Key 10 Mode | Normal* | ☐ | Toggle* | ☐ |
| 171F | Fn. Key 10 Label | | | | |

**2900 CNTRL. I/P LABELS**

| | | |
|---|---|---|
| 2901 | Control Input 1 | |
| 2902 | Control Input 2 | |
| 2903 | Control Input 3 | |
| 2904 | Control Input 4 | |
| 2905 | Control Input 5 | |
| 2906 | Control Input 6 | |
| 2907 | Control Input 7 | |
| 2908 | Control Input 8 | |
| 2909 | Control Input 9 | |
| 290A | Control Input 10 | |
| 290B | Control Input11 | |
| 290C | Control Input 12 | |
| 290D | Control Input 13 | |
| 290E | Control Input 14 | |
| 290F | Control Input 15 | |
| 2910 | Control Input 16 | |
| 2911 | Control Input 17 | |
| 2912 | Control Input 18 | |
| 2913 | Control Input 19 | |
| 2914 | Control Input 20 | |
| 2915 | Control Input 21 | |
| 2916 | Control Input 22 | |
| 2917 | Control Input 23 | |
| 2918 | Control Input 24 | |
| 2919 | Control Input 25 | |
| 291A | Control Input 26 | |
| 291B | Control Input 27 | |
| 291C | Control Input 28 | |
| 291D | Control Input 29 | |
| 291E | Control Input 30 | |
| 291F | Control Input 31 | |
| 2920 | Control Input 32 | |

**3500 OVERCURRENT**

| Group 1 Settings | | Group 1 Settings | Group 2 Settings | Group 3 Settings | Group 4 Settings |
|---|---|---|---|---|---|
| 3523 | I>1 Function | | | | |
| 3524 | I>1 Direction | | | | |
| 3527 | I>1 Current Set | | | | |
| 3529 | I>1 Time Delay | | | | |
| 352A | I>1 TMS | | | | |
| 352B | I>1 Time Dial | | | | |
| 352C | I>1 k(RI) | | | | |
| 352E | I>1 Reset Char. | | | | |
| 352F | I>1 tRESET | | | | |
| 3532 | I>2 Function | | | | |
| 3533 | I>2 Direction | | | | |
| 3536 | I>2 Current Set | | | | |
| 3538 | I>2 Time Delay | | | | |
| 3539 | I>2 TMS | | | | |
| 353A | I>2 Time Dial | | | | |
| 353B | I>2 k(RI) | | | | |
| 353D | I>2 Reset Char. | | | | |
| 353E | I>2 tRESET | | | | |
| 3540 | I>3 Status | | | | |
| 3541 | I>3 Direction | | | | |
| 3544 | I>3 Current Set | | | | |
| 3545 | I>3 Time Delay | | | | |
| 3547 | I>4 Status | | | | |
| 3548 | I>4 Direction | | | | |
| 354B | I>4 Current Set | | | | |
| 354C | I>4 Time Delay | | | | |
| 354E | I> Blocking | | | | |
| 354F | I> Char Angle | | | | |
| 3551 | V CONTROLLED O/C | | | | |
| 3552 | VCO Status | | | | |
| 3553 | VCO V< Setting | | | | |
| 3554 | VCO k Setting | | | | |

**3600 NEG. SEQ. O/C**

| Group 1 Settings | | Group 1 Settings | Group 2 Settings | Group 3 Settings | Group 4 Settings |
|---|---|---|---|---|---|
| 3610 | I2>1 Status | | | | |
| 3612 | I2>1 Direction | | | | |
| 3615 | I2>1 Current Set | | | | |
| 3617 | I2>1 Time Delay | | | | |
| 3620 | I2>2 Status | | | | |
| 3622 | I2>2 Direction | | | | |
| 3625 | I2>2 Current Set | | | | |
| 3627 | I2>2 Time Delay | | | | |
| 3630 | I2>3 Status | | | | |
| 3632 | I2>3 Direction | | | | |
| 3635 | I2>3 Current Set | | | | |
| 3637 | I2>3 Time Delay | | | | |
| 3640 | I2>4 Status | | | | |
| 3642 | I2>4 Direction | | | | |
| 3645 | I2>4 Current Set | | | | |
| 3647 | I2>4 Time Delay | | | | |
| 3650 | I2> Blocking | | | | |
| 3651 | I2> Char. Angle | | | | |
| 3652 | I2> V2pol Set | | | | |

**3700 BROKEN CONDUCTOR**

| Group 1 Settings | | Group 1 Settings | Group 2 Settings | Group 3 Settings | Group 4 Settings |
|---|---|---|---|---|---|
| 3701 | Broken Conductor | | | | |
| 3702 | I2/I1 Setting | | | | |
| 3703 | I2/I1 Time Delay | | | | |

**3800 EARTH FAULT1 (Measured)**

| Group 1 Settings | | Group 1 Settings | Group 2 Settings | Group 3 Settings | Group 4 Settings |
|---|---|---|---|---|---|
| 3801 | IN1> Input | | | | |
| 3825 | IN1>1 Function | | | | |
| 3826 | IN1>1 Direction | | | | |
| 3829 | IN1>1 Current | | | | |
| 382A | IN1>1 IDG Is | | | | |
| 382C | IN1>1 Time Delay | | | | |
| 382D | IN1>1 TMS | | | | |
| 382E | IN1>1 Time Dial | | | | |
| 382F | IN1>1 k(RI) | | | | |

**3800 EARTH FAULT1 (Measured)**

| Group 1 Settings | | Group 1 Settings | Group 2 Settings | Group 3 Settings | Group 4 Settings |
|---|---|---|---|---|---|
| 3830 | IN1>1 IDG Time | | | | |
| 3832 | IN1>1 Reset Char. | | | | |
| 3833 | IN1>1 tRESET | | | | |
| 3836 | IN1>2 Function | | | | |
| 3837 | IN1>2 Direction | | | | |
| 383A | IN1>2 Current | | | | |
| 383B | IN1>2 IDG Is | | | | |
| 383D | IN1>2 Time Delay | | | | |
| 383E | IN1>2 TMS | | | | |
| 383F | IN1>2 Time Dial | | | | |
| 3840 | IN1>2 k(RI) | | | | |
| 3841 | IN1>2 IDG Time | | | | |
| 3843 | IN1>2 Reset Char. | | | | |
| 3844 | IN1>2 tRESET | | | | |
| 3846 | IN1>3 Status | | | | |
| 3847 | IN1>3 Direction | | | | |
| 384A | IN1>3 Current | | | | |
| 384B | IN1>3 Time Delay | | | | |
| 384D | IN1>4 Status | | | | |
| 384E | IN1>4 Direction | | | | |
| 3851 | IN1>4 Current | | | | |
| 3852 | IN1>4 Time Delay | | | | |
| 3854 | IN1> Blocking | | | | |
| 3855 | IN1> POL | | | | |
| 3856 | IN1> Char. Angle | | | | |
| 3857 | IN1> Pol | | | | |
| 3859 | IN1> VNpol Set | | | | |
| 385A | IN1> V2pol Set | | | | |
| 385B | IN1> I2pol Set | | | | |

CM

**3900 EARTH FAULT2 (Derived)**

| Group 1 Settings | | Group 1 Settings | Group 2 Settings | Group 3 Settings | Group 4 Settings |
|---|---|---|---|---|---|
| 3901 | IN1> Input | | | | |
| 3925 | IN1>1 Function | | | | |
| 3926 | IN1>1 Direction | | | | |
| 3929 | IN1>1 Current | | | | |
| 392A | IN1>1 IDG Is | | | | |

**3900 EARTH FAULT2 (Derived)**

| Group 1 Settings | | Group 1 Settings | Group 2 Settings | Group 3 Settings | Group 4 Settings |
|---|---|---|---|---|---|
| 392C | IN1>1 Time Delay | | | | |
| 392D | IN1>1 TMS | | | | |
| 392E | IN1>1 Time Dial | | | | |
| 392F | IN1>1 k(RI) | | | | |
| 3930 | IN1>1 IDG Time | | | | |
| 3932 | IN1>1 Reset Char. | | | | |
| 3933 | IN1>1 tRESET | | | | |
| 3936 | IN1>2 Function | | | | |
| 3937 | IN1>2 Direction | | | | |
| 393A | IN1>2 Current | | | | |
| 393B | IN1>2 IDG Is | | | | |
| 393D | IN1>2 Time Delay | | | | |
| 393E | IN1>2 TMS | | | | |
| 393F | IN1>2 Time Dial | | | | |
| 3940 | IN1>2 k(RI) | | | | |
| 3941 | IN1>2 IDG Time | | | | |
| 3943 | IN1>2 Reset Char. | | | | |
| 3944 | IN1>2 tRESET | | | | |
| 3946 | IN1>3 Status | | | | |
| 3947 | IN1>3 Direction | | | | |
| 394A | IN1>3 Current | | | | |
| 394B | IN1>3 Time Delay | | | | |
| 394D | IN1>4 Status | | | | |
| 394E | IN1>4 Direction | | | | |
| 3951 | IN1>4 Current | | | | |
| 3952 | IN1>4 Time Delay | | | | |
| 3954 | IN1> Blocking | | | | |
| 3955 | IN1> POL | | | | |
| 3956 | IN1> Char Angle | | | | |
| 3957 | IN1> Pol | | | | |
| 3959 | IN1> VNpol Set | | | | |
| 395A | IN1> V2pol Set | | | | |
| 395B | IN1> I2pol Set | | | | |

CM

**3A01 SEF/REF PROTECTION**

| Group 1 Settings | | Group 1 Settings | Group 2 Settings | Group 3 Settings | Group 4 Settings |
|---|---|---|---|---|---|
| 3A01 | SEF/REF Options | | | | |
| 3A2A | ISEF>1 Function | | | | |
| 3A2B | ISEF>1 Direction | | | | |
| 3A2E | ISEF>1 Current | | | | |
| 3A2F | ISEF>1 IDG Is | | | | |
| 3A31 | ISEF>1 Delay | | | | |
| 3A32 | ISEF>1 TMS | | | | |
| 3A33 | ISEF>1 Time Dial | | | | |
| 3A34 | ISEF>1 IDG Time | | | | |
| 3A36 | ISEF>1 Reset Char. | | | | |
| 3A37 | ISEF>1 tRESET | | | | |
| 3A3A | ISEF>2 Function | | | | |
| 3A3B | ISEF>2 Direction | | | | |
| 3A3E | ISEF>2 Current | | | | |
| 3A3F | ISEF>2 IDG Is | | | | |
| 3A41 | ISEF>2 Delay | | | | |
| 3A42 | ISEF>2 TMS | | | | |
| 3A43 | ISEF>2 Time Dial | | | | |
| 3A44 | ISEF>2 IDG Time | | | | |
| 3A46 | ISEF>2 Reset Char. | | | | |
| 3A47 | ISEF>2 tRESET | | | | |
| 3A49 | ISEF>3 Status | | | | |
| 3A4A | ISEF>3 Direction | | | | |
| 3A4D | ISEF>3 Current | | | | |
| 3A4E | ISEF>3 Delay | | | | |
| 3A5 | ISEF>4 Status | | | | |
| 3A51 | ISEF>4 Direction | | | | |
| 3A54 | ISEF>4 Current | | | | |
| 3A55 | ISEF>4 Delay | | | | |
| 3A57 | ISEF> Blocking | | | | |
| 3A58 | ISEF POL | | | | |
| 3A59 | ISEF> Char. Angle | | | | |
| 3A5B | ISEF> VNpol Set | | | | |
| 3A5D | WATTMETRIC SEF | | | | |
| 3A5E | PN> Setting | | | | |
| 3A60 | RESTRICTED E/F | | | | |
| 3A61 | IREF> k1 | | | | |
| 3A62 | IREF> k2 | | | | |

**3A01 SEF/REF PROTECTION**

| Group 1 Settings | | Group 1 Settings | Group 2 Settings | Group 3 Settings | Group 4 Settings |
|---|---|---|---|---|---|
| 3A63 | IREF> Is1 | | | | |
| 3A64 | IREF> Is2 | | | | |
| 3A65 | IREF> Is | | | | |

**3B00 RESIDUAL O/V NVD**

| Group 1 Settings | | Group 1 Settings | Group 2 Settings | Group 3 Settings | Group 4 Settings |
|---|---|---|---|---|---|
| 3B01 | VN Input | | | | |
| 3B02 | VN>1 Function | | | | |
| 3B03 | VN>1 Voltage Set | | | | |
| 3B04 | VN>1 Time Delay | | | | |
| 3B05 | VN>1 TMS | | | | |
| 3B06 | VN>1 tReset | | | | |
| 3B07 | VN>2 Status | | | | |
| 3B08 | VN>2 Voltage Set | | | | |
| 3B09 | VN>2 Time Delay | | | | |

**3C00 THERMAL OVERLOAD**

| Group 1 Settings | | Group 1 Settings | Group 2 Settings | Group 3 Settings | Group 4 Settings |
|---|---|---|---|---|---|
| 3C01 | Characteristic | | | | |
| 3C02 | Thermal Trip | | | | |
| 3C03 | Thermal Alarm | | | | |
| 3C04 | Time Constant 1 | | | | |
| 3C05 | Time Constant 2 | | | | |



**3D00 NEG. SEQUENCE O/V**

| Group 1 Settings | | Group 1 Settings | Group 2 Settings | Group 3 Settings | Group 4 Settings |
|---|---|---|---|---|---|
| 3D01 | V2> Status | | | | |
| 3D02 | V2> Voltage Set | | | | |
| 3D03 | V2> Time Delay | | | | |

**3E00 COLD LOAD PICK-UP**

| Group 1 Settings | | Group 1 Settings | Group 2 Settings | Group 3 Settings | Group 4 Settings |
|---|---|---|---|---|---|
| 3E01 | tcold Time Delay | | | | |
| 3E02 | tclp Time Delay | | | | |
| 3E20 | OVERCURRENT | | | | |
| 3E21 | I>1 Status | | | | |

**3E00 COLD LOAD PICK-UP**

| Group 1 Settings | | Group 1 Settings | Group 2 Settings | Group 3 Settings | Group 4 Settings |
|---|---|---|---|---|---|
| 3E22 | I>1 Current Set | | | | |
| 3E24 | I>1 Time Delay | | | | |
| 3E25 | I>1 TMS | | | | |
| 3E26 | I>1 Time Dial | | | | |
| 3E27 | I>1 k(RI) | | | | |
| 3E29 | I>2 Status | | | | |
| 3E2A | I>2 Current Set | | | | |
| 3E2C | I>2 Time Delay | | | | |
| 3E2D | I>2 TMS | | | | |
| 3E2E | I>2 Time Dial | | | | |
| 3E2F | I>2 k(RI) | | | | |
| 3E31 | I>3 Status | | | | |
| 3E32 | I>3 Current Set | | | | |
| 3E33 | I>3 Time Delay | | | | |
| 3E35 | I>4 Status | | | | |
| 3E36 | I>4 Current Set | | | | |
| 3E37 | I>4 Time Delay | | | | |
| 3E39 | STAGE 1 E/F 1 | | | | |
| 3E3A | IN1>1 Status | | | | |
| 3E3B | IN1>1 Current | | | | |
| 3E3C | IN1>1 IDG Is | | | | |
| 3E3E | IN1>1 Time Delay | | | | |
| 3E3F | IN1>1 TMS | | | | |
| 3E40 | IN1>1 Time Dial | | | | |
| 3E41 | IN1>1 k(RI) | | | | |
| 3E43 | STAGE 1 E/F 2 | | | | |
| 3E44 | IN2>1 Status | | | | |
| 3E45 | IN2>1 Current | | | | |
| 3E46 | IN2>1 IDG Is | | | | |
| 3E48 | IN2>1 Time Delay | | | | |
| 3E49 | IN2>1 TMS | | | | |
| 3E4A | IN2>1 Time Dial | | | | |
| 3E4B | IN2>1 k(RI) | | | | |

**3F00 SELECTIVE LOGIC**

| Group 1 Settings | | Group 1 Settings | Group 2 Settings | Group 3 Settings | Group 4 Settings |
|---|---|---|---|---|---|
| 3F01 | OVERCURRENT | | | | |
| 3F02 | I>3 Time Delay | | | | |
| 3F03 | I>4 Time Delay | | | | |
| 3F04 | EARTH FAULT 1 | | | | |
| 3F05 | IN1>3 Time Delay | | | | |
| 3F06 | IN1>4 Time Delay | | | | |
| 3F07 | EARTH FAULT 2 | | | | |
| 3F08 | IN2>3 Time Delay | | | | |
| 3F09 | IN2>4 Time Delay | | | | |
| 3F0A | SENSITIVE E/F | | | | |
| 3F0B | ISEF>3 Delay | | | | |
| 3F0C | ISEF>4 Delay | | | | |

**4000 ADMIT. PROTECTION**

| Group 1 Settings | | Group 1 Settings | Group 2 Settings | Group 3 Settings | Group 4 Settings |
|---|---|---|---|---|---|
| 4001 | VN Threshold | | | | |
| 4002 | CT Input Type | | | | |
| 4003 | Correction Angle | | | | |
| 4004 | OVER ADMITTANCE | | | | |
| 4005 | YN> Status | | | | |
| 4006 | YN> Set | | | | |
| 4007 | YN> Set | | | | |
| 4008 | YN> Time Delay | | | | |
| 4009 | YN> tRESET | | | | |
| 400A | OVER CONDUCTANCE | | | | |
| 400B | GN> Status | | | | |
| 400C | GN> Direction | | | | |
| 400D | GN> Set | | | | |
| 400E | GN> Set | | | | |
| 400F | GN> Time Delay | | | | |
| 4010 | GN> tRESET | | | | |
| 4011 | OVER SUSCEPTANCE | | | | |
| 4012 | BN> Status | | | | |
| 4013 | BN> Direction | | | | |
| 4014 | BN> Set | | | | |

**4200 VOLTAGE PROTECTION**

| Group 1 Settings | | Group 1 Settings | Group 2 Settings | Group 3 Settings | Group 4 Settings |
|---|---|---|---|---|---|
| 4202 | V< Measur't. Mode | | | | |
| 4203 | V< Operate Mode | | | | |
| 4204 | V<1 Function | | | | |
| 4205 | V<1 Voltage Set | | | | |
| 4206 | V<1 Time Delay | | | | |
| 4207 | V<1 TMS | | | | |
| 4208 | V<1 Poledead Inh | | | | |
| 4209 | V<2 Status | | | | |
| 420A | V<2 Voltage Set | | | | |
| 420B | V<2 Time Delay | | | | |
| 420C | V<2 Poledead Inh | | | | |
| 420E | V> Measur't. Mode | | | | |
| 420F | V> Operate Mode | | | | |
| 4210 | V>1 Function | | | | |
| 4211 | V>1 Voltage Set | | | | |
| 4212 | V>1 Time Delay | | | | |
| 4213 | V>1 TMS | | | | |
| 4214 | V>2 Status | | | | |
| 4215 | V>2 Voltage Set | | | | |
| 4216 | V>2 Time Delay | | | | |

**4300 FREQ. PROTECTION**

| Group 1 Settings | | Group 1 Settings | Group 2 Settings | Group 3 Settings | Group 4 Settings |
|---|---|---|---|---|---|
| 4301 | UNDER FREQUENCY | | | | |
| 4302 | F<1 Status | | | | |
| 4303 | F<1 Setting | | | | |
| 4304 | F<1 Time Delay | | | | |
| 4305 | F<2 Status | | | | |
| 4306 | F<2 Setting | | | | |
| 4307 | F<2 Time Delay | | | | |
| 4308 | F<3 Status | | | | |
| 4309 | F<3 Setting | | | | |
| 430A | F<3 Time Delay | | | | |
| 430B | F<4 Status | | | | |
| 430C | F<4 Setting | | | | |
| 430D | F<4 Time Delay | | | | |
| 430E | F< Function Link | | | | |

**4300 FREQ. PROTECTION**

| Group 1 Settings | | Group 1 Settings | Group 2 Settings | Group 3 Settings | Group 4 Settings |
|---|---|---|---|---|---|
| 430F | OVER FREQUENCY | | | | |
| 4310 | F>1 Status | | | | |
| 4311 | F>1 Setting | | | | |
| 4312 | F>1 Time Delay | | | | |
| 4313 | F>2 Status | | | | |
| 4314 | F>2 Setting | | | | |
| 4315 | F>2 Time Delay | | | | |

**4400 DF/DT PROTECTION**

| Group 1 Settings | | Group 1 Settings | Group 2 Settings | Group 3 Settings | Group 4 Settings |
|---|---|---|---|---|---|
| 4401 | df/dt Avg. Cycles | | | | |
| 4404 | df/dt>1 Status | | | | |
| 4405 | df/dt>1 Setting | | | | |
| 4405 | df/dt>1 Dir'n. | | | | |
| 4406 | df/dt>1 Time | | | | |
| 440B | df/dt>2 Status | | | | |
| 440C | df/dt>2 Setting | | | | |
| 440D | df/dt>2 Dir'n. | | | | |
| 440E | df/dt>2 Time | | | | |
| 4412 | df/dt>3 Status | | | | |
| 4413 | df/dt>3 Setting | | | | |
| 4414 | df/dt>3 Dir'n. | | | | |
| 4415 | df/dt>3 Time | | | | |
| 4419 | df/dt>4 Status | | | | |
| 441A | df/dt>4 Setting | | | | |
| 441B | df/dt>4 Dir'n. | | | | |
| 441C | df/dt>4 Time | | | | |

**4500 CB FAIL & I<**

| Group 1 Settings | | Group 1 Settings | Group 2 Settings | Group 3 Settings | Group 4 Settings |
|---|---|---|---|---|---|
| 4502 | CB Fail 1 Status | | | | |
| 4503 | CB Fail 1 Timer | | | | |
| 4504 | CB Fail 2 Status | | | | |
| 4505 | CB Fail 2 Timer | | | | |
| 4506 | Volt Prot. Reset | | | | |
| 4507 | Ext. Prot. Reset | | | | |
| 4508 | WI Prot. Reset | | | | |

**4500 CB FAIL & I<**

| Group 1 Settings | | Group 1 Settings | Group 2 Settings | Group 3 Settings | Group 4 Settings |
|---|---|---|---|---|---|
| 4509 | I< Current Set | | | | |

**4600 SUPERVISION**

| Group 1 Settings | | Group 1 Settings | Group 2 Settings | Group 3 Settings | Group 4 Settings |
|---|---|---|---|---|---|
| 4602 | VTS Status | | | | |
| 4603 | VTS Reset Mode | | | | |
| 4604 | VTS Time Delay | | | | |
| 4605 | VTS I> Inhibit | | | | |
| 4606 | VTS I2> Inhibit | | | | |
| 4608 | CTS Status | | | | |
| 4609 | CTS VN< Inhibit | | | | |
| 460A | CTS IN> Set | | | | |
| 460B | CTS Time Delay | | | | |

**4700 FAULT LOCATOR**

| Group 1 Settings | | Group 1 Settings | Group 2 Settings | Group 3 Settings | Group 4 Settings |
|---|---|---|---|---|---|
| 4701 | Line Length | | | | |
| 4702 | Line Length | | | | |
| 4703 | Line Impedance | | | | |
| 4704 | Line Angle | | | | |
| 4705 | KZN Residual | | | | |
| 4706 | KZN Res. Angle | | | | |

**4800 SYSTEM CHECKS**

| Group 1 Settings | | Group 1 Settings | Group 2 Settings | Group 3 Settings | Group 4 Settings |
|---|---|---|---|---|---|
| 4815 | Live Voltage | | | | |
| 4816 | Dead Voltage | | | | |
| 4818 | CS1 Status | | | | |
| 4819 | CS1 Phase Angle | | | | |
| 481A | CS1 Slip Control | | | | |
| 481B | CS1 Slip Freq. | | | | |
| 481C | CS1 Slip Timer | | | | |
| 481D | CS2 Status | | | | |
| 481E | CS2 Phase Angle | | | | |
| 481F | CS2 Slip Control | | | | |
| 4820 | CS2 Slip Freq. | | | | |

**4800 SYSTEM CHECKS**

| Group 1 Settings | | Group 1 Settings | Group 2 Settings | Group 3 Settings | Group 4 Settings |
|---|---|---|---|---|---|
| 4821 | CS2 Slip Timer | | | | |
| 4822 | CS Undervoltage | | | | |
| 4823 | CS Overvoltage | | | | |
| 4824 | CS Dive. Voltage | | | | |
| 4825 | CS Voltage Block | | | | |
| 4827 | SS Status | | | | |
| 4828 | SS Phase Angle | | | | |
| 4829 | SS Under V Block | | | | |
| 482A | SS Undervoltage | | | | |
| 482B | SS Timer | | | | |
| 482F | CB Close Time | | | | |

**4900 AUTO-RECLOSE**

| Group 1 Settings | | Group 1 Settings | Group 2 Settings | Group 3 Settings | Group 4 Settings |
|---|---|---|---|---|---|
| 4901 | A/R Mode Select | | | | |
| 4902 | Number of Shots | | | | |
| 4903 | Number SEF Shots | | | | |
| 4904 | Sequence Co-ord. | | | | |
| 4905 | CS AR Immediate | | | | |
| 4908 | Dead Time 1 | | | | |
| 4909 | Dead Time 2 | | | | |
| 490A | Dead Time 3 | | | | |
| 490B | Dead Time 4 | | | | |
| 490C | CB Healthy Time | | | | |
| 490D | Start Dead t On | | | | |
| 490E | tReclaim Extend | | | | |
| 490F | Reclaim Time | | | | |
| 4910 | AR Inhibit Time | | | | |
| 4912 | AR Lockout | | | | |
| 4913 | EFF Maint. Lock | | | | |
| 4914 | AR Deselected | | | | |
| 4915 | Manual Close | | | | |
| 4916 | Trip 1 Main | | | | |
| 4917 | Trip 2 Main | | | | |
| 4918 | Trip 3 Main | | | | |
| 4919 | Trip 4 Main | | | | |
| 491A | Trip 5 Main | | | | |

**4900 AUTO-RECLOSE**

| Group 1 Settings | | Group 1 Settings | Group 2 Settings | Group 3 Settings | Group 4 Settings |
|---|---|---|---|---|---|
| 491B | Trip 1 SEF | | | | |
| 491C | Trip 2 SEF | | | | |
| 491D | Trip 3 SEF | | | | |
| 491E | Trip 4 SEF | | | | |
| 491F | Trip 5 SEF | | | | |
| 4920 | Man Close on Flt. | | | | |
| 4921 | Trip AR Inactive | | | | |
| 4922 | Reset Lockout by | | | | |
| 4924 | AR on Man Close | | | | |
| 4925 | Sys. Check Time | | | | |
| 4928 | AR INITIATION | | | | |
| 4929 | I>1 AR | | | | |
| 492A | I>2 AR | | | | |
| 492B | I>3 AR | | | | |
| 492C | I>4 AR | | | | |
| 492D | IN1>1 AR | | | | |
| 492E | IN1>2 AR | | | | |
| 492F | IN1>3 AR | | | | |
| 4930 | IN1>4 AR | | | | |
| 4931 | IN2>1 AR | | | | |
| 4932 | IN2>2 AR | | | | |
| 4933 | IN2>3 AR | | | | |
| 4934 | IN2>4 AR | | | | |
| 4935 | ISEF>1 AR | | | | |
| 4936 | ISEF>2 AR | | | | |
| 4937 | ISEF>3 AR | | | | |
| 4938 | ISEF>4 AR | | | | |
| 4939 | YN> AR | | | | |
| 493A | GN> AR | | | | |
| 493B | BN> AR | | | | |
| 493C | Ext. Prot. | | | | |
| 4940 | SYSTEM CHECKS | | | | |
| 4941 | AR with ChkSync. | | | | |
| 4942 | AR with SysSync. | | | | |
| 4943 | Live/Dead Ccts. | | | | |
| 4944 | No System Checks | | | | |
| 4945 | SysChk. on Shot 1 | | | | |

**4A00 INPUT LABELS**

| Group 1 Settings | | Group 1 Settings | Group 2 Settings | Group 3 Settings | Group 4 Settings |
|---|---|---|---|---|---|
| 4A01 | Opto Input 1 | | | | |
| 4A02 | Opto Input 2 | | | | |
| 4A03 | Opto Input 3 | | | | |
| 4A04 | Opto Input 4 | | | | |
| 4A05 | Opto Input 5 | | | | |
| 4A06 | Opto Input 6 | | | | |
| 4A07 | Opto Input 7 | | | | |
| 4A08 | Opto Input 8 | | | | |
| 4A09 | Opto Input 9 | | | | |
| 4A0A | Opto Input 10 | | | | |
| 4A0B | Opto Input 11 | | | | |
| 4A0C | Opto Input 12 | | | | |
| 4A0D | Opto Input 13 | | | | |
| 4A0E | Opto Input 14 | | | | |
| 4AOF | Opto Input 11 | | | | |
| 4A10 | Opto Input 16 | | | | |
| 4A11 | Opto Input 17 | | | | |
| 4A12 | Opto Input 18 | | | | |
| 4A13 | Opto Input 19 | | | | |
| 4A14 | Opto Input 20 | | | | |
| 4A15 | Opto Input 21 | | | | |
| 4A16 | Opto Input 22 | | | | |
| 4A17 | Opto Input 23 | | | | |
| 4A18 | Opto Input 24 | | | | |
| 4A19 | Opto Input 25 | | | | |
| 4A1A | Opto Input 26 | | | | |
| 4A1B | Opto Input 27 | | | | |
| 4A1C | Opto Input 28 | | | | |
| 4A1D | Opto Input 29 | | | | |
| 4A1E | Opto Input 30 | | | | |
| 4A1F | Opto Input 31 | | | | |
| 4A20 | Opto Input 32 | | | | |

CM

**4B00 OUTPUT LABELS**

| Group 1 Settings | | Group 1 Settings | Group 2 Settings | Group 3 Settings | Group 4 Settings |
|---|---|---|---|---|---|
| 4B01 | Relay 1 | | | | |
| 4B02 | Relay 2 | | | | |
| 4B03 | Relay 3 | | | | |
| 4B04 | Relay 4 | | | | |
| 4B05 | Relay 5 | | | | |
| 4B06 | Relay 6 | | | | |
| 4B07 | Relay 7 | | | | |
| 4B08 | Relay 8 | | | | |
| 4B09 | Relay 9 | | | | |
| 4B0A | Relay 10 | | | | |
| 4B0B | Relay 11 | | | | |
| 4B0C | Relay 12 | | | | |
| 4B0D | Relay 13 | | | | |
| 4B0E | Relay 14 | | | | |
| 4B0F | Relay 15 | | | | |
| 4B10 | Relay 16 | | | | |
| 4B11 | Relay 17 | | | | |
| 4B12 | Relay 18 | | | | |
| 4B13 | Relay 19 | | | | |
| 4B14 | Relay 20 | | | | |
| 4B15 | Relay 21 | | | | |
| 4B16 | Relay 22 | | | | |
| 4B17 | Relay 23 | | | | |
| 4B18 | Relay 24 | | | | |
| 4B19 | Relay 25 | | | | |
| 4B1A | Relay 26 | | | | |
| 4B1B | Relay 27 | | | | |
| 4B1C | Relay 28 | | | | |
| 4B1D | Relay 29 | | | | |
| 4B1E | Relay 30 | | | | |
| 4B1F | Relay 31 | | | | |
| 4B20 | Relay 32 | | | | |

CM

| Commissioning Engineer | Customer Witness |
|---|---|
| Date: | Date: |

# MAINTENANCE

MT

| | |
|---|---|
| **Date:** | **7th July 2005** |
| **Hardware Suffix:** | **J** |
| **Software Version:** | **31** |
| **Connection Diagrams:** | **10P145xx (xx = 01 to 07)** |

MT

# CONTENTS

MT

# 1. MAINTENANCE

## 1.1 Maintenance period

It is recommended that products supplied by AREVA T&D receive periodic monitoring after installation. In view of the critical nature of protective relays and their infrequent operation, it is desirable to confirm that they are operating correctly at regular intervals.

AREVA T&D protective relays are designed for a life in excess of 20 years.

MiCOM relays are self-supervizing and so require less maintenance than earlier designs of relay. Most problems will result in an alarm so that remedial action can be taken. However, some periodic tests should be done to ensure that the relay is functioning correctly and the external wiring is intact.

## 1.2 Maintenance checks

Although some functionality checks can be performed from a remote location by utilizing the communications ability of the relays, these are predominantly restricted to checking that the relay is measuring the applied currents and voltages accurately, and checking the circuit breaker maintenance counters. Therefore it is recommended that maintenance checks are performed locally (i.e. at the substation itself).

**Before carrying out any work on the equipment, the user should be familiar with the contents of the Safety and Technical Data sections and the ratings on the equipment's rating label.**

### 1.2.1 Alarms

The alarm status LED should first be checked to identify if any alarm conditions exist. If so, press the read key [ ] repeatedly to step through the alarms.

Clear the alarms to extinguish the LED.

### 1.2.2 Opto-isolators

The opto-isolated inputs can be checked to ensure that the relay responds to their energization by repeating the commissioning test detailed in section 5.2.6 of the Commissioning section (P145/EN CM).

### 1.2.3 Output relays

The output relays can be checked to ensure that they operate by repeating the commissioning test detailed in section 5.2.7 of the Commissioning section (P145/EN CM).



### 1.2.4 Measurement accuracy

If the power system is energized, the values measured by the relay can be compared with known system values to check that they are in the approximate range that is expected. If they are then the analog/digital conversion and calculations are being performed correctly by the relay. Suitable test methods can be found in sections 7.1.1 and 7.1.2 of the Commissioning section (P145/EN CM).

Alternatively, the values measured by the relay can be checked against known values injected into the relay via the test block, if fitted, or injected directly into the relay terminals. Suitable test methods can be found in sections 5.2.10 and 5.2.11 of the Commissioning section (P145/EN CM). These tests will prove the calibration accuracy is being maintained.

## 1.3 Method of repair

### 1.3.1 MiCOM P145 relay

If the relay should develop a fault whilst in service, depending on the nature of the fault, the watchdog contacts will change state and an alarm condition will be flagged. Due to the extensive use of surface-mount components faulty PCBs should be replaced, as it is not possible to perform repairs on damaged circuits. Thus either the complete relay or just the faulty PCB, identified by the in-built diagnostic software, can be replaced. Advice about identifying the faulty PCB can be found in the Troubleshooting section (P145/EN TS).

The preferred method is to replace the complete relay as it ensures that the internal circuitry is protected against electrostatic discharge and physical damage at all times and overcomes the possibility of incompatibility between replacement PCBs. However, it may be difficult to remove an installed relay due to limited access in the back of the cubicle and rigidity of the scheme wiring.

Replacing PCBs can reduce transport costs but requires clean, dry conditions on site and higher skills from the person performing the repair. However, if the repair is not performed by an approved service center, the warranty will be invalidated.

**Before carrying out any work on the equipment, the user should be familiar with the contents of the Safety and Technical Data sections and the ratings on the equipment's rating label. This should ensure that no damage is caused by incorrect handling of the electronic components.**

#### 1.3.1.1 Replacing the complete relay

The case and rear terminal blocks have been designed to facilitate removal of the complete relay should replacement or repair become necessary without having to disconnect the scheme wiring.

Before working at the rear of the relay, isolate all voltage and current supplies to the relay.

Note: The MiCOM range of relays have integral current transformer shorting switches which will close when the heavy duty terminal block is removed.

Disconnect the relay earth, IRIG-B and fiber optic connections, as appropriate, from the rear of the relay.

There are two types of terminal block used on the relay, medium and heavy duty, which are fastened to the rear panel using crosshead screws, as in Figure 1 of the Commissioning section (P145/EN CM).



Note: The use of a magnetic bladed screwdriver is recommended to minimize the risk of the screws being left in the terminal block or lost.

Without exerting excessive force or damaging the scheme wiring, pull the terminal blocks away from their internal connectors.

Remove the screws used to fasten the relay to the panel, rack, etc. These are the screws with the larger diameter heads that are accessible when the access covers are fitted and open.

**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 secure the front panel to the relay.**

Withdraw the relay carefully from the panel, rack, etc. because it will be heavy due to the internal transformers.

To reinstall the repaired or replacement relay, follow the above instructions in reverse, ensuring that each terminal block is relocated in the correct position and the case earth, IRIG-B and fiber optic connections are replaced. To facilitate easy identification of each terminal block, they are labeled alphabetically with 'A' on the left hand side when viewed from the rear.

Once reinstallation is complete the relay should be re-commissioned using the instructions in sections 1 to 8 of the Commissioning section (P145/EN CM), inclusive of this section.

#### 1.3.1.2 Replacing a PCB

Replacing printed circuit boards and other internal components of protective relays must be undertaken only by Service Centers approved by AREVA T&D. Failure to obtain the authorization of AREVA T&D After Sales Engineers prior to commencing work may invalidate the product warranty.

**Before removing the front panel to replace a PCB the auxiliary supply must be removed, and wait 5s for capacitors to discharge. It is also strongly recommended that the voltage and current transformer connections and trip circuit are isolated.**

AREVA T&D Automation Support teams are available world-wide, and it is strongly recommended that any repairs be entrusted to those trained personnel. For this reason, details on product disassembly and re-assembly are not included here.

## 1.4 Re-calibration

### 1.4.1 P145 relay

Re-calibration is not required when a PCB is replaced **unless it happens to be one of the boards in the input module;** the replacement of either directly affects the calibration.

Although it is possible to carry out re-calibration on site, this requires test equipment with suitable accuracy and a special calibration program to run on a PC. It is therefore recommended that the work be carried out by the manufacturer, or entrusted to an approved service center.

## 1.5 Changing the relay battery

Each relay has a battery 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.

This battery will periodically need changing, although an alarm will be given as part of the relay’s continuous self-monitoring in the event of a low battery condition.

If the battery-backed facilities are not required to be maintained during an interruption of the auxiliary supply, the steps below can be followed to remove the battery, but do not replace with a new battery.

**Before carrying out any work on the equipment, the user should be familiar with the contents of the safety and technical data sections and the ratings on the equipment's rating label.**



### 1.5.1 Instructions for replacing the battery

Open the bottom access cover on the front of the relay.

Gently extract the battery from its socket. If necessary, use a small, insulated screwdriver to prize the battery free.

Ensure that the metal terminals in the battery socket are free from corrosion, grease and dust.

The replacement battery should be removed from its packaging and placed into the battery holder, taking care to ensure that the polarity markings on the battery agree with those adjacent to the socket.

Note: Only use a type ½AA Lithium battery with a nominal voltage of 3.6V and safety approvals such as UL (Underwriters Laboratory), CSA (Canadian Standards Association) or VDE (Vereinigung Deutscher Elektrizitätswerke).

Ensure that the battery is securely held in its socket and that the battery terminals are making good contact with the metal terminals of the socket.

Close the bottom access cover.

#### 1.5.2 Post modification tests

To ensure that the replacement battery will maintain the time and status data if the auxiliary supply fails, check cell [0806: DATE and TIME, Battery Status] reads ‘Healthy’.

Additionally, if further confirmation that the replacement battery is installed correctly is required, the commissioning test described in section 5.2.3 of the Commissioning section (P145/EN CM), ‘Date and Time’, can be performed.

#### 1.5.3 Battery disposal

The battery that has been removed should be disposed of in accordance with the disposal procedure for Lithium batteries in the country in which the relay is installed.

### 1.6 Cleaning

Before cleaning the equipment ensure that all ac and dc supplies, current transformer and voltage transformer connections are isolated to prevent any chance of an electric shock whilst cleaning.

The equipment may be cleaned using a lint-free cloth moistened with clean water. The use of detergents, solvents or abrasive cleaners is not recommended as they may damage the relay’s surface and leave a conductive residue.

# TROUBLESHOOTING

TS

**Date:** **7th July 2005**
**Hardware Suffix:** **J**
**Software Version:** **31**
**Connection Diagrams:** **10P145xx (xx = 01 to 07)**

# CONTENTS

# 1. INTRODUCTION

Before carrying out any work on the equipment, the user should be familiar with the contents of the safety and technical data sections and the ratings on the equipment's rating label

The purpose of this section of the service manual is to allow an error condition on the relay to be identified so that appropriate corrective action can be taken.

Should the relay have developed a fault, it should be possible in most cases to identify which relay module requires attention. The Maintenance section (P145/EN MT), advises on the recommended method of repair where faulty modules need replacing. It is not possible to perform an on-site repair to a faulted module.

In cases where a faulty relay/module is being returned to the manufacturer or one of their approved service centers, completed copy of the Repair/Modification Return Authorization Form located at the end of this section should be included.

# 2. INITIAL PROBLEM IDENTIFICATION

Consult the table below to find the description that best matches the problem experienced, then consult the section referenced to perform a more detailed analysis of the problem.

| Symptom | Refer To |
|---|---|
| Relay fails to power up | Section 4 |
| Relay powers up - but indicates error and halts during power-up sequence | Section 5 |
| Relay Powers up but Out of Service LED is illuminated | Section 6 |
| Error during normal operation | Section 7 |
| Mal-operation of the relay during testing | Section 8 |

**Table 1: Problem identification**

# 3. POWER UP ERRORS

If the relay does not appear to power up then the following procedure can be used to determine whether the fault is in the external wiring, auxiliary fuse, power supply module of the relay or the relay front panel.

| Test | Check | Action |
|---|---|---|
| 1 | Measure auxiliary voltage on terminals 1 and 2; verify voltage level and polarity against rating the label on front.<br>Terminal 1 is –dc, 2 is +dc | If auxiliary voltage is present and correct, then proceed to test 2. Otherwise the wiring/fuses in auxiliary supply should be checked. |
| 2 | Do LEDs/and LCD backlight illuminate on power-up, also check the N/O watchdog contact for closing. | If they illuminate or the contact closes and no error code is displayed then error is probably in the main processor board (front panel). If they do not illuminate and the contact does not close then proceed to test 3. |
| 3 | Check Field voltage output (nominally 48V DC) | If field voltage is not present then the fault is probably in the relay power supply module. |

**Table 2: Failure of relay to power up**

# 4. ERROR MESSAGE/CODE ON POWER-UP

During the power-up sequence of the relay self-testing is performed as indicated by the messages displayed on the LCD. If an error is detected by the relay during these self-tests then an error message will be displayed and the power-up sequence will be halted. If the error occurs when the relay application software is executing then a maintenance record will be created and the relay will reboot.

| 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 then proceed to test 2. If the relay prompts for input by the user proceed to test 4. If the relay re-boots automatically then proceed 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 then contact the local service center stating the error code and relay information. If the same code is displayed proceed to test 3. |
| 3 | Error code Identification<br>Following text messages (in English) will be displayed if a fundamental problem is detected preventing the system from booting:<br>Bus Fail – address lines<br>SRAM Fail – data lines<br>FLASH Fail format error<br>FLASH Fail checksum<br>Code Verify Fail<br>The following hex error codes relate to errors detected in specific relay modules: | These messages indicate that a problem has been detected on the main processor board of the relay (located in the front panel). |
| | 0c140005/0c0d0000 | Input Module (inc. Opto-isolated inputs) |
| | 0c140006/0c0e0000 | Output Relay Cards |
| | Last 4 digits provide details on the actual error. | Other error codes relate to problems within the main processor board hardware or software. It will be necessary to contact AREVA T&D with details of the problem for a full analysis. |
| 4 | Relay displays message for corrupt settings and prompts for restoration of defaults to the affected settings. | The power up tests have detected corrupted relay settings, it is possible to restore defaults to allow the power-up to be completed. It will then be necessary to re-apply the application-specific settings. |

| Test | Check | Action |
|---|---|---|
| 5 | Relay resets on completion of power up - record error code displayed | Error 0x0E080000, programmable scheme logic error due to excessive execution time. Restore default settings by performing a power up with ⇐ and ⇒ keys depressed, confirm restoration of defaults at prompt using ↵ key. If relay powers up successfully, check programmable logic for feedback paths.<br><br>Other error codes will relate to software errors on the main processor board, contact AREVA T&D. |

**Table 3: Power-up self-test error**

## 5. OUT OF SERVICE LED ILLUMINATED ON POWER UP

| Test | Check | Action |
|---|---|---|
| 1 | Using the relay menu confirm whether the Commission Test/Test Mode setting is Enabled. Otherwise proceed to test 2. | If the setting is Enabled then disable the test mode and, verify that the Out of Service LED is extinguished. |
| 2 | Select and view the last maintenance record from the menu (in the View Records). | 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:<br>Bit Meaning<br>0 The application type field in the model number does not match the software ID<br>1 The application field in the model number does not match the software ID<br>2 The variant 1 field in the model number does not match the software ID<br>3 The variant 2 field in the model number does not match the software ID<br>4 The protocol field in the model number does not match the software ID<br>5 The language field in the model number does not match the software ID<br>6 The VT type field in the model number is incorrect (110V VTs fitted)<br>7 The VT type field in the model number is incorrect (440V VTs fitted)<br>8 The VT type field in the model number is incorrect (no VTs fitted) |

**Table 4: Out of service LED illuminated**

# 6. ERROR CODE DURING OPERATION

The relay performs continuous self-checking, if an error is detected then an error message will be displayed, a maintenance record will be logged and the relay will reset (after a 1.6 second delay). A permanent problem (for example due to a hardware fault) will generally be detected on the power up sequence, following which the relay will display an error code and halt. If the problem was transient in nature then the relay should reboot correctly and continue in operation. The nature of the detected fault can be determined by examination of the maintenance record logged.

There are also two cases where a maintenance record will be logged due to a detected error where the relay will not reset. These are detection of a failure of either the field voltage or the lithium battery, in these cases the failure is indicated by an alarm message, however the relay will continue to operate.

If the field voltage is detected to have failed (the voltage level has dropped below threshold), then a scheme logic signal is also set. This allows the scheme logic to be adapted in the case of this failure (for example if a blocking scheme is being used).

In the case of a battery failure it is possible to prevent the relay from issuing an alarm using the setting under the Date and Time section of the menu. This setting ‘Battery Alarm’ can be set to 'Disabled' to allow the relay to be used without a battery, without an alarm message being displayed.

# 7. MAL-OPERATION OF THE RELAY DURING TESTING

## 7.1 Failure of output contacts

An apparent failure of the relay output contacts may be caused by the relay configuration; the following tests should be performed to identify the real cause of the failure. Note that the relay self-tests verify that the coil of the contact has been energized, an error will be displayed if there is a fault in the output relay board.

| Test | Check | Action |
|---|---|---|
| 1 | Is the Out of Service LED illuminated? | Illumination of this LED may indicate that the relay is in test mode or that 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 then proceed to test 4, if not proceed to test 3. |
| 3 | Verify by examination of the fault record or by using the test port whether the protection element is operating correctly. | If the protection element does not operate verify whether the test is being correctly applied.<br>If the protection element does operate then it will be necessary to check the programmable logic, to ensure that the mapping of the protection element to the contacts is correct. |
| 4 | Using the Commissioning/Test mode function apply a test pattern to the relevant relay output contacts and verify whether they operate (note the correct external connection diagram should be consulted). A continuity tester can be used at the rear of the relay for this purpose. | If the output relay does operate then the problem must be in the external wiring to the relay. If the output relay does not operate this could indicate a failure of the output relay contacts (note that the self-tests verify that the relay coil is being energized). Ensure that the closed resistance is not too high for the continuity tester to detect. |

**Table 5: Failure of output contacts**

## 7.2 Failure of opto-isolated inputs

The opto-isolated inputs are mapped onto the relay internal signals using the programmable scheme logic. If an input does not appear to be recognized by the relay scheme logic the Commission Tests/Opto Status menu option can be used to verify whether the problem is in the opto-isolated input itself or the mapping of its signal to the scheme logic functions. If the opto-isolated input does appear to be read correctly then it will be necessary to examine its mapping within the programmable logic.

Ensure the voltage rating for the opto inputs has been configured correctly with applied voltage. If the opto-isolated input state is not being correctly read by the relay the applied signal should be tested. Verify the connections to the opto-isolated input using the correct wiring diagram. Next, using a voltmeter verify that 80% opto setting voltage is present on the terminals of the opto-isolated input in the energized state. If the signal is being correctly applied to the relay then the failure may be on the input card itself. Depending on which opto-isolated input has failed this may require replacement of either the complete analog input module (the board within this module cannot be individually replaced without re-calibration of the relay) or a separate opto board.

## 7.3 Incorrect analog signals

The measurements may be configured in primary or secondary to assist. If it is suspected that the analog quantities being measured by the relay are not correct then the measurement function of the relay can be used to verify the nature of the problem. The measured values displayed by the relay should be compared with the actual magnitudes at the relay terminals. Verify that the correct terminals are being used (in particular the dual rated CT inputs) and that the CT and VT ratios set on the relay are correct. The correct 120 degree displacement of the phase measurements should be used to confirm that the inputs have been correctly connected.

## 7.4 PSL editor troubleshooting

A failure to open a connection could be because of one or more of the following:

- The relay address is not valid (note: 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 relay and/or the type of connection
- Modem configuration is not valid. Changes may be necessary when using a modem
- The connection cable is not wired correctly or broken. See MiCOM S1 connection configurations
- The option switches on any KITZ101/102 this is in use may be incorrectly set

### 7.4.1 Diagram reconstruction after recover from relay

Although the extraction of a scheme from a relay is supported, the facility is provided as a way of recovering a scheme in the event that the original file is unobtainable.

The recovered scheme will be logically correct, but much of the original graphical information is lost. Many signals will be 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 (titles, notes, etc.) are lost.

Sometimes a gate type may not be what was expected, e.g. a 1-input AND gate in the original scheme will appear as an OR gate when uploaded. Programmable gates with an inputs-to-trigger value of 1 will also appear as OR gates.

### 7.4.2 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.

# 8. REPAIR AND MODIFICATION PROCEDURE

Please follow these 5 steps to return an Automation product to us:

**1. Get the Repair and Modification Authorization Form (RMA)**

Find a copy of the RMA form at the end of this section.

- To obtain an electronic version of the RMA form for e-mailing, please visit the following URL:
  http://www.areva-td.com/automationrepair

**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 RMA form to your local contact**

Find enclosed a list of local service contacts, worldwide.

**4. Receive from local service contact, the information required to ship the product**

Your local service contact will provide you with all the information:

- Pricing details
- RMA n°
- Repair center address

If required, an acceptance of the quote must be delivered before going to next stage.

TS

**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.

## LOCAL CONTACT LIST

| Country | Automation Support Manager | | Telephone and Fax Numbers | E-Mail |
|---|---|---|---|---|
| **NORTH AMERICA**<br><br>Canada | **CANADA :** | Brossard | **Tel:** (1) 450 923 7084<br>**Fax:** (1) 450 923 9571 | |
| USA (Products), Virgin Islands | **USA :** | Bethlehem | **Tel:** (1) 610 997 5100<br>**Fax:** (1) 610 997 5450 | automationrepair.us@areva-td.com |
| **CENTRAL AMERICA**<br><br>Anguilla, Antigua & Barbuda, Aruba, Barbados, Belize, Cayman Islands, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, El Salvador, Grenada, Guatemala, Guyana, Honduras, Jamaica, Kiribati, Mexico, Montserrat, Netherlands Antilles, Nicaragua, Panama, Republic of Haiti, Saint Kitts & Nevis, Santa Lucia, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago, Turks and Caicos Islands, Venezuela. | **MEXICO :** | | **Tel:** (52) 55 5387 4309<br>**Fax:** (52) 55 5387 4317 | support.automation-mexico@areva-td.com |
| **SOUTH AMERICA**<br><br>Argentina, Bolivia, Brazil, Chile, Ecuador, Falkland Islands, Paraguay, Peru, Uruguay. | **BRAZIL :** | Sao Paulo | **Tel:** (55) 11 3491 7271<br>**Fax:** (55) 11 3491 7256 | automationrepair.southamerica@areva-td.com |
| **EUROPE (MEDITERRANEAN)**<br><br>Albania, Andorra, Belgium, Bulgaria, Bosnia and Herzegovinia, Croatia, Cyprus, France, French DOM-TOM, Greece, Israel, Macedonia, Malta, Mauritius, Romania, Yugoslavia. | **FRANCE :** | Lattes | **Tel:** (33) 4 67 20 55 55<br>**Fax:** (33) 4 67 20 56 00 | automationrepair.medaf@areva-td.com |
| **EUROPE (EAST)**<br><br>Austria, Czech Republic, Germany, Hungary, Liechtenstein, Slovakia, Svalbard Islands, Switzerland, Turkey. | **GERMANY :** | Dresden | **Tel:** (49) 69 66 32 11 36<br>**Fax:** (49) 69 66 32 28 10 | Service-afs@areva-td.com |
| Armenia, Azerbaijan, Belarus, Estonia, Georgia, Latvia, Moldova, Poland, Ukraine. | **POLAND :** | Swiebodzice | **Tel:** (48) 748 548 410<br>**Fax:** (48) 748 548 548 | automationrepair.nce2@areva-td.com |
| **EUROPE (NORTH)**<br><br>Denmark, Finland, Iceland, Norway, Netherlands, Sweden. | **UK :** | Stafford | **Tel:** (44) 1785 272 156<br>**Fax:** (44) 1785 227 729 | automationrepair.uk@areva-td.com |
| **UNITED KINGDOM**<br><br>Faroe Islands, Ireland, UK | **UK :** | Stafford | **Tel:** (44) 1785 272 156<br>**Fax:** (44) 1785 227 729 | automationrepair.uk@areva-td.com |

| Country | Automation Support Manager | | Telephone and Fax Numbers | | E-Mail |
|---|---|---|---|---|---|
| **EUROPE (OTHER)** Italy | **ITALY :** | Bergamo | **Tel:** | (39) 0345 28 111 | automationrepair.italy@areva-td.com |
| | | | **Fax:** | (39) 0345 22 590 | |
| Russian Federation | **RUSSIA :** | Moscow | **Tel:** | (7) 095 231 29 49 | |
| | | | **Fax:** | (7) 095 231 29 45 | |
| Spain, Gibralter | **SPAIN :** | Madrid | **Tel:** | (34) 91 655 9043 | |
| | | | **Fax:** | (34) 91 305 9200 | |
| **AFRICA** All African countries | **FRANCE :** | Lattes | **Tel:** | (33) 4 67 20 55 55 | automationrepair.medaf@areva-td.com |
| | | | **Fax:** | (33) 4 67 20 56 00 | |
| **MIDDLE EAST** Bahrain, Iran, Iraq, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, United Arab Emirates, Yemen. | **UAE :** | Dubai | **Tel:** | (971) 6556 0559 | automationrepair.middleeast@areva-td.com |
| | | | **Fax:** | (971) 6556 1082 | |
| **ASIA** Afghanistan, Pakistan | **UAE :** | Dubai | **Tel:** | (971) 6556 0559 | automationrepair.middleeast@areva-td.com |
| | | | **Fax:** | (971) 6556 1082 | |
| Kazakhstan, Kyrghyzstan, Tajikistan, Turkmenistan, Uzbekistan. | **POLAND :** | Swiebodzice | **Tel:** | (48) 748 548 410 | automationrepair.nce2@areva-td.com |
| | | | **Fax:** | (48) 748 548 548 | |
| Bhutan, India, Maldives, Nepal, Sri Lanka | **INDIA :** | Chennai | **Tel:** | (91) 44 226 40 921 | automationsupport.india@areva-td.com |
| | | | **Fax:** | (91) 44 226 40 657 | |
| **EASTERN ASIA** Bangladesh, British Indian Ocean Territory, Brunei, Cambodia, Cocos Islands, Democratic People's Republic of Korea, East Timor, Hong Kong, Indonesia, Japan, Laos, Macau, Malaysia, Myanmar, Palau, Papua New Guinea, Philippines, Singapore, Solomon Islands, South Korea, Taiwan, Thailand, Tokelau, Tuvalu, Vietnam. | **SINGAPORE :** | | **Tel:** | (65) 6749 0777 | automationrepair.seasia@areva-td.com |
| | | | **Fax:** | (65) 6846 1796 | |
| China, Mongolia. | **CHINA :** | Shanghai | **Tel:** | (86) 21 5812 8822 | automationrepair.shanghai@areva-td.com |
| | | | **Fax:** | (86) 21 5812 8833 | |
| **OCEANIA** American Samoa, Australia, Christmas Islands, Cook Islands, Fiji, Guam, Heard and Mac Donalds Islands, Marshall Islands, Micronesia, Nauru, New Zealand, Niue, Norfolk Island, Northern Mariana Islands, Pitcairn, Samoa, Vanuatu. | **AUSTRALIA :** | Homebush Bay | **Tel:** | (61) 2 9739 3071 | automationrepair.pacific@areva-td.com |
| | | | **Fax:** | (61) 2 9739 3092 | |

TS

AREVA

# REPAIR/MODIFICATION RETURN AUTHORIZATION FORM

**FIELDS IN GREY TO BE FILLED IN BY AREVA T&D PERSONNEL ONLY**

| Reference **RMA:** | | Date: |
|---|---|---|
| **Repair Center Address (for shipping)** | **Service Type**<br>☐ Retrofit<br>☐ Warranty<br>☐ Paid service<br>☐ Under repair contract<br>☐ Wrong supply | LSC PO No.: |
| **AREVA T&D - Local Contact Details**<br>Name:<br>Telephone No.:<br>Fax No.:<br>E-mail: | | |

**IDENTIFICATION OF UNIT**

**Fields marked (M) are mandatory, delays in return will occur if not completed.**

| | |
|---|---|
| Model No./Part No.: **(M)** | Site Name/Project: |
| Manufacturer Reference: **(M)** | Commissioning Date: |
| Serial No.: **(M)** | Under Warranty: ☐ Yes ☐ No |
| Software Version: | Additional Information: |
| Quantity: | Customer P.O (if paid): |

**FAULT INFORMATION**

| | |
|---|---|
| **Type of Failure** | **Found Defective** |
| Hardware fail ☐ | During FAT/inspection ☐ |
| Mechanical fail/visible defect ☐ | On receipt ☐ |
| Software fail ☐ | During installation/commissioning ☐ |
| Other: | During operation ☐ |
| | Other: |
| **Fault Reproducibility** | |
| Fault persists after removing, checking on test bench ☐ | |
| Fault persists after re-energization ☐ | |
| Intermittent fault ☐ | |

AREVA

| Description of Failure Observed or Modification Required - *Please be specific* (M) |
|---|
| |

**FOR REPAIRS ONLY**

| | | |
|---|---|---|
| Would you like us to install an updated firmware version after repair? | ☐ Yes | ☐ No |

**CUSTOMS & INVOICING INFORMATION**

**Required to allow return of repaired items**

| **Value for Customs (M)** | |
|---|---|
| **Customer Invoice Address ((M) if paid)** | **Customer Return Delivery Address (full street address) (M)**<br><br>Part shipment accepted ☐ Yes ☐ No<br>**OR** Full shipment required ☐ Yes ☐ No |
| Contact Name:<br>Telephone No.:<br>Fax No.:<br>E-mail: | Contact Name:<br>Telephone No.:<br>Fax No.:<br>E-mail: |

**REPAIR TERMS**

1. **Please ensure that a copy of the import invoice is attached with the returned unit, together with the airway bill document.** Please fax/e-mail a copy of the appropriate documentation (M).
2. Please ensure the Purchase Order is released, for paid service, to allow the unit to be shipped.
3. Submission of equipment to AREVA T&D is deemed as authorization to repair and acceptance of quote.
4. Please ensure all items returned are marked as Returned for 'Repair/Modification' and **protected by appropriate packaging** (anti-static bag for each board and foam protection).

# SCADA COMMUNICATIONS

SC

**Date:** **7th July 2005**
**Hardware Suffix:** **J**
**Software Version:** **31**
**Connection Diagrams:** **10P145xx (xx = 01 to 07)**

SC

# CONTENTS



SC

SC

# FIGURES

# 1. SCADA COMMUNICATIONS

## 1.1 Introduction

This section outlines the remote communications interfaces of the MiCOM relay. The relay supports a choice of one of five protocols via the rear communication interface, selected via the model number when ordering. This is in addition to the front serial interface and 2nd rear communications port, which supports the Courier protocol only.

The rear EIA(RS)485 interface is isolated and is suitable for permanent connection whichever protocol is selected. The advantage of this type of connection is that up to 32 relays can be ‘daisy chained’ together using a simple twisted pair electrical connection.

It should be noted that the descriptions contained within this section do not aim to fully detail the protocol itself. The relevant documentation for the protocol should be referred to for this information. This section serves to describe the specific implementation of the protocol in the relay.

## 1.2 Rear port information and connection advice – EIA(RS)485 protocols

### 1.2.1 Rear communication port EIA(RS)485 interface

The rear EIA(RS)485 communication port is provided by a 3-terminal screw connector located on the back of the relay. See section P145/EN IN for details of the connection terminals. The rear port provides K-Bus/EIA(RS)485 serial data communication and is intended for use with a permanently wired connection to a remote control center. Of the three connections, two are for the signal connection, and the other is for the earth shield of the cable. When the K-Bus option is selected for the rear port, the two signal connections are not polarity conscious, however for MODBUS, IEC60870-5-103 and DNP3.0 care must be taken to observe the correct polarity.

The protocol provided by the relay is indicated in the relay menu in the ‘Communications’ column. Using the keypad and LCD, firstly check that the ‘Comms. settings’ cell in the ‘Configuration’ column is set to ‘Visible’, then move to the ‘Communications’ column. The first cell down the column shows the communication protocol being used by the rear port.

#### 1.2.1.1 EIA(RS)485 bus

The EIA(RS)485 two-wire connection provides a half-duplex fully isolated serial connection to the product. The connection is polarized and whilst the product’s connection diagrams indicate the polarization of the connection terminals it should be borne in mind that 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.

#### 1.2.1.2 Bus termination

The EIA(RS)485 bus must have 120Ω (Ohm) ½ Watt terminating resistors fitted at either end across the signal wires – see Figure 1. Some devices may be able to provide the bus terminating resistors by different connection or configuration arrangements, in which case separate external components will not be required. However, this product does not provide such a facility, so if it is located at the bus terminus then an external termination resistor will be required.

#### 1.2.1.3 Bus connections & topologies

The EIA(RS)485 standard requires that each device be directly connected to the physical cable that is the communications bus. Stubs and tees are expressly forbidden, as are star topologies. Loop bus topologies are not part of the EIA(RS)485 standard and are forbidden by it.

Two-core screened cable is recommended. The specification of the cable will be dependent on the application, although a multi-strand 0.5mm$^2$ per core is normally adequate. Total cable length must not exceed 1000m. The screen must be continuous and connected to ground at one end, normally at the master connection point; it is important to avoid circulating currents, especially when the cable runs between buildings, for both safety and noise reasons.

This product does not provide a signal ground connection. If a signal ground connection is present in the bus cable then it must be ignored, although it must have continuity for the benefit of other devices connected to the bus. At no stage must the signal ground be connected to the cables screen or to the product's chassis. This is for both safety and noise reasons.

### 1.2.1.4 Biasing

It may also 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 purposefully waits in receive mode, or even 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 consequentially not responding. Symptoms of this are poor response times (due to retries), increasing message error counters, erratic communications, and even a complete failure to communicate.

Biasing requires that the signal lines be weakly pulled to a defined voltage level of about 1V. 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; otherwise noise will be injected. Note that some devices may (optionally) be able to provide the bus bias, in which case external components will not be required.

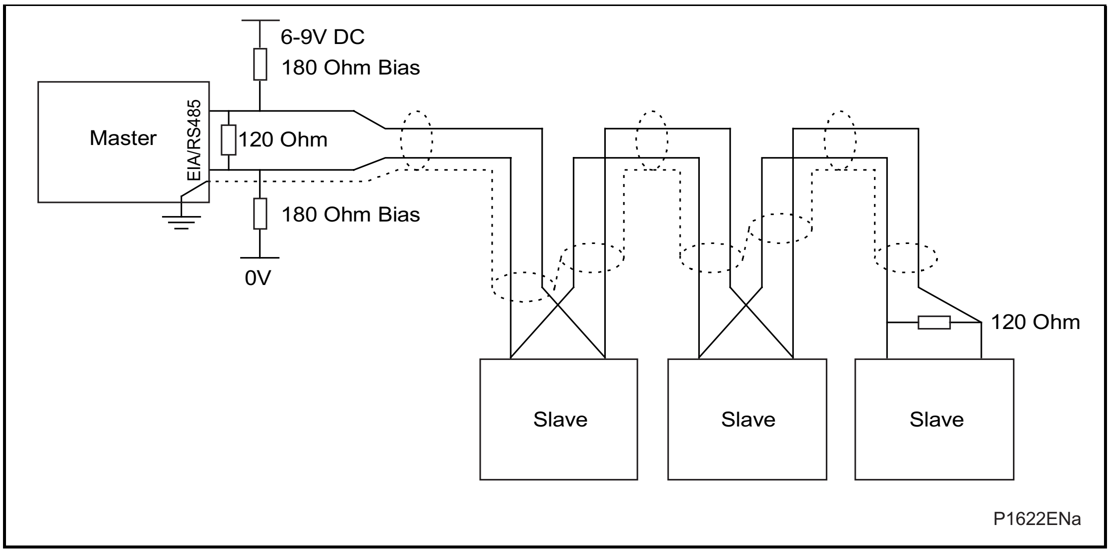



**Figure 1: EIA(RS)485 bus connection arrangements**

SC

It is possible to use the products field voltage output (48V DC) to bias the bus using values of 2.2kΩ (½W) as bias resistors instead of the 180Ω resistors shown in the above diagram.

Note the following warnings apply:

- It is extremely important that the 120Ω termination resistors are fitted. Failure to do so will result in an excessive bias voltage that may damage the devices connected to the bus.
- As the field voltage is much higher than that required, AREVA cannot assume responsibility for any damage that may occur to a device connected to the network as a result of incorrect application of this voltage.
- Ensure that the field voltage is not being used for other purposes (i.e. powering logic inputs) as this may cause noise to be passed to the communication network.

### 1.2.2 Courier communication

Courier works on a master/slave basis where the slave units contain information in the form of a database, and respond with information from the database when it is requested by a master unit.

The relay is a slave unit that is designed to be used with a Courier master unit such as MiCOM S1, MiCOM S10, PAS&T or a SCADA system.

To use the rear port to communicate with a PC-based master station using Courier, a KITZ K-Bus to EIA(RS)232 protocol converter is required. This unit is available from AREVA T&D. A typical connection arrangement is shown in Figure 2. For more detailed information on other possible connection arrangements refer to the manual for the Courier master station software and the manual for the KITZ protocol converter. Each spur of the K-Bus twisted pair wiring can be up to 1000m in length and have up to 32 relays connected to it.

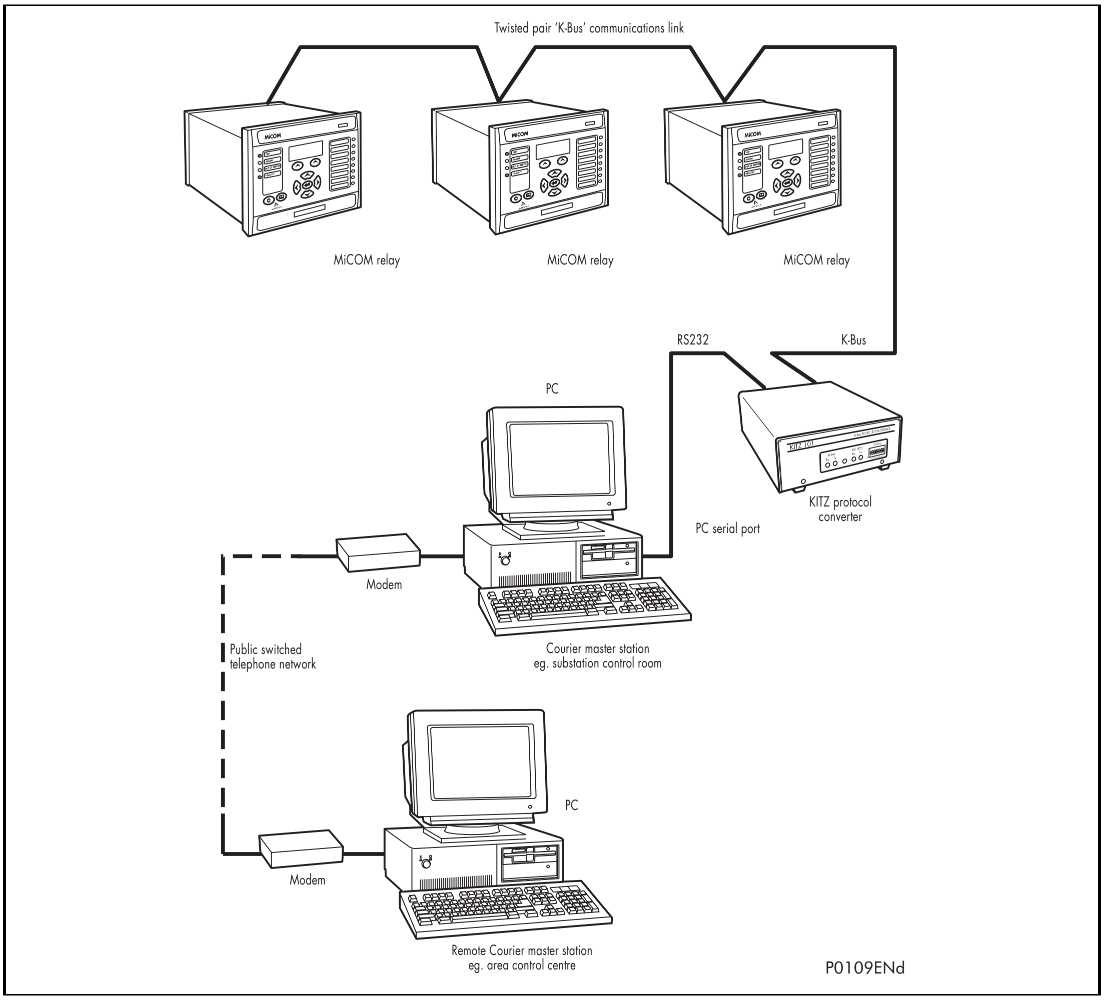



**Figure 2: Remote communication connection arrangements**

Having made the physical connection to the relay, the relay's communication settings must be configured. To do this use the keypad and LCD user interface. In the relay menu firstly check that the 'Comms. settings' cell in the 'Configuration' column is set to 'Visible', then move to the 'Communications' column. Only two settings apply to the rear port using Courier, the relay's address and the inactivity timer. Synchronous communication is used at a fixed baud rate of 64kbits/s.

Move down the 'Communications' column from the column heading to the first cell down which indicates the communication protocol:

| |
|---|
| Protocol<br>Courier |

The next cell down the column controls the address of the relay:

| |
|---|
| Remote address<br>1 |

Since up to 32 relays can be connected to one K-bus spur, as indicated in Figure 2, it is necessary for each relay to have a unique address so that messages from the master control station are accepted by one relay only. Courier uses an integer number between 0 and 254 for the relay address, which is set with this cell. It is important that no two relays have the same Courier address. The Courier address is then used by the master station to communicate with the relay. Default value of remote address is 255 and must be changed to a value in the range of 1 to 254 before use.

The next cell down controls the inactivity timer:

| |
|---|
| Inactivity timer<br>10.00 mins. |

The inactivity timer controls how long the relay will wait 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.

Note that protection and disturbance recorder settings that are modified using an on-line editor such as PAS&T must be confirmed with a write to the 'Save changes' cell of the 'Configuration' column. Off-line editors such as MiCOM S1 do not require this action for the setting changes to take effect.

### 1.2.3 MODBUS communication

MODBUS is a master/slave communication protocol, which can be used for network control. In a similar fashion to Courier, the system works by the master device initiating all actions and the slave devices, (the relays), responding to the master by supplying the requested data or by taking the requested action. MODBUS communication is achieved via a twisted pair EIA(RS)485 connection to the rear port and can be used over a distance of 1000m with up to 32 slave devices.

To use the rear port with MODBUS communication, the relay's communication settings must be configured. To do this use the keypad and LCD user interface. In the relay menu firstly check that the 'Comms. settings' cell in the 'Configuration' column is set to 'Visible', then move to the 'Communications' column. Four settings apply to the rear port using MODBUS, which are described below. Move down the 'Communications' column from the column heading to the first cell down which indicates the communication protocol:



| |
|---|
| Protocol<br>MODBUS |

The next cell down controls the MODBUS address of the relay:

| |
|---|
| MODBUS address<br>23 |

Up to 32 relays can be connected to one MODBUS spur, and therefore it is necessary for each relay to have a unique address so that messages from the master control station are accepted by one relay only. MODBUS uses an integer number between 1 and 247 for the relay address. It is important that no two relays have the same MODBUS address. The MODBUS address is then used by the master station to communicate with the relay.

The next cell down controls the inactivity timer:

| |
|---|
| Inactivity timer<br>10.00 mins. |

The inactivity timer controls how long the relay will wait 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.

The next cell down the column controls the baud rate to be used:

| |
|---|
| Baud rate<br>9600 bits/s |

MODBUS communication is asynchronous. Three baud rates are supported by the relay, '9600 bits/s', '19200 bits/s' and '38400 bits/s'. It is important that whatever baud rate is selected on the relay is the same as that set on the MODBUS master station.

The next cell down controls the parity format used in the data frames:

| |
|---|
| Parity<br>None |

The parity can be set to be one of 'None', 'Odd' or 'Even'. It is important that whatever parity format is selected on the relay is the same as that set on the MODBUS master station.

The next cell down controls the IEC time format used in the data frames:

| |
|---|
| MODBUS IEC time<br>Standard |

The MODBUS IEC time can be set to 'Standard' or 'Reverse'. For a complete definition see the relay menu database (P145/EN MD), datatype G12.

### 1.2.4 IEC60870-5 CS 103 communication

The IEC specification IEC60870-5-103: Telecontrol Equipment and Systems, Part 5: Transmission Protocols Section 103 defines the use of standards IEC60870-5-1 to IEC60870-5-5 to perform communication with protection equipment. The standard configuration for the IEC60870-5-103 protocol is to use a twisted pair EIA(RS)485 connection over distances up to 1000m. The relay operates as a slave in the system, responding to commands from a master station.

To use the rear port with IEC60870-5-103 communication, the relay's communication settings must be configured. To do this use the keypad and LCD user interface. In the relay menu firstly check that the 'Comms. settings' cell in the 'Configuration' column is set to 'Visible', then move to the 'Communications' column. Four settings apply to the rear port using IEC60870-5-103 that are described below. Move down the 'Communications' column from the column heading to the first cell that indicates the communication protocol:

| |
|---|
| Protocol<br>IEC60870-5-103 |

The next cell down controls the IEC60870-5-103 address of the relay:

| |
|---|
| Remote address<br>162 |

Up to 32 relays can be connected to one IEC60870-5-103 spur, and therefore it is necessary for each relay to have a unique address so that messages from the master control station are accepted by one relay only. IEC60870-5-103 uses an integer number between 0 and 254 for the relay address. It is important that no two relays have the same IEC60870-5-103 address. The IEC60870-5-103 address is then used by the master station to communicate with the relay.

The next cell down the column controls the baud rate to be used:

| |
|---|
| Baud rate<br>9600 bits/s |

IEC60870-5-103 communication is asynchronous. Two baud rates are supported by the relay, '9600 bits/s' and '19200 bits/s'. It is important that whatever baud rate is selected on the relay is the same as that set on the IEC60870-5-103 master station.

The next cell down controls the period between IEC60870-5-103 measurements:

| |
|---|
| Measure't. period<br>30.00 s |

The IEC60870-5-103 protocol allows the relay to supply measurements at regular intervals. The interval between measurements is controlled by this cell, and can be set between 1 and 60 seconds.

The following cell is not currently used but is available for future expansion

| |
|---|
| Inactive timer |

The next cell down can be used for monitor or command blocking:

| |
|---|
| CS103 blocking |

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

SC

- 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.

### 1.2.5 DNP3.0 communication

The DNP 3.0 protocol is defined and administered by the DNP User Group. Information about the user group, DNP 3.0 in general and protocol specifications can be found on their website: www.dnp.org

The relay operates as a DNP 3.0 slave and supports subset level 2 of the protocol plus some of the features from level 3. DNP 3.0 communication is achieved via a twisted pair EIA(RS)485 connection to the rear port and can be used over a distance of 1000m with up to 32 slave devices.

To use the rear port with DNP 3.0 communication, the relay's communication settings must be configured. To do this use the keypad and LCD user interface. In the relay menu firstly check that the 'Comms. setting' cell in the 'Configuration' column is set to 'Visible', then move to the 'Communications' column. Four settings apply to the rear port using DNP 3.0, which are described below. Move down the 'Communications' column from the column heading to the first cell that indicates the communications protocol:

| |
|---|
| Protocol<br>DNP 3.0 |

The next cell controls the DNP 3.0 address of the relay:

| |
|---|
| DNP 3.0 address<br>232 |

Up to 32 relays can be connected to one DNP 3.0 spur, and therefore it is necessary for each relay to have a unique address so that messages from the master control station are accepted by only one relay. DNP 3.0 uses a decimal number between 1 and 65519 for the relay address. It is important that no two relays have the same DNP 3.0 address. The DNP 3.0 address is then used by the master station to communicate with the relay.

The next cell down the column controls the baud rate to be used:

| |
|---|
| Baud rate<br>9600 bits/s |

DNP 3.0 communication is asynchronous. Six baud rates are supported by the relay '1200bits/s', '2400bits/s', '4800bits/s', '9600bits/s', '19200bits/s' and '38400bits/s'. It is important that whatever baud rate is selected on the relay is the same as that set on the DNP 3.0 master station.

The next cell down the column controls the parity format used in the data frames:

| |
|---|
| Parity<br>None |

SC

The parity can be set to be one of 'None', 'Odd' or 'Even'. It is important that whatever parity format is selected on the relay is the same as that set on the DNP 3.0 master station.

The next cell down the column sets the time synchronization request from the master by the relay:

| |
|---|
| Time Sync.<br>Enabled |

The time sync. can be set to either enabled or disabled. If enabled it allows the DNP 3.0 master to synchronize the time.

### 1.3 Fiber optic converter

An optional fiber optic card is available in this product. This converts the EIA(RS)485 protocols into a fiber optic output. This communication card is available for use on Courier, MODBUS, IEC60870-5-103 and DNP3.0 it adds the following setting to the communication column.

This controls the physical media used for the communication:

| |
|---|
| Physical link<br>Copper |

The default setting is to select the electrical EIA(RS)485 connection. If the optional fiber optic connectors are fitted to the relay, then this setting can be changed to 'Fiber optic'. This cell is also invisible if a second rear comms. port, or Ethernet card is fitted, as it is mutually exclusive with the fiber optic connectors, and occupies the same physical location.

### 1.4 Second rear communication port (SK4)

For relays with Courier, MODBUS, IEC60870-5-103 or DNP3.0 protocol on the first rear communications port there is the hardware option of a second rear communications port, which will run the Courier language. This can be used over one of three physical links: twisted pair K-Bus (non-polarity sensitive), twisted pair EIA(RS)485 (connection polarity sensitive) or EIA(RS)232.

The settings for this port are located immediately below the ones for the first port as described in previous sections of P145/EN IT. Move down the settings until the following sub heading is displayed.

| |
|---|
| REAR PORT2 (RP2) |

The next cell down indicates the language, which is fixed at Courier for RP2.

| |
|---|
| RP2 protocol<br>Courier |

The next cell down indicates the status of the hardware, e.g.

| |
|---|
| RP2 card status<br>EIA(RS)232 OK |

SC

The next cell allows for selection of the port configuration.

| |
|---|
| RP2 port config.<br>EIA(RS)232 |

The port can be configured for EIA(RS)232, EIA(RS)485 or K-Bus.

In the case of EIA(RS)232 and EIA(RS)485 the next cell selects the communication mode.

| |
|---|
| RP2 comms. mode<br>IEC60870 FT1.2 |

The choice is either IEC60870 FT1.2 for normal operation with 11-bit modems, or 10-bit no parity.

The next cell down controls the comms. port address.

| |
|---|
| RP2 address<br>255 |

Since up to 32 relays can be connected to one K-bus spur, as indicated in Figure 2, it is necessary for each relay to have a unique address so that messages from the master control station are accepted by one relay only. Courier uses an integer number between 0 and 254 for the relay address that is set with this cell. It is important that no two relays have the same Courier address. The Courier address is then used by the master station to communicate with the relay. The default value is 255 and must be changed in the range 0 to 254 before use.

The next cell down controls the inactivity timer.

| |
|---|
| RP2 inactivity timer<br>15 mins. |

The inactivity timer controls how long the relay will wait 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.

In the case of EIA(RS)232 and EIA(RS)485 the next cell down controls the baud rate. For K-Bus the baud rate is fixed at 64kbit/second between the relay and the KITZ interface at the end of the relay spur.

| |
|---|
| RP2 baud rate<br>19200 |

Courier communications is asynchronous. Three baud rates are supported by the relay, ‘9600 bits/s’, ‘19200 bits/s’ and ‘38400 bits/s’.

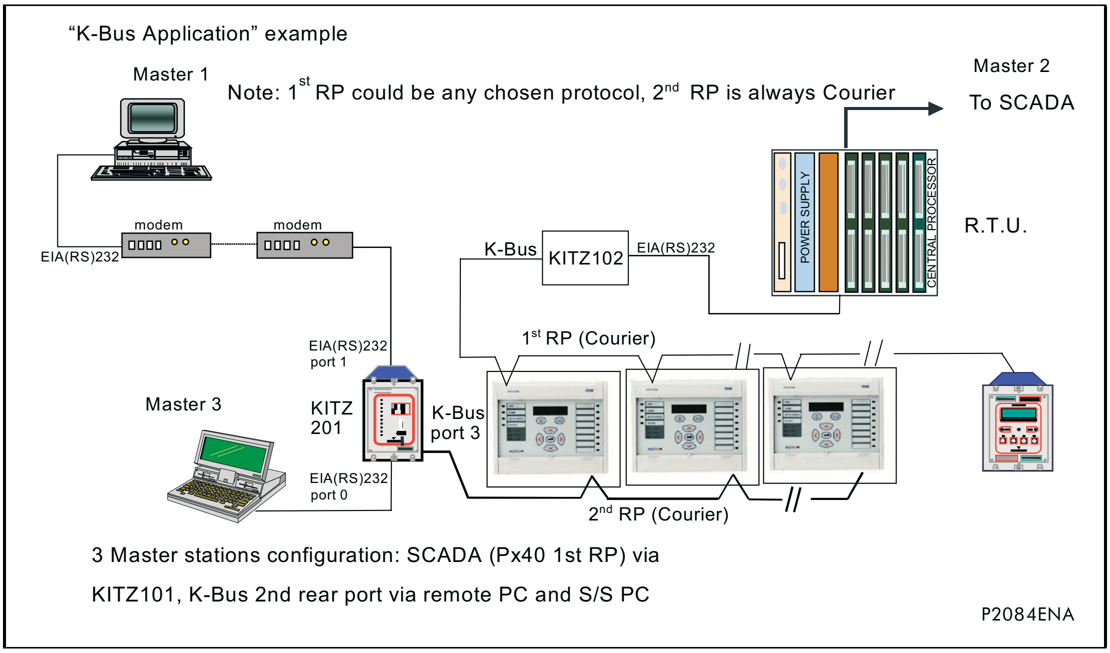



**Figure 3: Second rear port K-Bus application**

SC

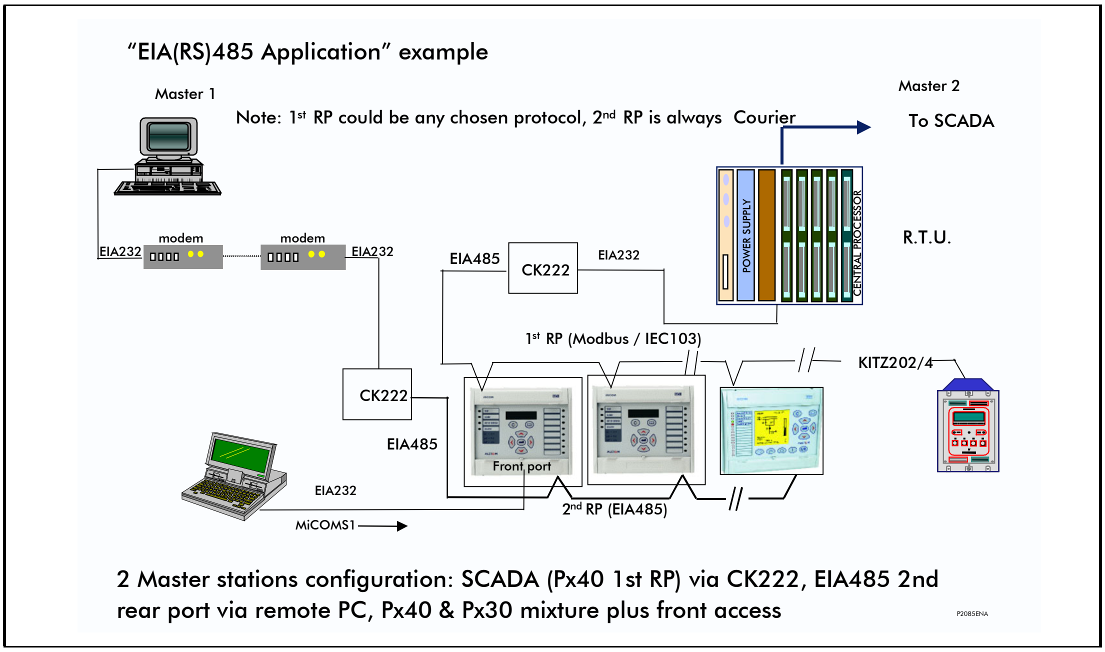



**Figure 4: Second rear port EIA(RS)485 example**

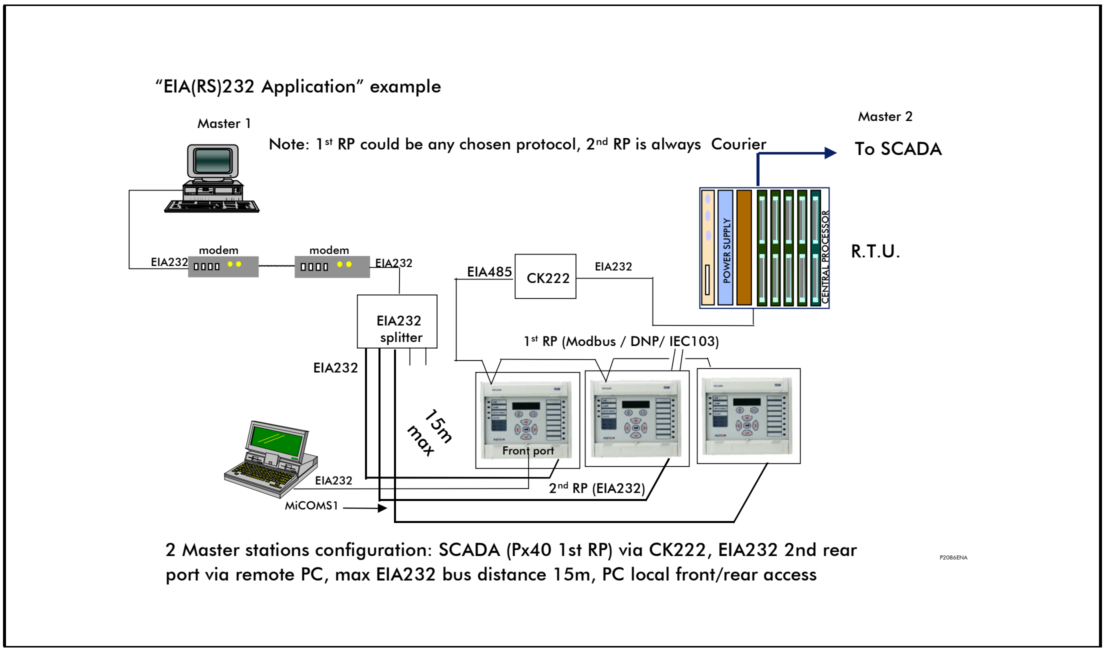



**Figure 5: Second rear port EIA(RS)232 example**

SC

# 2. COURIER INTERFACE

## 2.1 Courier protocol

K-Bus is based on EIA(RS)485 voltage levels with HDLC FM0 encoded synchronous signaling and its own frame format. The K-Bus twisted pair connection is unpolarized, whereas the EIA(RS)485 and EIA(RS)232 interfaces are polarized.

The EIA(RS)232 interface uses the IEC60870-5 FT1.2 frame format.

The relay supports an IEC60870-5 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, 11-bit frame, and a fixed device address.

The rear interface is used to provide a permanent connection for K-Bus and allows multi-drop connection. It should be noted that although K-Bus is based on EIA(RS)485 voltage levels it is a synchronous HDLC protocol using FM0 encoding. It is not possible to use a standard EIA(RS)232 to EIA(RS)485 converter to convert IEC60870-5 FT1.2 frames to K-Bus. Nor is it possible to connect K-Bus to an EIA(RS)485 computer port. A protocol converter, such as the KITZ101, should be employed for this purpose.

Alternatively for direct connections, the fiber optic converter card may be used to convert the rear EIA(RS)485 port into a fiber optic (ST) port. See section 1.3 for more information.

## 2.2 Supported command set

The following Courier commands are supported by the relay:

Protocol Layer

- Reset Remote Link
- Poll Status
- Poll Buffer*

Low Level Commands

- Send Event*
- Accept Event*
- Send Block
- Store Block Identifier
- Store Block Footer

Menu Browsing

- Get Column Headings
- Get Column Text
- Get Column Values
- Get Strings
- Get Text
- Get Value
- Get Column Setting Limits

Setting Changes

- Enter Setting Mode
- Preload Setting
- Abort Setting

Execute Setting

Reset Menu Cell

Set Value

Control Commands

Select Setting Group

Change Device Address*

Set Real Time

Note: Commands indicated with a * are not supported via the front Courier port.

### 2.3 Relay courier database

The Courier database is a two dimensional structure with each cell in the database being referenced by a row and column address. Both the column and the row can take a range from 0 to 255. Addresses in the database are specified as hexadecimal values; e.g. 0A02 is column 0A (10 decimal) row 02. Associated settings/data will be part of the same column, row zero of the column contains a text string to identify the contents of the column, i.e. a column heading.

P145/EN MD contains the complete database definition for the relay. For each cell location the following information is stated:

– Cell text

– Cell datatype

– Cell value

– Whether the cell is settable, if so

– Minimum value

– Maximum value

– Step size

– Password level required to allow setting changes

– String information (for Indexed String or Binary flag cells)

### 2.4 Setting changes

(See R6512, Courier User Guide - Chapter 9)

There are three categories of settings within the relay database:

– Control and support

– Disturbance recorder

– Protection settings group

Setting changes made to the control and support settings are implemented immediately and stored in non-volatile memory. Changes made to either the disturbance recorder settings or the protection settings groups are stored in a ‘scratchpad’ memory and are not immediately implemented by the relay.

To action setting changes stored in the scratchpad the save changes cell in the configuration column must be written to. This allows the changes to either be confirmed and stored in non-volatile memory, or the setting changes to be aborted.

### 2.4.1 Setting transfer mode

If it is necessary to transfer all of the relay settings to or from the relay a cell within the communication system data column can be used. This cell (location BF03) when set to 1 makes all of the relay settings visible. Any setting changes made, with the relay set in this mode, are stored in scratchpad memory (including control and support settings). When the value of BF03 is set back to 0 any setting changes are verified and stored in non-volatile memory.

## 2.5 Event extraction

Events can be extracted either automatically (rear port only) or manually (either Courier port). For automatic extraction all events are extracted in sequential order using the standard Courier event mechanism, this includes fault/maintenance data if appropriate. The manual approach allows the user to select events, faults, or maintenance data at random from the stored records.

### 2.5.1 Automatic event extraction

(See Chapter 7 Courier User Guide, publication R6512)

This method is intended for continuous extraction of event and fault information as it is produced. It is only supported via the rear Courier port.

When new event information is created the event bit is set within the status byte, this indicates to the master device that event information is available. The oldest, unextracted event can be extracted from the relay using the send event command. The relay will respond with the event data, which will be either a Courier Type 0 or Type 3 event. The Type 3 event is used for fault records and maintenance records.

Once an event has been extracted from the relay, the accept event can be used to confirm that the event has been successfully extracted. If all events have been extracted then the event bit will reset, if there are more events still to be extracted the next event can be accessed using the send event command as before.

### 2.5.2 Event types

Events will be created by the relay under the following circumstances:

- Change of state of output contact
- Change of state of opto input
- Protection element operation
- Alarm condition
- Setting change
- Password entered/timed-out
- Fault record (Type 3 Courier Event)
- Maintenance record (Type 3 Courier Event)

### 2.5.3 Event format

The send event command results in the following fields being returned by the relay:

- Cell reference
- Timestamp
- Cell text
- Cell value

The menu database, P145/EN MD, contains a table of the events created by the relay and indicates how the contents of the above fields are interpreted. Fault records and maintenance records will return a Courier Type 3 event, which contains the above fields together with two additional fields:

– Event extraction column

– Event number

These events contain additional information that is extracted from the relay using the referenced extraction column. Row 01 of the extraction column contains a setting that allows the fault/maintenance record to be selected. This setting should be set to the event number value returned within the record; the extended data can be extracted from the relay by uploading the text and data from the column.

#### 2.5.4 Manual event record extraction

Column 01 of the database can be used for manual viewing of event, fault, and maintenance records. The contents of this column will depend on the nature of the record selected. It is possible to select events by event number and to directly select a fault record or maintenance record by number.

Event Record Selection (Row 01) - This cell can be set to a value between 0 to 249 to select which of the 512 stored events is selected, 0 will select the most recent record; 249 the oldest stored record. 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) then the remainder of the column will contain the additional information.

Fault Record Selection (Row 05) – This cell can be used to directly select a fault record using a value between 0 and 4 to select one of up to five stored fault records. (0 will be the most recent fault and 4 will be the oldest). The column will then contain the details of the fault record selected.

Maintenance Record Selection (Row F0) – This cell can be used to select a maintenance record using a value between 0 and 4 and operates in a similar way to the fault record selection.

It should be noted that if this column is used to extract event information from the relay the number associated with a particular record will change when a new event or fault occurs.

### 2.6 Disturbance record extraction

Select Record Number (Row 01) - This cell can be used to select the record to be extracted. Record 0 will be the oldest unextracted record, already extracted older records will be assigned positive values, and negative values will be used for more recent records. To facilitate automatic extraction via the rear port the disturbance bit of the status byte is set by the relay whenever there are unextracted disturbance records.

Once a record has been selected, using the above cell, the time and date of the record can be read from cell 02. The disturbance record itself can be extracted using the block transfer mechanism from cell B00B.

As has been stated, the rear Courier port can be used to automatically extract disturbance records as they occur. This operates using the standard Courier mechanism defined in Chapter 8 of the Courier User Guide. The front Courier port does not support automatic extraction although disturbance record data can be extracted manually from this port.

### 2.7 Programmable scheme logic settings

The programmable scheme logic (PSL) settings can be uploaded from and downloaded to the relay using the block transfer mechanism defined in Chapter 12 of the Courier User Guide.

The following cells are used to perform the extraction:

- B204 Domain/: Used to select either PSL settings (Upload or download) or PSL configuration data (Upload only)
- B208 Sub-Domain: Used to select the Protection Setting Group to be uploaded/downloaded.
- B20C Version: Used on a download to check the compatibility of the file to be downloaded with the relay.
- B21C Transfer Mode: Used to set-up the transfer process.
- B120 Data Transfer Cell: Used to perform upload/download.

The programmable scheme logic settings can be uploaded and downloaded to and from the relay using this mechanism. If it is necessary to edit the settings MiCOM S1 must be used as the data format is compressed. MiCOM S1 also performs checks on the validity of the settings before they are downloaded to the relay.

# 3. MODBUS INTERFACE

The MODBUS interface is a master/slave protocol and it is defined by MODBUS.org: See

www.modbus.org

MODBUS Serial Protocol Reference Guide: PI-MBUS-300 Rev. E

## 3.1 Communication link

This interface also uses the rear EIA(RS)485 port (or converted fiber optic port) for communication using '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.

In summary, the character framing is 1 start bit, 8 bit data, either 1 parity bit and 1 stop bit, or two stop bits. This gives 11 bits per character.

The following parameters can be configured for this port using either the front panel interface or the front Courier port:

- Baud rate
- Device address
- Parity
- Inactivity time

## 3.2 MODBUS functions

The following MODBUS function codes are supported by the relay:

| | |
|---|---|
| 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 relay 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) |

SC

### 3.3 Response codes

| Code | MODBUS Description | MiCOM Interpretation |
|---|---|---|
| 01 | Illegal Function Code | The function code transmitted is not supported by the slave. |
| 02 | Illegal Data Address | The start data address in the request is not an allowable value. If any of the addresses in the range cannot be accessed due to password protection then all changes within the request are discarded and this error response will be returned. Note: If the start address is correct but the range includes non–implemented addresses this response is not produced. |
| 03 | Illegal Value | A value referenced in the data field transmitted by the master is not within range. Other values transmitted within the same packet will be executed if inside range. |
| 06 | Slave Device Busy | The write command cannot be implemented due to the database being locked by another interface. This response is also produced if the relay software is busy executing a previous request. |

### 3.4 Register mapping

The relay 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).

Note that the “extended memory file” (6xxxx) is not supported.

A complete map of the MODBUS addresses supported by the relay is contained in menu database, P145/EN MD, of this service manual.

Note that 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. Thus, the first register in a memory page is register address zero. The second register is register address 1 and so on. Note that the page number notation is not part of the address.



### 3.5 Event extraction

The relay supports two methods of event extraction providing either automatic or manual extraction of the stored event, fault, and maintenance records.

#### 3.5.1 Manual selection

There are three registers available to manually select stored records, there are also three read only registers allowing the number of stored records to be determined.

40100 - Select Event, 0 to 249

40101 - Select Fault, 0 to 4

40102 - Select Maintenance Record, 0 to 4

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 by the relay. If this event record is selected the additional registers allowing the fault or maintenance record details will also become populated.

### 3.5.2 Automatic 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 relay has any events stored that have not yet been extracted. This is performed by reading the relay status register 30001 (G26 data type). If the event bit of this register is set then the relay has unextracted 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.

### 3.5.3 Record data

The location and format of the registers used to access the record data is the same whether they have been selected using either of the two mechanisms detailed above.

| Event Description | MODBUS Address | Length | Comments |
|---|---|---|---|
| Time and Date | 30103 | 4 | See G12 data type description in section 3.8. |
| Event Type | 30107 | 1 | See G13 data type. Indicates type of event. |
| Event Value | 30108 | 2 | Nature of value depends on event type. This will contain the status as a binary flag for contact, opto, alarm, and protection events. |
| MODBUS Address | 30110 | 1 | This indicates the MODBUS register address where the change occurred.<br>Alarm 30011<br>Relays 30723<br>Optos 30725<br>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.<br>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.<br>1 means fault record data can be read from 30113 to 30199 (number of registers depends on the product).<br>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 clear independently the stored relay event/fault and maintenance records. This register also provides an option to reset the relay indications, which has the same effect on the relay as pressing the clear key within the alarm viewer using the front panel menu.

## 3.6 Disturbance record extraction

The relay provides facilities for both manual and automatic extraction of disturbance records. The extraction mechanisms are explained below:

### 3.6.1 Extraction mechanism

Records extracted over MODBUS from Px40 platform relays will be 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 relay. The data page is made up of 127 registers, giving a maximum transfer of 254 bytes per page.

#### 3.6.1.1 Interface registers

The following set of registers is presented to the master station to support the extraction of uncompressed disturbance records:

| MODBUS Register | Name | Description |
|---|---|---|
| 3x00001 | Status register | Provides the status of the relay as bit flags:<br>b0 – Out of service<br>b1 – Minor self test failure<br>b2 – Event<br>b3 – Time synchronization<br>b4 – Disturbance<br>b5 – Fault<br>b6 – Trip<br>b7 – Alarm<br>b8 to b15 – Unused<br>A ‘1’ on b4 indicates the presence of a disturbance. |

SC

| MODBUS Register | Name | Description |
|---|---|---|
| 3x00800 | N° of stored disturbances | Indicates the total number of disturbance records currently stored in the relay, both extracted and unextracted. |
| 3x00801 | Unique identifier of the oldest disturbance record | Indicates the unique identifier value for the oldest disturbance record stored in the relay. This is an integer value used in conjunction with the 'N° of stored disturbances' value to calculate a value for manually selecting records. |
| 4x00250 | Manual disturbance record selection register | This register is used to manually select disturbance records. The values written to this cell are an offset of the unique identifier value for the oldest record. The offset value, which ranges from 0 to the N° 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:<br>b0 – Select next event<br>b1 – Accept event<br>b2 – Select next disturbance record<br>b3 – Accept disturbance record<br>b4 – Select next page of disturbance data<br>b5 – Select data file |
| 3x00930 – 3x00933 | Record time stamp | These registers return the timestamp of the disturbance record. |
| 3x00802 | N° of registers in data page | This register informs the master station of the number of registers in the data page that are populated. |
| 3x00803 – 3x00929 | Data page registers | These 127 registers are used to transfer data from the relay to the master station. They are 16-bit unsigned integers. |
| 3x00934 | Disturbance record status register | The disturbance record status register is used during the extraction process to indicate to the master station when data is ready for extraction. See next table. |
| 4x00251 | Data file format selection | This is used to select the required data file format. This is reserved for future use. |

Note: Register addresses are provided in reference code + address format. E.g. 4x00001 is reference code 4x, address 1 (which is specified as function code 03, address 0x0000 in the MODBUS specification).

The disturbance record status register will report one of the following values:

SC

| State | Description |
|---|---|
| Idle | This will be the state reported when no record is selected; such as after power on or after a record has been marked as extracted. |
| Busy | The relay is currently processing data. |
| Page ready | The data page has been populated and the master station can now safely read the data. |
| Configuration complete | All of the configuration data has been read without error. |
| Record complete | All of the disturbance data has been extracted. |
| Disturbance overwritten | An error occurred during the extraction process where the disturbance being extracted was overwritten by a new record. |
| No 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 relay. |
| Command out of sequence | The master station issued a command to the relay that was not expected during the extraction process. |

### 3.6.2 Extraction procedure

The following procedure will be used to extract disturbances from the relay. The procedure is split into four sections:

1. Selection of a disturbance – either manually or automatically
2. Extraction of the configuration file
3. Extraction of the data file
4. Accepting the extracted record (automatic extraction only)

3.6.2.1 Manual extraction procedure

The procedure used to extract a disturbance manually is shown in Figure 6 below. The manual method of extraction does not allow for the acceptance of disturbance records.

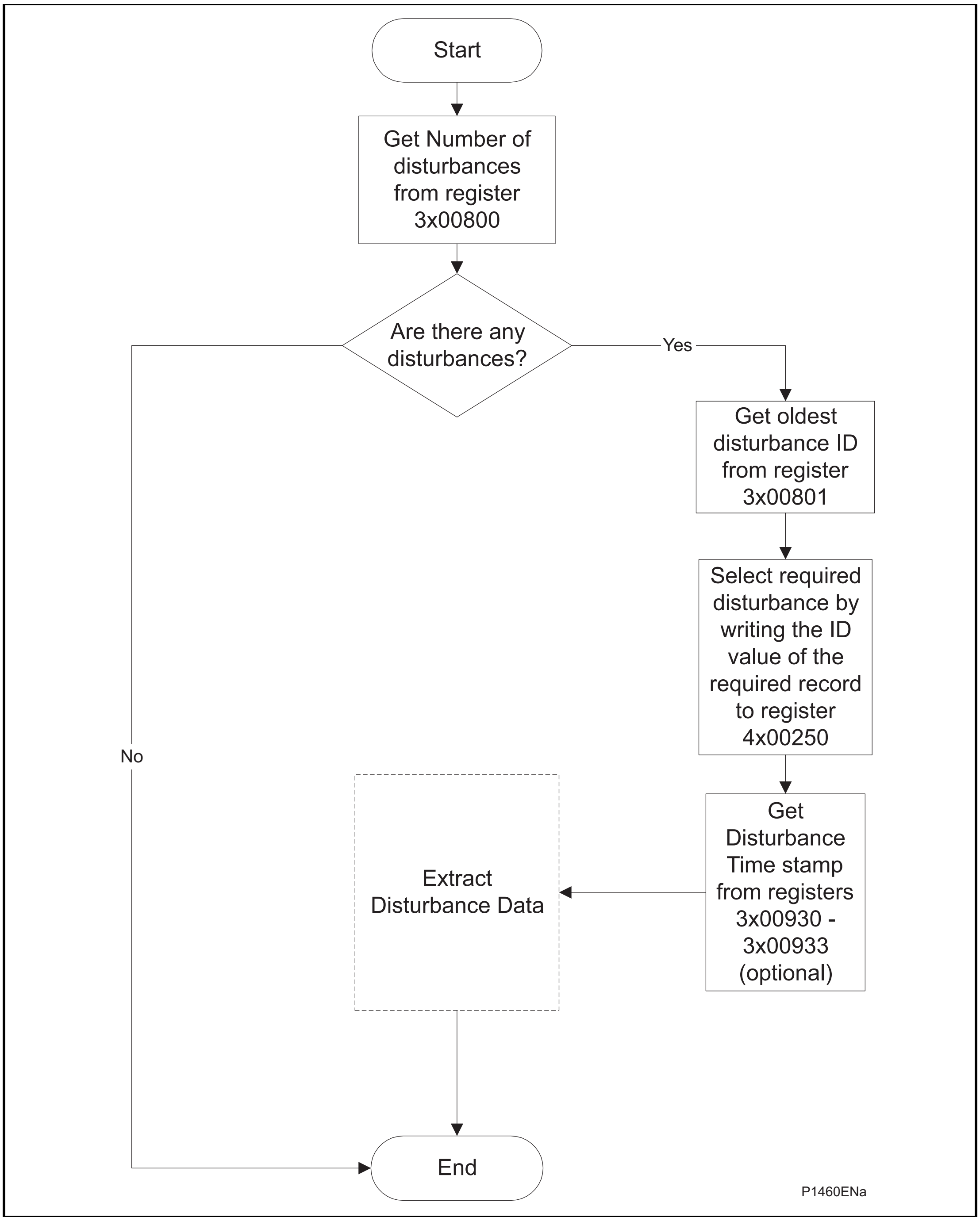



**Figure 6: Manual selection of a disturbance record**

3.6.2.2 Automatic extraction procedure

There are two methods that can be used for automatically extracting disturbances. Option 1 is simpler and is better at extracting single disturbance records, i.e. when the disturbance recorder is polled regularly. Option 2, however, 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 hence may have many stored records.

### 3.6.2.3 Automatic extraction procedure – option 1

The procedure for the first method is shown in Figure 7 below. This also shows the acceptance of the disturbance record once the extraction is complete.

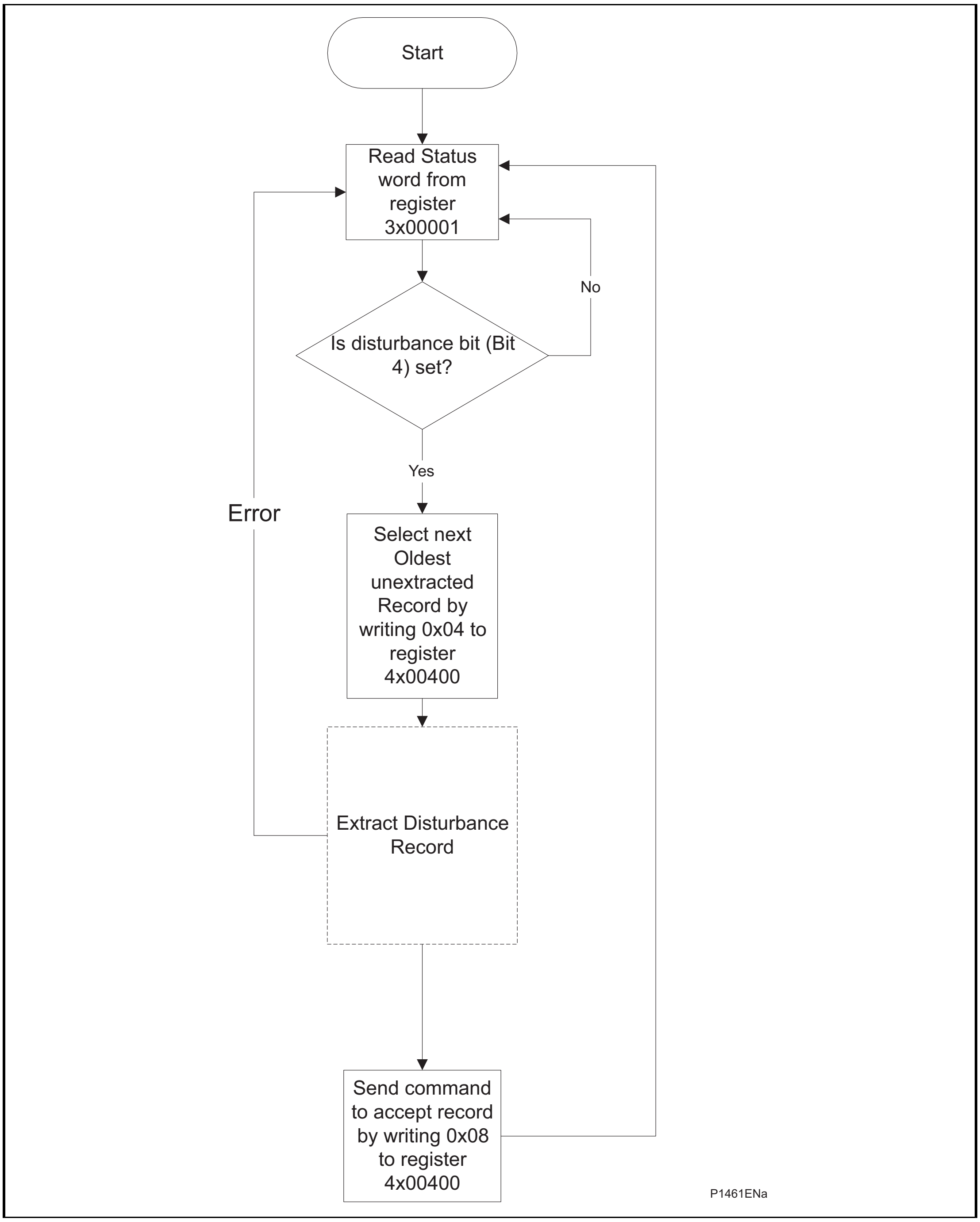



**Figure 7: Automatic selection of a disturbance – option 1**

3.6.2.4 Automatic extraction procedure – option 2

The second method that can be used for automatic extraction is shown in Figure 8 below. This also shows the acceptance of the disturbance record once the extraction is complete:

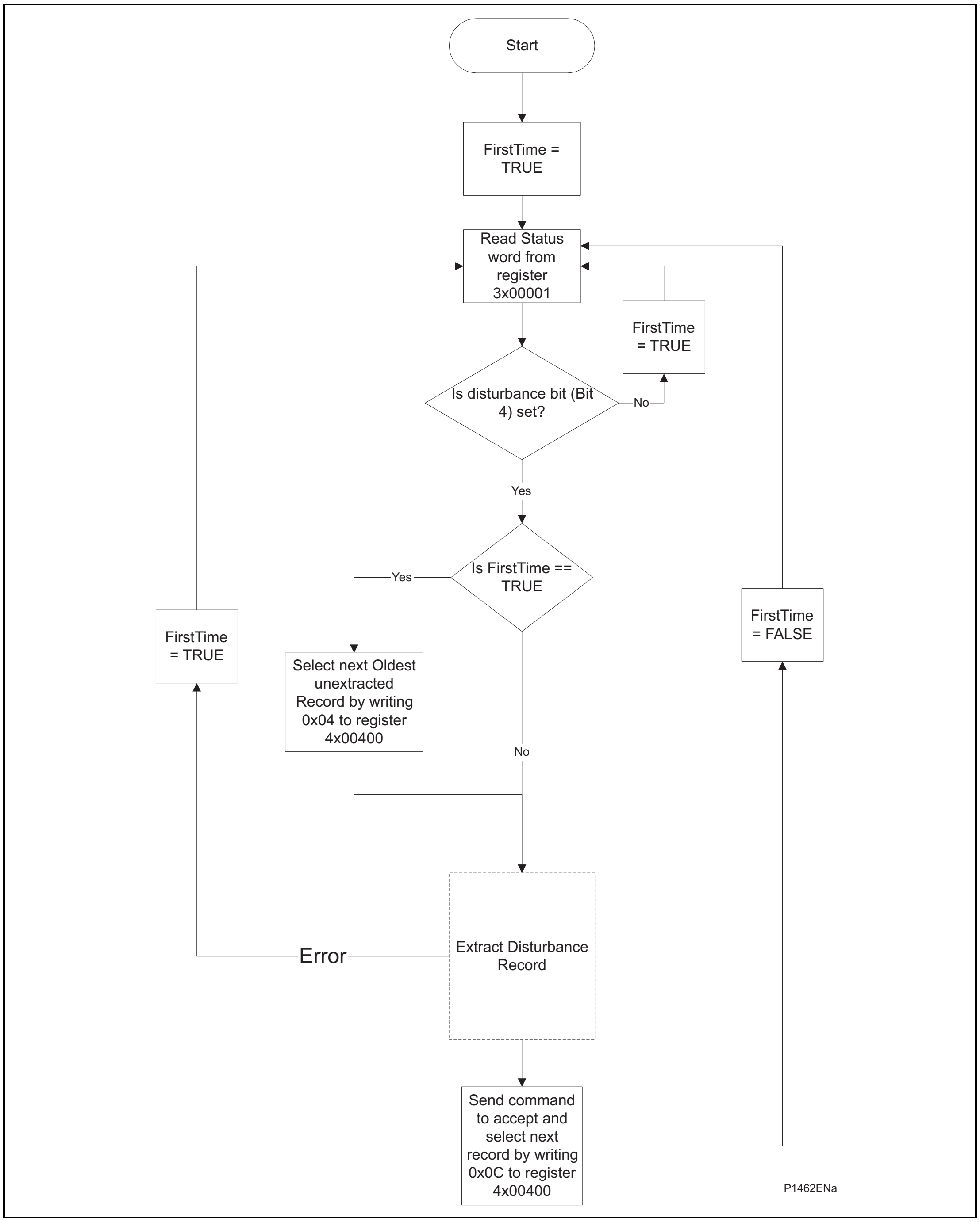



**Figure 8: Automatic selection of a disturbance – option 2**

### 3.6.3 Extracting the disturbance data

The extraction of the disturbance record, as shown in the three figures above, is a two-stage process that involves extracting the configuration file first and then the data file.

The following Figure 9 shows how the configuration file is extracted from the relay:

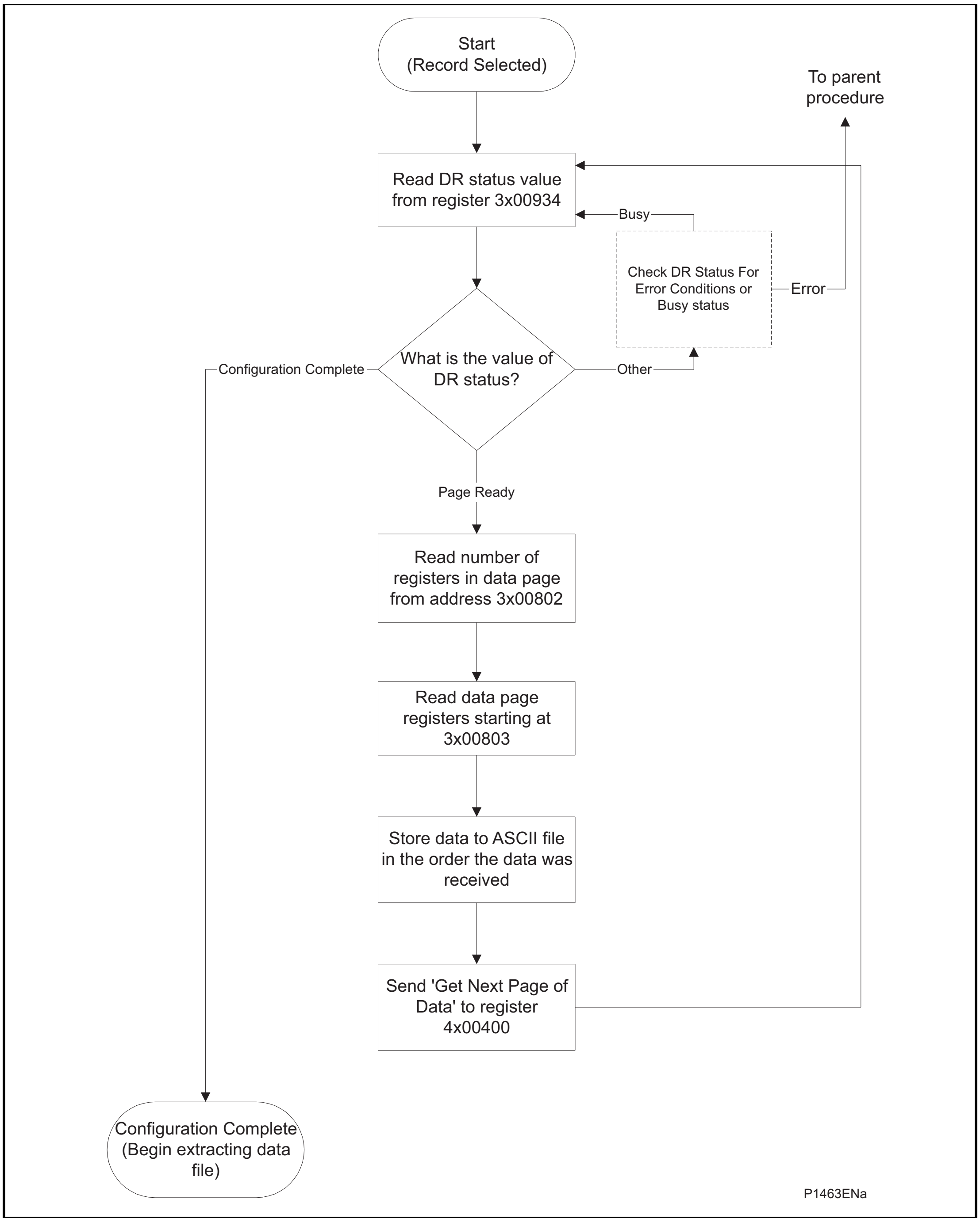
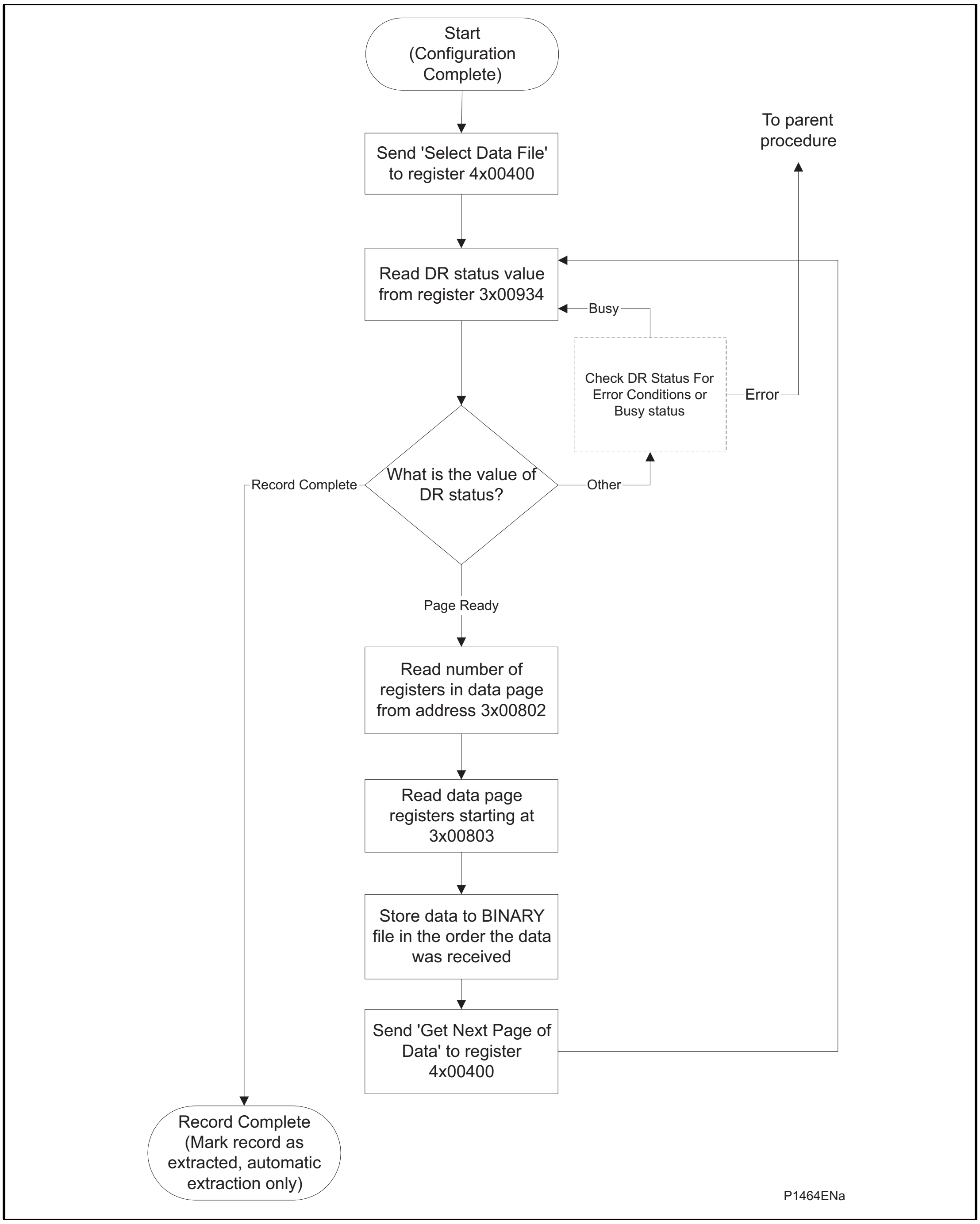



**Figure 9: Extracting the COMTRADE configuration file**

SC

The following Figure 10 shows how the data file is extracted:




SC

**Figure 10: Extracting the COMTRADE binary data file**

During the extraction of the COMTRADE files, an error may occur that will be reported on the DR Status register 3x00934. This can be caused by the relay overwriting the record being extracted or due to the master station issuing a command that is not within the bounds of the extraction procedure.

### 3.7 Setting changes

The relay settings can be split into two categories:

– Control and support settings

– Disturbance record settings and protection setting groups

Changes to settings within the control and support area are executed immediately. Changes to the protection setting groups or the disturbance recorder settings are stored in a temporary 'scratchpad' area and must be confirmed before they are implemented. All the relay 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 then the data associated with these addresses will be discarded.

– If a write operation is performed with values that are out of range then the illegal data response will be produced. Valid setting values within the same write operation will be executed.

– If a write operation is performed attempting to change registers that require a higher level of password access than is currently enabled then all setting changes in the write operation will be discarded.

### 3.7.1 Password protection

As described in the introduction to this service manual, the relay settings can be subject to password protection. The level of password protection required to change a setting is indicated in the relay setting database (P145/EN MD). Level 2 is the highest level of password access, level 0 indicates that no password is required.

The following registers are available to control password protection:

| | |
|---|---|
| 40001 & 40002 | Password entry |
| 40022 | Default password level |
| 40023 & 40024 | Setting to change password level 1 |
| 40025 & 40026 | Setting to change password level 2 |
| 30010 | Can be read to indicate current access level |

### 3.7.2 Control and support settings

Control and support settings are executed immediately on the write operation.

### 3.7.3 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 relay unless a confirm or an abort operation is performed. Register 40405 can be used either to confirm or abort the setting changes within the scratchpad area. It should be noted that the relay supports four groups of protection settings. The MODBUS addresses for each of the four groups are repeated within the following address ranges:

| | |
|---|---|
| Group 1 | 41000 - 42999 |
| Group 2 | 43000 - 44999 |
| Group 3 | 45000 - 46999 |
| Group 4 | 47000 - 48999 |

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 40402.

– 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 40407.

It should be noted that 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 40405.

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.

### 3.8 Date and time format (data type G12)

The date-time data type G12 allows *real* date and time information to be conveyed down to a resolution of 1ms. The structure of the data type is shown in Table 3-1 and is compliant with the IEC60870-5-4 “Binary Time 2a” format.

The seven bytes of the structure are packed into four 16-bit registers, such that byte 1 is transmitted first, followed by byte 2 through to byte 7, followed by a null (zero) byte to make eight bytes in total. Since register data is usually transmitted in big-endian format (high order byte followed by low order byte), 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.

| Byte | Bit Position | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 1 | $m^7$ | $m^6$ | $m^5$ | $m^4$ | $m^3$ | $m^2$ | $m^1$ | $m^0$ |
| 2 | $m^{15}$ | $m^{14}$ | $m^{13}$ | $m^{12}$ | $m^{11}$ | $m^{10}$ | $m^9$ | $m^8$ |
| 3 | IV | R | $I^5$ | $I^4$ | $I^3$ | $I^2$ | $I^1$ | $I^0$ |
| 4 | SU | R | R | $H^4$ | $H^3$ | $H^2$ | $H^1$ | $H^0$ |
| 5 | $W^2$ | $W^1$ | $W^0$ | $D^4$ | $D^3$ | $D^2$ | $D^1$ | $D^0$ |
| 6 | R | R | R | R | $M^3$ | $M^2$ | $M^1$ | $M^0$ |
| 7 | R | $Y^6$ | $Y^5$ | $Y^4$ | $Y^3$ | $Y^2$ | $Y^1$ | $Y^0$ |

Where:

- m = 0…59,999ms
- I = 0…59 minutes
- H = 0…23 Hours
- W = 1…7 Day of week; Monday to Sunday, 0 for not calculated
- D = 1…31 Day of Month
- M = 1…12 Month of year; January to December
- Y = 0…99 Years (year of century)
- R = Reserved bit = 0
- SU = summertime: 0 = standard time, 1 = summer time
- IV = invalid value: 0 = valid, 1 = invalid
- range = 0ms…99 years

**Table 3-1 G12 date & time data type structure**

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 datum.

The invalid bit has two applications:

1. It can indicate that the date-time information is considered inaccurate, but is the best information available.

2. Date-time information is not available.

The summertime bit is used to indicate that summertime (day light saving) is being used and, more importantly, to resolve the alias and time discontinuity which occurs when summertime starts and ends. This is important for the correct time correlation of time stamped records.

The day of the week field is optional and if not calculated will be set to zero.

The concept of time zone is not catered for by this data type and hence by the relay. It is up to the end user to determine the time zone utilized by the relay. Normal practice is to use UTC (universal co-ordinated time), which avoids the complications with day light saving time-stamp correlation's.

## 3.9 Power & energy measurement data formats (G29 & G125)

The power and energy measurements are available in two data formats; G29 integer format and G125 IEEE754 floating point format. For historical reasons the registers listed in the main part of the "Measurements 2" column of the menu database (see P145/EN MD) are of the G29 format. The floating point, G125, versions appear at the end of the column.

### 3.9.1 Data type G29

Data type G29 consists of three registers. The first register is the per unit power or energy measurement and is of type G28, which is a signed 16 bit quantity. The second and third registers contain a multiplier to convert the per unit value to a real value. The multiplier is of type G27, which is an unsigned 32-bit quantity. Thus, the overall value conveyed by the G29 data type must be calculated as G29 = G28×G27.

The relay 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. This limitation should be borne in mind 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 as 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, the use of the G29 values is only recommended when the MODBUS master cannot deal with the G125 IEEE754 floating point equivalents.

Note that 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:**

For A-Phase Power (Watts) (registers 30300 - 30302) for a 110V relay, In = 1A, VT ratio = 110V:110V and CT ratio = 1A:1A.

Applying A-phase 1A @ 63.51V

A-phase Watts = ((63.51V × 1A)/In = 1A) × (110/Vn = 110V) = 63.51 Watts

The G28 part of the value is the truncated per unit quantity, which will be equal to 64 (40h).

The multiplier is derived from the VT and CT ratios set in the relay, with the equation ((CT Primary) × (VT Primary)/110V). Thus, the G27 part of the value will equal 1. Hence the overall value of the G29 register set is 64×1 = 64W

The registers would contain:

30300 - 0040h

30301 - 0000h

30302 - 0001h

Using the previous example with a VT ratio = 110,000V; 110V and CT ratio = 10,000A:1A the G27 multiplier would be 10,000A $\times$ 110,000V/110 = 10,000,000. The overall value of the G29 register set is 64 $\times$ 10,000,000 = 640MW. (Note that there is an actual error of 49MW in this calculation due to loss of resolution.)

The registers would contain:

30300 - 0040h

30301 - 0098h

30302 - 9680h

### 3.9.2 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 relay's ability to resolve the measurement after it has applied the secondary or primary scaling factors as require. It does not suffer from the truncation errors or dynamic range limitations associated with the G29 data format.

# 4. IEC60870-5-103 INTERFACE

The IEC60870-5-103 interface is a master/slave interface with the relay as the slave device. The relay conforms to compatibility level 2; compatibility level 3 is not supported.

The following IEC60870-5-103 facilities are supported by this interface:

- Initialization (reset)
- Time synchronization
- Event record extraction
- General interrogation
- Cyclic measurements
- General commands
- Disturbance record extraction
- Private codes

## 4.1 Physical connection and link layer

Two connection options are available for IEC60870-5-103, either the rear EIA(RS)485 port or an optional rear fiber optic port. Should the fiber optic port be fitted the selection of the active port can be made via the front panel menu or the front Courier port, however the selection will only be effective following the next relay power up.

For either of the two modes of connection it is possible to select both the relay address and baud rate using the front panel menu/front Courier. Following a change to either of these two settings a reset command is required to re-establish communications, see reset command description below.

## 4.2 Initialization

Whenever the relay has been powered up, or if the communication parameters have been changed a reset command is required to initialize the communications. The relay will respond to either of the two reset commands (Reset CU or Reset FCB), the difference being that the Reset CU will clear any unsent messages in the relay's transmit buffer.

The relay 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 IEC60870-5-103 section of the menu database, P145/EN MD.

In addition to the above identification message, if the relay has been powered up it will also produce a power up event.

## 4.3 Time synchronization



The relay time and date can be set using the time synchronization feature of the IEC60870-5-103 protocol. The relay will correct for the transmission delay as specified in IEC60870-5-103. If the time synchronization message is sent as a send/confirm message then the relay will respond with a confirm. Whether the time-synchronization message is sent as a send confirm or a broadcast (send/no reply) message, a time synchronization Class 1 event will be generated/produced.

If the relay clock is being synchronized using the IRIG-B input then it will not be possible to set the relay time using the IEC60870-5-103 interface. An attempt to set the time via the interface will cause the relay to create an event with the current date and time taken from the IRIG-B synchronized internal clock.

### 4.4 Spontaneous events

Events are categorized using the following information:

- Function type
- Information number

The IEC60870-5-103 profile in the menu database, P145/EN MD, contains a complete listing of all events produced by the relay.

### 4.5 General interrogation

The GI request can be used to read the status of the relay, the function numbers, and information numbers that will be returned during the GI cycle are indicated in the IEC60870-5-103 profile in the menu database, P145/EN MD.

### 4.6 Cyclic measurements

The relay will produce measured values using ASDU 9 on a cyclical basis, this can be read from the relay using a Class 2 poll (note ADSU 3 is not used). The rate at which the relay produces new measured values can be controlled using the measurement period setting. This setting can be edited from the front panel menu/front Courier port and is active immediately following a change.

It should be noted that the measurands transmitted by the relay are sent as a proportion of 2.4 times the rated value of the analog value.

### 4.7 Commands

A list of the supported commands is contained in the menu database, P145/EN MD. The relay will respond to other commands with an ASDU 1, with a cause of transmission (COT) indicating 'negative acknowledgement'.

### 4.8 Test mode

It is possible using either the front panel menu or the front Courier port to disable the relay output contacts to allow secondary injection testing to be performed. This is interpreted as 'test mode' by the IEC60870-5-103 standard. An event will be produced to indicate both entry to and exit from test mode. Spontaneous events and cyclic measured data transmitted whilst the relay is in test mode will have a COT of 'test mode'.

### 4.9 Disturbance records

The disturbance records are stored in uncompressed format and can be extracted using the standard mechanisms described in IEC60870-5-103.

Note: IEC60870-5-103 only supports up to 8 records.



### 4.10 Blocking of monitor direction

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.

# 5. DNP3.0 INTERFACE

## 5.1 DNP3.0 protocol

The descriptions given here are intended to accompany the device profile document that is included in the menu database, P145/EN MD. The DNP3.0 protocol is not described here, please refer to the documentation available from the user group. The device profile document specifies the full details of the DNP3.0 implementation for the relay. This is the standard format DNP3.0 document that specifies which objects, variations and qualifiers are supported. The device profile document also specifies what data is available from the relay via DNP3.0. The relay operates as a DNP3.0 slave and supports subset level 2 of the protocol, plus some of the features from level 3.

DNP3.0 communication uses the EIA(RS)485 or fiber optic communication port at the rear of the relay. The data format is 1 start bit, 8 data bits, an optional parity bit and 1 stop bit. Parity is configurable (see menu settings below).

## 5.2 DNP3.0 menu setting

The settings shown below are available in the menu for DNP3.0 in the 'Communications' column.

| Setting | Range | Description |
|---|---|---|
| Remote Address | 0 – 65534 | DNP3.0 address of relay (decimal) |
| Baud Rate | 1200, 2400, 4800, 9600, 19200, 38400 | Selectable baud rate for DNP3.0 communication |
| Parity | None, Odd, Even | Parity setting |
| Time Sync. | Enabled, Disabled | Enables or disables the relay requesting time sync. from the master via IIN bit 4 word 1 |

## 5.3 Object 1 binary inputs

Object 1, binary inputs, contains information describing the state of signals within the relay which mostly form part of the digital data bus (DDB). In general these include the state of the output contacts and input optos, alarm signals and protection start and trip signals. The 'DDB number' column in the device profile document provides the DDB numbers for the DNP3.0 point data. These can be used to cross-reference to the DDB definition list that is also found in the menu database, P145/EN MD. The binary input points can also be read as change events via object 2 and object 60 for class 1-3 event data.

## 5.4 Object 10 binary outputs

Object 10, binary outputs, contains commands that can be operated via DNP3.0. As such the points accept commands of type pulse on [null, trip, close] and latch on/off as detailed in the device profile in the menu database, P145/EN MD and execute the command once for either command. The other fields are ignored (queue, clear, trip/close, in time and off time).

SC

Due to that fact that many of the relay's functions are configurable, it may be the case that some of the object 10 commands described below are not available for operation. In the case of a read from object 10 this will result in the point being reported as off-line and an operate command to object 12 will generate an error response.

Examples of object 10 points that maybe reported as off-line are:

– Activate setting groups - Ensure setting groups are enabled

– CB trip/close - Ensure remote CB control is enabled

– Reset NPS thermal - Ensure NPS thermal protection is enabled

– Reset thermal O/L - Ensure thermal overload protection is enabled

– Reset RTD flags - Ensure RTD Inputs is enabled

– Control Inputs - Ensure control inputs are enabled

## 5.5 Object 20 binary counters

Object 20, binary counters, contains cumulative counters and measurements. The binary counters can be read as their present 'running' value from object 20, or as a 'frozen' value from object 21. The running counters of object 20 accept the read, freeze and clear functions. The freeze function takes the current value of the object 20 running counter and stores it in the corresponding object 21 frozen counter. The freeze and clear function resets the object 20 running counter to zero after freezing its value.

## 5.6 Object 30 analog input

Object 30, analog inputs, contains information from the relay's measurements columns in the menu. All object 30 points are reported as fixed-point values although they are stored inside the relay in a floating-point format. The conversion to fixed-point format requires the use of a scaling factor, which differs for the various types of data within the relay e.g. current, voltage, phase angle etc. The data types supported are listed at the end of the device profile document with each type allocated a 'D number', i.e. D1, D2, etc. In the object 30 point list each data point has a D number data type assigned to it which defines the scaling factor, default deadband setting and the range and resolution of the deadband setting. The deadband is the setting used to determine whether a change event should be generated for each point. The change events can be read via object 32 or object 60 and will be generated for any point whose value has changed by more than the deadband setting since the last time the data value was reported.

Any analog measurement that is unavailable at the time it is read will be reported as offline, e.g. the frequency when the current and voltage frequency is outside the tracking range of the relay or the thermal state when the thermal protection is disabled in the configuration column. Note that all object 30 points are reported as secondary values in DNP3.0 (with respect to CT and VT ratios).

## 5.7 DNP3.0 configuration using MiCOM S1

A PC support package for DNP3.0 is available as part of the settings and records module of MiCOM S1. The S1 module allows configuration of the relay's DNP3.0 response. The PC is connected to the relay via a serial cable to the 9-pin front part of the relay – see Introduction (P145/EN IT). The configuration data is uploaded from the relay to the PC in a block of compressed format data and downloaded to the relay in a similar manner after modification. The new DNP3.0 configuration takes effect in the relay after the download is complete. The default configuration can be restored at any time by choosing 'All Settings' from the 'Restore Defaults' cell in the menu 'Configuration' column. In S1, the DNP3.0 data is displayed on a three-tabbed screen, one screen each for object 1, 20 and 30. Object 10 is not configurable.

### 5.7.1 Object 1

For every point included in the device profile document there is a check box for membership of class 0 and radio buttons for class 1, 2 or 3 membership. Any point that is in class 0 must be a member of one of the change event classes 1, 2 or 3.



Points that are configured out of class 0 are by default not capable of generating change events. Furthermore, points that are not part of class 0 are effectively removed from the DNP3.0 response by renumbering the points that are in class 0 into a contiguous list starting at point number 0. The renumbered point numbers are shown at the left-hand side of the screen in S1 and can be printed out to form a revised device profile for the relay. This mechanism allows best use of available bandwidth by only reporting the data points required by the user when a poll for all points is made.

### 5.7.2 Object 20

The running counter value of object 20 points can be configured to be in or out of class 0. Any running counter that is in class 0 can have its frozen value selected to be in or out of the DNP3.0 response, but a frozen counter cannot be included without the corresponding running counter. As with object 1, the class 0 response will be renumbered into a contiguous list of points based on the selection of running counters. The frozen counters will also be renumbered based on the selection; note that if some of the counters that are selected as running are not also selected as frozen then the renumbering will result in the frozen counters having different point numbers to their running counterparts. For example, object 20 point 3 (running counter) might have its frozen value reported as object 21 point 1.

### 5.7.3 Object 30

For the analog inputs, object 30, the same selection options for classes 0, 1, 2 and 3 are available as for object 1. In addition to these options, which behave in exactly the same way as for object 1, it is possible to change the deadband setting for each point. The minimum and maximum values and the resolution of the deadband settings are defined in the device profile document; MiCOM S1 will allow the deadband to be set to any value within these constraints.

# 6. UCA2.0 ETHERNET INTERFACE

## 6.1 What is UCA2.0?

UCA2.0 is a communication architecture that was created by the Electric Power Research Institute (EPRI) as a generic means of representing information for use across the electric and other utility industries.

UCA2.0 incorporates a family of basic communications protocols. The selection and organization of these protocols has been designed to provide great flexibility, and to reduce integration and vendor product costs.

### 6.1.1 Why interoperability

UCA2.0 responds to the utilities' desire of having easier integration for different vendors' products. Traditionally, one vendor's implementation of MODBUS, for example, could place the A phase amps at register 40002. Other devices on the network, such as a Remote Terminal Unit (RTU), would then be programmed with the location of this information. When a new vendor's product, using register 30028 to represent Phase A current is added to the network, the RTU's must be re-programmed to accept this new register. While making extensive changes to your existing system for each new device, you create several dialects of the original protocol and true interoperability cannot be realized.

UCA2.0 takes a lot of these integration problems out of the picture. A UCA2.0 compliant device, such as a MiCOM relay, is built using these integration-friendly concepts. Meaning that instead of 40002 being a register containing Phase A current (which varies from vendor to vendor), a variable with the GOMSFE naming: **'MMXU.MX.A.PhsAf'** exists in one or many places as defined by the wrappers.

### 6.1.2 What is GOMSFE?

The Generic Object Models for Substation and Feeder Equipment (GOMSFE) document acts as the "dictionary" which defines:

– Categories of information within a device

– Hierarchy in which this information is organized

– Standard naming conventions through which others communicate with the device

UCA2.0 compliant devices will have all data and functions available to respond to these "names" defined in GOMFSE. For example, the standard measurement data from the protection device, is given using these "names" as below:

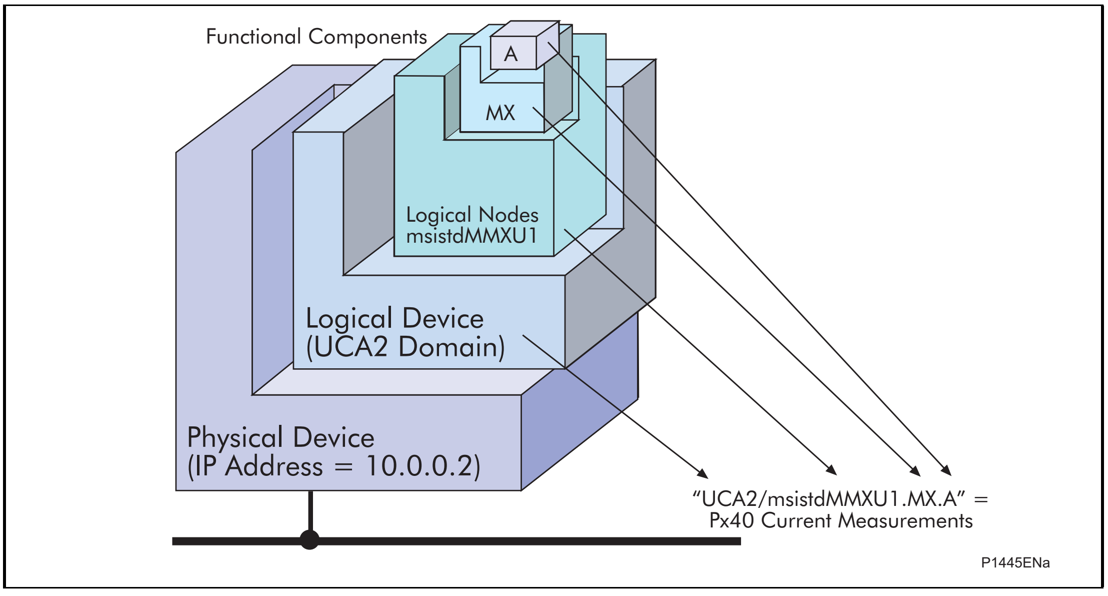



**Figure 11: Data representation over UCA2.0**

In UCA2.0, data is set up in a directory structure of a series of larger to smaller folders. To view Phase A amps or any other piece of data, you must know the location of the data within the informational hierarchy of GOMSFE.

### 6.1.3 How is UCA2.0 built up?

The information presented over UCA2.0 can be broken down into the following more understandable layers:

- Physical Address – Identifies the actual device within a system. Typically the devices name or IP address can be used (for example Feeder_1 or 10.0.0.2).
- Logical Device – Identifies an 'area' within the physical device. This is the upper level of the UCA2.0 data model. For the MiCOM relays, only 1 logical device exists; UCA2.0, which contains the actual relay data model.
- Wrapper/Brick Instance – Identifies the major functional areas within the UCA2.0 data model. 6 characters are used to define the functional group (wrapper) while the actual functionality (brick name) is identified by a 5 character name. For example brick name MMXU1 represents Polyphase measurements. By preceding this brick name with a wrapper 'msistd' the brick instance can be identified as containing standard polyphase measurements. In MiCOM Px40, wrappers are split into internal and external wrappers to allow better and simpler identification. In this example, external wrapper 'msi' = measurements, internal wrapper 'std' = standard. Please see the data model overview section and wrapper glossary for details of the wrappers used in each product and their meanings.
- Functional Component – This next layer is used to identify the type of data you will be presented with. Taking the MMXU1 brick, choices at this level could be a functional component called MX (measurement values) or DC (descriptions).
- A Data Element/Data Leaf – This is the actual data. If data leaf 'A' is read under the MX Functional Component, a measurement value will be returned. If the same data leaf is read under the DC Functional Component then a description will be returned.

Combining all this information together, a typical request may be seen to be:

Feeder_1 → UCA2.0\msistdMMXU1.MX.A

### 6.1.4 Summary

A UCA2.0 compliant device does not mean it is interchangeable, but does mean interoperable. You cannot simply replace one product with another, however the terminology is pre-defined and anyone with prior knowledge of UCA2.0 should be able very quickly integrate a new device without the need for mapping of all of the new data. UCA2.0 will inevitably bring improved substation communications and interoperability, at a lower cost to the end user.



### 6.1.5 Example of a functional component

Each brick within the data model has defined parts called object names, these are then split into standard Functional Components.

These Functional Components are:

| Functional Component | Description |
|---|---|
| CF | Configuration parameter(s) |
| CO | Control point(s) |
| DC | Descriptive (Menu) text |
| MX | Measurement value(s) |
| RP | Report control block |
| SG | Settings that belong to a setting group |
| SP | Settings that do not belong to a setting group (global to all setting groups) |
| ST | Status point(s) |

List of Functional Component symbols and their descriptions.

For below example, the admittance protection brick contains the 'Status Report Control Block' object (BrcbST). This belongs in the Functional Component RP and contains different Class Items such as BufTim, DatSet etc. These class items are where the actual data is stored.

| Object Name | FC | Class Item | Description |
|---|---|---|---|
| BrcbST | Status Report Control Block | | |
| | RP | BufTim | Buffer Time |
| | RP | DatSet | Data Set |

Elements under all Functional Components except CF and RP have a description (DC [menu text]). Elements belonging to the SP, SG, CO and MX Functional Components also have configuration parameters (CF).

The configuration parameter (CF) Functional Component may contain the following components. Depending upon the brick and object it is associated with. Some may have only deadbands, some may have increments, max./min. values and units.

- Incr./Incri – Setting Increment*
- Max./maxi – Maximum setting value*
- Min./mini – Minimum setting value*
- Db/dbf – Deadband value Integer, (f) indicates floating point deadband
- Ondur/offdur – On and Off duration for controls/commands
- U – Setting/Measurement units.

Note: * Components Incri/Maxi/Mini represents integer values instead of floating point.

### 6.2 Introduction to UCA2.0 GOOSE

The implementation of UCA2.0 Generic Object Orientated Substation Events (GOOSE) sets the way for cheaper and faster inter-relay communications. UCA2.0 GOOSE is based upon the principle of reporting the state of a selection of binary (i.e. ON or OFF) signals to other devices. In the case of Px40 relays, these binary signals are derived from the Programmable Scheme Logic Digital Data Bus signals.

UCA2.0 GOOSE messages are event-driven. When a monitored point changes state, e.g. from logic 0 to logic 1, a new message is sent. The device will wait for a pre-calculated time and then re-send the message. The calculation of this delay time is defined by GOMFSE. It increases with each re-transmission until the maximum delay time is reached (defined by the GOOSE Max. Cycle setting).

To ensure the fastest possible transfer of information, UCA2.0 GOOSE messages are sent as multicast packets over the network. An advantage to this method is the fact that all devices connected to the same network* will see the message.

Note: * Multicast messages cannot be routed across networks without specialized equipment.

The use of multicast messaging means that UCA2.0 GOOSE uses a publisher-subscriber system to transfer information around the network. When a device detects a change in one of it's monitored status points it publishes (i.e. sends) a message. Any device that is interested in the information subscribes (i.e. listens) to the data it contains.

### 6.2.1 UCA2.0 GOOSE message structure

The structure of information transmitted via UCA2.0 GOOSE is defined by the 'Protection Action' (PACT) common class template, defined by GOMFSE.

A UCA2.0 GOOSE message transmitted by a Px40 relay can carry up to 96 Digital Data Bus signals, where the monitored signals are characterized by a two-bit status value, or "bit-pair". The value transmitted in the bit-pair is customizable although GOMFSE recommends the following assignments:

| Bit Pair Value | Represents |
|---|---|
| 00 | A transitional or unknown state |
| 01 | A logical 0 or OFF state |
| 10 | A logical 1 or ON state |
| 11 | An invalid state |

UCA2.0 GOOSE message bit-pair assignment values.

The PACT common class splits the contents of a UCA2.0 GOOSE message into two main parts; 32 DNA bit-pairs and 64 User Status bit-pairs.

The DNA bit-pairs are intended to carry GOMSFE defined protection scheme information, where supported by the device. MiCOM Px40 implementation provides full end-user flexibility, as it is possible to assign any Digital Data Bus signal to any of the 32 DNA bit-pairs. The User Status bit pairs are intended to carry all 'user-defined' state and control information. As with the DNA, it is possible to assign any Digital Data Bus signal to these bit-pairs.

To ensure full compatibility with third party UCA2.0 GOOSE enabled products, it is recommended that the DNA bit-pair assignments be as per the definition given in GOMFSE.

SC

### 6.2.2 UCA2.0 GOOSE message configuration

A new UCA2.0 GOOSE message is transmitted whenever a monitored signal changes state (e.g. from logic 0 to logic 1). The reception of these messages in the presence of noise must be considered. Subscribing devices are reliant on the message reception in order to track the state of the device. Following a change of state, the bit-pairs being transmitted must be acquired dependably.

To ensure reliable reception of a device's state, a message retransmission strategy is used. This strategy works very well in the presence of burst noise. The probability of a single corrupted or missed message is greater than the probability of two successive corrupted or missed messages. This reduces rapidly as more messages are transmitted. It therefore seem sensible to rapidly transmit many UCA2.0 GOOSE messages in the hope that at least some will be received in the order of 10ms. However, rapidly transmitting many UCA2.0 GOOSE messages consumes available network bandwidth and increases the probability of collision delays. Network availability for other devices and protocols also decreases. Thus, the design of a UCA2.0 GOOSE scheme must allow sufficient network access time to all devices and other protocols, in order for the scheme to work reliably.

The reliability of a UCA2.0 GOOSE scheme relates to the maximum time that can elapse between message retransmissions, before the validity period expires. Each message has a validity period, if this is reached, the message is deemed to have expired. This is unacceptable, as you will no longer be sure of the device's state. When a message expires in this way, the subscribing device will revert to a set of safe default values. In order to prevent a message from expiring, a new (or retransmitted) message must be received within the expiry period.

Reliable schemes use a low message rate, which leads to the opposing demands of scheme dependability, which requires a high message rate. Reliable schemes achieve good network utilization, while the increased message rate of a dependable scheme increases the probability that the message is received in the order of 10 milliseconds. To make matters worse, these attributes are affected by many other parameters, some of which are:

- Number of transmitting devices on the network
- Responsiveness of the scheme to new events
- Probability of simultaneous event message transmission
- Probability of event avalanches
- Probability of message corruption on the network
- Ability of the network infrastructure to manage simultaneous broadcast/multicast messages

In practice, these parameters, which control the message transmission curves, cannot be calculated. Time must be allocated to the testing of schemes in just the same way a hardwired scheme must be tested.

As devices are added to the network, the number of possible interactions increases and the scope for error widens. Scheme availability can be decreased if interactions have not been adequately tested (in a realistic commissioning time). However, it should be noted that the message retransmission parameters would not affect the basic operation of UCA2.0 GOOSE, only its performance, especially under high event levels.

The parameters that control the message transmission curve are the minimum cycle time, maximum cycle time, and GOOSE increment settings.

The minimum cycle time is the time between the first event driven message being transmitted and the first retransmission. GOMFSE states that the minimum retransmission time will be in the order of 10ms.

The maximum cycle time is the maximum time between message retransmissions.

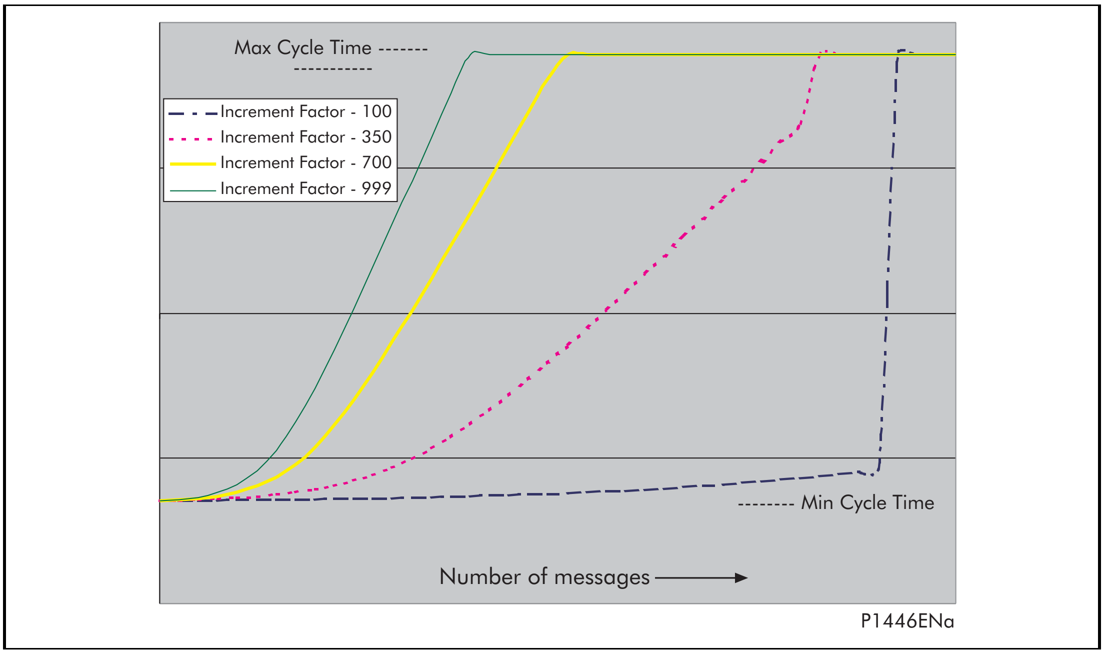



**Figure 12: GOOSE message transmission rates**

The Increment determines the rate at which the message 'steps-up' from min. cycle time to max. cycle time, as shown in Figure 12.

The validity of a message before it expires is double the maximum cycle time plus the minimum cycle time.

The general guidelines for establishing these parameters can be summarized as:

– Determine the minimum cycle time. GOMSFE recommends a value in the order of 10ms. However, if multiple devices can be triggered to transmit a new message simultaneously then the minimum cycle time values applied to each device should be different. This reduces the probability of experiencing message collisions, and increases reliability. The use of similar values may not produce sufficient time differentiation on the network to be of significant use. This limits the number of practical values that may be used whilst remaining close to the 10ms objective set by GOMSFE.

– Determine the maximum duration that a sending device's messages are valid. Given each device's minimum cycle time, the maximum cycle time will be half the message valid time, minus the minimum cycle time. A typical message valid time value for an inter-tripping scheme is 2s, which gives a typical maximum cycle time of 1s. Blocking schemes are typically more tolerant and message validity times can be extended.

– The increment value should be chosen such that it is as small as possible but different for each device sharing a common (or similar) minimum cycle time value. This will provide a degree of time differentiation as retransmissions occur. Small increment values cause the retransmission delay to slowly increase to the maximum value (increasing dependability), whereas a large increment value will cause it to rapidly increase (increasing reliability). See Figure 12.

– Analyzing which devices in the scheme are likely to respond simultaneously may require the subdivision of a scheme into smaller clusters of devices. This may also help in determining the retransmission parameters. Splitting large networks into smaller segments using routers etc. will help limit the effects of GOOSE message avalanches, but will require specialist equipment to pass (route) GOOSE messages between isolated segments.

### 6.3 UCA2.0 in MiCOM Px40

UCA2.0 is implemented in MiCOM Px40 relays by use of a separate Ethernet card. This card manages the majority of the UCA2.0 implementation and data transfer to avoid any impact on the performance of the protection.

### 6.3.1 Capability

The UCA2.0 interface provides the following capabilities:

1. Read and write access to relay settings and controls

   Setting cells associated with control & support functions (settings that do not belong to a protection group) are available in the set point (SP) functional component of a UCA2.0 brick.

   Setting cells associated with protection & control functions (settings that belong to a protection group) are available in the setting group (SG) functional component of a UCA2.0 brick.

2. Read access to measurements

   All measurands are presented under the measurement (MX) functional component of any supporting UCA2.0 brick.

3. Generation of reports on changes of measurements

   Measurement reports can be generated when user-defined criteria have been met. This will usually be in the form of a setting such as percentage change of a measurement (deadband). Reports are available for configuration under the reporting (RP) functional component of a UCA2.0 brick.

4. Generation of reports when an event record is created

   Status reports can be generated by protection events when user-defined reporting criteria have been met. This will usually be as a result of a protection element, such as phase overcurrent, starting or tripping. Reports are available for configuration under the reporting (RP) functional component of a UCA2.0 brick.

5. Support for time synchronization over an Ethernet link

   Time synchronization is supported using SMP (Station Management Protocol); this protocol is used to synchronize the internal real time clock of the relays. For further information on this protocol, please visit www.sisconet.com

6. GOOSE peer-to-peer communication

   GOOSE communications are included as part of the UCA2.0 implementation. Please see sections 2 and 4 for more details.

7. Disturbance record extraction

   Extraction of disturbance records is supported by the MiCOM Px40 relays. The record is extracted as an ASCII format COMTRADE file.

### 6.3.2 Network connectivity

SC

Note: This section presumes a prior knowledge of IP addressing and related topics. Further details on this topic may be found on the Internet (search for IP Configuration) and in numerous relevant books.

When configuring the relay for operation on a network, a unique IP address must be set on the relay. If the assigned IP address is duplicated elsewhere on the same network, the remote communications will operate in an indeterminate way. However, the relay will check for a conflict on every IP configuration change and at power up. An alarm will be raised if an IP conflict is detected. Similarly, a relay set with an invalid IP configuration (or factory default) will also cause an alarm to be displayed (Bad TCP/IP Cfg.).

The relay can be configured to accept data from networks other than the local network by using the 'Router Address' and 'Target Network' settings. The router address is the IP address of the router that is providing the sub-network interconnectivity. The Target Network is the base IP address of the remote network. Setting the target network to 000.000.000.000 will force the relay to use the specified router as the 'default gateway' for all data other than that produced on the local network.

### 6.3.3 Access to measurements

All the relay measurements are presented over UCA2.0 using the 'Measurement' functional component (MX) or parts of it. Reported measurement values are refreshed by the relay once per second, inline with the relay user interface. All measurements supported are listed in the product data model.

### 6.3.4 Settings

#### 6.3.4.1 Remote setting management

The UCA2.0 interface provides access to all setting groups within the relay. The visible setting group can be changed by the control 'EditSG' within the 'GLOBE' brick (write to this control).

The active setting group is changed by the control 'ActSG' within the 'GLOBE' brick, with the value of the corresponding setting group (Group2 = 2 etc.) to make active. If the specified setting group is disabled, an error response will be generated. Changing the active setting group does not affect the setting group visible for editing over the UCA2.0 interface.

Setting groups can be enabled or disabled, however it is possible to view any setting group regardless if disabled. It is not possible to set a disabled setting group as the active group, equally, it is not possible to disable the active setting group.

To confirm changes made within a setting group, the control 'SaveSG' in the GLOBE brick must be used. Writing a value (1, 2, 3 or 4) to 'SaveSG' will save any changes made to the corresponding setting group number.

#### 6.3.4.2 Accessing settings and controls

The UCA2.0 interface is able to read and write to both control and support settings (through the 'Set Point', SP functional component).

The protection settings use the 'Group Set Point', SG functional component.

The limits for settings are presented using the 'Configuration' (CF) functional component. Cell menu text is included through the use of the 'Description' (DC) functional component as UCA2.0 is not capable of transmitting settings as text strings. Such settings are enumerated, meaning simply that the choice is represented by a number instead of text. This enumeration is shown in the product data model.

Command cells are interpreted as UCA2.0 controls and are available for write access in the 'Control' (CO) functional component.

#### 6.3.4.3 UCA2.0 settings & statistics

The following settings and data allow support for the UCA2.0 implementation. Settings are detailed and explained in the following section. GOOSE statistics shown are used to monitor the GOOSE activity between relays.

| Col | Row | Description |
|---|---|---|
| 0E | 1F | Ethernet Comms. |
| 0E | 20 | IP Address |
| 0E | 21 | Subnet Mask |
| 0E | 24 | Number of Routes |
| 0E | 25 | Router Address 1 |
| 0E | 26 | Target Network 1 |
| 0E | 27 | Router Address 2 |
| 0E | 28 | Target Network 2 |
| 0E | 29 | Router Address 3 |
| 0E | 2A | Target Network 3 |
| 0E | 2B | Router Address 4 |
| 0E | 2C | Target Address 4 |
| 0E | 2D | Inactivity Timer |
| 0E | 2E | Default Pass Level |
| 0E | 2F | GOOSE Min. Cycle |
| 0E | 30 | GOOSE Max. Cycle |
| 0E | 31 | GOOSE Increment |
| 0E | 32 | GOOSE Start-up |
| 0E | 34 | GOOSE VIP Status |
| 0E | 3D | Ethernet Media |

| Col | Row | Name |
|---|---|---|
| 0E | 3F | GOOSE STATISTICS |
| 0E | 40 | Enrolled Flags |
| 0E | 41 | Tx Msg. Count. |
| 0E | 42 | Rx Msg. Count. |
| 0E | 43 | DDB Changes |
| 0E | 44 | Last Seq. Tx |
| 0E | 45 | Last Msg. Tx |
| 0E | 46 | Msg. Reject Count |
| 0E | 50 | IED View Select |
| 0E | 51 | IED Recv'd. Msgs. |
| 0E | 52 | IED Last Seq. Rx |
| 0E | 53 | IED Last Msg. Rx |
| 0E | 54 | IED Missed Msgs. |
| 0E | 55 | IED Missed Chngs. |
| 0E | 56 | IED Timeouts |
| 0E | 5F | IED Stats. Reset |
| 0E | 6A | Report Link Test |
| 0E | 6B | Link Time-out |
| | | |
| | | |

### 6.3.4.4 UCA2.0 connection settings

The settings shown are those configurable to allow the UCA2.0 interface to operate. These are available in the menu 'Communications' column.

| Setting | Range | Description |
|---|---|---|
| IP Address* | 000.000.000.000 to 255.255.255.255 | Unique network IP address that identifies the relay |
| Subnet Mask* | 000.000.000.000 to 255.255.255.255 | Identifies the sub-network that the relay is connected to |
| Number of Routes | 0 to 4 | The number of routers/target networks that the relay will recognize |
| Router Address 1* | 000.000.000.000 to 255.255.255.255 | Address of a router on the same network as the relay |
| Target Network 1* | 000.000.000.000 to 255.255.255.255 | Address of the network that router1 will connect. If IP address 000.000.000.000, the above router acts as the default router |
| Router Address 2* | 000.000.000.000 to 255.255.255.255 | As Router Address 1 |
| Target Network 2* | 000.000.000.000 to 255.255.255.255 | As Target Network 1 |
| Router Address 3* | 000.000.000.000 to 255.255.255.255 | As Router Address 1 |
| Target Network 3* | 000.000.000.000 to 255.255.255.255 | As Target Network 1 |

| Setting | Range | Description |
|---|---|---|
| Router Address 4* | 000.000.000.000 to 255.255.255.255 | As Router Address 1 |
| Target Network 4* | 000.000.000.000 to 255.255.255.255 | As Target Network 1 |
| Inactivity Timer | 1 to 30 | Minutes of inactivity before the relay releases a client's database lock |
| Default Pass Lvl | 0 to 2 | Default password level assigned to new client connections. The connected client can change password level at any time |
| Ethernet Media* | Copper or Fiber | The media type that the relay will communicate on |

Note: * Changing Ethernet Media setting forces all client connections to close and the Ethernet card to reboot.

## 6.4 UCA2.0 GOOSE in Px40

Enrolling a UCA2.0 GOOSE device is done through the Px40's GOOSE scheme logic. Each UCA2.0 GOOSE enabled device on the network transmits messages using a unique "Sending IED" name. If a relay is interested in receiving data from this device, the "Sending IED" name is simply added to the relay's list of 'interested devices'.

UCA2.0 GOOSE is normally disabled in the MiCOM Px40 products and is enabled by downloading a GOOSE scheme logic file that is customized.

### 6.4.1 UCA2.0 GOOSE configuration

#### 6.4.1.1 Configuration overview

The GOOSE scheme logic editor is used to enrol devices and also to provide support for mapping the Digital Data Bus signals (from the Programmable Scheme Logic) onto the UCA2.0 GOOSE bit-pairs.

If the relay is interested in data from other UCA2.0 GOOSE devices, their "Sending IED" names are added as 'enrolled' devices within the GOOSE scheme logic. The GOOSE scheme logic editor then allows the mapping of incoming UCA2.0 GOOSE message bit-pairs onto Digital Data Bus signals for use within the Programmable Scheme Logic.

The UCA2.0 GOOSE messaging is configured by way of the min. cycle time, max. cycle time, increment and message life period. Due to the risk of incorrect operation, specific care should be taken to ensure that the configuration is correct. For further details on configuring the messaging, please see section 6.2.2 above.

#### 6.4.1.2 Virtual inputs

The GOOSE scheme logic interfaces with the Programmable Scheme Logic by means of 32 virtual inputs. The virtual inputs are then used in much the same way as the opto status inputs.

The logic that drives each of the virtual inputs is contained within the relay's GOOSE scheme logic file. It is possible to map any number of bit-pairs, from any enrolled device, using logic gates onto a virtual input.

The following gate types are supported within the GOOSE scheme logic:

| Gate Type | Operation |
|---|---|
| AND | The GOOSE virtual input will only be logic 1 (i.e. ON) when all bit-pairs match the desired state. |
| OR | The GOOSE virtual input will be logic 1 (i.e. ON) when any bit-pair matches its desired state. |
| PROGRAMMABLE | The GOOSE virtual input will only be logic 1 (i.e. ON) when the majority of the bit-pairs match their desired state. |

Supported GOOSE scheme logic gates.

In terms of Programmable Scheme Logic, GOOSE virtual inputs are used in the same way as the opto input signals. They can be used for anything from inputs to complex logic implementations or directly mapped onto a programmable LED or relay contact output.

6.4.1.3 Virtual outputs

The Programmable Scheme Logic provides 32 virtual output signals that can be connected to incoming signals or outputs of logic gates. The virtual outputs are used in much the same way as contact output signals and their use can simplify otherwise complex logic assignments between Programmable Scheme Logic and GOOSE scheme logic bit-pairs. Any Digital Data Bus signal can be assigned to GOOSE scheme logic bit-pairs, not just the virtual outputs.

6.4.2 UCA2.0 GOOSE processing & pre-sets

Under certain circumstances, it may be necessary to force a bit-pair to be a pre-set value. This could be used for testing or when certain operating conditions exist.

6.4.2.1 Pre-processing

Prior to a UCA2.0 GOOSE message being transmitted, the DNA and user status bit-pairs can be forced to pre-set values as required. This is accomplished on a 'per bit-pair' basis either off-line using the GOOSE scheme logic editor or on-line using the following components of the GLOBE UCA2.0 data model brick:

– SelOutDNA

  Output selection for DNA bit pairs (pass through or preset)

– SelOutUserSt

  Output selection for UserSt bit pairs (pass through or preset)

– PresetDNA *

  Preset values for DNA bit pairs

– PresetUserSt *

  Preset values for UserSt bit pairs

Note: * Not used when SelOutDNA and SelOutUserSt are pass through.

#### 6.4.2.2 Post-processing

Immediately after receiving a UCA2.0 GOOSE message, the DNA and user status bit-pairs are processed and can be set to one of three possible values; pass through, default or forced. The selection is controlled off-line using the GOOSE scheme editor or on-line using the following components of the GLOBE UCA2.0 data model brick:

– SelinDNA

  Input selection for DNA bit pairs (pass though, default or forced)

– SelinUserSt

  Input selection for UserSt bit pairs (pass though, default or forced)

  – DefDNA *

    Default values for DNA bit pairs

  – ForDNA *

    Forced values for DNA bit pairs

  – DefUserSt *

    Default values for UserSt bit pairs

  – ForUserSt *

    Forced values for UserSt bit pairs

Note: * Not used when SelinDNA and SelinUserSt are pass through.

The input selection is accomplished on a 'per bit-pair' basis where; 'Pass through' uses the data received in the message. 'Default' uses a set of scheme safe values suitable if a device is unable to transmit messages. ' Forced' uses a set of overriding values for exercising required scheme functionality.

### 6.4.3 UCA2.0 GOOSE start-up modes

The MiCOM implementation supports two UCA2.0 GOOSE start-up modes. Promiscuous start-up is compatible with all UCA2.0 GOOSE devices. Broadcast start-up is specific to MiCOM devices and may not be compatible with other UCA2.0 GOOSE devices.

Within a single scheme, the start-up mode across all devices must be consistent to guarantee scheme operation.

#### 6.4.3.1 Promiscuous start-up

When a MiCOM relay switches on, the UCA2.0 GOOSE processes will be initiated. At this point, the relay knows its own configuration and from which other devices UCA2.0 GOOSE messages will be received.

The Ethernet hardware will be set into a promiscuous mode of operation, whereby it will receive all Ethernet messages regardless of their target address. When in promiscuous mode, unwanted messages will be filtered by examining the destination MAC address. It will accept messages under the following conditions:

– Those addressed to the relay

– All multicast messages

– All broadcast messages

All received UCA2.0 GOOSE messages will be checked against the scheme configuration. If the relay has subscribed to the received message, the transmitting device’s MAC address is recorded (enrolled).

When all subscribed devices have been enrolled, the relay will revert from promiscuous mode and enter normal mode to receive messages from the specified multicast MAC addresses of the enrolled devices.

When starting, the relay will transmit a message as soon as the DNA and user status bit-pairs are in a valid state. This allows subscribing devices to enrol this relay's MAC address.

If a received message is timed out, a network problem is deemed to exist and the Ethernet hardware will be placed in promiscuous mode. All messages will be monitored until the failed device(s) re-appear.

The promiscuous method places extra load on the relay when one or more subscribed devices are not operational and transmitting messages. This may be a problem in systems where there is much network traffic as there is chance that schemes may start experiencing problems.

#### 6.4.3.2 Broadcast start-up

When a MiCOM relay switches on, the UCA2.0 GOOSE process is initiated. At this point the relay knows its own configuration and from which other devices messages will be received.

The starting relay will broadcast (rather than multicast) a set of messages as soon as the DNA and user status bit-pairs are in a valid state. Other MiCOM devices on the network will recognize this broadcast message. If subscribed to the starting device, its MAC address is recorded and a message is transmitted back to the device (addressed not broadcast or multicast). This allows the starting device to configure its own GOOSE management. If the starting relay has subscribed to the received message, the transmitting device's MAC address is (enrolled).

This broadcast mechanism allows the starting device to construct a list of transmitting devices (from the returned messages), and allows other devices on the network to enrol the starting device. This approach achieves a known scheme state in a faster time when compared to the promiscuous start-up.

### 6.4.4 Ethernet hardware

The optional Ethernet card (ZN0012) has 2 variants which supports the UCA2.0 implementation, one card with RJ45 and ST (10Mb card), the other with RJ45 and SC (100Mb card). This allows the following connection media:

- 10BASE-T – 10Mb Copper Connection (RJ45 type)
- 10BASE-FL – 10Mb Fiber Optic Connection (ST type)
- 100BASE-TX – 100Mb Copper Connection (RJ45 type)
- 100BASE-FX – 100Mb Fiber Optic Connection (SC type)

This card is fitted into Slot A of the relay, which is the optional communications slot.

SC

When using UCA2.0 communications through the Ethernet card, the rear EIA(RS)485 and front EIA(RS)232 ports are also available for simultaneous use, using the Courier protocol.

Each Ethernet card has a unique 'Mac address' used for Ethernet communications, this is also printed on the rear of the card, alongside the Ethernet sockets.

#### 6.4.4.1 Ethernet disconnection

UCA2.0 'Associations' are unique and made to the relay between the client (master) and server (UCA2.0 device). In the event that the Ethernet is disconnected, such associations cannot be remade. Since there is no more interaction via the old association, the relay cancels it making it available for other clients.

#### 6.4.4.2 Loss of power

The relay allows the re-establishment of associations without a negative impact on the relays operation after having its power removed. As the relay acts as a server in this process, the client must request the association. Uncommitted setting are cancelled when power is lost, and reports requested by connected clients are reset and must be re-enabled by the client when it next creates the new association to the relay.

## 6.5 P145 UCA2.0 data model description

The P145 Feeder Protection relay data model presented in this document relates to Version 31 software release only. This document is designed to contain an overview of the data model. The full data model is available alongside all other product documentation from www.areva-td.com, your local sales representative or our 24hour customer contact center on +44 (0)1785 250070 or
www.areva-td.com/contactcentre/

The reader of this document is expected to be conversant with UCA2.0 and GOMSFE V0.92 terminology and have read the other UCA2.0 documentation in this section of the service manual.

### 6.5.1 Data model overview

The "UCA2.0" logical device data model consists of many bricks and wrappers. UCA2.0 specifies a 6 character string for a wrapper. To ensure ease of identification in MiCOM Px40 products, these wrappers are split into internal and external wrappers, each with 3 characters as below. These are listed in the following table along with the bricks used in this product range and their description.

| External Wrapper | Internal Wrapper | Brick | Index | Description |
|---|---|---|---|---|
| | | GLOBE | 0 | The globe instance |
| adm | | PADM | 0 | Admittance Protection - Common Settings |
| adm | adm | PADM | 1 | Admittance Protection - Admittance |
| adm | cnd | PADM | 1 | Admittance Protection - Conductance |
| adm | sus | PADM | 1 | Admittance Protection - Susceptance |
| alm | | GALM | 1 | Generic Alarms |
| asc | | RFGP | 0 | System Checks - Function Configuration |
| | | RSYN | 0 | System Checks - Common Settings |
| asc | spl | RSYN | 1 | System Checks - System Split Stage 1 |
| asc | syn | RSYN | 0 | System Checks - Check Sync. Common Settings |
| | | RSYN | 1 | System Checks - Check Sync. Stage 1 |
| | | RSYN | 2 | System Checks - Check Sync. Stage 2 |
| bkc | | PBKC | 1 | Broken Conductor (I2/I1) Protection |
| cbf | | RCBF | 1 | Circuit Breaker Failure Protection |
| cbr | | XCBR | 1 | Circuit Breaker Control/Monitoring |
| clp | | POCP | 0 | Cold Load Pickup - Common Settings |
| clp | efd | PTOC | 1 | Cold Load Pickup - (Derived) Earth Fault 2 Stage 1<br>(Overrides efdstgPTOC1 when active) |

SC

| External Wrapper | Internal Wrapper | Brick | Index | Description |
|---|---|---|---|---|
| clp | efm | PTOC | 1 | Cold Load Pickup - (Measured) Earth Fault 1 Stage 1<br>(Overrides efmstgPTOC1 when active) |
| clp | poc | PTOC | 1 | Cold Load Pickup - Phase Overcurrent Stage 1<br>(Overrides pocstgPTOC1 when active) |
| | | PTOC | 2 | Cold Load Pickup - Phase Overcurrent Stage 2<br>(Overrides pocstgPTOC2 when active) |
| | | PTOC | 3 | Cold Load Pickup - Phase Overcurrent Stage 3<br>(Overrides pocstgPTOC3 when active) |
| | | PTOC | 4 | Cold Load Pickup - Phase Overcurrent Stage 4<br>(Overrides pocstgPTOC4 when active) |
| Ctl | inp | GCTL | 1 | Control Inputs to Relay Logic (PSL) |
| Ctl | lbl | RLBL | 1 | Labels for Control Inputs (ctlinpGCTL1) |
| Ctl | mod | GESP | 1 | Operation Mode (Pulsed/Latched) for Control Inputs (ctlinpGCTL) |
| Efd | | POCP | 0 | (Derived) Earth Fault 2 - Common Settings |
| Efd | stg | PTOC | 1 | (Derived) Earth Fault 2 Stage 1 |
| | | PTOC | 2 | (Derived) Earth Fault 2 Stage 2 |
| | | PTOC | 3 | (Derived) Earth Fault 2 Stage 3 |
| | | PTOC | 4 | (Derived) Earth Fault 2 Stage 4 |
| efm | | POCP | 0 | (Measured) Earth Fault 1 – Common Settings |
| efm | stg | PTOC | 1 | (Measured) Earth Fault 1 Stage 1 |
| | | PTOC | 2 | (Measured) Earth Fault 1 Stage 2 |
| | | PTOC | 3 | (Measured) Earth Fault 1 Stage 3 |
| | | PTOC | 4 | (Measured) Earth Fault 1 Stage 4 |
| frc | | FRCF | 1 | Fault Recorder Configuration |
| frq | | PFRQ | 0 | Frequency Protection - Common Settings |
| frq | ofp | PFRQ | 1 | Over Frequency Protection Stage 1 |
| | | PFRQ | 2 | Over Frequency Protection Stage 2 |
| frq | ufp | PFRQ | 1 | Under Frequency Protection Stage 1 |
| | | PFRQ | 2 | Under Frequency Protection Stage 2 |
| | | PFRQ | 3 | Under Frequency Protection Stage 3 |
| | | PFRQ | 4 | Under Frequency Protection Stage 4 |
| grp | cfg | RFGP | 1 | Setting Group 1 Control |
| | | RFGP | 2 | Setting Group 2 Control |
| | | RFGP | 3 | Setting Group 3 Control |
| | | RFGP | 4 | Setting Group 4 Control |
| log | | ILOG | 1 | Record Control |
| msi | | MCFG | 0 | Measurements Configuration |
| msi | dvd | MMXU | 1 | Derived Measurements |
| msi | fxd | MDMD | 1 | Fixed Demand Measurements |

SC

| External Wrapper | Internal Wrapper | Brick | Index | Description |
|---|---|---|---|---|
| msi | pek | MDMD | 1 | Peak Demand Measurements |
| msi | rms | MMXU | 1 | RMS Based Measurements |
| msi | rol | MDMD | 1 | Rolling Demand Measurements |
| msi | sen | MMXU | 1 | Sensitive Input Measurements |
| msi | std | MFLO | 1 | Energy Flow Measurements |
| | | MMXU | 1 | Standard Measurements |
| | | MSQI | 1 | Sequence Measurements |
| | | SYNC | 1 | Synchronism Check Measurements |
| noc | | POCP | 0 | Neg. Sequence Overcurrent – Common Settings |
| noc | stg | PTOC | 1 | Negative Phase Sequence Overcurrent |
| nov | | RFGP | 0 | Negative Sequence Overvoltage Protection - Common Settings |
| nov | stg | POVR | 1 | Negative Sequence Overvoltage Protection |
| nvd | | RFGP | 0 | Residual Overvoltage Protection - Common Settings |
| nvd | stg | POVR | 1 | Residual Overvoltage Protection Stage 1 |
| | | POVR | 2 | Residual Overvoltage Protection Stage 2 |
| opt | cfg | GESP | 1 | Opto-Isolated Status Inputs - Configuration |
| opt | fil | RFGP | 1 | Opto-Isolated Status Inputs - Power System Frequency Filter Configuration |
| opt | lbl | RLBL | 1 | Opto-Isolated Status Inputs - Labels |
| opt | sts | GIND | 1 | Opto-Isolated Status Inputs - Status Indicators |
| poc | | POCP | 0 | Phase Overcurrent - Common Settings |
| poc | stg | PTOC | 1 | Phase Overcurrent Stage 1 |
| | | PTOC | 2 | Phase Overcurrent Stage 2 |
| | | PTOC | 3 | Phase Overcurrent Stage 3 |
| | | PTOC | 4 | Phase Overcurrent Stage 4 |
| pvp | | RFGP | 0 | Phase Voltage Protection - Common Settings |
| pvp | ovp | POUV | 1 | Phase Overvoltage Protection - Common Settings |
| | | POVR | 1 | Phase Overvoltage Protection Stage 1 |
| | | POVR | 2 | Phase Overvoltage Protection Stage 2 |
| pvp | uvp | POUV | 1 | Phase Undervoltage Protection - Common Settings |
| | | PUVR | 1 | Phase Undervoltage Protection Stage 1 |
| | | PUVR | 2 | Phase Undervoltage Protection Stage 2 |
| rdr | | RDRA | 1 | Disturbance Recorder Analog Configuration |
| | | RDRB | 1 | Disturbance Recorder Digital Configuration |
| | | RDRE | 1 | Disturbance Record Extraction |
| rly | lbl | RLBL | 1 | Output Contact - Labels |

| External Wrapper | Internal Wrapper | Brick | Index | Description |
|---|---|---|---|---|
| rly | sts | GIND | 1 | Output Contact - Status |
| sen | | RFGP | 1 | Sensitive Earth Fault (SEF & REF) - Common Settings |
| sen | ref | PDIF | 1 | Restricted Earth Fault Protection |
| sen | sef | POCP | 0 | Sensitive Earth Fault - Common Settings |
| | | PTOC | 1 | Sensitive Earth Fault Stage 1 |
| | | PTOC | 2 | Sensitive Earth Fault Stage 2 |
| | | PTOC | 3 | Sensitive Earth Fault Stage 3 |
| | | PTOC | 4 | Sensitive Earth Fault Stage 4 |
| sol | | RFGP | 0 | Selective Logic - Common Settings |
| sol | efd | PTOC | 3 | Selective Logic - Derived Earth Fault Stage 3 |
| | | PTOC | 4 | Selective Logic - Derived Earth Fault Stage 4 |
| sol | efm | PTOC | 3 | Selective Logic - Measured Earth Fault Stage 3 |
| | | PTOC | 4 | Selective Logic - Measured Earth Fault Stage 4 |
| sol | poc | PTOC | 3 | Selective Logic - Phase Overcurrent Stage 3 |
| | | PTOC | 4 | Selective Logic - Phase Overcurrent Stage 4 |
| sol | sef | PTOC | 3 | Selective Logic - Sensitive Earth Fault Stage 3 |
| | | PTOC | 4 | Selective Logic - Sensitive Earth Fault Stage 4 |
| thm | | PTHM | 1 | Thermal Protection |
| tst | | RTST | 1 | Commissioning Tests |
| txf | eft | RCTR | 1 | Neutral (Earth Fault) CT Ratio |
| txf | Nvd | RVTR | 1 | Neutral Voltage Displacement VT Ratio |
| txf | Phs | RCTR | 1 | Phase CT Ratios |
| | | RVTR | 1 | Phase VT Ratios |
| txf | Sen | RCTR | 1 | Sensitive CT Ratio |
| txf | Syn | RVTR | 1 | Check Sync. VT Ratio |
| txs | | RFGP | 0 | Transformer Supervision - Configuration |
| txs | Cts | RTXS | 1 | Transformer Supervision - CT |
| txs | Vts | RTXS | 1 | Transformer Supervision - VT/PT |

SC

### 6.5.2 Device identity

The device identify element provides a unique identity that describes the relay, its location, its classification etc. The device identity (DI) in the relay is defined as below:

| Item | Supported | Description | Default Value | Access |
|---|---|---|---|---|
| Name | ✓ | Name of device | "P145" | Read & Write |
| Class | ✓ | Product classification | "Protective Relay" | Read & Write |
| d | ✓ | Description of device | "?????" | Read & Write |
| Own | ✓ | Owner of device | "" | Read & Write |
| Loc | ✓ | Location | "" | Read & Write |
| VndID.Vnd | ✓ | The manufacturers name | "AREVA T&D" | Read & Write |

| Item | Supported | Description | Default Value | Access |
|---|---|---|---|---|
| VndID.Mdl | ✓ | Device model number | Device dependent | Read |
| VndID. DevMdls | ✓ | Device model name | Device dependent | Read & Write |
| VndID.SerNum | ✓ | The unique serial number | Device dependent | Read |
| VndID.SftRev | ✓ | The software version | Device dependent | Read |
| CommID. CommAdr | ✓ | Comm. address on gateway side | Device dependent | Read |
| CommID. CommRev | ✓ | The revision of the transport | Device dependent | Read |
| CommID.Pro | ✓ | Protocol used on gateway side | Device dependent | Read |
| CommID.Med | ✓ | Medium used on gateway side | Device dependent | Read |

Device identity (DI) implementation.

# 7. SK5 PORT CONNECTION

The lower 9-way D-type connector (SK5) is currently unsupported. Do not connect to this port.

# SYMBOLS AND GLOSSARY

**Date:** **7th July 2005**
**Hardware Suffix:** **J**
**Software Version:** **31**
**Connection Diagrams:** **10P145xx (xx = 01 to 07)**

**Logic Symbols**

| Symbols | Explanation |
|---|---|
| **<** | **Less than:** Used to indicate an "under" threshold, such as undercurrent (current dropout). |
| **>** | **Greater than:** Used to indicate an "over" threshold, such as overcurrent (current overload). |
| **&** | **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. |
| **BAR** | Block auto-reclose signal. |
| **BN>** | **Neutral over susceptance protection element:** Reactive component of admittance calculation from neutral current and residual voltage. |
| **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. |
| **CLP** | Cold load pick-up. |
| **CS** | Check synchronism. |
| **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. |
| **DEF** | **Directional earth fault protection:** A directionalized ground fault aided scheme. |

| Symbols | Explanation |
|---|---|
| **Df/dt** | Rate of change of frequency protection (ROCOF). |
| **Dly** | Time delay. |
| **DT** | **Abbreviation of "Definite Time":**<br>An element which always responds with the same constant time delay on operation. |
| **E/F** | **Earth fault:**<br>Directly equivalent to ground fault. |
| **FLC** | **Full load current:**<br>The nominal rated current for the circuit. |
| **Flt.** | **Abbreviation of "Fault":**<br>Typically used to indicate faulted phase selection. |
| **FN** | Function. |
| **Fwd.** | Indicates an element responding to a flow in the "Forward" direction. |
| **F>** | **An overfrequency element:**<br>Could be labelled 81O in ANSI terminology. |
| **F<** | **An underfrequency element:**<br>Could be labelled 81U in ANSI terminology. |
| **GN>** | **Neutral over conductance protection element:**<br>Real component of admittance calculation from neutral current and residual voltage. |
| **Gnd.** | **Abbreviation of "Ground":**<br>Used in distance settings to identify settings that relate to ground (earth) faults. |
| **GRP.** | **Abbreviation of "Group":**<br>Typically an alternative setting group. |
| **I** | Current. |
| **I^** | **Current raised to a power:**<br>Such as when breaker statistics monitor the square of ruptured current squared (^ power = 2). |
| **I<** | **An undercurrent element:**<br>Responds to current dropout. |
| **I>1** | **First stage of phase overcurrent protection:**<br>Could be labelled 51-1 in ANSI terminology. |
| **I>2** | **Second stage of phase overcurrent protection:**<br>Could be labelled 51-2 in ANSI terminology. |
| **I>3** | **Third stage of phase overcurrent protection:**<br>Could be labelled 51-3 in ANSI terminology. |
| **I>4** | **Fourth stage of phase overcurrent protection:**<br>Could be labelled 51-4 in ANSI terminology. |
| $I_0$ | **Zero sequence current:**<br>Equals one third of the measured neutral/residual current. |
| $I_1$ | Positive sequence current. |
| $I_2$ | Negative sequence current. |
| **I1** | Positive sequence current. |
| **I2** | Negative sequence current. |

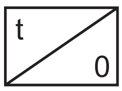
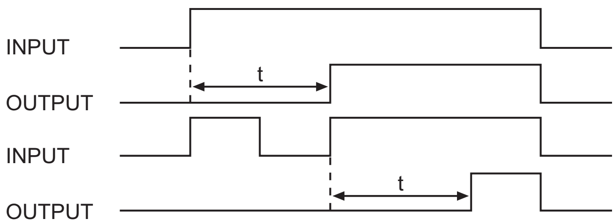
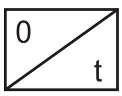
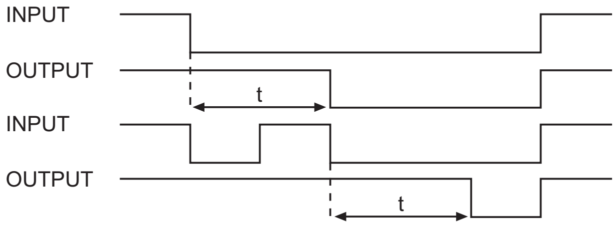
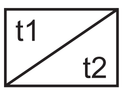
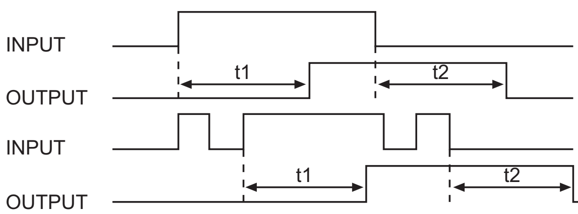
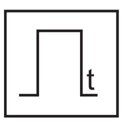
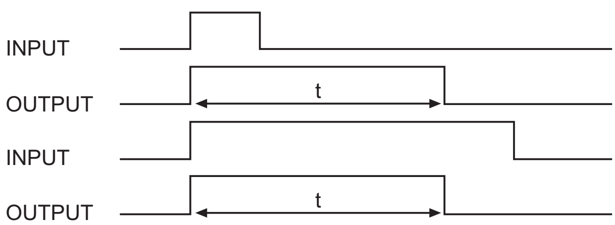
| Symbols | Explanation |
|---|---|
| **I2>** | Negative sequence overcurrent protection (NPS element). |
| **I2pol** | Negative sequence polarizing current. |
| **IA** | **Phase A current:**<br>Might be phase L1, red phase.. or other, in customer terminology. |
| **IB** | **Phase B current:**<br>Might be phase L2, yellow phase.. or other, in customer terminology. |
| **IC** | **Phase C current:**<br>Might be phase L3, blue phase.. or other, in customer terminology. |
| **ID** | **Abbreviation of "Identifier":**<br>Often a label used to track a software version installed. |
| **IDMT** | **Inverse definite minimum time:**<br>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:**<br>Software selectable as 1 amp or 5 amp to match the line CT input. |
| **IN** | **Neutral current, or residual current:**<br>This results from an internal summation of the three measured phase currents. |
| **IN>** | **A neutral (residual) overcurrent element:**<br>Detects earth/ground faults. |
| **IN>1** | **First stage of ground overcurrent protection:**<br>Could be labelled 51N-1 in ANSI terminology. |
| **IN>2** | **Second stage of ground overcurrent protection:**<br>Could be labelled 51N-2 in ANSI terminology. |
| **Inh** | An inhibit signal. |
| **ISEF>** | Sensitive earth fault overcurrent element. |
| **Inst.** | **An element with "instantaneous" operation:**<br>i.e. having no deliberate time delay. |
| **I/O** | **Abbreviation of "Inputs and Outputs":**<br>Used in connection with the number of optocoupled inputs and output contacts within the relay. |
| **I/P** | Abbreviation of "Input". |
| **kZN** | **The residual compensation factor:**<br>Ensuring correct reach for ground distance elements. |
| **LCD** | **Liquid crystal display:**<br>The front-panel text display on the relay. |
| **LD** | **Abbreviation of "Level Detector":**<br>An element responding to a current or voltage below its set threshold. |
| **LED** | **Light emitting diode:**<br>Red or green indicator on the relay front-panel. |
| **MCB** | **A "miniature circuit breaker":**<br>Used instead of a fuse to protect VT secondary circuits. |
| **N** | **Indication of "Neutral" involvement in a fault:**<br>i.e. a ground (earth) fault. |

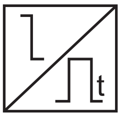
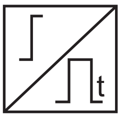
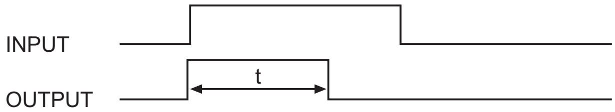
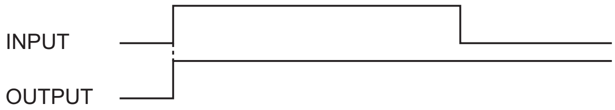
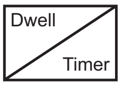
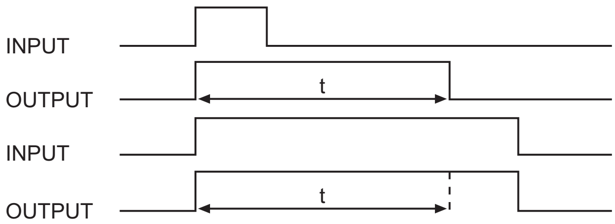
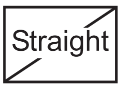
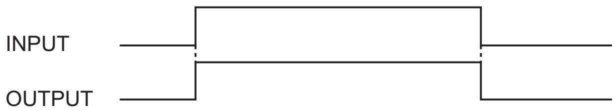
| Symbols | Explanation |
|---|---|
| **N/A** | Not applicable. |
| **N/C** | **A normally closed or "break" contact:**<br>Often called a "form B" contact. |
| **N/O** | **A normally open or "make" contact:**<br>Often called a "form A" contact. |
| **NPS** | Negative phase sequence. |
| **NXT** | **Abbreviation of "Next":**<br>In connection with hotkey menu navigation. |
| **NVD** | **Neutral voltage displacement:**<br>Equivalent to residual overvoltage protection. |
| **O/P** | Abbreviation of "output". |
| **Opto** | **An optocoupled logic input:**<br>Alternative terminology: binary input. |
| **P1** | **Used in IEC terminology to identify the primary CT terminal polarity:**<br>Replace by a dot when using ANSI standards. |
| **P2** | **Used in IEC terminology to identify the primary CT terminal polarity:**<br>The non-dot terminal. |
| **PCB** | Printed circuit board. |
| **Ph** | **Abbreviation of "Phase":**<br>Used in distance settings to identify settings that relate to phase-phase faults. |
| **Pol** | **Abbreviation of "Polarizing":**<br>Typically the polarizing voltage used in making directional decisions. |
| **PN>** | **Wattmetric earth fault protection:**<br>Calculated using residual voltage and current quantities. |
| **PSL** | **Programmable scheme logic:**<br>The part of the relay's logic configuration that can be modified by the user, using the graphical editor within MiCOM S1 software. |
| **R** | A resistance. |
| **R Gnd.** | **A distance zone resistive reach setting:**<br>Used for ground (earth) faults. |
| **RCA** | **Abbreviation of "Relay Characteristic Angle":**<br>The center of the directional characteristic. |
| **REF** | Restricted earth fault protection. |
| **Rev.** | Indicates an element responding to a flow in the "reverse" direction. |
| **RMS** | **The equivalent a.c. current:**<br>Taking into account the fundamental, plus the equivalent heating effect of any harmonics. Abbreviation of "root mean square". |
| **RP** | **Abbreviation of "Rear Port":**<br>The communication ports on the rear of the relay. |
| **Rx** | **Abbreviation of "Receive":**<br>Typically used to indicate a communication receive line/pin. |
| **S1** | **Used in IEC terminology to identify the secondary CT terminal polarity:**<br>Replace by a dot when using ANSI standards. |

| Symbols | Explanation |
|---|---|
| **S2** | **Used in IEC terminology to identify the secondary CT terminal polarity:**<br>The non-dot terminal. |
| **SEF** | Sensitive Earth Fault Protection. |
| **t** | A time delay. |
| **TCS** | Trip circuit supervision. |
| **TD** | **The time dial multiplier setting:**<br>Applied to inverse-time curves (ANSI/IEEE). |
| **TE** | **A standard for measuring the width of a relay case:**<br>One inch = 5TE units. |
| **TMS** | The time multiplier setting applied to inverse-time curves (IEC). |
| **Tx** | **Abbreviation of “Transmit”:**<br>Typically used to indicate a communication transmit line/pin. |
| **V** | Voltage. |
| **V<** | An undervoltage element. |
| **V<1** | **First stage of undervoltage protection:**<br>Could be labelled 27-1 in ANSI terminology. |
| **V<2** | **Second stage of undervoltage protection:**<br>Could be labelled 27-2 in ANSI terminology. |
| **V>** | An overvoltage element. |
| **V>1** | **First stage of overvoltage protection:**<br>Could be labelled 59-1 in ANSI terminology. |
| **V>2** | **Second stage of overvoltage protection:**<br>Could be labelled 59-2 in ANSI terminology. |
| $V_0$ | **Zero sequence voltage:**<br>Equals one third of the measured neutral/residual voltage. |
| $V_1$ | Positive sequence voltage. |
| $V_2$ | Negative sequence voltage. |
| **V2pol** | Negative sequence polarizing voltage. |
| **VA** | **Phase A voltage:**<br>Might be phase L1, red phase.. or other, in customer terminology. |
| **VB** | **Phase B voltage:**<br>Might be phase L2, yellow phase.. or other, in customer terminology. |
| **VC** | **Phase C voltage:**<br>Might be phase L3, blue phase.. or other, in customer terminology. |
| **VCO** | Voltage controlled overcurrent element. |
| **Vk** | IEC knee point voltage of a current transformer. |
| **Vn** | **The rated nominal voltage of the relay:**<br>To match the line VT input. |
| **VN** | Neutral voltage displacement, or residual voltage. |
| **VN>1** | First stage of residual (neutral) overvoltage protection. |
| **VN>2** | Second stage of residual (neutral) overvoltage protection. |
| **Vres.** | Neutral voltage displacement, or residual voltage. |

| Symbols | Explanation |
|---|---|
| **VT** | Voltage transformer. |
| **VTS** | **Voltage transformer supervision:**<br>To detect VT input failure. |
| **Vx** | **An auxiliary supply voltage:**<br>Typically the substation battery voltage used to power the relay. |
| **YN>** | **Neutral overadmittance protection element:**<br>Non-directional neutral admittance protection calculated from neutral current and residual voltage. |
| **$Z_0$** | Zero sequence impedance. |
| **$Z_1$** | Positive sequence impedance. |
| **$Z_2$** | Negative sequence impedance. |

**Logic Timers**

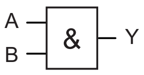
| Logic Symbols | Explanation | Time Chart |
|---|---|---|
|  | Delay on pick-up timer, t |  |
|  | Delay on drop-off timer, t |  |
|  | Delay on pick-up/drop-off timer |  |
|  | Pulse timer |  |

| Logic Symbols | Explanation | Time Chart |
|---|---|---|
|   | Pulse pick-up falling edge |   |
|   | Pulse pick-up raising edge |   |
|   | Latch |   |
|   | Dwell timer |   |
|   | **Straight (non latching):** Hold value until input reset signal |   |

## Logic Gates

### AND GATE

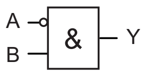
Symbol:




Truth Table:

| IN | | OUT |
|---|---|---|
| 0 | 1 | 0 |
| 0 | 1 | 0 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 1 |

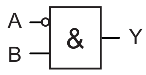
Symbol:




Truth Table:

| IN | | OUT |
|---|---|---|
| A | B | Y |
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 0 |
| 1 | 1 | 0 |

Symbol:

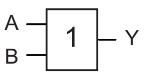



Truth Table:

| IN | | OUT |
|---|---|---|
| A | B | Y |
| 0 | 0 | 1 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 0 |

### OR GATE

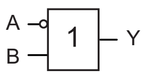
Symbol:




Truth Table:

| IN | | OUT |
|---|---|---|
| A | B | Y |
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 1 |

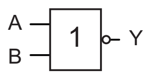
Symbol:




Truth Table:

| IN | | OUT |
|---|---|---|
| A | B | Y |
| 0 | 0 | 1 |
| 0 | 1 | 1 |
| 1 | 0 | 0 |
| 1 | 1 | 1 |

Symbol:

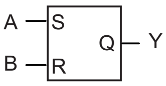



Truth Table:

| IN | | OUT |
|---|---|---|
| A | B | Y |
| 0 | 0 | 1 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 0 |

### R - S FLIP-FLOP

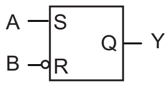
Symbol:




Truth Table:

| A | B | QN | QN+ | Active Mode |
|---|---|---|---|---|
| 0 | 0 | | | Hold Mode |
| 0 | 1 | 0 | | Hold Mode |
| | | 1 | 0 | Reset |
| 1 | 0 | 0 | 1 | Set |
| | | 1 | | Hold Mode |
| 0 | 0 | - | - | Inhibit Mode |

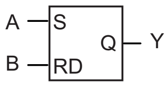
Symbol:




Truth Table:

| A | B | QN | QN+ | Active Mode |
|---|---|---|---|---|
| 0 | 0 | 0 | | Hold Mode |
| | | 1 | 0 | Reset |
| 0 | 1 | | | Hold Mode |
| 1 | 0 | - | - | Inhibit Mode |
| 0 | 1 | 0 | 1 | Set |
| | | 1 | | Hold Mode |

Symbol:




* RD = Reset Dominant

Truth Table:

| A | B | QN | QN+ | Active Mode |
|---|---|---|---|---|
| 0 | 0 | | | Hold Mode |
| 0 | 1 | | | 0 |
| 1 | 0 | 0 | 1 | Set |
| | | 1 | | Hold Mode |
| 1 | 1 | | | 0 |

### EXCLUSIVE OR GATE

Symbol:


Truth Table:

| IN | | OUT |
|---|---|---|
| A | B | Y |
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 0 |

Symbol:


Truth Table:

| IN | | OUT |
|---|---|---|
| A | B | Y |
| 0 | 0 | 1 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 1 |

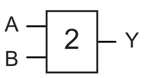
Symbol:


Truth Table:

| IN | | OUT |
|---|---|---|
| A | B | Y |
| 0 | 0 | 1 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 1 |

### MULTI INPUT GATE

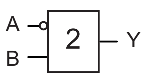
Symbol:




Truth Table:

| IN | | OUT |
|---|---|---|
| A | B | Y |
| 0 | 0 | 0 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 1 |

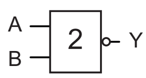
Symbol:




Truth Table:

| IN | | OUT |
|---|---|---|
| A | B | Y |
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 0 |
| 1 | 1 | 0 |

Symbol:




Truth Table:

| IN | | OUT |
|---|---|---|
| A | B | Y |
| 0 | 0 | 1 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 0 |

### NOT GATE

Symbol:


Inverter (NOT)

Truth Table:

| IN | OUT |
|---|---|
| A | Y |
| 0 | 1 |
| 1 | 0 |

# INSTALLATION

| | |
|---|---|
| **Date:** | **7th July 2005** |
| **Hardware Suffix:** | **J** |
| **Software Version:** | **31** |
| **Connection Diagrams:** | **10P145xx (xx = 01 to 07)** |

# CONTENTS



# FIGURES

# 1. RECEIPT OF RELAYS

Upon receipt, relays should be examined immediately to ensure no external damage has been sustained in transit. If damage has been sustained, a claim should be made to the transport contractor and AREVA T&D should be promptly notified.

Relays that are supplied unmounted and not intended for immediate installation should be returned to their protective polythene bags and delivery carton. Section 3 of P145/EN IN gives more information about the storage of relays.

# 2. HANDLING OF ELECTRONIC EQUIPMENT

A person's normal movements can easily generate electrostatic potentials of several thousand volts. Discharge of these voltages into semiconductor devices when handling electronic circuits can cause serious damage that, although not always immediately apparent, will reduce the reliability of the circuit. The relay's electronic circuits are protected from electrostatic discharge when housed in the case. Do not expose them to risk by removing the front panel or printed circuit boards unnecessarily.

Each printed circuit board incorporates the highest practicable protection for its semiconductor devices. However, if it becomes necessary to remove a printed circuit board, the following precautions should be taken to preserve the high reliability and long life for which the relay has been designed and manufactured.

Before removing a printed circuit board, ensure that you are at the same electrostatic potential as the equipment by touching the case.

Handle analog input modules by the front panel, frame or edges of the circuit boards. Printed circuit boards should only be handled by their edges. Avoid touching the electronic components, printed circuit tracks or connectors.

Do not pass the module to another person without first ensuring you are both at the same electrostatic potential. Shaking hands achieves equipotential.

Place the module on an anti-static surface, or on a conducting surface that is at the same potential as you.

If it is necessary to store or transport printed circuit boards removed from the case, place them individually in electrically conducting anti-static bags.

In the unlikely event that you are making measurements on the internal electronic circuitry of a relay in service, it is preferable that you are earthed to the case with a conductive wrist strap. Wrist straps should have a resistance to ground between 500kΩ to 10MΩ. If a wrist strap is not available you should maintain regular contact with the case to prevent a build-up of electrostatic potential. Instrumentation which may be used for making measurements should also be earthed to the case whenever possible.

More information on safe working procedures for all electronic equipment can be found in BS EN 100015: Part 1:1992. It is strongly recommended that detailed investigations on electronic circuitry or modification work should be carried out in a special handling area such as described in the British Standard document.

# 3. STORAGE

If relays are not to be installed immediately upon receipt, they should be stored in a place free from dust and moisture in their original cartons. Where de-humidifier bags have been included in the packing they should be retained.

To prevent battery drain during transportation and storage a battery isolation strip is fitted during manufacture. With the lower access cover open, presence of the battery isolation strip can be checked by a red tab protruding from the positive polarity side.

Care should be taken on subsequent unpacking that any dust, which has collected on the carton, does not fall inside. In locations of high humidity the carton and packing may become impregnated with moisture and the de-humidifier crystals will lose their efficiency.

Prior to installation, relays should be stored at a temperature of between –25˚C to +70˚C (-13˚F to +158˚F).

# 4. UNPACKING

Care must be taken when unpacking and installing the relays so that none of the parts are damaged and additional components are not accidentally left in the packing or lost. Ensure that any User's CDROM or technical documentation is NOT discarded – this should accompany the relay to its destination substation.

Note: With the lower access cover open, the red tab of the battery isolation strip will be seen protruding from the positive (+) side of the battery compartment. Do not remove this strip because it prevents battery drain during transportation and storage and will be removed as part of the commissioning tests.

Relays must only be handled by skilled persons.

The site should be well lit to facilitate inspection, clean, dry and reasonably free from dust and excessive vibration.

# 5. RELAY MOUNTING

MiCOM relays are dispatched either individually or as part of a panel/rack assembly.

Individual relays are normally supplied with an outline diagram showing the dimensions for panel cutouts and hole centers. This information can also be found in the product publication.

Secondary front covers can also be supplied as an option item to prevent unauthorized changing of settings and alarm status. They are available in size 60TE (GN0038 001) for the P145, suitable to fit the 60TE case model.

The design of the relay is such that the fixing holes in the mounting flanges are only accessible when the access covers are open and hidden from sight when the covers are closed.

If a P991 or MMLG test block is to be included, it is recommended that, when viewed from the front, it be positioned on the right-hand side of the relay (or relays) with which it is associated. This minimizes the wiring between the relay and test block, and allows the correct test block to be easily identified during commissioning and maintenance tests.

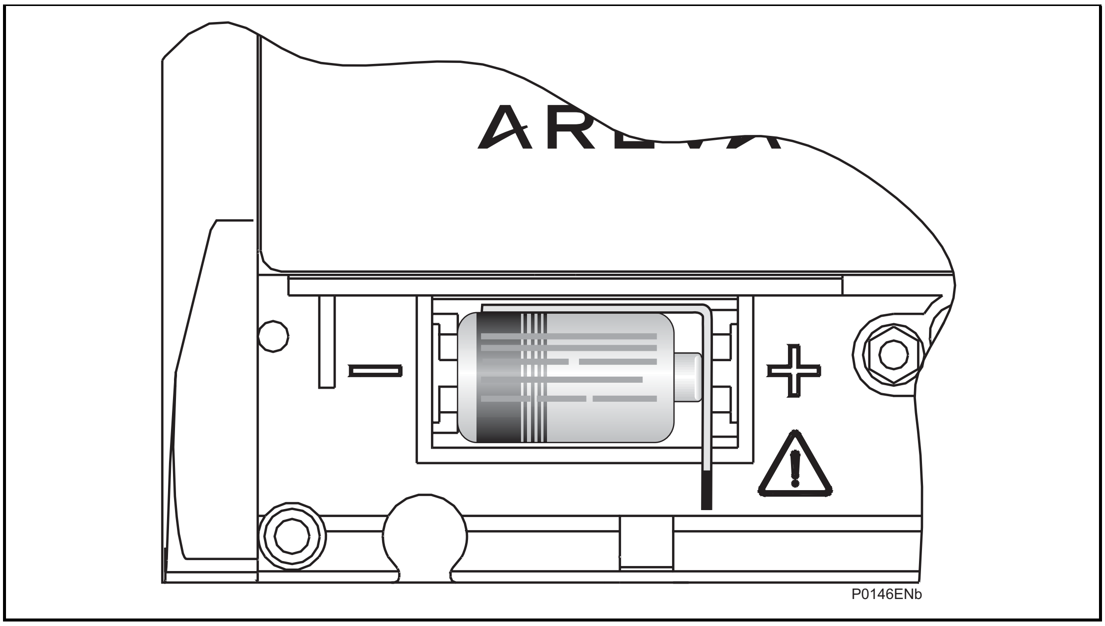



**Figure 1: Location of battery isolation strip**

If it is necessary to test correct relay operation during the installation, the battery isolation strip can be removed but should be replaced if commissioning of the scheme is not imminent. The red tab of the isolation strip can be seen protruding from the positive side of the battery compartment when the lower access cover is open. To remove the isolation strip, pull the red tab whilst lightly pressing the battery to prevent it falling out of the compartment. When replacing the battery isolation strip, ensure that the strip is refitted as shown in Figure 1, i.e. with the strip behind the battery with the red tab protruding.

## 5.1 Rack mounting

MiCOM relays may be rack mounted using single tier rack frames (our part number FX0021 001), as illustrated in Figure 2. These frames have been designed to have dimensions in accordance with IEC60297 and are supplied pre-assembled ready to use. On a standard 483mm rack system this enables combinations of widths of case 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 26mm intervals and the relays are attached via their mounting flanges using M4 Taptite self-tapping screws with captive 3mm thick washers (also known as a SEMS unit). These fastenings are available in packs of 5 (our part number ZA0005 105).

Note: Conventional self-tapping screws, including those supplied for mounting MIDOS relays, have marginally larger heads which can damage the front cover moulding if used.

Once the tier is complete, the frames are fastened into the racks using mounting angles at each end of the tier.

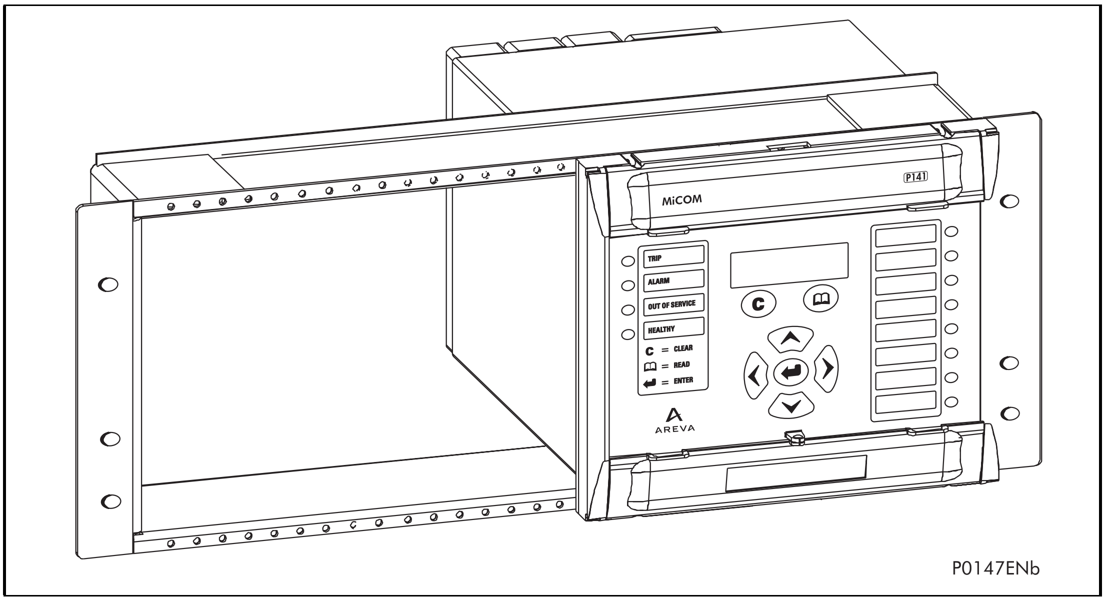



**Figure 2: Rack mounting of relays**

Relays can be mechanically grouped into single tier (4U) or multi-tier arrangements by means of the rack frame. This enables schemes using products from the MiCOM and MiDOS product ranges to be pre-wired together prior to mounting.

Where the case size summation is less than 80TE on any tier, or space is to be left for installation of future relays, blanking plates may be used. These plates can also be used to mount ancillary components. Table 1 shows the sizes that can be ordered.

Note: Blanking plates are only available in black.

Further details on mounting MiDOS relays can be found in publication R7012, “MiDOS Parts Catalogue and Assembly Instructions”.

| Case Size Summation | Blanking Plate Part Number |
|---|---|
| 5TE | GJ2028 101 |
| 10TE | GJ2028 102 |
| 15TE | GJ2028 103 |
| 20TE | GJ2028 104 |

Table 1: Blanking plates

### 5.2 Panel mounting

IN

The relays can be flush mounted into panels using M4 SEMS Taptite self-tapping screws with captive 3mm thick washers (also known as a SEMS unit). These fastenings are available in packs of 5 (our part number ZA0005 104).

Note: Conventional self-tapping screws, including those supplied for mounting MIDOS relays, have marginally larger heads which can damage the front cover moulding if used.

Alternatively tapped holes can be used if the panel has a minimum thickness of 2.5mm.

For applications where relays need to be semi-projection or projection mounted, a range of collars are available.

Where several relays are to mounted in a single cutout in the panel, it is advized that they are mechanically grouped together horizontally and/or vertically to form rigid assemblies prior to mounting in the panel.

Note: It is not advized that MiCOM relays are fastened using pop rivets as this will not allow the relay to be easily removed from the panel in the future if repair is necessary.

If it is required to mount a relay assembly on a panel complying to IEC 60529 IP52 enclosure protection, it will be necessary to fit a metallic sealing strip between adjoining relays (Part No. GN2044 001) and a sealing ring around the complete assembly.

| Width | Single Tier | Double Tier |
|---|---|---|
| 60TE | GJ9018 012 | GJ9018 028 |

Table 2: IP52 sealing rings

# 6. RELAY WIRING

This section serves as a guide to selecting the appropriate cable and connector type for each terminal on the MiCOM relay.

## 6.1 Medium and heavy duty terminal block connections

Key:

Heavy duty terminal block: CT and VT circuits, terminals with "D" prefix

Medium duty: All other terminal blocks (grey color)

Loose relays 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 relay terminal.

If required, AREVA T&D can supply M4 90° crimp ring terminals in three different sizes depending on wire size (see Table 3). Each type is available in bags of 100.

| Part Number | Wire Size | Insulation Color |
|---|---|---|
| ZB9124 901 | 0.25 - 1.65mm$^2$ (22 - 16AWG) | Red |
| ZB9124 900 | 1.04 - 2.63mm$^2$ (16 - 14AWG) | Blue |
| ZB9124 904 | 2.53 - 6.64mm$^2$ (12 - 10AWG) | Un-insulated* |

Table 3: M4 90° crimp ring terminals

*To maintain the terminal block insulation requirements for safety, an insulating sleeve should be fitted over the ring terminal after crimping.

The following minimum wire sizes are recommended:

Current Transformers 2.5mm$^2$

Auxiliary Supply, Vx 1.5mm$^2$

EIA(RS)485 Port See separate section

Other Circuits 1.0mm$^2$

Due to the limitations of the ring terminal, the maximum wire size that can be used for any of the medium or heavy duty terminals is 6.0mm$^2$ using ring terminals that are not pre-insulated. Where it required to only use pre-insulated ring terminals, the maximum wire size that can be used is reduced to 2.63mm$^2$ per ring terminal. If a larger wire size is required, two wires should be used in parallel, each terminated in a separate ring terminal at the relay.

The wire used for all connections to the medium and heavy duty terminal blocks, except the EIA(RS)485 port, should have a minimum voltage rating of 300Vrms.

It is recommended that the auxiliary supply wiring should be protected by a 16A high rupture capacity (HRC) fuse of type NIT or TIA. For safety reasons, current transformer circuits must never be fused. Other circuits should be appropriately fused to protect the wire used.

## 6.2 EIA(RS)485 port

IN

Connections to the EIA(RS)485 port are made using ring terminals. It is recommended that a 2 core screened cable is used with a maximum total length of 1000m or 200nF total cable capacitance. A typical cable specification would be:

Each core: 16/0.2mm copper conductors

PVC insulated

Nominal conductor area: 0.5mm$^2$ per core

Screen: Overall braid, PVC sheathed

See SCADA Communications (P145/EN CT) for detailed discussion on setting up an EIA(RS)485 bus.

## 6.3 IRIG-B connections (if applicable)

The IRIG-B input and BNC connector have a characteristic impedance of 50Ω. It is recommended that connections between the IRIG-B equipment and the relay are made using coaxial cable of type RG59LSF with a halogen free, fire retardant sheath.

## 6.4 EIA(RS)232 front port

Short term connections to the EIA(RS)232 port, located behind the bottom access cover, can be made using a screened multi-core communication cable up to 15m long, or a total capacitance of 2500pF. The cable should be terminated at the relay end with a 9-way, metal shelled, D-type male plug. The pin allocations are detailed in section 1.8 of Getting Started (P145/EN GS).

## 6.5 Ethernet port (if applicable)

Fiber Optic Port

The relays can have an optional 10 or 100 Mbps Ethernet port. FO connection is recommended for use in permanent connections in a substation environment. The 10Mbit port uses type ST connector and the 100Mbit port uses type SC connector, both compatible with 850nm multi-mode fiber-optic cable.

RJ-45 Metallic Port

The user can connect to either a 10Base-T or a 100Base-TX Ethernet hub; the port will automatically sense which type of hub is connected. Due to possibility of noise and interference on this part, it is recommended that this connection type be used for short-term connections and over short distance. Ideally where the relays and hubs are located in the same cubicle.

The connector for the Ethernet port is a shielded RJ-45. The table shows the signals and pins on the 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 |

Table 4: Signals on the Ethernet connector

## 6.6 Download/monitor port

Short term connections to the download/monitor port, located behind the bottom access cover, can be made using a screened 25-core communication cable up to 4m long. The cable should be terminated at the relay end with a 25-way, metal shelled, D-type male plug and linked as a parallel data connection.

### 6.7 Earth connection

Every relay must be connected to the cubicle earth bar using the M4 earth studs in the bottom left hand corner of the relay case. The minimum recommended wire size is $2.5mm^2$ and should have a ring terminal at the relay end.

To prevent any possibility of electrolytic action between brass or copper earth conductors and the rear of the relay, precautions should be taken. Examples include placing a nickel-plated washer between the conductor and the relay case, or using tinned ring terminals.

## 7. P145 CASE DIMENSIONS

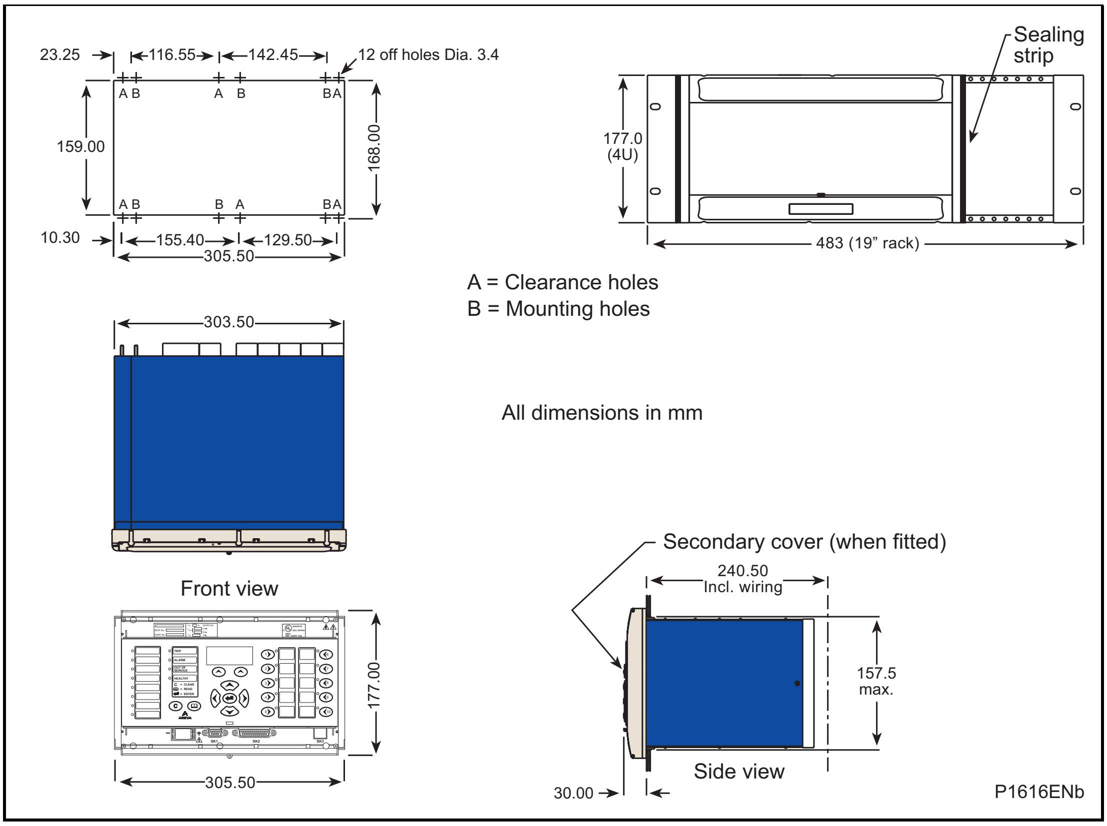



**Figure 3: Case dimensions**

# 8. P145 EXTERNAL CONNECTION DIAGRAMS

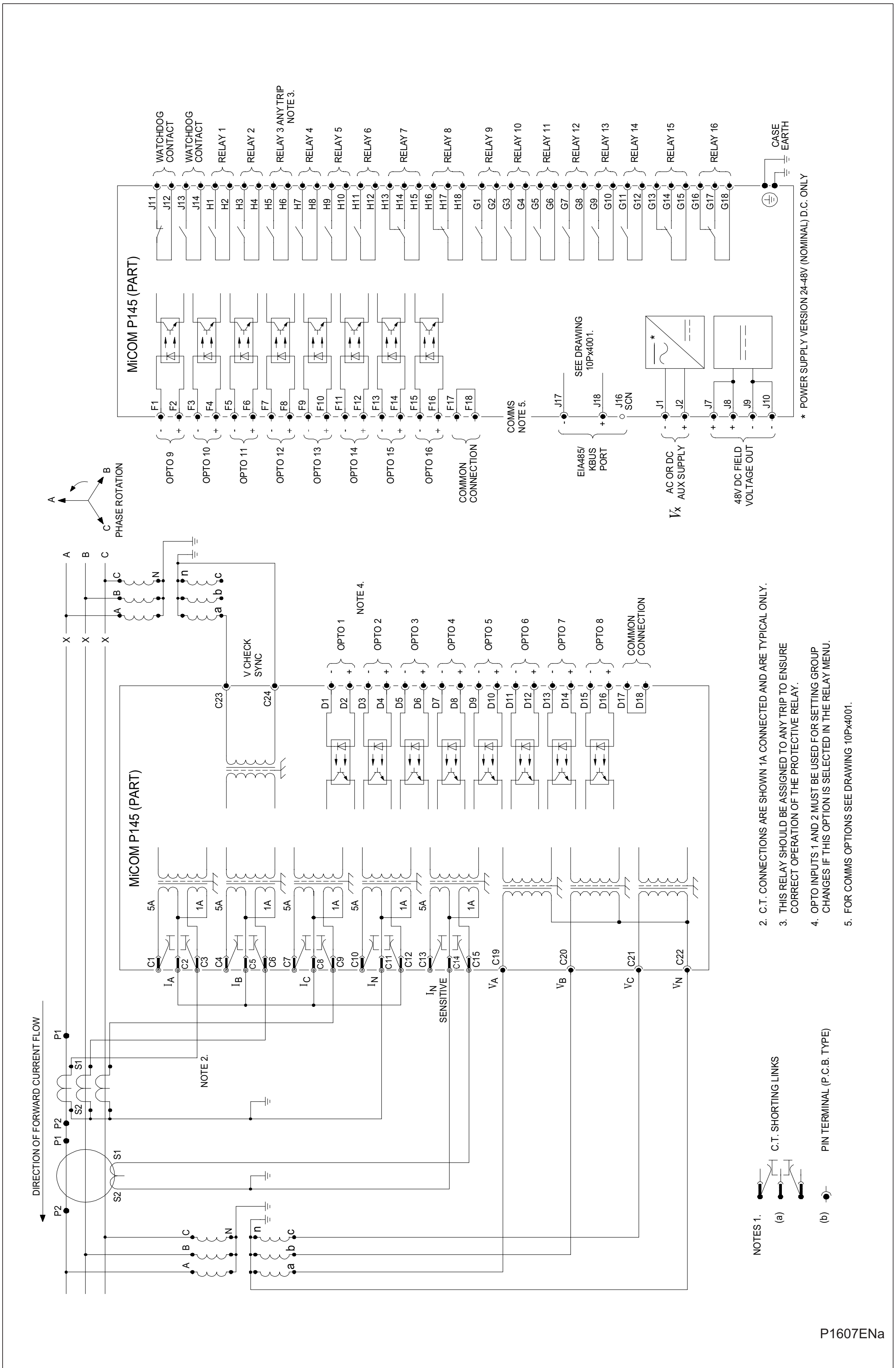



**Figure 4: Model A with 16 output contacts and 16 digital inputs**

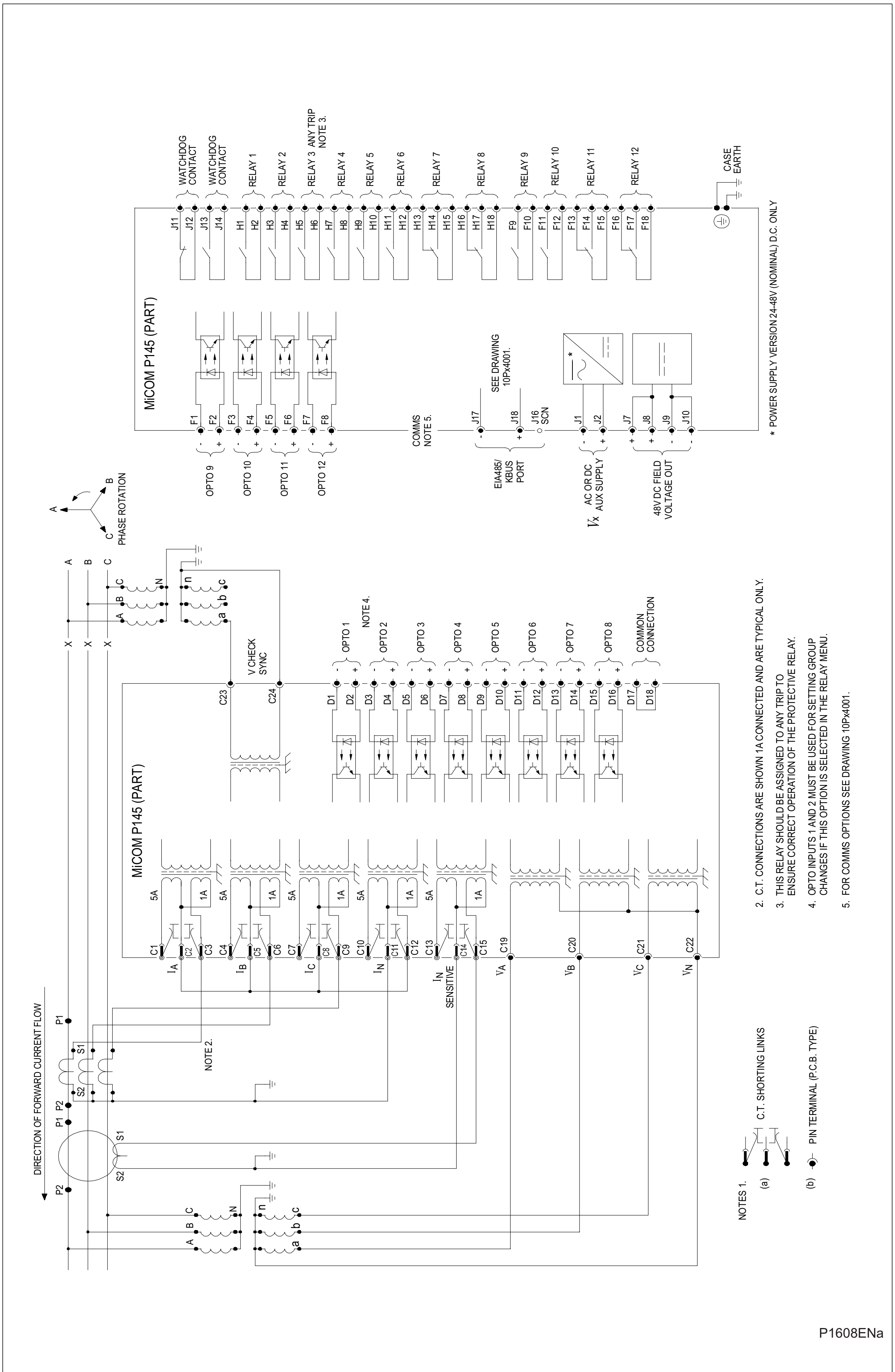



**Figure 5: Model B with 12 output contacts and 12 digital inputs**

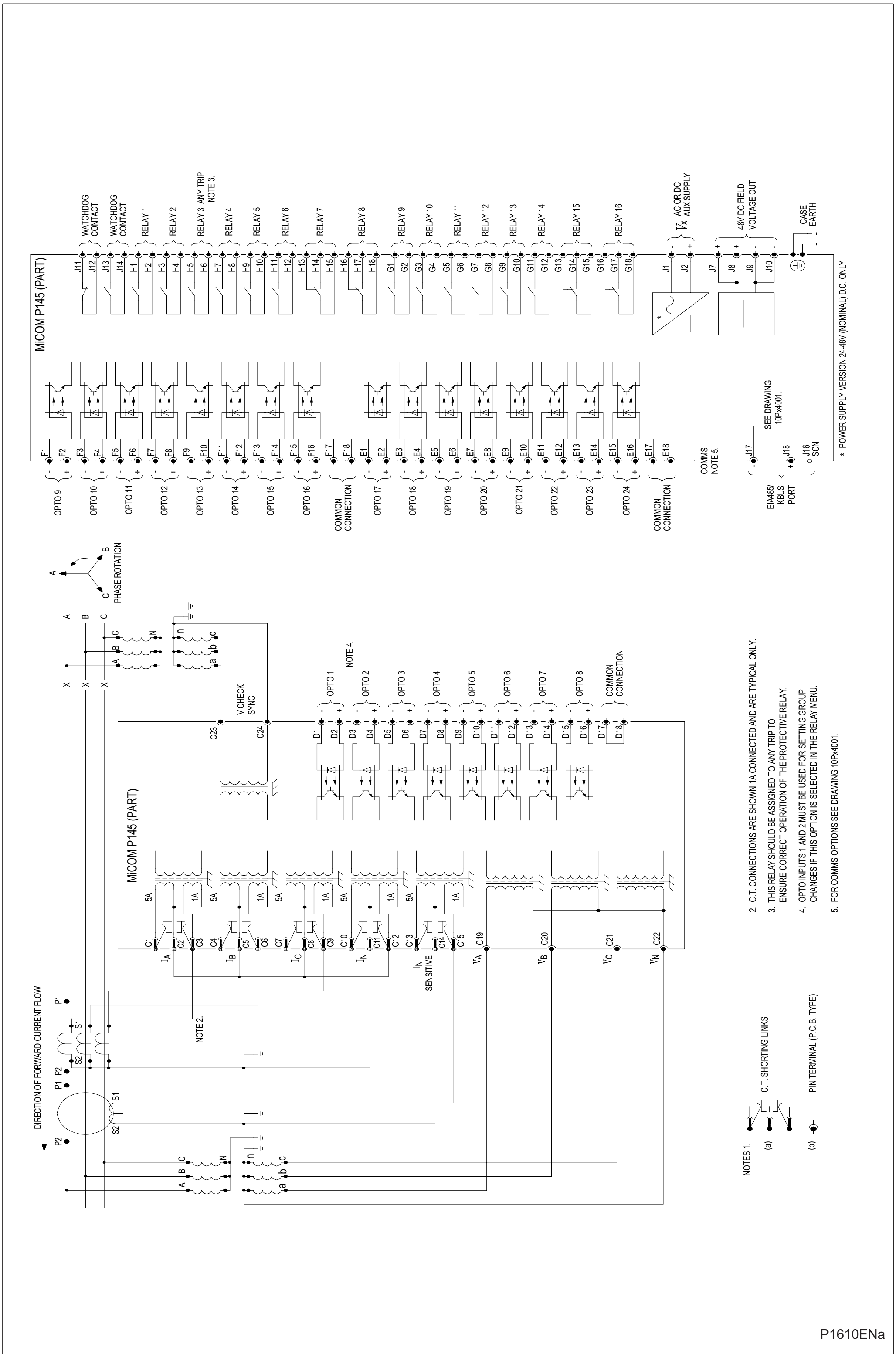



**Figure 6: Model C with 16 output contacts and 24 digital inputs**

IN

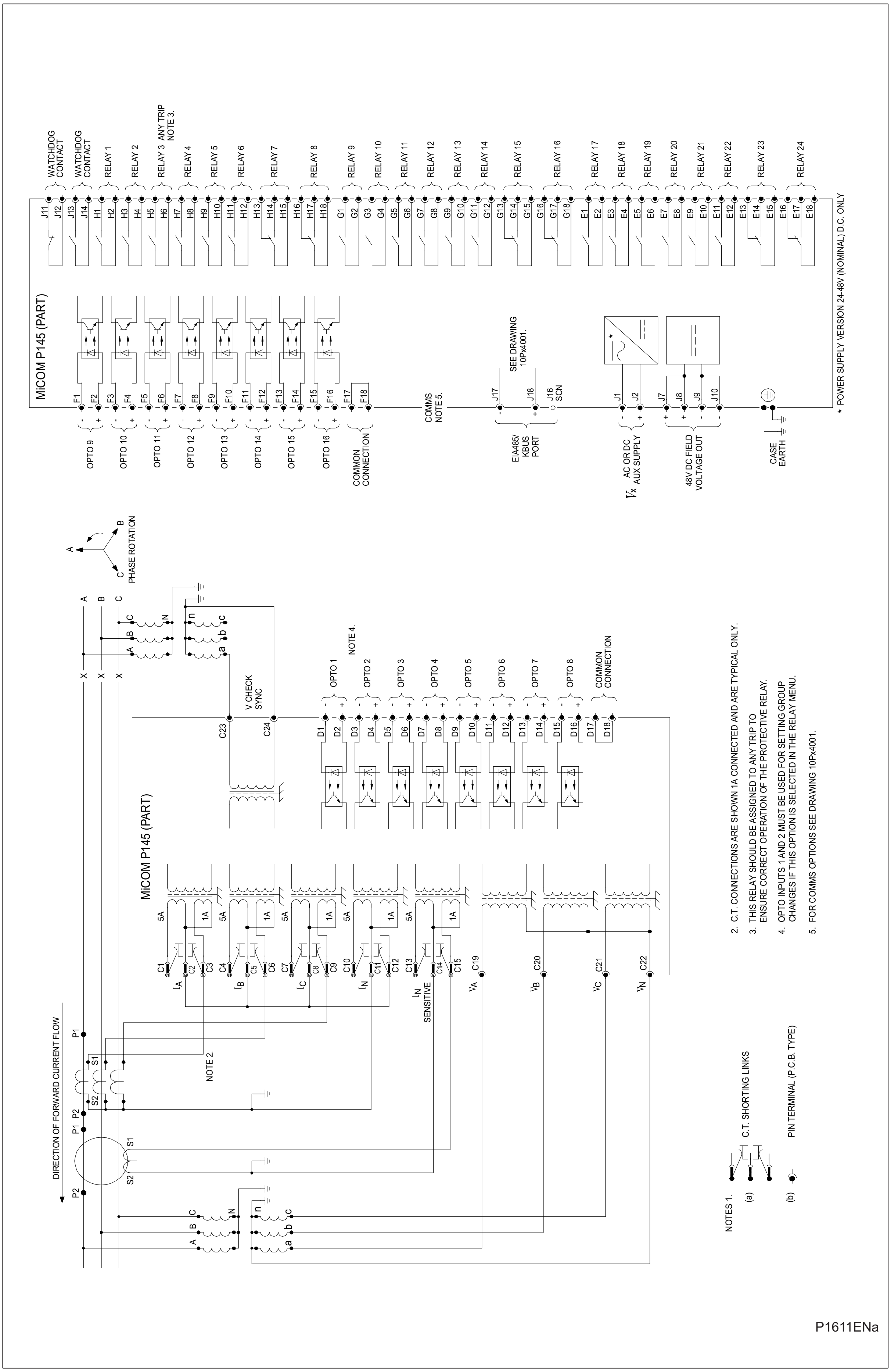



**Figure 7: Model D with 24 output contacts and 16 digital inputs**

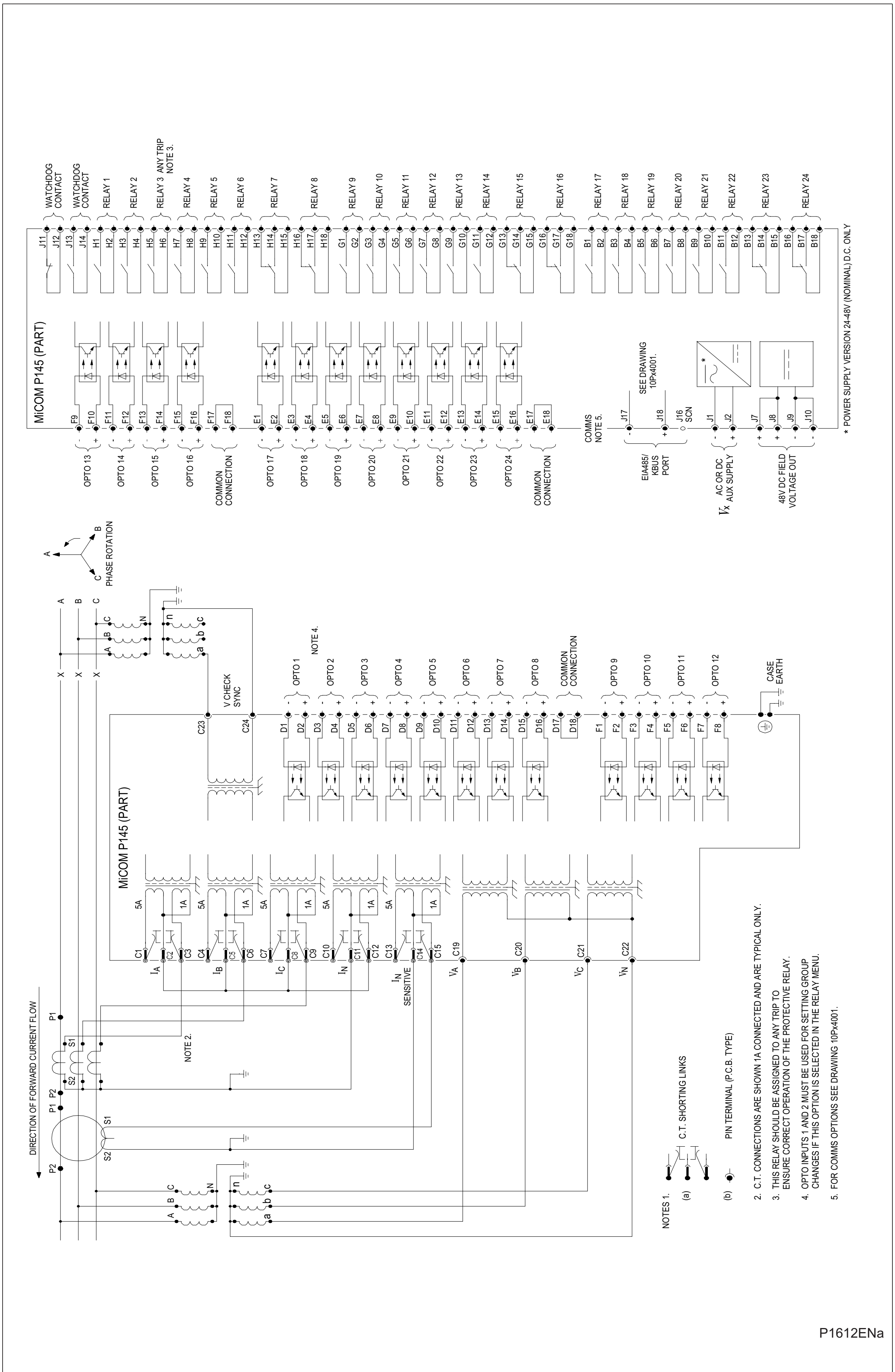



**Figure 8: Model E with 24 output contacts and 24 digital inputs**

IN

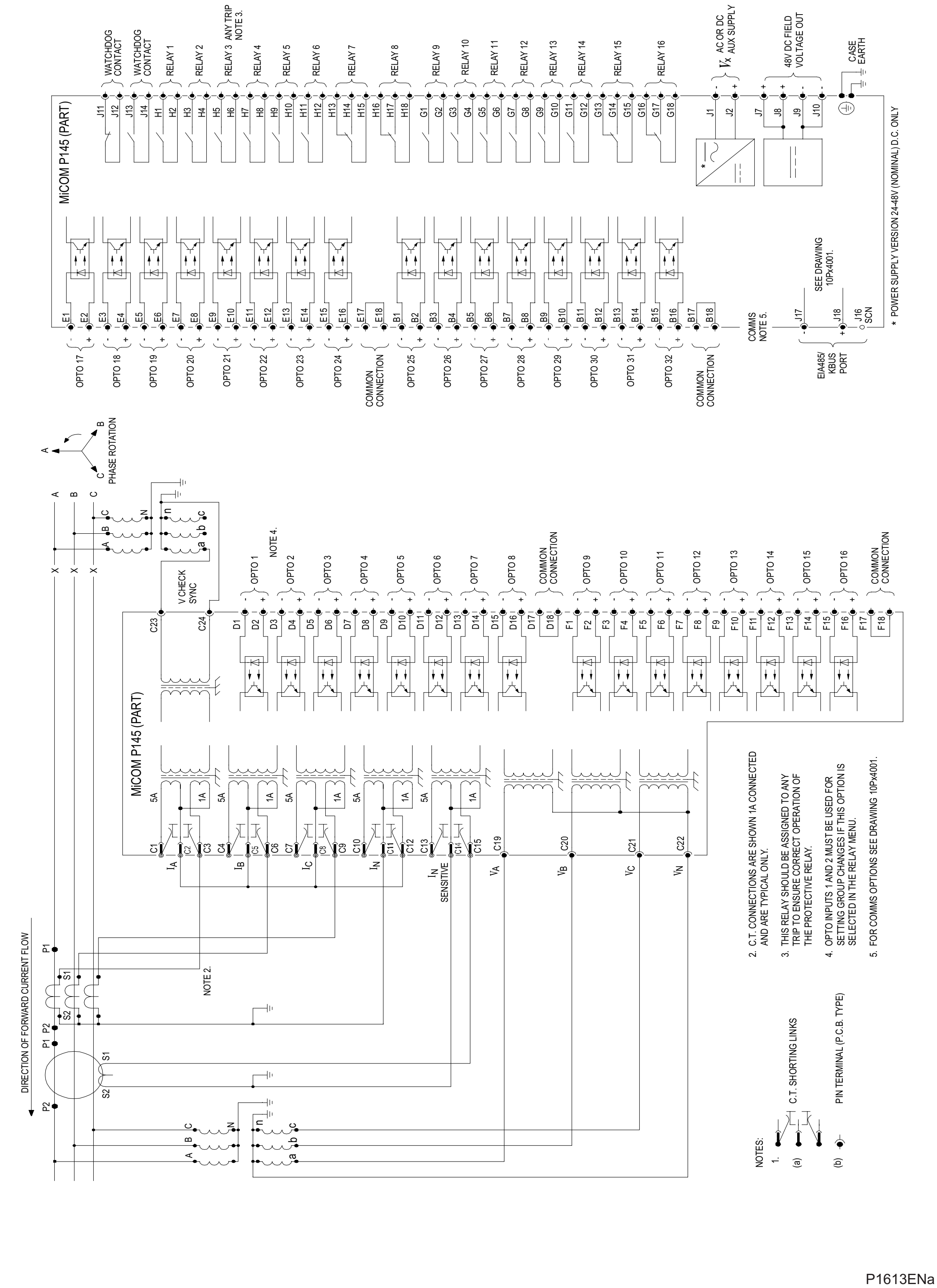



**Figure 9: Model F with 16 output contacts and 32 digital inputs**

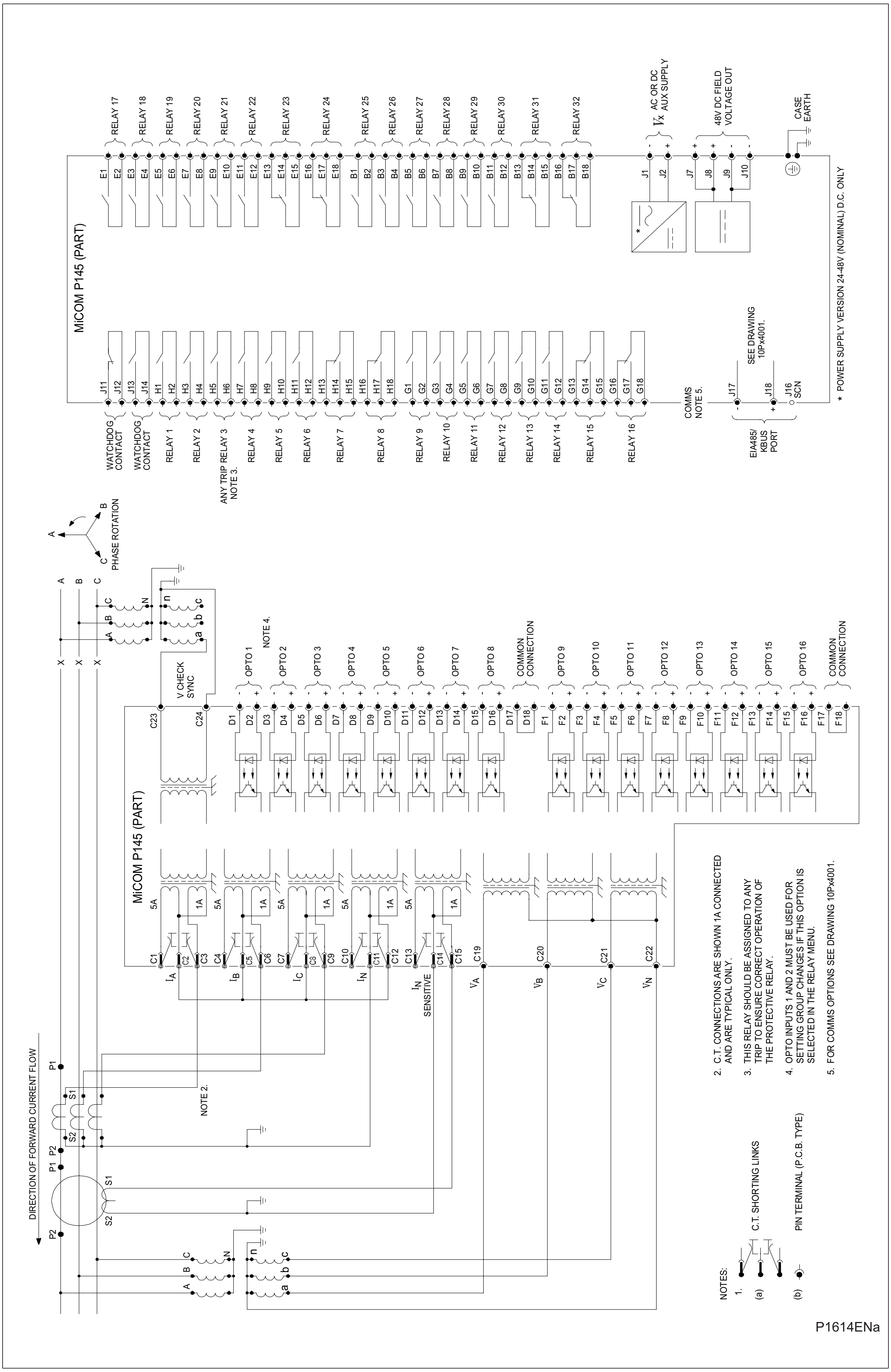



**Figure 10: Model G with 32 output contacts and 16 digital inputs**

# FIRMWARE AND SERVICE MANUAL VERSION HISTORY

| | |
|---|---|
| **Date:** | **7th July 2005** |
| **Hardware Suffix:** | **J** |
| **Software Version:** | **31** |
| **Connection Diagrams:** | **10P145xx (xx = 01 to 07)** |

| Relay type: P145 … | | | | | | |
|---|---|---|---|---|---|---|
| **Software Version** | | **Hardware Suffix** | **Original Date of Issue** | **Description of Changes** | **S1 Compatibility** | **Technical Documentation** |
| Major | Minor | | | | | |
| **31** | A | J | Mar 2005 | ✓ Original Issue<br>✓ P145 Evolution with extended User Interface (10 Function Keys and 18 tricolour LEDs).<br>✓ Control Input status stored in FLASH memory 10 Maintenance Records instead of 5.<br>✓ Programmable opto initiation of setting group change by DDB ddb signals (rather than fixed L1 and L2)<br>✓ Blocking of remote CB Trip/Close by DDB signals<br>✓ Inhibit of Earth Fault 1&2 by DDB signals<br>✓ Skip first shot of AR sequence by DDB signal | V2.12 | P145/EN M/A11 |

| Setting File Software Version / Relay Software Version | 31 | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 31 | ✓ | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | |

VH

| | | Relay Software Version | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 31 | | | | | | | | | | | | | | | | | | | | | | | | | |
| PSL File Software Version | 31 | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | |

VH

| Menu Text File Software Version \ Relay Software Version | 31 | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 31 | ✓ | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | |

# INDEX

## V



## W

Publication: P145/EN M/A11

TRANSMISSION & DISTRIBUTION Energy Automation & Information energy.automation-information@areva-td.com
www.areva.com