MiCOM P54x
(P541 & P542)

Technical Manual

P54x/EN M/H53

Version	Software Version	30
	Hardware Suffix	J

Current Differential Relay

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 Schneider Electric technical sales office and request the necessary information.

Any agreements, commitments, and legal relationships and any obligations on the part of Schneider Electric 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 Schneider Electric, it will invalidate the warranty, and may render the product unsafe.

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Section No	Description	Publication Reference
	Safety Information	Pxxx/EN SI/G12
1	Introduction	P54x/EN IT/H53
2	Technical Data	P54x/EN TD/H53
3	Getting Started (includes Menu Content Tables)	P54x/EN GS/H53
4	Settings	P54x/EN ST/H53
5	Operation (includes Scheme Logic Diagrams)	P54x/EN OP/H53
6	Application Notes	P54x/EN AP/H53
7	Programmable Logic	P54x/EN PL/H53
8	Measurements and Recording	P54x/EN MR/H53
9	Firmware Design (includes Relay Description)	P54x/EN FD/H53
10	Commissioning	P54x/EN CM/H53
11	Maintenance	Pxxx/EN MT/A22
12	Troubleshooting	Pxxx/EN TS/De7
13	SCADA Communications	P54x/EN SC/H53
14	Symbols and Glossary	Pxxx/EN SG/A05
15	Installation	P54x/EN IN/H53
16	Firmware and Service Manual Version History	P54x/EN VC/H53

Note	This manual covers the P54x (P541 and P542) range of products, which were released up to Software Version 30 and Hardware Suffix J. This manual does not cover the P543/P544/P545/P546 products. More up-to-date Software Versions and Hardware Suffix are available for the P543/P544/P545/P546 products. Please see www.schneider-electric.com for more details.

Notes:

SAFETY INFORMATION

CHAPTER SI

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Notes:

1 INTRODUCTION

This guide and the relevant equipment documentation provide full information on safe handling, commissioning and testing of this equipment. This Safety Information section also includes reference to typical equipment label markings.

Documentation for equipment ordered from Schneider Electric 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 which may be present on the equipment is fully understood by the recipient.

The technical data in this Safety Information section is typical only, see the technical data section of the relevant product publication(s) for data specific to a particular equipment.

WARNING	**Before carrying out any work on the equipment the user should be familiar with the contents of this Safety Information section and the ratings on the equipment's rating label.**

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

Language-specific, self-adhesive User Interface labels are provided in a bag for some equipment.

2 HEALTH AND SAFETY

The information in the Safety Information 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.

It is assumed that everyone who will be associated with the equipment will be familiar with the contents of that Safety Information section, or this Safety Guide.

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 also 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).

The equipment documentation gives instructions for its installation, commissioning, and operation. However, the manuals 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 Schneider Electric technical sales office and request the necessary information.

3 SYMBOLS AND LABELS ON THE EQUIPMENT

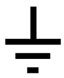
For safety reasons the following symbols and external labels, which may be used on the equipment or referred to in the equipment documentation, should be understood before the equipment is installed or commissioned.

3.1 Symbols

Caution: refer to equipment documentation

Caution: risk of electric shock

Protective Conductor (*Earth) terminal



Functional/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.*

***CAUTION:**	**The term “Earth” used throughout this technical manual is the direct equivalent of the North American term “Ground”.**

3.2 Labels

See Safety Guide (SFTY/4L M) for typical equipment labeling information.

4 INSTALLING, COMMISSIONING AND SERVICING

Manual Handling

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

Many injuries are caused by:

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

Follow the Health and Safety at Work, etc Act 1974, and the Management of Health and Safety at Work Regulations 1999.

Equipment Connections

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

The equipment documentation should be consulted before installing, commissioning, or servicing the equipment.

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

The clamping screws of all terminal block connectors, for field wiring, using M4 screws shall be tightened to a nominal torque of 1.3 Nm.

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

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 shall be made using insulated crimp terminations to ensure that terminal block insulation requirements are maintained for safety.

Watchdog (self-monitoring) contacts are provided in numerical relays to indicate the health of the device. Schneider Electric strongly recommends that these contacts are hardwired into the substation's automation system, for alarm purposes.

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.
- When the protective (earth) conductor terminal (PCT) is also used to terminate cable screens, etc., it is essential that the integrity of the protective (earth) conductor is checked after the addition or removal of such functional earth connections. For M4 stud PCTs the integrity of the protective (earth) connections should be ensured by use of a locknut or similar.

The recommended minimum protective conductor (earth) wire size is 2.5 mm^2 (3.3 mm^2 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.

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

Pre-Energization Checklist

Before energizing the equipment, the following should be checked:

- Voltage rating/polarity (rating label/equipment documentation);
- CT circuit rating (rating label) and integrity of connections;
- Protective fuse rating;
- Integrity of the protective conductor (earth) connection (where applicable);
- Voltage and current rating of external wiring, applicable to the application.

Accidental Touching of Exposed Terminals

If working in an area of restricted space, such as a cubicle, where there is a risk of electric shock due to accidental touching of terminals which do not comply with IP20 rating, then a suitable protective barrier should be provided.

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/CUL Listed or Recognized Equipment

To maintain UL and CSA/CUL Listing/Recognized status for North America the equipment should be installed using UL or CSA Listed or Recognized parts for the following items: connection cables, protective fuses/fuseholders or circuit breakers, insulation crimp terminals and replacement internal battery, as specified in the equipment documentation.

For external protective fuses a UL or CSA Listed fuse shall be used. The Listed type shall be a Class J time delay fuse, with a maximum current rating of 15 A and a minimum d.c. rating of 250 Vd.c., for example type AJT15.

Where UL or CSA Listing of the equipment is not required, a high rupture capacity (HRC) fuse type with a maximum current rating of 16 Amps and a minimum d.c. rating of 250 Vd.c. may be used, for example Red Spot type NIT or TIA.

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.

5 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 the equipment.

6 TECHNICAL SPECIFICATIONS FOR SAFETY

Unless otherwise stated in the equipment technical manual, the following data is applicable.

6.1 Protective Fuse Rating

The recommended maximum rating of the external protective fuse for equipments is 16A, High Rupture Capacity (HRC) Red Spot type NIT, or TIA, or equivalent. Unless otherwise stated in equipment technical manual, the following data is applicable. The protective fuse should be located as close to the unit as possible.

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

6.2 Protective Class

IEC 60255-27: 2005	Class I (unless otherwise specified in the equipment documentation).
EN 60255-27: 2005	This equipment requires a protective conductor (earth) connection to ensure user safety.

6.3 Installation Category

IEC 60255-27: 2005	Installation Category III (Overvoltage Category III)
EN 60255-27: 2005	Distribution level, fixed installation.
	Equipment in this category is qualification tested at 5 kV peak, 1.2/50 µs, 500 Ω, 0.5 J, between all supply circuits and earth and also between independent circuits.

6.4 Environment

The equipment is intended for indoor installation and use only. If it is required for use in an outdoor environment then it must be mounted in a specific cabinet of housing which will enable it to meet the requirements of IEC 60529 with the classification of degree of protection IP54 (dust and splashing water protected).

Pollution Degree	Pollution Degree 2 Compliance is demonstrated by reference to safety standards.
Altitude	Operation up to 2000m

INTRODUCTION

CHAPTER 1

Notes:

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Notes:

1 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 Schneider Electric.

Central to the MiCOM concept is flexibility.

MiCOM provides the ability to define an application solution and, through extensive communication capabilities, to 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 behaviour of the power system using disturbance and fault records. They can also provide measurements of the system at regular intervals to a control centre enabling remote monitoring and control to take place.

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

www.schneider-electric.com

2 MICOM DOCUMENTATION

This guides provide a functional and technical description of the MiCOM protection relay and a comprehensive set of instructions for the relay's use and application.

The previous documentation was to be divided into two separate volumes, namely:

Volume 1 **Technical Guide**
Contained information on the application of the relay and a technical description of its features. It was mainly intended for protection engineers concerned with the selection and application of the relay for the protection of the power system. It included these main chapters:

1. Introduction P54x/EN IT/E53
2. Application Notes P54x/EN AP/H53
3. Relay Description P54x/EN HW/G53
4. Technical Data P54x/EN TD/H53
5. Menu Content Tables P54x/EN HI/A42
6. SCADA Communications P54x/EN CT/G53
7. UCA2.0 Communications P54x/EN UC/B42
8. Relay Menu Database P54x/EN GC/H53
9. External Connection Diagrams P54x/EN CO/G42
10. Hardware / Software Version History & Compatibility P54x/EN VC/F53
11. Scheme Logic Diagrams P54x/EN LG/C53

Volume 2 **Operation Guide**
Contained information on the installation and commissioning of the relay, and included a section on fault finding. This volume was intended for site engineers who were responsible for the installation, commissioning and maintenance of the relay. It included these main chapters:

1. Introduction P54x/EN IT/E53
2. Installation P54x/EN IN/E42
3. P594 Installation Guide P594/EN IN/B11
4. Commissioning & Maintenance P54x/EN CM/G53
5. Problem Analysis P54x/EN PR/E53
6. Menu Content Tables P54x/EN HI/A42
7. Relay Menu Database P54x/EN GC/H53
8. External Connection Diagrams P54x/EN CO/G42
9. Hardware / Software Version History & Compatibility P54x/EN VC/F53
10. Scheme Logic Diagrams P54x/EN LG/C53
11. Repair Form

These have now been combined into a single technical manual, as shown in section 2.1. Duplicate chapters have been removed; and the following chapters merged into single chapters or renamed:

New chapter	Old chapters
Troubleshooting	(O) Problem Analysis (P54x/EN PR/E53) + (O) Repair Form
Communications	(T) SCADA Comms Guide (P54x/EN CT/G53) +
Installation	(O) Installation (P54x/EN IN/E42) + (T) External Connection Diagrams (P54x/EN CO/G42)

For technical information about Error Codes (these may appear as Hex or Decimal codes), please contact your Schneider Electric technical support representative.

2.1 Technical Manual

No	Description	Part No.
	Safety Information	**Pxxx/EN SI**
	Safety Information (includes information about Handling of Electronic Equipment).	
1	**Introduction**	**P54x/EN IT**
	A guide to this manual and the protection relay.	
2	**Technical Data**	**P54x/EN TD**
	Includes details of setting ranges, accuracy limits, recommended operating conditions, ratings and performance data. Compliance with technical standards is specified too.	
3	**Getting Started (was called Menu Content Tables)**	**P54x/EN GS**
	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.	
4	**Settings**	**P54x/EN ST**
	List of all relay settings, including ranges, step sizes and defaults, together with a brief explanation of each setting.	
5	**Operation (was called Scheme Logic Diagrams)**	**P54x/EN LG**
	A comprehensive and detailed functional description of all protection and non-protection functions.	
6	**Application Notes**	**P54x/EN AP**
	Comprehensive description of the features of the relay including the protection elements and other functions such as event and disturbance recording, fault location and programmable scheme logic. This includes a description of common power system applications, calculation of suitable settings, some typical worked examples, and how to apply the settings to the relay.	
7	**Programmable Scheme Logic (PSL)**	**P54x/EN GC**
	Overview of the PSL and a description of each logical node. This chapter includes the factory default PSL and an explanation of typical applications.	
8	**Measurements and Recording**	**P54x/EN MR**
	Detailed description of the relays recording and measurements functions including the configuration of the event and disturbance recorder and measurement functions.	
9	**Firmware Design (was called Relay Description)**	**P54x/EN FD**
	Overview of the operation of the relay’s hardware and software. This chapter includes information on the self-checking features and diagnostics of the relay.	
10	**Commissioning**	**P54x/EN CM**
	Instructions on how to commission the relay, comprising checks on the calibration and functionality of the relay.	
11	**Maintenance**	**Pxxx/EN MT**
	Generic instructions on general maintenance for the relay.	
12	**Troubleshooting (was called Problem Analysis)**	**Pxxx/EN TS**
	Advice on how to recognise failure modes and the recommended course of action. Includes the Repair Form.	
13	**SCADA Communications**	**P54x/EN SC**
	Provides detailed information about the communication interfaces of the relay, including a detailed description of how to access the settings stored in the relay. It also gives information on each of the communication protocols that can be used, and is intended to allow the user to design a custom interface to a SCADA system.	
14	**Symbols and Glossary**	**Pxxx/EN SG**
	Generic information about commonly used symbols and abbreviations.	

No	Description	Part No.
15	**Installation**	**P54x/EN IN**
	Recommendations on unpacking, handling, inspection and storage of the relay. Includes a guide to the mechanical and electrical installation and earthing recommendations. Also includes external wiring connections to the relay.	
16	**Hardware / Software Version History and Compatibility**	**P54x/EN VC**

Note	*Previous versions of the P54x documentation covered the P541, P542, P543, P544, P545 and P546 products. This version of the manual **only** covers products P541 and P542 only. Accordingly, references to products P543, P544, P545 and P546 have generally been removed from this version of the manual.*

2.2 Relay Menu Database

There is also a standalone Relay Menu Database document as follows:

Description	Part No
Relay Menu Database: User Interface / Courier / Modbus / IEC 60870-5-103/ DNP 3.0	P54x/EN MD/H53 V30
This contains a complete listing of all of the settings contained within the relay together with a brief description of each.	

TECHNICAL DATA

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1 REFERENCE CONDITIONS

The accuracy claims within this document are relevant for a relay operating under these reference conditions.

Quantity	Reference Conditions	Test Tolerance
General		
Ambient temperature	20°C	±2°C
Atmospheric pressure	86kPa to 106kPa	-
Relative humidity	45 to 75 %	-

Input Energising Quantity	Reference Conditions	Test Tolerance
Current	In	±5%
Voltage	Vn	±5%
Frequency	50 or 60Hz	±0.5%
Auxiliary supply	DC 24V, 48V or 110V AC 63.5V or 110V	±5%

Settings	Reference Value
Time Multiplier Setting	1.0
Time Dial (Software 30 or later)	1
Time Dial	7

2 PROTECTION FUNCTIONS

The following functional claims are applicable to the P540 range of current differential relays.

Note	*Not all the protection functions listed below are applicable to every relay.*

2.1 Phase Current Differential Protection

2.1.1 Phase Current Biased Differential Characteristic Settings

Name	Range	Step Size
Is1	0.2 - 2.0In	0.05In
Is2	1.0 - 30In	0.05In
K1	30 - 150%	5%

Characteristic shape determined by the following formula:

For $I_{bias} \leq I_{s2}$

$$|I_{diff}| = k_1|I_{bias}| + I_{S1}$$

For $I_{bias} > I_{s2}$

$$|I_{diff}| = k_2|I_{bias}| - (k_2 - k_2).\ \ I_{S2} + I_{S1}$$

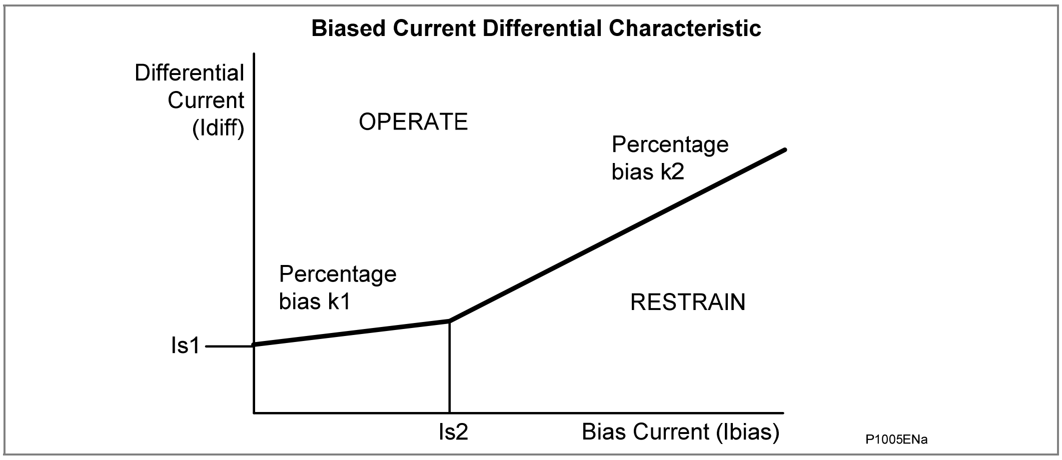

Figure 1 - Biased current differential characteristic

2.1.2 Phase Current Differential High Set Characteristic Settings (P541 and P542)

Name	Range	Step Size
I Diff >>	4.0 - 32.0In	0.01In

2.1.3 Differential Protection Operating and Reset Times

The time delay is user selectable as inverse time or definite time characteristics:

2.1.4 Inverse Definite Minimum Time (IDMT) Characteristic

IDMT characteristics are selectable from a choice of four IEC/UK and five IEEE/US curves as shown in Table 1.

The IEC/UK IDMT curves conform to this formula:

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

The IEEE/US IDMT curves conform to this formula:

Equation 2 $$t = TD \times \left(\frac{K}{(I/Is)^{\alpha} - 1} + L \right)$$

Where
- t = operation time
- K = constant
- I = measured current
- I_S = current threshold setting
- α = constant
- L = ANSI/IEEE constant (zero for IEC/UK curves)
- T = Time Multiplier Setting for IEC/UK curves
- TD = Time Dial Setting for IEEE/US curves

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

Table 1 - IDMT curve description

2.1.4.1 Required Time Multiplier Settings for IEC/UK Curves

Name	Range	Step Size
TMS	0.025 to 1.2	0.025

2.1.4.2 Required Time Dial Settings for IEEE/US Curves

Name	Range	Step Size
TD (software 30 or later)	0.1 - 100	0.05
TD	0.05 - 15	0.01

2.1.4.3 Definite Time Characteristic

Range	Step Size
0 to 100s	0.01s

The reset characteristics are instantaneous and typically less than 60ms plus protection channel signalling time.

2.1.5 Vectorial Compensation Settings (P541 and P542)

Setting	Phase shift	Action	
Yy0	0°	Do nothing	

Setting	Phase shift	Action	
Yd1	30° lag	Ia = (IA - IC) / $\sqrt{3}$ Ib = (IB - IA) / $\sqrt{3}$ Ic = (IC - IB) / $\sqrt{3}$	Where Ia, Ib and Ic are the corrected currents and
Yy2	60° lag	Ia = -IC Ib = -IA Ic = - IB	IA, IB and IC are the uncorrected phase currents
Yd3	90° lag	Ia = (IB - IC) / $\sqrt{3}$ Ib = (IC - IA) / $\sqrt{3}$ Ic = (IA - IB) / $\sqrt{3}$	
Yy4	120° lag	Ia = IB Ib = IC Ic = IA	
Yd5	150° lag	Yd11 and Invert	
Yy6	180° lag	Invert currents	
Yd7	150° lead	Yd1 and Invert	
Yy8	120° lead	Ia = IC Ib = IA Ic = IB	
Yd9	90° lead	Yd3 and Invert	
Yy10	60° lead	Ia = -IB Ib = -IC Ic = -IA	
Yd11	30° lead	Ia = (IA - IB) / $\sqrt{3}$ Ib = (IB - IC) / $\sqrt{3}$ Ic = (IC - IA) / $\sqrt{3}$	
Ydy0	0°	Ia = IA - (IA + IB + IC) / 3 Ib = IB - (IA + IB + IC) / 3 Ic = IC - (IA + IB + IC) / 3	
Ydy6	180° lag	Ydy0 and Invert	

Table 2 - Vectorial compensation settings

2.1.6 Current Transformer Ratio Compensation Setting

Name	Range	Step Size
Phase CT ratio correction	1 - 8	0.01

2.1.7 Accuracy

Pick-up		Formula ±10%
Drop-off		0.75 x Formula ±10%
IDMT characteristic shape		±5% or 40ms whichever is greater
DT operation		±2% or 20ms whichever is greater
Instantaneous Operation		<30ms
Reset time		<60ms
Repeatability		±2.5%
Characteristic	UK curves	IEC 60255-3 - 1998
	US curves	IEEE C37.112 - 1996
Vector compensation		No affect on accuracy
Current transformer ratio compensation		No affect on accuracy

High set characteristic setting	No affect on accuracy
Two ended scheme operation	No affect on accuracy
Three ended scheme operation	No affect on accuracy

2.2 Three Phase Non-Directional / Directional Overcurrent Protection

2.2.1 Setting Ranges

	Stage	Range	Step size
Phase element	1st Stage	0.08 - 4.0 In	0.01 In
	2nd Stage	0.08 - 4.0 In	0.01 In
	3rd Stage	0.08 - 32 In	0.01 In
	4th Stage	0.08 - 32 In	0.01 In

Table 3 - Setting ranges

2.2.2 Time Delay Settings

Each overcurrent element has an independent time setting and each time delay is capable of being blocked by an optically isolated input:

Element	Time delay type
1st Stage	Definite Time (DT) or Inverse Definite Minimum Time (IDMT)
2nd Stage	DT or IDMT
3rd Stage	DT
4th Stage	DT

Curve type	Reset time delay
IEC / UK curves	DT only
All other	IDMT or DT

2.2.2.1 Inverse Definite Minimum Time (IDMT) Characteristic

IDMT characteristics are selectable from a choice of four IEC/UK and five IEEE/US curves as shown in Table 4.

The IEC/UK IDMT curves conform to this formula:

Equation 3 $$t = T \times \left(\frac{K}{(I/Is)^{\alpha} - 1} + L \right)$$

The IEEE/US IDMT curves conform to this formula:

Equation 4 $$t = TD \times \left(\frac{K}{(I/Is)^{\alpha} - 1} + L \right)$$

Where:
- t = operation time
- K = constant
- I = measured current
- I_S = current threshold setting
- α = constant
- L = ANSI/IEEE constant (zero for IEC/UK curves)

T = Time Multiplier Setting for IEC/UK curves
TD = Time Dial Setting for IEEE/US curves

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

Table 4 - IDMT Curve descriptions for Standard, K, α and L Constants

2.2.2.2 Time Multiplier Settings for IEC/UK Curves

Name	Range	Step Size
TMS	0.025 to 1.2	0.025

2.2.2.3 Time Dial Settings for IEEE/US Curves

Name	Range	Step Size
TD (Software 30 or later)	0.1 to 100	0.01
TD	0.05-15	0.05

2.2.2.4 Definite Time Characteristic

Element	Range	Step Size
All stages	0 to 100s	10 ms

2.2.2.5 Reset Characteristics

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

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

The definite time can be set (as defined in IEC) to zero. Range 0 to 100 seconds in steps of 0.01 seconds.

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

All inverse reset curves conform to this formula:

Equation 5 $$t_{Reset} = TD \times \left(\frac{tr}{1 - (I/Is)^{\alpha}} \right)$$

Where:

t_{Reset} = reset time
tr = constant
I = measured current
I_S = current threshold setting
α = constant
TD = Time Dial Setting (same setting as used by IDMT curve)

IEEE/US IDMT Curve description	Standard	tr Constant	α Constant
Moderately Inverse	IEEE	4.85	2
Very Inverse	IEEE	21.6	2
Extremely Inverse	IEEE	29.1	2
Inverse	US-C08	5.95	2
Short Time Inverse	US-C02	2.261	2

Table 5 - IEEE/US IDMT Curve descriptions for Standard, K, tr and α Constants

2.2.2.6 Inverse Reset Characteristics

2.2.3 Accuracy

Pick-up		Setting ±5%
Drop-off		0.95 x Setting ±5%
Minimum trip level of IDMT elements		1.05 x Setting ±5%
IDMT characteristic shape		±5% or 40ms whichever is greater (under reference conditions)*
IEEE reset		±5% or 40ms whichever is greater
DT operation		±2% or 50ms whichever is greater
DT reset		Setting ±5%
Directional boundary accuracy (RCA ±90°)		±2° hysteresis 2°
Characteristic	UK curves	IEC 60255-3 - 1998
	US curves	IEEE C37.112 - 1996
* Reference conditions TMS=1, TD=1 and I> setting of 1A, accuracy operating range 2-20 Is		

2.2.4 IEC IDMT Curves

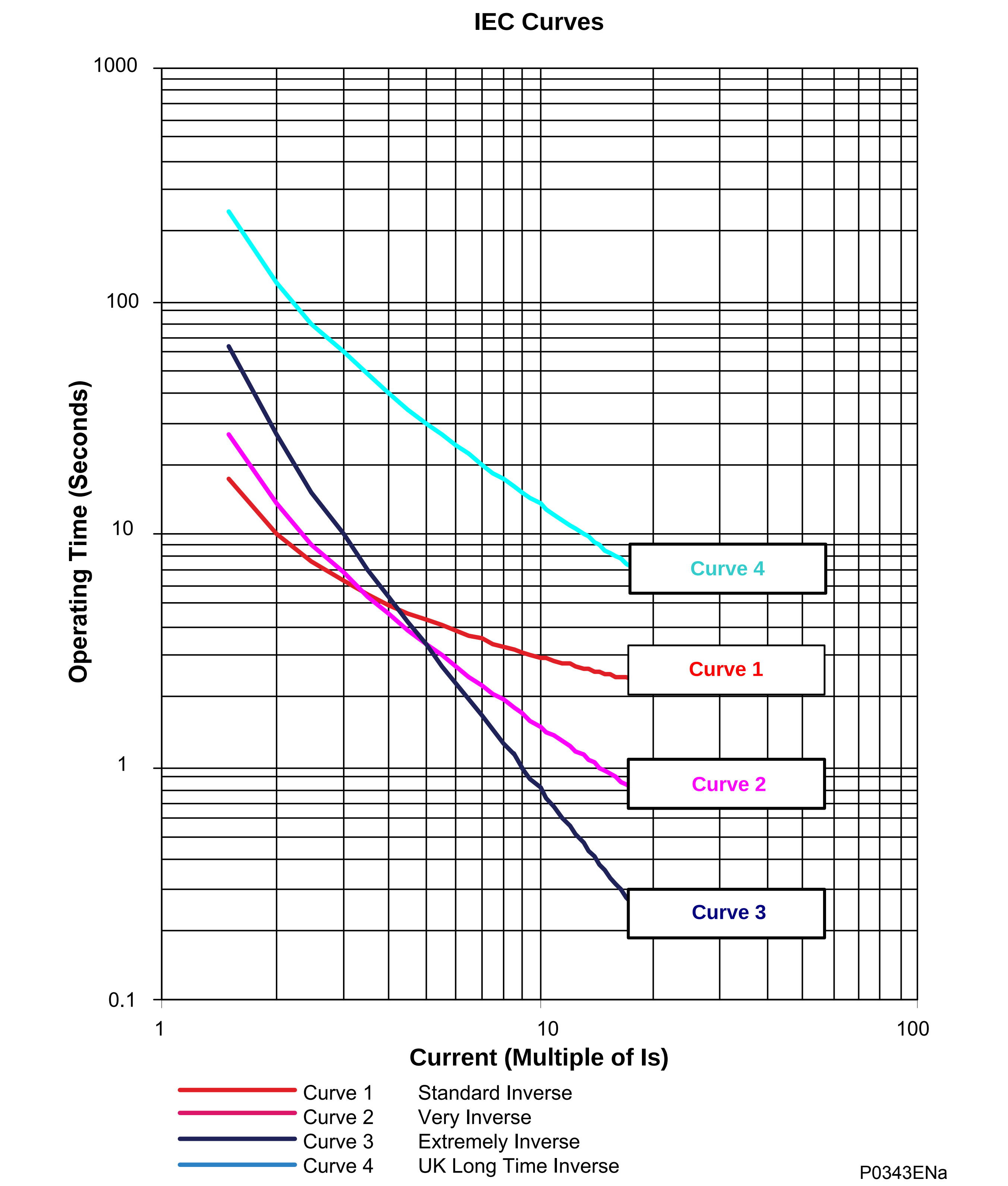

Figure 2 - IEC curves

2.2.5 ANSI/IEEE IDMT Curves

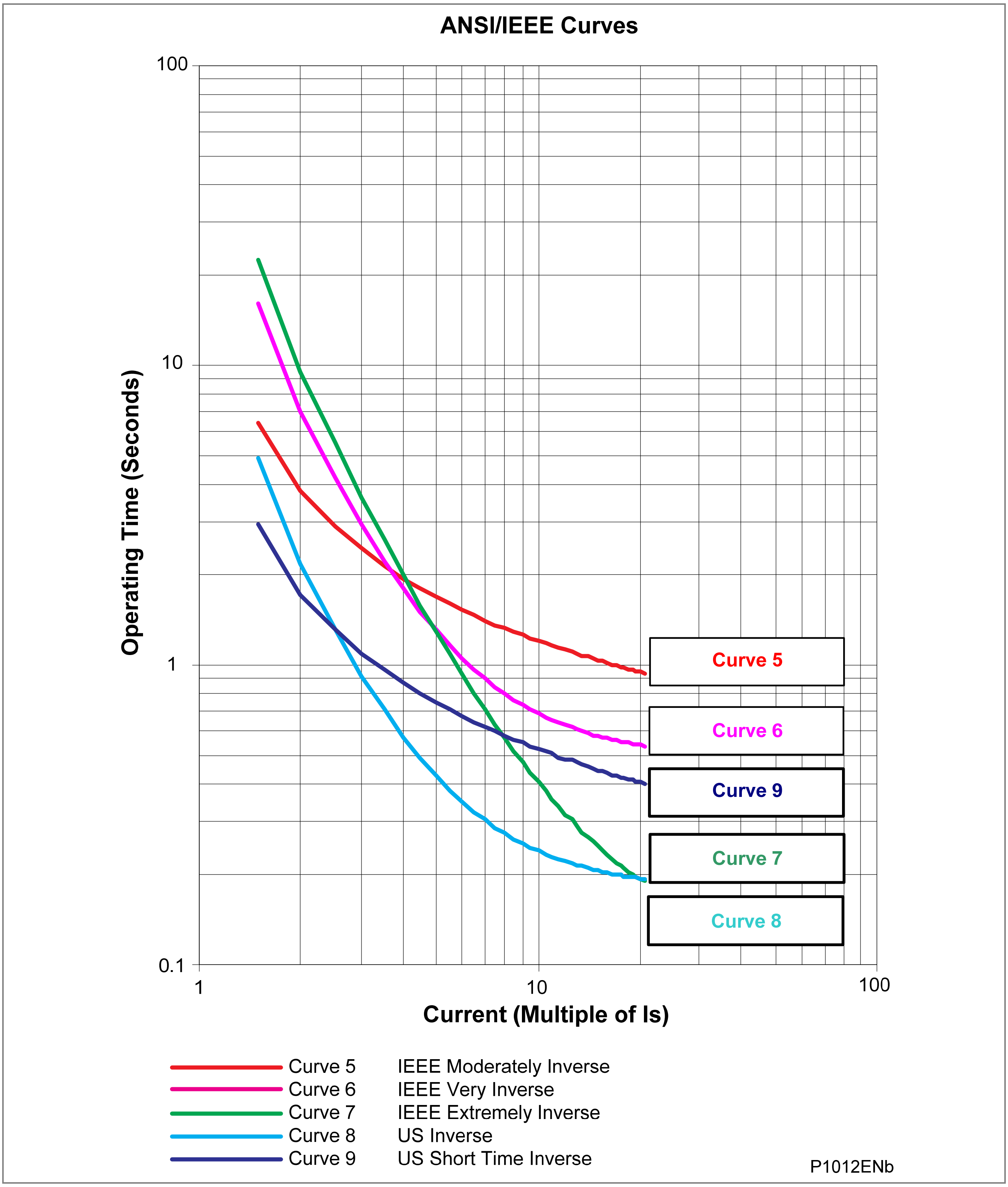

Figure 3 - ANSI/IEEE curves

2.3 Earth Fault Protection

2.3.1 Setting Ranges

2.3.1.1 Earth Fault

Fault Type	Stage	Range	Step Size
Earth Fault (EF)	1st Stage	0.08 - 4.0 In	0.01 In
	2nd Stage	0.08 - 4.0 In	0.01 In
	3rd Stage	0.08 - 32 In	0.01 In
	4th Stage	0.08 - 32 In	0.01 In

2.3.2 Time Delay Characteristics

The earth-fault measuring elements for EF are followed by an independently selectable time delay. These time delays are identical to those of the Phase Overcurrent time delay. The reset time delay is the same as the Phase overcurrent reset time.

2.3.3 Accuracy

2.3.3.1 Earth Fault

Pick-up	Setting ±5%
Drop-off	>0.85 x Setting
Minimum trip level of IDMT elements	1.05 x Setting ±5%
IDMT characteristic shape	±5% or 40ms whichever is greater (under reference conditions)*
IEEE reset	±10% or 40ms whichever is greater
DT operation	±2% or 50ms whichever is greater
DT reset	±5% or 50ms whichever is greater
Repeatability	7.5%
* Reference conditions TMS=1, TD=1 and IN> setting of 1A, accuracy operating range 2-20 Is	

2.3.3.2 Polarising Quantities

Zero Sequence Polarising

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

Negative Sequence Polarising

Operating boundary pick-up	±2°of RCA ±90°
Hysteresis	<2°
V2> Pick-up	Setting ±10%
V2> Drop-off	0.9 x Pick-up ±10%
I2> Pick-up	Setting ±10%
I2> Drop-off	0.9 x Pick-up+/-10%

2.4 Undercurrent

2.4.1 Setting Ranges

Name	Range	Step size
Phase I <	0.02 - 3.2 In	0.01 In

2.4.2 Accuracy

Pick-up	±10% or 25mA whichever is the greater
Operating time	<12ms
Reset	<15ms

2.5 Broken Conductor Logic

2.5.1 Setting Ranges

Settings	Range	Step size
I2/I1	0.2 - 1.0	0.01
Time delay	0 - 100s	0.1s

2.5.2 Accuracy

Pick-up	Setting ±2.5%
Drop-off	0.95 x Setting ±2.5%
DT operation	±2% or 50ms whichever is greater
Reset	<25ms

2.6 Transient Overreach and Overshoot

2.6.1 Accuracy

Additional tolerance due to increasing X/R ratios	±5% over the X/R ratio of 1 to 90
Overshoot of overcurrent elements	<40ms

2.7 Thermal Overload

2.7.1 Setting Ranges

Name	Setting Range	Step Size
Time constant	Single or Dual	-
Thermal trip current I_θ>>	0.08 - 4 I_N	0.01 I_N
Thermal alarm θ>	50 - 100% of θ>>	1% of θ>>
Time constant τ_1	1 - 200 minutes	1 minute
Time constant τ_2	1 - 200 minutes	1 minute

2.7.2 Accuracy

Pick-up	Thermal alarm	Calculated trip time ±10%*
	Thermal overload	Calculated trip time ±10%*
Repeatability		<5%
* Operating time measured with applied current of 20% above thermal setting.		

2.8 Direct Transfer Trip and Inter-Relay Command Transfer

Method	Time (plus protection signalling time)
Time for intertrip opto-input relay end A - output contact end B (opto with filter)	40ms
Time for intertrip opto-input relay end A - output contact end B (opto without filter)	30ms
Time for command transfer end A - PSL end B	15ms

2.9 Permissive Intertrip

2.9.1 Setting Ranges

Name	Setting Range	Step Size
Permissive intertrip timer	0 - 200 ms	5 ms

2.9.2 Accuracy

Operating level	Is1 ±5%
Drop off level	0.75 * Is1 ±10%
Instantaneous operating time	40ms + protection signalling channel time + permissive intertrip timer
Reset time	<40ms
Timer accuracy	Setting ±2% or 5ms whichever is greater

2.10 Protection Signalling Channel, Dual Redundancy, Channel Failure, Propagation Time Check and Error Statistics

2.10.1 Setting Ranges

Name	Setting Range	Step Size
Data rate	56 or 64kb/s	-
Scheme setting	2 terminal, 3 terminal or dual redundant	-
Clock setting	Internal or external	-
Address	0, 1A, 1B, 1C to 20A, 20B, 20C	1
Communications failure mode (dual redundant)	Channel 1, channel 2 and channel 1 & 2	-
Comm. fail timer	0.1 - 10s	0.1s
Comms Mode (Software 30 or later)	Standard or IEEE C37.94	

2.10.2 Accuracy

Data rate setting	No affect on protection operation
Operation with internal/external clock	No affect on protection operation
Scheme setting	Relay configurable as either 2 terminal, 3 terminal or dual redundant
Addressing	Allocation of an incorrect address causes the signal channel failure alarm
Channel failure alarm	Alarm raised when appropriate channel fails
Comm. fail timer	Setting ±100ms
Model compatibility	P541 and P542 compatible. P543, P544, P545 & P546 compatible. Note that connection of a relay with a non-compatible model produces an error message.

2.11 Compatibility with External interfaces

2.11.1 P590 Series optical fibre to electrical interface units - Performance

P541 and P542 are compatible with these interfaces	P591, P592, P593

3 SUPERVISORY FUNCTIONS

The following claims for Supervisory Functions are applicable to the P540 range of current differential relays (model specific as detailed).

3.1 Programmable Scheme Logic

3.1.1 Level Settings

Name	Range	Step Size
Time delay t	0-14400000ms	1ms

3.1.2 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

4 CONTROL

The following claims for Control Functions are applicable to the P540 range of current differential relays (model specific as detailed).

4.1 Autoreclose (P542)

4.1.1 Level Settings

Name		Range	Step Size
Number of shots (P542)		1 - 4	1
Dead time 1	(P542)	0.01s - 300s	0.01s
Dead time 2	(P542)	0.01s - 300s	0.01s
Dead time 3	(P542)	0.01s - 9999s	0.01s
Dead time 4	(P542)	0.01s - 9999s	0.01s
CB healthy time		0.01s - 9999s	0.01s
Reclaim time		1s - 600s	0.01s
AR Inhibit wind		0.01s - 600s	0.01s
Check sync time		0.01s - 9999s	0.01s

4.1.2 Accuracy

Timers	Setting ±2% or 20ms whichever is greater

4.2 Display Control and Setting Groups

4.2.1 Level Settings

Settings	Range	Step size
Setting groups	1 - 4	1

4.2.2 Performance

Setting groups	4 independent setting groups including independent programmable scheme logic for each group.

4.3 Differential Protection Re-Configuration/Inhibit Current Differential Protection

4.3.1 Performance

Current differential algorithm blocked by	Status
Energising the opto input assigned to inhibit current differential protection	Compliant
Unhealthy communications link	Compliant
Loss of power supply to any relay	Compliant

5 MEASUREMENTS AND RECORDING FACILITIES

These claims for Measurement & Recording facilities are applicable to the P540 range of current differential relays (model specific as detailed).

5.1 Measurements

Typically ±1%, but ±0.5% between 0.2 - 2 In/Vn.
Accuracy under reference conditions.

Measurand	Range	Accuracy
Phase current	0.05 to 3 In	±1.0% of reading
Phase local current	0.05 to 3 In	±1.0% of reading or ±(f-fn)/fn %
Phase remote current	0.05 to 3 In	±1.0% of reading or ±(f-fn)/fn %
Phase differential current	0.05 to 3 In	±5.0%
Bias current	0.05 to 3 In	±5.0%
Voltage	0.05 to 2 Vn	±1.0% of reading
Power (W)	0.2 to 2 Vn 0.05 to 3 In	±5.0% of reading at unity power factor
Reactive Power (VArs)	0.2 to 2 Vn 0.05 to 3 In	±5.0% of reading at unity power factor
Apparent Power (VA)	0.2 to 2 Vn 0.05 to 3 In	±5.0% of reading at unity power factor
Energy (Wh)	0.2 to 2 Vn 0.2 to 3 In	±5% of reading at unity power factor
Energy (Varh)	0.2 to 2 Vn 0.2 to 3 In	±5% of reading at zero power factor
Phase accuracy	0° to 360°	±2°
Frequency	45 to 65Hz	±1%
Power frequency	0° to 120°	±5%

5.2 IRIG-B and Real Time Clock

5.2.1 Features

Real time 24 hour clock settable in hours, minutes and seconds
Calendar settable from January 1994 to December 2092
Clock and calendar maintained via battery after loss of auxiliary supply
Internal clock synchronisation using IRIG-B
Time synchronisation by energisation of opto input

5.2.2 Performance

Year 2000	Compliant
Real time clock accuracy	< ±2 seconds / day
External clock synchronisation	Conforms to IRIG standard 200-98, format B
Opto input time synchronisation	Energisation of opto causes seconds on relay clock to snap or crawl to 00 seconds (rounding up or down to nearest minute)

6 POST FAULT ANALYSIS

The following claims for Post Fault Analysis Functions are applicable to the P540 range of current differential relays (model specific as detailed).

6.1 Fault Records

6.1.1 Features

Fault record generation on protection operation indicating	Time and date Setting group Start / trip element Faulted current and voltage magnitudes Remote, bias and differential currents Frequency Fault Clearance time CB operating time Protection operating time Fault location Autoreclose shot number
Alarm events generated on the following indications	Protection disabled/test mode VTS CB alarms Autoreclose Frequency out of range Battery status Incompatible relays Differential protection inhibited Configuration / reconfiguration error Field voltage fail Loopback test Signal fail alarm Signal propagation delay alarm Differential fail alarm C Diff Comm Mode (Software 30 or later) IEEE C37.94 (Software 30 or later) Setting groups

6.1.2 Performance

Fault record display indication and information	Correct
Alarm events display indication and information	Correct
Time and date stamping	±10ms of applied fault/event
Fault Clearance time	±2%
CB operating time	±10ms
Protection operating time	±2%

6.2 Disturbance Records

6.2.1 Level Settings

Settings	Range	Step size
Duration	0.1 - 10.5s	10ms
Trigger position	0 - 100%	0.1%
8 analogue channels, 32 digital channels, single or extended trigger modes		

6.2.2 Accuracy

Waveshape	Comparable with applied quantities
Magnitude and relative phases	±5% of applied quantities
Duration	±2%
Trigger position	±2% (minimum trigger 100ms)

7 PLANT SUPERVISION

These claims for Plant Supervision Functions are applicable to the P540 range of current differential relays (model specific as detailed).

7.1 CB State Monitoring Control and Condition Monitoring

7.1.1 Level Settings

Setting	Range	Step
Trip pulse time	0.01 - 5s	0.01s
Close pulse time	0.01 - 10s	0.01s
Broken current exponent	1 - 2	0.1
Excessive fault frequency	0 - 9999	1

7.1.2 Accuracy

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

7.2 CB State Monitoring Control, Breaker Fail and Backtrip, Breaker Fail Timer

7.2.1 Level Settings

Setting	Range	Step
Breaker fail timer 1	0 - 10s	0.01s
Breaker fail timer 2	0 - 10s	0.01s

7.2.2 Accuracy

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

8 LOCAL AND REMOTE COMMUNICATIONS

These claims for Local & Remote Communications are applicable to the P540 range of current differential relays (model specific as detailed).

8.1 Front Port

Front port	Communication Parameters (Fixed)
Protocol	Courier
Address	1
Message format	IEC 60870FT1.2
Baud rate	19200 bits/s

8.2 Rear Port 1

Rear port settings	Setting options	Setting available for
RP1 Address	0 - 254 (step 1) 0 - 255 (step 1) 1 - 247 (step 1) 0 - 65519 (step 1)	IEC* Courier Modbus DNP3.0
RP1 Inactiv Timer	1 - 30 minutes (step 1)	All
RP1 Baud Rate	1200 bits/s 2400 bits/s 4800 bits/s 9600 bits/s 19200 bits/s 38400 bits/s	DNP3.0 DNP3.0 DNP3.0 All (not KBus) All (not KBus) All except IEC* and KBus
RP1 Parity	“Odd”, “Even” or “None”	Modbus/DNP3.0
RP1 Meas Period	1 - 60 minutes (step 1)	IEC* only
RP1 Physical Link (Software 30 or later)	EIA(RS)485	Courier, Modbus, IEC* and DNP3.0
	Fibre optic	Courier (except when K-Bus selected or UCA2 option fitted) Modbus IEC* DNP3.0
RP1 Physical Link	EIA(RS)485 Fibre optic	IEC* IEC*
RP1 Time Sync	Enabled / Disabled	DNP 3.0
RP1 CS103 Blocking	Disabled / Monitor Block / Command Block	IEC* Only
RP1 Port Config	K-Bus / Courier (RS485)	Courier Only
RP1 Comms Mode	IEC 60870 FT1.2 / 10 bit	Courier Only
* IEC = IEC60870-5-103		

8.2.1 Performance

Front and rear ports conforming to Courier communication protocol	Compliant
Rear ports conforming to Modbus communication protocol	Compliant
Rear ports conforming to 870-5 103 communication protocol	Compliant
Rear ports conforming to DNP3.0 communication protocol	Compliant

8.3 Second Rear Communication Port

Setting	Setting Options	Setting available for
RP2 Port Config	EIA232, EIA485 or kbus	
RP2 Comms Mode	IEC60870 FT1.2, 11 bit frame or IEC60870, 10 bit frame	EIA232 and EIA485
RP2 Address	0 - 255 (step 1)	All
Rp2 InactivTimer	1 - 30 minutes (step 1)	All
RP2 Baud Rate	9600/19200/38400 bits/s	EIA232 and EIA485

Note *To avoid exceeding second rear communications port flash clearances the length of the cable, between the port and associated communications equipment should be limited to 300 metres. In situations where 300 metres may be insufficient ensure that the communications cable is not laid in close proximity to high current carrying conductors. The communications cable should be screened with screen earthed at one end only.*

9 DIAGNOSTICS

These claims for Diagnostic Functions are applicable to the P540 range of current differential relays (model specific as detailed).

9.1 Features

Power up self checking with watchdog indication of healthy condition
Watchdog and front display indication of a hardware or software failure occurring during power up or during normal in service operation

9.2 Performance

Power up / continuous self checks	Compliant
Watchdog operation	Compliant
Co-processor failure detection	Compliant
Time to power up	< 11s

10 RATINGS

These claims for Ratings are applicable to the P540 range of current differential relays (model specific as detailed) and P594 GPS Receiver Module.

10.1 Nominal Ratings

10.1.1 Currents (All P540 Range)

In = 1A or 5A ac rms.

Separate terminals are provided for the 1A and 5A windings, with the neutral input of each winding sharing one terminal.

All current inputs will withstand the following, with any current function setting:

Withstand	Duration
4 In	Continuous rating
4.5 In	10 minutes
5 In	5 minutes
6 In	3 minutes
7 In	2 minutes
30 In	10 seconds
50 In	3 seconds
100 In	1 second

Pass Criteria	Winding temperatures <105° C
	Dielectric withstand and insulation resistance unimpaired

10.1.2 Voltage Inputs (All P540 Range)

All voltage inputs will withstand the following, with any voltage function setting.

Nominal Voltage (Vn)	Operating range
100-120V_{ph-ph} rms.	0 to 200V_{ph-ph} rms.

Withstand (Vn = 100/120V)	Duration
240V_{ph-ph} rms.	Continuous rating (2Vn)
312V_{ph-ph} rms.	10 seconds (2.6Vn)

Pass Criteria	Winding temperatures <105° C
	Dielectric withstand and insulation resistance unimpaired

10.1.3 Auxiliary Voltages (All P540 Range + P594 as Indicated)

Three auxiliary power supply versions are available:

Nominal Ranges	Operative dc range	Operative ac range
24-48 V dc	19 - 65 V	Not available
48-110 V dc (30/100 V ac rms.) **	37 - 150 V	24 - 110 V
110-250 V dc (100/240 V ac rms.) **	87 - 300 V	80 - 265 V
** rated for AC or DC operation.		

Pass Criteria	All functions operate as specified within the operative ranges
	All power supplies operate continuously over their operative ranges, and environmental conditions

10.1.4 'Universal' Logic inputs

Nominal Battery Voltage (Vdc)	Standard 60% - 80%		50% - 70% (Software 30 or later)	
	No Operation (logic 0) Vdc	Operation (logic 1) Vdc	No Operation (logic 0) Vdc	Operation (logic 1) Vdc
24 / 27	<16.2	>19.2	<12.0	>16.8
30 / 34	<20.4	>24.0	<15.0	>21.0
48 / 54	<32.4	>38.4	<24.0	>33.6
110 / 125	<75.0	>88.0	<55.0	>77.0
220 / 250	<150.0	>176.0	<110	>154

10.1.5 Output Contacts

Make & Carry	30A for 3s
Carry	250A for 30ms 10A continuous
Break	DC: 50W resistive DC: 62.5W inductive (L/R = 50ms) AC: 2500VA resistive AC: 2500VA inductive (P.F. = 0.7)
Maxima:	10A and 300V
Loaded contact:	10,000 operation minimum
Unloaded contact:	100,000 operations minimum
Watchdog Contact	
Break	DC: 30W resistive DC: 15W inductive (L/R = 40ms) AC: 275VA inductive (P.F. = 0.7)

10.1.6 Field Voltage

Rated field voltage output	48V dc
Rated field voltage current limit	112mA ±20%
Operating range	40V to 60V
Alarm voltage	35 V ±5%

10.2 Burdens

10.2.1 Current

Reference current (In)	
Phase	<0.15VA at rated current

10.2.2 Voltage

Reference voltage (Vn)	
Vn = 100/120V	<0.02VA at 110V

10.2.3 Auxiliary Voltage

Typical Values

Type	Case size	Minimum*
P541	Size 8"/40TE	11W or 24VA
P542	Size 12"/60TE	11W or 24VA
* no output contacts or optos energised		

For each energised Opto powered from the Field Voltage or each energised Output Relay:

Each additional energised opto input	0.09W (24/27, 30/34, 48/54V)
Each additional energised opto input	0.12W (110/125V)
Each additional energised opto input	0.19W (220/250V)
Each additional energised output relay	0.13W

10.2.4 Logic Inputs

Typically 10mVA at 48v (field voltage)

10.2.5 Optically Isolated Inputs

Peak current of opto inputs when energised is 3.5mA (0-300V)

Maximum input voltage 300V dc (any setting).

11 CT REQUIREMENTS

11.1 Current Differential Protection

For accuracy, class X or class 5P Current Transformers (CTs) are strongly recommended. The knee point voltage of the CTs should comply with the minimum requirements of the formula shown below.

Vk ≥ K . In (Rct + 2 RL)

Where:

- Vk = Required IEC knee point voltage
- K = Dimensioning factor
- In = CT nominal secondary current
- Rct = CT resistance
- RL = One-way lead impedance from CT to relay

K is a constant depending on:

- If = Maximum value of through fault current for stability (multiple of In)
- X/R = Primary system X/R ratio

K is determined as follows:

For relays set at Is1 = 20%, Is2 = 2 In, k1 = 30%, k2 = 150%:

K ≥ 40 + (0.07 x (If x X/R))

And:	K	≥	65
This is valid for (If x X/R)	≤	1000	
For higher (If x X/R) up to 1600:	K	=	107

For relays set at Is1 = 20%, Is2 = 2 In, k1 = 30%, k2 = 100%:

K ≥ 40 + (0.35 x (If x X/R))

And:	K	≥	65
This is valid for	(If x X/R)	≤	600
For higher (If x X/R) up to 1600:	K	=	256.

11.2 Earth Fault Protection

Using core balance CT.

$Vk > 6 (N) (In)(R_{CT} + 2R_L)$

Where maximum X/R ratio =5 and the maximum earth fault current =2 x In

Where Vk, Rct, RL = (See above)

N = Max. earth fault current/core balance CT rated primary current

> *Note* *N should not be greater than 2. The core balance CT must be selected accordingly.*

12 HIGH VOLTAGE WITHSTAND

12.1 Dielectric Withstand, Impulse, Insulation Resistance and ANSI Test Requirements Insulation Test Voltage

12.1.1 Impulse

IEC 60255-5:2000

- 5kV 1.2/50μs impulse, common and differential mode - input, power supply, & terminal block communications connections.

12.1.2 Dielectric Withstand

IEC 60255-5:2000

- 2kV rms. for 1 minute between all terminals connected together and case earth.
- 2kV rms. for 1 minute between all terminals of independent circuits with terminals on each independent circuit connected together.
- 1kV rms. for 1 minute across watchdog contacts.

12.1.3 ANSI Dielectric Withstand

ANSI/IEEE C37.90. (1989) (Reaff. 1994)

- 1kV rms. for 1 minute across open contacts of the watchdog contacts.
- 1kV rms. for 1 minute across open contacts of changeover output contacts.
- 1.5kV rms. for 1 minute across normally open output contacts.

12.1.4 Insulation Resistance

IEC 60255-5:2000

- 100 MΩ minimum.

13 ELECTRICAL ENVIRONMENT

13.1 Performance Criteria

The following three classes of performance criteria are used within sections 13.2 to 13.12 (where applicable) to specify the performance of the MiCOM relay when subjected to the electrical interference. The performance criteria are based on the performance criteria specified in EN50263: 2000.

13.1.1 Class A

During the testing the relay shall not maloperate, upon completion of the testing the relay shall function as specified. A maloperation shall include a transient operation of the output contacts, operation of the watchdog contacts, reset of any of the relays microprocessors, an alarm indication, degradation of measurements or human-machine interface.

Communications must continue uncorrupted via the communications ports during the tests, however communications may continue with a higher bit error rate during the tests, provided that it recovers with no external intervention and does not allow data to be lost.

If the above performance criteria are satisfied, MiCOM Px40 Platform has passed the test for this performance criteria level.

13.1.2 Class B

During the testing the relay shall not maloperate, upon completion of the testing the relay shall function as specified. A maloperation shall include a transient operation of the output contacts, operation of the watchdog contacts, reset of any of the relays microprocessors, an alarm indication. Temporary degradation of measurements or human-machine interface is acceptable provided it self recovers and there is no loss of stored data.

Communications must continue uncorrupted via the communications ports during the tests, however communications may continue with a higher bit error rate during the tests, provided that it recovers with no external intervention and does not allow data to be lost.

If the above performance criteria are satisfied, MiCOM Px40 Platform has passed the test for this performance criteria level.

13.1.3 Class C

The MiCOM Px40 Platform relay shall power down and power up again in a controlled manner. The output relays are permitted to change state during the test as long as they reset once the relay powers up.

Communications to MiCOM Px40 Platform may be suspended during the testing as long as communications recovers with no external intervention after testing.

13.2 Auxilary Supply Tests, DC Interruption, etc.

13.2.1 DC Voltage Interruptions

IEC 60255-11:1979.

DC Auxiliary Supply Interruptions 2, 5, 10, 20ms. Performance criteria - Class A.

DC Auxiliary Supply Interruptions 50, 100, 200ms, 40s. Performance criteria - Class C.

13.2.2 DC voltage fluctuations

IEC 60255-11:1979.

AC 100Hz ripple superimposed on DC max. and min. auxiliary supply at 12% of highest rated DC.

Performance criteria - Class A.

13.3 AC Voltage Dips and Short Interruptions

13.3.1 AC Voltage Short Interruptions

IEC 61000-4-11:1994.

AC Auxiliary Supply Interruptions 2, 5, 10, 20ms. Performance criteria - Class A.
AC Auxiliary Supply Interruptions 50, 100, 200ms, 1s, 40s. Performance criteria - Class C.

13.3.2 AC Voltage Dips

IEC 61000-4-11:1994

AC Auxiliary Supply 100% Voltage Dips 2, 5, 10, 20ms. Performance criteria - Class A.
AC Auxiliary Supply 100% Voltage Dips 50, 100, 200ms, 1s, 40s. Performance criteria - Class C.

AC Auxiliary Supply 60% Voltage Dips 2, 5, 10, 20ms. Performance criteria - Class A.
AC Auxiliary Supply 60% Voltage Dips 50, 100, 200ms, 1s, 40s. Performance criteria - Class C.

AC Auxiliary Supply 30% Voltage Dips 2, 5, 10, 20ms. Performance criteria - Class A.
AC Auxiliary Supply 30% Voltage Dips 50, 100, 200ms, 1s, 40s. Performance criteria - Class C.

13.4 High Frequency Disturbance IEC 60255-22-1:1988 Class III.

1MHz burst disturbance test.

- 2.5kV common mode.
    - Power supply, field voltage, CTs, VTs, opto inputs, output contacts, IRIG-B and terminal block communications connections.
- 1kV differential mode.
    - Power supply, field voltage, CTs, VTs, opto inputs and output contacts.
- Performance criteria Class A.
- Fast Transients
- EN 61000-4-4:1995 (IEC 60255-22-4:2002), Level 3 and Level 4.
- 2kV 5kHz (Level 3) and 4kV 2.5kHz (Level 4) direct coupling.
- Power supply, field voltage, opto inputs, output contacts, CTs, VTs.
- 2kV 5kHz (Level 3) and 4kV 2.5kHz (Level 4) capacitive clamp.
- IRIG-B and terminal block communications connections.
- Performance criteria Class A.

13.5 Conducted / Radiated Emissions

13.5.1 Conducted Emissions

EN55022:1998 (EN60255-25:2000).

- 0.15 - 0.5MHz, 79dBμV (quasi peak) 66dBμV (average).
- 0.5 - 30MHz, 73dBμV (quasi peak) 60dBμV (average).

13.5.2 Radiated Emissions

EN55022:1998 (EN60255-25:2000).

- 30 - 230MHz, 40dBμV/m at 10m measurement distance.
- 230 - 1000MHz, 47dBμV/m at 10m measurement distance.

13.6 Conducted / Radiated Immunity

13.6.1 Conducted Immunity

EN 61000-4-6:1996 Level 3 (EN60255-22-6:2001).

- 10V emf @ 1kHz 80% am, 150kHz to 80MHz. Spot tests at 27MHz, 68MHz.
- Performance criteria Class A.

13.6.2 Radiated Immunity

EN 61000-4-3: 2002 Level 3 (IEC 60255-22-3:2000 Class III)

- 10 V/m 80MHz - 1GHz @ 1kHz 80% am.
- Spot tests at 80MHz, 160MHz, 450MHz, 900MHz and 900MHz (200Hz rep. freq., 50% duty cycle pulse modulated).
- Performance criteria Class A.

13.6.3 Radiated Immunity from Digital Radio Telephones

EN 61000-4-3: 2002 Level 4

- 30 V/m 800MHz - 960MHz and 1.4GHz - 2GHz @ 1kHz 80% am.
- Performance criteria Class A.

13.7 ElectroStatic Discharge (ESD)

EN61000-4-2:1995 Level 3 and Level 4 (EN60255-22-2:1996).

Level 4: 15kV air discharge.
Level 4: 8kV contact discharge.
Tests carried out both with and without cover fitted.

Performance criteria Class A.

13.8 Surge Immunity

EN61000-4-5:1995 Level 4 (EN60255-22-5:2002).

4kV common mode 12Ω source impedance, 2kV differential mode 2Ω source impedance, level 4.

Power supply.

4kV common mode 42Ω source impedance, 2kV differential mode 42Ω source impedance, Level 4.

Opto inputs, relays, field voltage, CT, VT.

4kV common mode 2Ω source impedance applied to cable screen.

Terminal block communications connections and IRIG-B.

2kV common mode 42Ω source impedance applied each line to earth.

RJ45 ethernet communications.

Performance criteria Class A.

13.9 Power Frequency Interference

NGTS* 2.13 Issue 3 April 1998, section 5.5.6.9.

500V rms. common mode.
250V rms. differential mode.

Voltage applied to all non-mains frequency inputs. Interference applied to all permanently connected communications circuits via the induced voltage method.

Performance criteria Class A.

* National Grid Technical Specification

13.10 Surge Withstand Capability (SWC)

ANSI/IEEE C37.90.1 2002

Oscillatory SWC Test.	2.5kV, 1MHz - common and differential mode - applied to all circuits except for IRIG-B and terminal block communications, which are tested using a capacitor clamp.
Fast Transient SWC Tests	4kV crest voltage - common and differential mode - applied to all circuits except for IRIG-B and terminal block communications, which are tested using a capacitor clamp.

Performance criteria Class A.

13.11 Radiated Immunity

ANSI/IEEE C37.90.2 1995

35 V/m 25MHz - 1GHz, no modulation applied to all sides.

35 V/m 25MHz - 1GHz, 100% pulse modulated, front only.

Performance criteria Class A.

13.12 Power Frequency Magnetic Field Immunity

EN61000-4-8:1993 Level 5.

100A/m field applied continuously in all planes for the EUT in a quiescent and tripping state

1000A/m field applied for 3s in all planes for the EUT in a quiescent and tripping state

Performance criteria Class A.

13.13 Pulse Magnetic Field Immunity

EN 61000-4-9:1993 Level 5.

1000A/m field applied in all planes for the EUT in a quiescent state

Performance criteria Class A.

13.14 Damped Oscillatory Magnetic Field immunity

EN61000-4-10:1993 Level 5.

100A/m field applied in all planes at 100kHz / 1MHz with a burst duration of 2 seconds

Performance criteria Class A.

13.15 Oscillatory Waves Immunity Test

EN61000-4-12:1995 Level 3.

2.5kV peak between independent circuits and case earth.

1.0kV peak across terminals of the same circuit.

Performance criteria Class A.

14 ATMOSPHERIC ENVIRONMENT

14.1 Temperature

IEC 60068-2-1:1990/A2:1994 - Cold

IEC 60068-2-2:1974/A2:1994 - Dry heat

IEC 60255-6:1988.

Operating Temperature Range		Storage Temperature Range	
Cold	**Dry Heat**	**Cold**	**Dry Heat**
-25 °C	55 °C	-25 °C	70 °C

14.2 Humidity

IEC 60068-2-3:1969

- Damp heat, steady state, 40° C ± 2° C and 93% relative humidity (RH) +2% -3%, duration 56 days.

IEC 60068-2-30:1980.

- Damp heat cyclic, six (12 + 12 hour cycles) of 55°C ±2°C 93% ±3% RH and 25°C ±3°C 93% ±3% RH.

14.3 Enclosure Protection

IEC 60529:1989.

IP52 front face

IP30 sides of case

IP10 rear of case

IP5x - Protected against dust, limited ingress permitted.

IP3x - Protected against solid foreign objects of 25mm diameter and greater.

IP1x - Protected against solid foreign objects of 50mm diameter and greater.

IPx2 - Protected against vertically falling drops of water with the product in 4 fixed positions of 15° tilt with a flow rate of 3mm/minute for 2.5 minutes.

Ipx0 - No protection against water ingress.

15 MECHANICAL ENVIRONMENT

15.1 Performance Criteria

The following severity classes are used, where applicable, to specify the performance to specify the performance of the MiCOM relay, when subjected to mechanical testing.

15.1.1 Severity Classes

The following table details the Class and Typical Applications of the vibration, shock bump and seismic tests detailed previously

Class	Typical Application
1	Measuring relays and protection equipment for normal use in power plants, substations and industrial plants and for normal transportation conditions
2	Measuring relays and protection equipment for which a very high security margin is required or where the vibration (shock and bump) (seismic shock) levels are very high, e.g. shipboard application and for severe transportation conditions.

15.1.2 Vibration (Sinusoidal)

IEC 60255-21-1:1988

Cross over frequency - 58 to 60 Hz

Vibration Response

Severity Class	Peak displacement below cross over frequency (mm)	Peak acceleration above cross over frequency (gn)	Number of sweeps in each axis	Frequency range (Hz)
2	0.075	1	1	10 - 150

Vibration Endurance

Severity Class	Peak acceleration (gn)	Number of sweeps in each axis	Frequency range (Hz)
2	2.0	20	10 - 150

15.1.3 Shock and Bump

IEC 60255-21-2:1988

Type of test	Severity Class	Peak acceleration (gn)	Duration of pulse (ms)	Number of Pulses in each direction
Shock response	2	10	11	3
Shock withstand	1	15	11	3
Bump	1	10	16	1000

15.1.4 Seismic

IEC 60255-21-3:1993

Cross over frequency - 8 to 9Hz
x = horizontal axis, y = vertical axis

Severity Class	Peak displacement below cross over frequency (mm)		Peak acceleration above cross over frequency (gn)		Number of sweep cycles in each axis	Frequency range (Hz)
	x	y	x	y		
2	7.5	3.5	2.0	1.0	1	1- 35

16 INFLUENCING QUANTITIES

16.1 Harmonics

Tolerances quoted are an additional tolerance with respect to measured accuracy without harmonics.

Harmonics applied 2nd - 17th	10% harmonics
Measurements / filtered relay inputs	Unaffected by harmonics
Fault locator	±2% of line length

16.2 Frequency

Operating frequency 45Hz - 65Hz		Affect
Overcurrent protection		Unaffected by frequency
Earth fault protection		Unaffected by frequency
Disturbance recorder		Unaffected by frequency
Check sync slip frequency		Unaffected by frequency
Differential protection	single end fed	± (f-fn)/fn %
	double end fed	± 2*(f-fn)/fn %

17 APPLICATION SPECIFIC

17.1 Magnetising Inrush Current

17.1.1 Level Settings

Setting	Range	Step
Id High set	4 - 32A	0.01A

17.1.2 Accuracy

Minimum Id setting for stability (60MVA)	>40% of max. peak inrush current
Operating times	<40ms

17.2 Stability Tests during Current Reversal Conditions

17.2.1 Features

Relay to remain stable for current reversals within the protected feeder

17.3 Performance

Stability during current reversals	Compliant

17.4 Transient Bias Characteristic for Switched Communication Channel

17.4.1 Level settings

Setting	Range	Step
Comm delay tol.	250 - 1000μs	50μs
Char mod time	0 - 2s	100μs

17.4.2 Performance

Propagation delay exceeding setting	Bias characteristic modified for set time delay
Timers	±2% or 20ms whichever is greater

18 MISCELLANEOUS

18.1 Analogue Inputs, Logic inputs, Outputs Relays

Relay	1A/5A dual rated CTs	100 / 120V VTs	Logic inputs	Output relays	Output LEDs	Test port
P541	4	0	8	7	8	TTL logic output
P542	4	0	16	14	8	TTL logic output
			status displayed on LCD	status displayed on LCD	test pattern available on front user interface	DDB* (*Digital Data Bus) signals mapped to front port for test purposes

18.2 Front User Interface

All relay settings configurable from front user interface with the exception of programmable scheme logic, GOOSE logic and DNP.	Compliant
Back light inactivity timer	15 min. ±1min.
Two levels of password protection. Protection critical cells have high level password protection with other cells requiring a lower or no password	Compliant
Password protection removable	Compliant

18.3 Battery Life

Battery life (assuming relay energised for 90% of time)	> 10 years
1/2 AA size 3.6 V lithium thionyl chloride battery (SAFT advanced battery reference LS14250)	
Low battery voltage, failure or absence of battery will be indicated	Compliant
The relay is protected against incorrect insertion of battery	Compliant
Removal of the battery with the relay energised will no affect records, events or real time clock	Compliant

18.4 Frequency Tracking

Relay will frequency track over its entire operating range		45 - 65Hz
The relay will frequency track off any voltage or current inputs		Compliant
The relay will frequency track down to these Levels:	Voltage	
	Current	
Effect of harmonic		None, relay tracks off fundamental frequency

18.5 K-Bus Compatibility

Relay K-Bus interface compatible with other relays of different product families using K-Bus.	Compliant
Relay K-Bus port operates over 1km range with loading at either end of transmission line.	Compliant

19 EC COMPLIANCE

19.1 EC EMC Compliance

Compliance to the European Community Directive 89/336/EEC amended by 93/68/EEC is claimed via the Technical Construction File route.

The Competent Body has issued a Technical Certificate and a Declaration of Conformity has been completed.

The following standard shall be used for reference and to establish conformity:

EN 50263:2000	ElectroMagnetic Compatibility (EMC) Product Standard for measuring relays and protection equipment.

19.2 EC LVD Compliance

Compliance with European Community Directive on Low Voltage 73/23/EEC is demonstrated by reference to generic safety standards:

- EN 61010-1:2001
- EN 60950-1:2001

GETTING STARTED

CHAPTER 3

Notes:

Note	*In the previous version of the manual, this chapter was called the Menu Content Tables. This new chapter includes some additional explanations of the product which were in chapter 1 of the previous manual.*

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1 INTRODUCTION TO THE RELAY

1.1 Introduction to the Relay

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 get started using the relay.

1.1.1 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.

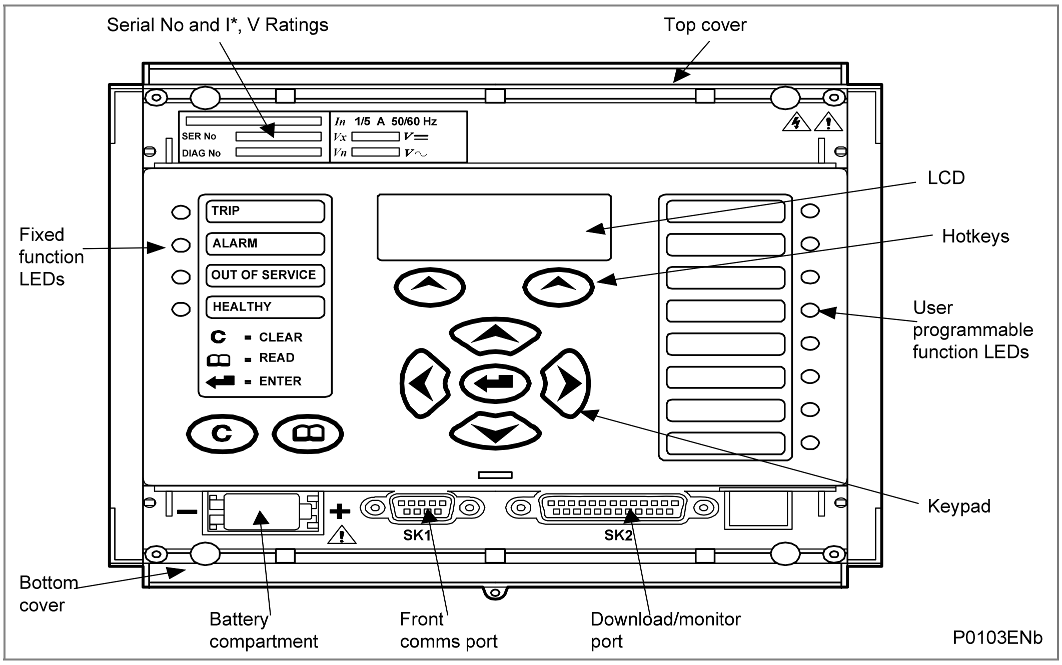

Figure 1 - Relay front view

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 9 key keypad comprising 4 arrow keys (, , and), an enter key ( ), a clear key ( ), a read key ( ) and 2 additional hotkeys ( ).
- 12 LEDs; 4 fixed function LEDs on the left hand side of the front panel and 8 programmable function LEDs on the right hand side.

Hotkey functionality:

- SCROLL
  Starts scrolling through the various default displays
- STOP
  Stops scrolling the default display

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 ½ 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.

The 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.

1.1.2 Relay Rear Panel

The rear panel of the relay is shown in Figure 2. All current and voltage signals*, digital logic input signals and output contacts are connected at the rear of the relay. Also connected at the rear is the twisted pair wiring for the rear EIA(RS)485 communication port, the IRIG-B time synchronising input and the optical fibre rear communication port which are both optional.

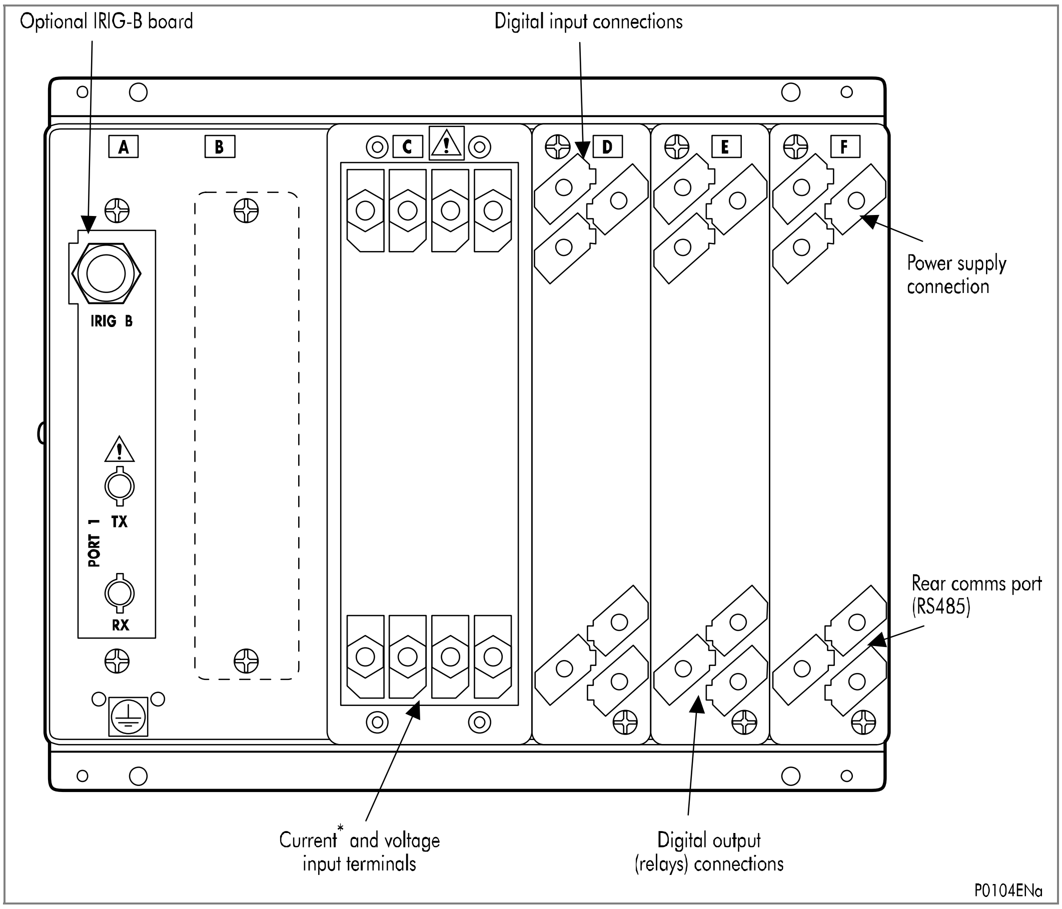

Figure 2 - Relay rear view

Refer to the wiring diagram in the External Connection Diagrams chapter (P54x/EN CO) for complete connection details.

1.2 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, DNP3.0 or UCA2.0. The protocol for the rear port must be specified when the relay is ordered.

The measurement information and relay settings which can be accessed from the five interfaces are summarised 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 synchronisation		•	•	•		•
Control commands	•	•	•	•	•	•

Table 1 - Measurement information, relay settings and interfaces

1.3 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 3, the top row of each column contains the heading which 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 the Relay Menu Database Chapter (P54x/EN GC) of the manual.

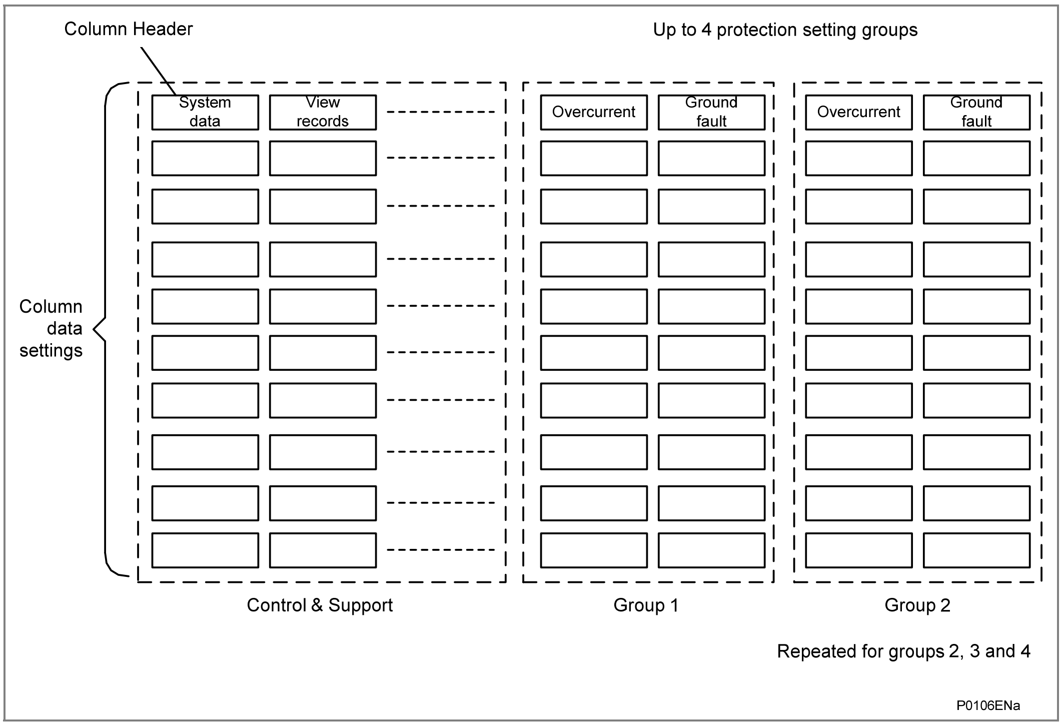

Figure 3 - Menu structure

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.

1.3.1 Protection Settings

The protection settings include the following items:

- protection element settings
- scheme logic settings
- auto-reclose and check synchronisation settings (where appropriate)*
- fault locator settings (where appropriate)*

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.

1.3.2 Disturbance Recorder Settings

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

1.3.3 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

1.4 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 summarised in Table 2.

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

Table 2 - Access levels

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 Schneider Electric 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. Additionally the current level of access for each interface is available for use in the PSL by mapping to the following DDB signals:

- HMI Access Lvl 1 or HMI Access Lvl 2
- FPort AccessLvl1 or FPort AccessLvl2
- RPrt1 AccessLvl1 or RPrt1 AccessLvl2
- RPrt2 AccessLvl1 or RPrt2 AccessLvl2

Each pair of DDB signals indicate the access level as follows:

- Lvl 1 off, Lvl 2 off = 0
- Lvl 1 on, Lvl 2 off = 1
- Lvl 1 off, Lvl 2 on = 2

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 level1, 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).

1.5 Relay Configuration

The relay is a multi-function device which 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.

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.

1.6 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.

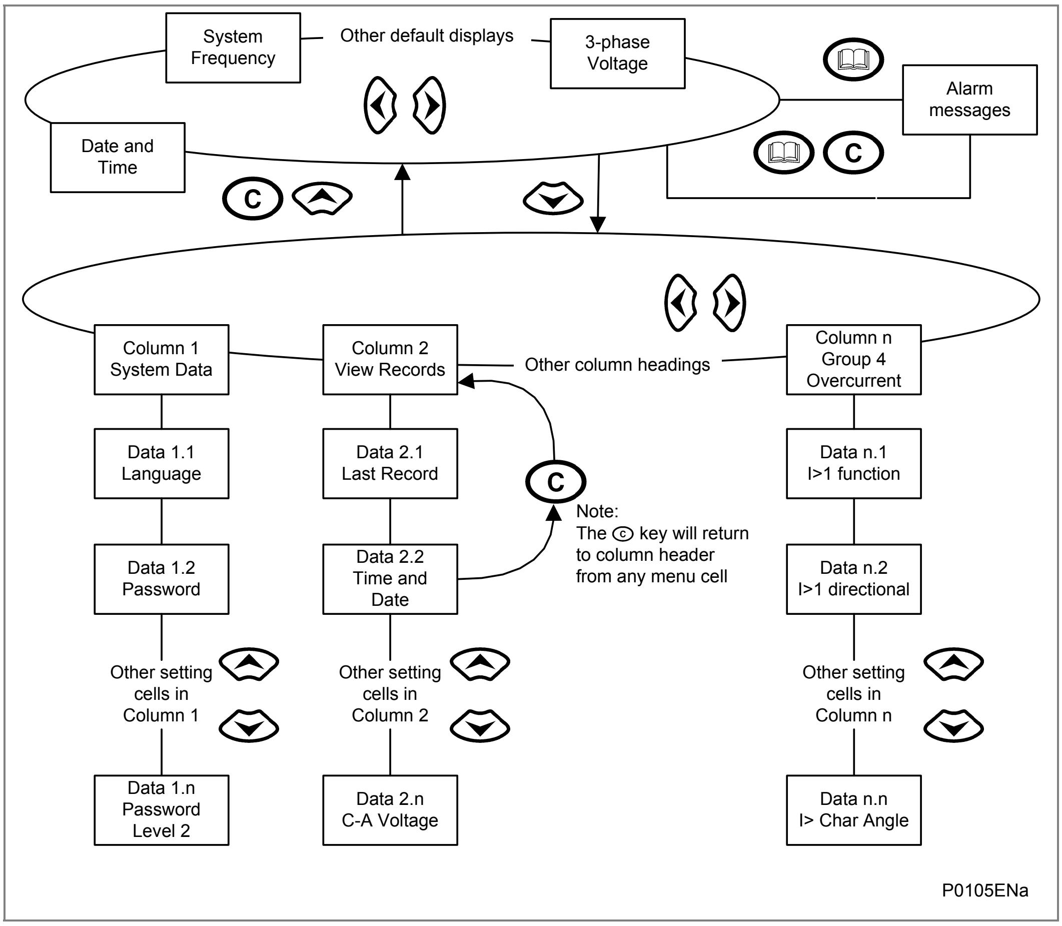

Figure 4 - Front panel user interface

1.6.1 Default Display and Menu Time-Out

The front panel menu has a selectable default display. The relay will time-out and return to the default display and turn the LCD backlight off after 15 minutes of keypad inactivity. If this happens any setting changes which have not been confirmed will be lost and the original setting values maintained.

The contents of the default display can be selected from the following options:
3-phase and neutral current, 3-phase voltage, power, system frequency, date and time, relay description, or a user-defined plant reference*. The default display is selected with the 'Default display' cell of the 'Measure't setup' column. Also, from the default display the different default display options can be scrolled through using the and keys. However the menu selected default display will be restored following the menu time-out elapsing. 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
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.

1.6.2 Menu Navigation and Setting Browsing

The menu can be browsed using the four arrow keys, following the structure shown in Figure 4. 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 C. 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 C 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.

1.6.3 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 C 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 centre 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.

1.6.3.1 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 application guide.

1.6.3.2 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 application guide.

1.6.3.3 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 application guide.

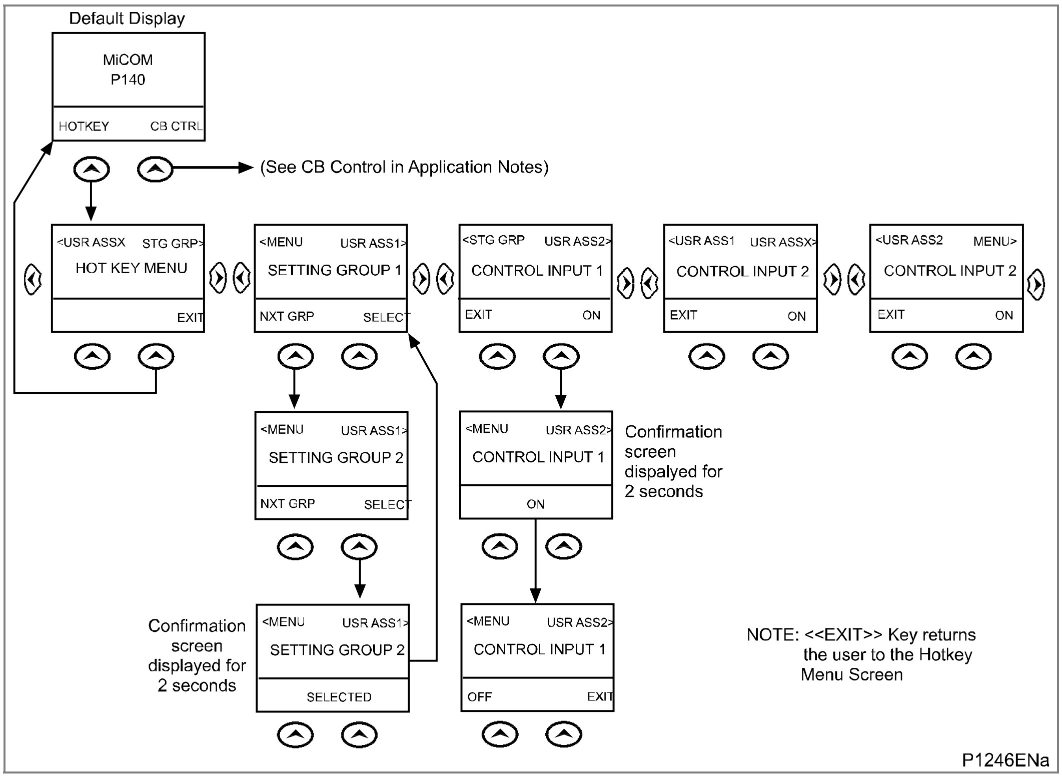

Figure 5 - Hotkey menu navigation

1.6.4 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.

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.

1.6.5 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, 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.

1.6.6 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?
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 'Update settings?' prompt.

1.7 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 6. This port supports the Courier communication protocol only. Courier is the communication language developed by Schneider Electric to allow communication with its range of protection relays. The front port is particularly designed for use with the relay settings program MiCOM S1 which is a Windows 98/NT based software package.

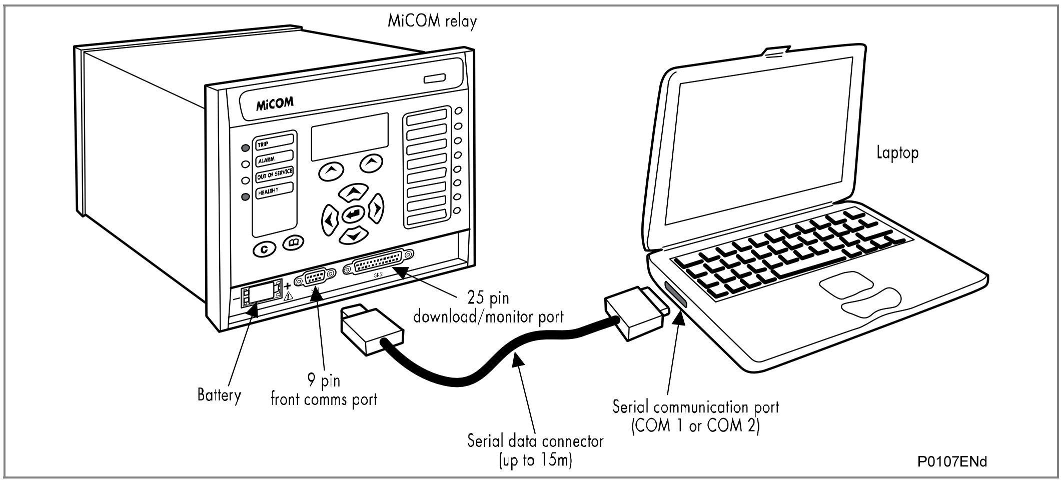

Figure 6 - Front port connection

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

Table 3 - Front port connections (9-pin cable)

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.	3	2	Rx Receive data
Pin no.	2	3	Tx Transmit data
Pin no.	7	5	0V Zero volts common

Table 4 - PC pin connections for 25-way and 9-way cables

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 6. 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.

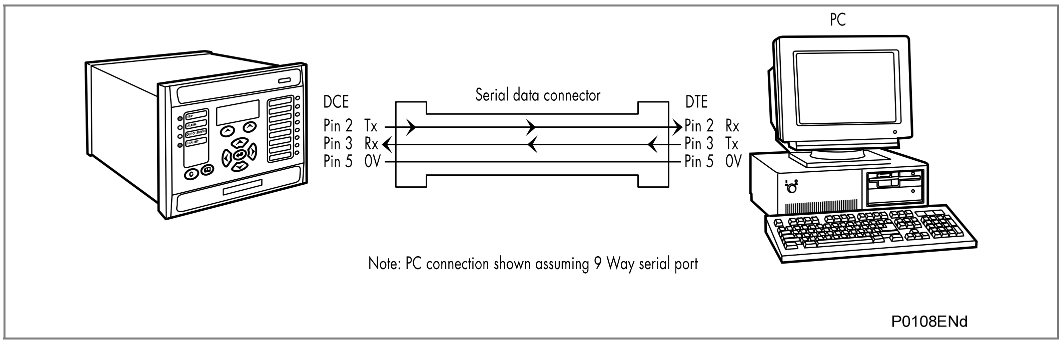

Figure 7 - PC - relay signal connection

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 Table 5:

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

Table 5 - Communication settings for the front port

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.

1.8 First Rear Communication Port

Rear port 1 (RP1) support one of four communication protocols (Courier, Modbus, DNP3.0, IEC 60870-5-103), the choice of which must be made when the relay is ordered. The rear communication port is provided by a 3-terminal screw connector located on the back of the relay. See Appendix B 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 centre. 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, IEC 60870-5-103 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.

1.8.1 Courier Communication

Courier is the communication language developed by Schneider Electric to allow remote interrogation of its range of protection relays. 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 which is designed to be used with a Courier master unit such as MiCOM S1, MiCOM S10, PAS&T or a SCADA system. MiCOM S1 is a Windows NT4.0/98 compatible software package which is specifically designed for setting changes with the relay.

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 Schneider Electric. A typical connection arrangement is shown in Figure 8. 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.

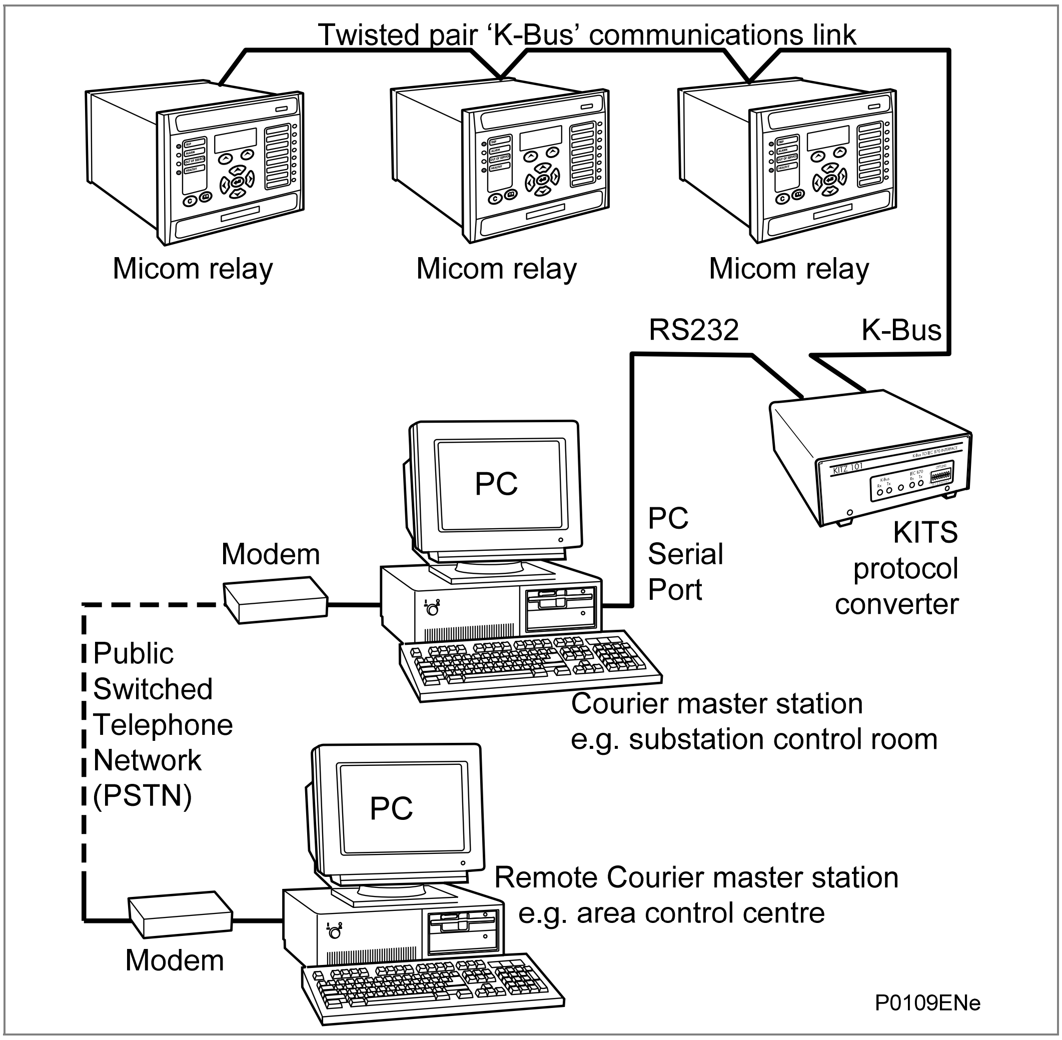

Figure 8 - Remote communication connection arrangements

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:

```
RP1 Protocol
Courier
```

The next cell down the column controls the address of the relay:

```
RP1 Address
                    1
```

Since up to 32 relays can be connected to one K-bus spur, as indicated in Figure 8, 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.

The next cell down controls the inactivity timer:

```
RP1 Inactivity timer
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.

As an alternative to running courier over K-Bus, courier over EIA485 may be selected. The next cell down indicates the status of the hardware, e.g.

```
RP1 Card Status
EIA232 OK
```

The next cell allows for selection of the port configuration

```
RP1 Port Config
EIA232 (EIA(RS)232)
```

The port can be configured for EIA485 or K-Bus.

In the case of EIA485 the next cell selects the communication mode.

```
RP1 Comms Mode
IEC60870 FT1.2
```

The choice is either IEC60870 FT1.2 for normal operation with 11-bit modems, or 10-bit no parity.

In the case of EIA485 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
19200
```

Courier communications is asynchronous. Three baud rates are supported by the relay, ‘9600 bits/s’, ‘19200 bits/s’ and ‘38400 bits/s’,

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.

1.8.2 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 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:

```
RP1 Protocol
Modbus
```

The next cell down controls the Modbus address of the relay:

```
RP1 Address
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:

```
RP1 InactivTimer
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:

```
RP1 Baud rate
9600 its/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:

```
RP1 Parity
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 format of the Date/Time (software 30 or later)

```
Modbus IEC Time
Standard
```

The format can be selected to either 'Standard' (as per IEC60870-5-4 'Binary Time 2a'), the default, or to 'Reverse' for compatibility with MICOM Px20 and Px30 product ranges.

For further information see the SCADA Communications chapter.

1.8.3 IEC 60870-5 CS 103 Communication

The IEC specification IEC 60870-5-103: Telecontrol Equipment and Systems, Part 5: Transmission Protocols Section 103 defines the use of standards IEC 60870-5-1 to IEC 60870-5-5 to perform communication with protection equipment. The standard configuration for the IEC 60870-5-103 protocol is to use a twisted pair connection over distances up to 1000m. As an option for IEC 60870-5-103, the rear port can be specified to use a fibre optic connection for direct connection to a master station. The relay operates as a slave in the system, responding to commands from a master station. The method of communication uses standardised messages which are based on the VDEW communication protocol.

To use the rear port with IEC 60870-5-103 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 IEC 60870-5-103 which are described below. Move down the 'Communications' column from the column heading to the first cell which indicates the communication protocol:

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

The next cell down controls the IEC 60870-5-103 address of the relay:

```
RP1 Address
162
```

Up to 32 relays can be connected to one IEC 60870-5-103 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. IEC 60870-5-103 uses an integer number between 0 and 254 for the relay address. It is important that no two relays have the same IEC 60870-5-103 address. The IEC 60870-5-103 address is then used by the master station to communicate with the relay.

The next cell down the column controls the baud rate to be used:

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

IEC 60870-5-103 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 IEC 60870-5-103 master station.

The next cell down controls the period between IEC 60870-5-103 measurements:

```
RP1 Meas period
30.00 s
```

The IEC 60870-5-103 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 next cell down the column controls the physical media used for the communication:

```
RP1 Physical link
EIA(RS)485
```

The default setting is to select the electrical EIA(RS)485 connection. If the optional fibre optic connectors are fitted to the relay, then this setting can be changed to 'Fibre optic'.

1.8.4 DNP 3.0 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 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 which indicates the communications protocol:

```
RP1 Protocol
DNP 3.0
```

The next cell controls the DNP 3.0 address of the relay:

```
RP1 Address
    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:

```
RP1 Baud rate
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:

```
RP1 Parity
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 DNP 3.0 master station.

The next cell down the column sets the time synchronisation request from the master by the relay:

```
RP1 Time Sync
Enabled
```

The time synch can be set to either enabled or disabled. If enabled it allows the DNP 3.0 master to synchronise the time.

1.9 Second Rear Communication Port (option)

For relays with Courier, Modbus, IEC60870-5-103 or DNP3 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 EIA485 (connection polarity sensitive) or EIA232.

The settings for this port are located immediately below the ones for the first port as described in previous sections of this chapter. 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
Courier
```

The next cell down indicates the status of the hardware, e.g.

```
RP2 Card Status
EIA232 OK
```

The next cell allows for selection of the port configuration

```
RP2 Port Config
EIA232 (EIA(RS)232)
```

The port can be configured for EIA232, EIA485 or K-Bus.

In the case of EIA232 and EIA485 the next cell selects the communication mode.

```
RP2 Comms Mode
IEC60870 FT1.2
```

The choice is either IEC60870 FT1.2 for normal operation with 11-bit modems, or 10-bit no parity.

1.10 Ethernet Rear Port (option)

If UCA2.0 is chosen when the relay is ordered, the relay is fitted with an Ethernet interface card.

See the UCA2.0 section of the SCADA Communications chapter (P54x/EN CT) for more detail of the Ethernet hardware.

2 MENUS

The following charts show all the menus available for the P54x product range. The charts include these menus:

- System Data
- View Records
- Measurements 1, Measurements 2, Measurements 3 and Measurements 4
- CB Operation
- CB Control
- Date and Time
- Configuration
- CT and VT Ratios
- Communications
- Commission Tests
- CB Monitor Setup
- I Diff Config
- Phase Diff - Group 1
- Distance - Group 1
- Overcurrent - Group 1
- Earth Fault - Group 1
- CB Fail & I< - Group 1
- Supervision - Group 1
- Fault Locator - Group 1"
- Input Labels
- Output Labels

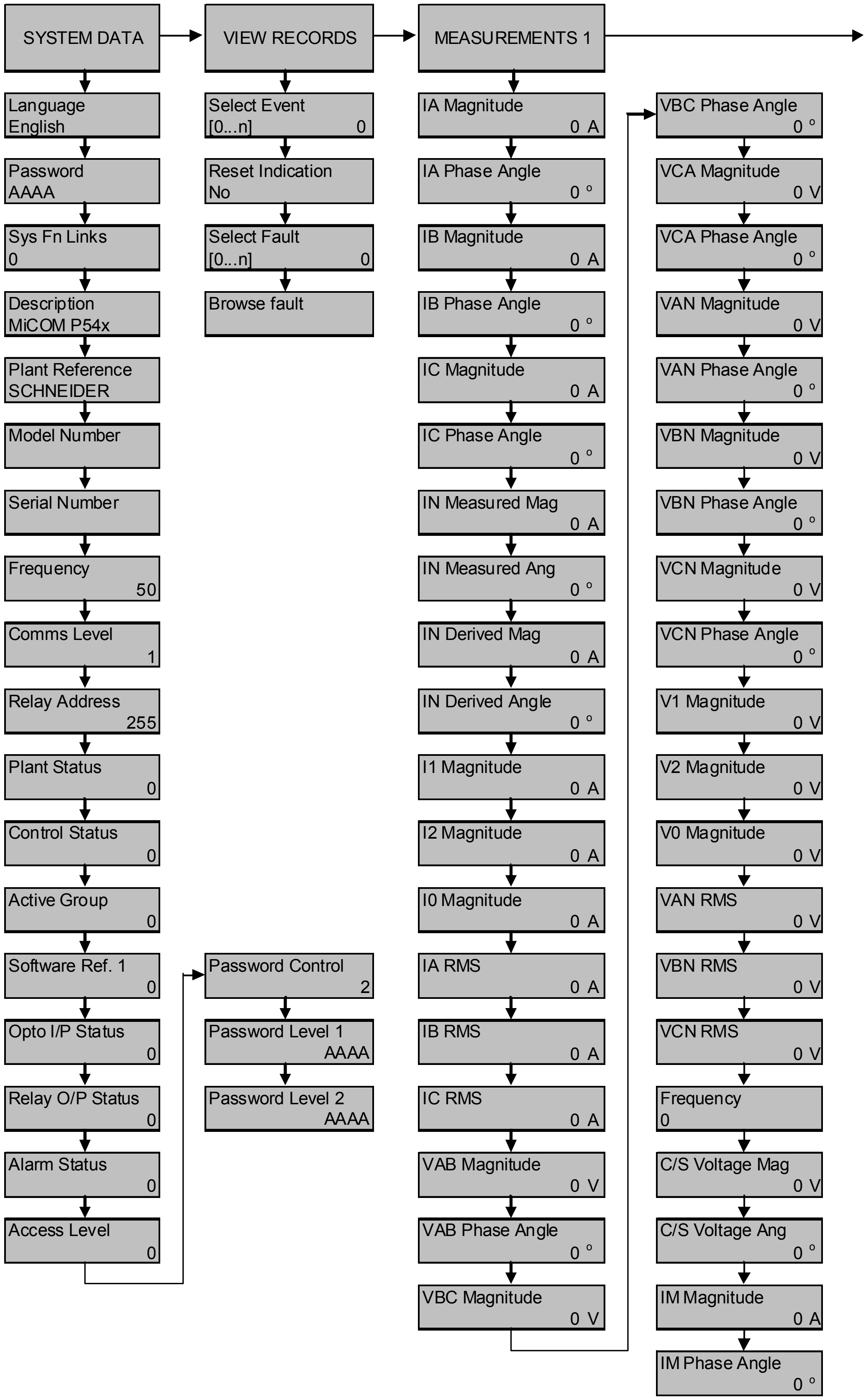

Figure 9 - System Data, View Records and Measurements 1 menus

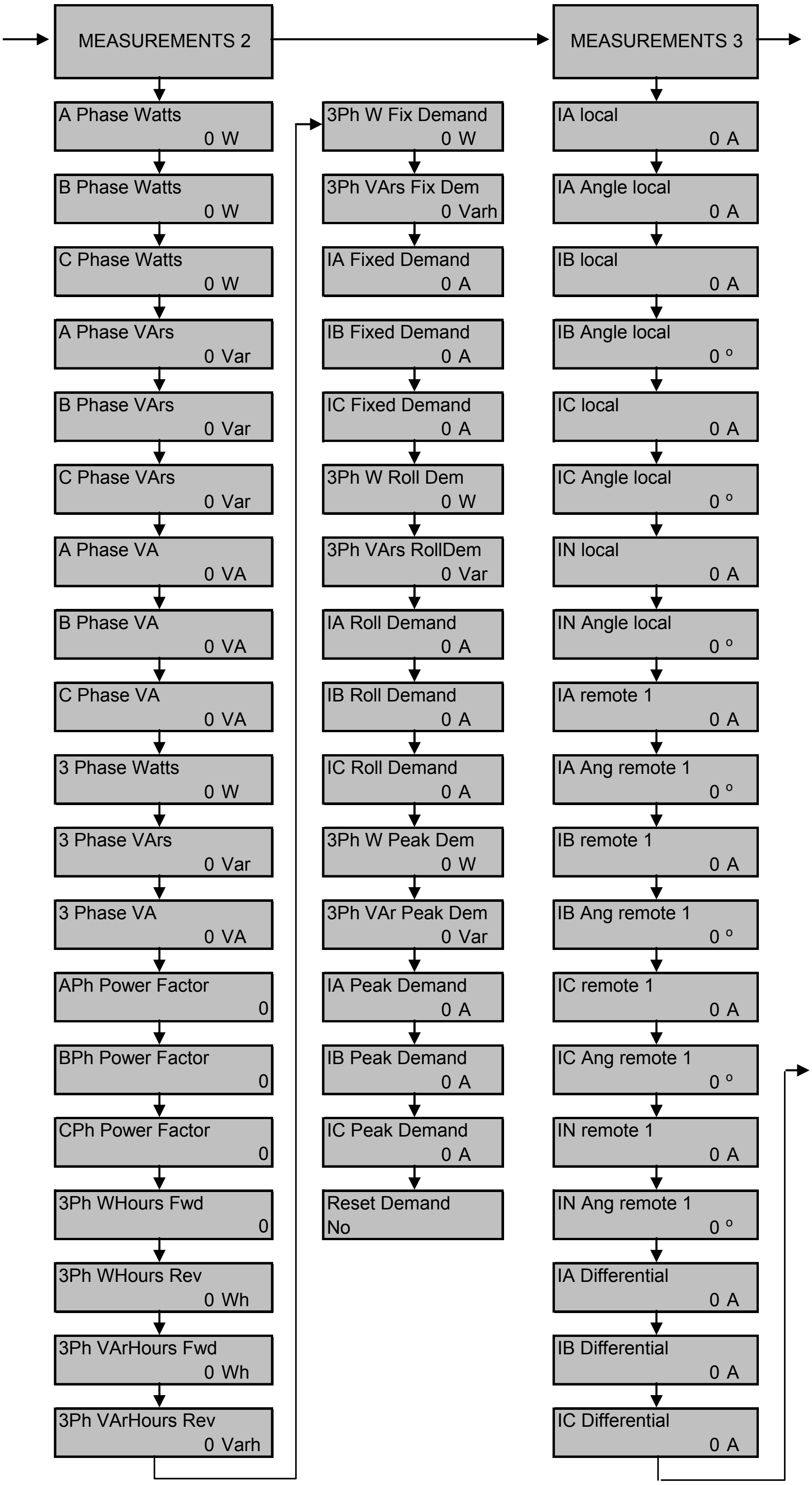

Figure 10 – Measurements 2 and Measurements 3 menus

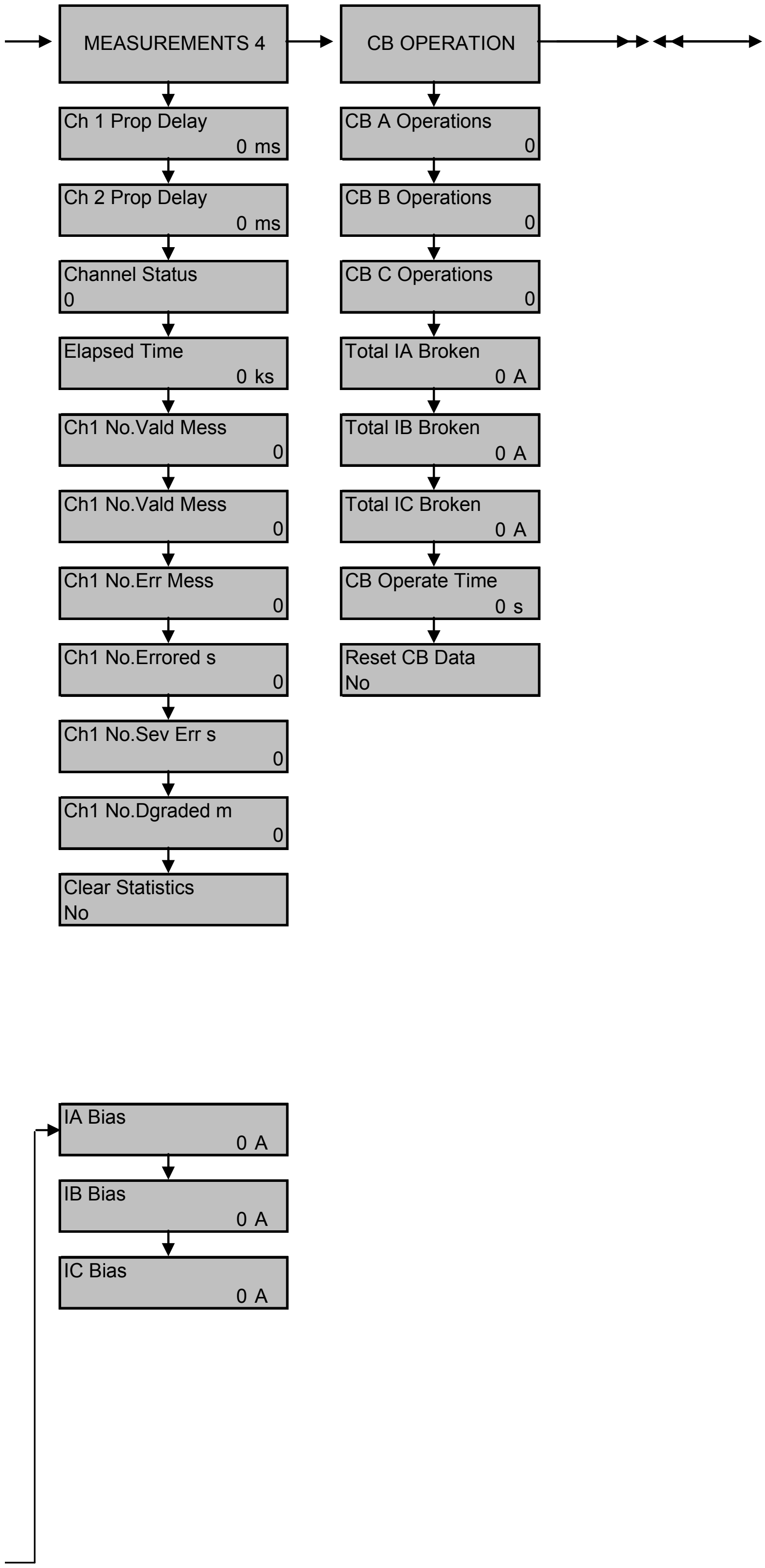

Figure 11 - Measurements 4 and CB Operation menu

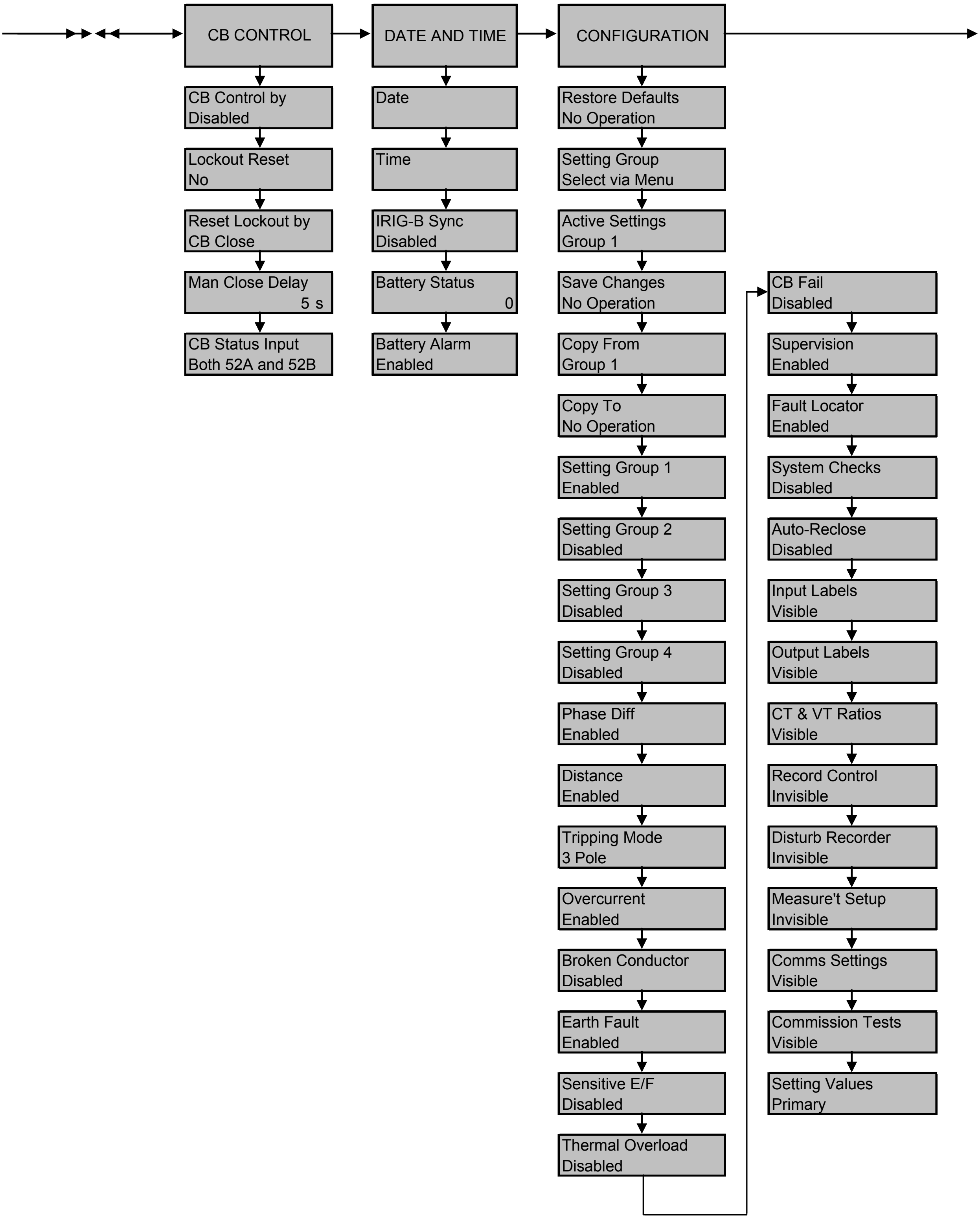

Figure 12 - CB Control, Date and Time and Configuration menus

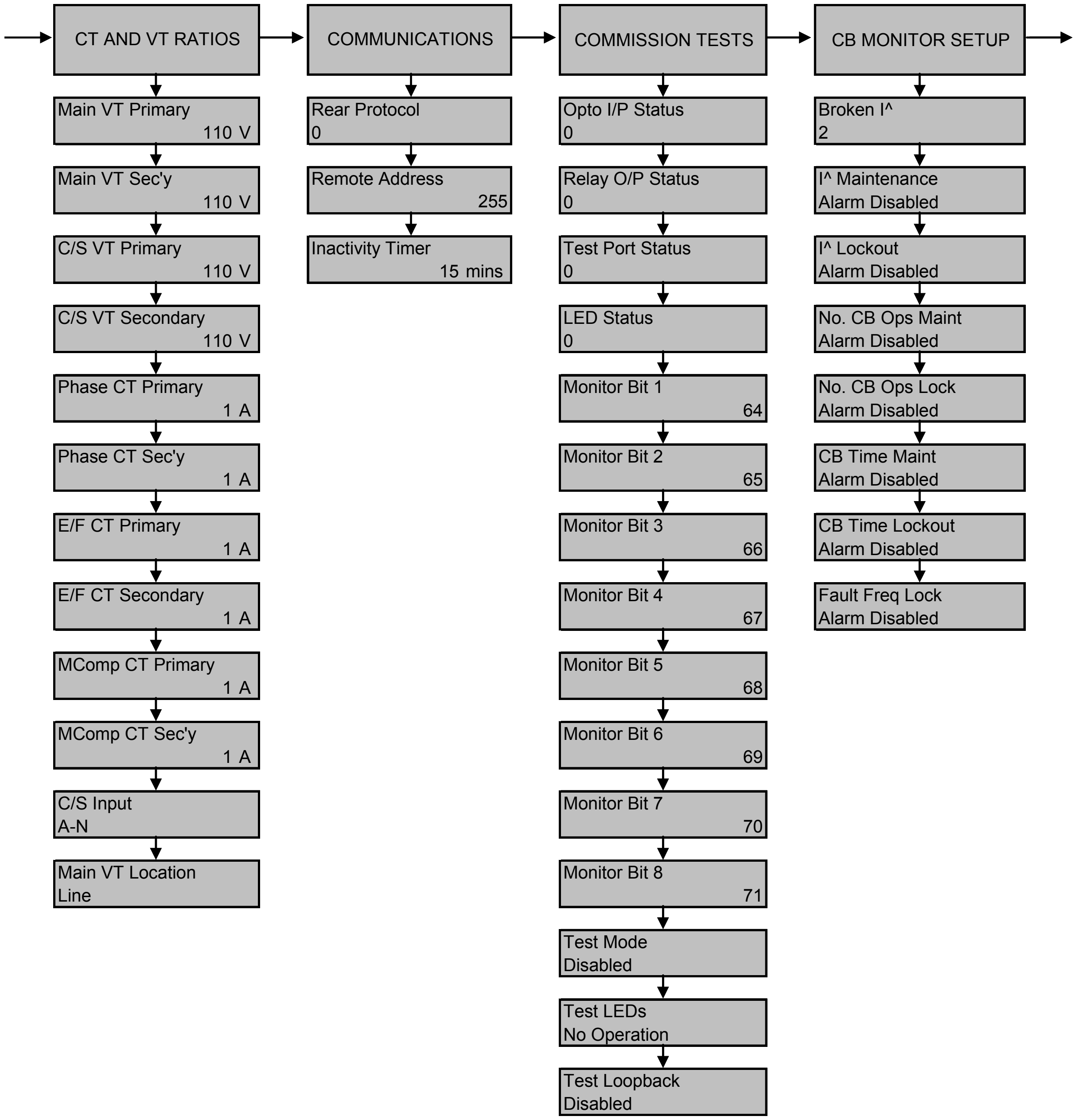

Figure 13 – CT and VT Ratios, Communications, Commission Tests and CB Monitor Setup menus

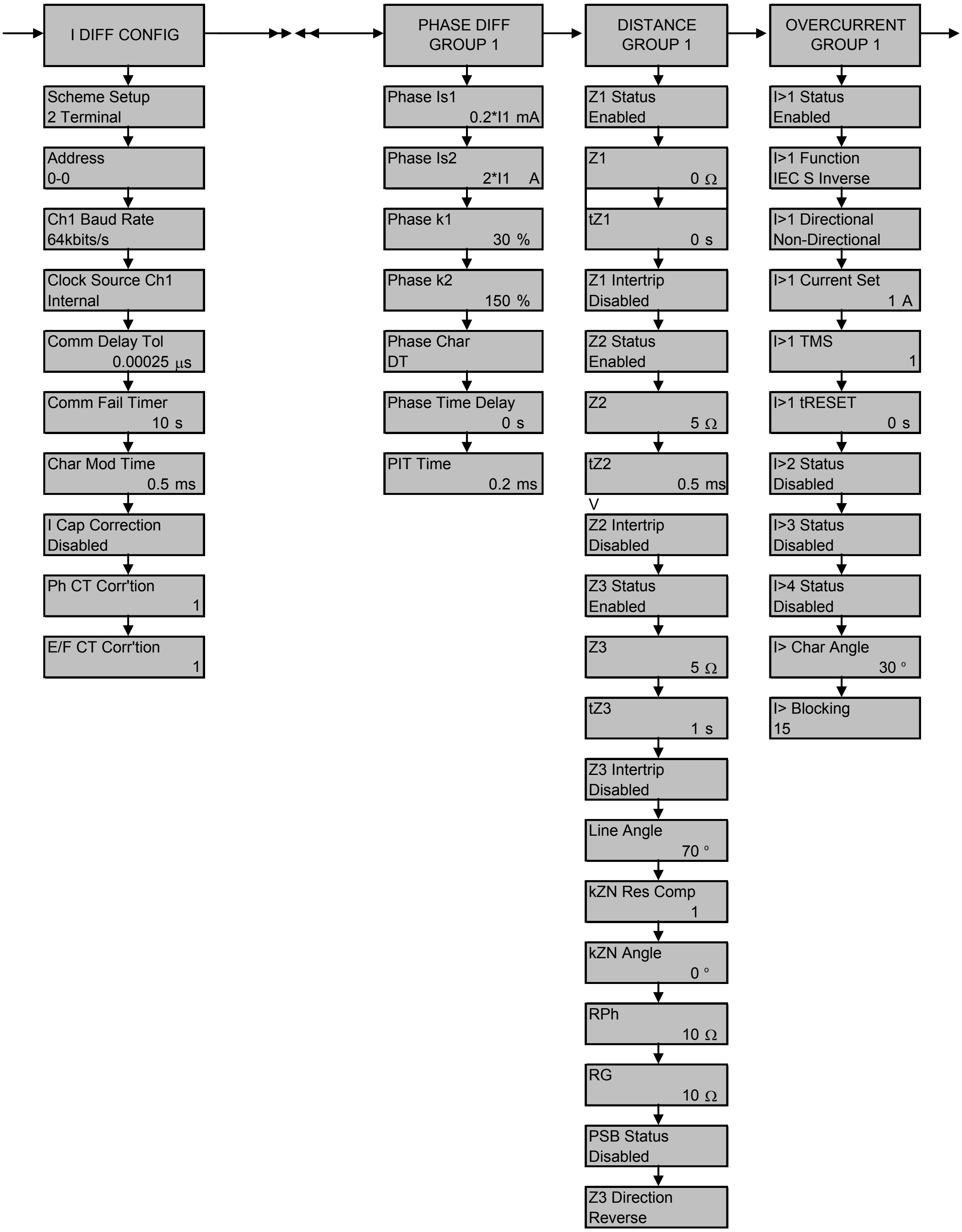

Figure 14 – Idiff Config, Phase Diff, Distance and Overcurrent menus

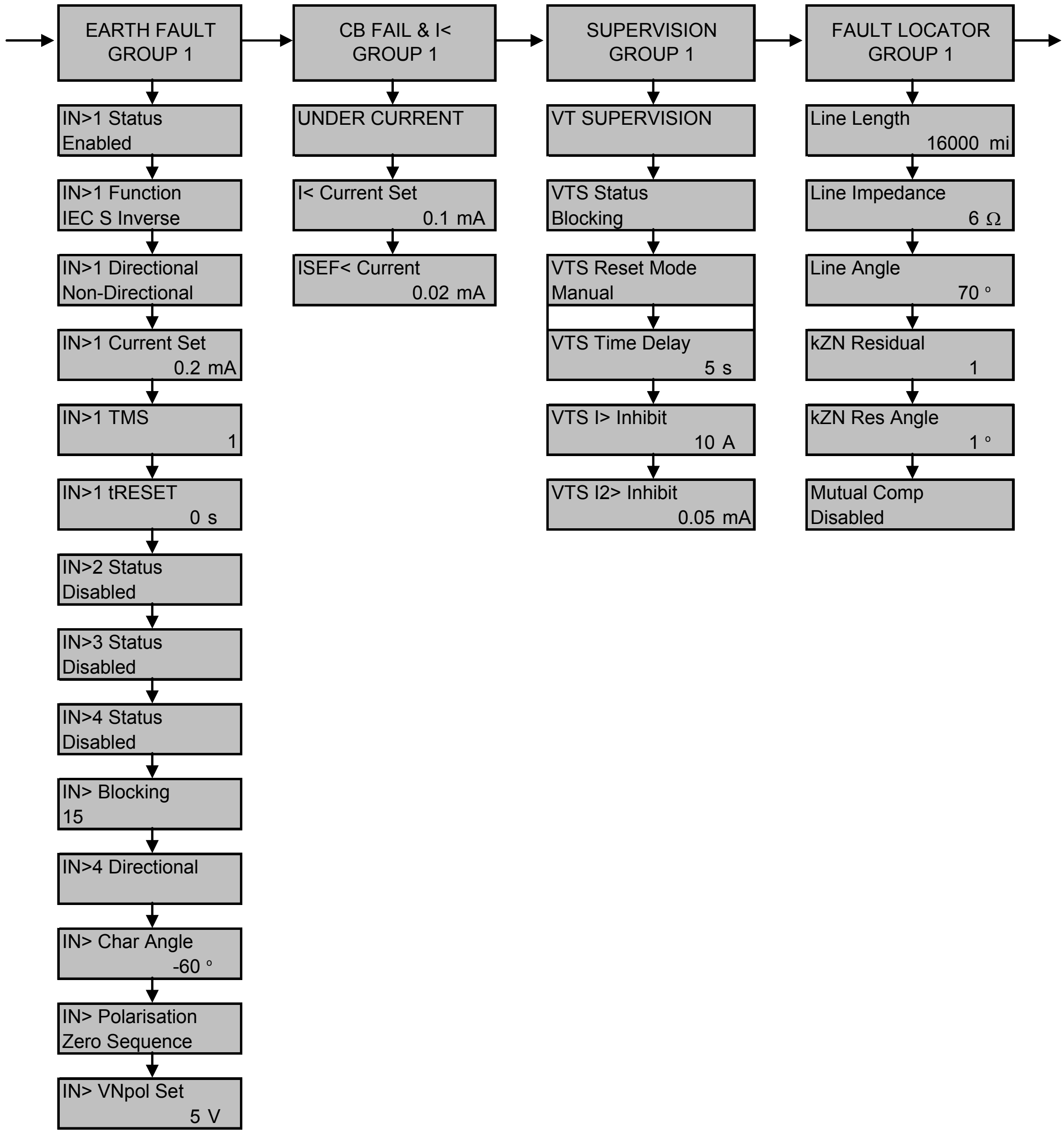

Figure 15 – Earth Fault, CB Fail & I<, Supervision and Fault Locator menus

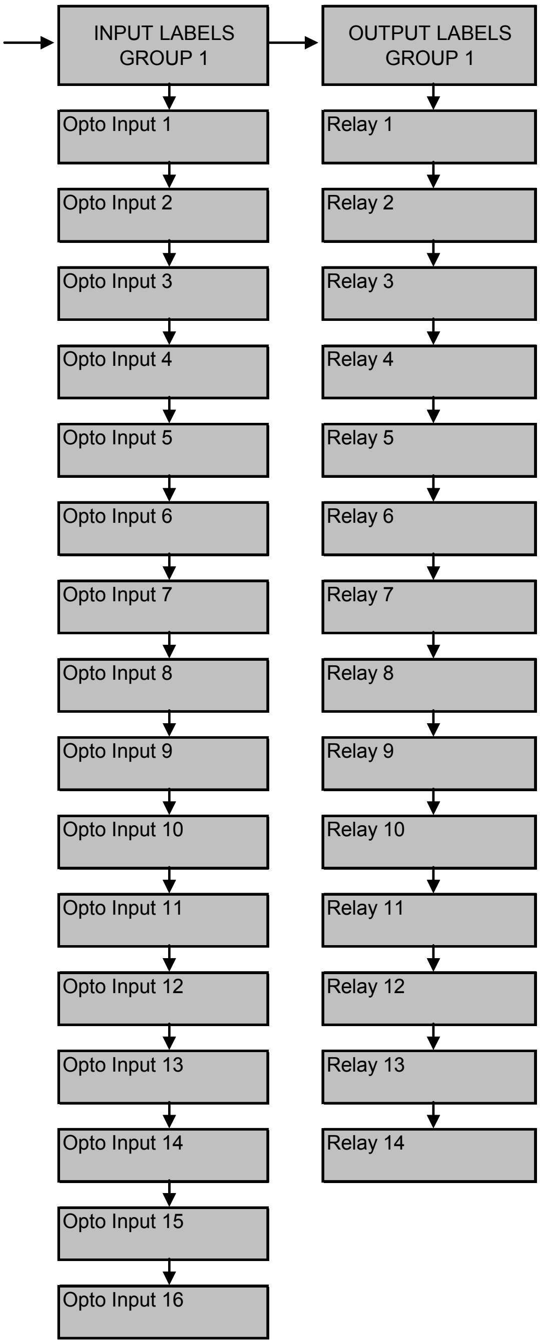

Figure 16 – Input Labels and Output Labels menus

SETTINGS

CHAPTER 4

Notes:

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1 INTRODUCTION

The MiCOM P54x 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 the Getting Started chapter P54x/EN GS for the detailed relay menu map). The relay is supplied with a factory-set configuration of default settings.

2 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, and 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
RELAY SETTINGS CONFIGURATION		
Restore Defaults	No Operation	No Operation All Settings Setting Group 1 Setting Group 2 Setting Group 3 Setting Group 4
Setting to restore a setting group to factory default settings.		
Setting Group	Select via Menu	Select via Menu, Select via Optos
Allows setting group changes to be initiated via Opto 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 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
Setting Group 3 (as above)	Disabled	Enabled or Disabled
Setting Group 4 (as above)	Disabled	Enabled or Disabled
Phase Diff	Enabled	Enabled or Disabled
To enable (activate) or disable (turn off) the Differential Protection. To get the differential protection fully active, it is necessary also to enable the differential protection in the group. Note that Phase Diff setting and InterMiCOM^{64} Fiber setting are mutually exclusive as with Phase Diff enabled, the digital message exchanged has the structure of the differential message (i.e. currents are sent to the remote end, etc) and with InterMiCOM^{64} Fiber the digital message exchanged has the structure and properties of the InterMiCOM^{64} Fiber.		

Menu Text	Default Setting	Available Settings
RELAY SETTINGS CONFIGURATION		
Overcurrent	Enabled	Enabled or Disabled
To enable (activate) or disable (turn off) the Phase Overcurrent Protection function. I> stages: ANSI 50/51/67P.		
Broken Conductor	Disabled	Enabled or Disabled
To enable (activate) or disable (turn off) the Broken Conductor function. I2/I1> stage: ANSI 46BC.		
Earth Fault	Disabled	Enabled or Disabled
To enable (activate) or disable (turn off) the back up Earth Fault Protection function. IN >stages: ANSI 50/51/67N.		
Residual O/V NVD	Disabled	Enabled or Disabled
To enable (activate) or disable (turn off) the Residual Overvoltage Protection function. VN>stages: ANSI 59N.		
Thermal Overload	Disabled	Enabled or Disabled
To enable (activate) or disable (turn off) the Thermal Overload Protection function. ANSI 49.		
CB Fail	Disabled	Enabled or Disabled
To enable (activate) or disable (turn off) the Circuit Breaker Fail Protection function. ANSI 50BF.		
Supervision	Enabled	Enabled or Disabled
To enable (activate) or disable (turn off) the Supervision (VTS & CTS) functions. ANSI VTS/CTS.		
Auto-reclose	Disabled	Enabled or Disabled
To enable (activate) or disable (turn off) the Auto-reclose function. 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 2nd 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 ratios. All subsequent settings input must be based in terms of this reference.		
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

Menu Text	Default Setting	Available Settings
RELAY SETTINGS CONFIGURATION		
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.		
InterMiCOM^{64} Fiber	Disabled	Enabled or Disabled
To enable (activate) or disable (turn off) InterMiCOM64 (integrated 56/64kbit/s teleprotection). Note that Phase Diff setting and InterMiCOM64 Fiber setting are mutually exclusive as with Phase Diff enabled, the digital message exchanged has the structure of the differential message (i.e. currents are sent to the remote end, etc) and with InterMiCOM64 Fiber the digital message exchanged has the structure and properties of the InterMiCOM64 Fiber.		
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.		

Table 1 - Relay Settings Configuration

2.1 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.

3 PROTECTION GROUP 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
- Programmable Scheme Logic (PSL) that also includes InterMiCOM^{64} signals mapping
- Protection Schemes
- 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.

3.1 Phase Differential

The column "GROUP x PHASE DIFF" is used to:

- Select the settings of the phase differential characteristic
- Define CT correction factors
- Set the amount of positive sequence current required for Differential current transformer supervision

The column "GROUP x PHASE DIFF" is invisible if disabled in 'CONFIGURATION' column.

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
PHASE DIFFERENTIAL				
Phase Diff	Enabled	Enabled or Disabled		
To enable (activate) or disable (turn off) the Differential protection function in the group.				
Phase Is1	0.2In	0.2In	2In	0.05In
Setting that defines the minimum pick-up level of the relay.				
Phase Is2	2In	1In	30In	0.05In
This setting defines the bias current threshold, above which the higher percentage bias k2 is used.				
Phase k1	30%	30%	150%	5%
The lower percentage bias setting used when the bias current is below Is2. This provides stability for small CT mismatches, whilst ensuring good sensitivity to resistive faults under heavy load conditions.				
Phase k2	150% (2 end or dual redundant) 100% (3 end)	30%	150%	5%
The higher percentage bias setting used to improve relay stability under heavy through fault current conditions.				
Phase Char	DT	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 differential protection element.				
Phase Time Delay	0s	0s	100s	0.01s
Setting for the time-delay for the definite time setting if selected. The setting is visible only when DT function is selected.				
Phase TMS	1	0.025	1.2	0.025

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
PHASE DIFFERENTIAL				
Setting for the time multiplier setting to adjust the operating time of the IEC IDMT characteristic.				
Phase Time Dial	0.01	0.01	100	0.01
Setting for the time multiplier setting to adjust the operating time of the IEEE/US IDMT curves. The Time Dial (TD) is a multiplier on the standard curve equation, in order to achieve the required tripping time. The reference curve is based on TD = 1. *Note: Certain manufacturer's use a mid-range value of TD = 5 or 7, so it may be necessary to divide by 5 or 7 to achieve parity.*				
PIT Time	0.2s	0s	0.2s	0.005s
This timer is initiated upon receipt of PIT flag in the message. Once this timer elapses, and as long as the current is above of Is1 setting, the relay closes its three phase differential trip contacts.				

Table 2 - GROUP x PHASE DIFF

3.2 Phase Overcurrent Protection

The overcurrent protection included in the MiCOM P54x provides four stage non-directional/ directional phase segregated overcurrent protection with independent time delay characteristics. All overcurrent and directional settings apply to each phase but are independent for each of the four stages. To arrange a single pole tripping by overcurrent protection, the default PSL needs to be modified.

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.	
PHASE OVERCURRENT PROTECTION				
I>1 Status	Enabled	Disabled, Enabled, Enabled VTS, Enabled Ch Fail, En VTSorCh Fail, En VTSandCh Fail		
Setting that defines first stage overcurrent operating status. Depending of this setting, I>1 will be enabled permanently or in case of Voltage Transformer Supervision (fuse fail) operation, or in case of communication channel fail, or a combination (and /or) of both.				
I>1 Function	IEC S Inverse	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 overcurrent 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	1s	0s	100s	0.01s
Setting for the time-delay for the definite time setting if selected for first stage element. The setting is visible only when DT function is selected.				
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

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
PHASE OVERCURRENT PROTECTION				
Setting for the time multiplier setting to adjust the operating time of the IEEE/US IDMT curves. The Time Dial (TD) is a multiplier on the standard curve equation, in order to achieve the required tripping time. The reference curve is based on TD = 1. *Note* *Certain manufacturer's use a mid-range value of TD = 5 or 7, so it may be necessary to divide by 5 or 7 to achieve parity.*				
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	0s	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, Enabled, Enabled VTS, Enabled Ch Fail, En VTSorCh Fail, En VTSandCh Fail		
Setting that defines first stage overcurrent operating status. Depending of this setting, I>3 will be enabled permanently or in case of Voltage Transformer Supervision (fuse fail) operation, or in case of communication channel fail, or a combination (and /or) of both.				
I>3 Current Set	10 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	0s	0s	100s	0.01s
Setting for the operating time-delay for third stage overcurrent element.				
I>3 Intertrip	Enabled	Enabled or Disabled		
Setting for the Intertrip				
I>4 Cells as for I>3 Above				
Settings the same as the third stage overcurrent element.				
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, Bits 5 to 7 are not used.		
Logic Settings that determine whether blocking signals from VT supervision affect certain overcurrent stages. 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. If I> Status is set 'Enabled VTS', no blocking should be selected in order to provide fault clearance by overcurrent protection during the VTS condition.				

Table 3 - Phase Overcurrent Protection

3.3 Broken Conductor

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
BROKEN CONDUCTOR				
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

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
BROKEN CONDUCTOR				
Setting for the function operating time delay.				

Table 4 - Broken Conductor

3.4 Earth Fault

The back-up earth fault overcurrent protection included in the MiCOM P54x provides four stage non-directional/directional three-phase overcurrent protection with independent time delay characteristics. All earth fault overcurrent and directional settings apply to all three phases but are independent for each of the four stages.

The first two stages of earth fault 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.	
EARTH FAULT				
IN>1 Status	Enabled	Disabled, Enabled, Enabled VTS, Enabled Ch Fail, En VTSorCh Fail, En VTSandCh Fail		
Setting that defines first stage overcurrent operating status. Depending of this setting, IN>1 will be enabled permanently or in case of Voltage Transformer Supervision (fuse fail) operation, or in case of communication channel fail, or a combination (and /or) of both.				
IN>1 Function	IEC S Inverse	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 earth fault overcurrent element.				
IN>1 Current Set	0.2 x In	0.08 x In	4.0 x In	0.01 x In
Pick-up setting for first stage overcurrent element.				
IN>1 Time Delay	1	0	100	0.01
Setting for the time-delay for the definite time setting if selected for first stage element. The setting is available only when DT function is selected.				
IN>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.				
IN>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. The Time Dial (TD) is a multiplier on the standard curve equation, in order to achieve the required tripping time. The reference curve is based on TD = 1. *Note* *Certain manufacturer's use a mid-range value of TD = 5 or 7, so it may be necessary to divide by 5 or 7 to achieve parity.*				
IN>1 Reset Char.	DT	DT or Inverse		N/A
Setting to determine the type of reset/release characteristic of the IEEE/US curves.				
IN>1 tRESET	0s	0s	100s	0.01s
Setting that determines the reset/release time for definite time reset characteristic.				
IN>2 Cells as for IN>1 above				
Setting the same as for the first stage earth fault overcurrent element.				

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
EARTH FAULT				
IN>3 Status	Enabled	Disabled, Enabled, Enabled VTS, Enabled Ch Fail, En VTSorCh Fail, En VTSandCh Fail		
Setting that defines first stage overcurrent operating status. Depending of this setting, IN>3 will be enabled permanently or in case of Voltage Transformer Supervision (fuse fail) operation, or in case of communication channel fail, or a combination (and /or) of both.				
IN>3 Current Set	10 x In	0.08 x In	32 x In	0.01 x In
Pick-up setting for third stage earth fault overcurrent element.				
IN>3 Time Delay	0s	0s	100s	0.01s
Setting for the operating time-delay for third stage earth fault overcurrent element.				
IN>4 Cells as for IN>3 Above				
Settings the same as the third stage earth fault overcurrent element.				
IN> 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, Bits 5 & 6 are not used.		
Logic Settings that determine whether blocking signals from VT supervision affect certain earth fault overcurrent stages. VTS Block - only affects directional earth fault 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. If IN> Status is set 'Enabled VTS', no blocking should be selected in order to provide earth fault clearance by earth fault overcurrent protection during VTS condition.				

Table 5 - Earth Fault

3.5 Thermal Overload

The thermal overload function within the MiCOM P54x 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				
Characteristic	Single	Disabled, Single or Dual		
Setting for the operating characteristic of the thermal overload element.				
Thermal Trip	1 x In	0.08 x In	4 x In	0.01 x In
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 minutes	1 minute
Setting for the second thermal time constant for the dual time constant characteristic.				

Table 6 - Thermal Overload

3.6 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.	
BREAKER FAIL				
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, during which breaker opening must be detected. There are timers per phase to cope with evolving faults, but the timer setting is common.				
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, during which breaker opening must be detected.				
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				
I< Current Set	0.1x In	0.02 x In	3.2 x In	0.01 x In
Setting that determines the circuit breaker fail timer reset current for overcurrent based protection circuit breaker fail initiation. This setting is also used in the pole dead logic to determine the status of the pole (dead or live).				
ISEF< Current	0.02x In_{SEF}	0.001x In_{SEF}	0.8x In_{SEF}	0.00005 x In
Setting that determines the circuit breaker fail timer reset current for Sensitive Earth Fault (SEF) protection circuit breaker fail initiation.				
Remove I> Start	Disabled	Disabled or Enabled		
Remove I> Start setting				
Remove IN> Start	Disabled	Disabled or Enabled		
Remove IN> Start setting				

Table 7 - Circuit Breaker Fail and Undercurrent Function

3.7 Auto-Reclose Function

The MiCOM P54x will initiate auto-reclose for fault clearances by any instantaneous trip allocated in the PSL to DDB Trip Inputs A,B or C (DDB 530,531 or 532 respectively). The default PSL includes differential trip, Zone 1 trip and aided trips. In addition, other distance zones, Aided DEF, Directional comparison, phase and earth overcurrent protection and Trip On Reclose (TOR) may be set to initiate auto-reclose, when required.

This is done in the settings (shown here after). Protection such as voltage, frequency, thermal etc. will block auto-reclose.

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

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
AUTO-RECLOSE FUNCTION				
Number of Shots	1	1	4	1
Sets the number of auto-reclose shots/cycles applicable for single phase faults. *Note* *<u>This setting also applies when auto-reclose is configured in 3 pole tripping applications</u>. Even though the trip mode may be 3 pole only, the fact that the initiation was a single phase fault type is memorized.* In single pole tripping applications, for a setting of "N" shots, the full cycle will allow one single pole trip and reclosure, plus (N-1) subsequent three phase shots. When the number of recurrent single pole faults exceeds the setting, the AR will lockout.				
1 Pole Dead Time	0.5s	0.05s	5s	0.01s
Sets the dead time (CB open interval) for a single pole auto-reclose cycle, first shot.				
Dead Time 1	0.3s	0.05s	30s	0.01s
Sets the dead time for the first auto-reclose cycle, except where a single pole trip has occurred.				
Dead Time 2	60s	1s	1800s	1s
Sets the dead time for the second auto-reclose cycle.				
Dead Time 3	60s	1s	3600s	1s
Sets the dead time for the third auto-reclose cycle.				
Dead Time 4	60s	1s	3600s	1s
Sets the dead time for the fourth auto-reclose cycle.				
CB Healthy Time	5s	1s	3600s	1s
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.				
tReclaim Extend	No Operation	0	1	1
tReclaim Extend setting				
Reclaim Time	180s	1s	600s	1s
Sets the auto-reclose reclaim timer – the time after which the sequence counter will reset to zero.				
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.				
EFF Main Lock	Allow Tripping	0 or 1		
EFF Main Lock setting. Block Protection Trips when Maint/EFF locked out.				
Trip 1 Main	No Block	0 or 1		
Block Main Prot for 1st Trip				
Trip 2 Main	Block Inst Prot	0 or 1		
Block Main Prot for 2nd Trip				
Trip 3 Main	Block Inst Prot	0 or 1		
Block Main Prot for 3rd Trip				
Trip 4 Main	Block Inst Prot	0 or 1		
Block Main Prot for 4th Trip				
Trip 5 Main	Block Inst Prot	0 or 1		
Block Main Prot for 5th Trip				

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
AUTO-RECLOSE FUNCTION				
Phase Diff AR	Initiate AR	0, 1 or 2		
Phase Diff AR setting				
I>1 AR	No Action	No action, Block AR or Initiate AR		
Setting that determines impact of the first stage overcurrent protection on AR operation.				
I>2 AR	No Action	No action, Block AR or Initiate AR		
Setting that determines impact of the first stage overcurrent protection on AR operation.				
I>3 AR	No Action	No action, Block AR or Initiate AR		
Setting that determines impact of the first stage overcurrent protection on AR operation.				
I>4 AR	No Action	No action, Block AR or Initiate AR		
Setting that determines impact of the first stage overcurrent protection on AR operation.				
IN>1 AR	No Action	No action, Block AR or Initiate AR		
Setting that determines impact of the first stage earth fault overcurrent protection on AR operation.				
IN>2 AR	No Action	No action, Block AR or Initiate AR		
Setting that determines impact of the first stage earth fault overcurrent protection on AR operation.				
IN>3 AR	No Action	No action, Block AR or Initiate AR		
Setting that determines impact of the first stage earth fault overcurrent protection on AR operation.				
IN>4 AR	No Action	No action, Block AR or Initiate AR		
Setting that determines impact of the first stage earth fault overcurrent protection on AR operation.				

Table 8 - Auto-Reclose Function

3.8 Input Labels

The column “GROUP x INPUT LABELS” is used to individually label each opto input that is available in the relay. The text is restricted to 16 characters and is available if ‘Input Labels’ are set visible under CONFIGURATION column.

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
INPUT LABELS				
Opto Input 1	Input L1	16 characters custom name		
Label for Opto Input 1				
Opto Input x	Input Lx	16 characters custom name		
Label for other Opto Inputs. x = up to 24, depending on relay model.				

Table 9 - Input Labels

3.9 Output Labels

The column “GROUP x OUTPUT LABELS” is used to individually label each output relay that is available in the relay. The text is restricted to 16 characters and is available if ‘Output Labels’ are set visible under CONFIGURATION column.

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
OUTPUT LABELS				
Relay 1	Output R1	16 characters custom name		
Label for output relay 1				
Relay x	Output Rx	16 characters custom name		
Label for other output relays. x = up to 32, depending on relay model.				

Table 10 - Output Labels

4 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:

- 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

4.1 System Data

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

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
SYSTEM DATA				
Language	English			
The default language used by the device. Selectable as English, French, German, Spanish.				
Password	****			
Device default password.				
Sys. Fn. Links	0			1
Setting to allow the fixed function trip LED to be self resetting (set to 1 to extinguish the LED after a period of healthy restoration of load current).				
Description	MiCOM P54x			
16 character relay description. Can be edited.				
Plant Reference	MiCOM			
Associated plant description and can be edited.				
Model Number	P54??1???M???0K			
Relay model number. This display cannot be altered.				
Serial Number	123456J			
Relay model number. This display cannot be altered.				
Frequency	50 Hz	50Hz or 60Hz		
Relay set frequency. Settable either 50 or 60Hz				
Comms. Level				
Displays the conformance of the relay to the Courier Level comms.				

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
SYSTEM DATA				
Relay Address 1	255	0	255	1
Sets the first rear port relay address.				
Plant Status	0000000000000010			
Displays the circuit breaker plant status.				
Control Status	0000000000000000			
Not used.				
Active Group	1	1	4	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	P54x____1__051_K			
Displays the relay software version including protocol and relay model. Software Reference is displayed for relay with IEC 61850 protocol only and this will display the software version of the Ethernet card.				
Opto I/P Status	000000000000000000000000			
Display the status of the available opto inputs fitted.				
Relay O/P Status	00000000000000000000000000000000			
Displays the status of all available output relays fitted.				
Alarm Status 1	00000000000000000000000000000000			
32 bit field gives status of first 32 alarms. Includes fixed and user settable alarms.				
Alarm Status 2	00000000000000000000000000000000			
Next 32 alarm status defined.				
Access Level	2			
Displays the current access level.				
Level 0	No password required	Read access to all settings, alarms, event records and fault records		
Level 1	Password 1 or 2 required	As level 0 plus: Control commands, e.g. circuit breaker open/close Reset of fault and alarm conditions, Reset LEDs Clearing of event and fault records		
Level 2	Password 2 required	As level 1 plus: All other settings		
Password Control	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.				

Table 11 - System Data

4.2 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

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
CB CONTROL				
CB control by	Disabled	Disabled, Local, Remote, Local + Remote, Opto, Opto + local, Opto + Remote, Opto + 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.				
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.				
A/R Telecontrol	No Operation	0, 1 or 2		
A/R Telecontrol setting (P542 only)				
A/R Status	Disabled	Auto mode or non auto mode		
A/R Status setting (P542 only)				
Total Re-closures	Data			
Displays the number of successful re-closures.				
Reset Total A/R	No	No, Yes		
Allows user to reset the auto-reclose counters.				
CB Status Input	52B 1 pole	None, 52A 1 pole, 52B 1 pole, 52A & 52B 1 pole, 52A 3 pole, 52B 3 pole, 52A & 52B 3 pole		
Setting to define the type of circuit breaker contacts that will be used for the circuit breaker control logic. Form “A” contacts match the status of the circuit breaker primary contacts, form “B” are opposite to the breaker status. When “1 pole” is selected, individual contacts must be assigned in the Programmable Scheme Logic for phase A, phase B, and phase C. Setting “3 pole” means that only a single contact is used, common to all 3 poles.				

Table 12 - Circuit Breaker Control

4.3 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 AND TIME				
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	Enabled or Disabled		
Setting that determines whether an unhealthy relay battery condition is alarmed or not.				

Table 13 - Date and Time

4.4 CT/VT Ratios

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
CT/VT RATIOS				
Phase CT Primary	1.000A	1A	30kA	1
Sets the phase current transformer input primary current rating.				
Phase CT Sec’y	1A	1A	5A	4
Sets the phase current transformer input secondary current rating.				
E/F CT Primary	1.000A	1A	30kA	1
Sets the sensitive earth fault current transformer input primary current rating.				
E/F CT Secondary	1A	1A	5A	4
Sets the sensitive earth fault current transformer input secondary current rating.				

Table 14 - CT/VT Ratios

4.5 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
RECORD CONTROL		
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		
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	
Chooses whether any individual DDBs should be deselected as a stored event, by setting the relevant bit to “0” (zero). Typically used for repetitive recurrent changes such as an Opto input assigned for Minute Pulse clock synchronizing.		
Up to… DDB 1022 - 992	11111111111111111111111111111111	
As above, for all DDBs through to 1022.		

Table 15 - Record Control

4.6 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. This reference is for Measurements 1. Measurements 3 uses always IA local as a reference		
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.		
Remote2 Values	Primary	Primary or Secondary
The setting defines whether the values measured via the 2nd Rear Communication port are displayed in primary or secondary terms.		

Table 16 - Measurements

4.7 Communications Settings

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 chapter (P54x/EN SC).

4.7.1 Communications Settings for Courier Protocol

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
RP1 OR RP2 Protocol	Courier			
Indicates the communications protocol that will be used on the rear communications port.				
RP1 OR 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.				
RP1 OR RP2 Inactivity Timer	15 mins.	1 min.	30 mins.	1 min.
This cell controls how long the relay will wait without receiving any messages on the rear port before it reverts to its default state, including resetting any password access that was enabled.				
RP1 OR RP2 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 OR RP2 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 OR 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.				
RP1 OR RP2 Baud Rate	19200 bits/s	9600 bits/s, 19200 bits/s or 38400 bits/s		
This cell controls the communication speed between relay and master station. It is important that both relay and master station are set at the same speed setting.				

Table 17 - Communications Settings for Courier Protocol

4.7.2 Communications Settings for IEC60870-5-103 Protocol

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
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 min.	30 mins.	1 min.
This cell controls how long the relay will wait without receiving any messages on the rear port before it reverts to its default state, including resetting any password access that was enabled.				
RP1 Baud Rate	19200 bits/s	9600 bits/s or 19200 bits/s		
This cell controls the communication speed between relay and master station. It is important that both relay and master station are set at the same speed setting.				
RP1 Measure't. Period	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:				
Disabled	No blocking selected.			
Monitor Blocking	When the monitor blocking DDB Signal is active high, either by energizing an opto input or control input, reading of the status information and disturbance records is not permitted. When in this mode the relay returns a "termination of general interrogation" message to the master station.			
Command Blocking	When the command blocking DDB signal is active high, either by energizing an opto input or control input, all remote commands will be ignored (i.e. CB Trip/Close, change setting group etc.). When in this mode the relay returns a "negative acknowledgement of command" message to the master station.			

Table 18 - Communications Settings for IEC60870-5-103 Protocol

4.7.3 Communications Settings for DNP3.0 Protocol

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
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 Meas Period	0	0, 1 or 2		
RP1 Measurement Period 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.				

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
RP1 Protocol	**DNP 3.0**			
RP1 Time Sync.	Disabled	Disabled or Enabled		
If set to 'Enabled' the DNP3.0 master station can be used to synchronize the time on the relay. If set to 'Disabled' either the internal free running clock, or IRIG-B input are used.				

Table 19 - Communications Settings for DNP3.0 Protocol

4.8 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 available 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 available output relays as a binary string, a '1' indicating an operated state and '0' a non-operated state. When the 'Test Mode' cell is set to 'Enabled' the 'Relay O/P Status' cell does not show the current status of the output relays and 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.		
LED Status		
This cell displays the status of the LEDs		
Monitor Bit 1	1060 (LED 1)	0 to 1407 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	1074 (LED 8)	0 to 1407
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 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'.		

Menu Text	Default Setting	Available Settings
COMMISSION TESTS		
Contact Test	No Operation	No Operation, Apply Test, Remove Test
When the ‘Apply Test’ command in this cell is issued the contacts set for operation (set to ‘1’) in the ‘Test Pattern’ cell change state. After the test has been applied the command text on the LCD will change to ‘No Operation’ and the contacts will remain in the Test State until reset issuing the ‘Remove Test’ command. The command text on the LCD will again revert to ‘No Operation’ after the ‘Remove Test’ command has been issued. Note When the ‘Test Mode’ cell is set to ‘Enabled’ the ‘Relay O/P Status’ cell does not show the current status of the output relays and 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 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’.		
Test Auto-reclose	No Operation	No Operation, Trip 3 Pole, Trip Pole A, Trip Pole B, Trip Pole C
This is a command used to simulate a single pole or three phase tripping in order to test Auto-reclose cycle.		
Static Test	Disabled	Disabled or Enabled
When Static test is “Enabled”, delta phase selectors and the delta directional line are bypassed to allow the user to test the relay with older injection test sets that are incapable of simulating real dynamic step changes in current and voltage. Resulting trip times will be slower, as extra filtering of distance comparators is also switched-in.		
Loopback Mode	Disabled	Disabled, Internal, External
Setting that allows communication loopback testing.		
IM64 TestPattern	0000000000000000	
This cell is used to set the DDB signals included in the User Defined Inter-Relay Commands IM64 when the ‘IM64 Test Mode’ cell is set to ‘Enable’.		
IM64 Test Mode	Disabled	Disabled or Enabled
When the ‘Enable” command in this cell is issued the DDB set for operation (set to ‘1’) in the ‘Test Pattern’ cell change state.		
DDB 31 - 0	00000000000000000000001000000000	
Displays the status of DDB signals 0-31.		
DDB 1022 - 992	00000000000000000000000000000000	
For monitoring all DDB signals up to 1022.		

Table 20 - Commissioning Tests

4.9 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 ruptured current facility and those features that can be set to raise an alarm, or lockout the CB.

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
CB CONDITION 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 or 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 or Alarm Enabled		
Setting which determines if an alarm will be raised or not when the cumulative I^lockout counter threshold is exceeded.				
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 or 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 or 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 or 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 or 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 or Alarm Enabled		
Enables the excessive fault frequency 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	0s	9999s	1s

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
CB CONDITION MONITOR SETUP				
Sets the time period over which the circuit breaker operations are to be monitored. Should the set number of trip operations be accumulated within this time period, an alarm can be raised. Excessive fault frequency/trips can be used to indicate that the circuit may need maintenance attention (e.g. Tree-felling or insulator cleaning).				

Table 21 - Circuit Breaker Condition Monitor Setup

4.10 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 - 16	24 - 27	24 - 27, 30 - 34, 48 - 54, 110 - 125, 220 - 250		
Each opto input can individually be set to a nominal voltage value if custom is selected for the global setting. The number of inputs may be up to 16, depending on MiCOM P54x model and I/O configuration.				
Opto Filter Cntl.	111111110111011111111011			
Selects each input with a pre-set filter of ½ cycle that renders the input immune to induced noise on the wiring. The number of available bits may be 16 or 24, depending on the I/O configuration.				
Characteristics	Standard 60% - 80%	Standard 60% - 80%, 50% - 70%		
Selects the pick-up and drop-off characteristics of the optos. Selecting the standard setting means they nominally provide a Logic 1 or On value for Voltages ≥80% of the set lower nominal voltage and a Logic 0 or Off value for the voltages ≤60% of the set higher nominal voltage.				

Table 22 - Opto Configuration

4.11 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. The setting is not visible if ‘Control Inputs’ are set invisible under the CONFIGURATION column.

Menu Text	Default Setting	Setting Range	Step Size
CONTROL INPUTS			
Ctrl I/P Status	00000000000000000000000000000000		
Cell that is used to set (1) and reset (0) the selected Control Input by simply scrolling and changing the status of selected bits. This command will be then recognized and executed in the PSL. Alternatively, each of the 32 Control input can also be set and reset using the individual menu setting cells as follows:			
Control Input 1	No Operation	No Operation or Set or Reset	
Setting to allow Control Inputs 1 set/ reset.			
Control Input 2 to 32	No Operation	No Operation or Set or Reset	

Menu Text	Default Setting	Setting Range	Step Size
CONTROL INPUTS			
Cell as for Control Input 1			

Table 23 - Control Inputs

4.12 Control Input Configuration

Instead of operating the control inputs as described in the above section, they could also be set to perform a pre-defined control function. This is achieved by mapping in the Hotkey menu. The operating mode for each of the 32 Control Inputs can be set individually.

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.			
Control Input 2 to 32	Latched	Latched, Pulsed	
Configures the control inputs as either 'latched' or 'pulsed'.			
Ctrl Command 2 to 32	Set/Reset	Set/Reset, In/Out, Enabled/Disabled, On/Off	
Allows the SET / RESET text, displayed in the hotkey menu, to be changed to something more suitable for the application of an individual control input, such as "ON / OFF", "IN / OUT" etc.			

Table 24 - Control Input Configuration

4.13 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.			

Table 25 - Control Input Labels

4.14 Direct Access Keys

The Direct Access keys are the “0” and “1” keys situated directly below the LCD display. The user may assign the function of these two keys, to signal direct commands into the PSL logic.

Menu Text	Default Setting	Setting Range	Step Size
CONFIGURATION			
Direct Access	Enabled	Disabled or Enabled	
The front direct access keys that are used as a short cut function of the menu may be:			
Disabled	No function visible on the LCD		
Enabled	All control functions mapped to the Hotkeys and Control Trip/Close are available		

Table 26 - Direct Access keys

5 DISTURBANCE RECORDER SETTINGS (OSCILLOGRAPHY)

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 this 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	IA, IB, IC, IN, IN Sensitive, VA, VB, VC		
Selects any available analog input to be assigned to this channel (including derived IN residual current).				
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 O/P Contact, Any Opto Inputs, or Internal Digital Signals		
The digital channels may monitor 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 3 operation 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.				

Table 27 - Disturbance recorder settings (oscillography)

OPERATION

CHAPTER 5

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Notes:

1 KEY TABLE

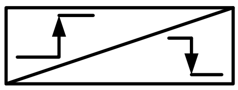
Key	Description
SET	Setting
DDB	Digital Data Bus
INTSIG	Internal Signal
LD	Level Detector
CTRL SET	Control Setting (from front panel display or remote communications)
COMMAND	Command (from front panel display or communications)
RD	Reset Dominant
SD	Set Dominant
	Raising Edge / Falling Edge

Table 1 - Key table

Note 1	*The diagrams in this chapter are fixed, and are an accurate indication of the relay's performance.*
Note 2	*The diagrams in this chapter correspond to the latest version of the relay at time of manual issue.*

2 SCHEME LOGIC DIAGRAMS

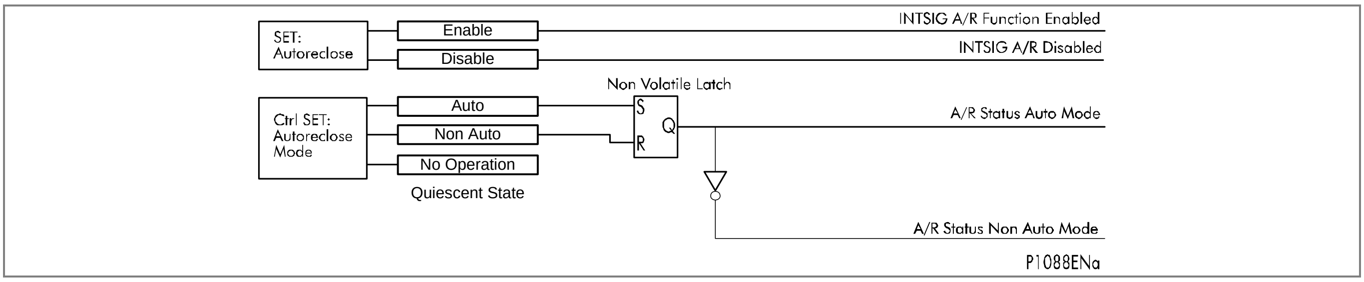


Figure 1 - Autoreclose P542 In/Out of Service Selection

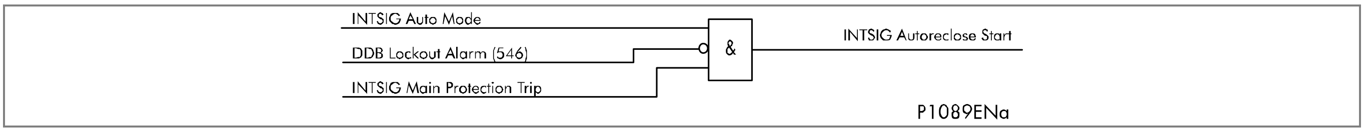


Figure 2 - Autoreclose P542 Protection Monitor

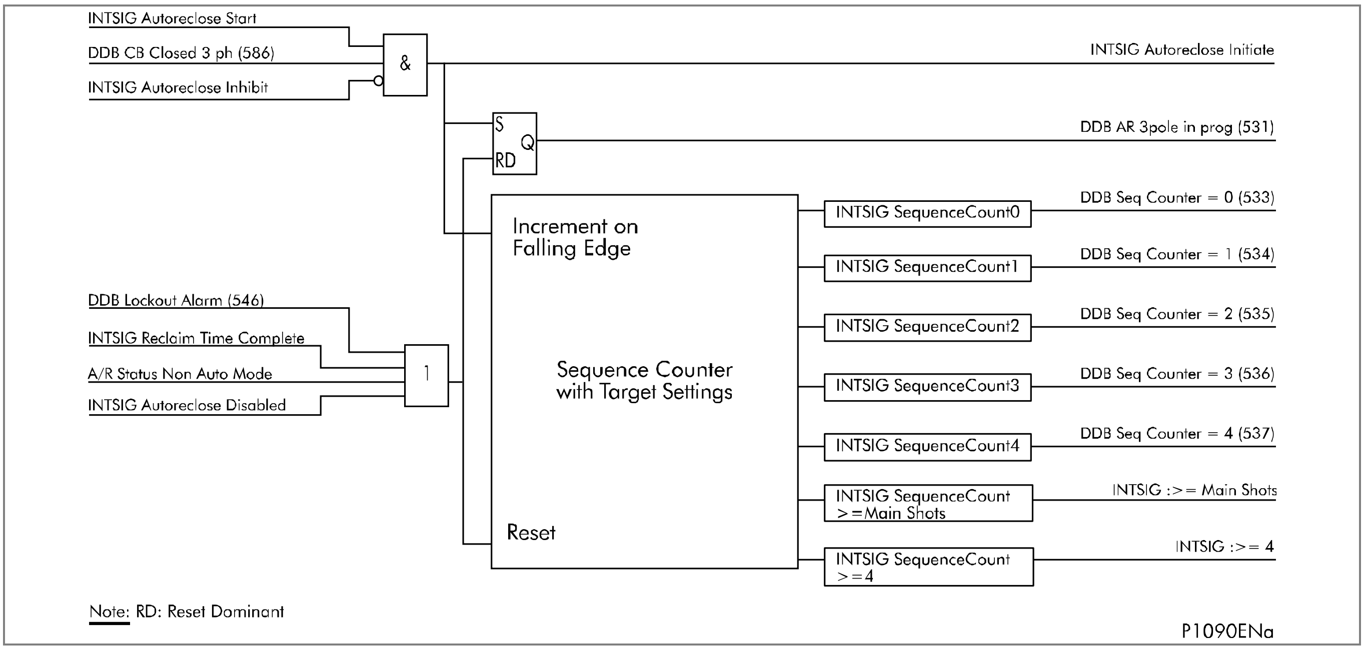


Figure 3 - Autoreclose P542 Initiate Sequence

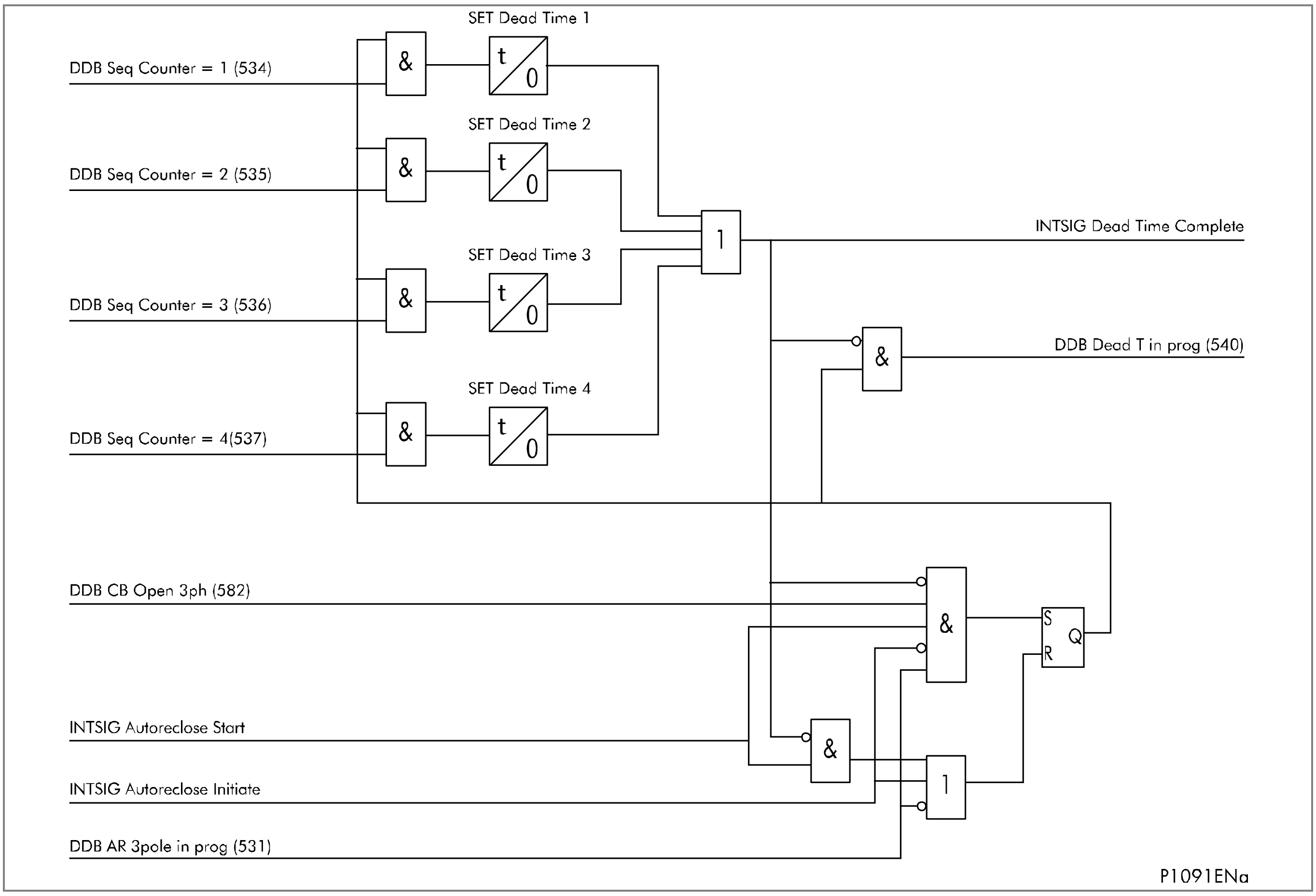


Figure 4 - Autoreclose P542 Dead Times

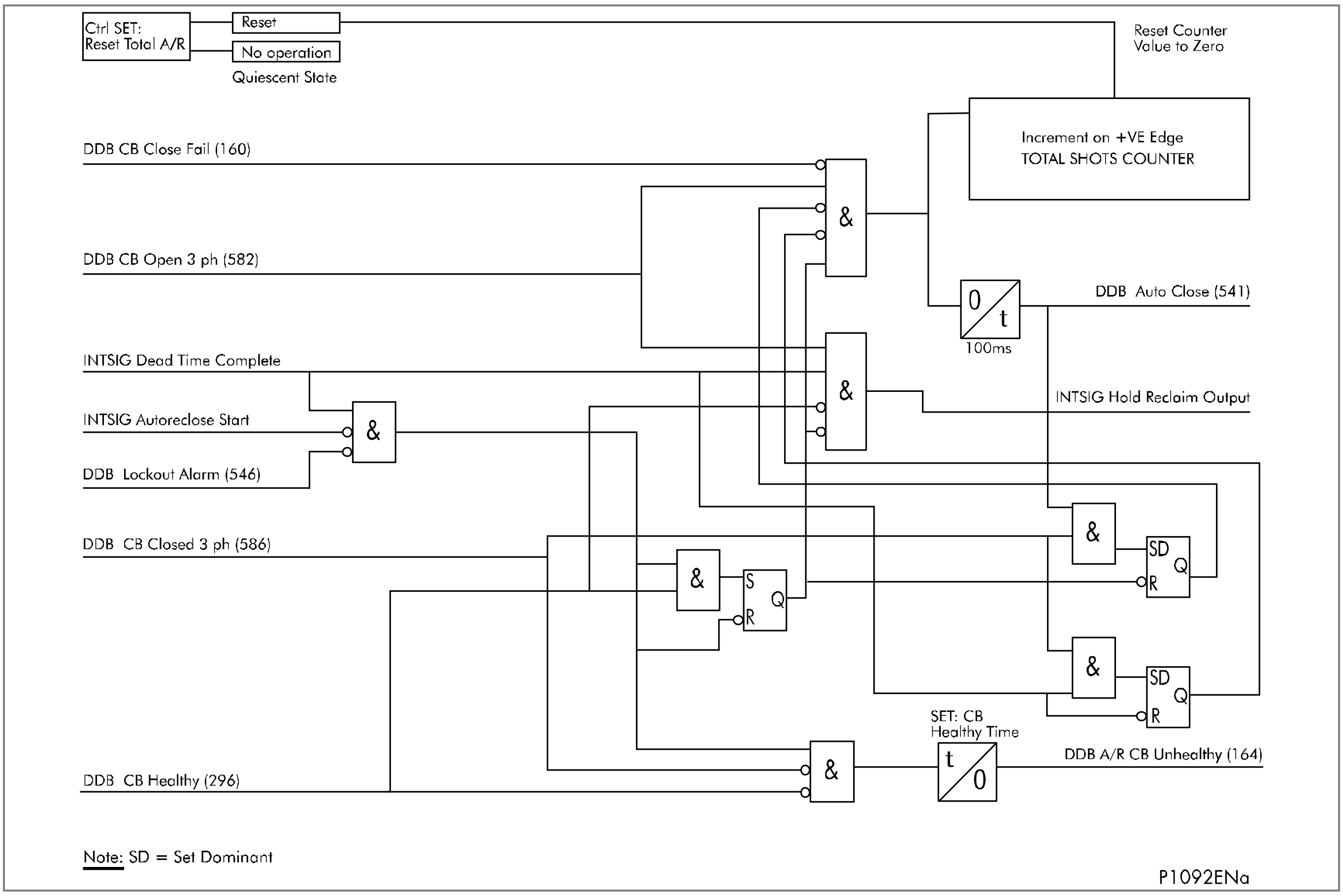


Figure 5 - Autoreclose P542 Close Circuit Breaker

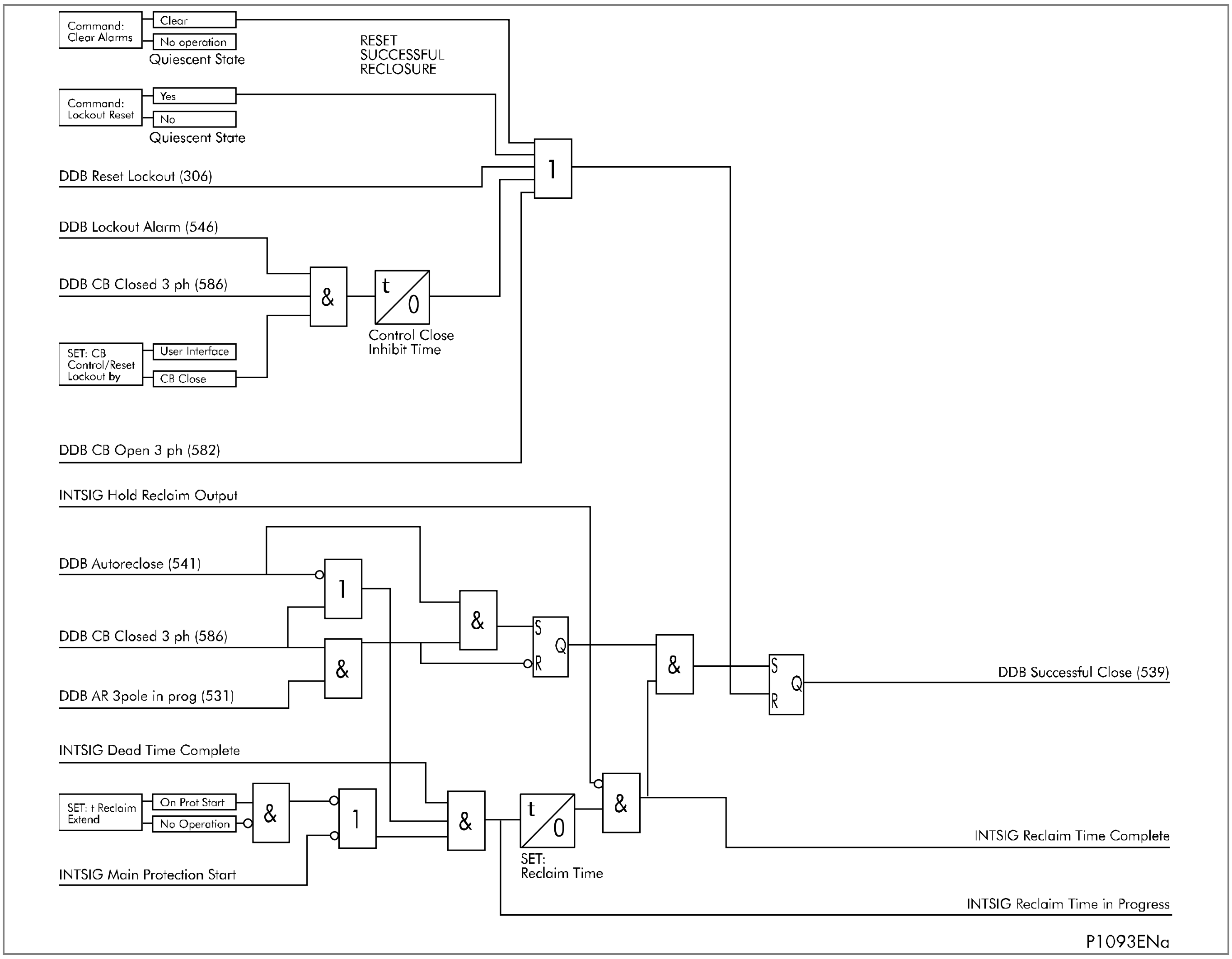


Figure 6 - Autoreclose P542 Reclaim Time

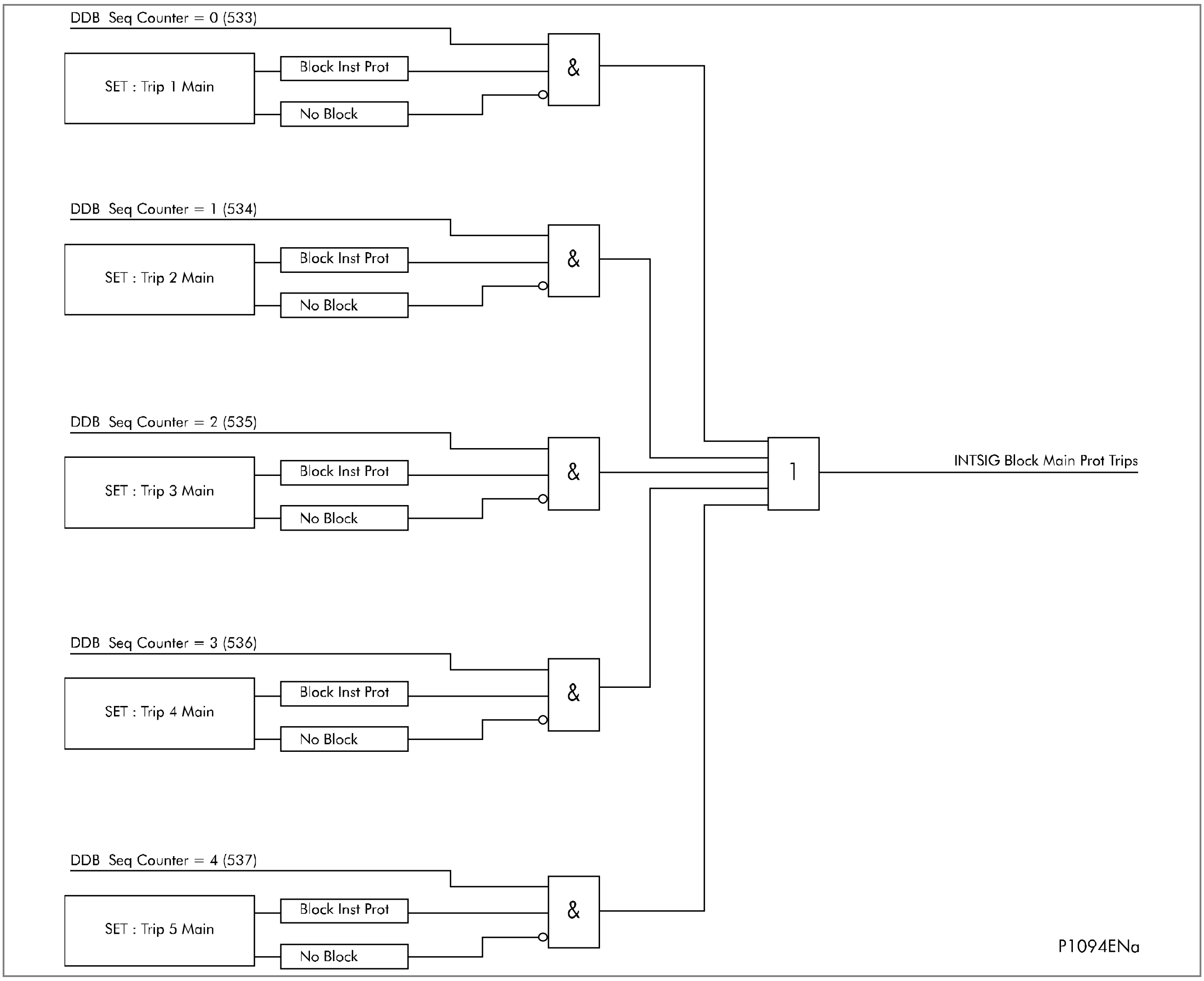


Figure 7 - Autoreclose P542 Block Protection (1)

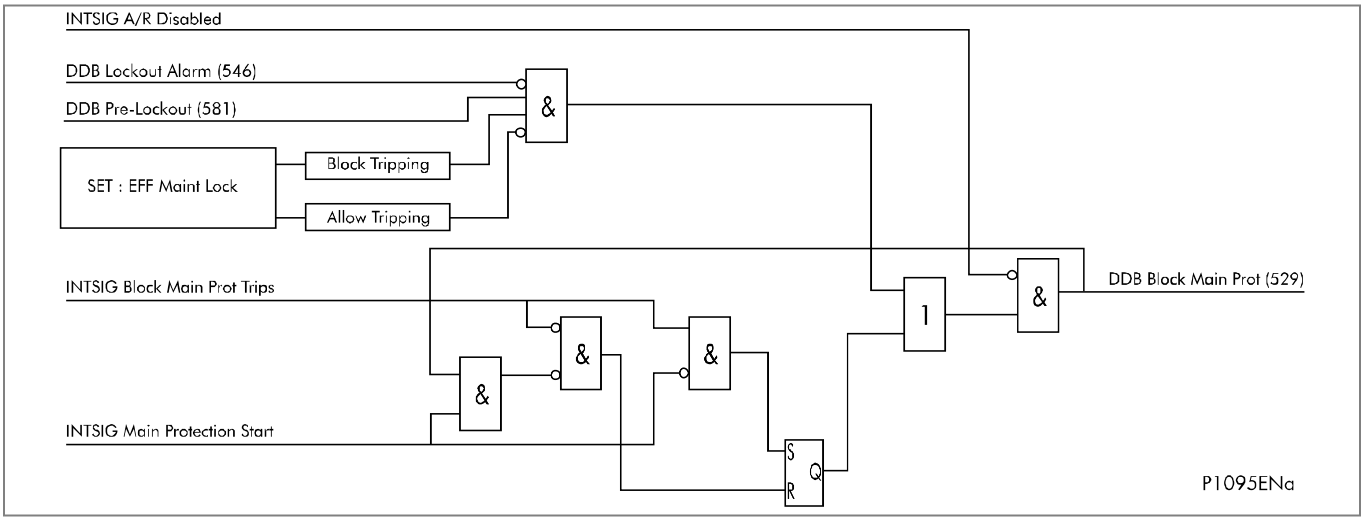


Figure 8 - Autoreclose P542 Block Protection (2)

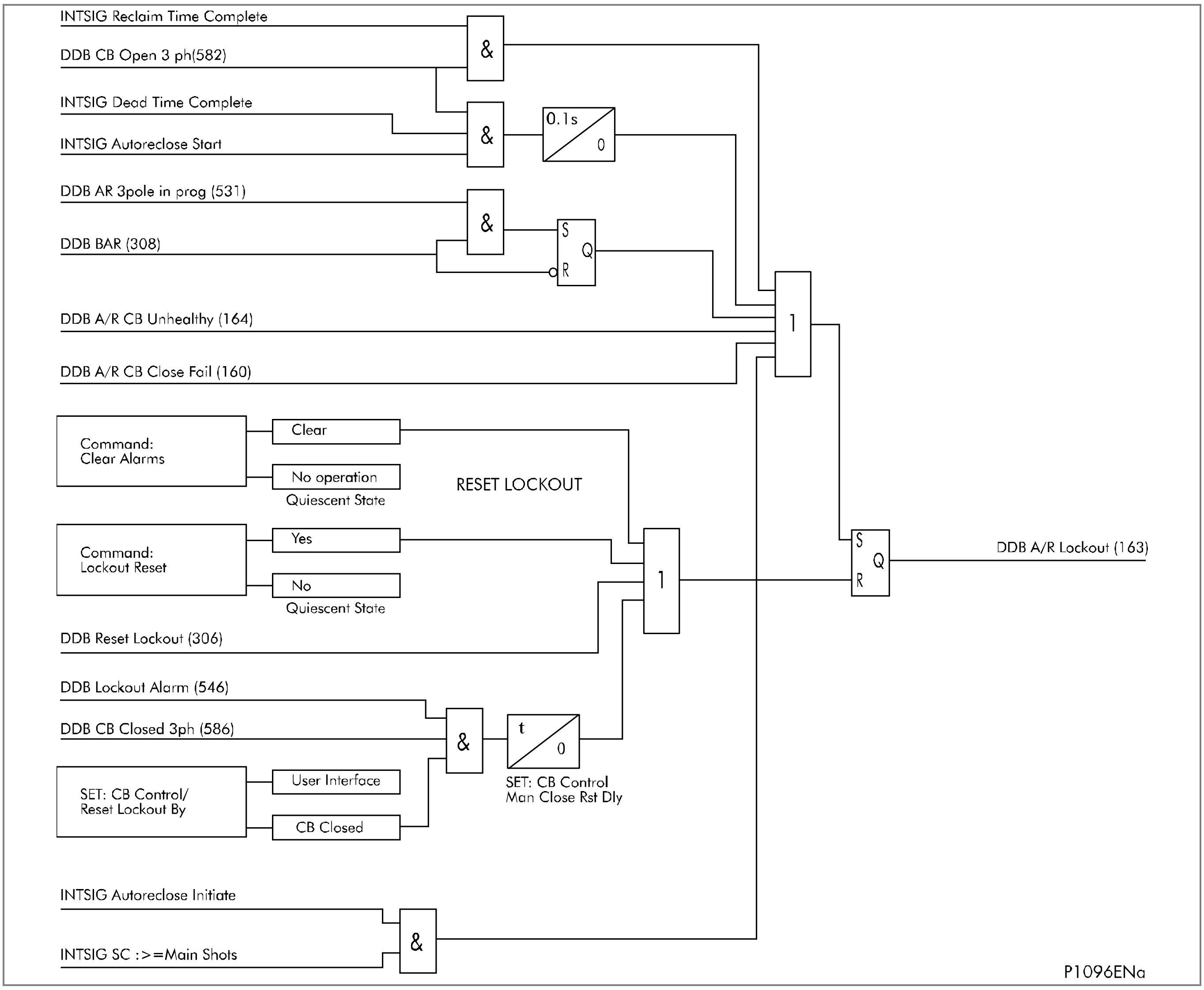


Figure 9 - Autoreclose P542 Lockout

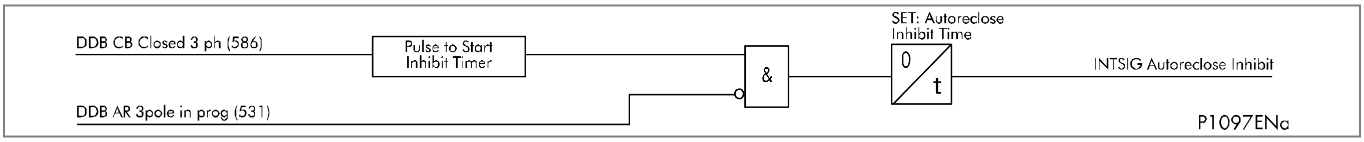


Figure 10 - Autoreclose P542 Inhibit

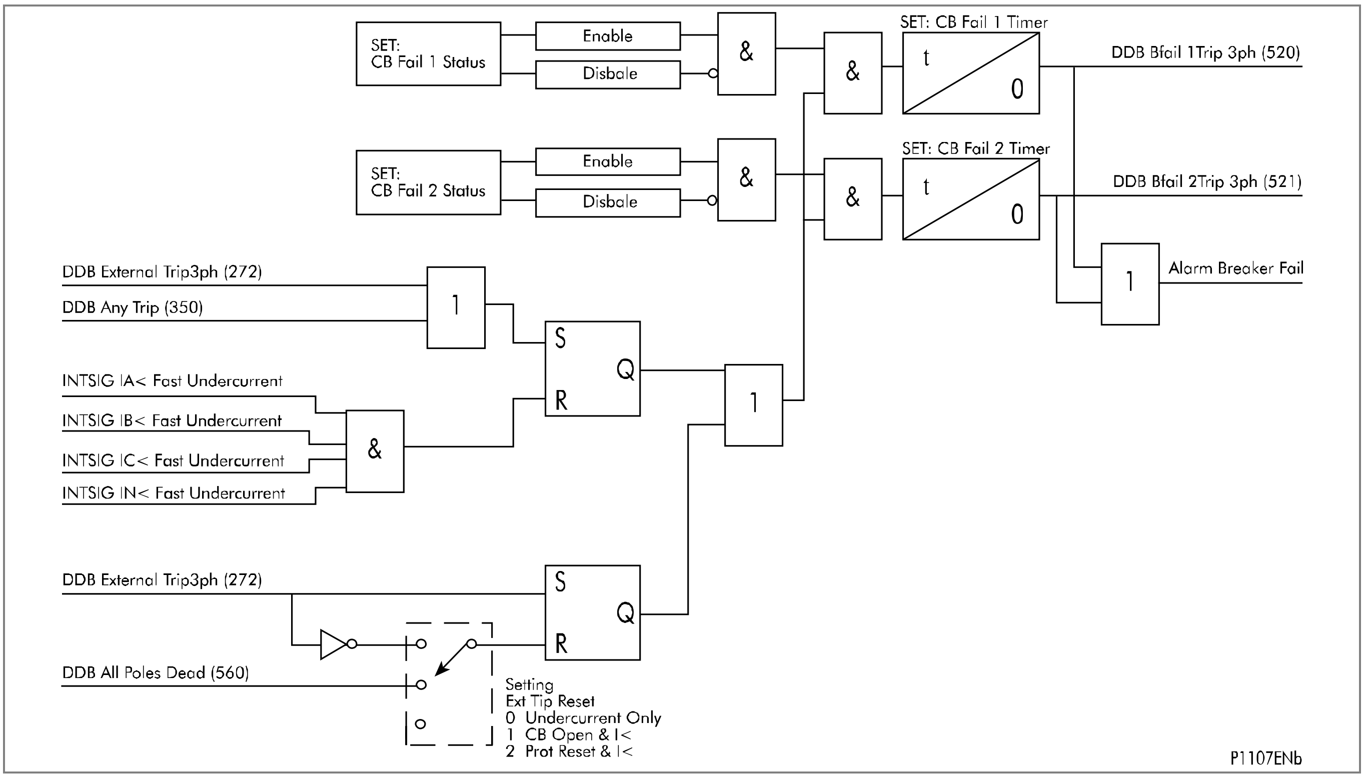


Figure 11 - CB failure for P541/P542 with Three Pole Tripping

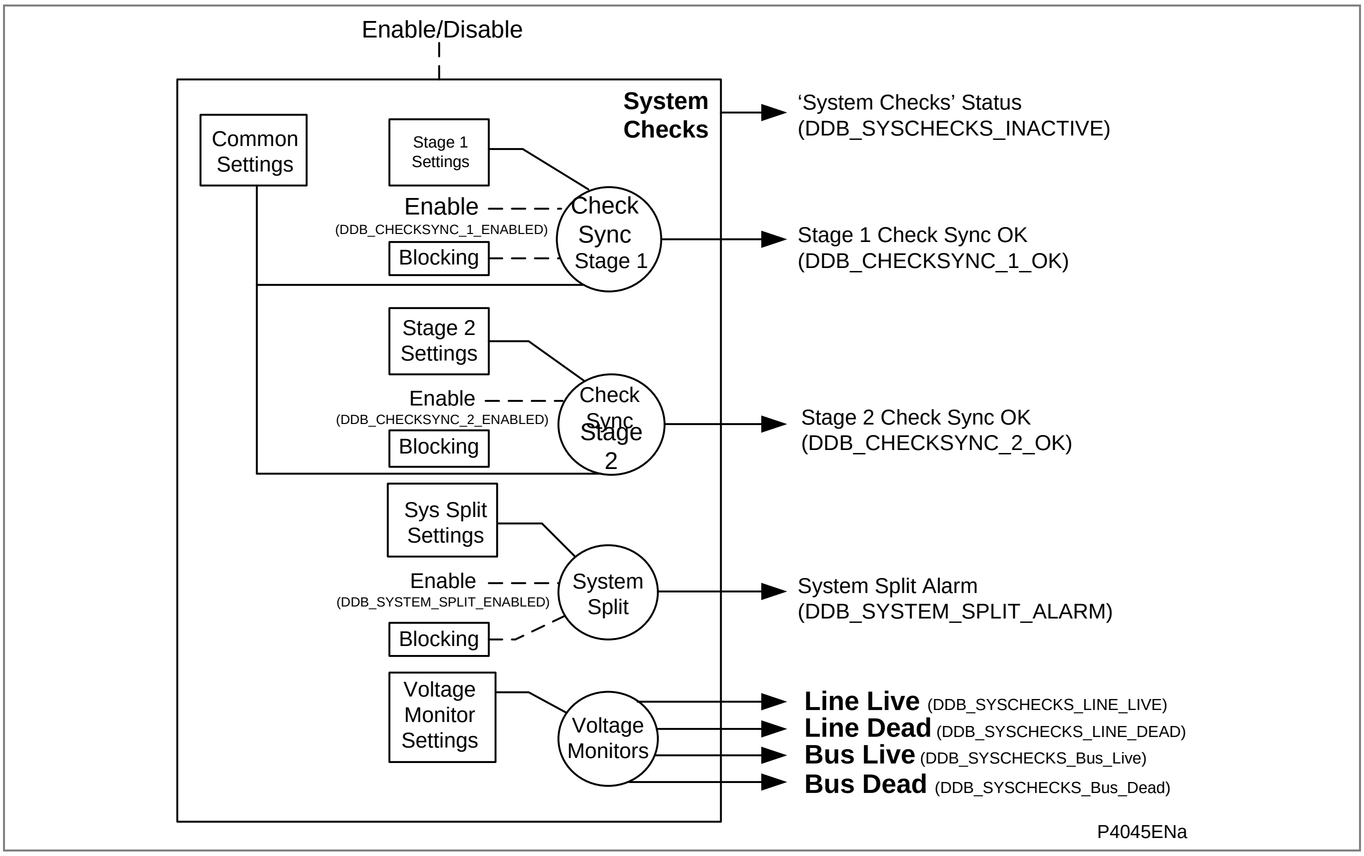


Figure 12 - Check Synch

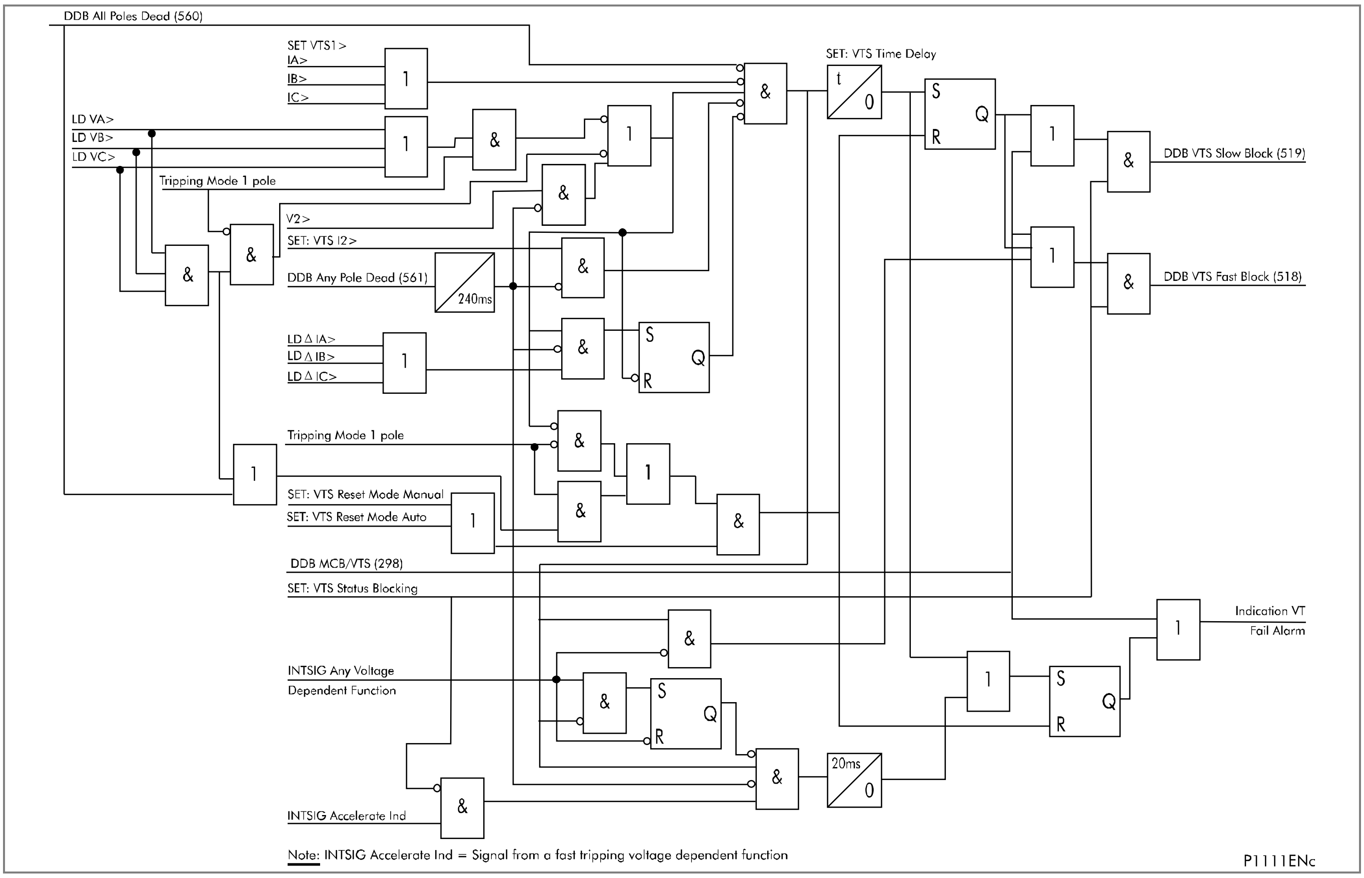


Figure 13 - VTS Logic

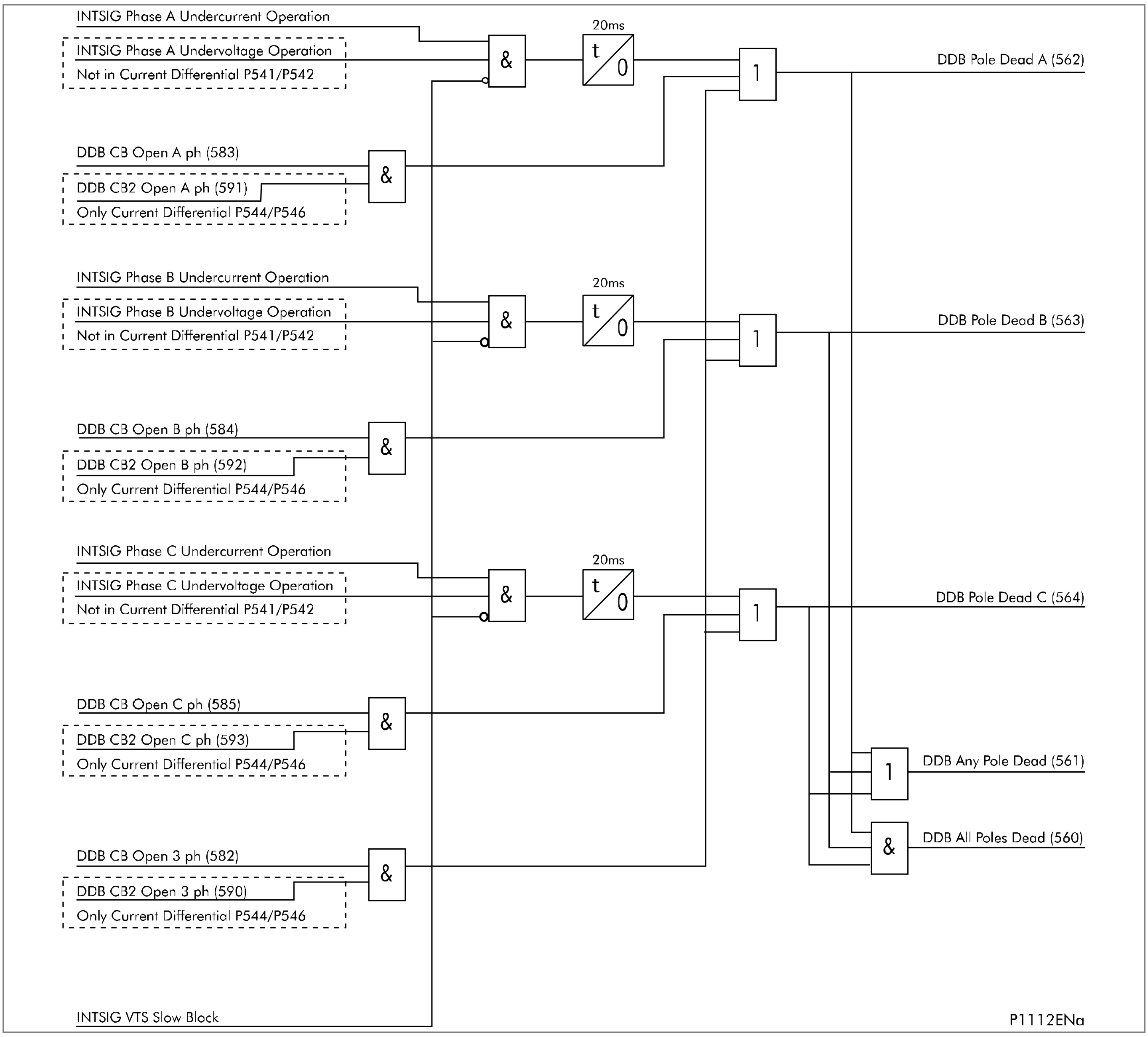


Figure 14 - Pole Dead Logic

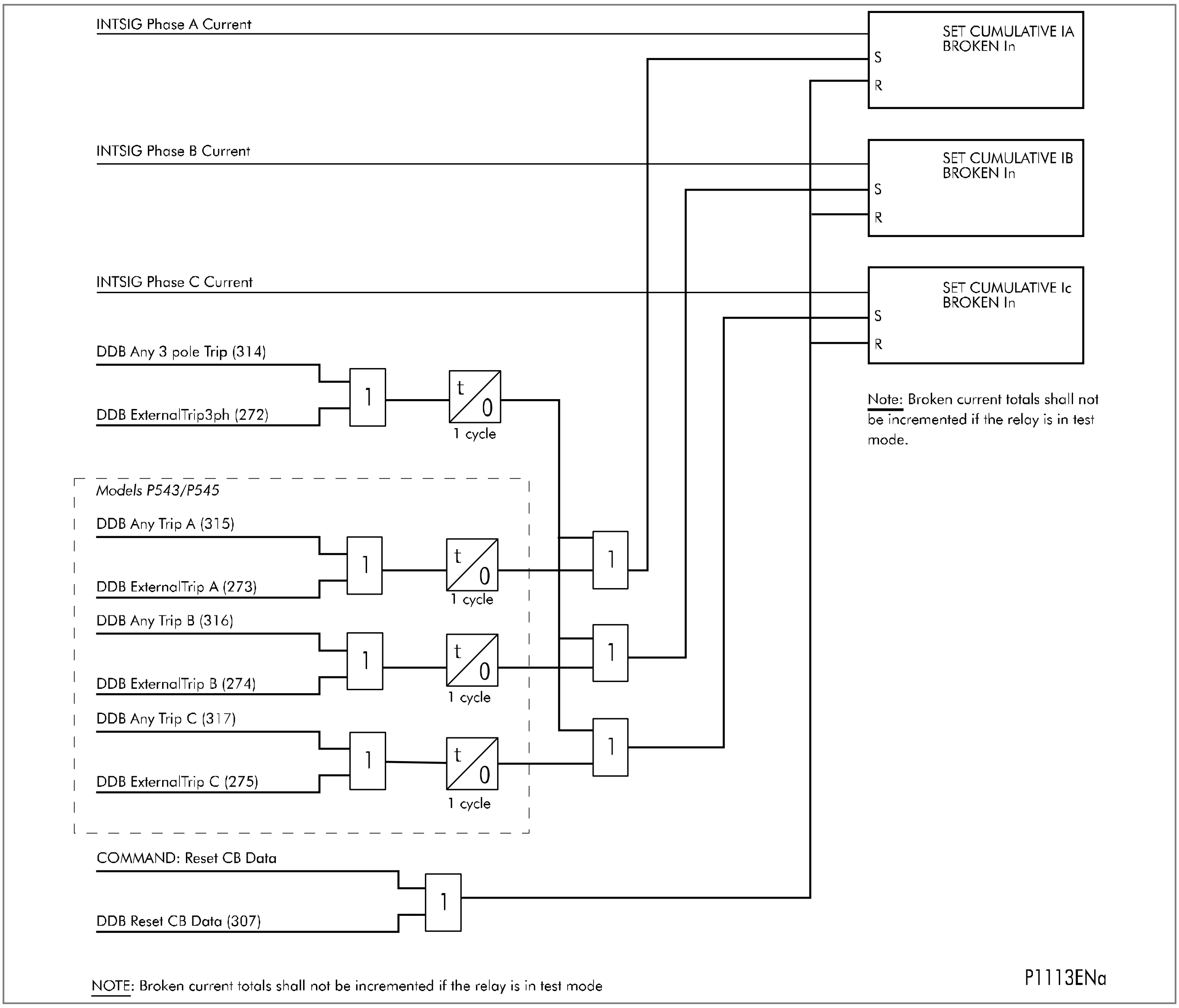


Figure 15 - Circuit Breaker Condition Monitoring Broken Current P541/P542

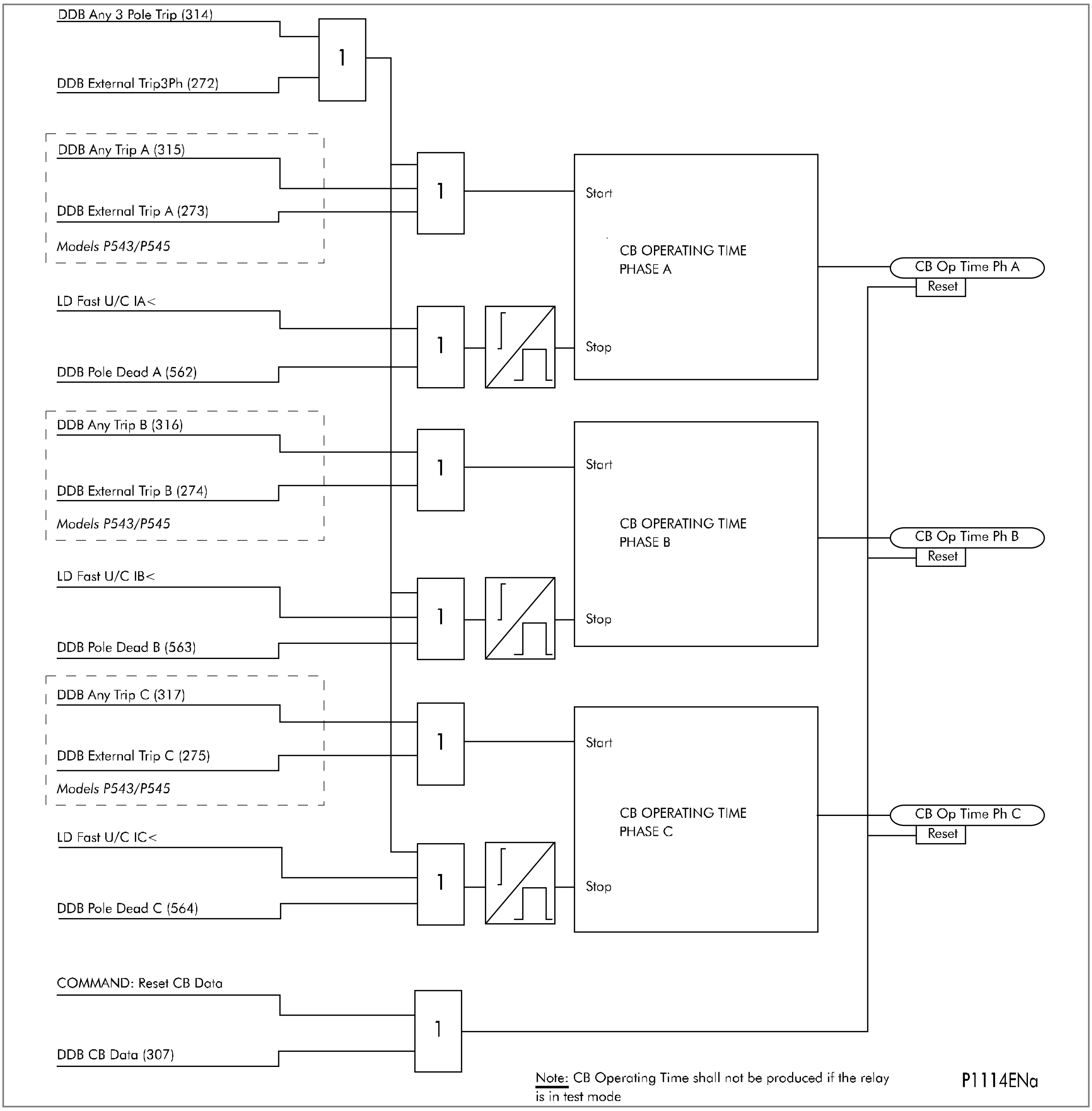


Figure 16 - Circuit Breaker Condition Monitoring Operation Time P541/P542

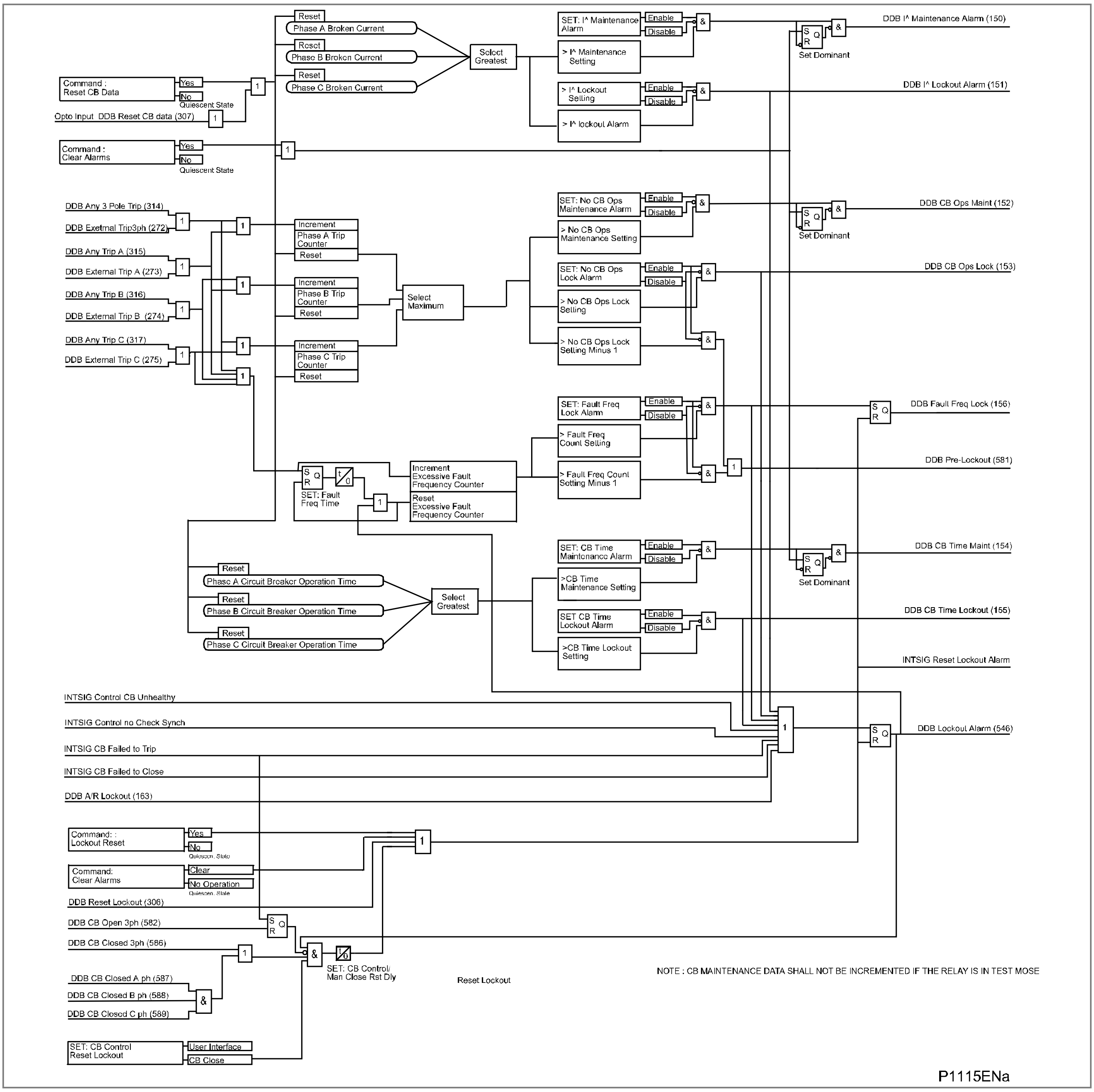


Figure 17 - CB Monitoring P541/P542

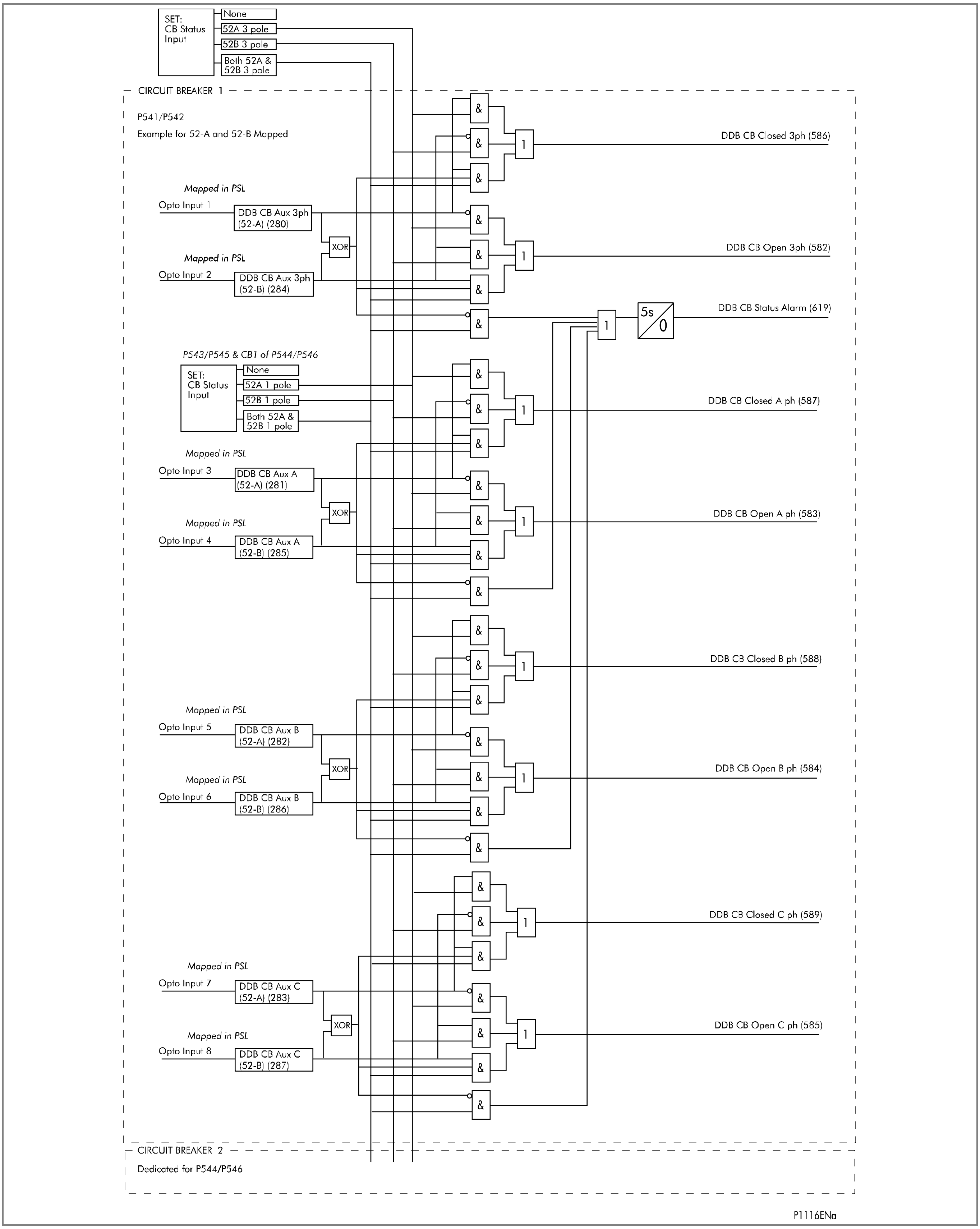


Figure 18 - Circuit Breaker State Monitor P541/P542

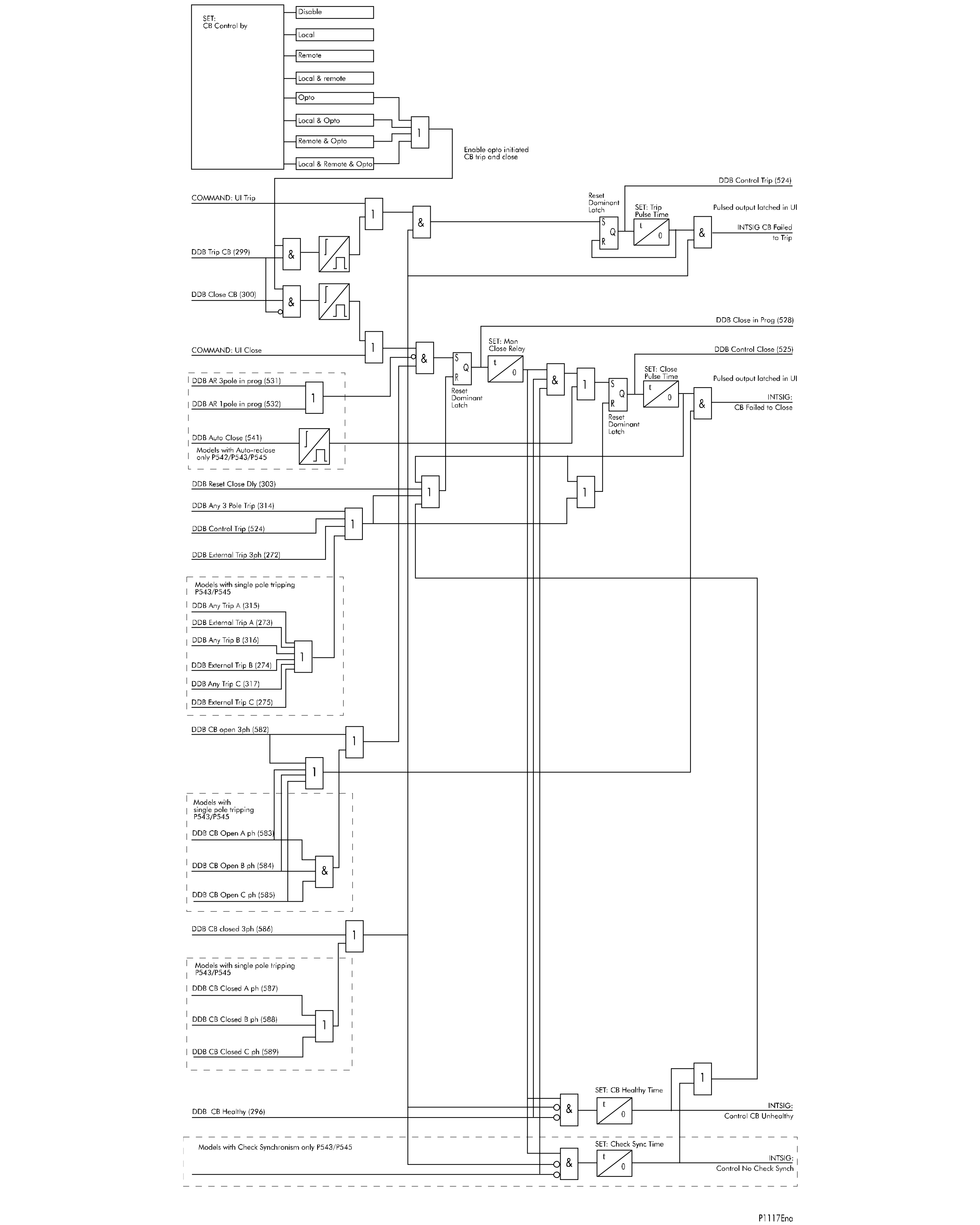


Figure 19 - Circuit Breaker Control for P541/P542

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CHAPTER 6

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1 INTRODUCTION

1.1 Protection of Overhead Lines and Cable Circuits

Overhead lines, typically ranging from 10kV distribution lines to 800kV transmission lines, are probably the most fault susceptible items of plant in a modern power system. It is therefore essential that the protection associated with them provides secure and reliable operation.

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 autoreclose cycles are therefore commonly used in conjunction with instantaneous tripping elements to increase system availability. For permanent faults it is essential that only the faulted section of plant is isolated. As such, high speed, discriminative fault clearance is often a fundamental requirement of any protection scheme on a distribution network.

The requirements for a transmission network must also take into account system stability. Where systems are not highly interconnected the use of single-phase tripping and high-speed autoreclosure is often required. This in turn dictates the need for very high speed protection to reduce overall fault clearance times.

Many line configurations exist which need to be addressed. Transmission applications may typically consist of 2 or 3 terminal applications, possibly fed from breaker-and-a-half or mesh arrangements. Lower voltage applications may again be 2 or 3 terminal configurations with the added complications of in zone transformers or small teed load transformers.

Charging current may also adversely affect protection. This is a problem particularly with cables and long transmission lines. Both the initial inrush and steady state charging current must not cause relay maloperation and preferably should not compromise protection performance.

Physical distance must be taken into account. Some EHV transmission lines can be up to several hundred kilometres in length. If high speed, discriminative protection is to be applied, it will be necessary to transfer information between line ends. This not only puts the onus on the security of signalling equipment but also on the protection in the event of loss of this signal.

Back-up protection is also an important feature of any protection scheme. In the event of equipment failure, such as signalling equipment or switchgear, for example, it is necessary to provide alternative forms of fault clearance. It is desirable to provide back-up protection which can operate with minimum time delay and yet discriminate with both the main protection and protection elsewhere on the system.

1.2 P540 Relay

Using the latest numerical technology, MiCOM relays include devices designed for the application to a wide range of power system plant such as motors, generators, busbars, feeders, overhead lines and cables.

Each relay is designed around a common hardware and software platform in order to achieve a high degree of commonality between products. One such product is the P540 relay. The relay has been designed to cater for the protection of a wide range of overhead lines and underground cables from distribution to the highest transmission voltage levels.

The relay also includes a comprehensive range of non-protection features to aid with power system diagnosis and fault analysis.

1.2.1 Protection Features

The P541 and P542 models cover a range of applications, including the protection of three 3 terminal lines. The protection features of each model are summarized here:

- Phase current differential protection - Phase segregated biased differential protection provides the main protection element for the relay. Provides high speed, discriminative protection for all fault types.
- Transformer inrush restraint and ratio/vector compensation - Allows the differential elements to be applied on transformer feeders where the transformer forms part of the protected zone.
- Thermal protection - 2 stage thermal protection for line/cable/transformer.
- Broken conductor protection - To detect open circuit faults
- Circuit breaker fail protection - Two stage breaker fail protection
- Direct/permissive intertrip and control bit transfer - Independent intertripping facility using the relay's protection communications channels, plus 8 inter-relay communications bits for command and status transfer.
- Dual redundant communications - Option for dual communications channels to provide a high degree of security ("hot standby" approach).
- Protection communications supervision - To detect failure of protection communications and enable remedial action to be taken, i.e. switch in communication independent back-up protections
- Graphical Programmable Scheme Logic (PSL) - Allowing user defined protection and control logic to suit particular customer applications
- Direct interface to IEEE C.37.94 optical multiplexers - (software 30 or later)

1.2.2 Non-Protection Features

Here is a summary of the P540 relay non-protection features.

- Local/remote measurements - Various measurement values from the local and remote line ends available for display on the relay or accessed from the serial communications.
- Fault/event/disturbance records - Available from the serial communications or on the relay LCD display (fault and event records only).
- Real time clock/time synchronization - Time synchronization possible from relay IRIG-B input, or a SCADA command.

- Four setting groups - Independent setting groups to cater for switched feeding or customer specific applications.
- Circuit breaker state monitoring - Provides indication of discrepancy between circuit breaker auxiliary contacts.
- Circuit breaker control - Control of the circuit breaker can be achieved either locally via the user interface or remotely.
- Circuit breaker condition monitoring - Provides records/alarm outputs regarding the number of CB operations, pole by pole cumulative interruption duty, and the breaker operating time.
- Commissioning test facilities.
- Remote serial communications - To allow remote access to the relays. The following communications protocols are supported: Courier, MODBUS, IEC60870-5, UCA2 (software 20 or later) and DNP3.0.
- Continuous self monitoring - Power on diagnostics and self checking routines to provide maximum relay reliability and availability.
- Time synchronization via opto input (software 20 or later).
- Choice of pickup/drop-off levels for optical isolators - (software 30 or later)

2 APPLICATION OF INDIVIDUAL PROTECTION FUNCTIONS

The following sections detail the individual protection functions in addition to where and how they may be applied. Each section also gives an extract from the respective menu columns to demonstrate how the settings are actually applied to the relay.

The P540 relays each include a column in the menu called the 'CONFIGURATION' column. As this affects the operation of each of the individual protection functions, it is described in the following section.

2.1 Configuration Column

Table 1 shows the configuration column:

MENU TEXT	DEFAULT SETTING	AVAILABLE SETTINGS
CONFIGURATION		
Restore Defaults	No Operation	No Operation
		All Settings
		Setting Group 1
		Setting Group 2
		Setting Group 3
		Setting Group 4
Setting Group	Select via Menu	Select via Menu
		Select via Optos
Active Settings	Group 1	Group1
		Group 2
		Group 3
		Group 4
Save Changes	No Operation	No Operation
		Save
		Abort
Copy From	Group 1	Group1, 2, 3 or 4
Copy To	No Operation	No Operation Group1, 2, 3 or 4
Setting Group 1	Enabled	Enabled or Disabled
Setting Group 2	Disabled	Enabled or Disabled
Setting Group 3	Disabled	Enabled or Disabled
Setting Group 4	Disabled	Enabled or Disabled
Phase Diff	Enabled	Enabled or Disabled
Tripping Mode	3 Pole	3 Pole1 & 3 Pole
Filter Control	Enabled	Enabled or Disabled
Overcurrent	Enabled	Enabled or Disabled
Broken Conductor	Disabled	Enabled or Disabled
Thermal Overload	Disabled	Enabled or Disabled
CB Fail	Disabled	Enabled or Disabled
Supervision	Enabled	Enabled or Disabled
Fault Locator	Enabled	Enabled or Disabled
System Checks	Disabled	Enabled or Disabled

MENU TEXT	DEFAULT SETTING	AVAILABLE SETTINGS
Auto-Reclose	Disabled	Enabled or Disabled
Input Labels	Visible	Invisible or Visible
Output Labels	Visible	Invisible or Visible
CT & VT Ratios	Visible	Invisible or Visible
Event Recorder	Invisible	Invisible or Visible
Disturb Recorder	Invisible	Invisible or Visible
Measure't Setup	Invisible	Invisible or Visible
Comms Settings	Visible	Invisible or Visible
Commission Tests	Visible	Invisible or Visible
Setting Values	Primary	Primary or Secondary
Control Inputs	Visible	Invisible or Visible
Ctrl I/P Config (software 20 or later)	Visible	Invisible or Visible
Ctrl I/P Labels (software 20 or later)	Visible	Invisible or Visible
Direct Access (software 20 or later)	Visible	Disabled/Enabled
LCD Contrast (software 20 or later)	11	0-31

Table 1 - Configuration column

The aim of the Configuration column is to allow general configuration of the relay from a single point in the menu. Any of the functions that are disabled or made invisible from this column do not then appear within the main relay menu.

2.2 Phase Current Differential Protection

The primary protection element of the P540 relays is phase segregated current differential protection. This technique involves the comparison of the currents at each line terminal. A communications path is therefore an essential requirement of any such scheme. The P540 relays use a 56/64 Kbits/s digital communications system either for direct optical connection between ends, or via a multiplexed link.

2.2.1 Differential Protection Configuration

Following is a copy of the 'I DIFF CONFIG' column on the relay menu. All configuration settings relating to the differential protection within the relay can be found in this column.

I DIFF CONFIG	Default Setting	Min	Max	Step
Scheme Set-up	2 Terminal	3 Terminal, 2 Terminal, Dual Redundant		
Address	0-0	0-0, 1-A, 2-A, 3-A, 4-A, ……..20-A 1-B, 2-B, 3-B, 4-B, 5-B, ……..20-B 1-C, 2-C, 3-C, 4-C, 5-C, ……..20-C		
		56kbits/s, 64kbits/s		
		Internal, External		
Clock Source Ch2	Internal	(Where Multiplexer has its own clock set External, otherwise set to Internal)		
Comm Delay Tol (See 7.1.6.1)	0.00025s	0.00025s	0.001s	0.00005s
Comm Fail Timer	10s	0.1s	10s	0.1s
Comm Fail Mode	Channel 1+2	Channel 1, Channel 2, Channel1+2		
Char Mod Time (See 7.1.6.1)	0.5s	0s	0.5s	0.0001s
I Cap Correction (See 2.2.4)	Disabled	Enabled, Disabled		
Susceptance (See 2.2.4)	10nmho*In	10nmho*In	10mho*In	10nmho*In
Inrush Restraint	Disabled	Enabled, Disabled		
Vectorial Comp	Yy0	Yy0, Yd1, Ydy2, Yd3, Ydy4, Yd5, Yy6, Yd7, Ydy8, Yd9, Ydy10, Yd11, Ydy0, Ydy6		
Ph CT Correction	1	1	8	0.01
Re-Configuration	Three Ended	Three Ended, Two Ended (L&R1), Two Ended (L&R2), Two Ended (R1&R2)		
Baud Rate Ch2	64kbit/s	56kbit/s, 64kbits		
Comms Mode (software 30 or later)	Standard	Standard, IEEE C37.94		
Ch1 N*64kbits/s (software 30 or later)	1	Auto, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12		
Ch2 N*64kbits/s (software 30 or later)	1	Auto, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12		

Table 2 - Menu configuration column

2.2.2 Phase Differential Characteristics

The basic operating principle of differential protection is to calculate the difference between the currents entering and leaving a protected zone. The protection operates when this difference exceeds a set threshold.

Differential currents may also be generated during external fault conditions due to CT saturation. To provide stability for through fault conditions, the relay adopts a biasing technique. This method effectively raises the setting of the relay in proportion to the value of through fault current to prevent relay maloperation. Figure 1 shows the operating characteristics of the P540 phase differential element.

The differential current is calculated as the vector summation of the currents entering the protected zone. The bias current is the average of the measured current at each line end. It is found by the scalar sum of the current at each terminal, divided by two.

Each of these calculations is done on a phase by phase basis. The level of bias used for each element is the highest of the three calculated for optimum stability.

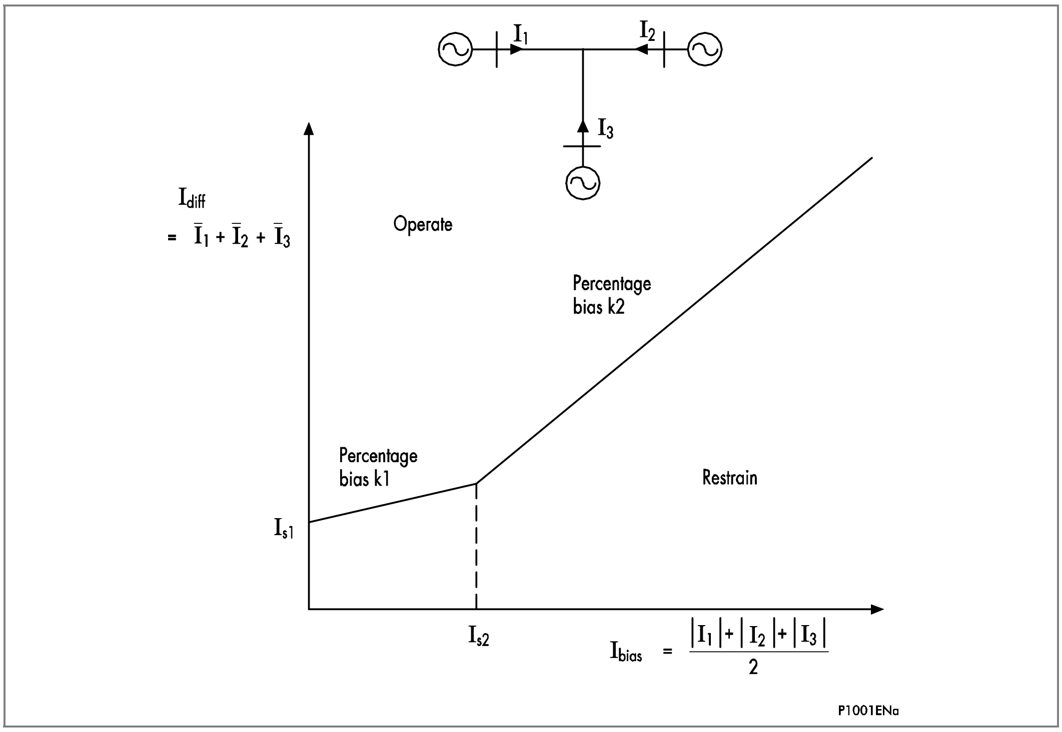

Figure 1 - Relay bias characteristic

The characteristic is determined by four protection settings:

Is1	The basic differential current setting which determines the minimum pick-up level of the relay.
k1	The lower percentage bias setting used when the bias current is below Is2. This provides stability for small CT mismatches, whilst ensuring good sensitivity to resistive faults under heavy load conditions.
Is2	A bias current threshold setting, above which the higher percentage bias k2 is used.
k2	The higher percentage bias setting used to improve relay stability under heavy through fault current conditions.

The tripping criteria can be formulated as:

For $|I_{bias}| < I_{s2}$

$$|I_{diff}| > k1.|I_{bias}| + I_{s1}$$

For $|I_{bias}| > I_{s2}$

$$|I_{diff}| > k2.|I_{bias}| - (k2 - k1).\ I_{s2} + I_{s1}$$

When a trip is issued by the differential element, in addition to tripping the local breaker, the relay will send a differential intertrip signal to the remote terminals. This will ensure tripping of all ends of the protected line, even for marginal fault conditions.

The differential protection can be time delayed using either a definite or inverse time characteristic. Table 3 details the settings available for the Phase Differential protection element.

PHASE DIFF	Default Setting	Min	Max	Step
Phase Is1	0.2In	0.2In	2In	0.5In
Phase Is2	2In	1In	30In	0.05In
Phase k1	30%	30%	150%	5%
Phase k2	150%	30%	150%	5%
Phase Char (see 2.6 for characteristic data)	DT	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		
Phase Time Delay	0	0s	100s	0.01s
Phase TMS	1	0.025	1.2	0.025
Phase Time Dial (Software 30 and later)	1	0.1	100	0.05
Phase Time Dial	7	0.5	15	0.1
PIT Time	0.2s	0s	0.2s	0.005s
Inrush High	4In	4In	32In	0.01In

Table 3 - Menu phase differential column

The Id High Set element is an unrestrained element designed to provide high speed operation in the event of CT saturation. Where transformer inrush restraint is used, the resultant second harmonic current produced from CT saturation may cause slow relay operation. The high set element will be automatically enabled when inrush restraint is enabled, otherwise it is not operational. The high set element should be set in excess of 40% of the peak magnetizing inrush level.

2.2.3 Time Alignment of Current Vectors

2.2.3.1 Time Alignment of Current Vectors without GPS Input (Traditional Technique)

To calculate differential current between line ends it is necessary that the current samples from each end are taken at the same moment in time. This can be achieved by time synchronizing the sampling, or alternatively, by the continuous calculation of the propagation delay between line ends. The P540 range of relays has adopted this second technique.

Consider a two-ended system as shown in Figure 2.

Two identical relays, A and B are placed at the two ends of the line. Relay A samples its current signals at time tA1, tA2 etc., and relay B at time tB1, tB2 etc. Note that the sampling instants at the two ends will not, in general, be coincidental or of a fixed relationship, due to slight drifts in sampling frequencies.

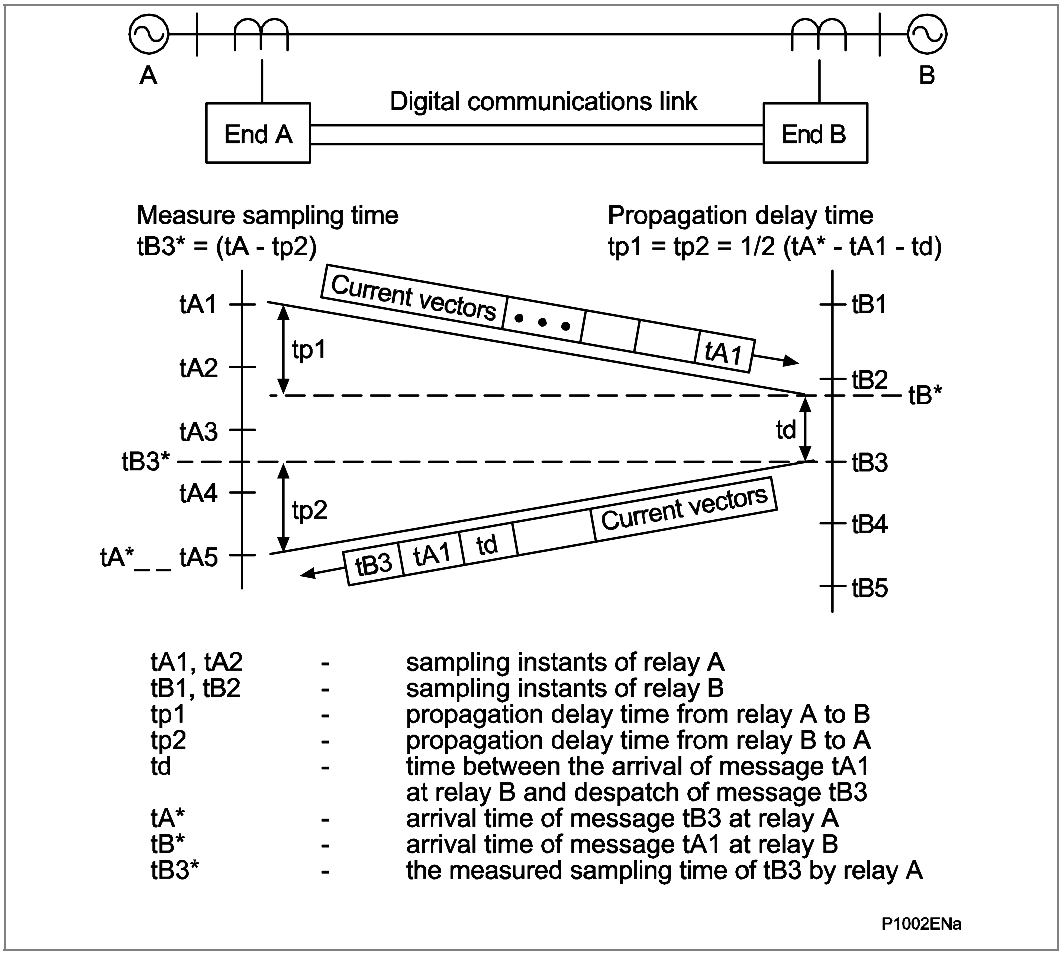

Figure 2 - Propagation delay measurement

Assume that at time tA1, relay A sends a data message to relay B. The message contains a time tag, tA1, together with other timing and status information and the current vector values calculated at tA1. The message arrives at end B after a channel propagation delay time, tp1. Relay B registers the arrival time of the message as tB*.

Since relays A and B are identical, relay B also sends out data messages to end A. Assume relay B sends out a data message at tB3. The message therefore contains the time tag tB3. It also returns the last received time tag from relay A (i.e. tA1) and the delay time, td, between the arrival time of the received message, tB*, and the sampling time, tB3, i.e. td = (tB3 - tB*).

The message arrives at end A after a channel propagation delay time, tp2. Its arrival time is registered by relay A as tA*. From the returned time tag, tA1, relay A can measure the total elapsed time as (tA* - tA1). This equals the sum of the propagation delay times tp1, tp2 and the delay time td at end B.

Hence:

(tA* - tA1) = (td + tp1 + tp2)

The relay assumes that the transmit and receive channels follow the same path and so have the same propagation delay time. This time can therefore be calculated as:

tp1 = tp2 = ½(tA* - tA1 - td)

Note that the propagation delay time is measured for each received sample and this can be used to monitor any change on the communication link.

As the propagation delay time has now been deduced, the sampling instant of the received data from relay B (tB3*) can be calculated. As shown in Figure 2, the sampling time tB3* is measured by relay A as:

tB3* = (tA* - tp2)

In Figure 2, tB3* is between tA3 and tA4. To calculate the differential and bias currents, the vector samples at each line end must correspond to the same point in time. It is necessary therefore to time align the received tB3* data to tA3 and tA4. This can be achieved by rotating the received current vector by an angle corresponding to the time difference between tB3* and tA3 (and tA4). For example a time difference of 1ms would require a vector rotation of $^{1}/_{20}$ * 360° = 18° for a 50Hz system.

As two data samples can be compared with each data message, the process needs to be done only once every two samples, thus reducing the communication bandwidth required. Note that the current vectors of the three phases need to be time aligned separately.

2.2.4 Capacitive Charging Current

The charging current of a line or cable will be seen as differential current. If this current is of a sufficiently high magnitude, as is the case for cables and long feeders, then relay maloperation could occur. Two issues are apparent with charging current; the first being inrush during line energization and the second being steady state charging current.

Inrush charging current is predominately high order harmonics (9th and 11th for example). The Fourier filtering used by the P540 relays will remove these frequency components and hence provide stability.

Steady state charging current is nominally at fundamental frequency and hence may cause relay maloperation.

Where the P541 and P542 relays are used, it must be ensured that the base current setting on the relay (Is1) is set to at least 2.5x the line steady state charging current to avoid possible maloperation.

2.2.5 Protection of Transformer Feeders

In applying the well established principles of differential protection to transformers, a variety of considerations have to be taken into account. These include compensation for any phase shift across the transformer, possible unbalance of signals from current transformers either side of windings, and the effects of the variety of earthing and winding arrangements. In addition to these factors, which can be compensated for by correct application of the relay, the effects of normal system conditions on relay operation must also be considered. The differential element must restrain for system conditions which could result in maloperation of the relay, such as high levels of magnetizing current during inrush conditions.

In traditional transformer feeder differential schemes, the requirements for phase and ratio correction were met by correct selection of line current transformers. Within the P541 and P542, software Interposing CTs (ICTs) are provided which can give the required compensation. The advantage of having replica ICTs is that it gives the P540 relays the flexibility to cater for line CTs connected in either star or delta, as well as being able to compensate for a variety of system earthing arrangements. The P541 and P542 relays also include a magnetizing inrush restraint facility.

2.2.5.1 Transformer Magnetising Inrush and High Set Differential Setting

The magnetizing inrush current to a transformer appears as a large operating signal to the differential protection. Special measures are taken with the relay design to ensure that no maloperation occurs during inrush.

Figure 3 shows a transformer magnetizing characteristic. To minimize material costs, weight and size, transformers are generally operated near to the 'knee point' of the magnetizing characteristic. Consequently, only a small increase in core flux above normal operating levels will result in a high magnetizing current.

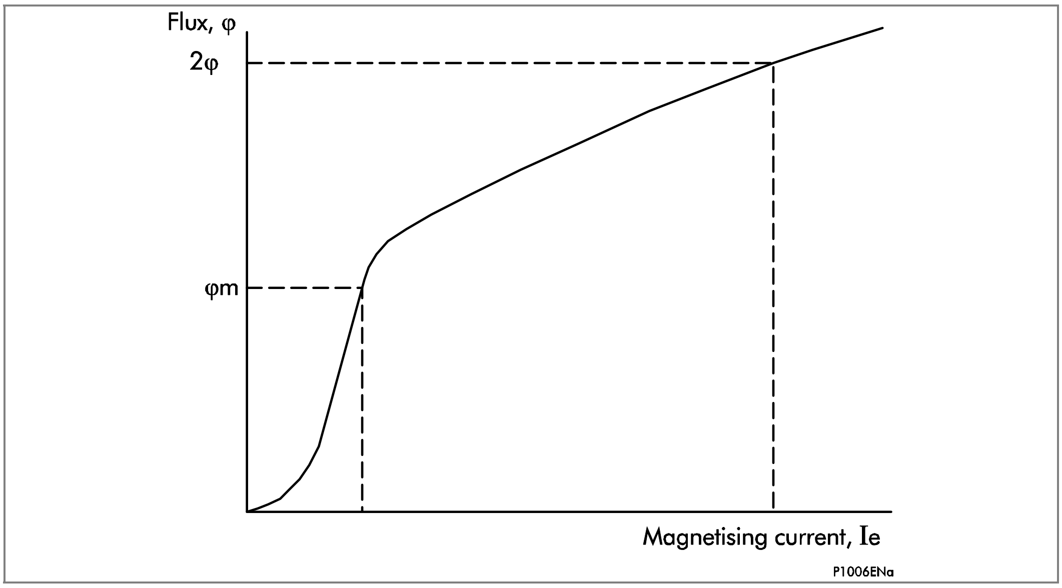

Figure 3 - Transformer magnetizing characteristic

Under normal steady state conditions, the magnetizing current associated with the operating flux level is relatively small (usually less than 1% of rated current). However, if a transformer winding is energised at a voltage zero, with no remnant flux, the flux level during the first voltage cycle (2 x normal max. flux) will result in core saturation and in a high, non-sinusoidal magnetizing current waveform. This current is commonly referred to as magnetizing inrush current and may persist for several cycles. The magnitude and duration of magnetizing inrush current waveforms are dependent upon a number of factors, such as transformer design, size, system fault level, point on wave of switching, number of banked transformers, etc. Figure 4 shows typical transformer magnetizing currents for steady state and inrush conditions.

The magnetizing inrush current contains a high percentage of second harmonic. The P541 and P542 relays filter out this component of the waveform and use it as an additional bias quantity. The total bias used by the relay will therefore be a combination of the average load current on the line plus a multiple of the second harmonic component of the current. The multiplying factor is used to ensure stability and is a factory pre-set value.

Where P541 and P542 relays are used and inrush restrain function is enabled, it must be ensure that this function is enabled at each end to avoid possible maloperation.

High Set Differential Setting:

When inrush restrain is enabled, a high set differential protection becomes active. This unrestrained instantaneous ' Id High Set ' is provided to ensure rapid clearance for heavy internal faults with saturated CTs. The high set is not restrained by magnetizing inrush; hence the setting must be set such that it will not operate for the largest inrush currents expected. It is difficult to accurately predict the maximum anticipated level of inrush current. Typical waveforms peak values are of the order of 8-10x rated current. A worst case estimation of inrush could me made by dividing the transformer full load current by the per unit leakage reactance quoted by the transformer manufacturer. A setting range 4In -32In (RMS values) is provided on P541 and P542 relays

2.2.5.2 Ratio Correction (All Models)

To ensure correct operation of the differential element, it is important that under load and through fault conditions, the currents into the differential element of the relay balance. In many cases, the HV and LV current transformer primary ratings will not exactly match the transformer winding rated currents. Ratio correction factors are therefore provided. The CT ratio correction factors are applied to ensure that the signals to the differential algorithm are correct. A ratio correction factor is provided which is adjustable from 1 to 8 in steps of 0.01.

To minimize unbalance due to tap changer operation, current inputs to the differential element should be matched for the mid-tap position.

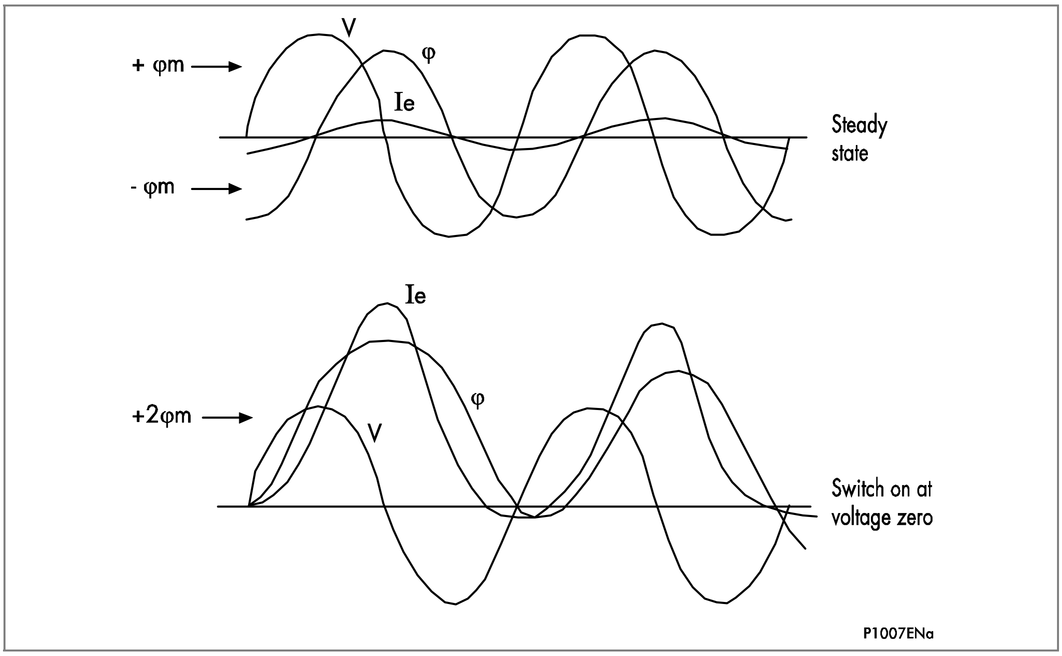

Figure 4 - Magnetizing inrush waveforms

Ideally, the compensated current values should be arranged to be as close as possible to relay rated current to provide optimum relay sensitivity. The corrected currents should not, however, be arranged to exceed relay rated current under through load conditions.

2.2.5.3 Phase Correction and Zero Sequence Current Filtering

To compensate for any phase shift between two windings of a transformer, it is necessary to provide phase correction. This was traditionally provided by the appropriate delta connection of main line CTs.

Phase correction is provided in the P540 relays via software interposing CTs. The phase correction settings available with P540 relays are given in Table 2.

In addition to compensating for the phase shift of the protected transformer, it is also necessary to mimic the distribution of primary zero sequence current in the protection scheme.

Figure 5 shows the need for zero sequence current filtering for differential protection across a transformer. The power transformer delta winding acts as a ‘trap’ to zero sequence current. This current is therefore only seen on the star connection side of the transformer and hence as differential current.

The filtering of zero sequence current has traditionally been provided by appropriate delta connection of main line CT secondary windings. In the P540 relays, zero sequence current filtering is automatically implemented in software when a delta connection is set for a software interposing CT. Where a transformer winding can pass zero sequence current to an external earth fault, it is essential that some form of zero sequence current filtering is employed. This would also be applicable where in zone earthing transformers are used.

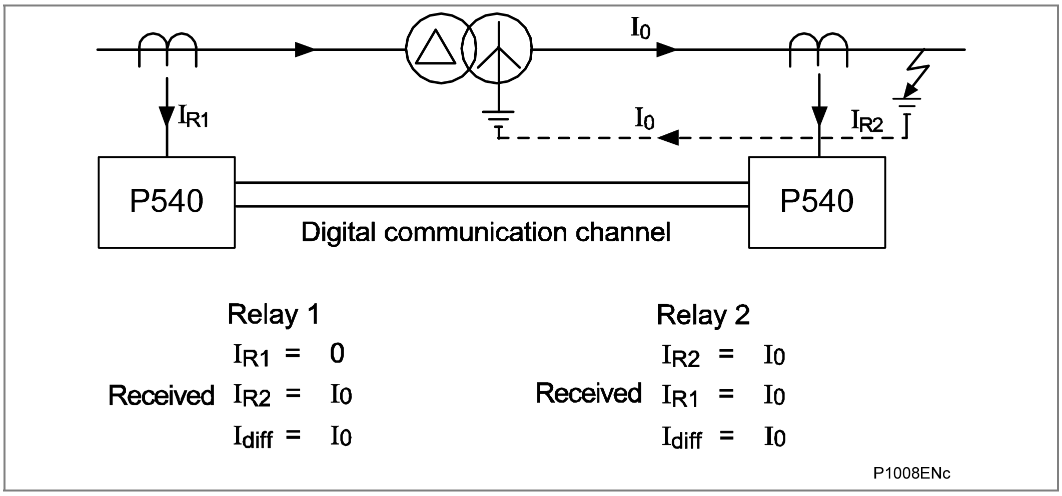

Figure 5 - Need for zero-sequence current filtering

Some examples of selection of phase compensation factors are shown in Table 4.

Transformer Connection	Transformer Phase Shift	Vectorial Compensation (Relay setting)	
		HV	LV
Dy1	- 30^{o}	Yy0 (0 deg)	Yd11 (+30 deg)
Yd1	- 30^{o}	Yd1 (-30 deg)	Yy0 (0 deg)
Dy5	- 150^{o}	Yy0 (0 deg)	Yd7 (+150 deg)
Yd5	- 150^{o}	Yd5 (-150 deg)	Yy0 (0 deg)
Dy7	+ 150^{o}	Yy0 (0 deg)	Yd5 (-150 deg)
Yd7	+ 150^{o}	Yd7 (+150 deg)	Yy0 (0 deg)
Dy11	+ 30^{o}	Yy0 (0 deg)	Yd1 (-30 deg)
Yd11	+ 30^{o}	Yd11 (+30 deg)	Yy0 (0 deg)

Table 4 - Examples of selection of phase compensation factors

2.2.6 3 to 2 Terminal Reconfiguration

The P540 relays can be configured for the protection of two or three terminal lines. This allows any of the relays to be applied to a two-ended line which may be converted to a three terminal line at a later date. Since only the ‘configuration’ setting needs to be changed to configure the relay for two or three terminal operation, no hardware changes are required when the third terminal is added, provided that 2 channels of fiber optics are already fitted.

For operational reasons, it may be necessary, under certain circumstances, to switch out one line end and its associated relay on a three terminal circuit. By altering the ‘Reconfiguration’ setting at any end of the line, an operator can command any pair of relays to work as a two terminal system. The ‘configured out’ relay can then be switched off, leaving the line to be protected by the other two relays. A restore command can be issued to reconfigure the system back to three terminal operations.

Four reconfiguration settings are available:

- Three ended
- Two ended local and remote 1 (L & R1)

- Two ended local and remote 2 (L & R2)
- Two ended remote 1 and remote 2 (R1 & R2)

Before a configuration command can be successfully initiated, it is necessary to energize the ‘reconfiguration interlock’ and ‘Inhibit Current Differential’ opto isolated inputs. The latter input will disable tripping via the current differential elements from all three relays to ensure that the scheme will remain stable during reconfiguration.

It must be ensured that the line end to be ‘configured out‘ is open before issuing a reconfiguration command. If this is not done, any current flowing in or out of the ‘configured out’ end will be seen as fault current and may cause the other relays to operate.

If the new configuration setting issued to the local relay is L & R1 or L & R2, the trip outputs of the two ‘2-ended’ relays will remain inhibited by the ‘Inhibit Current Differential’ input at the local relay. The ‘inhibit trip/alarm outputs’ opto should be de-energised to enable the trip outputs reconfigured scheme. If the new configuration setting is R1 & R2, the output contacts of the two remote relays will not be inhibited as they will ignore all commands from the local relay.

The scheme may be restored to a three terminal configuration by selecting ‘three ended‘ at any terminal. This will occur irrespective of the status of the opto inputs but is subject to a healthy communications channel being detected.

2.2.7 Mesh Corner and 1½ Breaker Switched Substations

Where a line is fed from a mesh corner or 1½ breaker switched substation, as shown in Figure 6, then two options are available for CT connections to the relay. The first is by paralleling the two sets of line CTs into a common input, ‘A’. The second is by using two separate inputs for each set of line CTs, ‘B’.

In the case of a through fault as shown, the relay connected to circuit ‘A’ should see no current and as such, will remain stable. Under this condition, it should be noted that no bias is produced in the relay. To ensure relay stability, the two sets of line CTs should be as near as identical in all characteristics, and equally loaded, such that the relaying connection is at the equipotential point of the secondary leads.

In the case of circuit ‘B’ no differential current should result. A large bias current will however exist, providing a high degree of stability in the event of a through fault. This bias will also ensure stability where CTs are not closely matched. Thus, circuit ‘B’ is the preferred connection for such applications.

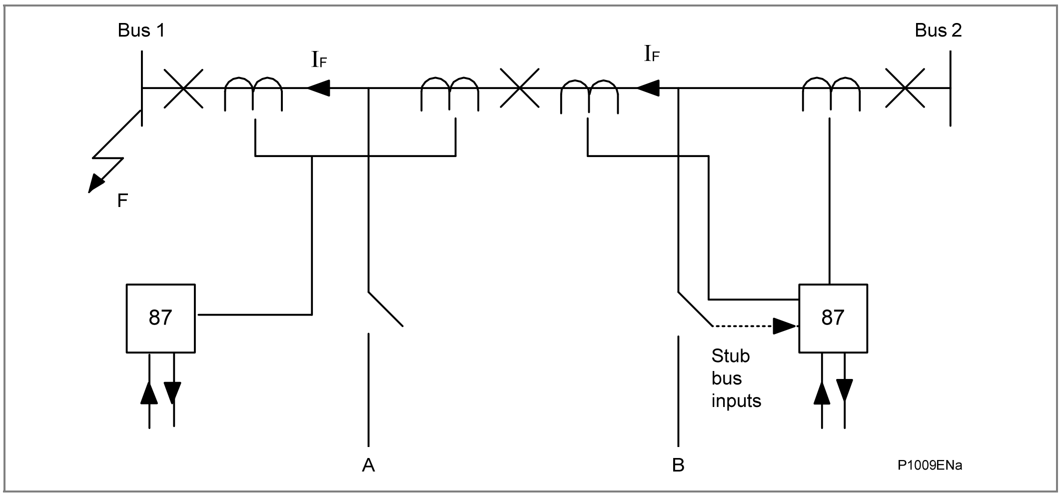

Figure 6 - Breaker and a half switched substation

2.2.8 Small Tapped Loads (Tee Feeds)

Where transformer loads are tapped off the protected line it is not always necessary to install CTs at this location. Provided that the tee-off load is light, differential protection can be configured for the main line alone. The settings 'Phase Char', 'Phase Time Delay' and 'TMS' or 'Time Dial' in Table 3 allow the differential element to time grade with IDMT overcurrent relays or fuses protecting the tap. This keeps stability of the differential protection for external faults on the tee circuit.

2.2.9 Additional Protection Considerations

2.2.9.1 Minimum Operating Current

It should be noted that the minimum operating current is related, but not equal to, the Is1 setting.

Consider a single end fed fault with no load but fault current, I:

$$|I_{diff}| = I$$
$$|I_{bias}| = ½I$$

Assuming |Ibias| < Is2, then, using the equations from section 2.1, the relay will operate if:

$$|I_{diff}| > k1.|I_{bias}| + I_{s1} \quad \text{or}$$
$$I > k1.½I + I_{s1} \quad \text{or}$$
$$I > I_{s1} / (1 - 0.5\ k1)$$

The minimum operating current is therefore a function of the Is1 and k1 settings. Since k1 is recommended to be set to 30%, the minimum operating current will be:

$$I_{min} = 1.176\ I_{s1}$$

For most applications a minimum setting of 0.2 pu is recommended. This will give the relay a sensitivity of 0.235 pu.

2.2.9.2 Relay Sensitivity under Heavy Load Conditions

The sensitivity of the relay is governed by its settings and also the magnitude of load current in the system. For a three-ended system, with relays X, Y and Z, the following applies:

$$|I_{diff}| = |(I_X + I_Y + I_Z)|$$
$$|I_{bias}| = 0.5\ (|I_X| + |I_Y| + |I_Z|)$$

Assume a load current of I_L flowing from end X to Y and Z. Assume also a high resistance fault of current I_F being singly fed from end X. For worst case analysis, we can assume also I_F to be in phase with I_L :

$$I_X = I_L + I_F$$
$$I_Y = -yI_L \text{ where } 0<y<1$$
$$I_Z = -(1-y)\ I_L$$
$$|I_{diff}| = |I_F|$$
$$|I_{bias}| = |I_L| + 0.5\ |I_F|$$

Relay sensitivity when |Ibias| < Is2:

For |Ibias| < Is2, the relay would operate if |Idiff| > k1 |Ibias| + Is1

or $|I_F| > k1\,(|I_L| + 0.5\,|I_F|) + Is1$
or $(1 - 0.5\,k1)\,|I_F| > (k1\,|I_L| + Is1)$
or $|I_F| > (k1\,|I_L| + Is1) / (1 - 0.5\,k1)$

For Is1 = 0.2 pu, k1 = 30% and Is2 =2.0 pu, then

For $|I_L|$ = 1.0 pu, the relay would operate if $|I_F|$ > 0.59 pu
For $|I_L|$ = 1.59 pu, the relay would operate if $|I_F|$ > 0.80 pu

If $|I_F|$ = 0.80 pu and $|I|$ = 1.59 pu, then |Ibias| = 1.99 pu which reaches the limit of the low percentage bias curve.

Relay sensitivity when |Ibias| > Is2:

For |Ibias| > Is2, the relay would operate if

$|Idiff| > k2\,|Ibias| - (k2 - k1)\,Is2 + Is1$

or $|I_F| > k2\,(|I_L| + 0.5\,|I_F|) - (k2 - k1)\,Is2 + Is1$
or $(1 - 0.5\,k2)\,|I_F| > (k2\,|I_L| - (k2 - k1)\,Is2 + Is1)$
or $|I_F| > (k2\,|I_L| - (k2 - k1)\,Is2 + Is1) / (1 - 0.5\,k2)$

For Is1 = 0.2 pu, k1 = 30%, Is2 = 2.0 pu and k2 = 100%, then,

For $|I_L|$ = 2.0 pu, the relay would operate if $|I_F|$ > 1.6 pu
For $|I_L|$ = 2.5 pu, the relay would operate if $|I_F|$ > 2.6 pu

Fault Resistance Coverage:
Assuming the fault resistance, R_F, is much higher than the line impedance and source impedance, then for a 33kV system and 400/1 CT:

$$|I_F| = (Vph\text{-}n / R_F) * (1/CT\ ratio)\ pu$$
$$= ((33000 / \sqrt{3}) / R_F) / 400\ pu$$
$$= 47.63/R_F\ pu$$

Based on the above analysis, the relay will detect a fault current in excess of 0.59 pu with a load current of 1 pu flowing. The fault resistance would have to be less than 47.63/0.59 = 81Ω in this case.

With a short time overload current of 2.0 pu, the relay will be able to detect a fault resistance of 47.63/1.6 = 30Ω or lower.

2.2.10 Example Setting

2.2.10.1 Differential Element

All four settings are user adjustable. This flexibility in settings allows the relay characteristic to be tailored to suit particular sensitivity and CT requirements. To simplify the protection engineer's task, we strongly recommend three of the settings be fixed to:

Is2	=	2.0 pu
k1	=	30%
k2	=	150% (2 terminal applications) or 100% (3 terminal applications)

These settings will give a relay characteristic suitable for most applications. It leaves only the Is1 setting to be decided by the user. The value of this setting should be in excess of any mismatch between line ends, if any, and should also account for line charging current, where necessary.

By considering the circuit shown in Figure 7, the settings for the phase current differential element can be established.

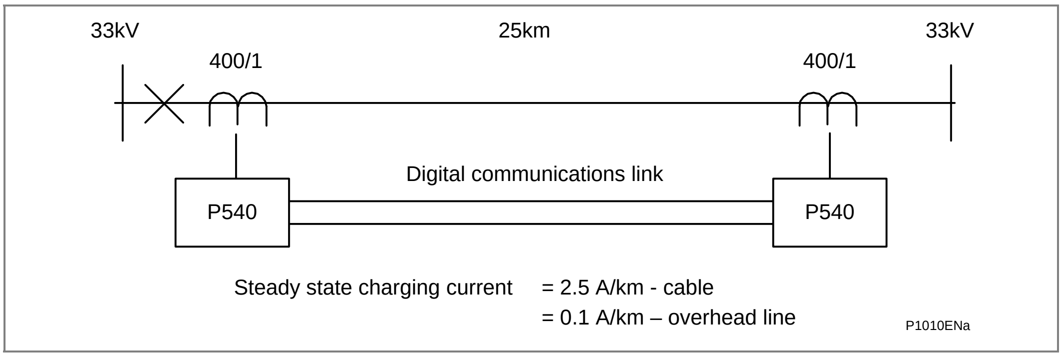

Figure 7 - Typical plain feeder circuit

The following settings should be set as follows:

Is2 = 2.0 pu
k1 = 30 %
k2 = 150 % (for a two terminal application)

This leaves the setting of Is1 to be established.

In the case of a P541 relay being used, no facility to account for line charging current is available. The setting of Is1 must therefore be set above 2.5 times the steady state charging current value. In this example, assume a cable is used:

Is1 > 2.5 x Ich

Is1 > 2.5 x (25km x 2.5 A/km)

Is1 > 156.25 A

The line CTs are rated at 400 amps primary. The setting of Is1 must therefore exceed 156.25/400 = 0.391 pu.

Therefore select:

Is1 = 0.4 pu

2.2.10.2 Transformer Feeder Examples

Ratio Correction Example:

The P541 relay is suitable for the protection of transformer feeders. An example is shown in Figure 8.

20MVA Transformer, Dyn1, 33/11kV
HV CT ratio - 400/1
LV CT ratio - 1500/1

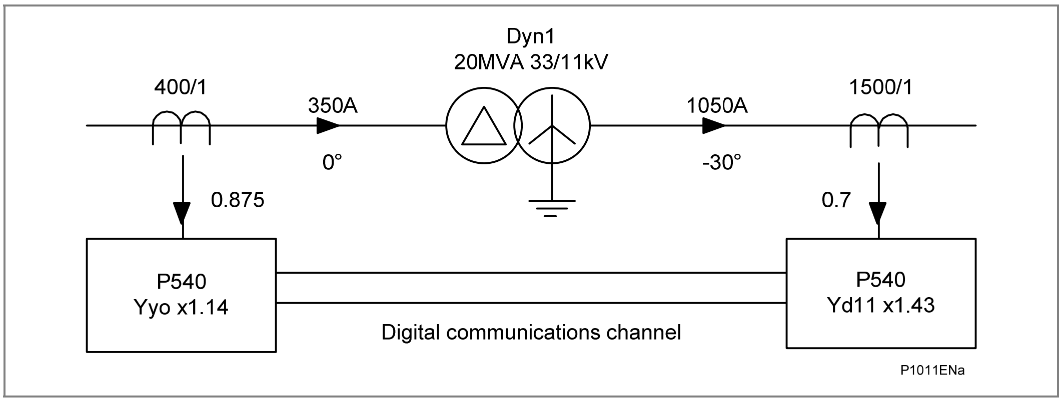

Figure 8 - Typical transformer feeder circuit

It is necessary to calculate the required ratio correction factor to apply to the relays' at each line end.

33kV full load current = 20 MVA / (33kV.$\sqrt{3}$) = 350A
Secondary current = 350 x 1/400 = 0.875A
11kV full load current = 20 MVA / (11kV.$\sqrt{3}$)= 1050A
Secondary current = 1050 x 1/1500 = 0.7A

Each of these secondary currents should be corrected to relay rated current; in this case 1A.

HV ratio correction factor 1 / 0.875 = 1.14 [Setting applied to relay]
LV ratio correction factor 1 / 0.7 = 1.43 [Setting applied to relay]

When a Star/Delta software interposing CT is chosen, no additional account has to be taken for the $\sqrt{3}$ factor which would be introduced by the delta winding. This is accounted for by the relay.

Phase Correction Example:

Using the same transformer as shown in Figure 8 it is now necessary to correct for the phase shift between the HV and LV windings.

The transformer connection shows that the delta connected high voltage line current leads the low voltage line current by 30°. To ensure that this phase shift does not create a differential current, the phase shift must be corrected in the LV secondary circuit. The LV relay software interposing CT is effectively a winding replica of the main power transformer. It not only provides a +30° phase shift, but also performs the necessary function of filtering out any LV zero sequence current component.

Hence, the HV relay setting requires no phase shift or zero sequence current filtering (as HV winding is delta connected). The LV relay setting requires phase shifting by +30° and also requires zero sequence current filtering (as LV winding is star connected).

Set:

HV = Yy0
LV = Yd11 (+30°)

It is important when considering the software ICT connection, to account for both the phase shift and zero sequence current filtering. For example, with the transformer in Figure 8, it would have been possible to provide phase compensation by applying Yd1 and Yy0 settings to the HV and LV relays respectively. Although this provides correct phase shift compensation, no zero sequence current filtering exists on the LV side and hence relay maloperation could occur for an external earth fault.

2.2.10.3 Teed Feeder Example

P541 and P542 relays can not account for charging line current, therefore the setting Is1 must be 2.5 times the steady state charging current.

2.2.10.4 Three Winding Transformer in Zone with Different Rated CTs Example

P541 and P542 relays are suitable for the protection of three winding transformers in zone. An example is shown in Figure 9.

100MVA/100MVA/30MVA Transformer, Ynyn0d1, 400kV/110kV/30kV

HV, 400kV CT ratio - 600/1

MV,110 kV CT ratio - 1200/1

LV, 30kV CT ratio - 2000/5

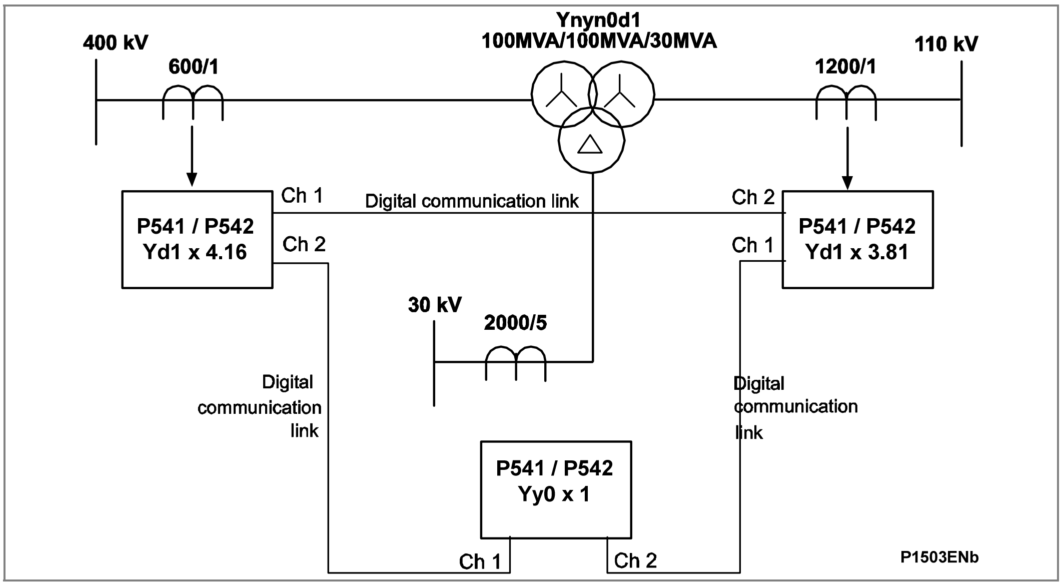

Figure 9 - Three Winding Transformer in Zone Application

These three relays must be rated differently, i.e. 1A for HV and MV side and 5 A for 30 kV side. This does not present a problem for P54x relays as the digital signals representing the currents are in pu.

It is necessary to calculate the required ratio Correction Factor (CF) as well as the phase correction factor for each end. To choose the appropriate vector compensation, it is necessary to account for phase current and zero sequence current filtering as explained in example 2.2.11.2.

To calculate the correction factor range, it is necessary to use the same MVA base for the three sides of the transformer although the third winding actually has a lower rated MVA. This is to ensure secondary current balance for all conditions.

For HV side : 100 MVA/ (400 kV.√3) = 144.34 A.

Secondary current = 144.34 x 1/600 = 0.24 A

For MV side : 100 MVA/ (110 kV.√3) = 524.86 A.

Secondary current = 524.86 x 1/1200 = 0.44 A

For LV side : 100 MVA/ (30 kV.√3) = 1924.5 A.

Secondary current =1924.5x 5/2000 = 4.81 A

Each secondary current should be corrected to relay rated current, in this case 1A for HV and MV side and 5 A for 30 kV side

HV ratio correction factor = 1/0.24 = 4.16
MV ratio correction factor = 1/0.44 = 2.29
LV ratio correction factor = 5/4.81 = 1.04

To choose the vector compensation connection, it should be noted that the Wye connected HV line is in phase with the MV line current and leads the LV line current by 30^o. Therefore for LV side, the phase shift must be compensated.

To account for the zero sequence current filtering in the case of an external earth fault, it is necessary to connect the Wye connected power transformer windings to an Interposing Current Transformer (internal relay ICT) to trap the zero sequence current (the secondary side being connected delta).

To account for both vector compensation and zero sequence current filtering, the following vectorial compensation setting is recommended:

For HV side = Yd1 (-30 deg)
For MV side = Yd1 (-30 deg)
For LV side = Yy0 (0 deg)

Note that it is not necessary to include the $\sqrt{3}$ factor in the calculation as this is incorporated in the relay algorithm.

P541 and P542 relays are suitable for transformer applications, as such an inrush restrain is provided on these relay models. By enabling inrush restrain, an additional current differential high setting (Id High set) becomes enabled.

When the inrush restrain feature is enabled, it is necessary that this function is enabled in the relay at each line end (3 ends).

For the differential calculation the same recommended settings for the previous examples are recommended:

Is1 = 0.2 In
Is2 = 2 In
K1 = 30%
K2 = 100%

Therefore, settings in secondary values are:

For relays rated to 1A (HV and MV sides) Is1 = 200 mA and Is2 = 2 A

For relay rated to 5A (LV side) Is1 = 1A and Is2 = 10 A

For the current differential high setting (Id High set) the setting must be in excess of the anticipated inrush current after ratio correction. Assuming that maximum inrush is 12 times the nominal transformer current, it would be safe to set the relays at 15 times the nominal current, therefore the setting would be:

Id high set : for HV side = 15In = 15A
for MV side = 15In = 15A
for LV side = 15In = 75 A

2.3 Phase Fault Overcurrent Protection

Phase fault overcurrent protection is provided as an alternative form of back-up protection.

The P541 and P542 relays have four overcurrent stages. The first two stages have a selectable IDMT or DT characteristic. The third and fourth stages have a DT characteristic only.

The VTS element of the relay can be selected to either block the directional element or simply remove the directional control.

The overcurrent elements will need to be co-ordinated with any other protection elements on the system, in order to provide discriminative fault clearance. The overcurrent menu column is shown in Table 5.

OVERCURRENT	Default Setting	Min	Max	Step
I>1 Status	Enabled	Disabled, Enabled, Enabled Ch Fail		
I>1 Function	IEC S Inverse	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		
I>1 Current Set	1In	0.08In	4.0In	0.01In
I>1 Time Delay	1s	0s	100s	0.01s
I>1 TMS	1	0.025	1.2	0.025
I>1 Time Dial (Software 30 or later)	1	0.1	100	0.05
I>1 Time Dial	7	0.5	15	0.1
I>1 Reset Char	DT		DT, Inverse	
I>1 tRESET	0s	0s	100s	0.01s
I>2 (Cells as for I>1 above)				
I>3 Status	Disabled	Disabled, Enabled, Enabled Ch Fail		
I>3 Current Set	1In	0.8In	32In	0.01In
I>3 Time Delay	1s	0s	100s	0.01s
I>3 Intertrip	Enabled	Enabled, Disabled		
I>4 (Cells as for I>3 above but no intertrip)				
I> Function Link (See comment below)	00001111	00000000	11111111	1

Table 5 - Overcurrent protection settings

The I> Function Link settings have the following effect:

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

A/R Block The autoreclose logic can be set to block instantaneous overcurrent elements after a prescribed number of shots. This is set in the autoreclose column when a block instantaneous signal is generated then only those overcurrent stages selected to a '1' in the I> Function Link will be blocked.

For the IDMT characteristics the following options are available.

The IEC/UK IDMT curves conform to this formula:

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

The IEEE/US IDMT curves conform to this formula:

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

t = operation time
K = constant
I = measured current
Is = current threshold setting
α = constant
L = ANSI/IEEE constant (zero for IEC curves)
T = Time multiplier setting for IEC/UK curves
TD = Time multiplier setting for IEEE/US curves

IDMT Characteristics

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

Table 6 - IDMT Curves constants

Note *The IEEE and US curves are set differently to the IEC/UK curves, with regard to the time setting. A Time Multiplier Setting (TMS) is used to adjust the operating time of the IEC curves, whereas a time dial setting is employed for the IEEE/US curves. Both the TMS and Time Dial settings act as multipliers on the basic characteristics but the scaling of the time dial is approximately 10 times that of the TMS, as shown in the previous menu. 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.*

2.3.1 Overcurrent Intertripping Feature

Where the third stage of the overcurrent protection is being used for instantaneous high set operation, it is possible to configure the relay to send an intertrip signal to the remote relay from this stage. This intertrip command is phase segregated and so can be used in conjunction with single phase tripping arrangements.

Note that when instantaneous overcurrent elements are used, they must still provide discriminative fault clearance. This must be achieved through choice of setting such that the pick up level of the element is greater than the fault level at the remote line terminal under maximum generation conditions. This will ensure that the element will only operate for faults within the protected line.

2.3.2 Overcurrent Back-up on Communication Channel Failure

An application advantage of enabling overcurrent protection following differential protection communications channel failure, is the ability to reduce back-up protection fault clearance times. This can be best demonstrated on a ring main application as shown in Figure 10.

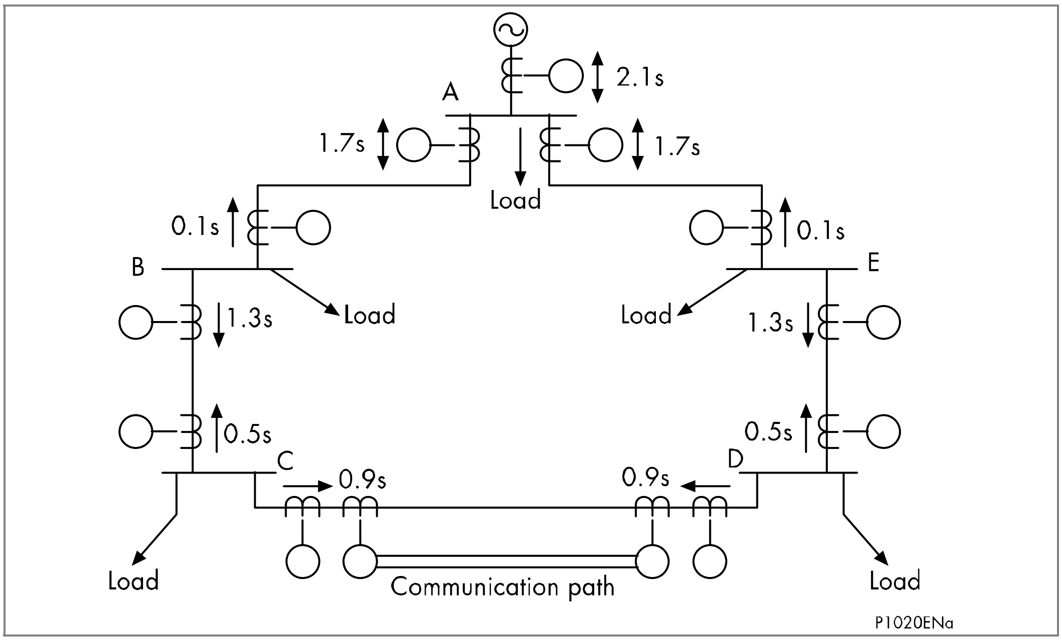

Figure 10 - Ring main application - overcurrent back-up

If Directional OverCurrent (DOC) protection were applied to the ring circuit, conventional grading of relays would lead to typical operating times as shown. This tends to result in long protection operating times, particularly at the source substation, ‘A’ (1.7s in this case).

If a differential scheme is applied to each circuit as main protection, with DOC as back-up protection, then it is possible to greatly reduce the DOC operating times. Considering the circuit between ‘C’ and ‘D’, the DOC operating times were 0.9s at each terminal respectively. If the DOC protection is only enabled when the differential communications channel has failed, then these operating times may be reduced. In this case the only overcurrent devices in service will be those associated with circuit ‘C-D’ and those on the source incomers at ‘A’. Discrimination is therefore only necessary between these relays. Hence the relays between ‘C’ and ‘D’ can be set to 0.1s, for example, and the incomer relays set to 0.5s. This principle applies equally to the other circuits around the ring such that all the relays at substations ‘B’, ‘C’, ‘D’, and ‘E’ can be given typical operating times of 0.1s.

This philosophy would work equally well with non-directional overcurrent protection, as discrimination for faults on other circuits can be maintained by the differential protection on those circuits.

The above operating times are typical only. Care must be taken when setting these relays such that discrimination is still achieved with any downstream protection on any of the load circuits.

2.3.3 Example Setting

Settings for the time delayed overcurrent element should be selected to ensure discrimination with surrounding protection. It is not intended to include a grading example in this section. Information on grading can be found in the Network Protection and Automation Guide (NPAG). The setting example shown below is thus only concerned with correct application of the second element when used to provide high speed, instantaneous protection.

It must be ensured that the element will only respond to faults on the protected line. The system under consideration is that shown in Figure 12. The worst case scenario for this is when only one of the parallel lines is in service, resulting in the largest branch current.

Two cases must be considered. The first is a fault at Blue River substation, the relay seeing fault current contribution via Green Valley, and the second is a fault at Green Valley, the relay seeing fault current contribution via Blue River.

Case 1:

Source impedance = $\frac{230^2\text{ kV}}{5000\text{ MVA}}$ = 10.58 ohms

Line impedance = 48.4 ohms

Fault current seen by relay = $\frac{230000}{\sqrt{3} * [10.58 + 48.4]}$

= 2251A

Case 2:

Source impedance = $\frac{230^2}{3000}$ = 17.63 ohms

Line impedance = 48.4 ohms

Fault current seen by relay = $\frac{230000}{\sqrt{3} * [17.63 + 48.4]}$

= 2011A

The overcurrent setting must therefore be in excess of 2251A. To provide an adequate safety margin, a setting of 130% of the minimum requirement should be chosen (i.e. 1.3 x 2251 = 2961A).

The relay is connected to a 1200/5A CT. A setting of (2961/1200) x In = 2.468 In must be chosen

Therefore set I>2 Current Set = 2.47 In

2.3.4 Directional OverCurrent (DOC) Characteristic Angle Settings

The relay uses a 90° connection angle for the DOC elements. The relay characteristic angles in this case are nominally set to:

+30° Plain feeders, zero sequence source behind relay.

+45° Transformer feeder, zero sequence source in front of relay.

2.4 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 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. Overtemperature 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.

In order to apply this protection element, the thermal time constant for the protected item of plant is therefore required.

The following sections will show that different items of plant possess different thermal characteristics, due to the nature of their construction. The relay provides two characteristics which may be selected according to the application.

2.4.1 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:

$$\exp(-t/\tau) = (I^2 - (k.I_{FLC})^2) / (I^2 - I_P^2)$$

Where:

t	=	Time to trip, following application of the overload current, I;
τ	=	Heating and cooling time constant of the protected plant;
I	=	Largest phase current;
I_{FLC}	=	Full load current rating (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».

2.4.2 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 time constants must be set. The thermal curve is defined as:

$$0.4 \exp(-t/\tau 1) + 0.6 \exp(-t/\tau 2) = (I^2 - (k.I_{FLC})^2) / (I^2 - I_P^2)$$

Where:

$\tau 1$	=	Heating and cooling time constant of the transformer windings;
$\tau 2$	=	Heating and cooling time constant for the insulating oil.

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.

Table 7 shows the menu settings for the thermal protection element:

THERMAL	Default	Min	Max	Step
Thermal Char	Single	Disabled, Single, Dual		
Thermal Trip	1In	0.08In	3.2In	0.01In
Thermal Alarm	70%	50%	100%	1%
Time Constant 1	10 minutes	1 minutes	200 minutes	1 minutes
Time Constant 2	5 minutes	1 minutes	200 minutes	1 minutes

Table 7 - Menu settings for the thermal protection element

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

2.4.3 Setting Guidelines

2.4.3.1 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 Table 8, Table 9 and Table 10. 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 τ 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

Table 8 - τ in minutes, for different voltages and conductor cross-sections

Other plant items:

	Time constant τ (minutes)	Limits
Dry-type transformers	40 60 - 90	Rating < 400 kVA Rating 400 - 800 kVA

	Time constant τ (minutes)	Limits
Air-core reactors	40	
Capacitor banks	10	
Overhead lines	10	Cross section ≥ 100 mm^2 Cu or $150mm^2$ Al
Busbars	60	

Table 9 - Other plant items

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

2.4.3.2 Dual Time Constant Characteristic

The current setting is calculated as:

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

Typical time constants:

	τ1 (minutes)	τ2 (minutes)	Limits
Oil-filled transformer	5	120	Rating 400 - 1600 kVA

Table 10 - Typical time constants

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 Table 8, Table 9 and Table 10 are typical only. Reference should always be made to the plant manufacturer for accurate information.

2.5 Earth Fault Protection

The P540 relays include backup earth fault protection. This uses a derived earth fault element (where the residual current to operate the element is derived from the addition of the three line CT currents). The derived earth fault element has four stages of protection. The first two stages can be set either inverse time or definite time only.

A feature also exists whereby the protection can be enabled upon failure of the differential protection communication channel.

The VTS element of the relay can be selected to either block the directional element or simply remove the directional control.

The earth fault elements will need to be co-ordinated with any other protection elements on the system, in order to provide discriminative fault clearance.

The earth fault menu columns are shown in Table 11.

EARTH FAULT	Default Setting	Min	Max	Step
IN>1 Status	Enabled	Disabled, Enabled, Enabled Ch Fail		
IN>1 Function	IEC S Inverse	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		

Table 11 - Derived earth fault protection settings

The IN> Function Link settings have the following effect:

VTS Block: When the relevant is set to 1, operation of the Voltage Transformer Supervision (VTS) will block the stage if it directionalized. When set to 0 the stage will revert to non-directional upon operation of the VTS.

A/R Block: The autoreclose logic can be set to block instantaneous earth fault elements after a prescribed number of shots. This is set in the autoreclose column. When a block instantaneous signal is generated then only those earth fault stages selected to a '1' in the IN> Function Link will be blocked.

The inverse time characteristic available for the earth fault protection are the same as those for the overcurrent element.

2.6 Circuit Breaker Fail (CBF) Protection

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 (CBF) 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, CBF Protection 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.

2.6.1 Breaker Failure Protection Configurations

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

Simple CBF, where only ‘CB Fail 1 Timer’ is enabled. For any protection trip, the ‘CB Fail 1 Timer’ is started, and normally reset when the circuit breaker opens to isolate the fault. If breaker opening is not detected, ‘CB Fail 1 Timer’ times out and closes an output contact assigned to breaker fail (using the PSL). 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.

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 PSL.

2.6.2 Reset Mechanisms for Breaker Fail Timers

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

Where circuit breaker auxiliary contacts are defective, or cannot be relied 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.

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 Table 12.

Initiation (menu-selectable)	CB fail timer reset mechanism
Current based protection - (e.g. 50/51/46/21/87..)	The resetting mechanism is fixed. [IA< operates] & [IB< operates] & [IC< operates] & [IN< operates]
Sensitive earth fault element	The resetting mechanism is fixed. [ISEF< operates]
External protection-	Three options are available. The user can select any or all of the options. [All I< and IN< elements operate] [External trip reset] [All I< and IN< elements operate CB open (all 3 poles) AND [All I< and IN< elements operate]

Table 12 - Resetting options

The selection in the relay menu is grouped as follows:

CB FAIL + I<	Default	Min	Max	Step
Breaker Fail (Sub-Heading)				
CB Fail 1 Status	Enabled	Enabled, Disabled		
CB Fail 1 Timer	0.2s	0s	10s	0.01s
CB Fail 2 Status	Disabled	Enabled, Disabled		
CB Fail 2 Timer	0.4s	0s	10s	0.01s
CBF Ext Reset	CB Open & I<	I< Only, CB Open & I<, Prot Reset & I<		
Under Current (Sub-Heading)				
I< Current Set	0.1In	0.02In	3.2In	0.01In
ISEF< Current	0.02In	0.001In	0.8In	0.00025In
Blocked O/C (Sub-Heading)				
Remove I> Start	Disabled	Enabled, Disabled		
Remove IN> Start	Disabled	Enabled, Disabled		

Table 13 - Selection in the relay group

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

2.6.3 Typical Settings

2.6.3.1 Breaker Fail Timer Settings

Typical timer settings to use are as follows:

CB Fail Reset mechanism	tBF time delay	Typical delay for 2½ cycle CB
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

CB Fail Reset mechanism	tBF time delay	Typical delay for 2½ cycle CB
Undercurrent elements	CB interrupting time + undercurrent element operating time (max) + safety margin	50+12+50 = 125 ms

Table 14 - Typical timer settings

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 2½ cycle circuit breaker. Note that where auxiliary tripping relays are used, an additional 10-15 ms must be added to allow for trip relay operation.

2.6.3.2 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 (SEF) protection undercurrent element must be set less than the respective trip setting, typically as follows:

ISEF< = (ISEF> trip) / 2

2.7 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 which initiate flashovers. Alternatively, they may arise from other causes such as birds on overhead lines or mechanical damage to cables etc. Such faults result in an appreciable increase in current and hence in the majority of applications are easily detectable.

Another type of unbalanced fault that can occur on the system is the series or open circuit fault. These can arise from broken conductors, maloperation of single phase switchgear, or single-phasing of fuses. Series faults will not cause an increase in phase current on the system and hence are not readily detectable by standard protection. 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.

The relay incorporates an element which measures the ratio of negative to positive phase sequence current (I2/I1). 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.

2.7.1 Setting Guidelines

When a conductor open circuit occurs, current from the positive sequence network will be series injected into the negative and zero sequence networks across the break.

In the case of 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 impedances in each sequence network), the ratio I2/I1 will be 50%.

It is possible to calculate the ratio of I2/I1 that will occur for varying system impedances, by referring to the following equations:

$$I1F = \frac{Eg\ (Z_2 + Z_0)}{Z_1 Z_2 + Z_1 Z_0 + Z_2 Z_0}$$

$$I2F = \frac{-Eg\ Z_0}{Z_1 Z_2 + Z_1 Z_0 + Z_2 Z_0}$$

Where:
Eg = System voltage
Z_0 = Zero sequence impedance
Z_1 = Positive sequence impedance
Z_2 = Negative sequence impedance

Therefore;

$$\frac{I2F}{I1F} = \frac{Z_0}{Z_0 + Z_2}$$

It follows that, for an open circuit in a particular part of the system, I2/I1 can be determined from the ratio of zero sequence to negative sequence impedance. It must be noted however, that this ratio may vary depending upon the fault location. It is desirable therefore to apply as sensitive a setting as possible. In practice, this minimum setting is governed by the levels of standing negative phase sequence current present on the system. 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. Hence, a long time delay is necessary to ensure co-ordination with other protective devices. A 60 second time delay setting may be typical.

Note that during a single pole open condition, which would occur for single phase tripping/reclosing applications, the broken conductor protection is disabled.

Table 15 shows the relay menu for the Broken Conductor protection, including the available setting ranges and factory defaults:

MENU TEXT	DEFAULT SETTING	SETTING RANGE		STEP SIZE
		MIN	MAX	
GROUP 1 BROKEN CONDUCTOR				
Broken Conductor	Disabled	Enabled/Disabled		N/A
I2/I1	1	0.2	1	0.01
I2/I1 Time Delay	0	0s	100s	1s

Table 15 - Relay menu for the Broken Conductor protection

2.7.2 Example Setting

The following information was recorded by the relay during commissioning;

$I_{full\ load}$ = 1000A

I2/I1= 50A

Therefore the quiescent I2/I1 ratio is given by;

I2/I1 = 50/1000 = 0.05

To allow for tolerances and load variations a setting of 200% of this value may be typical: Therefore set I2/I1 = 0.1

Set I2/I1 Time Delay = 60s to allow adequate time for short circuit fault clearance by time delayed protections.

2.8 Intertripping Facilities

2.8.1 Permissive InterTrip (PIT)

The P540 relays include a facility to send a Permissive InterTrip (PIT) command over the protection communication channel, as shown in Figure 11.

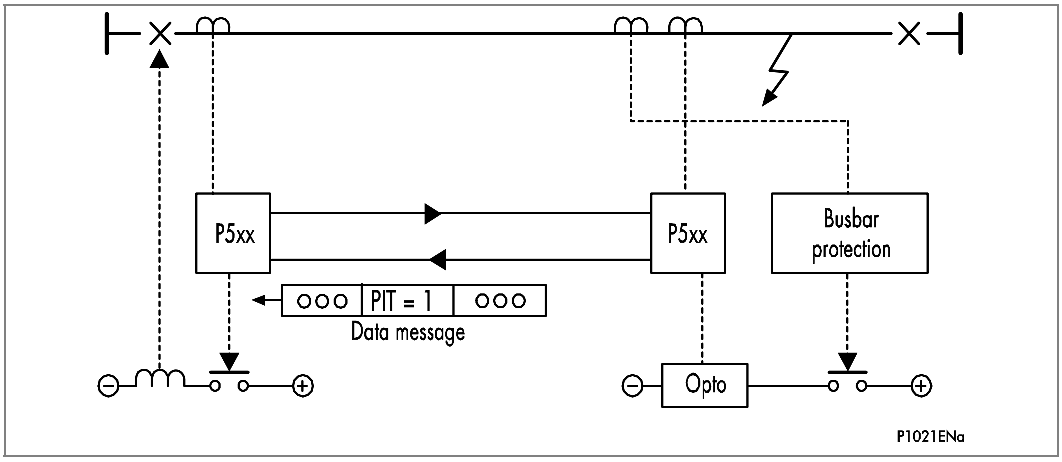

Figure 11 - Permissive intertrip

An opto input can be assigned for this purpose. When energised, the PIT flag is set in the communication message. Upon receipt of this message the remote relay initiates a timer which, when the timer, providing that the current at this end is above it's basic current threshold setting (Is1), times out, the relay closes it's three phase differential trip contacts. The remote relay provides indication of the permissive intertrip.

The permissive intertrip timer is settable between 0 and 200ms. This time should be set to provide discrimination with other protection. For example, in Figure 11, the time delay should be set to allow the busbar protection to clear the fault in the event of a genuine busbar fault. A typical setting may be 100 - 150ms.

2.8.2 User Defined Intertrip/Inter-Relay Commands

The P540 relays include a facility to send 8 user defined commands per channel over the protection communication channel.

These commands can be used for direct intertripping as explained below or alternatively can be used for applications such as distance and DEF aided channel schemes, breaker fail backtripping to upstream circuit breakers, forcing remote end autoreclosing for successful local autoreclosure or providing SCADA information from the remote end substation. In such applications the functionality of each of the 8 bits in P540 relay's data message is programmed in the PSL. The logic condition to assert a logic "1" for transmitting each bit, and the response of the relay upon receipt of an active bit must both be set.

2.8.2.1 Direct Intertrip

This is an example of user defined intertripping. The P540 relays include a facility to send a direct intertrip command over the protection communication channel as shown in Figure 12.

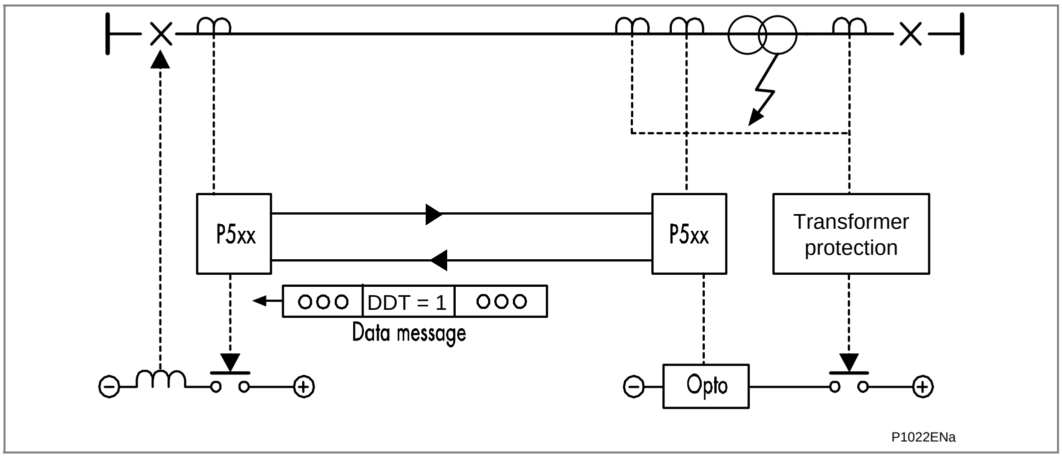

Figure 12 - Direct intertrip

An opto input can be assigned for this purpose. When energised, the DIT flag is set in the communication message. Upon receipt of this message the remote relay will operate a user specified output contact. The remote relay will also provide indication of the direct intertrip. Indication at the local terminal would be provided by the initiating device.

3 APPLICATION OF NON PROTECTION FUNCTIONS

3.1 Three Phase Auto-Reclosing (Applicable to P542)

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 flash-over, 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-energised. 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 semi-permanent fault could be caused by a small tree branch falling on the line. Here the cause of the fault would not be removed by the immediate tripping of the circuit, but could be burnt away during a time delayed trip.

Permanent faults could be broken conductors, transformer faults, cable faults or machine faults which must be located and repaired before the supply can be restored.

In the majority of fault incidents, if the faulty line is immediately tripped out, and time is allowed for the fault arc to de-ionize, reclosure of the circuit breakers will result in the line being successfully re-energised. Autoreclose 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, autoreclosing is applied mainly to radial feeders where system stability problems do not generally arise. The main advantages to be derived from using autoreclose 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 autoreclose instantaneous protection can be used which means shorter fault duration's which gives rise to less fault damage and fewer permanent faults.

As 80% of overhead line faults are transient, elimination of loss of supply from such faults, by the introduction of autoreclosing gives obvious benefits. Furthermore, auto-reclosing may allow a particular substation to be run unattended. In the case of unattended substations, the number of visits by personnel to reclose a circuit breaker manually after a fault can be substantially reduced, an important consideration for substations in remote areas.

The introduction of autoreclosing 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 autoreclosing, the scheme is normally arranged to block the instantaneous protection after the first trip. Therefore, if the fault persists after reclosure, 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 the 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 which 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 reclosing on to a faulty cable is likely to aggravate the damage.

Table 16 shows the relay settings for the auto-reclose function, including the available setting ranges and factory defaults:

MENU TEXT	DEFAULT SETTING	SETTING RANGE		STEP SIZE
		MIN	MAX	
CB CONTROL				
AR Telecontrol	No Operation (Control Cell)	Auto/Non Auto		
AR Status	Auto	Auto/ Non Auto	Indicates if AR is enabled or not, as selected by AR Telecontrol	
Total Reclosures	X		Total number of AR closures performed by the relay	
Reset Total A/R	No (Control Cell)		No/Yes	
GROUP 1: AUTORECLOSE				
Number of Shots	1	1	4	1
Dead Time 1	10s	0.01s	300s	0.01s
Dead Time 2	60s	0.01s	300s	0.01s
Dead Time 3	180s	0.01s	9999s	0.01s
Dead Time 4	180s	0.01s	9999s	0.01s
CB Healthy Time	5s	0.01s	9999s	0.01s
tReclaim Extend	Continue	Suspend/Continue		
Reclaim Time	180s	1s	600s	0.01s
AR Inhibit Time	5s	0.01s	600s	0.01s
EFF Maint Lock	Allow Tripping	Allow Tripping/ Block Tripping		
Trip 1 Main	No Block	No Block/ Block Inst Prot		
Trip 2 Main	Block Inst Prot	No Block/Block Inst Prot		
Trip 3 Main	Block Inst Prot	No Block/ Block Inst Prot		
Trip 4 Main	Block Inst Prot	No Block/ Block Inst Prot		
Trip 5 Main	Block Inst Prot	No Block/ Block Inst Prot		
Reset Lockout by	User Interface	User Interface, Select NonAuto		
AR INITIATION	Sub Heading			
Phase Diff AR	Initiate AR	No Action/Initiate AR/Block AR		
Neutral Diff AR	No Action	No Action/Initiate AR/Block AR		
I>1 AR	No Action	No Action/Initiate AR/Block AR		
I>2 AR	No Action	No Action/Initiate AR/Block AR		
I>3 AR	No Action	No Action/Initiate AR/Block AR		
I>4 AR	No Action	No Action/Initiate AR/Block AR		
IN>1 AR	No Action	No Action/Initiate AR/Block AR		
IN>2 AR	No Action	No Action/Initiate AR/Block AR		

MENU TEXT	DEFAULT SETTING	SETTING RANGE		STEP SIZE
		MIN	MAX	
IN>3 AR	No Action	No Action/Initiate AR/Block AR		
IN>4 AR	No Action	No Action/Initiate AR/Block AR		

Table 16 - Relay settings for the auto-reclose function

In addition to these settings, function links in the OVERCURRENT AND EARTH FAULT columns are also required to fully integrate the autoreclose logic in the relay. Refer to the relevant sections in this manual.

CB Status signals must also be available within the relay.

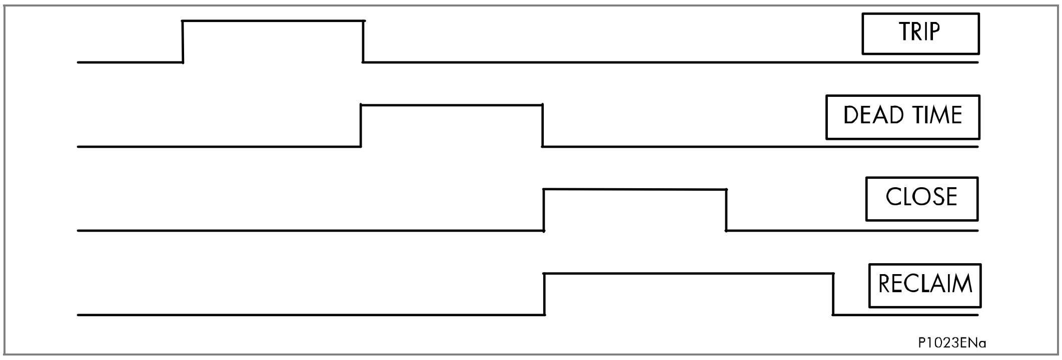

Figure 13 - P542 Auto Reclose Timing Diagram

3.1.1 Logic Functions

3.1.1.1 Opto-Isolated Logic Inputs

The autoreclose function uses three inputs in the logic, which can be allocated to any of the opto-isolated inputs on the relay via the PSL. Contacts from external equipment may be used to influence the auto-recloser via such inputs. The function of these inputs is described below, identified by their DDB signal text.

The inputs can be selected to accept either a normally open or a normally closed contact, programmable via the PSL editor.

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 sufficient energy in the circuit breaker before the CB can be reclosed. The DDB 296: 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, sufficient energy is not detected by the relay from the DDB 296: CB Healthy input 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 to this function, and deliberate application of a logic “1” onto this DDB signal within the PSL. Assigning a PSL gate with no inputs and an inverted output will mean that the signal is always high, and the circuit breaker deemed to be “healthy”. Alternatively, it is possible to energize the CB healthy opto input from a circuit breaker open auxiliary contact (52b).

BAR

The DDB 308: BAR input will block autoreclose and cause a lockout if autoreclose is in progress. It can be used when protection operation without autoreclose is required. A typical example is on a transformer feeder, where autoreclosing may be initiated from the feeder protection but blocked from the transformer protection.

Reset Lockout

The DDB 306: Reset Lockout input can be used to reset the autoreclose function following lockout and reset any autoreclose alarms, provided that the signals which initiated the lockout have been removed.

3.1.1.2 Autoreclose Logic Outputs

The following DDB signals can be masked to a relay contact in the PSL or assigned to a Monitor Bit in Commissioning Tests, to provide information about the status of the autoreclose cycle. These are described below, identified by their DDB signal text.

AR in Progress

The DDB 531: AR 3 pole in Progress signal is present during the complete reclose cycle from initiation to the end of the reclaim time.

Successful Close

The DDB 539: Successful Close output indicates that an autoreclose cycle has been successfully completed. A successful autoreclose 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 autoreclose cycle. The successful autoreclose output is reset at the next CB trip or from one of the reset lockout methods; see Section 0 'Reset from lockout'.

AR Status

The DDB 542: AR Status output indicates whether the autoreclose is in or out of service. Autoreclose is in service when the relay is in Auto mode and out of service when in the Non Auto mode.

Block Main Prot

The DDB 529: Block Main Prot output indicates that the instantaneous protection (I>3, I>4, IN>3, IN>4) is being blocked by the autoreclose logic during the autoreclose cycle. Blocking of the instantaneous stages for each trip of the autoreclose cycle is programmed using the Overcurrent and Earth Fault function link settings, I> Function Link, IN> Func Link and the Trip 1/2/3/4/5 Main settings.

Dead T in Prog

The DDB 540: Dead T in Prog output indicates that the dead time is in progress. This signal may be useful during relay commissioning to check the operation of the autoreclose cycle.

Auto-Close

The DDB 541: Auto Close output indicates that the autoreclose logic has issued a close signal to the CB. This output feeds a signal to the control close pulse timer and remains on until the CB has closed. This signal may be useful during relay commissioning to check the operation of the autoreclose cycle.

3.1.1.3 Auto Reclose Alarms

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

AR CB Unhealthy (Latched)

The DDB 164: AR CB Unhealthy alarm indicates that the DDB 296: CB Healthy input was not energised at the end of the CB Healthy Window time, leading to a lockout condition.

The DDB 296: 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 'Reset from lockout'.

AR Lockout (Self Reset)

The DDB163: AR Lockout alarm indicates that the relay is in a lockout status and that further reclose attempts will not be made; see Section 3.1.3.6 'AR Lockout' for more details. This alarm can be reset using one of the reset lockout methods; see'Reset from lockout'.

3.1.2 Auto-Reclose Logic Operating Sequence

The autoreclose function provides multishot three phase autoreclose control. It can be adjusted to perform a single shot, two shot, three shot or four shot cycle, selectable via Number of Shots. Dead times for all shots (reclose attempts) are independently adjustable. The number of shots is directly related to the type of faults likely to occur on the system and the voltage level of the system. Generally, on medium voltage networks where the percentage of transient and semi-permanent faults is likely to be high, a multi-shot autoreclose device will increase the possibility of the distribution line being successfully re-energised following reclosure of the circuit breaker. For more information, please refer to Section 3.1.4 'Setting guidelines'.

An autoreclose cycle is internally initiated by operation of a protective element, provided the circuit breaker is closed until the instant of protection operation. The dead time (Dead Time 1, Dead Time 2, Dead Time 3, and Dead Time 4) starts when the protection has reset. 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, from the internal check synchronizing element and that the circuit breaker closing spring, or other energy source, is fully charged indicated from the DDB 296: CB Healthy input. The CB close signal is cut-off when the circuit breaker closes.

When the CB has closed the reclaim time (Reclaim Time) starts. If the circuit breaker does not trip again, the autoreclose 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 autoreclose cycle, or, if all programmed reclose attempts have been made, goes to lockout.

The total number of autoreclosures is shown in the CB Control menu under Total Reclosures. This value can be reset to zero with the Reset Total A/R command.

For more information please refer to setting guidelines.

3.1.3 Main Operating Features

3.1.3.1 Operation Modes

The autoreclose function has two operating modes:

- AUTO — Autoreclose is in service
- NON AUTO — Autoreclose is out of service

A/R Telecontrol, under the CB CONTROL column, can be used to temporarily disable the autoreclose function, as may be required during CB maintenance. This is achieved by setting A/R Telecontrol to Non-Auto. Autoreclose can be re-enabled by setting A/R Telecontrol to Auto.

The enabled/disabled status of the autoreclose function can be checked by viewing the AR Status cell under the CB CONTROL column.

3.1.3.2 Autoreclose Initiation

Autoreclose is initiated from the internal protection on the relay. Each stage of overcurrent and earth fault protection can be programmed to initiate autoreclose, Initiate AR, not initiate autoreclose, No Action, or for high set instantaneous stages, block autoreclose, 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. For example if I>1 is set to Initiate Main AR, operation of the I>1 protection stage will initiate autoreclose; if IN>1 is set to No Action, operation of the IN>1 protection stage will lead to a CB trip but no reclose.

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

3.1.3.3 Blocking Instantaneous Protection during Autoreclose Cycle

Instantaneous protection may be blocked during each for each trip in the autoreclose cycle. This is selected using the Trip 1/2/3/4/5 Main settings. These allow the Instantaneous elements of phase and earth fault protection to be selectively disabled 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 enabled during normal healthy line conditions but will be blocked for the first shot of autoreclose following a protection operation.

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 Protection the instantaneous protection will be blocked for the last CB Trip before lockout occurs.

Note	*The instantaneous protection stages must be identified in the Overcurrent, Earth Fault function link settings, I> Function Link, IN> Func Link, respectively.*

3.1.3.4 Reclaim Timer Initiation

The tReclaim on Strt setting allows the user to control whether the timer is suspended from the protection element start or not. When a setting of Continue 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 time delayed protection can operate before the autoreclose function is reset. If the autoreclose 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 on Strt to Suspend. This facility allows the operation of the reclaim timer to be suspended, after CB reclosure, 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 AR (initiate autoreclose) or No Action (not initiate autoreclose) from the AR Initiation settings. This feature ensures that the reclaim time cannot time out and reset the autoreclose before the time delayed protection has operated. Since the Reclaim Timer will be suspended, it is unnecessary to use a timer setting in excess of the protection operating time, therefore a short reclaim time can be used. Short reclaim time settings can help to prevent unnecessary lockout for a succession of transient faults in a short period, for example during a thunderstorm. For more information, please refer to Section 3.1.4 ‘Setting guidelines’.

3.1.3.5 Autoreclose Inhibit Following Manual Close

The "AR Inhibit Time" timer setting can be used to prevent autoreclose being initiated when the CB is manually closed onto a fault. Autoreclose is disabled for the AR Inhibit Time following manual CB Closure.

3.1.3.6 AR lockout

If protection operates during the reclaim time, following the final reclose attempt, the relay will be driven to lockout and the autoreclose function will be disabled until the lockout condition is reset. This will produce an alarm, DDB163: AR Lockout. The DDB 308: BAR input will block autoreclose and cause a lockout if autoreclose is in progress.

Lockout will also occur if the CB energy is low and the CB fails to close, i.e. the CB Healthy input has not operated at the end of the CB Healthy Time, as indicated by DDB 164: AR CB Unhealthy alarm.

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 and CB failed to close and manual close no check synchronism and CB unhealthy.*

Reset from Lockout

The DDB 188: Reset Lockout input can be used to reset the autoreclose function following lockout and reset any autoreclose 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 is used to enable/ disable reset of lockout automatically from a manual close after the manual close time AR Inhibit Time.

3.1.4 Setting Guidelines

3.1.4.1 Number of Shots

There are no clear-cut rules for defining the number of shots for any particular application. In general, medium voltage systems use only two or three shot autoreclose 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.
- If statistical information on a particular system shows a moderate percentage of semi-permanent faults which could be burned out, two or more shots are justified. In addition to this, if fused ‘tees’ are used and the fault level is low, the fusing time may not discriminate with the main IDMT relay and it would then be useful to have several shots. This would warm up the fuse to such an extent that it would eventually blow before the main protection operated.

3.1.4.2 Dead Timer Setting

The factors which influence the choice of dead timer setting are detailed next.

Load

Due to the great diversity of load which may exist on a system it may prove very difficult to arrive at an optimum dead time. However, it is possible to address each type of load individually and thereby arrive at typical dead time. The most common types of load are addressed below;

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 should be sufficient to allow the motor no-volt device to operate. Typically, a minimum dead time of 0.2-0.3 seconds has been suggested to allow this device to operate. Induction motors, on the other hand, can withstand supply interruptions, up to a maximum of 0.5 seconds and re-accelerate successfully. In general dead times of 3-10 seconds are normally satisfactory, but there may be special cases for which additional time is required to permit the resetting of manual controls and safety devices.

Loss of supply to lighting circuits, such as street lighting may be important for safety reasons as intervals of 10 seconds or more may be dangerous for road traffic. The main considerations for domestic customers are those of inconvenience. An important measurement criteria for many power utilities is the number of minutes lost per year to customers which will be reduced on feeders using autoreclose and will also be affected by the dead time settings used.

These are only suggested guidelines, for more information please refer to the NPAG.

Circuit Breaker

For high-speed autoreclose 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.

Since a circuit breaker is a mechanical device, it will have an inherent contact separation time. This operating time for a modern circuit breaker is usually within the range of 50-100ms, but could be longer with older designs.

After tripping, time must be allowed for the mechanism to reset before applying a closing pulse. This resetting time will vary depending on the circuit breaker, but is typically 0.1 seconds.

Once the circuit breaker has reset, the breaker can begin to close. 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 the 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 0.2 seconds.

Where high speed reclosing is required, for the majority of medium voltage applications, the circuit breaker mechanism itself dictates the minimum dead time. However, the fault de-ionizing time may also have to be considered. High-speed autoreclose may be required to maintain stability on a network with two or more power sources. For high-speed autoreclose the system disturbance time should be minimized by using fast protection, <50 ms, such as distance or feeder differential protection and fast circuit breakers < 100 ms. Fast fault clearance can reduce the required fault arc de-ionizing time. For stability between two sources a dead time of <300 ms may typically be required. The minimum system dead time only considering the CB is the mechanism reset time plus the CB closing time. A solenoid mechanism will not be suitable for high-speed autoreclose as the closing time is generally too long.

Fault De-Ionizing Time

For high-speed autoreclose 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. This can be approximated from:

De-ionizing time = (10.5 + ((system voltage in kV) / 34.5)) / frequency

For 66 kV = 0.25 s (50Hz)

For 132 kV = 0.29 s (50 Hz)

Protection Reset

It is essential that the protection fully resets during the dead time, so that correct time discrimination will be maintained after reclosure onto a fault. For high-speed autoreclose instantaneous reset of protection is required.

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 - 100 seconds

4th dead time = 60 - 100 seconds
(uncommon in the UK, however elsewhere such as in South Africa)

3.1.4.3 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 autoreclose the reclaim time may be set longer than the spring charging time to ensure there is sufficient energy in the circuit breaker to perform a trip-close-trip cycle. For delayed autoreclose there is no need as the dead time can be extended by an extra CB healthy check window time if there is insufficient energy in the CB. If there is insufficient energy after the check window time the 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.

The reclaim time must be long enough to allow any time delayed protection initiating autoreclose to operate. Failure to do so would result in premature resetting of the autoreclose scheme and re-enabling of instantaneous protection. If this condition arose, a permanent fault would effectively look like a number of transient faults, resulting in continuous autoreclosing unless additional measures were taken to overcome this such as excessive fault frequency lockout protection. It is possible to have short reclaim times by blocking the reclaim time from the protection start signals. If short reclaim times are to be used then the switchgear rating may dictate the minimum reclaim time. The advantage of a short reclaim time is that there are less lockouts of the CB, however, there will be more CB operations and so maintenance periods would be reduced.

Where motor-wound spring closed circuit breakers are used, the reclaim time must be at least as long as the spring winding time for high-speed autoreclose to ensure that the breaker can perform a trip-close-trip cycle.

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 Autoreclose /Check Synchronization Interface (Software 20 and later)

Output signals from the internal system check function and signals from an external system check device are combined and made available as two internal inputs to the autoreclose function. One internal input permits autoreclose based on system check conditions being met. The other internal input permits immediate autoreclose based on check synchronism conditions being met, if this feature is enabled (CS AR Immediate).

If an external system check device is to be used with the internal autoreclose function then logic inputs are available for the purpose and can be assigned to opto-isolated inputs using the PSL. These logic inputs are:

- AR Check Synch OK
- AR System Check OK/SYNC

3.3 Circuit Breaker State Monitoring

An operator at a remote location requires a reliable indication of the state of the switchgear. Without an indication that each circuit breaker is either open or closed, the operator has insufficient information to decide on switching operations. 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.

3.3.1 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 these 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 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 options:

None 52A 52B Both 52A and 52B	P541 & P542

Table 17 - CB Status Input Cell Options

Selection of the inputs used for CB status is user definable in the CB Status Input cell under the CB control menu. The inputs used to determine the circuit breakers status can be either 52a and/or 52b contacts for single or three pole.

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 Table 18. 52A and 52B inputs are assigned to relay opto-isolated inputs via the PSL.

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

Table 18 - Auxiliary Contact Positions, CB States Detected and Action

Where single pole tripping is used (available on certain relays only) then an open breaker condition will only be given if all three phases indicate and open condition. Similarly for a closed breaker condition indication that all three phases are closed must be given. For single pole tripping applications 52A-a, 52A-b and 52A-c and/or 52B-a, 52B-b and 52B-c inputs should be used.

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.

The 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.

3.4.1 Circuit Breaker Condition Monitoring Features

For each circuit breaker trip operation the relay records statistics as shown in Table 19 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:

CB Condition	Default	Min	Max	Step
CB operations (3 pole tripping)	0	0	10000	1
CB A operations (1 & 3 pole tripping)	0	0	10000	1
CB B operations (1 & 3 pole tripping)	0	0	10000	1
CB C operations (1 & 3 pole tripping)	0	0	10000	1
Total IA Broken	0	0	25000In^	1
Total IB Broken	0	0	25000In^	1
Total IC Broken	0	0	25000In^	1In^
CB operate time	0	0	0.5s	0.001
Reset CB Data	No	Yes, No		

Table 19 - CB Condition values

The above counters may be reset to zero, for example, following a maintenance inspection and overhaul.

Table 20, detailing the options available for the CB condition monitoring, is taken from the relay menu. It includes the setup of the current broken facility and those features which can be set to raise an alarm or CB lockout.

CB Monitor Setup	Default	Min	Max	Step
Broken I^	2	1	2	0.1
I^ Maintenance	Alarm	Alarm disabled, Alarm enabled disabled		
I^ Maintenance	1000In^	1In^	25000In^	1In^
I^ Lockout	Alarm	Alarm disabled, Alarm enabled disabled		
I^ Lockout	2000In^	1In^	25000In^	1In^
No CB ops maint	Alarm	Alarm disabled, Alarm enabled disabled		
No CB ops maint	10	1	10000	1
No CB ops lock	Alarm	Alarm disabled, Alarm enabled disabled		
No CB ops lock	20	1	10000	1
CB time maint	Alarm	Alarm disabled, Alarm enabled disabled		
CB time maint	0.1s	0.005s	0.5s	0.001s
CB time lockout	Alarm	Alarm disabled, Alarm enabled disabled		
CB time lockout	0.2s	0.005s	0.5s	0.001s

CB Monitor Setup	Default	Min	Max	Step
Fault freq lock	Alarm	Alarm disabled, Alarm enabled disabled		
Fault freq count	10	0	9999	1
Fault freq time	3600s	0	9999s	1s

Table 20 - CB Monitor Setup values

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 PSL) to accept a trigger from an external device. The signal that is mapped to the opto is called ‘External Trip’.

Note	*The CB condition monitoring counters will not be updated, when in Commissioning test mode.*

3.4.2 Setting Guidelines

3.4.2.1 Setting the Σ I^ Thresholds

Where overhead lines are prone to frequent faults and are protected by Oil Circuit Breakers (OCBs), 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 Σ 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 OCBs, the dielectric withstand of the oil generally decreases as a function of $\Sigma I^2 t$. 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 programme must be fully compliant with the switchgear manufacturer’s instructions.

3.4.2.2 Setting the Number of Operations Thresholds

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 autoreclose 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 (OCBs) 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 autoreclosure when repeated further fault interruptions could not be guaranteed. This minimizes the risk of oil fires or explosion.

3.4.2.3 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.

3.4.2.4 Setting the Excessive Fault Frequency Thresholds

A circuit breaker may be rated to break fault current a set number of times before maintenance is required. However, successive circuit breaker operations in a short period of time may result in the need for increased maintenance. 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 Circuit Breaker Control

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

- Local tripping and closing, via the relay menu
- Local tripping and closing, via relay opto-isolated inputs
- Remote tripping and closing, using the relay communications
- Local tripping via the hot keys on the user interface (from software 20 and onwards)

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 14. Where this feature is not required the same output contact(s) can be used for both protection and remote tripping.

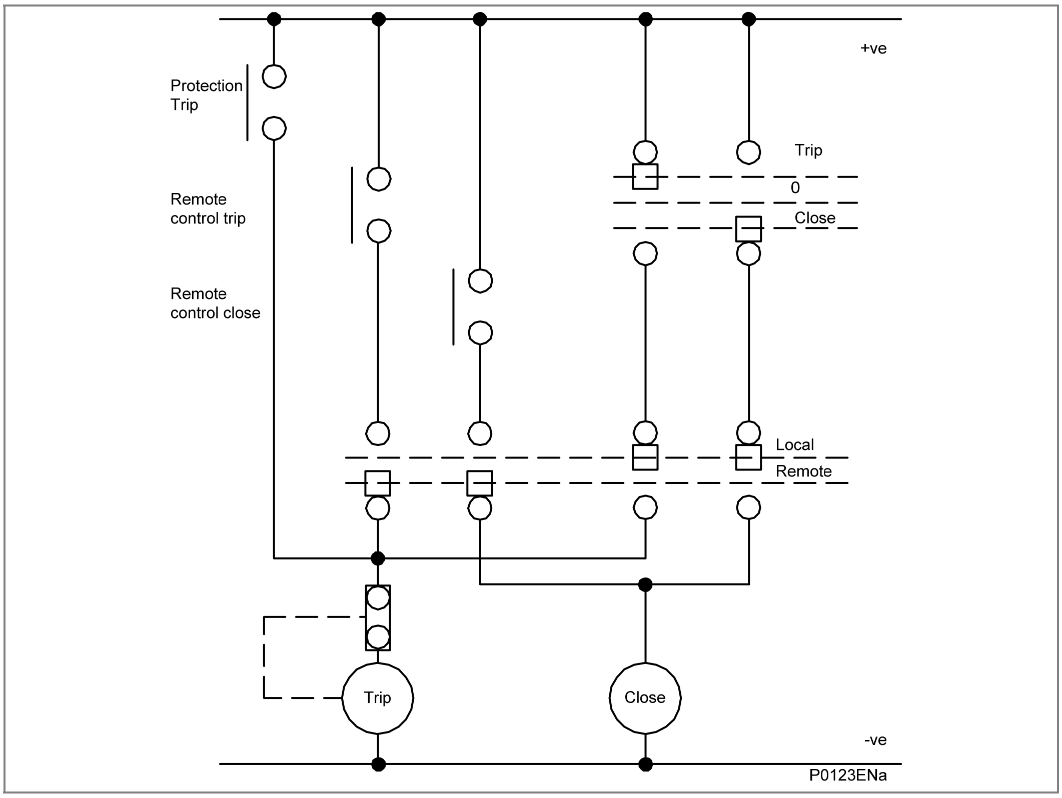

Figure 14 - Remote control of circuit breaker

Table 21 is taken from the relay menu and shows the available settings and commands associated with circuit breaker control. Depending on the relay model some of the cells may not be visible:

CB Control	Default	Min	Max	Step
CB Control by	Disabled	Disabled, Local, Remote, Local+Remote, Opto, Opto+local, Opto+Remote, Opto+Rem+local		
Close pulse time	0.5s	0.01s	10s	0.01s
Trip pulse time	0.5s	0.01s	5s	0.01s
Man close delay	10s	0.01s	600s	0.01s
CB Healthy Time	5s	0.01s	9999s	0.01s
Check Synch Time	5s	0.01s	9999s	0.01s
Lockout reset	No	No, Yes		
Reset lockout by	CB Close	User Interface, CB Close		
Man close RstDly	5s	0.01s	600s	0.01s
A/R Telecontrol	No operation	No operation, auto, non-auto (refer to autoreclose notes for further information)		
Single pole (1&3 pole A/R only)	Disabled	Disabled, enabled (refer to autoreclose notes for further information)		
Three pole (1&3 pole A/R only)	Enabled	Disabled, enabled (refer to autoreclose notes for further information)		
A/R status (Indication of current mode only)	Auto Mode	Auto mode, non-auto mode (refer to autoreclose notes for further information)		
Total reclosures	0	0	10000	1
Reset total A/R	No	No, Yes		

CB Control	Default	Min	Max	Step
CB status input (P541, P542)	None	None, 52A, 52B, Both 52A and 52B		

Table 21 - Available settings and commands associated with CB control

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’ cell above). 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 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 of the 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 checksynch 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 (‘Healthy Window’) 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.

Where auto-reclose is used it may be desirable to block its operation when performing a manual close. In general, the majority of faults following a manual closure will be permanent faults and it will be undesirable to auto-reclose. The ‘Man Close RstDly’ timer setting is the time for which auto-reclose will be disabled following a manual closure of the breaker.

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 PSL.

Note that the ‘Healthy Window’ timer and ‘C/S Window’ 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.

3.5.1 CB Control using “Hotkeys” (Software 20 and onwards)

The hotkeys allow direct access to the manual trip and close commands without the need to enter the SYSTEM DATA column. The CB trip and close functionality via the hotkey menu is identical to that of the SYSTEM DATA menu.

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 15 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.

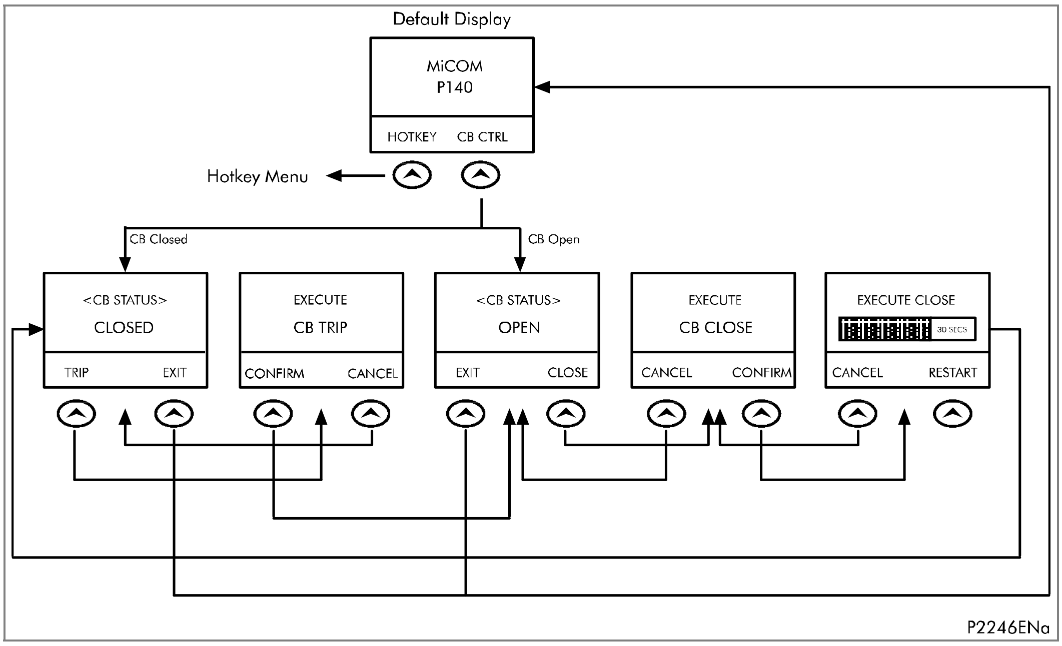

Figure 15 - CB Control hotkey menu

3.6 Event and Fault Records

The relay records and time tags up to 512 events (from software 20 and 250 events for software 13 or previous) 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.

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 below:

VIEW RECORDS	
LCD Reference	**Description**
Select Event	Setting range from 0 to 511 (for software 20. 249 for software 13 or previous). This selects the required event record from the possible 512 (for software 20. 250 for software 13 or previous) 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 4. This selects the required fault record from the possible 5 that may be stored. A value of 0 corresponds to the latest fault and so on.
	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.
Maint Type	These cells are numbers representative of the occurrence. They form a specific error code which should be quoted in any related correspondence to Schneider Electric.
Maint Data	
Reset Indication	Either Yes or No. This serves to reset the trip LED indications provided that the relevant protection element has reset.

Table 22 - View Records

For extraction from a remote source via communications, refer to the SCADA Communications chapter (P54x/EN CT), where the procedure is fully explained.

Note that a full list of all the event types and the meaning of their values is given in the Relay Menu Database publication.

3.6.1 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:

3.6.1.1 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”
```

The Event Value is an 8 or 16 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.

3.6.1.2 Change of State of one or more Output Relay Contacts

If one or more of the output relay contacts has 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 here:

```
Time & Date of Event
“OUTPUT CONTACTS”
“Event Value
010101010101010101010”
```

The Event Value is a 7, 14 or 21 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.

3.6.1.3 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 shown here:

Alarm Condition	Resulting Event	
	Event Text	Event Value
Battery Fail	Battery Fail ON/OFF	Number from 0 to 31
Field Voltage Fail	Field V Fail ON/OFF	Number from 0 to 31
Setting group via opto invalid	Setting Grp Invalid ON/OFF	Number from 0 to 31
Protection Disabled	Prot’n Disabled ON/OFF	Number from 0 to 31
Frequency out of range	Freq out of Range ON/OFF	Number from 0 to 31
VTS Alarm	VT Fail Alarm ON/OFF	Number from 0 to 31
CB Trip Fail Protection	CB Fail ON/OFF	Number from 0 to 31
User Alarm (Self Reset) software 12 or later	SR User Alarm X* ON/OFF	Number from 47 to 54
User Alarm (Manual Reset) software 12 or later	MR User Alarm Y* ON/OFF	Number from 55 to 63
*X in range 1 to 8, Y in range 9 to 16		

Table 23 - Relay alarm conditions

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.

3.6.1.4 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.

3.6.1.5 General Events

A number of events come under the heading of 'General Events' - an example is shown here:

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	UI=6, F=11, R=16, R2=38

Table 24 - Example of general events

A complete list of the 'General Events' is given in the Relay Menu Database publication (P54x/EN MD/H53).

3.6.1.6 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.

3.6.1.7 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 5 such 'events' and is accessed from the 'Select Maint' 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 and in further detail in Menu Database publication (P54x/EN MD/H53).

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.

3.6.1.8 Setting Changes

Changes to any setting within the relay are logged as an event. Two examples are shown here:

Type of Setting Change	Displayed Text in Event Record	Displayed Value
Control/Support Setting	C & S Changed	0

Type of Setting Change	Displayed Text in Event Record	Displayed Value
Group 1 Change	Group 1 Changed	1

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'.*

Table 25 - Example of events

3.6.2 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.

3.6.3 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 November 2000 15:32:49 GMT I>1 Start ON 2147483881

Schneider Electric: MiCOM

Model Number: P541

Address: 001 Column: 00 Row: 23

Event Type: Protection operation

Monday 03 November 2000 15:32:52 GMT Fault Recorded 0

Schneider Electric: MiCOM

Model Number: P541

Address: 001 Column: 01 Row: 00

Event Type: Fault record

Monday 03 November 2000 15:33:11 GMT Logic Inputs 00000000

Schneider Electric: MiCOM

Model Number: P541

Address: 001 Column: 00 Row: 20

Event Type: Logic input changed state

Monday 03 November 2000 15:34:54 GMT Output Contacts 0010000

Schneider Electric: MiCOM

Model Number: P541

Address: 001 Column: 00 Row: 21

Event Type: Relay output changed state

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 the Relay Menu Database publication (P54x/EN MD).

3.6.4 Event Filtering

It is possible to disable the reporting of events from any user interface that supports setting changes. The settings which control the various types of events are in the Record Control column.

The effect of setting each to disabled is as follows:

Alarm Event	None of the occurrences that produce an alarm will result in an event being generated. The presence of any alarms is still reported by the alarm LED flashing and the alarm bit being set in the communications status byte. Alarms can still be read using the Read key on the relay front panel.
Relay O/P Event	No event will be generated for any change in relay output state.
Opto Input Event	No event will be generated for any change in logic input state.
General Event	No General Events will be generated.
Fault Rec Event	No event will be generated for any fault that produces a fault record. The fault records can still be viewed by operating the “Select Maint” setting in column 0100.
Protection Event	Any operation of protection elements will not be logged as an event.

Table 26 - Effects of alarm events

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.

3.7 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 is dependent upon the selected recording duration but the relays typically have the capability of storing a minimum of 50 records (for software 20. 20 for software 13 or previous), each of 0.5 (for software 20. 10.5 for software 13 or previous) seconds duration. 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.

The recorder stores actual samples which are taken at a rate of 24 (for software 20. 12 for software 13 or previous) samples per cycle.

Each disturbance record consists of eight analogue data channels and thirty-two digital data channels. Note that the relevant CT and VT ratios for the analogue channels are also extracted to enable scaling to primary quantities).

Note	*When a 5A CT is used it must be ensured that the CT ratio entered is ≥ 5:5 to ensure correct operation of the disturbance recorder.*

The ‘DISTURBANCE RECORDER’ menu column is shown in Table 27:

MENU TEXT	DEFAULT SETTING	SETTING RANGE		STEP SIZE
		MIN	MAX	
DISTURB RECORDER				
Duration	1.5s	0.1s	10.5s	0.01s
Trigger Position	33.3%	0	100%	0.1%
Trigger Mode	Single	Single or Extended		

MENU TEXT	DEFAULT SETTING	SETTING RANGE		STEP SIZE
		MIN	MAX	
DISTURB RECORDER				
Analog Channel 1	VAN	VAN,VBN,VCN,VCHECK SYNC,IA, IB, IC, IN, IM, IN SEF		
Analog Channel 2	VBN	As above		
Analog Channel 3	VCN	As above		
Analog Channel 4	IA	As above		
Analog Channel 5	IB	As above		
Analog Channel 6	IC	As above		
Analog Channel 7	IN	As above		
Analog Channel 8	IN SEF	As above		
Digital Inputs 1 to 32	Relays 1 to 7/14/32 and Optos 1 to 8/16/24	Any of 7 or 14 or 32 O/P Contacts or Any of 8 /16 or 24 Opto Inputs or Internal Digital Signals		
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		

Table 27 - Disturbance Recorder column

Note	*The available analogue and digital signals will differ between relay types and models and so the individual Courier database in the SCADA Communications chapter (P54x/EN CT) should be referred to when determining default settings etc.*

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 analogue channels is selectable from the available analogue 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 SCADA Communications chapter (P54x/EN CT). Note, however, that it is not possible to extract a disturbance record from both the front and rear communications ports simultaneously.

3.8 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 are summarized below:

- Phase voltages and currents, with phase angles
- Phase to phase voltage and currents, with phase angles
- Sequence voltages and currents, with phase angles
- Slip Frequency (from software 20 and onwards)
- Power and energy quantities
- Rms. voltages and currents
- Peak, fixed and rolling demand values

There are also measured values from the protection functions, which also displayed under the measurement columns of the menu; these are described in the section on the relevant protection function.

3.8.1 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 Discrete Fourier Transform (DFT) used by the relay protection functions and present both magnitude and phase angle measurement.

3.8.2 Sequence Voltages and Currents

Sequence quantities are produced by the relay from the measured Fourier values; these are displayed as magnitude values.

3.8.3 Slip Frequency (from software 20 and Onwards)

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.

3.8.4 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 Table 28:

Measurement Mode	Parameter	Signing
0 (Default, P = VI*)	Export Power	+
	Import Power	-
	Lagging VArs	+
	Leading VArs	-
1	Export Power	-
	Import Power	+
	Lagging VArs	+
	Leading VArs	-

Measurement Mode	Parameter	Signing
2	Export Power	+
	Import Power	-
	Lagging VArs	-
	Leading VArs	+
3	Export Power	-
	Import Power	+
	Lagging VArs	-
	Leading VArs	+

Table 28 - Power and energy options

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.

3.8.5 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.

3.8.6 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.

3.8.6.1 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.

3.8.6.2 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.

3.8.6.3 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.

3.8.7 Settings

These settings under the heading Measurement Setup can be used to configure the relay measurement function.

Measurement Setup	Default Value	Options/Limits
Default Display	Description	Description/Plant Reference/Frequency/Access Level/3Ph + N Current/3Ph Voltage/Power/Date and time
Local Values	Primary	Primary/Secondary
Remote Values	Primary	Primary/Secondary
Measurement Ref	VA	VA/VB/VC/IA/IB/IC
Measurement Mode	0	0 to 3 Step 1
Fix Dem Period	30 minutes	1 to 99 minutes step 1 minute
Roll Sub Period	30 minutes	1 to 99 minutes step 1 minute
Num Sub Periods	1	1 to 15 step 1
Remote 2 Values (software 12 and onwards)	Primary	Primary/Secondary

Table 29 - Measurement Setup settings

3.8.7.1 Default Display

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.

3.8.7.2 Local Values

This setting controls whether measured values via the front panel user interface and the front Courier port are displayed as primary or secondary quantities.

3.8.7.3 Remote Values

This setting controls whether measured values via the rear communication port are displayed as primary or secondary quantities.

3.8.7.4 Remote2 Values (from software 12 and onwards)

The setting applies to relays with second rear port and controls whether measured values via the second rear communication port are displayed or secondary quantities.

3.8.7.5 Measurement Ref

Using this setting the phase reference for all angular measurements by the relay can be selected.

3.8.7.6 Measurement Mode

This setting is used to control the signing of the real and reactive power quantities; the signing convention used is defined in Table 29.

3.8.7.7 Fixed Demand Period

This setting defines the length of the fixed demand window.

3.8.7.8 Rolling Sub-Period and Number of Sub-Periods

These two settings are used to set the length of the window used for the calculation of rolling demand quantities and the resolution of the slide for this window.

3.8.7.9 Distance Unit

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 visa versa.

3.8.7.10 Fault Location

The calculated fault location can be displayed using one of several options selected using this setting.

3.9 Changing Setting Groups

The setting groups can be changed either by opto inputs, by a menu selection or via the hot keys (software 20 and onwards) on the user interface. In the Configuration column if ‘Setting Group - select via opts’ is selected then Optos 1 and 2, which are dedicated for setting group selection, can be used 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 - Group 1/2/3/4’ can be used to select the setting group. If this option is used then opto inputs 1 and 2 can be used for other functions in the PSL.

The setting group can be changed via the hotkey menu (software 20 and onwards) providing ‘Setting Group select via menu’ is chosen.

OPTO 1	OPTO 2	Selected Setting Group
0	0	1
1	0	2
0	1	3
1	1	4

Table 30 - Changing Setting Groups

WARNING **Setting groups comprise both Settings and PSL. Each is independent per group - not shared as common. The settings are generated in the Settings and Records application within MiCOM S1, or can be applied directly from the relay front panel menu. The PSL can only be set using the PSL Editor application within MiCOM S1, generating files with extension “.psl”. It is essential that where the installation needs application-specific PSL, 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.**

3.10 Control Inputs (Software 20 and above)

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 which are: “CONTROL INPUTS”, “CTRL I/P CONFIG” and “CTRL I/P LABELS”. The function of these columns is described here:

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	

Table 31 - Control Inputs

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 PSL 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	

Table 32 - Ctrl I/P Config

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	

Table 33 - Ctrl I/P Labels

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 energised 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.*

3.11 RTC Synchronization via Opto-Inputs (Software 20 and later)

In modern protective schemes it is often desirable to synchronize the relays Real Time Clock (RTC) 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 P540 range offers the facility to synchronize via an opto-input by routing it in PSL to DDB#347 (Time Synch). 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 synch function is shown below:

Time of "Synch 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*	

Table 34 - Synch Pulse Times

To avoid the event buffer from being filled with unnecessary time synch events, it is possible to ignore any event that generated by the time synch opto input. This can be done by applying these settings:

Menu Text	Value
RECORD CONTROL	
Opto Input Event	Enabled
Protection Event	Enabled
DDB 63 - 32 (Opto Inputs)	Set "Time Synch" associated opto to 0.

Table 35 - Record Control

To improve the recognition time of the time synch 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 (CONFIGURATION 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 the Relay Description chapter (P54x/EN HW).

4 FACTORY DEFAULT SETTINGS

The relay includes PSL. The purpose of this logic is multi-functional and includes:

- Enables the mapping of opto-isolated inputs, relay output contacts and the programmable LEDs.
- Provides relay output conditioning (delay on pick-up/drop-off, dwell time, latching or self-reset).
- Fault Recorder start mapping, i.e. which internal signals initiate a fault record.
- Enables customer specific scheme logic to be generated through the use of the PSL editor inbuilt into the MiCOM S1 support software.

Further information regarding editing and the use of PSL can be found in the MiCOM S1 user manual. The following section details the default settings of the PSL. Changes to these defaults can only be carried out using the PSL editor and not via the front plate.

WARNING	**The default PSL diagrams shown in the Relay Menu Database (P54x/EN GC) contain additional notes to guide the user in drawing or modifying a custom PSL for a specific application. Where the installation needs application-specific PSL, the appropriate .psl file MUST be 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.**

4.1 Logic Input Mapping

	P541	P542
1	L1 Intertrip 1	L1 Intertrip 1
2	L2 PIT	L2 PIT
3	L3 Inhibit Diff	L3 Inhibit Diff
4	L4 Interlock	L4 Interlock
5	L5 Reset LEDs	L5 Reset LEDs
6	L6 External Trip	L6 External Trip
7	L7 CB Aux 52-A	L7 CB Aux 52-A
8	L8 CB Aux 52-B	L8 CB Aux 52-B
9		L9 Not Used
10		L10 Not Used
11		L11 Not Used
12		L12 Not Used
13		L13 Not Used
14		L14 Reset Lckout
15		L15 CB Healthy
16		L16 BAR

Table 36 - Logic input mapping

4.2 Relay Output Mapping

	P541	P542
1	R1 Intertrip 1	R1 Intertrip 1
2	R2 SignalingFail	R2 SignalingFail
3	R3 Any Trip	R3 Any Trip
4	R4 General Alarm	R4 General Alarm
5	R5 CB Fail Time1	R5 CB Fail Time1
6	R6 Cntl CB Close	R6 Cntl CB Close
7	R7 Cntl CB Trip	R7 Cntl CB Trip
8		R8 Diff Trip
9		R9 I> Trip
10		R10 IN> Trip
11		R11 AR in Prog
12		R12 SuccessClose
13		R13 AR Lockout
14		R14 AR InService

Table 37 - Relay output mapping

4.3 Relay Output Conditioning

	P541	P542
1	Dwell 100ms	Dwell 100ms
2	Disabled	Disabled
3	Dwell 100ms	Dwell 100ms
4	Dwell 500ms	Dwell 500ms
5	Dwell 100ms	Dwell 100ms
6	Disabled	Disabled
7	Disabled	Disabled
8		Disabled
9		Disabled
10		Disabled
11		Disabled
12		Disabled
13		Disabled
14		Disabled

Table 38 - Relay output conditioning

4.4 LED Mapping

	P541	P542
1	Diff Trip	Diff Trip
2	Backup Trip	Backup Trip
3	Thermal Alarm	Thermal Alarm
4	Signaling Fail	Signaling Fail
5	Any Start	Any Start
6	Not Used	AR in Progress
7	Not Used	AR Lockout
8	Test Loopback	Test Loopback

Table 39 - LED Mapping

4.5 LED Output Conditioning

	P541	P542
1	Latched	Latched
2	Latched	Latched
3	Disabled	Disabled
4	Disabled	Disabled
5	Disabled	Disabled
6	Disabled	Disabled
7	Disabled	Disabled
8	Disabled	Disabled

Table 40 - LED Output Conditioning

4.6 Fault Recorder Start Mapping

	P541	P542
	Any Trip	Any Trip

Table 41 - Fault recorder start mapping

5 CURRENT TRANSFORMER REQUIREMENTS

5.1 Current Differential Protection

For accuracy, class X or class 5P Current Transformers (CTs) are strongly recommended. The knee point voltage of the CTs should comply with the minimum requirements of this formula:

Vk ≥ K . In (Rct + 2 RL)

Where:

Vk	=	Required IEC knee point voltage
K	=	Dimensioning factor
In	=	CT nominal secondary current
Rct	=	CT resistance
RL	=	One-way lead impedance from CT to relay

K is a constant depending on:

If	=	Maximum value of through fault current for stability (multiple of In)
X/R	=	Primary system X/R ratio

K is determined as follows:

For relays set at Is1 = 20%, Is2 = 2 In, k1 = 30%, k2 = 150%:

K ≥ 40 + (0.07 x (If x X/R))

And: K ≥ 65

This is valid for (If x X/R) ≤ 1000 ”

For higher (If x X/R) up to 1600: ”

K = 107.

For relays set at Is1 = 20%, Is2 = 2 In, k1 = 30%, k2 = 100%:

K ≥ 40 + (0.35 x (If x X/R))

And: K ≥ 65

This is valid for (If x X/R) ≤ 600 ”

For higher (If x X/R) up to 1600: “

K = 256.

6 COMMISSIONING TEST MENU

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.

Table 42 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 1023 See Relay Menu Database chapter (P54x/EN GC) for details of digital data bus signals
Monitor Bit 2	65 (LED 2)	
Monitor Bit 3	66 (LED 3)	
Monitor Bit 4	67 (LED 4)	
Monitor Bit 5	68 (LED 5)	
Monitor Bit 6	69 (LED 6)	
Monitor Bit 7	70 (LED 7)	
Monitor Bit 8	71 (LED 8)	
Test Mode	Disabled	Disabled Test Mode Contacts Blocked
Test Pattern	All bits set to 0	0 = Not Operated 1 = Operated
Contact Test	No Operation	No Operation Apply Test Remove Test
Test LEDs	No Operation	No Operation Apply Test
Test Autoreclose	No Operation	No Operation Trip 3 Pole Trip Pole A Trip Pole B Trip Pole C
Test Loopback	Disabled	Disabled External Internal
DDB Status	-	-

Table 42 - Commission Tests

6.1 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 energised opto-isolated input and a '0' a de-energised 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 energised with a suitable dc voltage.

6.2 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 'Contacts Blocked' 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.*

6.3 Test Port Status

This menu cell displays the status of the eight 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 PSL 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 6.11 of this chapter.

6.4 LED Status

The 'LED Status' cell is an eight bit binary string that indicates 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.

6.5 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 DDB signal number (0 - 511) from the list of available DDB signals in the Relay Menu Database document. The pins of the monitor/download port used for monitor bits are given in Table 43. The signal ground is available on pins 18, 19, 22 and 25.

Monitor Bit	1	2	3	4	5	6	7	8
Monitor/ Download Port Pin	11	12	15	13	20	21	23	24

Table 43 - Monitor Bits

Caution	**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.**

6.6 Test Mode

This menu cell is to allow secondary injection testing to be performed on the relay. It also enables a facility to directly test the output contacts by applying menu controlled test signals. To select test mode the option 'Test Mode' should be selected. This takes the relay out of service causing an alarm condition to be recorded and the yellow 'Out of Service' LED to illuminate. 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. However the output contacts are still active in this mode. To disable the output contacts in addition to the above select 'Blocked'. Once testing is complete the cell must be set back to 'Disabled' to restore the relay back to service. Test mode can also be selected by energizing an opto mapped to the Test Mode signal.

Caution	**When the 'test mode' cell is set to 'blocked' the relay scheme logic does not drive the output relays and hence the protection will not trip the associated circuit breaker if a fault occurs.** **However, the communications channels with remote relays remain active which, if suitable precautions are not taken, could lead to the remote ends tripping when current transformers are isolated or injection tests are performed.**

6.7 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.

6.8 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 'Contacts Blocked' 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.*

6.9 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'.

6.10 Test Autoreclose

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 'Trip 3 Pole' 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.

Similarly, where single pole auto-reclosing is available, the cycles for each single pole can be checked by sequentially issuing the 'Trip Pole A', ' Trip Pole B' or 'Trip Pole C', as appropriate.

Note	*The factory settings for the relay's PSL has the 'AR Trip Test' signal mapped to relay 3. If the PSL has been changed, it is essential that this signal remains mapped to relay 3 for the 'Test Autoreclose' facility to work.*

6.11 Test Loopback

During commissioning it is necessary to connect the protection communication transmit and receive ports together. This may be done externally using optical fiber or internally. This option automatically changes the protection address to 0-0 and in the case of 'Internal' routes the transmitter to the receiver internally to the relay.

6.12 DDB Status

This collection of menu cells display the status of all the Digital Data Bus (DDB) signals as a binary string, a '1' indicates 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.

6.13 Using a Monitor/Download Port Test Box

A monitor/download port test box containing 8 LEDs and a switchable audible indicator is available from Schneider Electric, 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 any of the eight monitor pins or remain silent so that indication of state is by LED alone.

7 COMMUNICATIONS BETWEEN RELAYS

7.1 Communications Link Options

A number of communications options are available, for the communication channels between P540 system ends. The various connection options are shown below. Choosing between each of these options will depend on the type of communications equipment that is available.

Where existing suitable multiplexer communication equipment is installed for other communication between substations, the 850nm option together with an appropriate ITU-T compatible electrical interface (P590 series unit) should be selected to match the existing multiplexer equipment. For further information on the P590 optical fiber to electrical interface units, refer to section 7.3.

Where an IEEE C37.94 compatible multiplexer is installed the 850nm option should be configured to interface directly to the multiplexer, refer to section 7.1.5.

Where no multiplexer is installed, the direct optical fiber connection can be used, refer to sections 7.1.1, 7.1.2, 7.1.3 and 7.1.4. The type of fiber used (multi-mode or single-mode and wavelength) will be determined by the distance between the ends of the P540 relay system, refer to section 7.2.

In any configuration, except the IEEE C37.94, the data rate may be selected as either 64kbit/sec or 56kbit/sec, refer also to section 7.8.

7.1.1 Direct Optical Fiber Link, 850nm Multi-Mode Fiber

The relays are connected directly using two 850nm multi-mode optical fibers for each signalling channel. Multi-mode fiber type 50/125μm or 62.5/125μm is suitable. BFOC/2.5 type fiber optic connectors are used. These are commonly known as “ST” connectors.

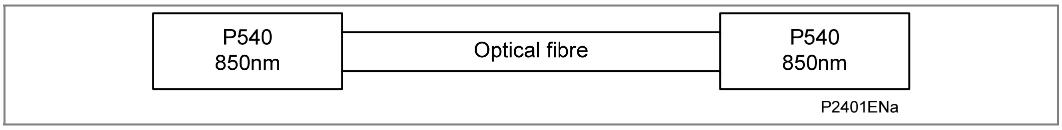

Figure 16 - This is typically suitable for connection up to 1km.

7.1.2 Direct Optical Fiber Link, 1300nm Multi-Mode fiber

The relays are connected directly using two 1300nm multi-mode fibers for each signalling channel. Multi-mode fiber type 50/125μm or 62.5/125μm is suitable. BFOC/2.5 type fiber optic connectors are used.

This is typically suitable for connection up to 30km.

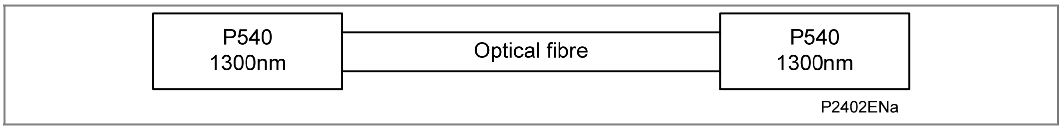

Figure 17 - Direct Optical Fiber Link, 1300nm Multi-Mode fiber

7.1.3 Direct Optical Fiber Link, 1300nm Single-Mode Fiber

The relays are connected directly using two 1300nm single-mode fibers, type 9/125μm for each signalling channel. BFOC/2.5 type fiber optic connectors are used.

This is typically suitable for connection up to 65km.

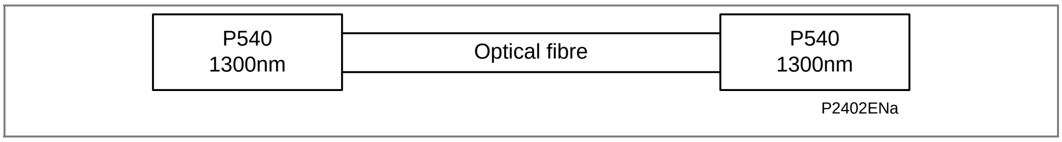

Figure 18 - Direct Optical Fiber Link, 1300nm Multi-Mode fiber

7.1.4 Direct Optical Fiber Link, 1550nm Single-Mode Fiber

The relays are connected directly using two 1550nm single-mode fibers, type 9/125μm for each signalling channel. BFOC/2.5 type fiber optic connectors are used.

This is typically suitable for connection up to 90km.

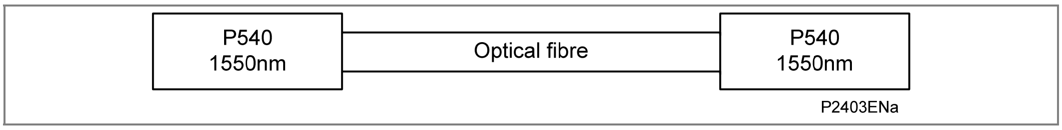

Figure 19 - Direct Optical Fiber Link, 1550nm Single-Mode Fiber

7.1.5 IEEE C37.94 Interface to Multiplexer (from Software 30)

A P540 relay with 850nm short haul optical interface is connected directly to the multiplexer by 850nm multi-mode optical fiber. Multi-mode fiber type 50/125μm or 62.5/125μm is suitable. BFOC/2.5 type fiber optic connectors are used.

The setting Comms Mode should be set to IEEE C37.94. Note the relay must be powered off and on before this setting change becomes effective.

The IEEE C37.94 standard defines an N*64kbits/s standard where N can be 1 - 12. N can be selected on the P540 or alternatively set to Auto in which case the relay will configure itself to match the multiplexer.

7.1.6 Switched Communication Networks

7.1.6.1 Switched Communication Networks

The P540 relays make use of digital communication signalling channels for the differential protection. For correct operation of this protection element, it is essential that the integrity of this link is continuously checked. It is also a requirement of this link that ‘go’ (tp1) and ‘return’ (tp2) times are similar (a difference of up to 1ms can be tolerated). Times greater than this can result in relay instability.

Where switched communications networks are used, it is possible that during switching, a transient time period may exist with different ‘go’ and ‘return’ times. All P540 relays include a facility to ensure protection stability during this transient period.

One of the checks performed on the communications link is a check on the calculated propagation delay for each data message. During normal operation the difference in calculated time should be minimal (possible delays being introduced by multiplexers or other intermediary communication equipment). If successive calculated propagation delay times exceed a user settable value (250 - 1000μs). The P540 raise a comm delay alarm and initiate a change in relay setting for a short time period (Char Mod Time setting) to overcome any switching delay. This change in setting is shown in Figure 21 whereby the relay bias setting, k1, is increased to 200%. This characteristic provides stability for all load conditions and will still allow tripping for most internal fault conditions.

Figure 20 shows a possible scenario for a switched network. Initially the P540 relays are communicating via path 1. The go and return times for this path are 2ms and hence the calculated propagation delay is (2 + 2)/2 = 2ms. When the channel is switched to path 2, a small time period exists where the P540's could be sending messages via path 1 and returning via path 2.

The calculated propagation delay will now be (2 + 5)/2 = 3.5ms. The resultant 1.5ms error at each line end may cause the relay to maloperate due to incorrect time alignment of current vectors (see Section 2.2.3). After a short delay, both 'go' and 'return' paths will follow route 2 and the calculated propagation delay will be (5 + 5)/2 = 5ms. The relay will now be stable, as correct current vector time alignment exists at each line end.

The Char Mod timer is started when a change in propagation delay is detected. Any subsequent change during this period will cause the timer to restart. In the above example the timer will start for the first change (2 to 3.5ms). The second change (3.5ms to 5ms) will cause the timer to restart, thus allowing for multiple switching between communication paths.

A change in propagation delay may result in a temporary failure of the protection communications channel. If this occurs, the propagation delay change may not be detected by the relay. To overcome this problem, the Char Mod Timer is re-started when the channel recovers from a protection communications channel failure if the Char Mod Timer was running when the channel failure occurred.

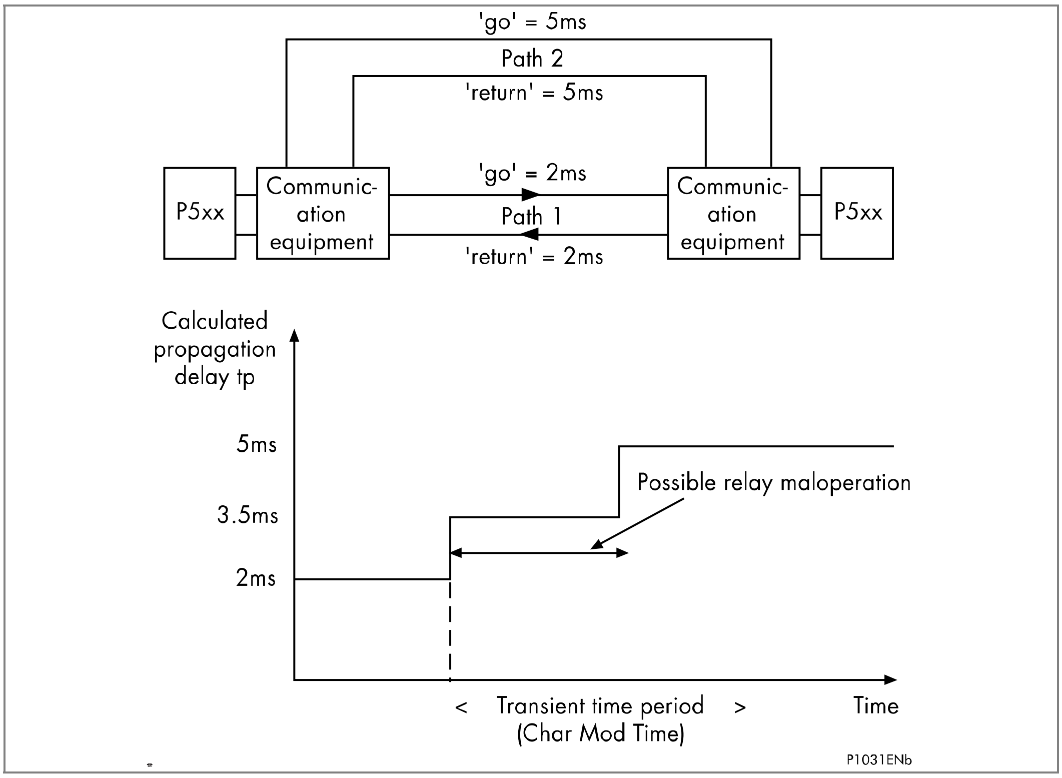

Figure 20 - Switched communication network

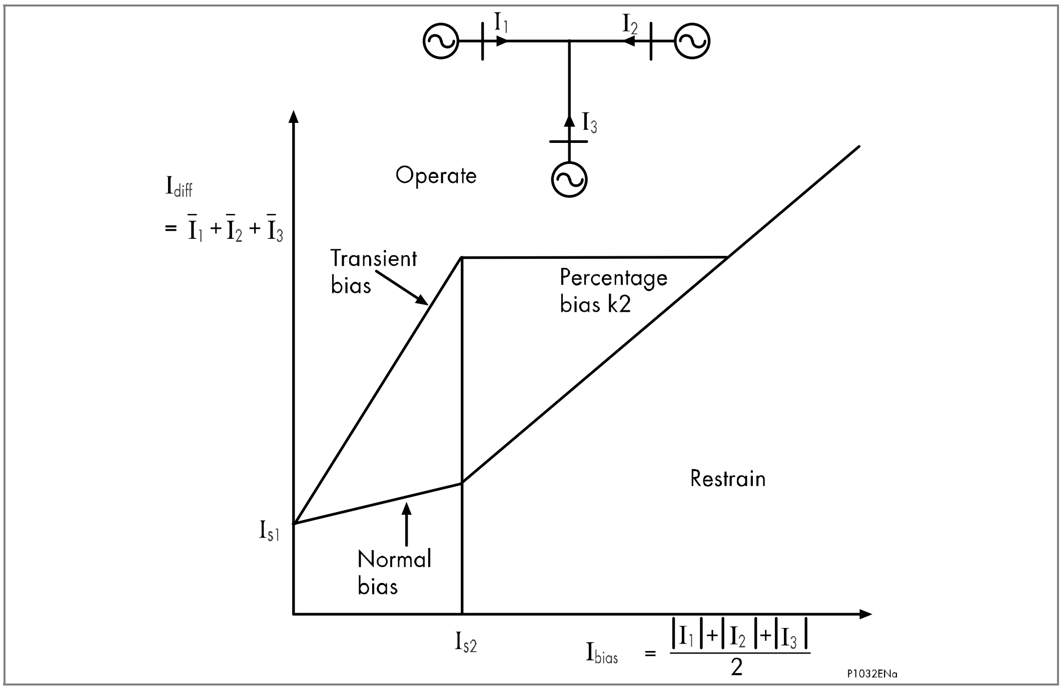

Figure 21 - Transient bias characteristic

7.2 Optical Budgets

When applying any of the P540 range of current differential relays it is important to select the appropriate protection communications interface. This will depend on the fiber used and distance between devices. Table 44 shows the optical budgets of the available communications interfaces.

	850nm Multi mode	1300nm Multi mode	1300nm Single mode	1550nm Single mode
Min. transmit output level (average power)	-19.8dBm	-10dBm	-10dBm	-10dBm
Receiver sensitivity (average power)	-25.4dBm	-37dBm	-37dBm	-37dBm
Optical budget	5.6dB	27.0dB	27.0dB	27.0dB
Less safety margin (3dB)	2.6dB	24.0dB	24.0dB	24.0dB
Typical cable loss	2.6dB/km	0.8dB/km	0.4dB/km	0.3dB/km
Max. transmission distance	1km	30.0km	60.0km	80km

Table 44 - Optical budgets

The total optical budget is given by transmitter output level minus the receiver sensitivity and will indicate the total allowable losses that can be tolerated between devices. A safety margin of 3dB is also included in Table 44. This allows for degradation of the fiber as a result of ageing and any losses in cable joints. The remainder of the losses will come from the fiber itself. The figures given are typical only and should only be used as a guide.

In general, the 1300nm and 1550nm interfaces will be used for direct connections between relays. The 850nm would be used where multiplexing equipment is employed.

7.3 P590 Series Optical Fiber to Electrical Interface Units

In order to connect the P540 relays via a Pulse Code Modulation (PCM) multiplexer network or digital communication channel, Type P590 type interface units are required. The following interface units are available:

- P591 interface to multiplexing equipment supporting ITU-T (formerly CCITT) Recommendation G.703 co-directional electrical interface
- P592 interface to multiplexing equipment supporting ITU-T Recommendation V.35 electrical interface
- P593 interface to multiplexing or ISDN equipment supporting ITU-T Recommendation X.21 electrical interface

The data rate for each unit can be 56kbit/sec or 64kbit/sec as required for the data communications link, refer to section 7.8.

One P590 unit is required per relay data channel (i.e. for each transmit and receive signal pair). It provides optical to electrical and electrical to optical signal conversion between the P540 relay and the multiplexer. The interface unit should be located as close to the PCM multiplexer as possible, to minimize any effects on the data of electromagnetic noise or interference.

The units are housed in a 20TE MiCOM case.

Fiber optic connections to the unit are made through BFOC/2.5 type connectors, more commonly known as 'ST' connectors.

The optical characteristics are similar to the P540 850nm multi-mode fiber optic interface (refer to section 7.2).

7.3.1 Multiplexer Link with G.703 using Auxiliary Optical Fibers and P591

A P540 relay with 850nm short haul optical interface is connected to a P591 unit by 850nm multi-mode optical fiber. Multi-mode fiber type 50/125μm or 62.5/125μm is suitable. BFOC/2.5 type fiber optic connectors are used. The P591 unit converts the data between optical fiber and ITU-T compatible G.703 co-directional electrical interface. The G.703 output must be connected to an ITU-T compatible G.703 co-directional channel on the multiplexer.

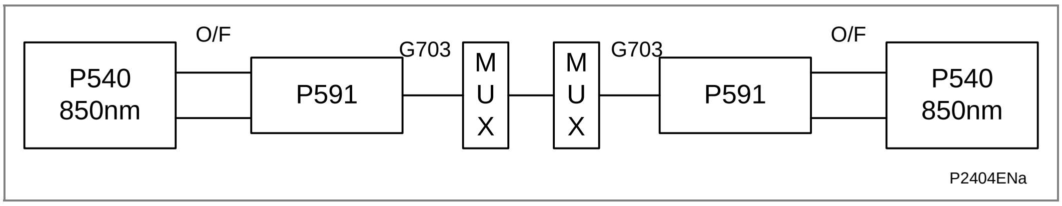

Figure 22 - P540 relay with G703 & 850nm interface connected to P591

The G.703 signals are isolated by pulse transformers to 1kV.

Since the G.703 signals are only of ±1V magnitude, the cable connecting the P591 unit and the multiplexer must be properly screened against electromagnetic noise and interference. The interface cable should consist of twisted pairs of 24AWG, overall shielded, and have a characteristic impedance of about 120Ω. It is generally recommended that the interface cable shield should be connected to the multiplexer frame ground only. The choice of grounding depends however on local codes and practices.

Electrical connections to the P591 unit are made via a standard 28-way Midos connector. Please refer to External Connection Diagram chapter (P54x/EN CO) for the external connection diagram.

The P540 must be set with Clock Source as 'External', refer to section 7.7.

7.3.2 Multiplexer Link with V.35 using Auxiliary Optical Fibers and P592

A P540 relay with 850nm short haul optical interface is connected to a P592 unit by 850nm multi-mode optical fiber. Multi-mode fiber type 50/125μm or 62.5/125μm is suitable. BFOC/2.5 type fiber optic connectors are used. The P592 unit converts the data between optical fiber and ITU-T compatible V.35 electrical interface. The V.35 output must be connected to an ITU-T compatible V.35 channel on the multiplexer.

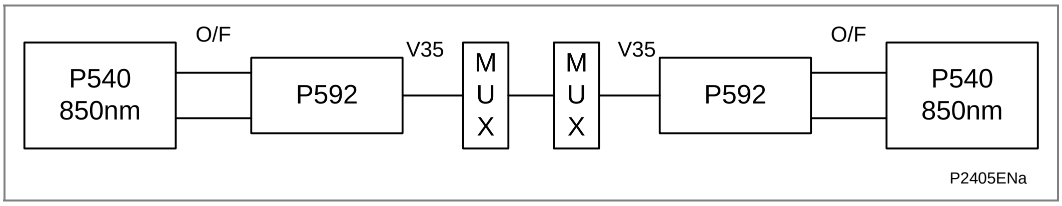

Figure 23 - P540 relay with V35 & 850nm interface connected to P592

Connections of V.35 signals to the P592 unit are made via a standard female 34 pin 'M' block connector. Since the V.35 signals are either of ±0.55V or ±12V magnitude, the cable connecting the unit to the multiplexer must be properly screened against electromagnetic noise and interference. The interface cable should consist of twisted pairs of wires which are shielded, and have a characteristic impedance of about 100Ω. It is generally recommended that the interface cable shield is connected to the multiplexer frame ground. The choice of grounding depends however on local codes and practices.

The P592 front panel consists of five indicating LEDs and six DIL (Dual In Line) switches.

The switch labelled 'Clockswitch' is provided to invert the V.35 transmit timing clock signal if required.

The switch labelled 'Fiber-optic Loopback' is provided to allow a test loopback of the communication signal across the fiber optic terminals. When switched on, the red LED labelled 'Fiber-optic Loopback' is illuminated.

The switch labelled 'V.35 Loopback' is provided to allow a test loopback of the communication signal across the X.21 terminals. It loops the incoming V.35 'Rx' data lines internally back to the outgoing V.35 'Tx' data lines. When switched on, the red LED labelled 'V.35 Loopback' is illuminated.

The switch labelled 'DSR' is provided to select/ignore the DSR (Data Set Ready) handshaking control signal. The red LED labelled DSR Off is extinguished either when DSR is asserted or when overridden by setting the DSR switch On.

The switch labelled 'CTS' is provided to select/ignore the CTS (Clear To Send) handshaking control signal. The red LED labelled CTS Off is extinguished either when CTS is asserted or when overridden by setting the CTS switch On.

The switch labelled 'Data Rate' is provided to allow the selection of 56 or 64k bits/s data rate, as required by the PCM multiplexing equipment.

The LED labelled 'Supply Healthy' is green and provides indication that the unit is correctly powered.

Please refer to the Installation chapter (P54x/EN IN) for the External Connection Diagrams.

The P540 may be set either with Clock Source as 'External' for a multiplexer network which is supplying a master clock signal, or with Clock Source as 'Internal' for a multiplexer network recovering signal timing from the equipment. Refer to Section 7.7.

7.3.3 Multiplexer Link with X.21 using Auxiliary Optical Fibers and P593

The P593 unit supports the ITU-T Recommendation X.21 interface. It is approved as line interface equipment by the British Approvals Board for Telecommunications (BABT) for connection to the services described in this section; Licence Certificate Number NS/1423/1/T/605362.

A P540 relay with 850nm short haul optical interface is connected to a P593 unit by 850nm multi-mode optical fiber. Multi-mode fiber type 50/125μm or 62.5/125μm is suitable. BFOC/2.5 type fiber optic connectors are used. The P593 unit converts the data between optical fiber and ITU-T compatible X.21 electrical interface. The X.21 output must be connected to an ITU-T compatible X.21 channel on the multiplexer or ISDN digital data transmission link.

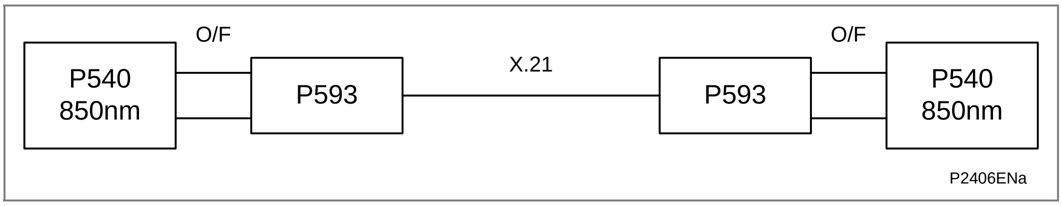

Figure 24 - P540 relay with X.21 & 850nm interface connected to P593

The P540 relays require a permanently open communications channel. Consequently, no communications handshaking is required, and it is not supported in the P593 unit. The signals supported are shown in Table 45.

ITU-T Recommendation X.21 is closely associated with EIA specifications RS422 and RS449. The P593 can be used with RS422 or RS449 communications channels which require only the signals shown in Table 45.

ITU-T designation	Description	Connector pin	Direction
-	Case earth	1	-
G	Common return	8	-
T	Transmit data A	2	From P593
T	Transmit data B	9	From P593
R	Receive data A	4	To P593
R	Receive data B	11	To P593
S	Signal element timing A	6	To P593
S	Signal element timing B	13	To P593

Table 45 - X.21 circuits supported by P593 unit

Connections of X.21 signals to the P593 unit are made via a standard male 15 way D-type connector, wired as a DTE device. The interface cable should consist of twisted pairs of 24AWG, overall shielded, and have a characteristic impedance of about 100Ω. It is generally recommended that the interface cable shield is connected to the multiplexer frame ground. The choice of grounding depends however on local codes and practices.

Please refer to the Installation chapter (P54x/EN IN) for the External Connection Diagrams.

The P540 must be set with Clock Source as 'External', refer to section 7.7.

The P593 front panel consists of four indicating LEDs and two switches.

The LED labelled ‘Supply healthy’ is green and provides indication that the unit is correctly powered.

The LED labelled ‘Clock’ is green and provides indication that an appropriate X.21 signal element timing signal is presented to the unit.

One of the switches is labelled ‘Fiber Optic Loopback’. This is provided to allow a test loopback of the communication signal across the fiber optic terminals. When switched on, the red LED labelled ‘Fiber Optic Loopback’ is illuminated.

The second switch is labelled ‘X.21 Loopback’. This is provided to allow a test loopback of the communication signal across the X.21 terminals. It loops the incoming X.21 ‘Rx’ data lines internally back to the outgoing X.21 ‘Tx’ data lines, and also loops the incoming fiber optic ‘Rx’ data line (via the X.21 signal conversion circuitry) back to the outgoing fiber optic ‘Tx’ data line. When switched on, the red LED labelled ‘X.21 Loopback’ is illuminated.

7.4 Protection Communications Scheme Set-Up

The Scheme Set-up setting selects the connection between the system ends. A two ended system may have a single communication channel between the ends (“2 Terminal” option) or two independent communication channels to achieve dual redundancy (“Dual Redundant” option). A three-ended system is selected by the option “3 Terminal”.

7.4.1 Dual Redundant (“Hot Standby”)

If one of the channels has failed, the communication between the relays can still be maintained by the other healthy channel.

The dual redundant model provides redundancy for communication channels by transmitting and receiving messages over both channels. Each channel is monitored continuously by the relay. The messages from both channels are used to perform the relay functions. If only one channel is available, the messages from this healthy channel are used to perform the relay functions.

The messages are transmitted over the 2 channels alternately. Every message received is validated and processed, so that both channels are continuously monitored.

7.5 Protection Communications Address

The protection communication messages include an address field to ensure correct scheme connection.

There are twenty one options for groups of addresses. Each group is applied to one protection system, two ended or three ended, so there are two or three addresses within a group respectively.

All the address patterns are carefully chosen so as to provide optimum noise immunity against bit corruption. There is no preference as to which address group is better than the other.

The groups of addresses available when “2 Terminal” or “Dual Redundant” scheme is selected are as follows:

	Relay A	Relay B
Universal Address	0-0	0-0
Address Group 1	1-A	1-B
Address Group 2	2-A	2-B
Address Group 3	3-A	3-B
Address Group 4	4-A	4-B
Address Group 5	5-A	5-B
Address Group 6	6-A	6-B
Address Group 7	7-A	7-B
Address Group 8	8-A	8-B
Address Group 9	9-A	9-B
Address Group 10	10-A	10-B
Address Group 11	11-A	11-B
Address Group 12	12-A	12-B
Address Group 13	13-A	13-B
Address Group 14	14-A	14-B
Address Group 15	15-A	15-B
Address Group 16	16-A	16-B
Address Group 17	17-A	17-B
Address Group 18	18-A	18-B
Address Group 19	19-A	19-B
Address Group 20	20-A	20-B

Table 46 - Address groups for Relay A and B

For two relays to communicate with one another, their addresses have to be in the same address group. One relay should be assigned with address A and the other with address B. For example, if the group 1 address is used, the one relay should be given the address 1-A, and the other relay should be given the address 1-B.

The relay with address 1-A will only accept messages with the 1-A address and will send out messages carrying address 1-B. The relay assigned with address 1-B will only accept messages with address 1-B and will send out messages carrying address 1-A.

The groups of addresses available when “3 Terminal” scheme is selected are as follows:

	Relay A	Relay B	Relay C
Address Group 1	1-A	1-B	1-C
Address Group 2	2-A	2-B	2-C

	Relay A	Relay B	Relay C
Address Group 3	3-A	3-B	3-C
Address Group 4	4-A	4-B	4-C
Address Group 5	5-A	5-B	5-C
Address Group 6	6-A	6-B	6-C
Address Group 7	7-A	7-B	7-C
Address Group 8	8-A	8-B	8-C
Address Group 9	9-A	9-B	9-C
Address Group 10	10-A	10-B	10-C
Address Group 11	11-A	11-B	11-C
Address Group 12	12-A	12-B	12-C
Address Group 13	13-A	13-B	13-C
Address Group 14	14-A	14-B	14-C
Address Group 15	15-A	15-B	15-C
Address Group 16	16-A	16-B	16-C
Address Group 17	17-A	17-B	17-C
Address Group 18	18-A	18-B	18-C
Address Group 19	19-A	19-B	19-C
Address Group 20	20-A	20-B	20-C

Table 47 - Address groups for Relay A, B and C

For three relays to work together as a protection system, their addresses must be in the same group and they should be assigned separately with addresses A, B and C.

They must also have a fixed connection configuration, as shown in Figure 25, in which channel 1 of one relay is connected to channel 2 of another relay.

For example, if the group 1 address is used, addresses 1-A, 1-B and 1-C should be assigned to relays A, B and C respectively. Relay A will only accept messages with address 1-A and will send messages carrying addresses 1-B and 1-C to channel 1 and channel 2 respectively. Relay B will only accept messages with address 1-B and will send messages carrying addresses 1-C and 1-A to channel 1 and to channel 2 respectively. Similarly relay C will only accept messages with address 1-C and will send messages carrying addresses 1-A and 1-B to channel 1 and to channel 2 respectively.

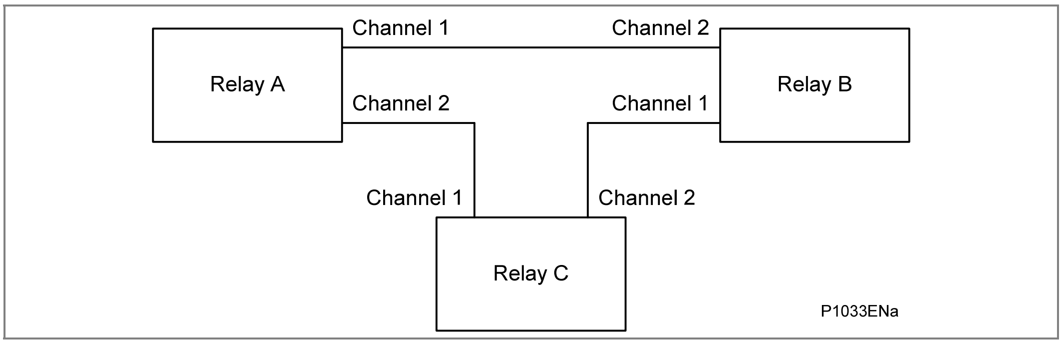

Figure 25 - 3-terminal system connection

7.6 Reconfiguration of Three-Ended System

This function only applies to relays which are set-up for 3-Terminal operation. The operation depends on the status of the communication channels, the relays in the scheme and various time periods. There are two general areas of operation, these being the change in configuration by a user and that generated by an energization of a relay. The various considerations applying to each of these cases are given below.

Four settings are provided as follows:

- Three Ended
- Two Ended Local and Remote 1 (L & R1)
- Two Ended Local and Remote 2 (L & R2)
- Two Ended Remote 1 and Remote 2 (R1 & R2)

Remote 1 and Remote 2 relate to protection signalling channel 1 and 2 respectively.

The operation of the reconfiguration is described in 7.6.1 and 7.6.2.

7.6.1 User Reconfiguration

This covers the normal set-up of the relays into a 2-ended or 3-ended scheme depending on the state of the protected line and the relays. The facilities provided allow the user to initially use two relays to protect a two ended line and later to upgrade the scheme to three ended using a further relay. It also allows one end of a three ended scheme to be isolated and the other two ends to operate as a two ended scheme. This allows tests to be performed on the end that has been isolated and also allows for that relay to be removed altogether.

The change in configuration is enabled by two external interlocks and by the current state of the relay and its communications. If the scheme is changed from 3-ended to 2-ended, it is considered to be a reconfigure command. If the scheme is changed from 2-ended to 3-ended, it is considered to be a restore command. The checks performed for a reconfiguration are slightly different to those for a restore.

The operation of the change configuration logic is as follows.

1. The configuration setting is changed.
2. The relay detects the change in setting and attempts to implement the new setting.
3. If the relay configuration is 2-ended and the new setting is also 2-ended then the relay will block the change and issue a configuration error alarm.
4. If the relay configuration is 2-ended and the new setting is 3-ended then the relay will check that all the communications are healthy and send out the restore command to the other relays. It will then check that the scheme has stabilized at 3-ended after one second.
5. If any of the communications in the scheme were failed or if the scheme has not stabilized at 3-ended then the relay will return to its original 2-ended setting and issue a configuration error alarm.
6. If the scheme did stabilize at 3-ended then the Re-configuration setting will be updated.
7. If the relay configuration is 3-ended and the new setting is 2-ended L & R1 then the relay will first check that the two interlock opto-inputs, “Inhibit Diff” and “Interlock” are energised (note that the “Inhibit Diff” opto-input will inhibit the differential tripping, but the backup protection can still operate the trip outputs). These inputs are allocated to opto-inputs L3 and L4 in the default PSL. The relay then checks that the communication with Remote 1 relay is healthy and sends out the

command to the remote relays. It will then check that the scheme has stabilized at 2-ended L & R1 after one second.

8. If the interlocks are not energised or the communication with Remote 1 relay has failed or the scheme does not stabilize at 2-ended L & R1 then the relay will return to 3-ended and will issue a configuration error alarm.
9. If the scheme did stabilize at 2-ended L & R1 then the Re-configuration setting will be updated.
10. If the relay configuration is 3-ended and the new setting is 2-ended L & R2 then the relay reacts similarly to a 2-ended L & R1 reconfiguration.
11. If the relay configuration is 3-ended and the new setting is 2-ended R1 & R2 then the relay reacts similarly to a 2-ended L & R1 reconfiguration.

7.6.2 Energization Reconfiguration

This type of configuration occurs when a relay is energised and the relay attempts to go into a configuration compatible with the other relays in the scheme. As far as possible the scheme will go to that which the user set up. There are, however, certain conditions which may prevent this from occurring.

The configuration that the relay takes up at power on is governed by these factors:

1. the scheme currently configured on the remote relays
2. the status of the communication links
3. the configuration stored in non volatile memory before power down

Upon energization of a relay, the following events occur:

1. The relay checks whether any messages are arriving. If so then the configuration command in the first messages to arrive will be used as the relay configuration. This is subject to certain conditions. If the relay has a choice of 2-ended and 3-ended, it will assume the 2-ended scheme unless both incoming commands are 3-ended. If all three relays are 3-ended then they will remain so.
2. If no messages arrive from either end then after one second the relay will change to the configuration that was last selected, i.e. the configuration before power down. Once messages begin to arrive again, the relay will check them for validity against the current scheme. If one relay is 3-ended and the other is 2-ended then the configuration will change to 2-ended. If both are 3-ended or the same 2-ended scheme then that will become the configuration. If two relays have different 2-ended configurations then they are unable to determine which one to use and will each generate a configuration error alarm and each relay will remain in its current configuration. This condition can be cleared by restoring the relays or by removing the supply to the relay with the incorrect configuration.
3. If all the relays in a scheme are energised simultaneously then the configuration will revert to 3-ended if all the communication channels are healthy. This occurs because all the relays are waiting to be told their configuration and all default to 3-ended. This is a very unlikely event in normal use.
4. In cases where a communication channel has only half failed i.e. the receive channel has failed but not the transmit channel, then there may be configuration errors on power up due to the fact that the relays are not communicating correctly. If the status is available via the third relay and healthy communications via its two channels then the scheme will stabilize correctly.

7.7 Clock Source

A clock source is required to synchronize data transmissions between the system ends. This may be provided either by the P540 relays (internal) or may be a function of the telecommunications equipment (external). The P540 relays have a setting for each of Channel 1 and Channel 2 to set the Clock Source to either “Internal” or “External” according to the communications system configuration.

This setting is not applicable if IEEE C37.94 mode selected.

7.7.1 Internal Clock Source

The Clock Source should be set to “Internal” at all system ends, where they are connected by direct optical fiber, as the P540 at each end has to supply the clock.

7.7.2 External Clock Source

The Clock Source should be set to “External” at all system ends, where the ends are connected by multiplexer equipment which is receiving a master clock signal from the multiplexer network. It is important that there is a single master clock source on the multiplexer network and that the multiplexer equipment at each end is synchronized to this clock.

7.8 Data Rate

The data rate for signalling between the two or three ends may be set to either 64kbit/sec or 56kbit/sec as appropriate.

If there is a direct fiber connection between the ends, the data rate would usually be set to 64kbit/sec, as this gives a slightly faster trip time.

If there is a multiplexer network between the ends, then this will determine the data rate to be used by the P540 system. The electrical interface to the multiplexer (G.703 co-directional, V.35, or X.21) will be provided on either a 64kbit/sec or 56kbit/sec channel, and the P540 at each end must be set to match this data rate.

Generally, North American multiplexer networks are based on 56kbit/sec (and multiples thereof) channels, whereas multiplexer networks in the rest of the world are based on 64kbit/sec (and multiples thereof) channels.

This setting is not applicable if IEEE C37.94 mode selected.

7.9 Communication Alarm

A communication alarm is raised by the relay if the message error rate rises above 25% and persists over a defined period of time (refer to section 7.12 below). This is equivalent to a Bit Error Rate (BER) of 1.5×10^{-3}.

A communication alarm is also raised if the received message indicates failure of the signalling channel at the remote end.

7.10 Communication Error Statistics

To aid the bit error evaluation of the communication link, communication error statistics are kept by the relay. These give the number of Errored messages detected, the number of Lost Messages, and the number of Valid Messages received for each of the two channels. The number of errored messages detected complies with ITU-T G8.21 and is as follows:

Number of errored seconds	Number of seconds containing 1 or more errored or lost messages
Number of severely errored seconds	Number of seconds containing 31 or more errored or lost messages
Number of degraded minutes	Number of minutes containing 2 or more errored or lost messages
Note any severely errored seconds are ignored when working out the minute intervals	

Table 48 - Error messages

The number of lost messages recorded is intended as an indicator for noises under normal communication conditions and not for recording long communication breaks. The lost message count is accumulated by incrementing a counter when a message is rejected by the Error code check, message length check and the sequential time tag check.

The error statistics are automatically cleared on power-up. They can also be cleared using the Clear Statistics setting in Measurements column of the menu.

7.11 Communications Delay Timer

The communications delay timer is the maximum difference in the measured channel propagation delay time between consecutive messages that the relay will tolerate before switching the settings, as described in section 7.1.6.

This setting is factory set to the minimum value of 250µs. It should be increased to a suitable value if the propagation delay time is expected to vary considerably such as in the case of a microwave link with multiple repeaters.

7.12 Communications Fail Timer

The communication fail timer is the time during which communication errors must be continuously detected before the channel is declared failed. This governs the implementation of the communication alarm and the ‘Protection Scheme Inoperative’ alarm. The setting is normally set to the maximum of 9.9 seconds so that the two alarms will not be affected by short bursts of noises or interruptions. The communication fail time setting however may be set to a lower value of say 200 or 300ms if the alarm contacts are to be used for enabling standby protection, or to signal a change-over to reserve communication facilities should the communication link become noisy or fail completely.

7.13 Communications Fail Mode

The Communications Fail Mode is used to select the channel(s) responsible for raising the communication alarm when configured for dual redundant communications. Three options are available: ‘Ch 1 Fail’, ‘Ch 2 Fail’, and ‘Ch 1 and 2 Fail’. If ‘Ch 1 Fail’ is selected, the communication alarm will only be raised if channel 1 has failed. If ‘Ch 2 Fail’ is selected, the communication alarm will only be raised if channel 2 has failed. If ‘Ch 1 and 2 Fail’ is selected, the communication alarm will be raised if either channel has failed.

Notes:

PROGRAMMING SCHEME LOGIC (PSL)

CHAPTER 7

Notes:

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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 Studio.

1.2 MiCOM S1 Studio Px40 PSL Editor

To start the Px40 PSL editor, either click the  icon or from the Micom S1 Studio main menu, select **Tools > PSL PSL editor (Px40)**.

The PSL editor lets you connect to any MiCOM device front port, retrieve and edit its PSL files and send the modified file back to a MiCOM Px40 device.

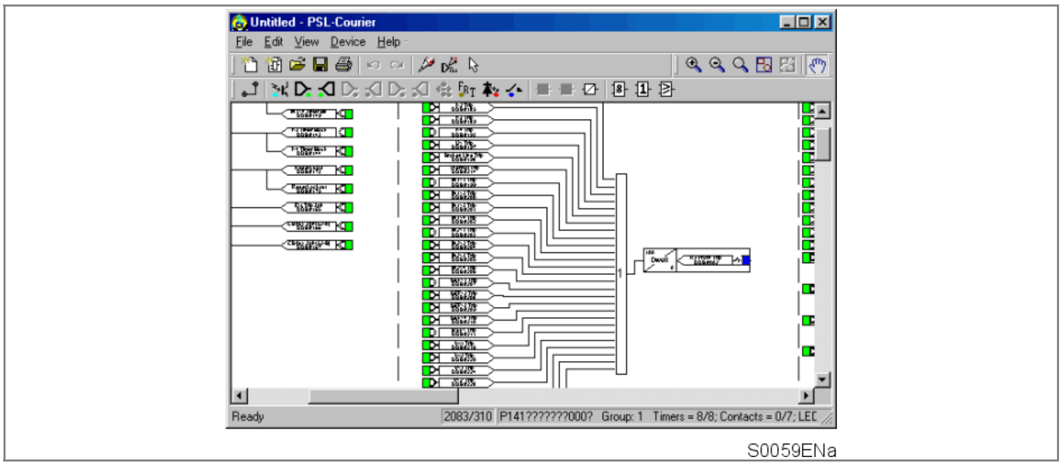


Figure 1 - PSL editor module

1.3 How to use MiCOM Px40 PSL Editor

The MiCOM Px40 PSL editors let you:

- 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 Studio 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, then compares it with the stored model number. A "wildcard" comparison is used. If a model mismatch occurs, a warning is generated before sending starts. Both the stored model number and the number read from the relay are displayed with the warning. However, the user must decide if the settings to be sent are compatible with the relay that is connected. Ignoring the warning could lead to undesired behavior of 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:

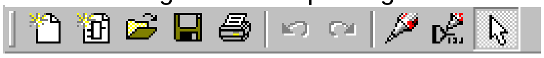
- One or more gates, LED signals, contact signals, and/or timers have their outputs linked directly back to their inputs. An erroneous link of this sort could lock up the relay, or cause other more subtle problems to arise.
- Inputs to Trigger (ITT) exceeds the number of inputs. If a programmable gate has its ITT value set to greater than the number of actual inputs; the gate can never activate. 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.

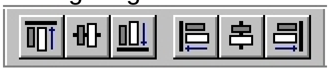
1.5.1 Standard Tools

For file management and printing.



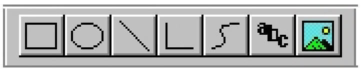
1.5.2 Alignment Tools

To align logic elements horizontally or vertically into groups.



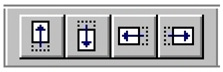
1.5.3 Drawing Tools

To add text comments and other annotations, for easier reading of PSL schemes.



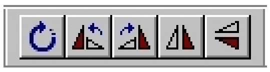
1.5.4 Nudge Tools

To move logic elements.



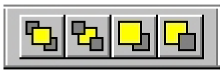
1.5.5 Rotation Tools

To spin, mirror and flip.



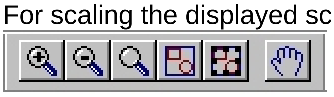
1.5.6 Structure Tools

To change the stacking order of logic components.



1.5.7 Zoom and Pan Tools

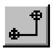
For scaling the displayed screen size, viewing the entire PSL, or zooming to a selection.



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.

P2718ENa



Link
Create a link between two logic symbols.

Opto Signal
Create an opto signal.

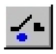
Input Signal
Create an input signal.

Output Signal
Create an output signal.

Trigger Signal
Create a fault record trigger.

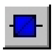
LED Signal

Create an LED input signal that repeats the status of tri-color LED.

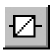


Contact Signal
Create a contact signal.

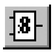
LED Conditioner
Create an LED conditioner.



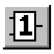
Contact Conditioner
Create a contact conditioner.



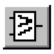
Timer
Create a timer.



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.

1.6.1 Signal Properties Menu

The logic signal toolbar is used for the selection of logic signals. To use this:

Use the logic toolbar to select logic signals.
This is enabled by default but to hide or show it, select **View** > **Logic Toolbar**.

Zoom in or out of a logic diagram using the toolbar icon or select **View** > **Zoom Percent**.

Right-click any logic signal and a context-sensitive menu appears.

Certain logic elements show the **Properties…** option. Select this and a **Component Properties** window appears. The Component Properties window and the signals listed vary depending on the logic symbol selected.

The following subsections describe each of the available logic symbols.

1.6.2 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. Right-click the input and select **Properties…**. The **Link Properties** window appears.

Figure 2 - Link properties

1.6.2.1 Rules for Linking Symbols

An inverted link is shown with a small circle on the input to a gate. A link must be connected to the input of a gate to be inverted.

Links can only be started from the output of a signal, gate, or conditioner, and can only be ended at an input to any element.

Signals can only be an input or an output. To follow the convention for gates and conditioners, input signals are connected from the left and output signals to the right. The Editor automatically enforces this convention.

A link is refused for the following reasons:

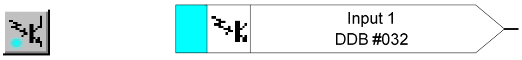
- An attempt to connect to a signal that is already driven. The reason for the refusal may not be obvious because the signal symbol may appear elsewhere in the diagram.

  Right-click the link and select Highlight to find the other signal. Click anywhere on the diagram to disable the highlight.
- An attempt is made to repeat a link between two symbols. The reason for the refusal may not be obvious because the existing link may be represented elsewhere in the diagram.

1.6.3 Opto Signal Properties

Each opto input can be selected and used for programming in PSL. Activation of the opto input drives an associated DDB signal.

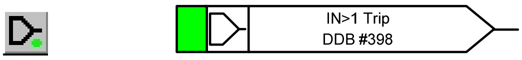
For example, activating opto Input L1 asserts DDB 032 in the PSL.



1.6.4 Input Signal Properties

Relay logic functions provide logic output signals that can be used for programming in PSL. Depending on the relay functionality, operation of an active relay function drives an associated DDB signal in PSL.

For example, DDB 398 is asserted in the PSL if the active earth fault 1, stage 1 protection operate/trip.



1.6.5 Output Signal Properties

Relay logic functions provide logic input signals that can be used for programming in PSL. Depending on the relay functionality, activation of the output signal will drive an associated DDB signal in PSL and cause an associated response to the relay function.

For example, if DDB 306 is asserted in the PSL, it will run the reset lockout function.

1.6.6 Fault Recorder Trigger Properties

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.

1.6.7 LED Signal Properties

All programmable LEDs will drive associated DDB signal when the LED is activated.

For example DDB 070 will be asserted when LED 7 is activated.

1.6.8 Contact Signal Properties

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.

1.6.9 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.

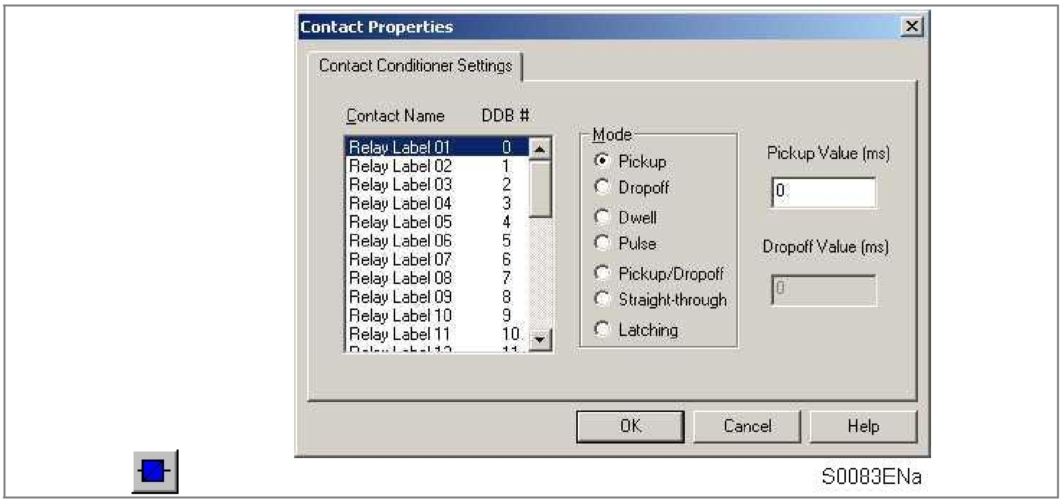


Figure 3 - Contact conditioner settings

1. Select the contact **name** from the **Contact Name** list (only shown when inserting a new symbol).
1. Choose the conditioner type required in the **Mode** tick list.
2. Set the **Pick-up** Time (in milliseconds), if required.
3. Set the **Drop-off** Time (in milliseconds), if required.

1.6.10 Timer Properties

Each timer can be selected for pick up, drop off, dwell, pulse or pick-up/drop-off operation.

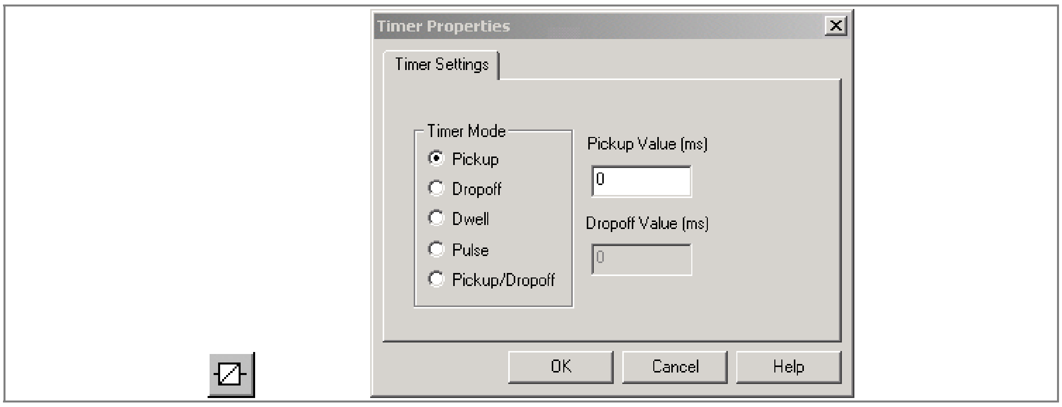
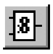


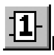
Figure 4 - Timer settings

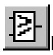
4. Choose the operation mode from the **Timer Mode** tick list.
5. Set the Pick-up Time (in milliseconds), if required.
6. Set the Drop-off Time (in milliseconds), if required.

1.6.11 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.

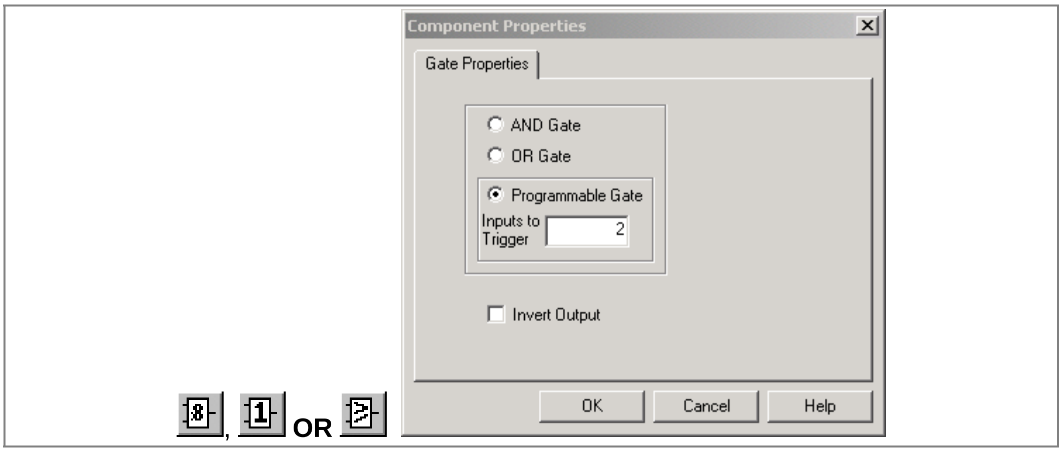


Figure 5 - Gate properties

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.

1.6.12 SR Programmable Gate Properties

A **Programmable** SR gate can be selected to operate with these latch properties:

S input	R input	O - Standard	O - Set input dominant	O - Rest input dominant
0	0	0	0	0
0	1	0	0	0
1	0	1	1	1
1	1	0	1	1

Table 1 - SR programmable gate properties

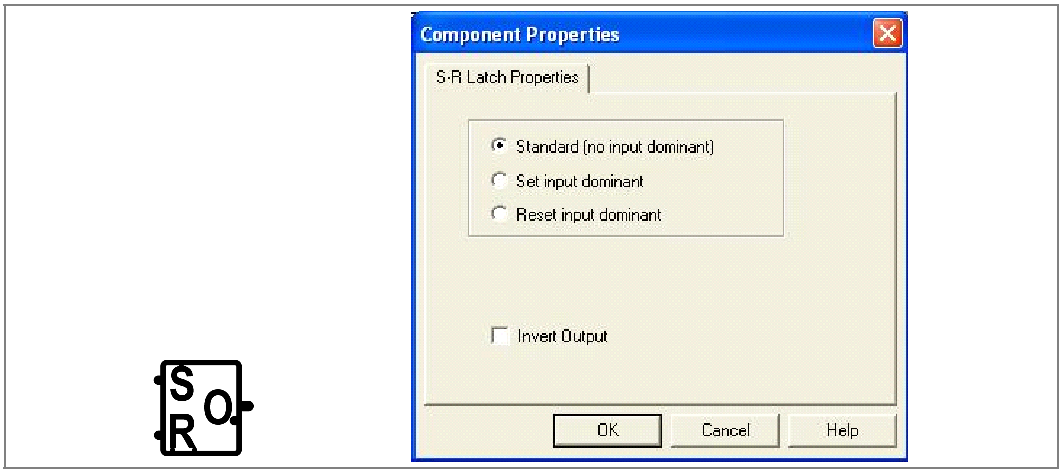


Figure 6 - SR latch component properties

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.

2 DESCRIPTION OF LOGIC NODES

DDB No	Source	Description	English Text	P541	P542
0	Output Condition	Output Relay 1	Output Label 1(Setting)	*	*
1	Output Condition	Output Relay 2	Output Label 2(Setting)	*	*
2	Output Condition	Output Relay 3	Output Label 3(Setting)	*	*
3	Output Condition	Output Relay 4	Output Label 4(Setting)	*	*
4	Output Condition	Output Relay 5	Output Label 5(Setting)	*	*
5	Output Condition	Output Relay 6	Output Label 6(Setting)	*	*
6	Output Condition	Output Relay 7	Output Label 7(Setting)	*	*
7	Output Condition	Output Relay 8	Output Label 8(Setting)		*
8	Output Condition	Output Relay 9	Output Label 9(Setting)		*
9	Output Condition	Output Relay 10	Output Label 10(Setting)		*
10	Output Condition	Output Relay 11	Output Label 11(Setting)		*
11	Output Condition	Output Relay 12	Output Label 12(Setting)		*
12	Output Condition	Output Relay 13	Output Label 13(Setting)		*
13	Output Condition	Output Relay 14	Output Label 14(Setting)		*
14	Output Condition	Output Relay 15	Output Label 15(Setting)		
15	Output Condition	Output Relay 16	Output Label 16(Setting)		
16	Output Condition	Output Relay 17	Output Label 17(Setting)		
17	Output Condition	Output Relay 18	Output Label 18(Setting)		
18	Output Condition	Output Relay 19	Output Label 19(Setting)		
19	Output Condition	Output Relay 20	Output Label 20(Setting)		
20	Output Condition	Output Relay 21	Output Label 21(Setting)		
21	Output Condition	Output Relay 22	Output Label 22(Setting)		
22	Output Condition	Output Relay 23	Output Label 23(Setting)		
23	Output Condition	Output Relay 24	Output Label 24(Setting)		
24	Output Condition	Output Relay 25	Output Label 25(Setting)		
25	Output Condition	Output Relay 26	Output Label 26(Setting)		
26	Output Condition	Output Relay 27	Output Label 27(Setting)		
27	Output Condition	Output Relay 28	Output Label 28(Setting)		
28	Output Condition	Output Relay 29	Output Label 29(Setting)		
29	Output Condition	Output Relay 30	Output Label 30(Setting)		
30	Output Condition	Output Relay 31	Output Label 31(Setting)		
31	Output Condition	Output Relay 32	Output Label 32(Setting)		
32	Opto	Opto Input 1	Opto Label 1(Setting)	*	*
33	Opto	Opto Input 2	Opto Label 2(Setting)	*	*
34	Opto	Opto Input 3	Opto Label 3(Setting)	*	*
35	Opto	Opto Input 4	Opto Label 4(Setting)	*	*
36	Opto	Opto Input 5	Opto Label 5(Setting)	*	*
37	Opto	Opto Input 6	Opto Label 6(Setting)	*	*
38	Opto	Opto Input 7	Opto Label 7(Setting)	*	*
39	Opto	Opto Input 8	Opto Label 8(Setting)	*	*
40	Opto	Opto Input 9	Opto Label 9(Setting)		*
41	Opto	Opto Input 10	Opto Label 10(Setting)		*

DDB No	Source	Description	English Text	P541	P542
42	Opto	Opto Input 11	Opto Label 11(Setting)		*
43	Opto	Opto Input 12	Opto Label 12(Setting)		*
44	Opto	Opto Input 13	Opto Label 13(Setting)		*
45	Opto	Opto Input 14	Opto Label 14(Setting)		*
46	Opto	Opto Input 15	Opto Label 15(Setting)		*
47	Opto	Opto Input 16	Opto Label 16(Setting)		*
48	Opto	Opto Input 17	Opto Label 17(Setting)		
49	Opto	Opto Input 18	Opto Label 18(Setting)		
50	Opto	Opto Input 19	Opto Label 19(Setting)		
51	Opto	Opto Input 20	Opto Label 20(Setting)		
52	Opto	Opto Input 21	Opto Label 21(Setting)		
53	Opto	Opto Input 22	Opto Label 22(Setting)		
54	Opto	Opto Input 23	Opto Label 23(Setting)		
55	Opto	Opto Input 24	Opto Label 24(Setting)		
56 to 63		Unused			
64	Output Condition	Programmable LED 1	LED 1	*	*
65	Output Condition	Programmable LED 2	LED 2	*	*
66	Output Condition	Programmable LED 3	LED 3	*	*
67	Output Condition	Programmable LED 4	LED 4	*	*
68	Output Condition	Programmable LED 5	LED 5	*	*
69	Output Condition	Programmable LED 6	LED 6	*	*
70	Output Condition	Programmable LED 7	LED 7	*	*
71	Output Condition	Programmable LED 8	LED 8	*	*
72	PSL	Input to Relay Output Condition	Relay Cond 1	*	*
73	PSL	Input to Relay Output Condition	Relay Cond 2	*	*
74	PSL	Input to Relay Output Condition	Relay Cond 3	*	*
75	PSL	Input to Relay Output Condition	Relay Cond 4	*	*
76	PSL	Input to Relay Output Condition	Relay Cond 5	*	*
77	PSL	Input to Relay Output Condition	Relay Cond 6	*	*
78	PSL	Input to Relay Output Condition	Relay Cond 7	*	*
79	PSL	Input to Relay Output Condition	Relay Cond 8		*
80	PSL	Input to Relay Output Condition	Relay Cond 9		*
81	PSL	Input to Relay Output Condition	Relay Cond 10		*
82	PSL	Input to Relay Output Condition	Relay Cond 11		*
83	PSL	Input to Relay Output Condition	Relay Cond 12		*
84	PSL	Input to Relay Output Condition	Relay Cond 13		*
85	PSL	Input to Relay Output Condition	Relay Cond 14		*
86	PSL	Input to Relay Output Condition	Relay Cond 15		
87	PSL	Input to Relay Output Condition	Relay Cond 16		
88	PSL	Input to Relay Output Condition	Relay Cond 17		
89	PSL	Input to Relay Output Condition	Relay Cond 18		
90	PSL	Input to Relay Output Condition	Relay Cond 19		
91	PSL	Input to Relay Output Condition	Relay Cond 20		
92	PSL	Input to Relay Output Condition	Relay Cond 21		

DDB No	Source	Description	English Text	P541	P542
93	PSL	Input to Relay Output Condition	Relay Cond 22		
94	PSL	Input to Relay Output Condition	Relay Cond 23		
95	PSL	Input to Relay Output Condition	Relay Cond 24		
96	PSL	Input to Relay Output Condition	Relay Cond 25		
97	PSL	Input to Relay Output Condition	Relay Cond 26		
98	PSL	Input to Relay Output Condition	Relay Cond 27		
99	PSL	Input to Relay Output Condition	Relay Cond 28		
100	PSL	Input to Relay Output Condition	Relay Cond 29		
101	PSL	Input to Relay Output Condition	Relay Cond 30		
102	PSL	Input to Relay Output Condition	Relay Cond 31		
103	PSL	Input to Relay Output Condition	Relay Cond 32		
104	PSL	Input to LED Output Condition	LED Cond IN 1	*	*
105	PSL	Input to LED Output Condition	LED Cond IN 2	*	*
106	PSL	Input to LED Output Condition	LED Cond IN 3	*	*
107	PSL	Input to LED Output Condition	LED Cond IN 4	*	*
108	PSL	Input to LED Output Condition	LED Cond IN 5	*	*
109	PSL	Input to LED Output Condition	LED Cond IN 6	*	*
110	PSL	Input to LED Output Condition	LED Cond IN 7	*	*
111	PSL	Input to LED Output Condition	LED Cond IN 8	*	*
112	PSL	Input to Auxiliary Timer 1	Timer in 1	*	*
113	PSL	Input to Auxiliary Timer 2	Timer in 2	*	*
114	PSL	Input to Auxiliary Timer 3	Timer in 3	*	*
115	PSL	Input to Auxiliary Timer 4	Timer in 4	*	*
116	PSL	Input to Auxiliary Timer 5	Timer in 5	*	*
117	PSL	Input to Auxiliary Timer 6	Timer in 6	*	*
118	PSL	Input to Auxiliary Timer 7	Timer in 7	*	*
119	PSL	Input to Auxiliary Timer 8	Timer in 8	*	*
120	PSL	Input to Auxiliary Timer 9	Timer in 9	*	*
121	PSL	Input to Auxiliary Timer 10	Timer in 10	*	*
122	PSL	Input to Auxiliary Timer 11	Timer in 11	*	*
123	PSL	Input to Auxiliary Timer 12	Timer in 12	*	*
124	PSL	Input to Auxiliary Timer 13	Timer in 13	*	*
125	PSL	Input to Auxiliary Timer 14	Timer in 14	*	*
126	PSL	Input to Auxiliary Timer 15	Timer in 15	*	*
127	PSL	Input to Auxiliary Timer 16	Timer in 16	*	*
128	Auxiliary Timer	Output from Auxiliary Timer 1	Timer out 1	*	*
129	Auxiliary Timer	Output from Auxiliary Timer 2	Timer out 2	*	*
130	Auxiliary Timer	Output from Auxiliary Timer 3	Timer out 3	*	*
131	Auxiliary Timer	Output from Auxiliary Timer 4	Timer out 4	*	*
132	Auxiliary Timer	Output from Auxiliary Timer 5	Timer out 5	*	*
133	Auxiliary Timer	Output from Auxiliary Timer 6	Timer out 6	*	*
134	Auxiliary Timer	Output from Auxiliary Timer 7	Timer out 7	*	*
135	Auxiliary Timer	Output from Auxiliary Timer 8	Timer out 8	*	*
136	Auxiliary Timer	Output from Auxiliary Timer 9	Timer out 9	*	*

DDB No	Source	Description	English Text	P541	P542
137	Auxiliary Timer	Output from Auxiliary Timer 10	Timer out 10	*	*
138	Auxiliary Timer	Output from Auxiliary Timer 11	Timer out 11	*	*
139	Auxiliary Timer	Output from Auxiliary Timer 12	Timer out 12	*	*
140	Auxiliary Timer	Output from Auxiliary Timer 13	Timer out 13	*	*
141	Auxiliary Timer	Output from Auxiliary Timer 14	Timer out 14	*	*
142	Auxiliary Timer	Output from Auxiliary Timer 15	Timer out 15	*	*
143	Auxiliary Timer	Output from Auxiliary Timer 16	Timer out 16	*	*
144	PSL	Trigger for Fault Recorder	Fault REC TRIG	*	*
145	Group Selection	Setting Group via opto invalid	SG-opto Invalid	*	*
146	Commission Test	Test Mode Enabled	Prot'n Disabled	*	*
147	VT Supervision	VTS Indication	VT Fail Alarm		
148	Distance	Power Swing	Power Swing		
149	Breaker Fail	BF Block AR	CB Fail Alarm	*	*
150	CB Monitoring	Broken Current Alarm	I^ Maint Alarm	*	*
151	CB Monitoring	Broken Current lookout	I^ Lockout Alarm	*	*
152	CB Monitoring	Maintenance Alarm	CB OPs Maint	*	*
153	CB Monitoring	Maintenance Lockout	CB OPs Lock	*	*
154	CB Monitoring	Excessive Op Time Alarm	CB Time Maint	*	*
155	CB Monitoring	Excessive Op Time Lookout	CB Time Lockout	*	*
156	CB Monitoring	EFF Lockout	Fault Freq Lock	*	*
157	CB Status	CB Status Alarm	CB Status Alarm	*	*
158	Current Differential	GPS Alarm	GPS Alarm		
159	CB Control	CB Failed to Trip	CB Trip Fail	*	*
160	CB Control	CB Failed to Close	CB Close Fail	*	*
161	CB Control	Control CB Unhealthy	Man CB Unhealthy	*	*
162	CB Control	Control No Checksync	No C/S Man Close		
163	Autoreclose	Autoclose Lockout/RLY BAR	A/R Lockout		*
163	Breaker Fail	Autoclose Lockout/RLY BAR	CB2 Fail Alarm		
164	Autoreclose	No Healthy (AR)	A/R CB Unhealthy		*
165	Autoreclose	No Check Sync / AR Fail	A/R No Checksync		
166	Current Differential	Incompatible relays	Incompatible Rly	*	*
167	Commission Test	Loop Back Test Enabled	Test Loopback	*	*
168	Current Differential	Signaling failure alarm	Signalling Fail	*	*
169	Current Differential	Signaling Propagation Delay Alarm	Comm Delay Alarm	*	*
170	Current Differential	Differential protection failure alarm	C Diff Failure	*	*
171	Current Differential	Diff Protection inhibited	C Diff Inhibited	*	*
172	Current Differential	Configuration Error	Config Error	*	*
173	Current Differential	Re-Configuration Error	Re-Config Error	*	*
174	Frequency Tracking	Frequency out of range	F out of range	*	*
175 to 183		Unused	Alarm 36 to Alarm 44	*	*
185		IEEE C37.94 Communications Alarms	Alarm 46	*	*
186		System Split alarm	Alarm 47	*	*
187	PSL	SR User Alarm 1	Alarm 48	*	*
188	PSL	SR User Alarm 2	Alarm 49	*	*

DDB No	Source	Description	English Text	P541	P542
189	PSL	SR User Alarm 3	Alarm 50	*	*
190	PSL	SR User Alarm 4	Alarm 51	*	*
191	PSL	SR User Alarm 5	Alarm 52	*	*
192	PSL	SR User Alarm 6	Alarm 53	*	*
193	PSL	SR User Alarm 7	Alarm 54	*	*
194	PSL	SR User Alarm 8	Alarm 55	*	*
195	PSL	MR User Alarm 9	Alarm 56	*	*
196	PSL	MR User Alarm 10	Alarm 57	*	*
197	PSL	MR User Alarm 11	Alarm 58	*	*
198	PSL	MR User Alarm 12	Alarm 59	*	*
199	PSL	MR User Alarm 13	Alarm 60	*	*
200	PSL	MR User Alarm 14	Alarm 61	*	*
201	PSL	MR User Alarm 15	Alarm 62	*	*
202	PSL	MR User Alarm 16	Alarm 63	*	*
203 to 206		Reserved			
207 to 223		Unused			
224	Menu		Control Input 1	*	*
225	Menu		Control Input 2	*	*
226	Menu		Control Input 3	*	*
227	Menu		Control Input 4	*	*
228	Menu		Control Input 5	*	*
229	Menu		Control Input 6	*	*
230	Menu		Control Input 7	*	*
231	Menu		Control Input 8	*	*
232	Menu		Control Input 9	*	*
233	Menu		Control Input 10	*	*
234	Menu		Control Input 11	*	*
235	Menu		Control Input 12	*	*
236	Menu		Control Input 13	*	*
237	Menu		Control Input 14	*	*
238	Menu		Control Input 15	*	*
239	Menu		Control Input 16	*	*
240	Menu		Control Input 17	*	*
241	Menu		Control Input 18	*	*
242	Menu		Control Input 19	*	*
243	Menu		Control Input 20	*	*
244	Menu		Control Input 21	*	*
245	Menu		Control Input 22	*	*
246	Menu		Control Input 23	*	*
247	Menu		Control Input 24	*	*
248	Menu		Control Input 25	*	*
249	Menu		Control Input 26	*	*
250	Menu		Control Input 27	*	*

DDB No	Source	Description	English Text	P541	P542
251	Menu		Control Input 28	*	*
252	Menu		Control Input 29	*	*
253	Menu		Control Input 30	*	*
254	Menu		Control Input 31	*	*
255	Menu		Control Input 32	*	*
256	PSL	Permissive Intertrip	Perm Intertrip	*	*
257	PSL	Stub Bus Enabled	Stub Bus Enabled		
258	PSL	Inhibit Current Differential	Inhibit C Diff	*	*
259	PSL	Reconfiguration Interlock	Recon Interlock	*	*
260	PSL	Block Phase Overcurrent Stage 1 time delay	I>1 Timer Block	*	*
261	PSL	Block Phase Overcurrent Stage 2 time delay	I>2 Timer Block	*	*
262	PSL	Block Phase Overcurrent Stage 3 time delay	I>3 Timer Block	*	*
263	PSL	Block Phase Overcurrent Stage 4 time delay	I>4 Timer Block	*	*
264	PSL	Block Standby Earth Fault Stage 1 time delay	IN>1 Timer Block	*	*
265	PSL	Block Standby Earth Fault Stage 2 time delay	IN>2 Timer Block	*	*
266	PSL	Block Standby Earth Fault Stage 3 time delay	IN>3 Timer Block	*	*
267	PSL	Block Standby Earth Fault Stage 4 time delay	IN>4 Timer Block	*	*
268	PSL	Block SEF Stage 1 time delay	ISEF>1 Timer Blk		
269	PSL	Block SEF Stage 2 time delay	ISEF>2 Timer Blk		
270	PSL	Block SEF Stage 3 time delay	ISEF>3 Timer Blk		
271	PSL	Block SEF Stage 4 time delay	ISEF>4 Timer Blk		
272	PSL	External Trip 3ph	External Trip3ph	*	*
273	PSL	External Trip A	External Trip A		
274	PSL	External Trip B	External Trip B		
275	PSL	External Trip C	External Trip C		
276	PSL	CB2 External Trip 3Ph	CB2 Ext Trip3ph		
277	PSL	CB2 External Trip Aph	CB2 Ext Trip A		
278	PSL	CB2 External Trip Bph	CB2 Ext Trip B		
279	PSL	CB2 External Trip Cph	CB2 Ext Trip C		
280	PSL	52-A CB Contact Input	CB Aux 3ph(52-A)	*	*
281	PSL	52-A CB Contact Input A Phase	CB Aux A(52-A)		
282	PSL	52-A CB Contact Input B Phase	CB Aux B(52-A)		
283	PSL	52-A CB Contact Input C Phase	CB Aux C(52-A)		
284	PSL	52-B CB Contact Input	CB Aux 3ph(52-B)	*	*
285	PSL	52-B CB Contact Input A Phase	CB Aux A(52-B)		
286	PSL	52-B CB Contact Input B Phase	CB Aux B(52-B)		
287	PSL	52-B CB Contact Input C Phase	CB Aux C(52-B)		
288	PSL	52-A CB 2 Contact Input	CB2Aux 3ph(52-A)		
289	PSL	52-A CB Contact Input A Phase	CB2Aux A(52-A)		
290	PSL	52-A CB Contact Input B Phase	CB2Aux B(52-A)		
291	PSL	52-A CB Contact Input C Phase	CB2Aux C(52-A)		
292	PSL	52-B CB Contact Input	CB2Aux 3ph(52-B)		
293	PSL	52-B CB Contact Input A Phase	CB2Aux A(52-B)		
294	PSL	52-B CB Contact Input B Phase	CB2Aux B(52-B)		

DDB No	Source	Description	English Text	P541	P542
295	PSL	52-B CB Contact Input C Phase	CB2Aux C(52-B)		
296	PSL	CB Healthy	CB Healthy	*	*
297	PSL	CB Healthy 2	CB2 Healthy		
298	PSL	MCB/VTS opto	MCB/VTS		
299	PSL	Logic Input Trip	Trip CB	*	*
300	PSL	Logic Input Close	Close CB	*	*
301	PSL	Logic Input Trip 2	Trip CB2		
302	PSL	Logic Input Close 2	Close CB2		
303	PSL	Reset Manual CB Close Timer Delay	Reset Close Dly	*	*
304	PSL	Reset Latched Relays & LED’s	Reset Relays/LED	*	*
305	PSL	Reset Thermal State	Reset Thermal	*	*
306	PSL	Reset Lockout Opto Input	Reset Lockout		*
307	PSL	Reset CB Maintance values	Reset CB Data	*	*
308	PSL	Block Autoreclose / BAR	BAR		*
309	PSL	Enable 1 pole reclose	En 1pole reclose		
310	PSL	Enable 3 pole reclose	En 3pole reclose		
311	PSL	Pole Discrepancy	Pole Discrepancy		
312		Unused			
313	PSL	Inhibit Power Swing Blocking	Inhibit PSB		
314	PSL	Trip 3 Phase - Input to Trip Latching Logic	Any 3 Pole Trip		
315	PSL	A Phase Trip- Input to Trip Latching Logic	Any Trip A		
316	PSL	B Phase Trip- Input to Trip Latching Logic	Any Trip B		
317	PSL	C Phase Trip- Input to Trip Latching Logic	Any Trip C		
318	PSL	Commissioning Tests	Test Mode	*	*
319	PSL	Propagagtion Delay Equal	Prop Delay Equal	*	*
320	PSL	User Defined Intertrip	Ch 1 Intertrip 1	*	*
321	PSL	User Defined Intertrip	Ch 1 Intertrip 2	*	*
322	PSL	User Defined Intertrip	Ch 1 Intertrip 3	*	*
323	PSL	User Defined Intertrip	Ch 1 Intertrip 4	*	*
324	PSL	User Defined Intertrip	Ch 1 Intertrip 5	*	*
325	PSL	User Defined Intertrip	Ch 1 Intertrip 6	*	*
326	PSL	User Defined Intertrip	Ch 1 Intertrip 7	*	*
327	PSL	User Defined Intertrip	Ch 1 Intertrip 8	*	*
328	PSL	User Defined Intertrip	Ch 2 Intertrip 1	*	*
329	PSL	User Defined Intertrip	Ch 2 Intertrip 2	*	*
330	PSL	User Defined Intertrip	Ch 2 Intertrip 3	*	*
331	PSL	User Defined Intertrip	Ch 2 Intertrip 4	*	*
332	PSL	User Defined Intertrip	Ch 2 Intertrip 5	*	*
333	PSL	User Defined Intertrip	Ch 2 Intertrip 6	*	*
334	PSL	User Defined Intertrip	Ch 2 Intertrip 7	*	*
335	PSL	User Defined Intertrip	Ch 2 Intertrip 8	*	*
336	PSL	Loopback	Loopback Mode	*	*
337	PSL	Block Distance Zone 1	Z1 Block		
338	PSL	Block Distance Zone 2	Z2 Block		

DDB No	Source	Description	English Text	P541	P542
339	PSL	Block Distance Zone 3	Z3 Block		
340	PSL	Command Blocking	Command Blocking	*	*
341	PSL	Monitor Blocking	Monitor Blocking	*	*
342	PSL	PSB Unblock	PSB Unblock		
343	PSL	CS1 Enabled	CS1 Enabled		
344	PSL	CS2 Enabled	CS2 Enabled		
345	PSL	SysSplit Enabled	SysSplit Enabled		
346	PSL		AR Check Sync OK		
347	PSL	Time Synch	Time Synch	*	*
348		Unused			
349		Unused			
350	All Protection	Any Trip	Any Trip	*	*
351	Current Differential	Differential Trip	Diff Trip	*	*
352	Current Differential	Differential Trip A	Diff Trip A	*	*
353	Current Differential	Differential Trip B	Diff Trip B	*	*
354	Current Differential	Differential Trip C	Diff Trip C	*	*
355	Current Differential	Differential Intertrip	Diff Intertrip	*	*
356	Current Differential	Differential Intertrip A	Diff Intertrip A	*	*
357	Current Differential	Differential Intertrip B	Diff Intertrip B	*	*
358	Current Differential	Differential Intertrip C	Diff Intertrip C	*	*
359	Current Differential	Direct Intertrip	Direct Intertrip		
360	Current Differential	Permissive Intertrip	Perm Intertrip	*	*
361	Distance	Any Zone 1 Trip	Zone 1 Trip		
362	Distance	Zone 1 A Phase Trip	Zone 1 A Trip		
363	Distance	Zone 1 B Phase Trip	Zone 1 B Trip		
364	Distance	Zone 1 C Phase Trip	Zone 1 C Trip		
365	Distance	Zone 1 N Trip	Zone 1 N Trip		
366	Distance	Any Zone 2 Trip	Zone 2 Trip		
367	Distance	Zone 2 A Phase Trip	Zone 2 A Trip		
368	Distance	Zone 2 B Phase Trip	Zone 2 B Trip		
369	Distance	Zone 2 C Phase Trip	Zone 2 C Trip		
370	Distance	Zone 2 N Trip	Zone 2 N Trip		
371	Distance	Any Zone 3 Trip	Zone 3 Trip		
372	Distance	Zone 3 A Phase Trip	Zone 3 A Trip		
373	Distance	Zone 3 B Phase Trip	Zone 3 B Trip		
374	Distance	Zone 3 C Phase Trip	Zone 3 C Trip		
375	Distance	Zone 3 N Trip	Zone 3 N Trip		
376	Autoreclose	Pole Discrepancy	Pole Discrepancy		
377	Current Differential	BU Intertrip	BU Intertrip	*	*
378	Current Differential	BU Intertrip A	BU Intertrip A	*	*
379	Current Differential	BU Intertrip B	BU Intertrip B	*	*
380	Current Differential	BU Intertrip C	BU Intertrip C	*	*
381	Current Differential	Force 3 pole backup Intertrip	Force 3pole BU		
382	Phase Overcurrent	1st Stage O/C Trip 3ph	I>1 Trip	*	*

DDB No	Source	Description	English Text	P541	P542
383	Phase Overcurrent	1st Stage O/C Trip A	I>1 Trip A	*	*
384	Phase Overcurrent	1st Stage O/C Trip B	I>1 Trip B	*	*
385	Phase Overcurrent	1st Stage O/C Trip C	I>1 Trip C	*	*
386	Phase Overcurrent	2nd Stage O/C Trip 3ph	I>2 Trip	*	*
387	Phase Overcurrent	2nd Stage O/C Trip A	I>2 Trip A	*	*
388	Phase Overcurrent	2nd Stage O/C Trip B	I>2 Trip B	*	*
389	Phase Overcurrent	2nd Stage O/C Trip C	I>2 Trip C	*	*
390	Phase Overcurrent	3rd Stage O/C Trip 3ph	I>3 Trip	*	*
391	Phase Overcurrent	3rd Stage O/C Trip A	I>3 Trip A	*	*
392	Phase Overcurrent	3rd Stage O/C Trip B	I>3 Trip B	*	*
393	Phase Overcurrent	3rd Stage O/C Trip C	I>3 Trip C	*	*
394	Phase Overcurrent	4th Stage O/C Trip 3ph	I>4 Trip	*	*
395	Phase Overcurrent	4th Stage O/C Trip A	I>4 Trip A	*	*
396	Phase Overcurrent	4th Stage O/C Trip B	I>4 Trip B	*	*
397	Phase Overcurrent	4th Stage O/C Trip C	I>4 Trip C	*	*
398	Earth Fault	1st Stage SBEF Trip	IN>1 Trip	*	*
399	Earth Fault	2nd Stage SBEF Trip	IN>2 Trip	*	*
400	Earth Fault	3rd Stage SBEF Trip	IN>3 Trip	*	*
401	Earth Fault	4th Stage SBEF Trip	IN>4 Trip	*	*
402	Sensitive Earth Fault	1st Stage SEF Trip	ISEF>1 Trip		
403	Sensitive Earth Fault	2nd Stage SEF Trip	ISEF>2 Trip		
404	Sensitive Earth Fault	3rd Stage SEF Trip	ISEF>3 Trip		
405	Sensitive Earth Fault	4th Stage SEF Trip	ISEF>4 Trip		
406	Broken Conductor	Broken Conductor Trip	Broken Wire Trip	*	*
407	Thermal Overload	Thermal Overload Trip	Thermal Trip	*	*
408	Current Differential	Stub Bus Trip	Stub Bus Trip		
409	Autoreclose	Autoreclose trip test	Trip 3 Pole		*
410	Autoreclose	Autoreclose trip test A phase	Trip Pole A		
411	Autoreclose	Autoreclose trip test B phase	Trip Pole B		
412	Autoreclose	Autoreclose trip test C Phase	Trip Pole C		
413 to 429		Unused			
430		Zone 1 Start	Zone 1 Start		
431		Zone 2 Start	Zone 2 Start		
432		Zone 3 Start	Zone 3 Start		
433		Differential Start	Diff Start	*	*
434	All Protection	Any Start	Any Start	*	*
435	Current Differential	Differential Start A	Diff Start A	*	*
436	Current Differential	Differential Start B	Diff Start B	*	*
437	Current Differential	Differential Start C	Diff Start C	*	*
438	Distance	Zone 1 A Phase Start	Zone 1 A Start		
439	Distance	Zone 1 B Phase Start	Zone 1 B Start		
440	Distance	Zone 1 C Phase Start	Zone 1 C Start		
441	Distance	Zone 1 N Start	Zone 1 N Start		
442	Distance	Zone 2 A Phase Start	Zone 2 A Start		

DDB No	Source	Description	English Text	P541	P542
443	Distance	Zone 2 B Phase Start	Zone 2 B Start		
444	Distance	Zone 2 C Phase Start	Zone 2 C Start		
445	Distance	Zone 2 N Start	Zone 2 N Start		
446	Distance	Zone 3 A Phase Start	Zone 3 A Start		
447	Distance	Zone 3 B Phase Start	Zone 3 B Start		
448	Distance	Zone 3 C Phase Start	Zone 3 C Start		
449	Distance	Zone 3 N Start	Zone 3 N Start		
450	Distance	Zone 6 Start (PSB Start)	Zone 6 Start		
451	Overcurrent	1st Stage O/C Start 3ph	I>1 Start	*	*
452	Overcurrent	1st Stage O/C Start A	I>1 Start A	*	*
453	Overcurrent	1st Stage O/C Start B	I>1 Start B	*	*
454	Overcurrent	1st Stage O/C Start C	I>1 Start C	*	*
455	Overcurrent	2nd Stage O/C Start 3ph	I>2 Start	*	*
456	Overcurrent	2nd Stage O/C Start A	I>2 Start A	*	*
457	Overcurrent	2nd Stage O/C Start B	I>2 Start B	*	*
458	Overcurrent	2nd Stage O/C Start C	I>2 Start C	*	*
459	Overcurrent	3rd Stage O/C Start 3ph	I>3 Start	*	*
460	Overcurrent	3rd Stage O/C Start A	I>3 Start A	*	*
461	Overcurrent	3rd Stage O/C Start B	I>3 Start B	*	*
462	Overcurrent	3rd Stage O/C Start C	I>3 Start C	*	*
463	Overcurrent	4th Stage O/C Start 3ph	I>4 Start	*	*
464	Overcurrent	4th Stage O/C Start A	I>4 Start A	*	*
465	Overcurrent	4th Stage O/C Start B	I>4 Start B	*	*
466	Overcurrent	4th Stage O/C Start C	I>4 Start C	*	*
467	Earth Fault	1st Stage SBEF Start	IN>1 Start	*	*
468	Earth Fault	2nd Stage SBEF Start	IN>2 Start	*	*
469	Earth Fault	3rd Stage SBEF Start	IN>3 Start	*	*
470	Earth Fault	4th Stage SBEF Start	IN>4 Start	*	*
471	Sensitive Earth Fault	1st Stage SEF Start	ISEF>1 Start		
472	Sensitive Earth Fault	2nd Stage SEF Start	ISEF>2 Start		
473	Sensitive Earth Fault	3rd Stage SEF Start	ISEF>3 Start		
474	Sensitive Earth Fault	4th Stage SEF Start	ISEF>4 Start		
475	Thermal Overload	Thermal Overload Alarm	Thermal Alarm	*	*
476	Overcurrent	I> Blocked O/C Start	I> BlockStart	*	*
477	Overcurrent	IN/ISEF> Blocked O/C Start	IN/SEF>Blk Start	*	*
478 to 486		Unused			
487	Battery Fail Monitor	Platform Alarm 0	Battery Fail	*	*
488		Platform Alarm 2		*	*
489	Ehernet Card	Platform Alarm 3	GOOSE IED Absent	*	*
490	Ehernet Card	Platform Alarm 4	NIC Not Fitted	*	*
491	Ehernet Card	Platform Alarm 5	NIC No Response	*	*
492	Ehernet Card	Platform Alarm 6	NIC Fatal Error	*	*
493	Ehernet Card	Platform Alarm 7	NIC Soft. Reload	*	*
494	Ehernet Card	Platform Alarm 8	Bad TCP/IP Cfg.	*	*

DDB No	Source	Description	English Text	P541	P542
495	Ehernet Card	Platform Alarm 9	Bad OSI Config.	*	*
496	Ehernet Card	Platform Alarm 10	NIC Link Fail	*	*
497	Ehernet Card	Platform Alarm 11	NIC SW Mis-Match	*	*
498	Ehernet Card	Platform Alarm 12	IP Addr Conflict	*	*
499		Platform Alarm 13		*	*
500		Platform Alarm 14		*	*
501		Platform Alarm 15		*	*
502		Platform Alarm 16		*	*
503		Platform Alarm 17	Backup Setting	*	*
504		Platform Alarm 18		*	*
505		Platform Alarm 19		*	*
506		Platform Alarm 20		*	*
507		Platform Alarm 21		*	*
508		Platform Alarm 22		*	*
509		Platform Alarm 23		*	*
510		Platform Alarm 24		*	*
511		Platform Alarm 25		*	*
512		Platform Alarm 26		*	*
513		Platform Alarm 27		*	*
514		Platform Alarm 28		*	*
515		Platform Alarm 29		*	*
516		Platform Alarm 30		*	*
517		Platform Alarm 31		*	*
518	VT Supervision	VTS Fast Block	VTS Fast Block		
519	VT Supervision	VTS Slow Block	VTS Slow Block		
520	Breaker Fail	tBF1 Trip 3Ph	Bfail1 Trip 3ph	*	*
521	Breaker Fail	tBF2 Trip 3Ph	Bfail2 Trip 3ph	*	*
522	Breaker Fail	Autoreclose Block Main Protection	CB2 Fail1 Trip		
523	Breaker Fail	Autoreclose Block SEF Protection	CB2 Fail2 Trip		
524	CB Control	Control Trip	Control Trip	*	*
525	CB Control	Control Close	Control Close	*	*
526	CB Control	Control Trip 2	Control Trip 2		
527	CB Control	Control Close 2	Control Close 2		
528	CB Control	Control Close in Progress	Close in Prog	*	*
529	Autoreclose	AR Block Main Protection	Block Main Prot		*
530	Autoreclose	AR Block SEF Protection	Block SEF Prot		*
531	Autoreclose	Auto Reclose/(AR 3 pole) in Progress	AR 3pole in prog		*
532	Autoreclose	AR 1pole in progress	AR 1pole in prog		
533	Autoreclose	Seq Counter = 0	Seq Counter = 0		*
534	Autoreclose	Seq Counter = 1	Seq Counter = 1		*
535	Autoreclose	Seq Counter = 2	Seq Counter = 2		*
536	Autoreclose	Seq Counter = 3	Seq Counter = 3		*
537	Autoreclose	Seq Counter = 4	Seq Counter = 4		*
538	Autoreclose	Seq Counter = 5	Seq Counter = 5		

DDB No	Source	Description	English Text	P541	P542
539	Autoreclose	Successful Reclosure	Successful Close		*
540	Autoreclose	Dead Time in Progress	Dead T in Prog		*
541	Autoreclose	Auto Close/ AR Close	Auto Close		*
542	Autoreclose	Autoreclose In/Out of service	A/R Status		*
543	Autoreclose	Autoreclose In/Out of service	A/R Status 3P		
544	Autoreclose	Autoreclose In/Out of service	AR Status 1P		
545	Autoreclose	AR Force 3 pole trips	Force 3 pole		
546	CB Control	Composite Lockout Alarm	Lockout Alarm	*	*
547	Field Voltage Monitor	Field Voltage Failure	Field Volts Fail	*	*
548	Undercurrent	IA< operate	IA< Start	*	*
549	Undercurrent	IB< operate	IB< Start	*	*
550	Undercurrent	IC< operate	IC< Start	*	*
551	Undercurrent	ISEF< operate	ISEF< Start	*	*
552	Undercurrent	PSL Internal Node 5	CB1 IA< Start		
553	PSL	PSL Internal Node 6	CB1 IB< Start		
554	Undercurrent	PSL Internal Node 7	CB1 IC< Start		
555	Undercurrent	PSL Internal Node 8	CB1 ISEF< Start		
556	Undercurrent	PSL Internal Node 9	CB2 IA< Start		
557	Undercurrent	PSL Internal Node 10	CB2 IB< Start		
558	Undercurrent	PSL Internal Node 11	CB2 IC< Start		
559	Undercurrent	PSL Internal Node 12	CB2 ISEF< Start		
560	Poledead	All Poles Dead	All Poles Dead	*	*
561	Poledead	Any Pole Dead	Any Pole Dead	*	*
562	Poledead	Phase A Pole Dead	Pole Dead A		
563	Poledead	Phase B Pole Dead	Pole Dead B		
564	Poledead	Phase C Pole Dead	Pole Dead C		
565	All Protection	Accelerate Ind	VTS Acc Ind		
566	All Protection	Any Voltage Dependent	VTS Volt Dep		
567	VT Supervision	Ia over threshold	VTS Ia>		
568	VT Supervision	Ib over threshold	VTS Ib>		
569	VT Supervision	Ic over threshold	VTS Ic>		
570	VT Supervision	Va over threshold	VTS Va>		
571	VT Supervision	Vb over threshold	VTS Vb>		
572	VT Supervision	Vc over threshold	VTS Vc>		
573	VT Supervision	I2 over threshold	VTS I2>		
574	VT Supervision	V2 over threshold	VTS V2>		
575	VT Supervision	Superimposed Ia over threshold	VTS Ia delta>		
576	VT Supervision	Superimposed Ib over threshold	VTS Ib delta>		
577	VT Supervision	Superimposed Ic over threshold	VTS Ic delta >		
578	All SEF Stages	Current Prot SEF Trip	B Fail SEF Trip		
579	Autoreclose	Control System Check OK	Ctl Check Synch		
580	Autoreclose	AR System Check OK/SYNC	AR Sys Check OK		
581	Autoreclose	Pre-Lockout	Pre-Lockout		*
582	CB Status Monitor	3 ph CB Open	CB Open 3 ph	*	*

DDB No	Source	Description	English Text	P541	P542
583	CB Status Monitor	Ph A CB Open	CB Open A ph		
584	CB Status Monitor	Ph B CB Open	CB Open B ph		
585	CB Status Monitor	Ph C CB Open	CB Open C ph		
586	CB Status Monitor	3 ph CB Closed	CB Closed 3 ph	*	*
587	CB Status Monitor	Ph A CB Closed	CB Closed A ph		
588	CB Status Monitor	Ph B CB Closed	CB Closed B ph		
589	CB Status Monitor	Ph C CB Closed	CB Closed C ph		
590	CB Status Monitor	3 ph CB2 Open	CB2 Open 3 ph		
591	CB Status Monitor	Ph A CB2 Open	CB2 Open A ph		
592	CB Status Monitor	Ph B CB2 Open	CB2 Open B ph		
593	CB Status Monitor	Ph C CB2 Open	CB2 Open C ph		
594	CB Status Monitor	3 ph CB2 Closed	CB2 Closed 3 ph		
595	CB Status Monitor	Ph A CB2 Closed	CB2 Closed A ph		
596	CB Status Monitor	Ph B CB2 Closed	CB2 Closed B ph		
597	CB Status Monitor	Ph C CB2 Closed	CB2 Closed C ph		
598	Frequency Tracking	Freq High	Freq High	*	*
599	Frequency Tracking	Freq Low	Freq Low	*	*
600	Frequency Tracking	Freq Not found	Freq Not found	*	*
601	Frequency Tracking	Stop Freq Track	Stop Freq Track	*	*
602	Current Differential	Protection Signaling Failure Alarm - Ch1 Rx	SignalFail Ch1Rx	*	*
603	Current Differential	Protection Signaling Failure Alarm - Ch1 Tx	SignalFail Ch1Tx	*	*
604	Current Differential	Protection Signaling Failure Alarm - Ch2 Rx	SignalFail Ch2Rx	*	*
605	Current Differential	Protection Signaling Failure Alarm - Ch2 Tx	SignalFail Ch2Tx	*	*
606	PSL	Remote 1 GPS Fail	Ch 1 GPS Fail		
607	PSL	Remote 2 GPS Fail	Ch 2 GPS Fail		
608	Current Differential	relay is already configured	Config Same	*	*
609	Current Differential	reconfigure was successful	Reconfig Pass	*	*
610	Current Differential	reconfigure was unsuccessful	Reconfig Fail	*	*
611	Current Differential	restore was successful	Restore Pass	*	*
612	Current Differential	restore was unsuccessful	Restore Fail	*	*
613	Current Differential	Inhibit Current Differential	Inhibit C Diff	*	*
614	Overcurrent	Overcurrent Intertrip Enabled	I>3 Intertrip	*	*
615	Distance	Zone 1 Intertrip Enabled	Z1 Intertrip		
616	Distance	Zone 2 Intertrip Enabled	Z2 Intertrip		
617	Distance	Zone 3 Intertrip Enabled	Z3 Intertrip		
618	Menu	Single Pole Trip Enable	1 Pole Trip En		
619	CB Status	CB Status Alarm	CB Status Alarm	*	*
620	CB Status	CB Status Alarm 2	CB2 Status Alarm		
621	PSL	User Defined Intertrip	Ch 1 Intertrip 1	*	*
622	PSL	User Defined Intertrip	Ch 1 Intertrip 2	*	*
623	PSL	User Defined Intertrip	Ch 1 Intertrip 3	*	*
624	PSL	User Defined Intertrip	Ch 1 Intertrip 4	*	*
625	PSL	User Defined Intertrip	Ch 1 Intertrip 5	*	*
626	PSL	User Defined Intertrip	Ch 1 Intertrip 6	*	*

DDB No	Source	Description	English Text	P541	P542
627	PSL	User Defined Intertrip	Ch 1 Intertrip 7	*	*
628	PSL	User Defined Intertrip	Ch 1 Intertrip 8	*	*
629	PSL	User Defined Intertrip	Ch 2 Intertrip 1	*	*
630	PSL	User Defined Intertrip	Ch 2 Intertrip 2	*	*
631	PSL	User Defined Intertrip	Ch 2 Intertrip 3	*	*
632	PSL	User Defined Intertrip	Ch 2 Intertrip 4	*	*
633	PSL	User Defined Intertrip	Ch 2 Intertrip 5	*	*
634	PSL	User Defined Intertrip	Ch 2 Intertrip 6	*	*
635	PSL	User Defined Intertrip	Ch 2 Intertrip 7	*	*
636	PSL	User Defined Intertrip	Ch 2 Intertrip 8	*	*
637	PFSO	I2> detector	I2>		
638	UI	HMI Access Lvl 1	HMI Access Lvl 1	*	*
639	UI	HMI Access Lvl 2	HMI Access Lvl 2	*	*
640	UI	FPort AccessLvl1	FPort AccessLvl1	*	*
641	UI	FPort AccessLvl2	FPort AccessLvl2	*	*
642	UI	RPrt1 AccessLvl1	RPrt1 AccessLvl1	*	*
643	UI	RPrt1 AccessLvl2	RPrt1 AccessLvl2	*	*
644	UI	RPrt2 AccessLvl1	RPrt2 AccessLvl1	*	*
645	UI	RPrt2 AccessLvl2	RPrt2 AccessLvl2	*	*
646	AR	Unused			
647		Live Line	Live Line		
648		Dead Line	Dead Line		
649		Live Bus	Live Bus		
650		Dead Bus	Dead Bus		
651		Check Sync 1 OK	Check Sync 1 OK		
652		Check Sync 2 OK	Check Sync 2 OK		
653		SysChks Inactive	SysChks Inactive		
654 to 656		Unused			
657		Ch1 Loss Of Signal	Ch1 Signal Lost	*	*
658		Ch1 Path "Yellow"	Ch1 Path Yellow	*	*
659		Ch1 Mismatch Received N	Ch1 Mismatch RxN	*	*
660		Ch2 Loss Of Signal	Ch2 Signal Lost	*	*
661		Ch2 Path "Yellow"	Ch2 Path Yellow	*	*
662		Ch2 Mismatch Received N	Ch2 Mismatch RxN	*	*
663 to 671		Unused			
672		GOOSE VIP 1	Virtual Input 1	*	*
673		GOOSE VIP 2	Virtual Input 2	*	*
674		GOOSE VIP 3	Virtual Input 3	*	*
675		GOOSE VIP 4	Virtual Input 4	*	*
676		GOOSE VIP 5	Virtual Input 5	*	*
677		GOOSE VIP 6	Virtual Input 6	*	*
678		GOOSE VIP 7	Virtual Input 7	*	*
679		GOOSE VIP 8	Virtual Input 8	*	*

DDB No	Source	Description	English Text	P541	P542
680		GOOSE VIP 9	Virtual Input 9	*	*
681		GOOSE VIP 10	Virtual Input 10	*	*
682		GOOSE VIP 11	Virtual Input 11	*	*
683		GOOSE VIP 12	Virtual Input 12	*	*
684		GOOSE VIP 13	Virtual Input 13	*	*
685		GOOSE VIP 14	Virtual Input 14	*	*
686		GOOSE VIP 15	Virtual Input 15	*	*
687		GOOSE VIP 16	Virtual Input 16	*	*
688		GOOSE VIP 17	Virtual Input 17	*	*
689		GOOSE VIP 18	Virtual Input 18	*	*
690		GOOSE VIP 19	Virtual Input 19	*	*
691		GOOSE VIP 20	Virtual Input 20	*	*
692		GOOSE VIP 21	Virtual Input 21	*	*
693		GOOSE VIP 22	Virtual Input 22	*	*
694		GOOSE VIP 23	Virtual Input 23	*	*
695		GOOSE VIP 24	Virtual Input 24	*	*
696		GOOSE VIP 25	Virtual Input 25	*	*
697		GOOSE VIP 26	Virtual Input 26	*	*
698		GOOSE VIP 27	Virtual Input 27	*	*
699		GOOSE VIP 28	Virtual Input 28	*	*
700		GOOSE VIP 29	Virtual Input 29	*	*
701		GOOSE VIP 30	Virtual Input 30	*	*
702		GOOSE VIP 31	Virtual Input 31	*	*
703		GOOSE VIP 32	Virtual Input 32	*	*
704		GOOSE Out 1	Virtual Output 1	*	*
705		GOOSE Out 2	Virtual Output 2	*	*
706		GOOSE Out 3	Virtual Output 3	*	*
707		GOOSE Out 4	Virtual Output 4	*	*
708		GOOSE Out 5	Virtual Output 5	*	*
709		GOOSE Out 6	Virtual Output 6	*	*
710		GOOSE Out 7	Virtual Output 7	*	*
711		GOOSE Out 8	Virtual Output 8	*	*
712		GOOSE Out 9	Virtual Output 9	*	*
713		GOOSE Out 10	Virtual Output10	*	*
714		GOOSE Out 11	Virtual Output11	*	*
715		GOOSE Out 12	Virtual Output12	*	*
716		GOOSE Out 13	Virtual Output13	*	*
717		GOOSE Out 14	Virtual Output14	*	*
718		GOOSE Out 15	Virtual Output15	*	*
719		GOOSE Out 16	Virtual Output16	*	*
720		GOOSE Out 17	Virtual Output17	*	*
721		GOOSE Out 18	Virtual Output18	*	*
722		GOOSE Out 19	Virtual Output19	*	*
723		GOOSE Out 20	Virtual Output20	*	*

DDB No	Source	Description	English Text	P541	P542
724		GOOSE Out 21	Virtual Output21	*	*
725		GOOSE Out 22	Virtual Output22	*	*
726		GOOSE Out 23	Virtual Output23	*	*
727		GOOSE Out 24	Virtual Output24	*	*
728		GOOSE Out 25	Virtual Output25	*	*
729		GOOSE Out 26	Virtual Output26	*	*
730		GOOSE Out 27	Virtual Output27	*	*
731		GOOSE Out 28	Virtual Output28	*	*
732		GOOSE Out 29	Virtual Output29	*	*
733		GOOSE Out 30	Virtual Output30	*	*
734		GOOSE Out 31	Virtual Output31	*	*
735		GOOSE Out 32	Virtual Output32	*	*
736 to 749		Unused			
750	FL	Fixed Logic Internal Node			
751	FL	Fixed Logic Internal Node			
752	FL	Fixed Logic Internal Node			
753	FL	Fixed Logic Internal Node			
754	FL	Fixed Logic Internal Node			
755	FL	Fixed Logic Internal Node			
756	FL	Fixed Logic Internal Node			
757	FL	Fixed Logic Internal Node			
758	FL	Fixed Logic Internal Node			
759	FL	Fixed Logic Internal Node			
760	FL	Fixed Logic Internal Node			
761	FL	Fixed Logic Internal Node			
762	FL	Fixed Logic Internal Node			
763	FL	Fixed Logic Internal Node	BU Trip Send A	*	*
764	FL	Fixed Logic Internal Node	BU Trip Send B	*	*
765	FL	Fixed Logic Internal Node	BU Trip Send C	*	*
766	FL	Fixed Logic Internal Node	Backup Enabled	*	*
767 to 823		Unused			
824 to 973	PSL	PSL Internal Node		*	*
974 to 1022		Unused			

Table 2 - Description of Logic Nodes

2.1 Factory Default Programmable Scheme Logic (PSL)

The P54x model options are as follows:

Model/Cortec Number	CT Inputs	Opto Inputs	Relay Outputs
P541x1xxxxx30xJ	4	8	7
P542x1xxxxx30xJ	4	16	14

Table 3 - Default settings

Additional details are provided in the P54x Cortec tables.

2.2 Logic Input Mappings

The default mappings for each of the opto-isolated inputs are as shown in Table 4:

	P541		P542	
Opto-Input No	Relay Text	Function	Relay Text	Function
1	Input L1	L1 Inhibit Diff	Input L1	L1 Inhibit Diff
2	Input L2	L2 Interlock	Input L2	L2 Interlock
3	Input L3	L3 Aid 1 Receive	Input L3	L3 Aid 1 Receive
4	Input L4	L4 Aid 1 COS/LGS	Input L4	L4 Aid 1 COS/LGS
5	Input L5	L5 Reset LEDs	Input L5	L5 Reset LEDs
6	Input L6	L6 Ext Trip A	Input L6	L6 CB2 AuxA 52-B
7	Input L7	L7 Ext Trip B	Input L7	L7 CB2 AuxB 52-B
8	Input L8	L8 Ext Trip C	Input L8	L8 CB2 AuxC 52-B
9			Input L9	L9 CB AuxA 52-B
10			Input L10	L10 CB AuxB 52-B
11			Input L11	L11 CB AuxC 52-B
12			Input L12	L12 MCB/VTS
13			Input L13	L13 CB1 CloseMan
14			Input L14	L14 CB2 CloseMan
15			Input L15	L15 Not Used
16			Input L16	L16 Stub Bus En

Table 4 - P541/P542 Opto Input Mappings

2.3 Relay Output Contact Mappings

The default mappings for each of the relay output contacts are as shown in Table 5:

	P541			P542		
Relay Contact No	**Relay Text**	**Relay Conditioner**	**Function**	**Relay Text**	**Relay Conditioner**	**Function**
1	Output R1	Straight-through	R1 Trip Z1	Output R1	Straight-through	R1 Trip Diff/Z1
2	Output R2	Straight-through	R2 SignalingFail	Output R2	Straight-through	R2 SignalingFail
3	Output R3	Dwell 100ms	R3 Any Trip	Output R3	Dwell 100ms	R3 Any Trip
4	Output R4	Dwell 500ms	R4 General Alarm	Output R4	Dwell 500ms	R4 General Alarm
5	Output R5	Straight-through	R5 IM64 1	Output R5	Straight-through	R5 IM64 1
6	Output R6	Dwell 100ms	R6 CB Fail Time1	Output R6	Dwell 100ms	R6 CB1 Fail1Trip
7	Output R7	Straight-through	R7 Cntl CB Close	Output R7	Straight-through	R7 Cntl CB1 Close
8				Output R8	Straight-through	R8 Cntl CB1 Trip
9				Output R9	Dwell 100ms	R9 Trip A
10				Output R10	Dwell 100ms	R10 Trip B
11				Output R11	Dwell 100ms	R11 Trip C
12				Output R12	Dwell 100ms	R12 CB2 Fail1Trip
13				Output R13	Straight-through	R13 CntlCB2Close
14				Output R14	Straight-through	R14 Cntl CB2Trip

Table 5 - P541/P542 relay output contacts default mappings

2.4 Programmable LED Output Mappings

The default mappings for each of the programmable LEDs are as shown in Table 6:

	P541			P542		
LED No	**LED Input Connection/Text**	**Latched**	**LED Function Indication**	**LED Input Connection/Text**	**Latched**	**LED Function Indication**
1	LED 1 Red	Yes	Diff Trip	LED 1 Red	Yes	Diff Trip
2	LED 2 Red	Yes	Dist Inst Trip	LED 2 Red	Yes	Dist Inst Trip
3	LED 3 Red	Yes	Dist Delay Trip	LED 3 Red	Yes	Dist Delay Trip
4	LED 4 Red	No	Signaling Fail	LED 4 Red	No	Signaling Fail
5	LED 5 Red	No	Any Start	LED 5 Red	No	Any Start
6	LED 6 Red	No	AR in Progress	LED 6 Red	No	Not Used
7	LED 7 Grn.	No	AR Lockout	LED 7 Grn.	No	Not Used
8	LED 8 Red	No	Test Loopback	LED 8 Red	No	Test Loopback

Table 6 - P541/P542 programmable LED default mappings

2.5 Fault Recorder Start Mappings

The default mappings for the signal which initiates a fault record is as shown below:

Initiating Signal	Fault Trigger
DDB Any Trip (522)	Initiate fault recording from main protection trip

2.6 PSL DATA Column

The MiCOM P54x 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 08:59:32.047	This cell displays the date and time when the PSL was down loaded to the relay.
Grp. 1 PSL 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.*

Table 7 - Cell functions

3 MICOM P541 PROGRAMMABLE LOGIC

3.1 P541 Opto Input Mappings

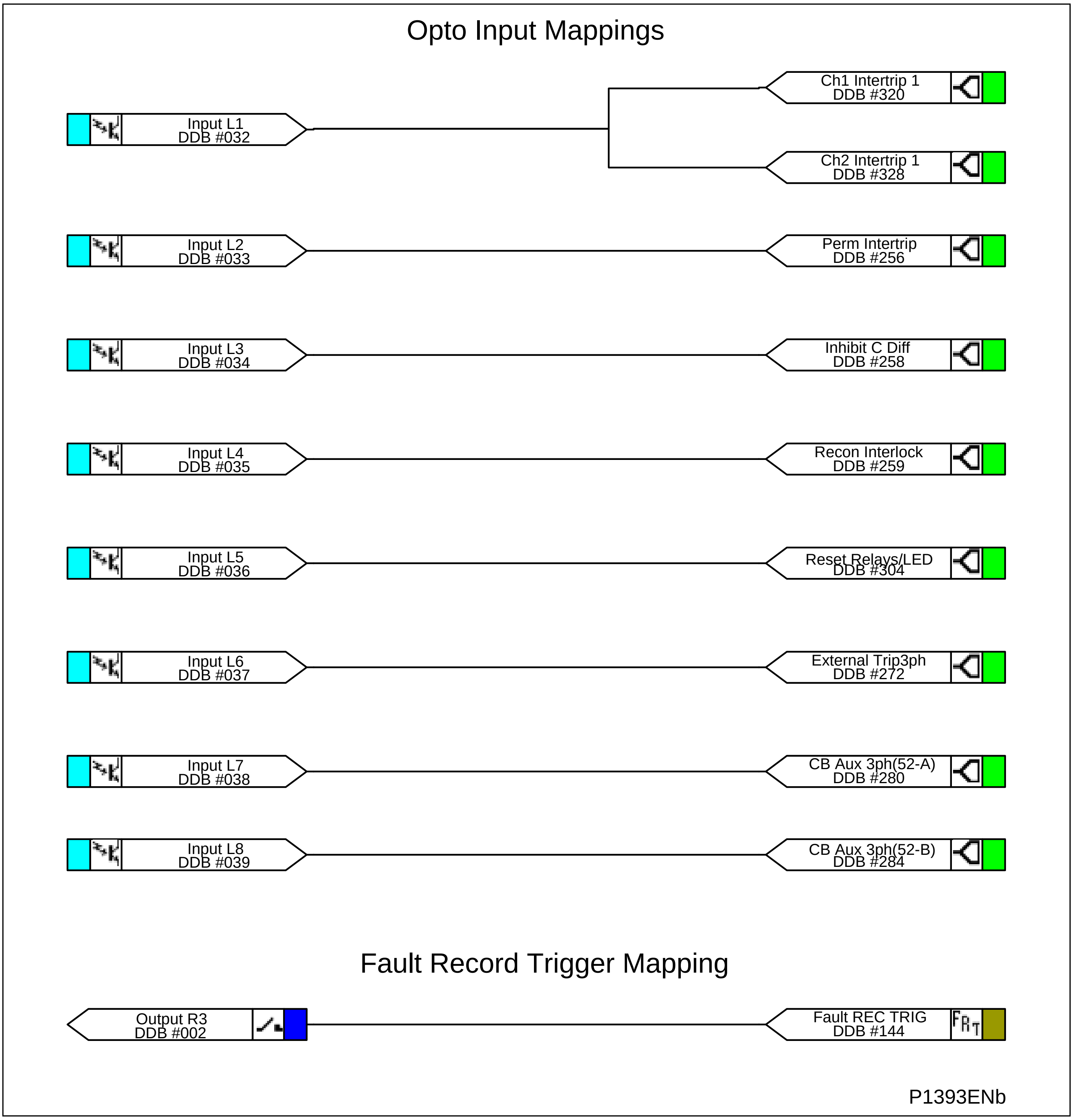


Figure 7 - P541, Page 1

3.2 P541 Output Relay Mapping 1

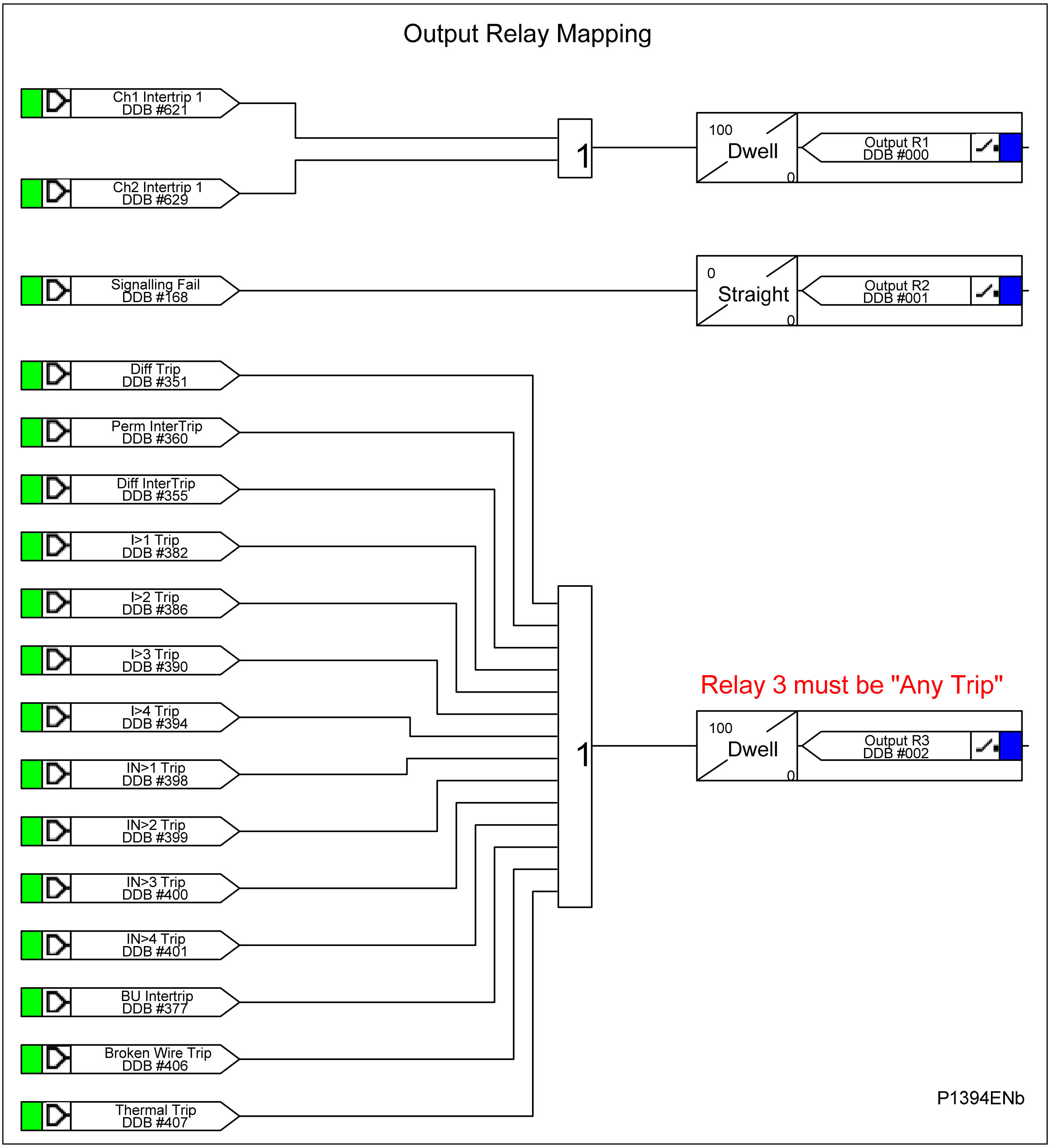


Figure 8 - P541, Page 2

3.3 P541 Output Relay Mapping 2

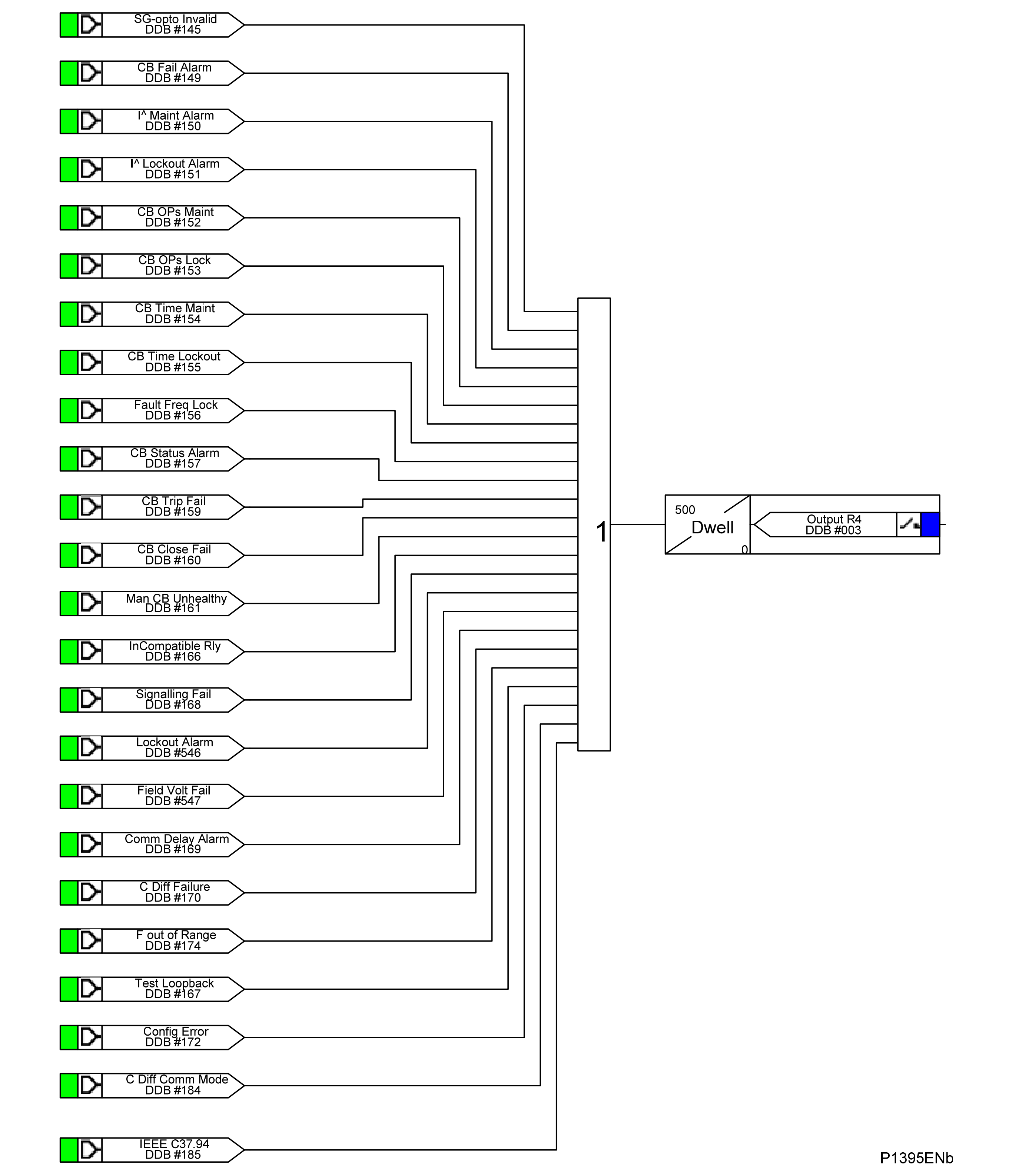


Figure 9 - P541, Page 3

3.4 P541 Output Relay Mapping 3

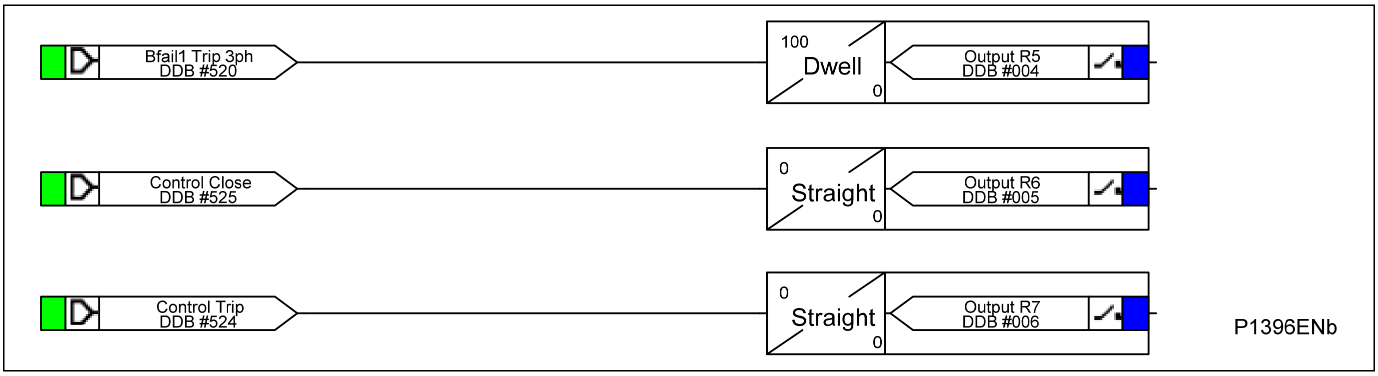


Figure 10 - P541, Page 4

3.5 P541 LED Mapping

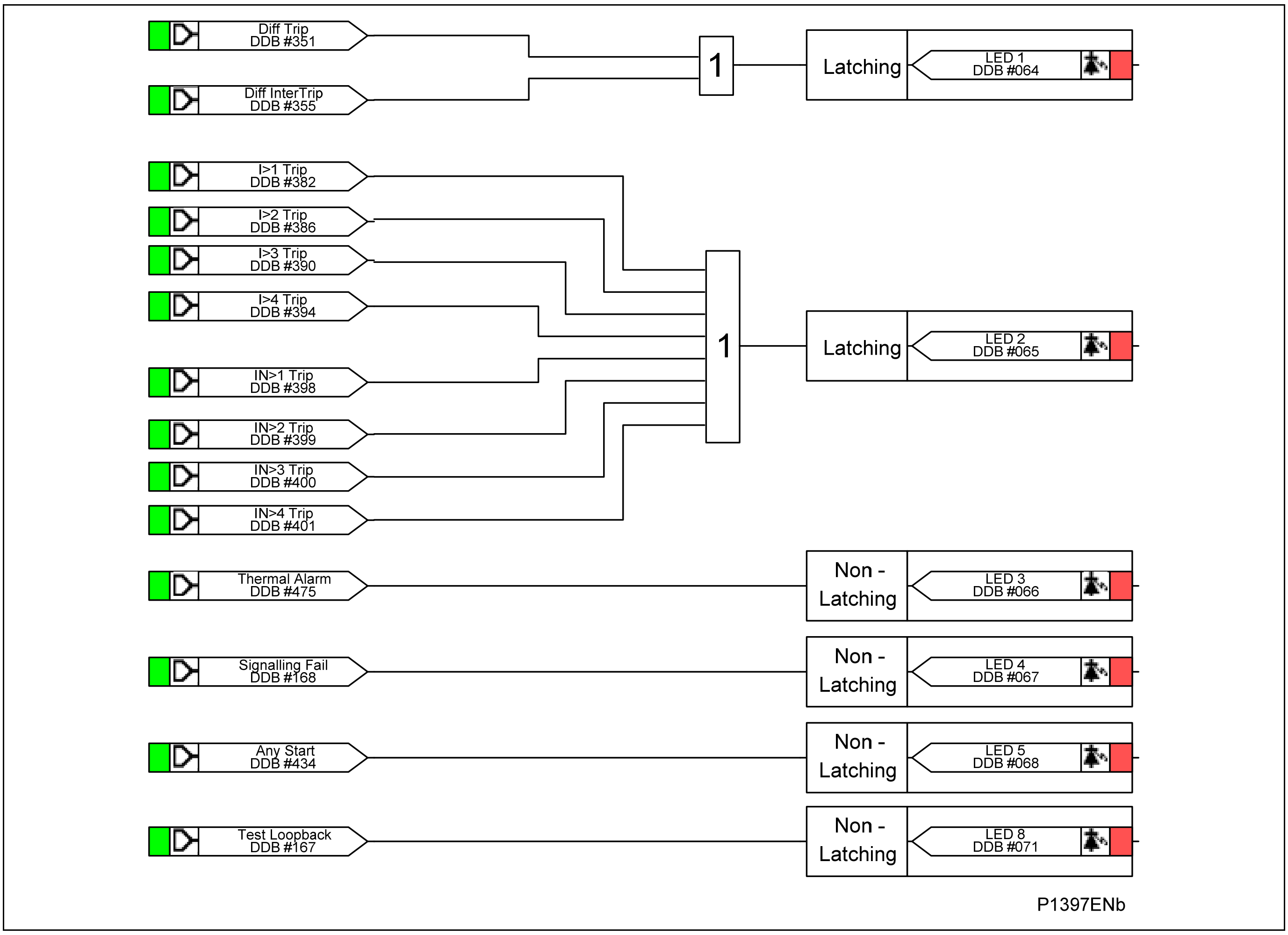


Figure 11 - P541, Page 5

4 MICOM P542 PROGRAMMABLE LOGIC

4.1 P542 Opto Input Mappings

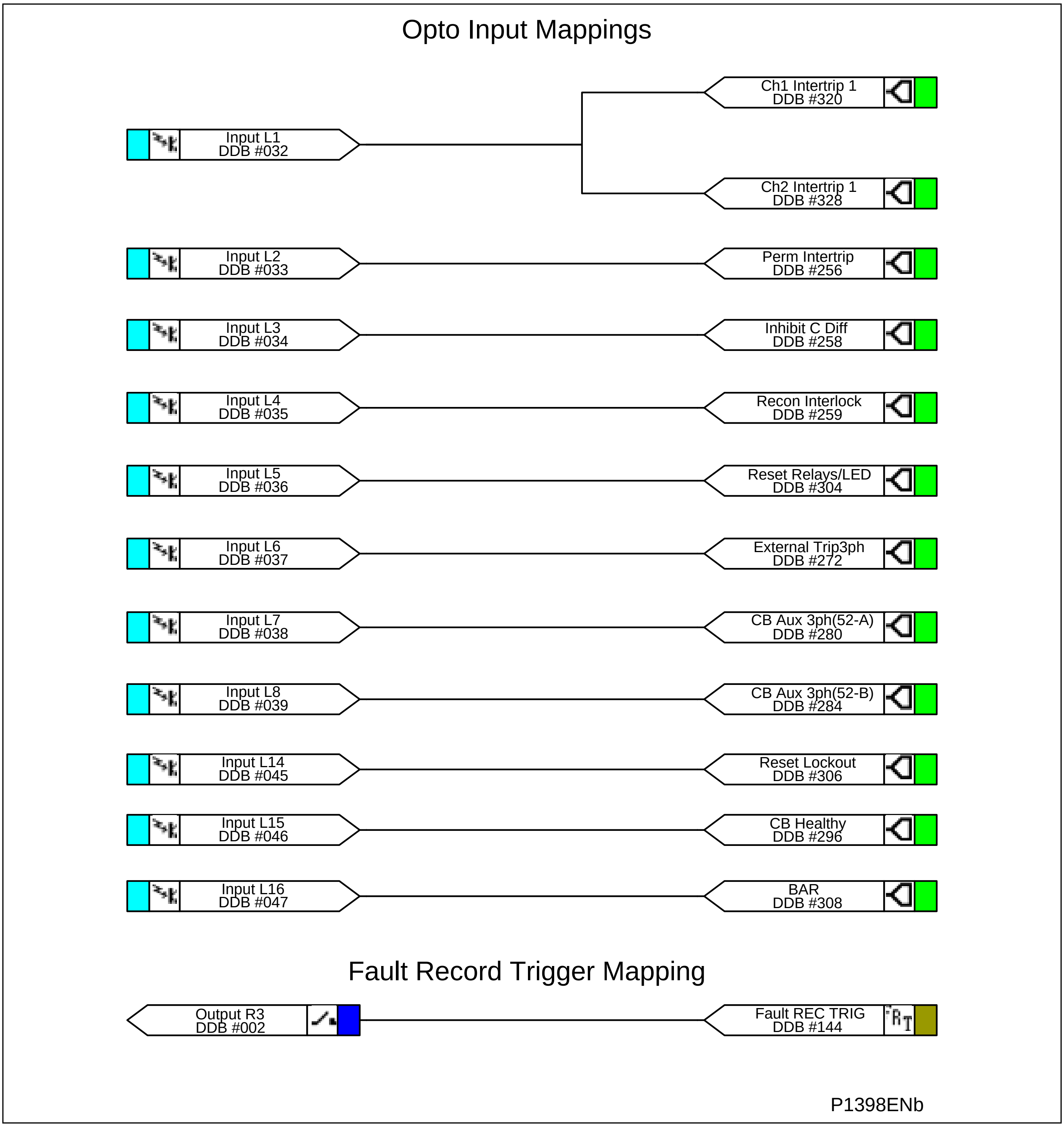


Figure 12 - P542, Page 1

4.2 P542 Output Relay Mapping 1

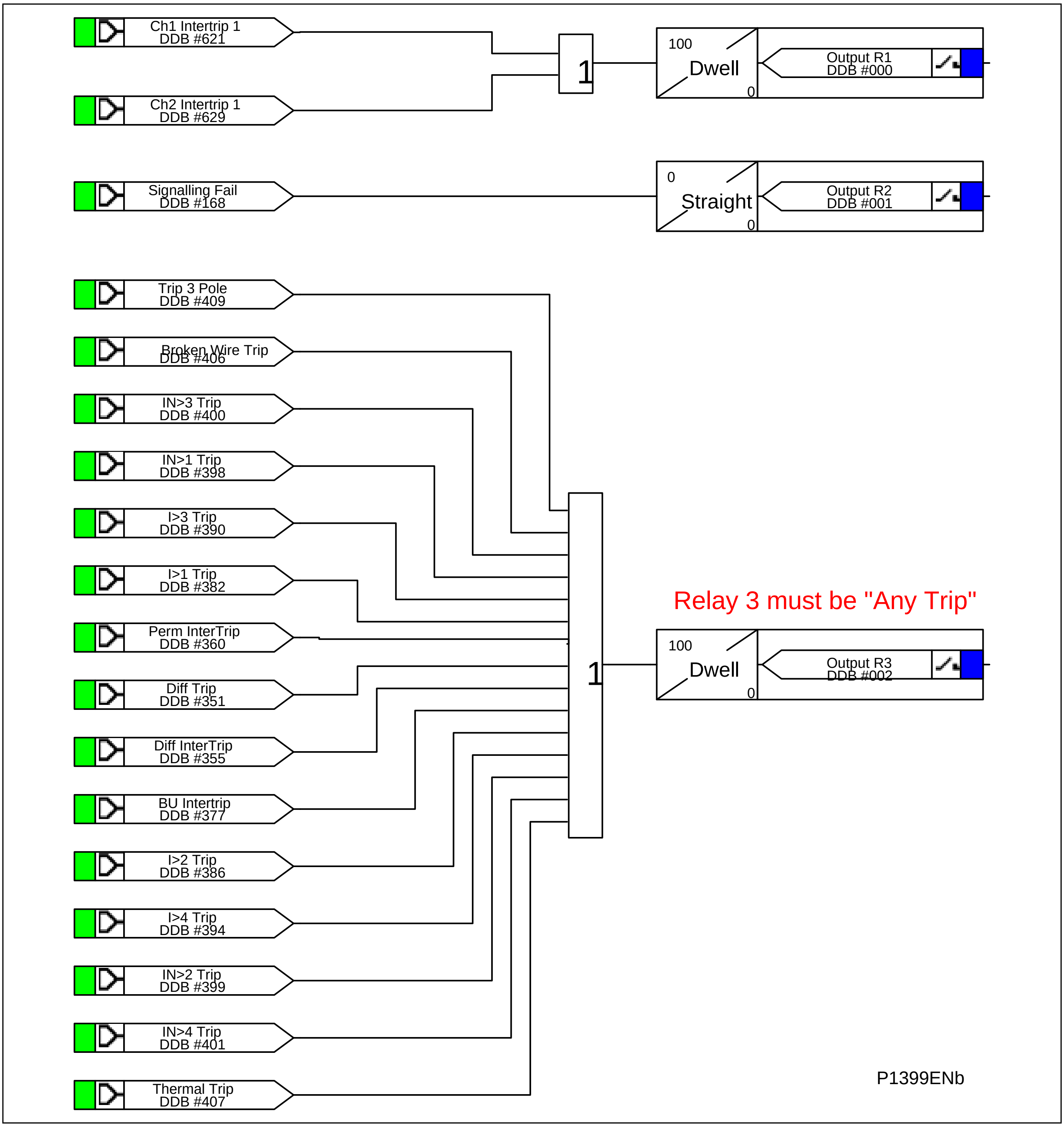


Figure 13 - P542, Page 2

4.3 P542 Output Relay Mapping 2

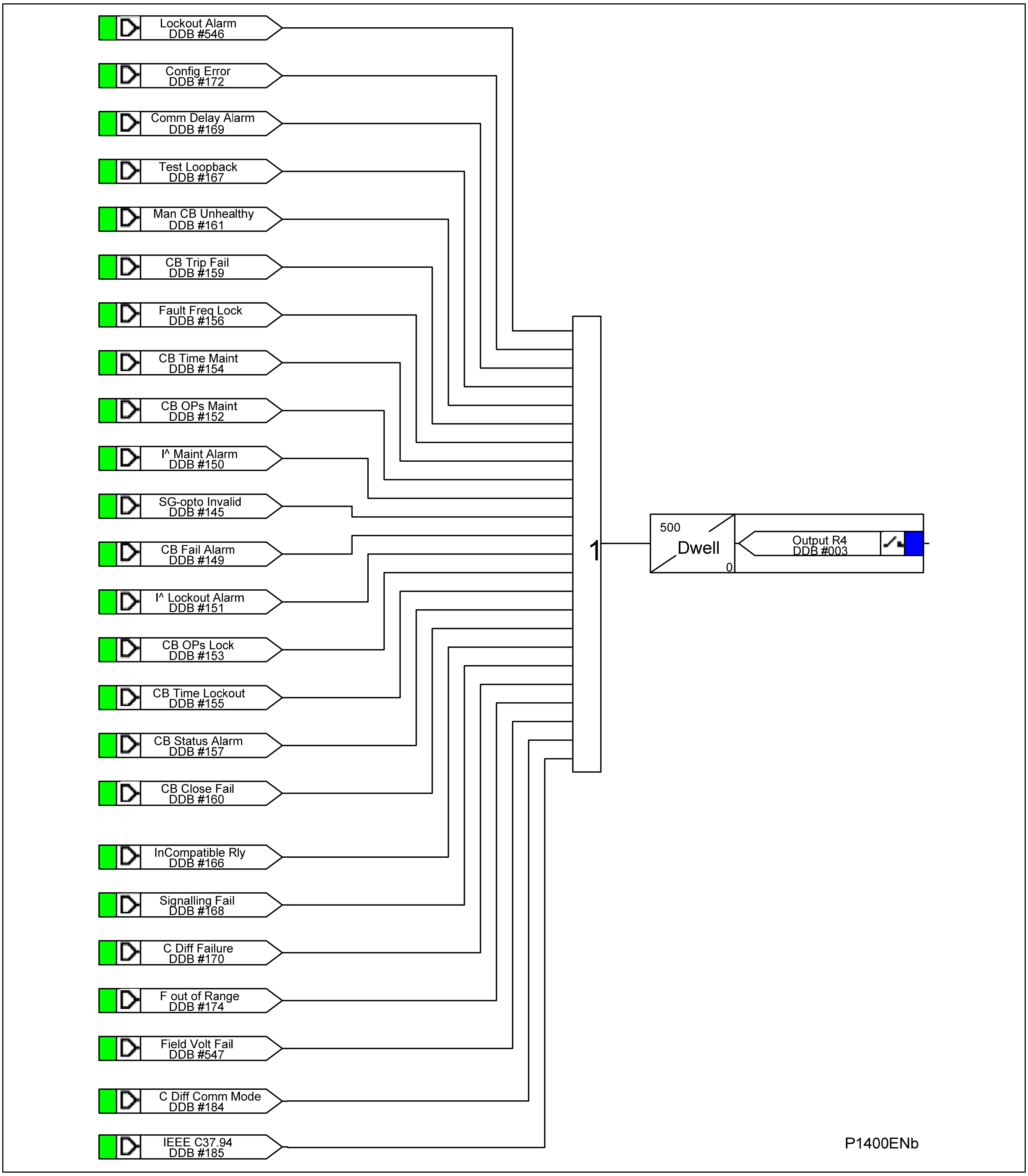


Figure 14 - P542, Page 3

4.4 P542 Output Relay Mapping 3

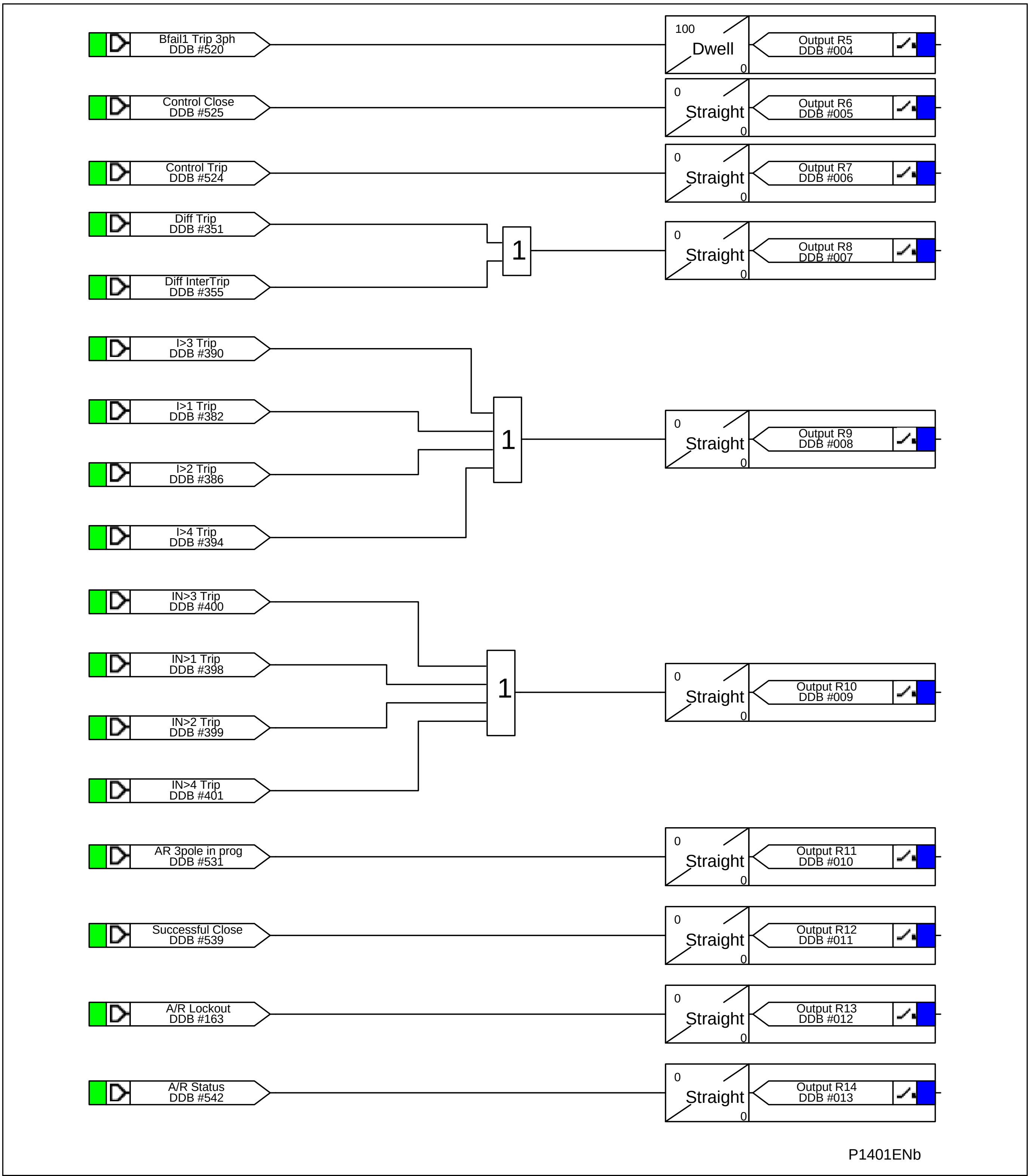


Figure 15 - P542, Page 4

4.5 P542 LED Mapping

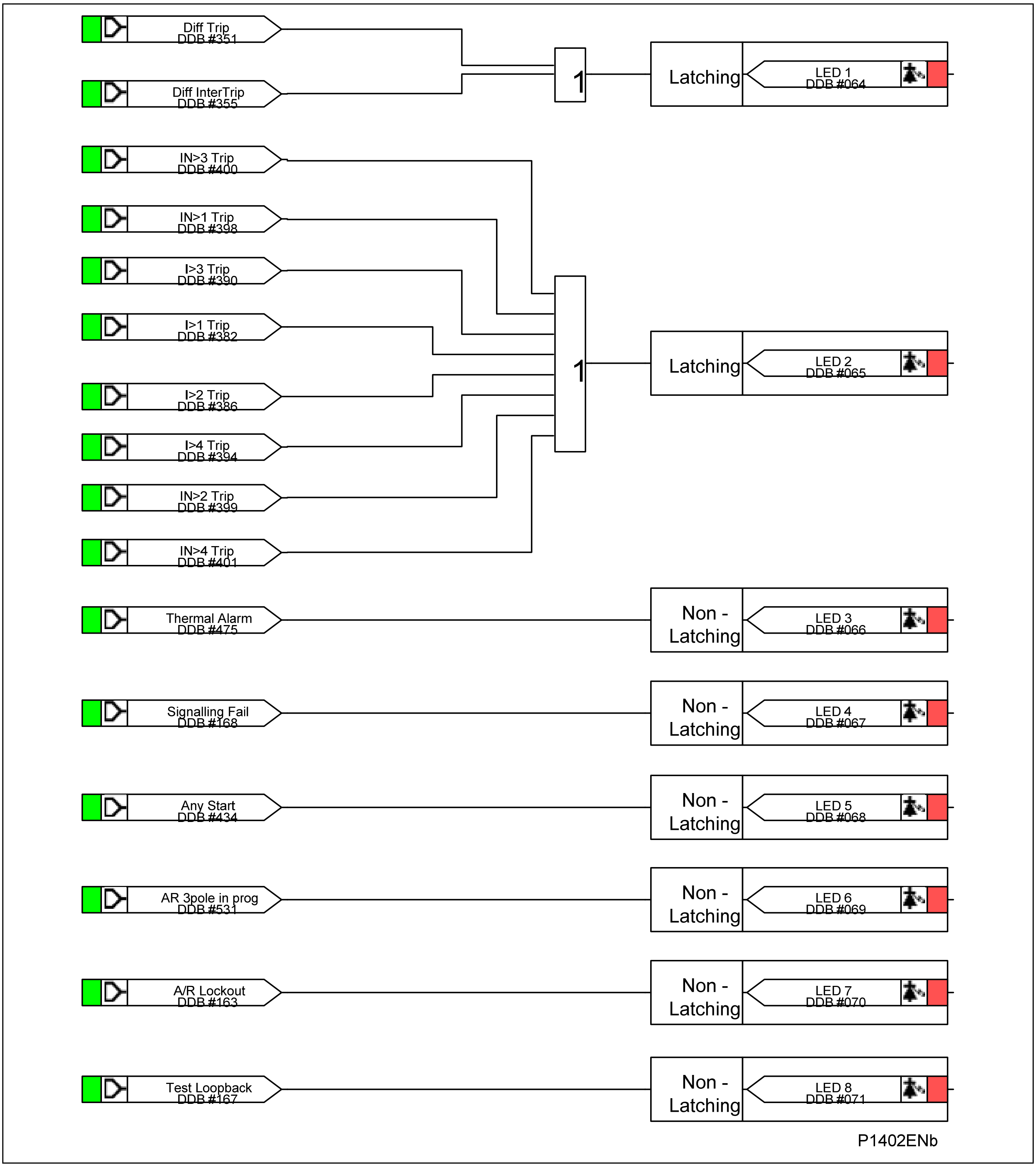


Figure 16 - P542, Page 5

Notes:

MEASUREMENTS AND RECORDING

CHAPTER 8

Notes:

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1 INTRODUCTION

The P54x relay 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.

2 EVENT AND FAULT RECORDS

The relay records and time tags up to 250 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 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 Table 1:

VIEW RECORDS	
LCD Reference	**Description**
Select Event	Setting range from 0 to 249. This selects the required event record from the possible 250 that may be stored. A value of 0 corresponds to the latest event and so on.
Time & Date	Time & Date Stamp for the event given by the internal Real Time Clock.
Event Text	Up to 32 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 4. This selects the required fault record from the possible 5 that may be stored. A value of 0 corresponds to the latest fault and so on.
	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 4. This selects the required maintenance report from the possible 5 that may be stored. A value of 0 corresponds to the latest report and so on.
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.

Table 1 - View Records

For extraction from a remote source via communications, refer to the SCADA Communications section (P54x/EN CT), where the procedure is fully explained.

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. These sections show the various items that constitute an event:

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 the protection algorithm ran, the new status is logged as an event. When this event is selected to be viewed on the LCD, these three applicable cells will become visible:

Time & date of event
“LOGIC INPUTS 1”
“Event Value 0101010101010101”

The Event Value is an 8, 12, 16 or 24-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.

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 the protection algorithm ran, the new status is logged as an event. When this event is selected to be viewed on the LCD, these three applicable cells will become visible:

Time & date of event
“OUTPUT CONTACTS 1”
“Event Value 010101010101010101010”

The Event Value is an 8, 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.

2.1.3 Relay Alarm Conditions

Any alarm conditions generated by the relays will also be logged as individual events. Table 2 shows examples of some 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

Table 2 - Alarm conditions and events

Table 2 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.

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.

2.1.5 General Events

A number of events come under the heading of 'General Events' - see Table 3:

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

Table 3 - Examples of General Events

A complete list of the 'General Events' is given in the Relay Menu Database (P54x/EN MD), which is a separate document, available for downloading from our website.

www.schneider-electric.com

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.

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 5 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.

2.1.8 Setting Changes

Changes to any setting within the relay are logged as an event. Two examples are shown in Table 4:

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		

Table 4 - Examples of Setting Changes

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'.*

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.

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 2006 15:32:49 GMT I>1 Start ON

MiCOM: MiCOM P54x
Model Number: P54XXXXXXXXXXXJ
Address: 001 Column: 00 Row: 23
Event Type: Protection operation

Monday 03 January 2006 15:32:52 GMT Fault Recorded

MiCOM: MiCOM P54x
Model Number: P54XXXXXXXXXXXJ
Address: 001 Column: 01 Row: 00
Event Type: Fault record

Monday 03 January 2006 15:33:11 GMT Logic Inputs

MiCOM: MiCOM P54x
Model Number: P54XXXXXXXXXXXJ
Address: 001 Column: 00 Row: 20
Event Type: Logic input changed state

Monday 03 January 2006 15:34:54 GMT Output Contacts

MiCOM: MiCOM P54x
Model Number: P54XXXXXXXXXXXJ
Address: 001 Column: 00 Row: 21
Event Type: Relay output changed state

Monday 03 January 2006 15:35:55 GMT A/R Lockout ON

MiCOM: MiCOM P54x
Model Number: P54XXXXXXXXXXXJ

Address: 001 Column: 00 Row: 22
Event Type: Alarm event

Tuesday 04 January 2006 20:18:22.988 GMT Zone 1 Trip ON

MiCOM: MiCOM P54x
Model Number: P54XXXXXXXXXXXJ
Address: 001 Column: 0F Row: 30
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 the Relay Menu Database document (P54x/EN MD). This is a standalone document not included in this manual.

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 shown in Table 5:

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.		
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	

Menu Text	Default Setting	Available Settings
Displays the status of DDB signals 1022 - 992.		

Table 5 - Event filtering

Note	*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 (P54x/EN MD).

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 20 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.

The recorder stores actual samples that are taken at a rate of 48 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 Table 6:

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	IA, IB, IC, IN, IN Sensitive, VA, VB, VC, IM		
Selects any available analog input to be assigned to this channel (including derived IN residual current).				
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 O/P Contact, Any Opto Inputs, or Internal Digital Signals		
The digital channels may monitor 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 3 operation 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.				

Table 6 - Disturb. Recorder

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 chapter.

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 P54x relay is able to measure and display the following quantities as summarized.

- Phase Voltages
- Local and Remote Currents
- Differential and Bias Currents on a Per Phase Basis
- 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.

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 Discrete Fourier Transform (DFT) used by the relay protection functions and present both magnitude and phase angle measurement.

Currents mentioned above can be seen on the Measurement 1 column. P54x also shows local and remote currents in Measurement 3 column. These currents have the same treatment as the currents used for differential protection purposes.

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.

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.

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 Table 7:

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	+ – – +
3	Export Power Import Power Lagging Vars Leading VArs	– + – +

Table 7 - Measurement Mode options

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.

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.

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.

4.6.1 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.

4.6.2 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.

4.6.3 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.

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.		
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. This reference is for Measurements 1. Measurements 3 uses always IA local as a reference.		
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 (P54x/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.		
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.		
Remote2 Values	Primary	Primary or Secondary
The setting defines whether the values measured via the 2nd Rear Communication port are displayed in primary or secondary terms.		

Table 8 - Measurement Setup settings

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 in Table 9:

MEASUREMENTS 1		MEASUREMENTS 2		MEASUREMENTS 3		MEASUREMENTS 4	
IA Magnitude	0 A	IA Fixed Demand	0 A	IA Local	0 A	Ch 1 Prop Delay	
IA Phase Angle	0 deg	IB Fixed Demand	0 A	IA Angle Local	0 deg	Ch 2 Prop Delay	
IB Magnitude	0 A	IC Fixed Demand	0 A	IB Local	0 A	Channel Status	
IB Phase Angle	0 deg	IA Roll Demand	0 A	IB Angle Local	0 deg	Elapsed Time	
IC Magnitude	0 A	IB Roll Demand	0 A	IC Local	0 A	Ch1 No.Vald Mess	
IC Phase Angle	0 deg	IC Roll Demand	0 A	IC Angle Local	0 deg	Ch1 No.Err Mess	
IN Measured Mag.	0 A	IA Peak Demand	0 A	IA remote 1	0 A	Ch1 No.Errored s	
IN Measured Angle	0 deg	IB Peak Demand	0 A	IA Ang remote 1	0 deg	Ch1 No.Sev Err s	
IN Derived Mag.	0 A	IC Peak Demand	0 A	IB remote 1	0 A	Ch1 No.Dgraded m	
IN Derived Angle	0 deg	Reset Demand	No	IB Ang remote 1	0 deg	Ch2 No.Vald Mess	
I1 Magnitude	0 A			IC remote 1	0 A	Ch2 No.Err Mess	
I2 Magnitude	0 A			IC Ang remote 1	0 deg	Ch2 No.Errored s	
I0 Magnitude	0 A			IA remote 2	0 A	Ch2 No.Sev Err s	
IA RMS	0 A			IA Ang remote 2	0 deg	Ch2 No.Dgraded m	
IB RMS	0 A			IB remote 2	0 A	Clear Statistics	
IC RMS	0 A			IB Ang remote 2	0 deg		
Frequency				IC remote 2	0 A		
				IC Ang remote 2	0 deg		
				IA Differential	0 A		
				IB Differential	0 A		
				IC Differential	0 A		
				IA Bias	0 A		
				IB Bias	0 A		
				IC Bias	0 A		
				Thermal State	%		
				Reset Thermal			

Table 9 - Measurements

4.8.1 Measurements 4 Column:

Channel 1 and Channel 2 propagation times are displayed in seconds. These times are the ones calculated with asynchronous sampling (some times called “ping pong” method).

Ch1/Ch2 Rx Prop Delay Ch1 and Ch1/Ch2 Tx Prop Delay are displayed in seconds. These times are the ones calculated with synchronous sampling (by using GPS), therefore they are displayed only when GPS method is active (setting PROT COMMS - IM64/GPS Sync/Enabled)

‘Channel Status 1’ is a diagnostics flag associated with Channel 1 condition (Channel 2 is the same).

Bit “H/W B to J mode” If a relay suffix K is communicating with a relay suffix B, G or J, this bit is "1"

Bit “Passthrough”	Ch1 data received via Ch2 in 3 ended configuration - self healing indication
Bit “Message Level”	Indicates poor Channel 1 quality
Bit “Timeout”	Indication that no valid message is received over Channel 1 during ‘Channel Timeout’ window
Bit “Mismatch Rxn”	Indication of mismatch between InterMiCOM64 Ch1 setting and Multiplexer
Bit “Path Yellow”	One way communication. Local relay that is sending over Ch1 indicates that remote end is not receiving
Bit “Signal Lost”	Mux indicates signal lost over Channel 1
Bit “Mux Clk F Error”	This is an alarm that appears if the Channel 1 baud rate is outside the limits 52Kbis/s or 70 Kbits/s
Bit “Remote GPS”	Indicates the status of the remote GPS on Channel 1
Bit “Local GPS”	Indicates the status of the local GPS on Channel 1
Bit “Tx”	Indication of transmission on Channel 1
Bit “Rx”	Indication of reception on Channel 1

‘IM64 Rx Status’ is a 16 bit word that displays the status of received commands as “1” or “0”.

‘Last Reset on’ displays the time and date of last statistics reset.

‘Ch1/Ch2 No. of valid messages’ displays the number of received valid messages over channel 1/2 since last statistics reset.

‘Ch1/Ch2 No. of Errored messages’ displays the number of invalid messages over channel 1/Ch 2 since last statistics reset.

The number of errored messages complies with ITU- G8.21 and is as follows:

‘Ch1/Ch2 No. Errored seconds’ displays the number of seconds containing 1 or more errored or lost messages

‘Ch1/Ch2 No. Severely Errored sconds‘ displays the number of seconds containing 31 or more errored or lost messages (see note).

Note	*Any severely errored seconds are ignored when working out the minutes intervals*

‘Ch1/Ch2 No. Degraded minutes’ displays the number of minutes containing 2 or more errored or lost messages.

The number of lost messages recorded is intended as an indicator for noises under normal communication conditions and not for recording long communication breaks. The lost message count is accumulated by incrementing a counter when a message is rejected by the Error code check, message length check and the sequential time tag check.

The error statistics are automatically cleared on power-up. They can also be cleared using the Clear Statistics setting in Measurements column of the menu.

FIRMWARE DESIGN

CHAPTER 9

Notes:

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1 RELAY OVERVIEW

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 which 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 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 and communication interfaces).

1.1.2 Co-Processor Board

Used to process the current differential protection algorithms and associated communication. It contains the optical fibre transmit and receive hardware and serial data communication controller for the differential protection signalling.

1.1.3 Input Module

The input module converts the information contained in the analogue 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 analogue to digital conversion and the isolated digital inputs.

1.1.4 Analogue/Digital Input Module

The input module converts the information contained in the analogue 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 analogue to digital conversion (with local storage of the calibration data). The later also provides the isolated wide-ranging digital inputs, with a choice of pickup/drop-off levels, which may be used in conjunction with a range of auxiliary supply inputs.

1.1.5 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 which provide the output contacts.

The power supply module also provides a 48V external field supply to drive the opto isolated digital inputs.

1.1.6 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 fibre optic rear communication port, for use with IEC 60870 communication only.

1.1.7 Second Rear Communications 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.

1.1.8 Ethernet Board

This is a mandatory board for UCA2.0 enabled relays. It provides network connectivity through copper or fibre 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 use slot A in the relay case.
All modules are connected by a parallel data and address bus which 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.

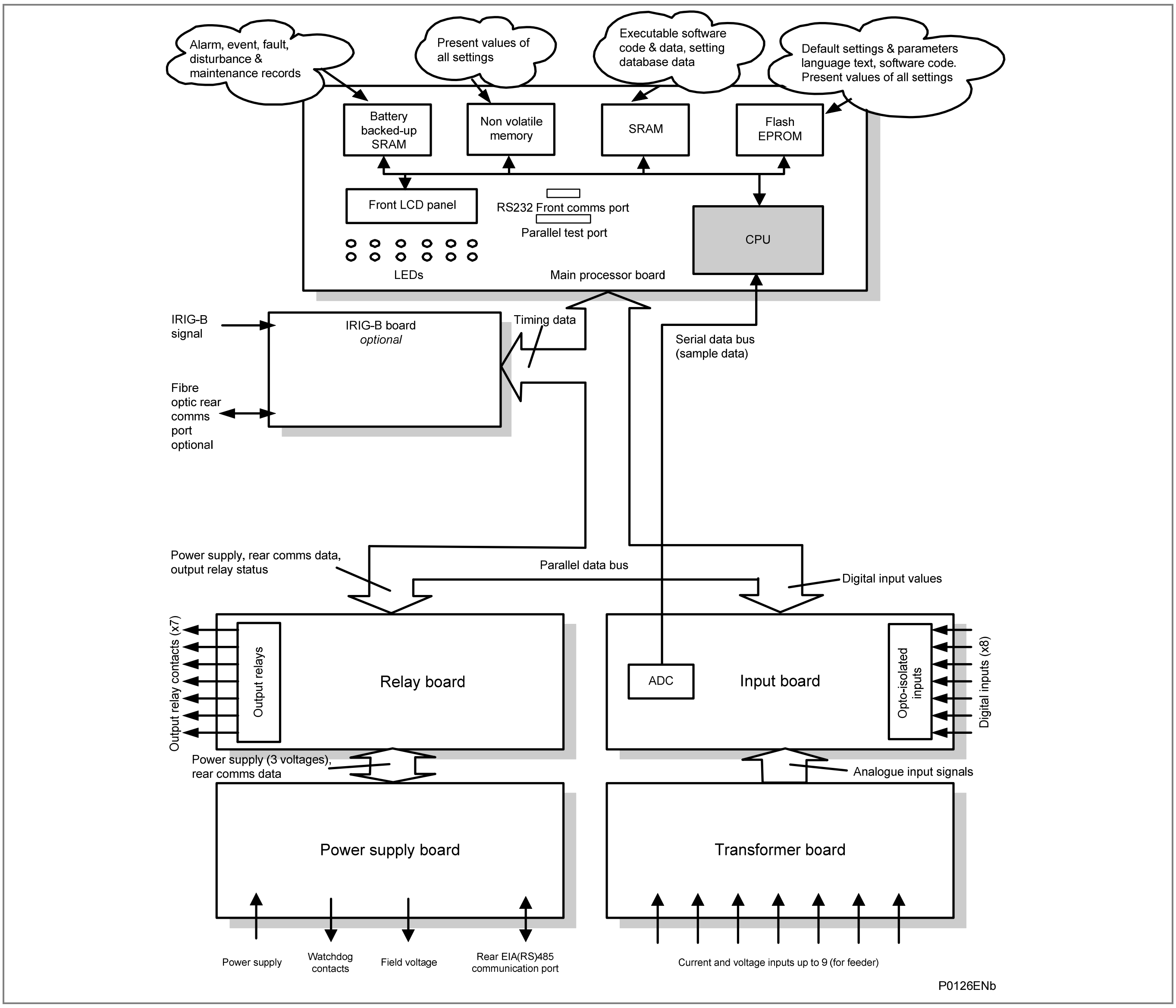

Figure 1 - Relay modules and information flow

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.

1.2.1 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.

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.

1.2.3 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 which provides direct compatibility with Courier communications. For all other interfaces (i.e. the front panel keypad and LCD interface, Modbus and IEC 60870-5-103) 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.

1.2.4 Protection and 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.

1.2.5 Disturbance Recorder

The analogue 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.

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.

2.1 Processor Board

The relay is based around a TMS320VC33-150MHz (peak speed), floating point, 32-bit Digital Signal Processor (DSP) operating at a clock frequency of half this speed. 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 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, text and configuration data including the present setting values, and 2MB of battery backed-up SRAM for the storage of disturbance, event, fault and maintenance record data.

2.2 Co-processor Board

A second processor board is used in the relay for the processing of the current differential protection algorithms. The processor used on the second board is the same as that used on the main processor board. The second processor board has provision for fast access (zero wait state) SRAM for use with both program and data memory storage. This memory can be accessed by the main processor board via the parallel bus, and this route is used at power-on to download the software for the second processor from the flash memory on the main processor board. Further communication between the two processor boards is achieved via interrupts and the shared SRAM. The serial bus carrying the sample data is also connected to the co-processor board, using the processor's built-in serial port, as on the main processor board.

The co-processor board also handles all communication with the remote differential relay(s). This is achieved via optical fibre communications and hence the co-processor board holds the optical modules to transmit and receive data over the fibre links.

2.3 Internal Communication Buses

The relay has two internal buses for the communication of data between different modules. The main bus is a parallel link which 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 which operates as a master while all other modules within the relay are slaves.

The second bus is a serial link which 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 which is used to read the sample data from the serial bus. The serial bus is also carried on the 64-way ribbon cable.

2.4 Input Module

The input module provides the interface between the relay processor board and the analogue and digital signals coming into the relay. The input module consist of two PCBs; the main input board and a transformer board. The P541 and P542 relays provide four current inputs.

2.4.1 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 nominal voltage input is 110V.

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.

2.4.2 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 analogue-to-digital conversion for the analogue signals. Hence it takes the differential analogue 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 analogue signals are passed through an anti-alias filter before being multiplexed into a single analogue-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.

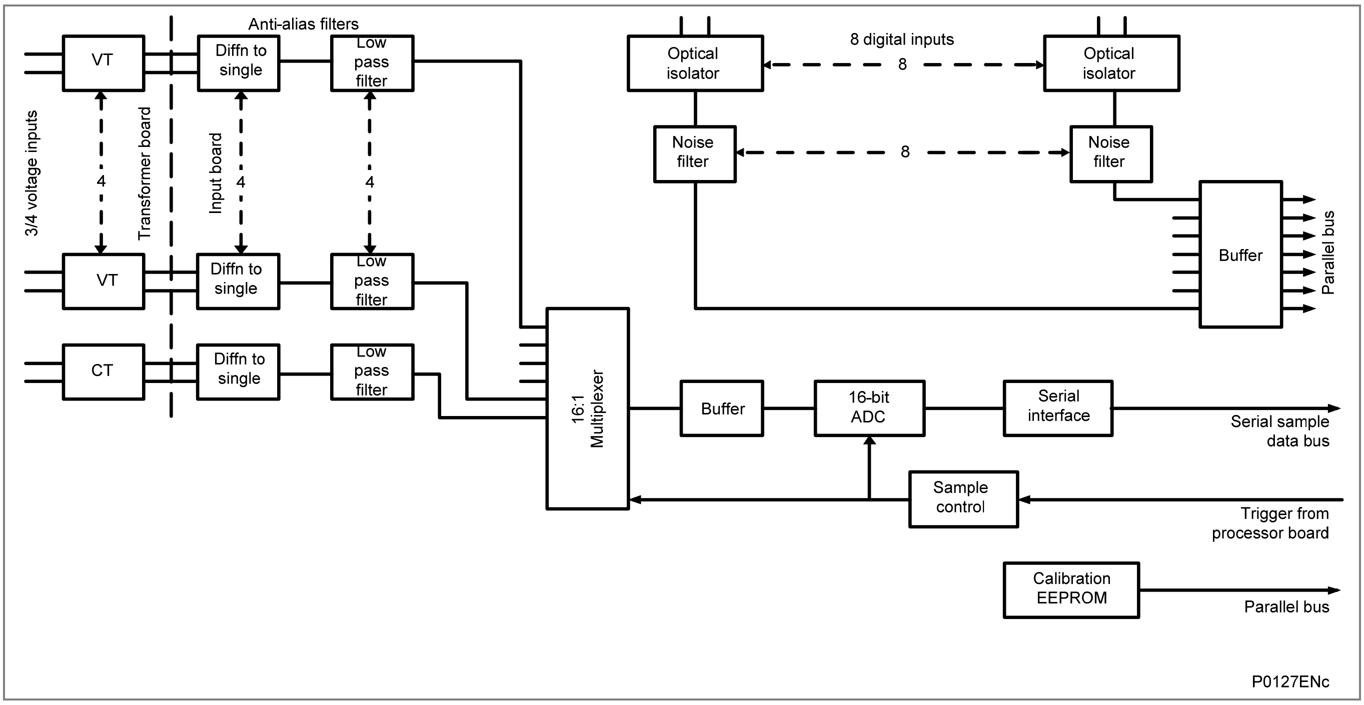

Figure 2 - Main input board

The signal multiplexing arrangement provides for 16 analogue channels to be sampled. The P540 range of products provide up to 9 current inputs and 4 voltage inputs. Three spare channels are used to sample three 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 which is driven by the frequency tracking function on the main processor board.

The calibration non volatile memory holds the calibration coefficients which are used by the processor board to correct for any amplitude or phase errors introduced by the transformers and analogue 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 analogue signals; to isolate the relay's electronics from the power system environment. A 48V 'field voltage' supply is provided at the back of the relay for use in driving the digital opto-inputs. 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. Depending on the relay model, more than 8 digital input signals can be accepted by the relay. This is achieved by the use of an additional opto-board which contains the same provision for 8 isolated digital inputs as the main input board, but does not contain any of the circuits for analogue signals which are provided on the main input board.

2.4.3 Universal Opto Isolated Logic Inputs

The P540 series relays are 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 i.e. thereby allowing different voltages for different circuits e.g. signalling, tripping. From software version 30 onwards they can also be programmed as Standard 60% - 80% or 50% - 70% to satisfy different operating constraints.

Threshold levels are as follows:

Nominal Battery Voltage (Vdc)	Standard 60% - 80%		50% - 70%	
	No Operation (logic 0) Vdc	Operation (logic 1) Vdc	No Operation (logic 0) Vdc	Operation (logic 1) Vdc
24 / 27	<16.2	>19.2	<12.0	>16.8
30 / 34	<20.4	>24.0	<15.0	>21.0
48 / 54	<32.4	>38.4	<24.0	>33.6
110 / 125	<75.0	>88.0	<55.0	>77.0
220 / 250	<150.0	>176.0	<110	>154

Table 1 - Threshold levels

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 selectable filtering which can be utilised. This allows use of 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. 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.

2.5 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.

2.5.1 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 options are shown in Table 2.

Nominal dc range	Nominal ac range
24 - 48V	dc only
48 - 110V	30 - 100V rms
110 - 250V	100 - 240V rms

Table 2 - 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 analogue 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. One further voltage level is provided by the power supply board which 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, IEC 60870-5-103 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 which is connected to the parallel bus.

The watchdog facility provides two output relay contacts, one normally open and one normally closed which 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 energisation, to approximately 10A.

2.5.2 Output Relay Board

The output relay board holds seven relays, three with normally open contacts and four 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 seven additional output contacts may be provided, through the use of up to three extra relay boards.

2.6 IRIG-B Board

The IRIG-B board is an order option which 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 synchronise 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 fibre optic transmitter/receiver which can be used for the rear communication port instead of the EIA(RS)485 electrical connection (IEC 60870 only).

2.7 Second Rear Communications Board

For relays with Courier, Modbus, IEC60870-5-103 or DNP3 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.

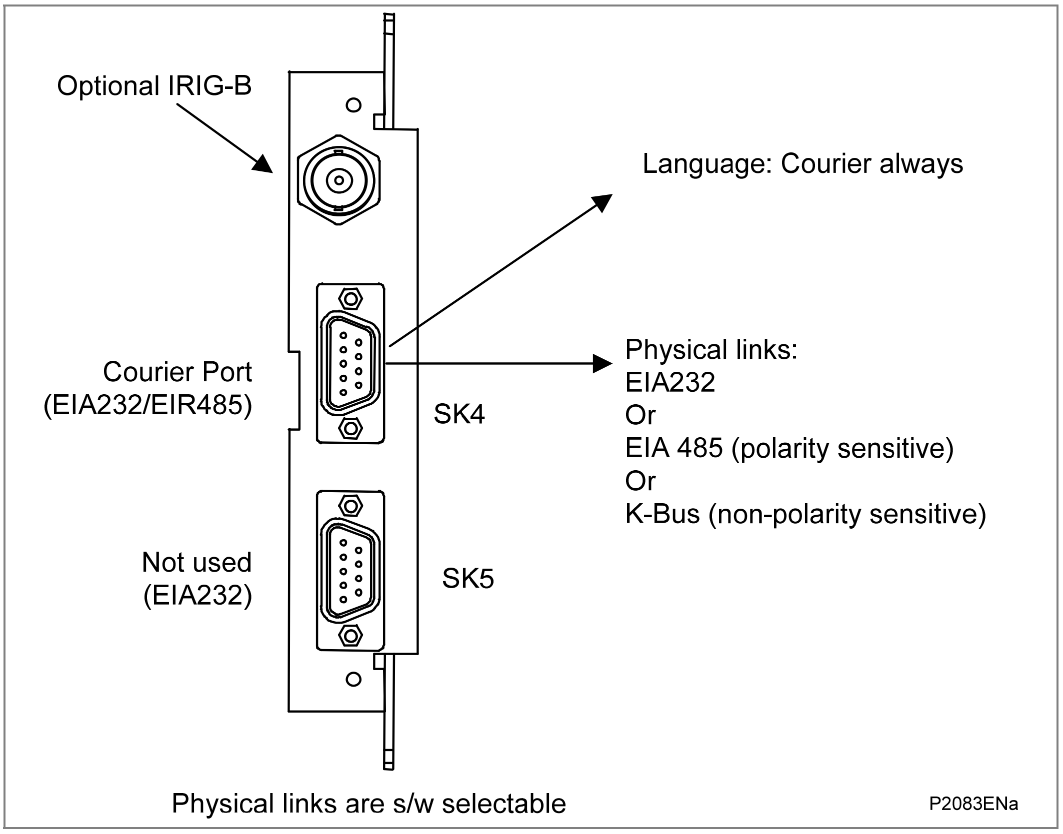

Figure 3 - Rear comms port

2.8 Ethernet Board

The ethernet board, presently only available for UCA2 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 fibre network connections use an ST style connector while 100Mb connections use the SC style fibre 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/MMS server as supplied by Sisco inc. The extra memory block also holds the UCA2 data model supported by the relay.

2.9 Mechanical Layout

The case materials of the relay are constructed from pre-finished steel which has a conductive covering of aluminium and zinc. This provides good earthing at all joints giving a low impedance path to earth which 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 minimise 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 aluminium backing plate.

3 RELAY SOFTWARE

The relay software was introduced in the overview of the relay at the start of this chapter. 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 behaviour of the relay. Figure 4 shows the structure of the relay software.

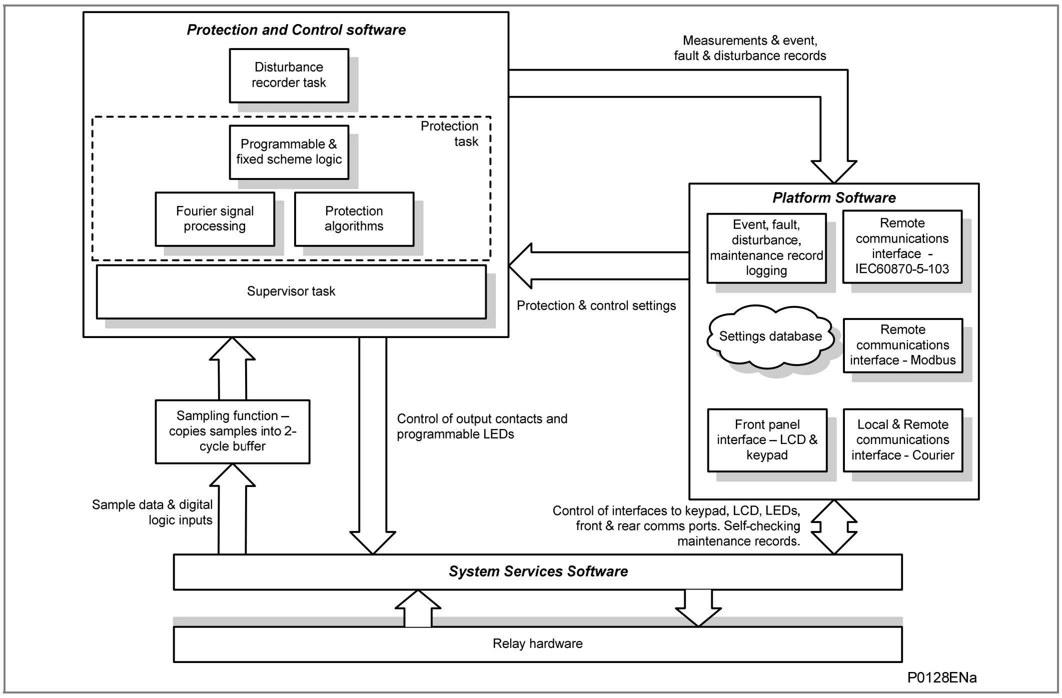

Figure 4 - Relay software structure

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.

3.2 System Services Software

As shown in Figure 3, 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 non-volatile flash EPROM at power up.

3.3 Platform Software

The platform software has three main functions:

- control the logging of records that are generated by the protection software, including alarms and event, fault, and maintenance records.
- store and maintain a database of all of the relay's settings in non-volatile memory.
- 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, DNP 3.0, UCA2).

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 chapter.

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 chapter on the user interface). If a setting change affects the protection & control task, the database advises it of the new values.

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.

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 organise 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 which controls the start-up of the task and deals with the exchange of messages between the task and the platform software.

3.4.1 Overview - Protection and Control Scheduling

After initialisation at start-up, the protection and control task on the main processor board is suspended until the co-processor board re-starts via an interrupt. In the case were the co-processor board has failed the protection task will automatically start after six analogue samples have been received. In normal operation the task will be re-started by the co-processor four times per cycle, which corresponds to the frequency of data message transmission on the differential communication system. The acquisition of samples on the main processor board 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, these samples are also stored concurrently by the co-processor.

3.4.2 Signal Processing

The sampling function provides filtering of the digital input signals from the opto-isolators and frequency tracking of the analogue 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 analogue 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.

When the protection and control task is re-started by the sampling function, it calculates the Fourier components for the analogue signals. 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. The DFT provides an accurate measurement of the fundamental frequency component, and effective filtering of harmonic frequencies and noise. This performance is achieved in conjunction with the relay input module which provides hardware anti-alias filtering to attenuate frequencies above the half sample rate, and frequency tracking to maintain a sample rate of 24 samples per cycle. 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.

3.4.3 Current Differential Protection - Co-Processor Board

All of the processing for the current differential protection algorithm and the communication protocol associated with it is made on the co-processor board. The differential protection is based on the relays at the line ends exchanging data messages four times per cycle. To achieve this the co-processor takes the frequency-tracked samples at 24 samples per cycle from the input board and converts these to 8 samples per cycle based on the nominal frequency (i.e. not frequency tracked). The co-processor calculates the Fourier transform of the fixed rate samples after every sample, using a one-cycle window. This generates current measurements eight times per cycle which are used for the differential protection algorithm and transmitted to the remote relay(s) using the High-level Data Link Control (HDLC) communication protocol.

The co-processor is also responsible for managing intertripping commands via the communication link, and re-configuration instigated from the remote relay(s).
Data exchange between the co-processor board and the main processor board is achieved through the use of shared memory on the co-processor board. When the main processor accesses this memory, the co-processor is temporarily halted. After the co-processor code has been copied onto the board at initialisation, the main traffic between the two boards consists of setting change information, commands from the main processor, differential protection measurements and output data.

3.4.4 Programmable Scheme Logic (PSL)

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, 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.

3.4.5 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.

3.4.6 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 which can also store the data in COMTRADE format, thus allowing the use of other packages to view the recorded data.

4 SELF TESTING AND 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.

4.1 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 signalled 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:

4.1.1 System Boot

The integrity of the flash EPROM 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 EPROM to ensure that the two are the same and that no errors have occurred in the transfer of data from flash EPROM to SRAM. The entry point of the software code in SRAM is then called which is the relay initialisation code.

4.1.2 Initialisation Software

The initialisation process includes the operations of initialising 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 initialisation process the relay checks the:

- status of the battery
- integrity of the battery backed-up SRAM that is used to store event, fault and disturbance records
- voltage level of the field voltage supply which is used to drive the opto-isolated inputs
- operation of the LCD controller
- watchdog operation

At the conclusion of the initialisation software the supervisor task begins the process of starting the platform software. The checking that is made in the process of starting the co-processor board is as follows:

- a check is made for the presence of, and a valid response from, the co-processor board
- the SRAM on the co-processor board is checked with a test bit pattern before the co-processor code is transferred from the flash EPROM
- the integrity of the co-processor code is checked using a checksum before and after transferring it to the co-processor
- detection of the correct number of differential signalling channels is checked

Any of these checks which produces an error results in the co-processor board being left out of service and the relay relying on the other protection functions which are provided by the main processor board.

4.1.3 Platform Software Initialisation and 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.

4.2 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 chapter) and the results reported to the platform software. The functions that are checked are as follows:

- flash EPROM containing all program code and language text is verified by a checksum
- code and constant data held in SRAM is checked against the corresponding data in flash EPROM to check for data corruption
- SRAM containing all data other than the code and constant data is verified with a checksum
- non volatile memory containing setting values is verified by a checksum, whenever its data is accessed
- battery status
- level of the field voltage
- 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 analogue data acquisition system is continuously checked by the acquisition function every time it is executed, by means of sampling the reference voltages
- operation of the co-processor board is checked, including the SRAM and code, the response of the board to setting changes, incorrect received data, failure of the communication channel and general watchdog to indicate continued operation of the software on the board
- operation of the IRIG-B board is checked, where it is fitted, by the software that reads the time and date from the board
- 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 initialisations 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 which will operate.

Notes:

COMMISSIONING

CHAPTER 10

Notes:

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Notes:

1 INTRODUCTION

The MiCOM P540 current differential 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).

When P590 interface units are used to convert the optical signal from the P540 relay to an electrical signal for the multiplexer, the P590 units should be commissioned in conjunction with the relay.

Caution	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 SETTING FAMILIARIZATIONS

When commissioning a MiCOM P540 relay for the first time, sufficient time should be allowed to become familiar with the method by which the settings are applied.

The Introduction (P54x/EN IT) contains a detailed description of the menu structure of P540 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.

3 EQUIPMENT REQUIRED FOR COMMISSIONING

3.1 Minimum Equipment Required

- Overcurrent test set with interval timer.
- 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)
- 2 Lengths of 50/125μm fibre optic cable (approximately 1 metre long), terminated at each end with a ST connector
- 2 Lengths of 9/125μm fibre optic cable (approximately 1 metre long), terminated at each end with a ST connector if 1300 or 1550 fibre options fitted
- Optical power meter with sensitivity 0 to -50dBm (to measure the optical signal level)

Note	*Modern test equipment may contain many of the above features in one unit.*

3.2 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 convertor (if EIA(RS)485 K-Bus port is being tested and one is not already installed).
- EIA(RS)485 to EIA(RS)232 convertor (if EIA(RS)485 Modbus port is being tested).
- A printer (for printing a setting record from the portable PC).

4 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 unauthorised 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 Schneider Electric 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.*

4.1 With the Relay De-Energised

Caution	**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 which 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.

4.1.1 Visual Inspection

Carefully examine the relay to see that no physical damage has occurred since installation.

The rating information given under the top access cover on the front of the relay should be checked to ensure it is correct for the particular 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.

4.1.2 Current Transformer Shorting Contacts

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.

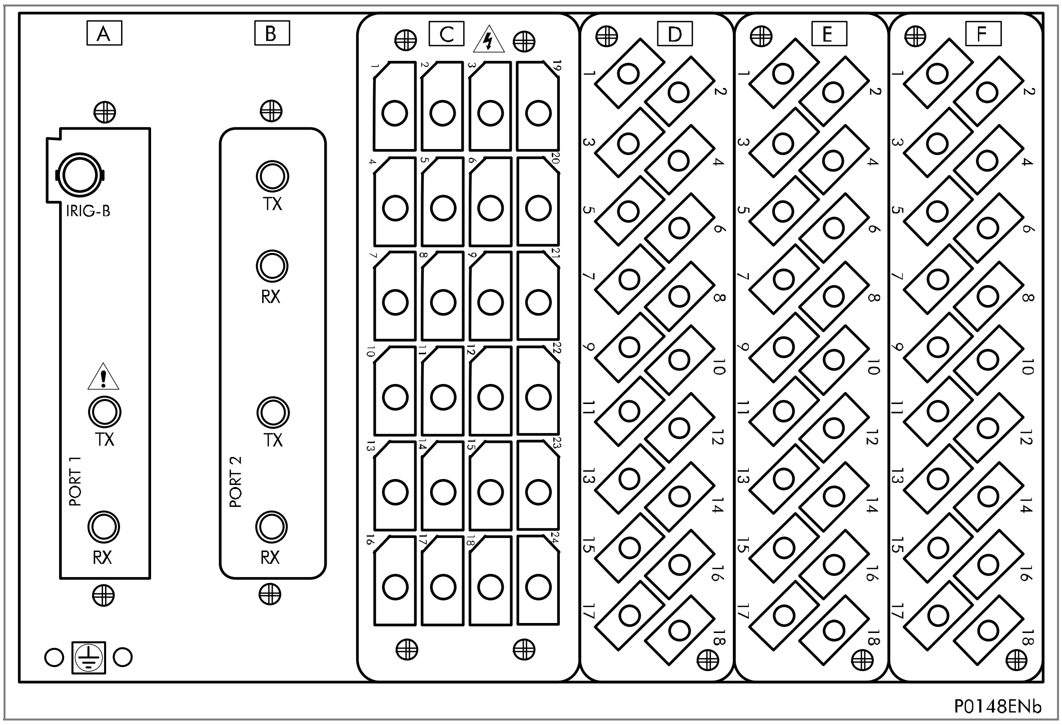

Figure 1 - Rear terminal blocks on size 40TE case

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 minimise 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 1A - common 5A
I_A	C3 - C2 - C1
I_B	C6 - C5 - C4
I_C	C9 - C8 - C7
I_N	C15 - C14 - C13

Current input	Shorting contact between terminals 1A - common 5A
I_M	C12- C11 - C10
$I_A(2)$	-
$I_B(2)$	-
$I_C(2)$	-
$I_N(2)$	-

Table 1 - Current transformer shorting contact locations.

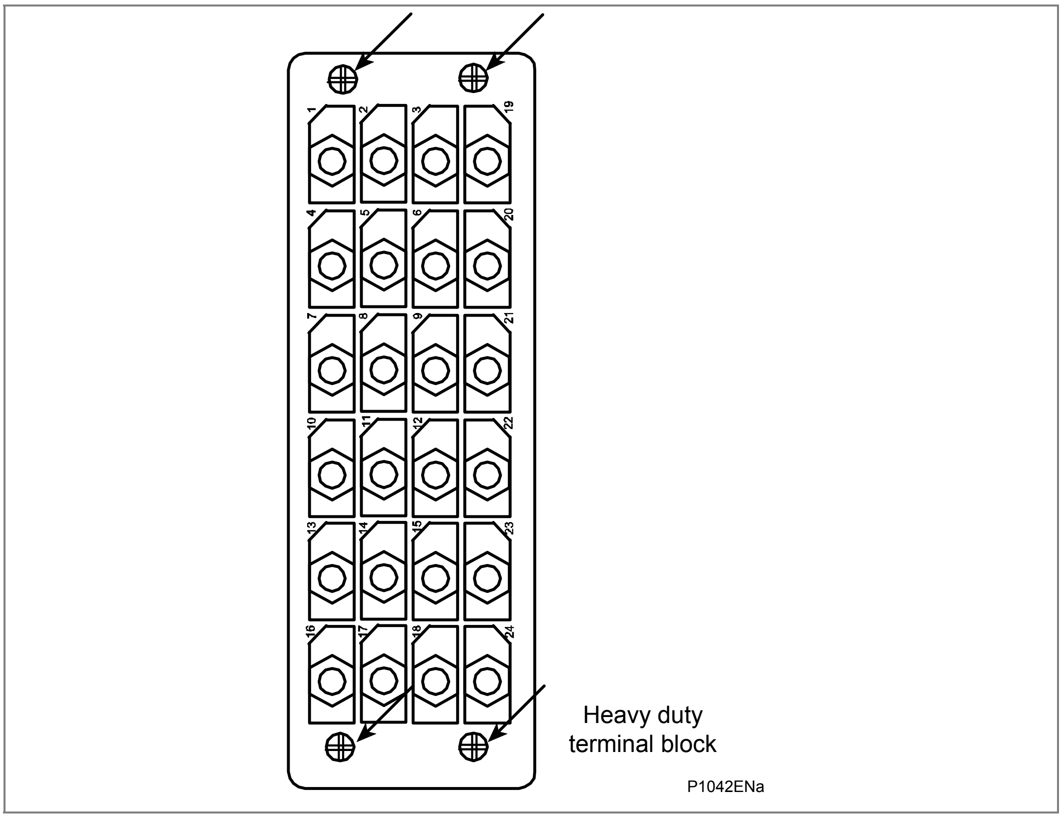

Figure 2 - Location of securing screws for heavy duty terminal blocks.

4.1.3 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:

- Terminal (a) - Voltage transformer circuits.
- Terminal (b) - Current transformer circuits
- Terminal (c) - Auxiliary voltage supply.
- Terminal (d) - Field voltage output and opto-isolated control inputs.
- Terminal (e) - Relay contacts.
- Terminal (f) - EIA(RS)485 communication port.
- Terminal (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.

4.1.4 External Wiring

Check that the external wiring is correct to the relevant relay diagram or scheme diagram. The relay diagram number appears on the rating label under the top access cover on the front of the relay. The corresponding connection diagram will have been supplied with the Schneider Electric order acknowledgement for 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 (coloured 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.

4.1.5 Watchdog Contacts

Using a continuity tester, check that the watchdog contacts are in the states given in Table 2 for a de-energised relay.

Terminals		Contact state	
		Relay de-energised	Relay energised
F11 - F12 J11 - J12	(P541) (P542)	Closed	Open
F13 - F14 J13 - J14	(P541 & P542) (P542)	Open	Closed

Table 2 - Watchdog contact status

4.1.6 Auxiliary Supply

The P540 relay can be operated from either a dc only or an 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 energising 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
110 - 250V	(100 - 240V)	87 to 300V	80 to 265V

Table 3 - Operational range of auxiliary supply Vx

It should be noted that the P540 relay can withstand an ac ripple of up to 12% of the upper rated voltage on the dc auxiliary supply.

Caution **Do not energise the relay or interface unit using the battery charger with the battery disconnected as this can irreparably damage the relay's power supply circuitry.**

Caution **Energise 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.**

4.2 With the Relay Energised

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 and, if installed, the P590 interface units.

Caution **The current and voltage transformer connections must remain isolated from the relay for these checks. The trip circuit should also remain isolated to prevent accidental operation of the associated circuit breaker. The inter-relay communication channel should be disconnected to prevent the remote end relay being affected during the tests.**

4.2.1 Watchdog Contacts

Using a continuity tester, check the watchdog contacts are in the states given in Table 2 for an energised relay.

4.2.2 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 a "*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 decremented (lighter), as required.

Caution	**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.**

4.2.3 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.

4.2.3.1 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 energised.

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, then remove the auxiliary supply from the relay. Leave the relay de-energised for approximately 30 seconds. On re-energisation, the time in cell (0801: DATE and TIME, Date/Time) should be correct.

Reconnect the IRIG-B signal.

4.2.3.2 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-energisation, the time in cell (0801: DATE and TIME, Date/Time) should be correct.

4.2.4 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 energised 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.*

4.2.4.1 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.

4.2.4.2 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.

4.2.4.3 Testing the User-Programmable LEDS

To test the user-programmable LEDs set cell (0F10: COMMISSION TESTS, Test LEDs) to ‘Apply Test’. Check that all 8 LEDs on the right-hand side of the relay illuminate.

4.2.5 Field Voltage Supply

The relay generates a field voltage of nominally 48V that can be used to energise the opto-isolated inputs (alternatively the substation battery may be used).

Measure the field voltage across the terminals 7 and 9 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	
	P541	P542
+ve	F7 & F8	J7 & J8
-ve	F9 & F10	J9 & J10

Table 4 - Field voltage terminals

4.2.6 Input Opto-Isolators

This test checks that all the opto-isolated inputs on the relay are functioning correctly. The P541 relay has 8 opto-isolated inputs while the P542 relay has 16 opto-isolated inputs.

The opto-isolated inputs should be energised one at a time, see external connection diagrams (Appendix B) for terminal numbers. Ensuring correct polarity, connect the field supply voltage to the appropriate terminals for the input being tested.

Note	*The opto-isolated inputs may be energised from an external 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.*

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 energised input and a ‘0’ indicating a de-energised input. When each opto-isolated input is energised one of the characters on the bottom line of the display will change to indicate the new state of the inputs.

4.2.7 Output Relays

This test checks that all the output relays are functioning correctly. The P541 relays have 7 output relays while P542 relay has 14 output relays.

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 energised 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 Installation chapter.

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 is not exceeded by the associated output relay being operated for too long. It is therefore advised that the time between application and removal of contact test is kept to the minimum.*

Repeat the test for relays 2 to 7 for P541 relays or relays 2 to 14 for P542.

Return the relay to service by setting cell (0F0D: COMMISSION TESTS, Test Mode) to 'Disabled'.

4.2.8 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.

4.2.8.1 Courier Communications

If a K-Bus to EIA(RS)232 KITZ protocol convertor is installed, connect a portable PC running the appropriate software to the incoming (remote from relay) side of the protocol converter.

If a KITZ protocol convertor is not installed, it may not be possible to connect the PC to the type installed. In this case a KITZ protocol convertor and portable PC running appropriate software should be temporarily connected to the relay's K-Bus port. The terminal numbers for the relay's K-Bus port are given in Table 5. However, as the installed protocol convertor is not being used in the test, only the correct operation of the relay's K-Bus port will be confirmed

Connection		Terminal	
K-Bus	**Modbus or VDEW**	**P541**	**P542**
Screen	Screen	F16	J16
1	+ve	F17	J17
2	-ve	F18	J18

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 convertor (usually a KITZ but could be a SCADA RTU). The relay's 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.

4.2.8.2 Modbus Communications

Connect a portable PC running the appropriate Modbus Master Station software to the relay's EIA(RS)485 port via a EIA(RS)485 to EIA(RS)232 interface convertor. 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 settings in the application software 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.

4.2.8.3 IEC60870-5-103 (VDEW) Communications

If the relay has the optional fibre optic communications port fitted, the port to be used should be selected by setting cell (0E07: COMMUNICATIONS, Physical Link) to ‘Fibre Optic’ or ‘EIA(RS)485’.

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 fibre 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.

4.2.8.4 DNP 3.0 Interface

Connect a portable PC running the appropriate DNP 3.0 software to the relay's EIA(RS)485 port via a EIA(RS)232 interface convertor. 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.

4.2.9 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 relay’s rear communications port and any protocol converter necessary.

4.2.9.1 K-Bus Configuration

If a K-Bus to EIA(RS)232 KITZ protocol convertor 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 convertor is not installed, it may not be possible to connect the PC to the relay installed. In this case a KITZ protocol convertor and portable PC running appropriate software should be temporarily connected to the relay’s second rear communications port configured for K-Bus. The terminal numbers for the relay’s K-Bus port are given in Table 6. However, as the installed protocol convertor is not being used in the test, only the correct operation of the relay’s K-Bus port will be confirmed.

Pin*	Connection
4	EIA485 - 1 (+ ve)
7	EIA485 - 2 (- ve)
* - All other pins unconnected.	

Table 6 - 2nd rear communications port K-Bus terminals

Ensure that the communications baud rate and parity settings in the application software are set the same as those on the protocol convertor (usually a KITZ but could be a SCADA RTU). The relay’s Courier address in cell (0E90: COMMUNICATIONS, RP2 Address) must be set to a value between 1 and 254. The second rear communication’s 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.

4.2.9.2 EIA(RS)485 Configuration

If an EIA(RS)485 to EIA(RS)232 convertor (e.g. Schneider Electric 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 relay's EIA(RS)485 port are given in Table 5.

Ensure that the communications baud rate and parity settings in the application software are set the same as those in the relay. The relay's Courier address in cell (0E90: COMMUNICATIONS, RP2 Address) must be set to a value between 1 and 254. The second rear communication's 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.

4.2.9.3 EIA(RS)232 Configuration

Connect a portable PC running the appropriate software (e.g. MiCOM S1) to the rear EIA(RS)232 port of the relay. The rear port is actually compliant with EIA(RS)574 (the 9-pin version of EIS(RS)232). For more details, please see www.tiaonline.org.

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
# - These pins are control lines for use with a modem.	

Table 7 - Second rear communications port EIA(RS)232 terminals

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 relay's EIA(RS)232 port are given in Table 7.

Ensure that the communications baud rate and parity settings in the application software are set the same as those in the relay. The relay's Courier address in cell (0E90: COMMUNICATIONS, RP2 Address) must be set to a value between 1 and 254. The second rear communication's 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.

4.3 Current Differential Communications

This test verifies that the relay's current differential fibre optic communications ports and, if installed, P590 interface units, used for communications between the P540 current differential relays at each end of the feeder being protected, are operating correctly.

A P590 unit will be situated near the multiplexer in applications where communications between P540 relays is via multiplexed communication channels and the PCM multiplexer is installed remote from the relay room. This unit provides bi-directional optical to electrical signal conversion between the cross-site optical fibre from the relay and the electrical interface of the multiplexer.

The method of testing is similar whether communications between relays is via dedicated optical fibres or using a P590 unit to interface the relay's fibre optic communications channel to a multiplexer. However, where P590 interface units are being used, there are a number of extra tests on the P590 units that need to be performed before testing of the communications can begin.

Caution	**When connecting or disconnecting optical fibres DO NOT look into the transmit port or the end of the optical fibre.**

4.3.1 Direct Fibre Optic Communications

Set cell (0F12 Test Loopback) to 'External'.

Using a length of fibre optic cable, refer to the Installation chapter, section 6.7, terminated with a ST connector at each end, connect the Channel 1 transmit (Tx) and Channel 1 receive (Rx) ports on the rear of the relay together. If Channel 2 is being used (Three terminal or dual redundant application) connect the Channel 2 transmit and receive ports on the rear of the relay together. The relay will now respond as if it is connected to a remote relay with the current at the remote end equal to and in phase with the current injected at the local end. Reset any alarm indications and check that no further communications failure alarms are raised. As the loopback alarm is still active it will not reset. Check channel status, propagation delays and communication statistics in (MEASUREMENTS 4) column.

Alternatively use the internal loopback feature by setting cell (0F12 Test Loopback) to 'Internal'. In this mode it is not necessary to change the fibre.

4.3.2 Communications using P591 Interface Units

The P591 converts the optical output of the P540 relay to an electrical signal for a PCM multiplexer with G.703 interfaces. The unit is housed in a size 20TE case and should be located near to the multiplexer.

Before loopback testing can begin, some other checks must be completed.

4.3.2.1 Visual Inspection

Carefully examine the unit to see that no physical damage has occurred since installation.

The rating information given under the top access cover on the front of the unit should be checked to ensure it is correct for the particular installation.

Ensure that the case earthing connection, top left-hand corner at the rear of the case, is used to connect the unit to a local earth bar using an adequate conductor.

4.3.2.2 Insulation

Insulation resistance tests are only necessary during commissioning if it is required for them to be done and they haven't 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. The auxiliary dc supply terminals should be temporarily connected together.

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 P591.

4.3.2.3 External Wiring

Caution **Check that the external wiring is correct to the relevant connection diagram or scheme diagram. The connection diagram number appears on the rating label under the top access cover on the front of the P591. The corresponding connection diagram will have been supplied with the Schneider Electric order acknowledgement for the P591.**

It is especially important that the dc supplies are wired with the correct polarity.

4.3.2.4 Auxiliary Supply

P591 units operate from a dc only auxiliary supply within the operative range of 19V to 65V for a 24 - 48V version and 87.5V to 300V for a 110 - 250V version.

Without energising the P591 units measure the auxiliary supply to ensure it is within the operating range.

It should be noted that the P591 interface unit is designed to withstand an ac ripple component of up to 12% of the normal dc auxiliary supply. However, in all cases the peak value of the dc supply must not exceed the maximum specified operating limit.

Caution **Do not energise the P591 using the battery charger with the battery disconnected as this can irreparably damage the unit's power supply circuitry.**

Caution **Energise the P591 only if the auxiliary supply is within the specified operating ranges. If a P991 test block is provided, it may be necessary to link across the front of the test plug to connect the auxiliary supply to the P591.**

4.3.2.5 Light Emitting Diodes (LEDs)

On power up the green 'SUPPLY HEALTHY' LED should have illuminated and stayed on, thus indicating that the P591 is healthy.

4.3.2.6 Loopback Test

Remove any external wiring from terminals 3, 4, 7 and 8 at the rear of each P591 unit. Loopback the G.703 signals on each unit by connecting a wire link between terminals 3 and 7, and a second wire between terminals 4 and 8.

Measure and record the optical signal strength received by the P591 by disconnecting the optical fibre from the receive port on the rear of the unit and connecting it to an optical power meter. The mean level should be in the range -16.8dBm to -25.4dBm. If the mean level is outside of this range check the size and type of fibre being used.

Measure and record the optical output power of the transmit port of the P591 using the optical power meter and length of 50/125μm optical fibre. The mean value should be in the range -16.8dBm to -22.8dBm.

Ensure that the Transmit (Tx) and Receive (Rx) optical fibres between the P540 relay and P591 units are connected.

Return to the P540 relay and set cell (0F12 Test Loopback) to 'External'. The relay will then respond as if it is connected to a remote relay with the current at the remote end equal to and in phase with the current injected at the local end.

Reset alarm indications. The loopback alarm is still active it will not reset. Channel status, propagation delays and communication statistics should be checked in (MEASUREMENTS 4) column.

4.3.3 Communications using P592 Interface Units

The P592 converts the optical output of the P540 relay to an electrical signal for a PCM multiplexer with V.35 interfaces. The unit is housed in a size 20TE case and should be located near to the multiplexer.

Before loopback testing can begin, some other checks must be completed.

4.3.3.1 Visual Inspection

Carefully examine the unit to see that no physical damage has occurred since installation.

The rating information given under the top access cover on the front of the unit should be checked to ensure it is correct for the particular installation.

Ensure that the case earthing connection, top left-hand corner at the rear of the case, is used to connect the unit to a local earth bar using an adequate conductor.

4.3.3.2 Insulation

Insulation resistance tests are only necessary during commissioning if it is required for them to be done and they haven't 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. The auxiliary dc supply terminals should be temporarily connected together.

Caution **The V.35 circuits of the P592 are isolated from all other circuits but are electrically connected to the outer case. The circuits must not therefore be insulation or impulse tested to the case.**

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 P592.

4.3.3.3 External Wiring

Check that the external wiring is correct to the relevant connection diagram or scheme diagram. The connection diagram number appears on the rating label under the top access cover on the front of the P592. The corresponding connection diagram will have been supplied with the Schneider Electric order acknowledgement for the P592.

Caution	**It is especially important that the dc supplies are wired with the correct polarity.**

4.3.3.4 Auxiliary Supply

P592 units operate from a dc only auxiliary supply within the operative range of 19V to 300V.

Without energising the P592 units measure the auxiliary supply to ensure it is within the operating range.

It should be noted that the P592 interface unit is designed to withstand an ac ripple component of up to 12% of the normal dc auxiliary supply. However, in all cases the peak value of the dc supply must not exceed the maximum specified operating limit.

Do not energise the P592 using the battery charger with the battery disconnected as this can irreparably damage the unit’s power supply circuitry.

Caution	**Energise the P592 only if the auxiliary supply is within the specified operating ranges. If a P991 test block is provided, it may be necessary to link across the front of the test plug to connect the auxiliary supply to the P592.**

4.3.3.5 Light Emitting Diodes (LEDs)

On power up the green ‘SUPPLY HEALTHY’ LED should have illuminated and stayed on indicating that the P592 is healthy.

The four red LEDs can be tested by appropriate setting of the DIL switches on the unit’s front plate. Set the data rate switch according to the communication channel bandwidth available. Set all other switches to 0. To illuminate the ‘DSR OFF’ and ‘CTS OFF’ LEDs, disconnect the V.35 connector from the rear of the P592 and set the ‘DSR’ and ‘CTS’ switches to ‘0’. The ‘OPTO LOOPBACK’ and ‘V.35 LOOPBACK’ LEDs can be illuminated by setting their corresponding switches to ‘1’.

Once operation of the LEDs has been established set all DIL switches, except for the ‘OPTO LOOPBACK’ switch, to ‘0’ and reconnect the V.35 connector.

4.3.3.6 Loopback Test

With the ‘OPTO LOOPBACK’ switch in the ‘1’ position the receive and transmit optical ports are electrically connected together. This allows the optical fibre communications between the P540 relay and the P592 to be tested, but not the internal circuitry of the P592 itself.

Measure and record the optical signal strength received by the P592 by disconnecting the optical fibre from the receive port on the rear of the unit and connecting it to an optical power meter. The mean level should be in the range -16.8dBm to -25.4dBm. If the mean level is outside of this range check the size and type of fibre being used.

Measure and record the optical output power of the transmit port of the P592 using the optical power meter and length of 50/125μm optical fibre. The mean value should be in the range -16.8dBm to -22.8dBm.

Ensure that the Transmit (Tx) and Receive (Rx) optical fibres between the P540 relay and P592 units are connected.

Return to the P540 relay and set cell (0F12 Test Loopback) to ‘External’. The relay will then respond as if it is connected to a remote with the current at the remote end equal to and in phase with the current injected at the local end.

Reset alarm indications. The loopback alarm is still active it will not reset. Channel status, propagation delays and communication statistics should be checked in (MEASUREMENTS 4) column.

4.3.4 Communications using P593 Interface Units

The P593 converts the optical output of the P540 relay to an electrical signal for a PCM multiplexer with X.21 interfaces. The unit is housed in a size 20TE case and should be located near to the multiplexer.

Before loopback testing can begin, some other checks must be completed.

4.3.4.1 Visual Inspection

Warning **Electrostatic Discharge (ESD) precautions must be applied while the secondary cover is removed from the unit.**

If applicable replace the secondary front cover from the unit. Carefully examine the unit to see that no physical damage has occurred since installation.

The rating information given under the top access cover on the front of the unit should be checked to ensure it is correct for the particular installation.

Ensure that the case earthing connection, top left-hand corner at the rear of the case, is used to connect the unit to a local earth bar using an adequate conductor.

4.3.4.2 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. The auxiliary dc supply terminals should be temporarily connected together.

The X.21 circuits of the P593 are isolated from all other circuits but are electrically connected to the outer case. The circuits must not therefore be insulation or impulse tested to the case.

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 P593.

4.3.4.3 External Wiring

Check that the external wiring is correct to the relevant connection diagram or scheme diagram. The connection diagram number appears on the rating label under the top access cover on the front of the P593. The corresponding connection diagram will have been supplied with the Schneider Electric order acknowledgement for the P593.

Caution	**It is especially important that the dc supplies are wired with the correct polarity.**

4.3.4.4 Auxiliary Supply

P593 units operate from a dc only auxiliary supply within the operative range of 19.5V to 300V.

Without energising the P593 units measure the auxiliary supply to ensure it is within the operating range.

It should be noted that the P593 interface unit is designed to withstand an ac ripple component of up to 12% of the normal dc auxiliary supply. However, in all cases the peak value of the dc supply must not exceed the maximum specified operating limit.

Caution	**Do not energise the P593 using the battery charger with the battery disconnected as this can irreparably damage the unit's power supply circuitry.**

Caution	**Energise the P593 only if the auxiliary supply is within the specified operating ranges. If a P991 test block is provided, it may be necessary to link across the front of the test plug to connect the auxiliary supply to the P593.**

4.3.4.5 Light Emitting Diodes (LEDs)

On power up the green ‘SUPPLY’ LED should have illuminated and stayed on indicating that the P593 is healthy.

Set the ‘X.21 LOOPBACK’ switch to ‘ON’. The green ‘CLOCK’ and red ‘X.21 LOOPBACK’ LEDs should illuminate. Reset the ‘X.21 LOOPBACK’ switch to the ‘OFF’ position.

Set the ‘OPTO LOOPBACK’ switch to ‘ON’. The red ‘OPTO LOOPBACK’ LED should illuminate. Do not reset the “OPTO LOOPBACK’ switch as it is required in this position for the next test.

4.3.4.6 Loopback Test

With the ‘OPTO LOOPBACK’ switch in the ‘ON’ position the receive and transmit optical ports are electrically connected together. This allows the optical fibre communications between the P540 relay and the P593 to be tested, but not the internal circuitry of the P593 itself.

Measure and record the optical signal strength received by the P593 by disconnecting the optical fibre from the receive port on the rear of the unit and connecting it to an optical power meter. The mean level should in the range -16.8dBm to -25.4dBm. If the mean level is outside of this range check the size and type of fibre being used.

Measure and record the optical output power of the transmit port of the P593 using the optical power meter and length of 50/125μm optical fibre. The mean value should be in the range -16.8dBm to -22.8dBm

Ensure that the transmit (Tx) and receive (Rx) optical fibres between the P540 relay and P593 units are connected.

Set the ‘OPTO LOOPBACK’ switch to ‘OFF’ and ‘X.21 LOOPBACK’ switch to ‘ON’ respectively. With the ‘X.21 LOOPBACK’ switch in this position the ‘Receive Data’ and ‘Transmit Data’ lines of the X.21 communication interface are connected together. This allows the optical fibre communications between the P540 relay and the P593, and the internal circuitry of the P593 itself to be tested.

Return to the P540 relay and set cell (0F12 Test Loopback) to ‘External’. The relay will then respond as if it is connected to a remote relay with the current at the remote end equal to and in phase with the current injected at the local end.

Reset alarm indications. The Loopback alarm is still active it will not reset. Channel status, propagation delays and communication statistics should be checked in (MEASUREMENTS 4) column.

4.3.5 IEEE C37.94 Compatible Multiplexers (Software 30 or later)

See section 4.3.1 for loopback tests which are also appropriate for the IEEE C37.94 interface.

4.4 Current Inputs

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).

This test verifies that the accuracy of current measurement is within the acceptable tolerances.

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 the Installation chapter for appropriate terminal numbers, checking its magnitude using a multimeter. 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 8). If cell (0D02: MEASURE’T SETUP, Local Values) is set to ‘Secondary’, the value displayed should be equal to the applied current.

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) (0203: IB Magnitude) (0205: IC Magnitude)	$\frac{\text{[0A07 : Phase CT Primary]}}{\text{[0A08 : Phase CT Secondary]}}$
(0207: IN Measured Mag)	$\frac{\text{[0A07 : E/F CT Primary]}}{\text{[0A0A : E/F CT Secondary]}}$
(0232: IM Magnitude)	$\frac{\text{[0A07 : MC amp CT Primary]}}{\text{[0A08 : MC amp CT Secondary]}}$

Table 8 - CT ratio settings

5 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 5.1 and 5.2.

Note	*The trip circuit should remain isolated during these checks to prevent accidental operation of the associated circuit breaker.*

5.1 Apply Application-Specific Settings

The setting checks ensure that all of the application-specific relay settings for the particular installation have been correctly applied to the relay. The settings consist of:

- Specific settings
- Programmable Scheme Logic
- DNP3 configuration (dnp3 versions only)
- Goose files (UCA2 versions only)

Caution	**The trip circuit should remain isolated during these checks to prevent accidental operation of the associated circuit breaker.**

5.2 Demonstrate Correct Relay Operation

Tests 4.2.9 and 4.2.10 have already demonstrated that the relay is within calibration, thus the purpose of these tests is as follows:

To determine that the primary protection function of the relay, current differential, can trip according to the correct application settings.

To verify correct setting of any backup phase overcurrent protection.

To verify correct assignment of the trip contacts, by monitoring the response to a selection of fault injections.

5.2.1 Current Differential Bias Characteristic

To avoid spurious operation of any distance, overcurrent, earth fault or breaker fail elements, these should be disabled for the duration of the differential element tests. This is done in the relay's CONFIGURATION column. Ensure that cells (090D: Distance), (0910: Overcurrent), (0913: Earth Fault) and (0920: CB Fail) are all set to “Disabled”. Make a note of which elements need to be re-enabled after testing. The relay should also be set to loopback mode isolating it from the remote end. Refer to Section 4.3.1.

5.2.1.1 Connect the Test Circuit

The following tests require a variable transformer and two resistors connected as shown in Figure 3. Alternatively an injection test set can be used to supply Ia and Ib.

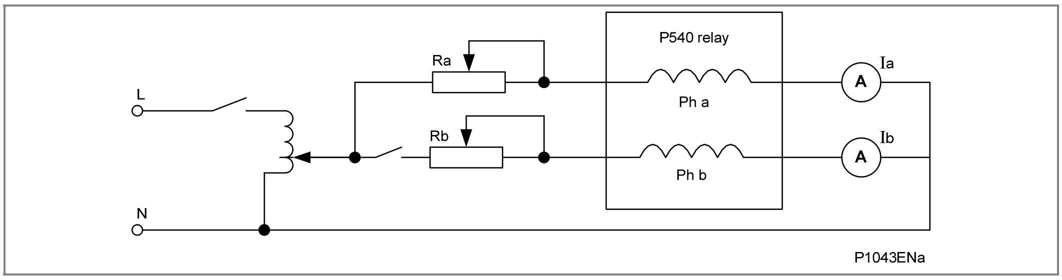

Figure 3 - Connection for Bias Characteristic Testing

A current is injected into the A phase which is used as the bias current and another current is injected into the B phase which is used as differential current. Ia is always greater than Ib.

5.2.1.2 Lower Slope

If three LEDs have been assigned to give phase segregated trip information, Trip A, Trip B and Trip C, these may be used to indicate correct per-phase operation. If not, monitor options will need to be used - see the next paragraph.

Go to the COMMISSION TESTS column in the menu, scroll down and change cells (0F05: Monitor Bit 1) to 352, (0F06: Monitor Bit 2) to 353 and (0F07: Monitor Bit 3) to 354. Doing so, cell (0F04: Test Port Status) will appropriately set or reset the bits that now represent Phase A Trip (DDB #352), Phase B Trip (DDB #353) and Phase C Trip (DDB #354) with the rightmost bit representing Phase A Trip. From now on you should monitor the indication of (0F04: Test Port Status). Also make sure that the relay is in loopback mode by setting cell (0F12 Test Loopback) to 'External' and applying either a loop-back fibre on the relay or loopback is selected on the P590 as described in 4.2.8. Alternatively setting cell (0F12 Test Loopback) to 'Internal'.

Adjust the variac and the resistor to give a bias current of 1pu in the A-phase. (NOTE: 1pu = 1A into terminals C3-C2 for 1A applications; or 1pu = 5A into terminals C1-C2 for 5A applications). The relay will trip and any contacts associated with the A-phase will operate, and bit 1 (rightmost) of (0F04: Test Port Status) will be set to 1. Some LEDs, including the yellow alarm LED, will go off, but ignore them for the moment.

When the current in A Phase is established, close the switch and slowly increase the current in the B phase from zero until Phase B trips (bit 2 of (0F04: Test Port Status) is set to 1). Record the phase B current magnitude and check that it corresponds to the information overleaf.

Switch OFF the ac supply, read and clear all alarms.

Bias Current		Differential current	Magnitude of differential current	
Phase	Magnitude	Phase		
A	1pu	B	2 Terminal & Dual Redundant	0.25pu +/-10%
			3 Terminal	0.216pu +/-10%

Table 9 - Bias and Differential Currents

Assumption: I_{s1} = 0.2pu, k_1 = 30%, I_{s2} = 2.0pu

For other differential settings or current injected into A phase (I_a), the formula below can be used (enter slope in pu form, i.e. percentage/100):

Two-Terminal & Dual Redundant:

B phase operate current is 0.5 x (I_{s1} + (I_a x k_1)) pu +/- 10% -

Three-Terminal:

B phase operate current is 0.333 x (I_{s1} + (1.5 x I_a x k_1)) pu +/- 10% -

Ensure that $I_a < I_{S2}$

5.2.1.3 Upper Slope

Repeat the test in 5.2.1.2 with the bias current set in the A-phase to be 3pu.

When the current in A Phase is established, close the switch and slowly increase the current in the B phase from zero until phase B trips (bit 2 of (0F04: Test Port Status) is set to 1). Record the phase B current magnitude and check that it corresponds to the information below.

Switch OFF the ac supply and reset the alarms.

Bias Current		Differential current	Magnitude of differential current		
Phase	**Magnitude**	**Phase**		**k_2**	
A	3pu	B	2 Terminal & Dual Redundant	150%	1.15pu +/-10%
				100%	0.9pu +/-10%
			3 Terminal	150%	1.51pu +/-10%
				100%	1.1pu +/-10%

Table 10 - Bias and Differential Currents

Assumption: I_{s1} = 0.2pu, k_1 = 30%, I_{s2} = 2.0pu, k_2 as above

For other differential settings or current injected into A phase (I_a), the formula below can be used (enter slopes in pu form, i.e. percentage/100):

Two-Terminal & Dual Redundant:

Operate current is 0.5 x ((I_a x k_2) - ((k_2 - k_1) x I_{s2}) + I_{s1}) pu +/- 20%

Three-Terminal:

Operate current is 0.333 x ((1.5 x I_a x k_2) - ((k_2 - k_1) x I_{s2}) + I_{s1}) pu +/- 20%

Ensure that $I_a > I_{S2}$

Note	*Especially for 5A applications the duration of current injections should be short to avoid overheating of the variac or injection test set.*

5.2.2 Current Differential Operation and Contact Assignment

5.2.2.1 Phase A

Retaining the same test circuit as before, prepare for an instantaneous injection of 3pu current in the A phase, with no current in the B phase (B phase switch open). Connect a timer to start when the fault injection is applied, and to stop when the trip occurs. To verify correct output contact mapping use the trip contacts that would be expected to trip the circuit breaker(s), as shown in Table 11. For two breaker applications, stop the timer once both CB1 and CB2 trip contacts have closed. This can be achieved by connecting the contacts in series to stop the timer.

Tripping	Single Breaker	Two Circuit Breakers
Three Pole Tripping	Any Trip	Any Trip (CB1) and Any Trip (CB2)
Single Pole Tripping	Trip A	Trip A (CB1) and Trip A (CB2)

Table 11 - Single and Dual Circuit Breakers

5.2.2.2 Phase B

Reconfigure the test equipment to inject fault current into the B phase. Repeat the test in 5.2.2.1, this time ensuring that the breaker trip contacts relative to B phase operation close correctly. Record the phase B trip time. Switch OFF the ac supply and reset the alarms.

5.2.2.3 Phase C

Repeat 5.2.2.2 (Phase B) for the C phase.

The average of the recorded operating times for the three phases should be less than 40ms for 50Hz, and less than 35ms for 60Hz when set for instantaneous operation. Switch OFF the ac supply and reset the alarms.

Notes	*For applications using magnetising inrush current restraint, use a test current higher than the (310E: Inrush High) setting to obtain fast operating times. At least twice setting is recommended.*

Where an IDMT or definite time delay is set in the GROUP 1 PHASE DIFF menu column, the expected operating time is typically within +/- 5% of that for the curve equation plus the "instantaneous" delay quoted above.

Important	**Upon completion of the tests any distance, overcurrent, earth fault or breaker fail elements which were disabled for testing purposes must have their original settings restored in the CONFIGURATION column.**

5.2.3 Distance Protection Operation and Contact Assignment

5.2.3.1 Phase A

Prepare a dynamic A phase to neutral fault, at half the Zone 1 reach. Connect a timer to start when the fault injection is applied, and to stop when the trip occurs. To verify correct output contact mapping use the trip contacts that would be expected to trip the circuit breaker(s), as shown in Table 12. For two breaker applications, stop the timer once CB1 and CB2 trip contacts have both closed, monitored by connecting the contacts in series to stop the timer if necessary.

	Single Breaker	Two Circuit Breakers
Three Pole Tripping	Any Trip	Any Trip (CB1) and Any Trip (CB2)
Single Pole Tripping	Trip A	Trip A (CB1) and Trip A (CB2)

Table 12 - Single and Dual Circuit Breakers

Apply the fault and record the phase A trip time. Switch OFF the ac supply and reset the alarms.

5.2.3.2 Phase B

Reconfigure to test a B phase fault. Repeat the test in 5.2.3.1, this time ensuring that the breaker trip contacts relative to B phase operation close correctly. Record the phase B trip time. Switch OFF the ac supply and reset the alarms.

5.2.3.3 Phase C

Repeat 5.2.3.2 for the C phase.

The average of the recorded operating times for the three phases should typically be less than 60ms for 50Hz, and less than 50ms for 60Hz when set for instantaneous operation. Switch OFF the ac supply and reset the alarms.

Where a non-zero tZ1 time delay is set in the DISTANCE menu column, the expected operating time is typically within +/- 5% of the tZ1 setting plus the “instantaneous” delay quoted above.

5.2.3.4 Time Delay Settings for Zones 2 and 3

Only a visual check that the correct time delay settings have been applied is needed. The relevant settings are (3307: tZ2) and (330B: tZ3).

Upon completion of the tests any current differential, overcurrent, earth fault, breaker fail or supervision elements which were disabled for testing purposes must have their original settings restored in the CONFIGURATION column.

5.2.4 Backup Phase Overcurrent Protection

If the overcurrent protection function is being used, the I>1 element should be tested. If not, skip to section 5.3.

To avoid spurious operation of any current differential, distance, overcurrent, earth fault or breaker fail elements, these should be disabled for the duration of the overcurrent tests. This is done in the relay's CONFIGURATION column. Make a note of which elements need to be re-enabled after testing.

Note	*If the I>1 element is set to be "Enabled on Channel Fail" it will be necessary to deliberately force a communications channel failure in order to test it. This can be achieved by removing the loopback test, and ensuring that the relay cannot communicate with the remote end relay.*

Set cell (0F12: Test Loopback) to "Disabled"

Observe that the relay raises a Comms Fail alarm.

5.2.4.1 Connect the Test Circuit

Determine which output relay has been selected to operate when an I>1 trip occurs by viewing the relay's Programmable Scheme Logic (PSL).

The PSL 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 PSL, output relay 3 should be used for the test as it operates for any trip condition.

The associated terminal numbers can be found either from the Installation chapter or Table 8.

Connect the output relay so that its operation will trip the test set and stop the timer.

Caution	**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 (3503: GROUP 1 OVERCURRENT, I>1 Directional) is set to 'Directional Fwd', the current should flow out of terminal C2 but into C2 if set to 'Directional Rev'.

If cell (3503: GROUP 1 OVERCURRENT, I>1 Directional) 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 stop when the current is applied and stage 1 has been set for directional operation, the connections may be incorrect for the direction of operation set. Try again with the current connections reversed.*

5.2.4.1.1 Perform the Test

Ensure that the timer is reset.

Apply a current of twice the setting in cell (3504: 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.

5.2.4.1.2 Check the Operating Time

Check that the operating time recorded by the timer is in the range shown in Table 13.

Note	*Except for the definite time characteristic, the operating times given in Table 6 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 13 must be multiplied by the setting of cell (3506: GROUP 1 OVERCURRENT, I>1 TMS) for IEC and UK characteristics or cell (3507: 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	(3505: I>1 Time Delay) setting	Setting ±2%
IEC S Inverse	10.03	9.53 - 10.53
IEC V Inverse	13.50	12.83 - 14.18
IEC E Inverse	26.67	24.67 - 28.67
UK LT Inverse	120.00	114.00 - 126.00
IEEE M Inverse	3.8	3.61 - 4.0
IEEE V Inverse	7.03	6.68 - 7.38
IEEE E Inverse	9.50	9.02 - 9.97
US Inverse	2.16	2.05 - 2.27
US ST Inverse	12.12	11.51 - 12.73

Table 13 - Characteristic operating times for I>1

Upon completion of the tests any current differential, distance, overcurrent, earth fault, breaker fail or supervision elements which were disabled for testing purposes must have their original settings restored in the CONFIGURATION column.

5.3 Check Trip and Auto-Reclose Cycle (P542 Only)

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 Autoreclose) 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.

5.4 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.

Unless previously agreed to the contrary, the application-specific PSL will not be checked as part of the commissioning tests.

Due to the versatility and possible complexity of the programmable scheme logic, it is beyond the scope of these commissioning instructions to detail suitable test procedures. Therefore, when PSL tests must be performed, written tests which will satisfactorily demonstrate the correct operation of the application-specific PSL should be devised by the Engineer who created it. These should be provided to the Commissioning Engineer together with the diskette containing the PSL setting file.

6 END TO END TESTS

In section 4.3 a loopback test was initiated on the relay fibre optic communications channels, together with the P590 interface units, if installed, to verify correct operation of the communications channel local to the P540 relay whilst completing the remaining tests. In this section the loopback test is removed and, if possible, satisfactory communications between P540 relays in the same group will be confirmed.

Note	*The trip circuit should remain isolated during these checks to prevent accidental operation of the associated circuit breaker.*

6.1 Remove the Loopback Test

As well as removing the loopback test, this section checks that all wiring and optical fibres are reconnected. If P592 or P593 interface units are installed the application-specific settings will also be applied.

Check the alarm records to ensure that no communications failure alarms have occurred whilst the loopback test has been in progress.

Set cell (0F12 Test Loopback) to ‘Disabled’.

Restore the communications channels as per the appropriate sub-section below.

6.1.1 Direct Fibre Optic Communications

Remove the loopback test fibre and reconnect the fibre optic cables for communications between relays, ensuring correct placement.

Caution	**When connecting or disconnecting optical fibres DO NOT look into the transmit port or the end of the optical fibre.**

6.1.2 Communications using P591 Interface Units

Return to the P591 units.

Caution	**Ensure that all the external wiring that was been removed to perform testing is replaced according to the relevant connection diagram or scheme diagram.**

If applicable, replace the secondary front cover on the P591 units.

6.1.3 Communications using P592 Interface Units

Return to the P592 units.

Caution	**Ensure that all the external wiring that was been removed to perform testing is replaced according to the relevant connection diagram or scheme diagram.**

Set the ‘V.35 LOOPBACK’ switch to the ‘0’ position.

Set the ‘CLOCK SWITCH’, ‘DSR’, ‘CTS’ and ‘DATA RATE’ DIL switches on each unit to the positions required for the specific application and ensure the ‘OPTO LOOPBACK’ switch is in the ‘0’ position.

If applicable, replace the secondary front cover on the P592 units.

Note	*V.35 Loopback on the remote P592 can be selected to check the communications between the local relay, the local P592 and the communication link itself.*

6.1.4 Communications using P593 Interface Units

Return to the P593 units.

Caution	**Ensure that all the external wiring that was been removed to perform testing is replaced according to the relevant connection diagram or scheme diagram.**

Set the 'X.21 LOOPBACK' switch to the 'OFF' position and ensure the 'OPTO LOOPBACK' switch is also in the 'OFF' position.

If applicable, replace the secondary front cover on the P593 units.

Note	*X.21 Loopback on the remote P593 can be selected to check the communications between the local relay, the local P593 and the X.21 communication link itself. This setting on the local P593 can also be used to check the communications between the local relay and the local P593 if required.*

6.2 Verify Communications between Relays

The following communication checks confirm that the optical power at the transmit and receive ports of the local relay are within the recommended operating limits. However, these checks can only be performed with the relays, and P590 interface units, if installed, at the other ends of the feeder known to be functional and energised.

Measure and record the optical signal strength received by the local P540 relay by disconnecting the optical fibre from the Channel 1 receive port and connecting it to an optical power meter. The mean level should be in the range -16.8dBm to -25.4dBm for an 850nm port and in the range -7dBm to -37dBm for either a 1300nm or 1550nm port. If the mean level is outside of this range check the size and type of fibre being used.

Caution	**When connecting or disconnecting optical fibres DO NOT look into the transmit port or the end of the optical fibre.**

Repeat for Channel 2 receive port (if applicable).

Measure and record the optical power of the Channel 1 transmit port using the optical power meter and length of optical fibre. The mean value should be in the range -16.8dBm to 22.8dBm for an 850nm port and in the range -7dBm to -13dBm for either a 1300nm or 1550nm port.

Repeat for Channel 2 transmit port (if applicable).

Ensure that all transmit (Tx) and receive (Rx) optical fibres are reconnected to the P540, ensuring correct placement.

Reset any alarm indications and check that no further communications failure alarms are raised. Check channel status and propagation delays in (MEASUREMENTS 4) column. Clear the statistics and record the number of valid messages and the number of errored messages after a minimum period of 1 hour. Check that the ratio of errored/good messages is better than 10^{-4}.

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.
- measure the magnitude of capacitive current.
- ensure the on-load differential current is well below the relay setting.
- check the polarity of the line current transformers at each end is consistent.
- Directionality check for distance elements.

However, these checks can only be carried out if there are no restrictions preventing the energisation of the plant being protected and the other P540 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.

Caution **Ensure that all the external wiring that was been removed to perform testing is replaced according to the relevant connection diagram or scheme diagram.**

7.1 Confirm Current and Voltage Transformer Wiring

7.1.1 Voltage Connections (if applicable)

Caution **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 VBC VCA VAN VBN VCN	(0214: VAB Magnitude) (0216: VBC Magnitude) (0218: VCA Magnitude) (021A: VAN Magnitude) (021C: VBN Magnitude) (021E: VCN Magnitude)	[0A01 : Main VT Primary] / [0A02 : Main VT Secondary]
VCHECKSYNC	(022E: C/S Voltage Mag)	[0A03 : C/S VT Primary] / [0A04 : C/S VT Secondary]

Table 14 - 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 7). 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

Caution	**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 centre.

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.

Note	*Under normal load conditions the earth fault function will measure little, if any, current. It is therefore necessary to simulate a phase to neutral fault. This can be achieved by temporarily disconnecting one or two of the line current transformer connections to the relay and shorting the terminals of these current transformer secondary windings.*

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 6). Again the values should be within 1% of the expected value, plus an additional allowance for the accuracy of the test equipment being used.

Note	*If a single dedicated current transformer is used for the earth fault function, it is not possible to check the relay's measured values.*

7.2 Measure Capacitive Charging Current

With the feeder energised from one end only, compare the local and remote measured currents in the MEASUREMENTS 3 menu column to confirm that the feeder capacitive charging current is similar to that expected on all three phases.

Check that the setting of cell (3105: GROUP 1 PHASE DIFF, Phase Is1) is higher than 2.5 times the capacitive charging current. If this is not the case, notify the Engineer who determined the original settings of the setting required to ensure stability under normal operating conditions.

7.3 Check Differential Current

With the feeder supplying load current check that the relay measurements in the MEASUREMENTS 3 menu column are as expected and that the differential current is similar to the value of capacitive charging current previously measured for all three phases.

7.4 Check Consistency of Current Transformer Polarity

The load current should be high enough to be certain beyond doubt that the main current transformers are connected with the same polarity to each relay in the group.

There is a possibility on cable circuits with high line capacitance that the load current could be masked by the capacitive charging current. If necessary reverse the connections to the main current transformers and check that the ‘A’ phase differential current in cell (0419: MEASUREMENTS 3, IA Differential) is significantly higher than for the normal connection. If the differential current falls with the connection reversed, the main current transformers may not be correct and should be thoroughly checked. Repeat the test for phases ‘B’ and ‘C’ using cells (0420: MEASUREMENTS 3, IB Differential) and (0419: MEASUREMENTS 3, IC Differential) respectively.

8 FINAL CHECKS

The tests are now complete.

Caution **Remove all test or temporary shorting leads, etc. Ensure that all the external wiring that was been removed to perform testing is replaced according to the relevant connection diagram 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 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 MAINTENANCE

9.1 Maintenance Period

It is recommended that products supplied by Schneider Electric receive periodic monitoring after installation. As with all products some deterioration with time is inevitable. 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.

Schneider Electric protective relays are designed for a life in excess of 20 years.

MiCOM P540 current differential relays are self-supervising 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.

The operation of the P590 interface units, when installed, is continuously monitored by the P540 relay and a communication failure alarm will therefore be given if a P590 should cease to work properly.

Note	*A communication failure alarm could be caused by the failure of the equipment forming the communication link and can not in itself be conclusive evidence of a faulty P590 interface unit.*

If a Preventative Maintenance Policy exists within the customer's organisation then the recommended product checks should be included in the regular programme. Maintenance periods will depend on many factors, such as:

- operating environment
- accessibility of the site
- amount of available manpower
- importance of the installation in the power system
- consequences of failure

9.2 Maintenance Checks

Although some functionality checks can be performed from a remote location by utilising 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).

Caution	**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.**

9.2.1 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.

9.2.2 Opto-Isolators

The opto-isolated inputs can be checked to ensure that the relay responds to their energisation by repeating the commissioning test detailed in Section 4.2.6 of this chapter.

9.2.3 Output Relays

The output relays can be checked to ensure that they operate by repeating the commissioning test detailed in Section 4.2.7 of this chapter.

9.2.4 Measurement Accuracy

If the power system is energised, 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 analogue/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 this chapter.

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 4.4 of this chapter. These tests will prove the calibration accuracy is being maintained.

9.3 Method of Repair

9.3.1 P540 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 chapter.

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 centre, the warranty will be invalidated.

Caution	**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.**

9.3.1.1 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 fibre optic connections, as appropriate, from the rear of the relay.

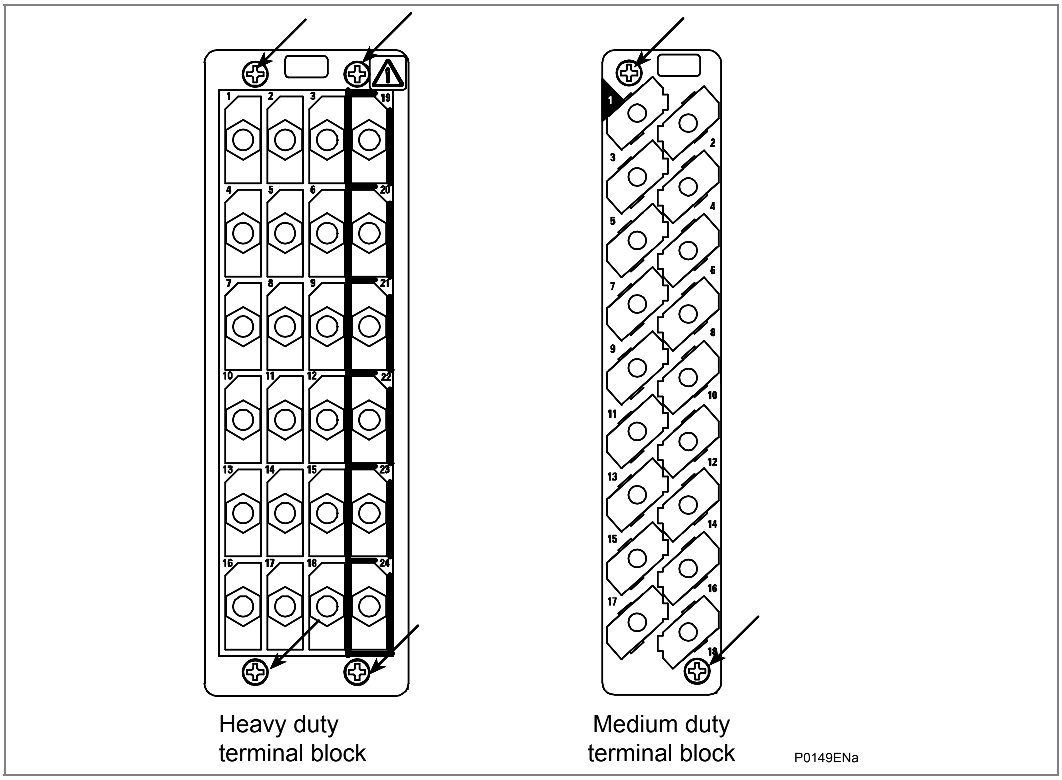

Figure 4 - Location of securing screws for terminal blocks

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 4.

Note	*The use of a magnetic bladed screwdriver is recommended to minimise 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.

Caution	**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 fibre optic connections are replaced. To facilitate easy identification of each terminal block, they are labelled alphabetically with 'A' on the left hand side when viewed from the rear.

Once reinstallation is complete the relay should be recommissioned using the instructions in sections 1 to 8 inclusive of this chapter.

9.3.1.2 Replacing a PCB

If the relay fails to operate correctly refer to the Troubleshooting chapter, to help determine which PCB has become faulty.

To replace any of the relay's PCBs it is necessary to first remove the front panel.

Caution	**Before removing the front panel to replace a PCB the auxiliary supply must be removed. It is also strongly recommended that the voltage and current transformer connections and trip circuit are isolated.**

Open the top and bottom access covers. With size 60TE/80TE cases the access covers have two hinge-assistance T-pieces which clear the front panel moulding when the access covers are opened by more than 90°, thus allowing their removal.

If fitted, remove the transparent secondary front cover. A description of how to do this is given in the 'Introduction' (P54x/EN IT).

By applying outward pressure to the middle of the access covers, they can be bowed sufficiently so as to disengage the hinge lug allowing the access cover to be removed. The screws that fasten the front panel to the case are now accessible.

The size 40TE case has four crosshead screws fastening the front panel to the case, one in each corner, in recessed holes. The size 60TE/80TE case has an additional two screws, one midway along each of the top and bottom edges of the front plate. Undo and remove the screws.

Caution	**Do not remove the screws with the larger diameter heads which are accessible when the access covers are fitted and open. These screws hold the relay in its mounting (panel or cubicle).**

When the screws have been removed, the complete front panel can be pulled forward and separated from the metal case.

Caution should be observed at this stage because the front panel is connected to the rest of the relay circuitry by a 64-way ribbon cable.

Additionally, from here on, the internal circuitry of the relay is exposed and not protected against electrostatic discharges, dust ingress, etc. Therefore ESD precautions and clean working conditions should be maintained at all times.

The ribbon cable is fastened to the front panel using an IDC connector; a socket on the cable itself and a plug with locking latches on the front panel. Gently push the two locking latches outwards which will eject the connector socket slightly. Remove the socket from the plug to disconnect the front panel.

The PCBs within the relay are now accessible. Figure 5 and Figure 6 show the PCB locations for the current differential relays in a size 40TE case (P541) and a size 60TE/80TE cases with a single set of transformers (P542).

Note	*The numbers above the case outline identify the guide slot reference for each PCB. Each PCB has a label stating the corresponding guide slot number to ensure correct re-location after removal. To serve as a reminder of the slot numbering there is a label on the rear of the front panel metallic screen.*

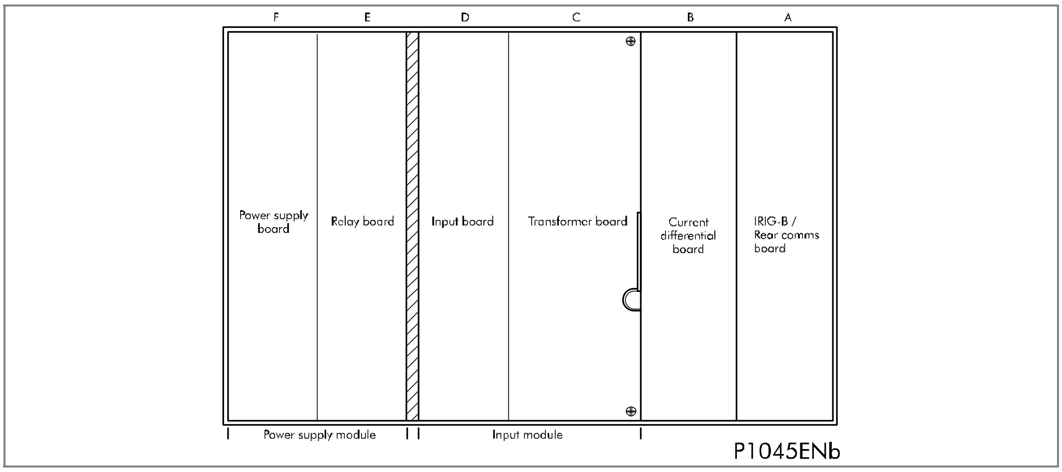

Figure 5 - P541 PCB/module locations (viewed from front)

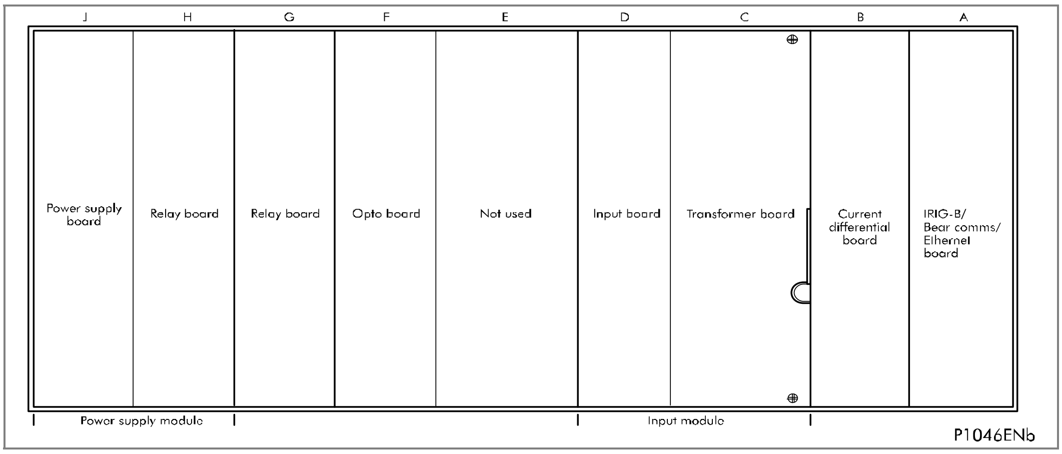

Figure 6 - P542 PCB/module locations (viewed from front)

The 64-way ribbon cable to the front panel also provides the electrical connections between PCBs with the connections being via IDC connectors.

The slots inside the case to hold the PCBs securely in place each correspond to a rear terminal block. Looking from the front of the relay these terminal blocks are labelled from right to left.

Note	*To ensure compatibility, always replace a faulty PCB with one of an identical part number.*

9.3.1.2.1 Replacement of the Main Processor Board

The main processor board is located in the front panel, not within the case as with all the other PCBs. Place the front panel with the user interface face-down and remove the six screws from the metallic screen, as shown in Figure 7. Remove the metal plate.

There are two further screws, one each side of the rear of the battery compartment recess, that hold the main processor PCB in position. Remove these screws.

The user interface keypad is connected to the main processor board via a flex-strip ribbon cable. Carefully disconnect the ribbon cable at the PCB-mounted connector as it could easily be damaged by excessive twisting.

The front panel can then be re-assembled with a replacement PCB using the reverse procedure. Ensure that the ribbon cable is reconnected to the main processor board and all eight screws are re-fitted.

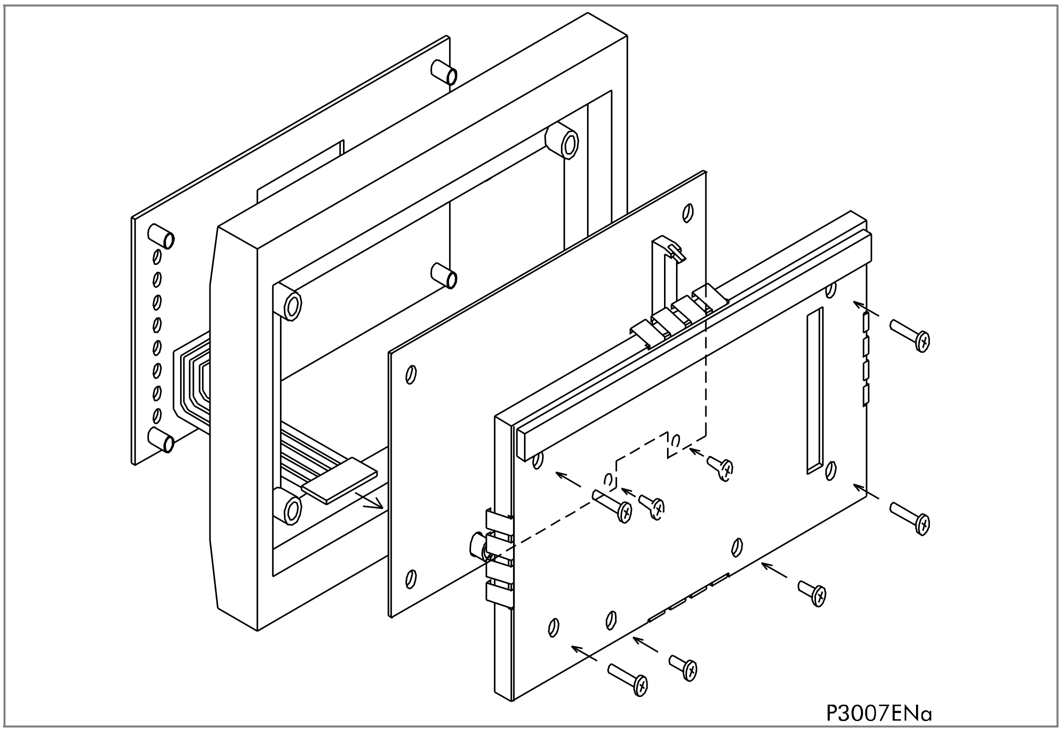

Figure 7 - Front panel assembly

Refit the front panel using the reverse procedure to that given in section 9.3.1.2. After refitting and closing the access covers on size 60TE/80TE cases, press at the location of the hinge-assistance T-pieces so that they click back into the front panel moulding.

After replacement of the main processor board, all the settings required for the application will need to be re-entered. Therefore, it is useful if an electronic copy of the application-specific settings is available on disk. Although this is not essential, it can reduce the time taken to re-enter the settings and hence the time the protection is out of service.

Once the relay has been reassembled after repair, it should be recommissioned in accordance with the instructions in sections 1 to 8 inclusive of this chapter.

9.3.1.2.2 Replacement of the IRIG-B Board

Depending on the model number of the relay, the IRIG-B board may have connections for IRIG-B signals, IEC60870-5-103 (VDEW) communications, both or not be present at all.

To replace a faulty board, disconnect all IRIG-B and/or IEC60870-5-103 connections at the rear of the relay.

The board is secured in the case by two screws accessible from the rear of the relay, one at the top and another at the bottom, as shown in Figure 8. Remove these screws carefully as they are not captive in the rear panel of the relay.

Gently pull the IRIG-B board forward and out of the case.

To help identify that the correct board has been removed, Figure 9 illustrates the layout of the IRIG-B board with both IRIG-B and IEC60870-5-103 options fitted (ZN0007 003). The other versions (ZN0007 001 and ZN0007 002) use the same PCB layout but have less components fitted.

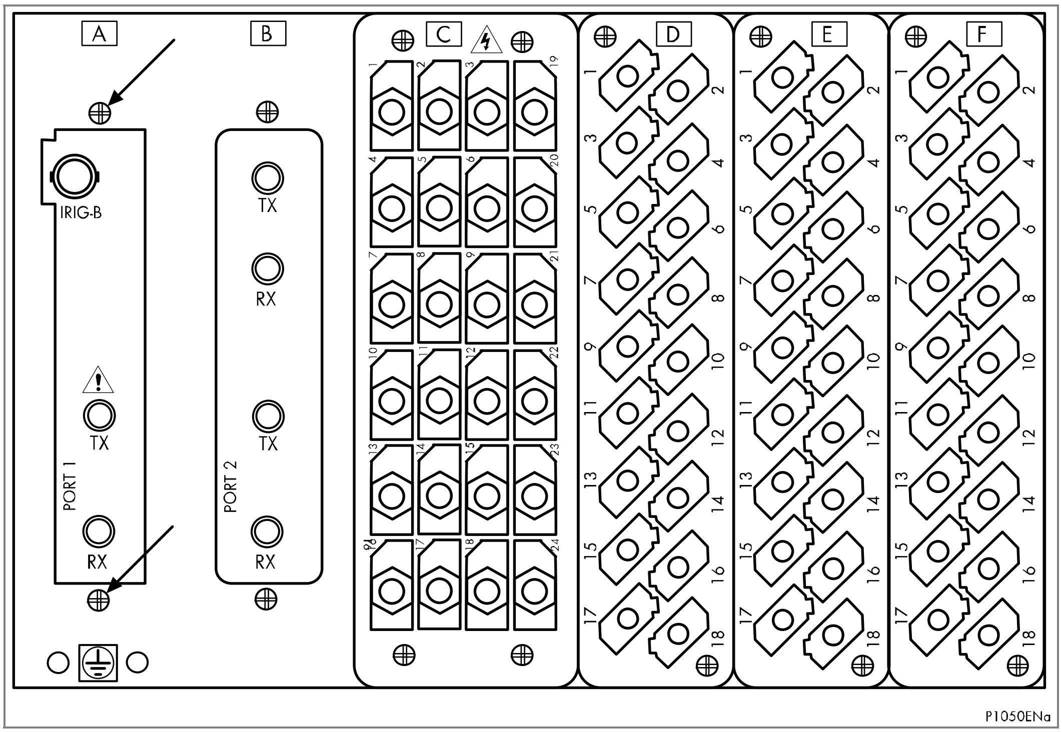

Figure 8 - Location of securing screws for IRIG-B board

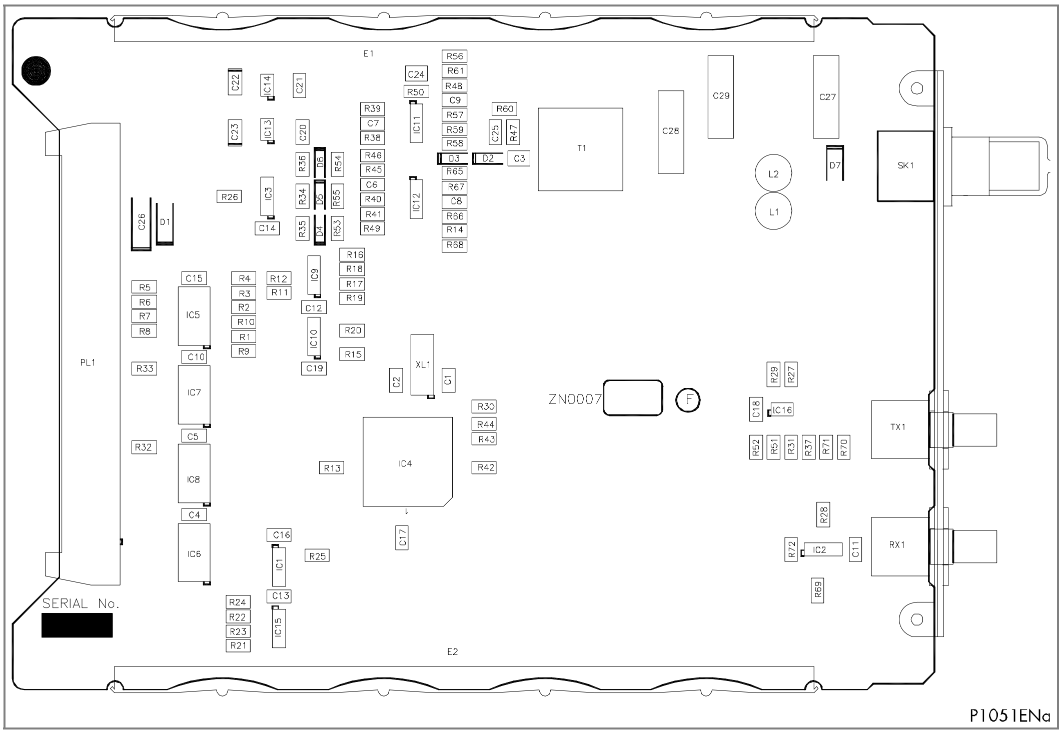

Figure 9 - Typical IRIG-B board

Before fitting the replacement PCB check that the number on the round label adjacent to the front edge of the PCB matches the slot number into which it will be fitted. If the slot number is missing or incorrect write the correct slot number on the label.

The replacement PCB should be carefully slotted into the appropriate slot, ensuring that it is pushed fully back on to the rear terminal blocks and the securing screws are re-fitted.

Reconnect all IRIG-B and/or IEC60870-5-103 connections at the rear of the relay.

Refit the front panel using the reverse procedure to that given in section 9.3.1.2. After refitting and closing the access covers on size 60TE/80TE cases, press at the location of the hinge-assistance T-pieces so that they click back into the front panel moulding.

Once the relay has been reassembled after repair, it should be recommissioned in accordance with the instructions in sections 1 to 8 inclusive of this chapter.

9.3.1.2.3 Replacement of the Input Module

The input module comprises of two boards fastened together, the transformer board and the input board.

The module is secured in the case by two screws on its right-hand side, accessible from the front of the relay, as shown in Figure 10. Remove these screws carefully as they are not captive in the front plate of the module.

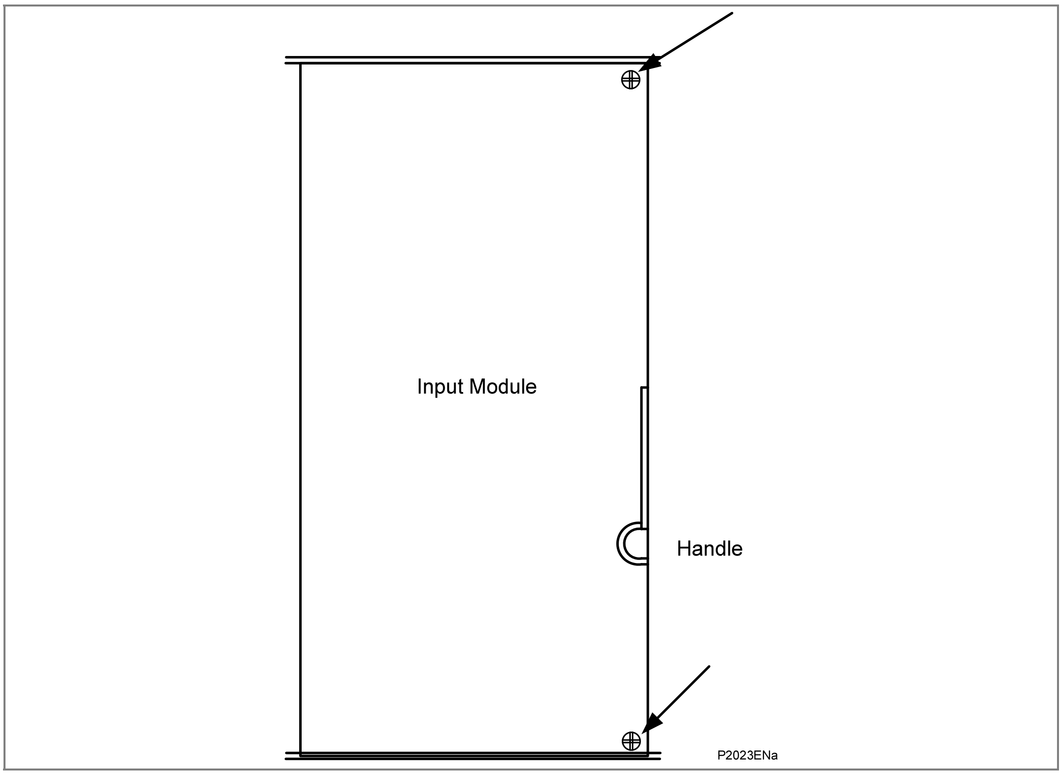

Figure 10 - Location of securing screws for input module

On the right-hand side of the analogue input module there is a small metal tab which brings out a handle. Grasping this handle firmly, pull the module forward, away from the rear terminal blocks. A reasonable amount of force will be required to achieve this due to the friction between the contacts of two terminal blocks, one medium duty and one heavy duty.

Note	*Care should be taken when withdrawing the input module as it will suddenly come loose once the friction of the terminal blocks has been overcome. This is particularly important with unmounted relays as the metal case will need to be held firmly whilst the module is withdrawn.*

Remove the module from the case, taking care as it is heavy because it contains all the relay’s input voltage and current transformers.

Before fitting the replacement module check that the number on the round label adjacent to the front edge of the PCB matches the slot number into which it will be fitted. If the slot number is missing or incorrect write the correct slot number on the label.

The replacement module can be slotted in using the reverse procedure, ensuring that it is pushed fully back on to the rear terminal blocks. To help confirm that the module has been inserted fully there is a V-shaped cut-out in the bottom plate of the case that should be fully visible. Re-fit the securing screws.

Note	The transformer and input boards within the module are calibrated together with the calibration data being stored on the input board. Therefore it is recommended that the complete module is replaced to avoid on-site recalibration having to be performed.

Refit the front panel using the reverse procedure to that given in section 9.3.1.2. After refitting and closing the access covers on size 60TE/80TE cases, press at the location of the hinge-assistance T-pieces so that they click back into the front panel moulding.

Once the relay has been reassembled after repair, it should be recommissioned in accordance with the instructions in sections 1 to 8 inclusive of this chapter.

9.3.1.2.4 Replacement of the Power Supply Board

The power supply board is fastened to a relay board to form the power supply module and is located on the extreme left-hand side of all MiCOM current differential relays.

Pull the power supply module forward, away from the rear terminal blocks and out of the case. A reasonable amount of force will be required to achieve this due to the friction between the contacts of the two medium duty terminal blocks.

The two boards are held together with push-fit nylon pillars and can be separated by pulling them apart. Care should be taken when separating the boards to avoid damaging the inter-board connectors located near the lower edge of the PCBs towards the front of the power supply module.

The power supply board is the one with two large electrolytic capacitors on it that protrude through the other board that forms the power supply module. To help identify that the correct board has been removed, Figure 11 illustrates the layout of the power supply board for all voltage ratings.

Before re-assembling the module with a replacement PCB check that the number on the round label adjacent to the front edge of the PCB matches the slot number into which it will be fitted. If the slot number is missing or incorrect write the correct slot number on the label.

Re-assemble the module with a replacement PCB ensuring the inter-board connectors are firmly pushed together and the four push-fit nylon pillars are securely located in their respective holes in each PCB.

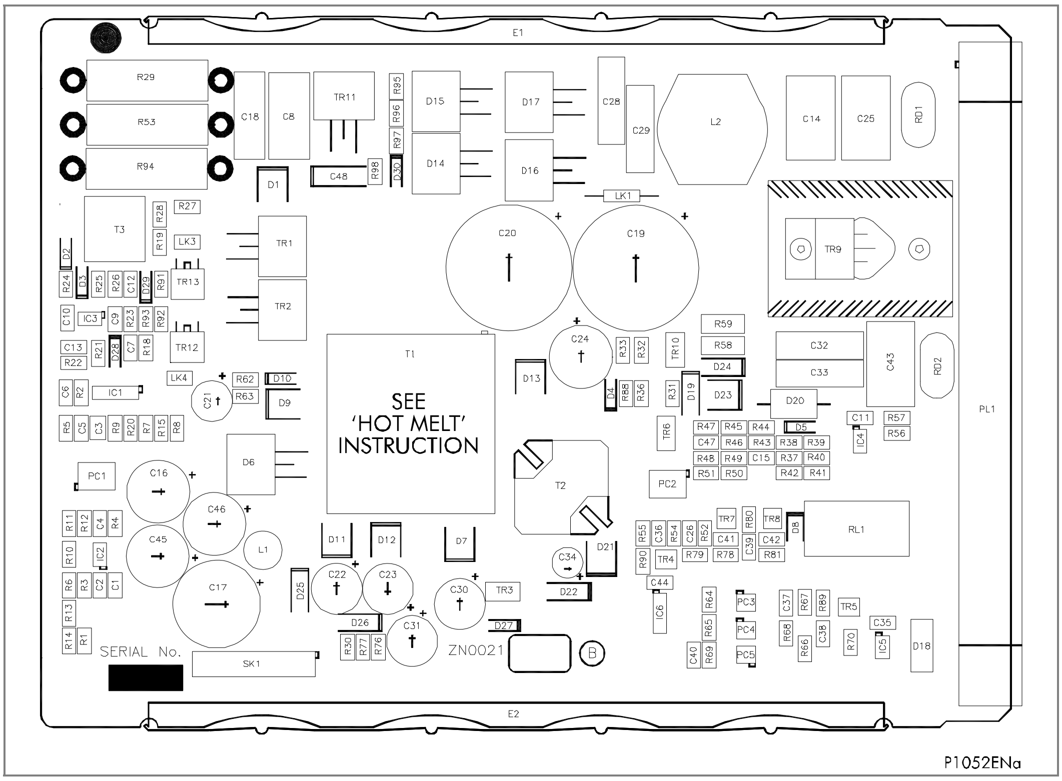

Figure 11 - Typical power supply board

Slot the power supply module back into the relay case, ensuring that it is pushed fully back on to the rear terminal blocks.

Refit the front panel using the reverse procedure to that given in section 9.3.1.2. After refitting and closing the access covers on size 60TE/80TE cases, press at the location of the hinge-assistance T-pieces so that they click back into the front panel moulding.

Once the relay has been reassembled after repair, it should be recommissioned in accordance with the instructions in sections 1 to 8 inclusive of this chapter.

9.3.1.2.5 Replacement of the Relay Board in the Power Supply Module

Remove and replace the relay board in the power supply module as described in 9.3.1.2.4 above.

The relay board is the one with holes cut in it to allow the transformer and two large electrolytic capacitors of the power supply board to protrude through. To help identify that the correct board has been removed, Figure 12 illustrates the layout of the relay board.

Before re-assembling the module with a replacement relay board check that the number on the round label adjacent to the front edge of the PCB matches the slot number into which it will be fitted. If the slot number is missing or incorrect write the correct slot number on the label.

Ensure the setting of the link (located above IDC connector) on the replacement relay board is the same as the one being replaced before replacing the module in the relay case.

Once the relay has been reassembled after repair, it should be recommissioned in accordance with the instructions in sections 1 to 8 inclusive of this chapter.

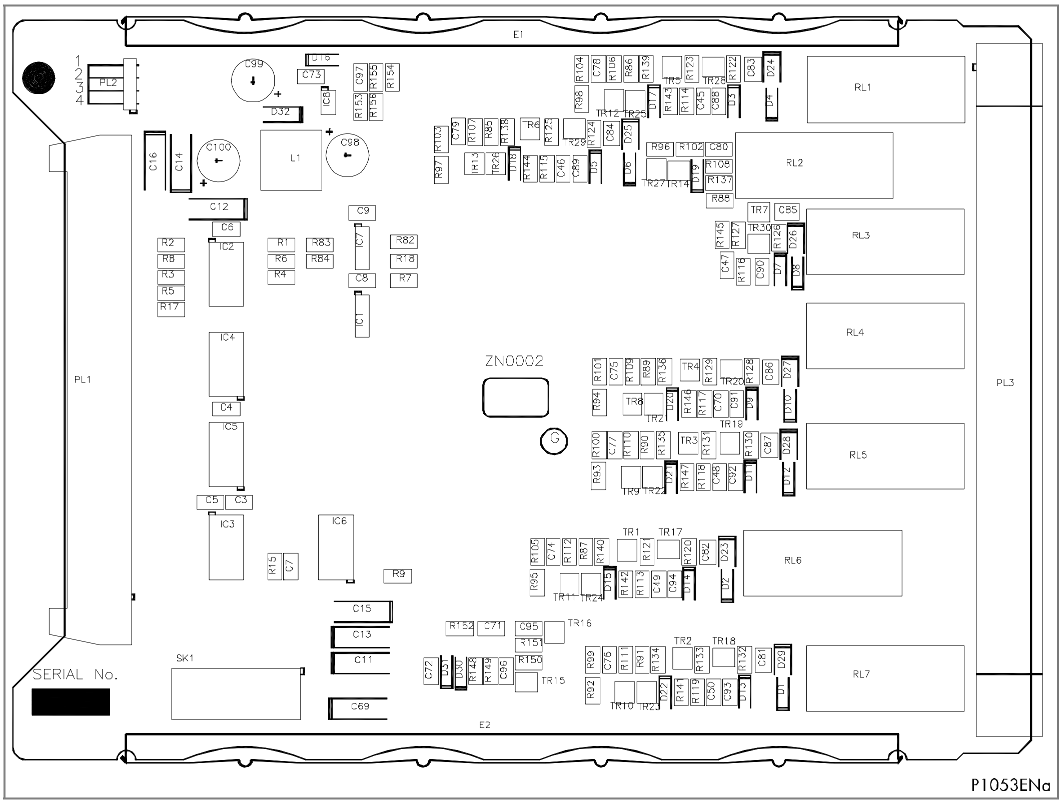

Figure 12 - Typical relay board

9.3.1.2.6 Replacement of the Opto and Separate Relay Boards

The P542 current differential relay has additional boards to the P541. These boards provide extra output relays and optically-isolated inputs to those in the power supply and input modules respectively.

To remove either, gently pull the faulty PCB forward and out of the case.

If the relay board is being replaced, ensure the setting of the link (located above IDC connector) on the replacement relay board is the same as the one being replaced. To help identify that the correct board has been removed, Figure 12 and Figure 13 illustrate the layout of the relay and opto boards respectively.

Before fitting the replacement PCB check that the number on the round label adjacent to the front edge of the PCB matches the slot number into which it will be fitted. If the slot number is missing or incorrect write the correct slot number on the label.

The replacement PCB should be carefully slid into the appropriate slot, ensuring that it is pushed fully back on to the rear terminal blocks.

Refit the front panel using the reverse procedure to that given in section 9.3.1.2. After refitting and closing the access covers on size 60TE/80TE cases, press at the location of the hinge-assistance T-pieces so that they click back into the front panel moulding.

Once the relay has been reassembled after repair, it should be recommissioned in accordance with the instructions in sections 1 to 8 inclusive of this chapter.

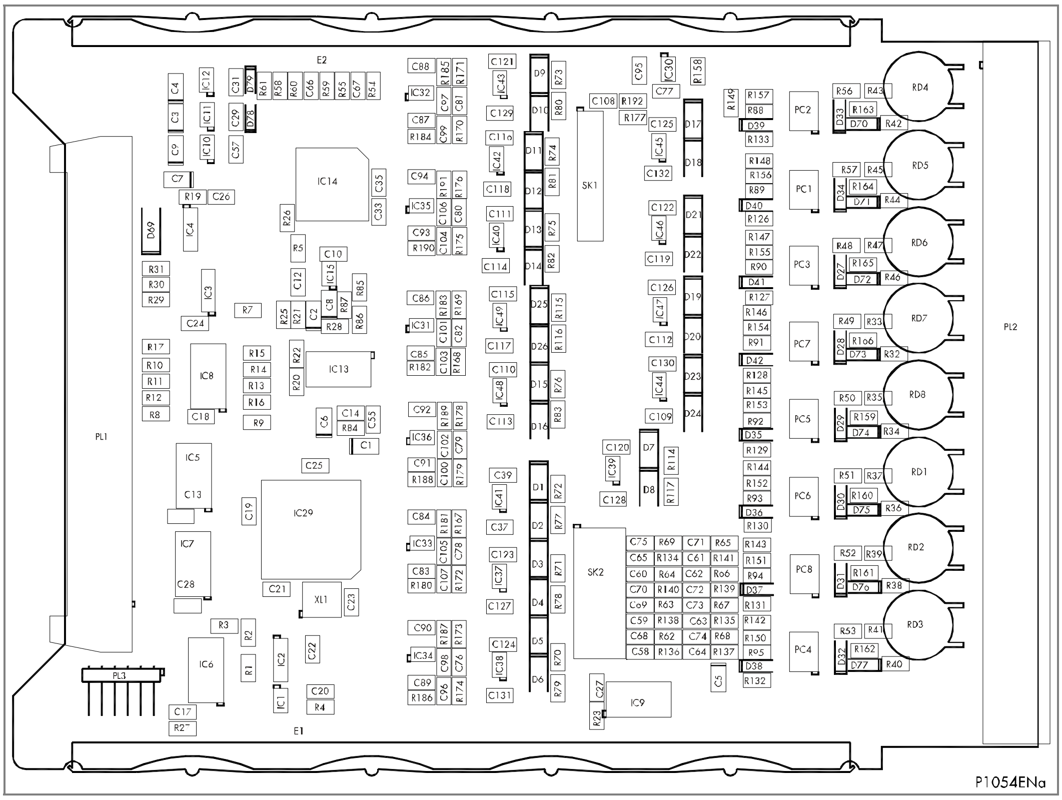

Figure 13 - Typical opto board

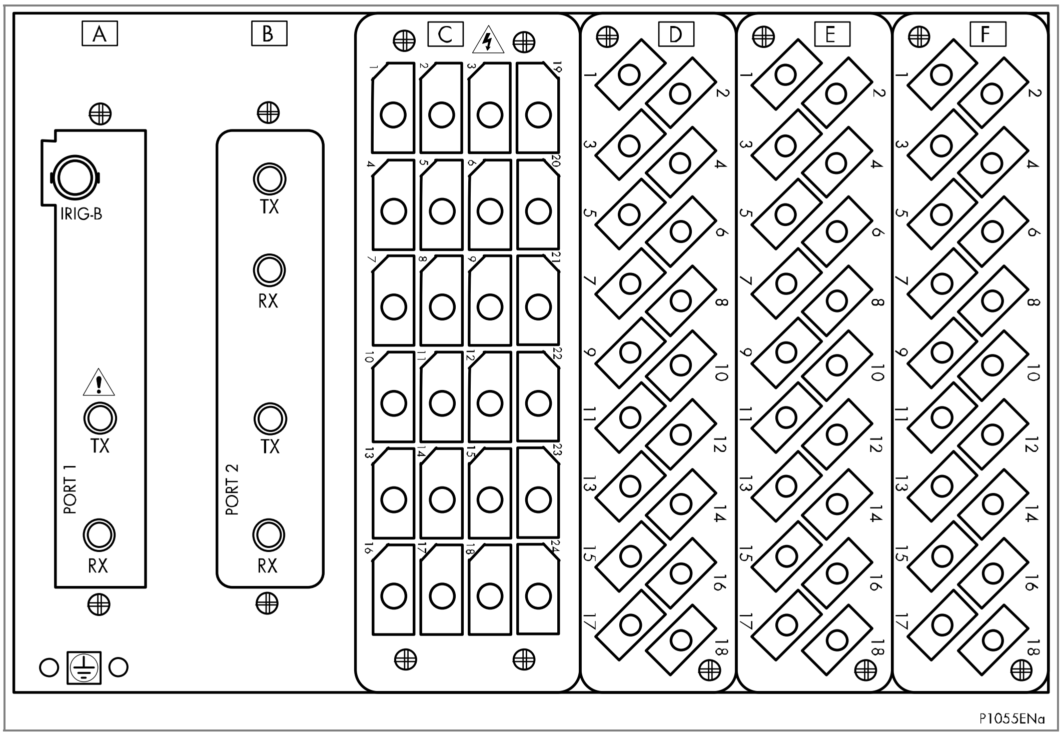

Figure 14 - Location of securing screws for current differential board

9.3.1.2.7 Replacement of the Current Differential Board

Before replacing a faulty current differential board, disconnect fibre optic cable connections at the rear of the relay.

The board is secured in the case by two screws accessible from the rear of the relay, one at the top and another at the bottom, as shown in Figure 10. Remove these screws carefully as they are not captive in the rear panel of the relay.

Using the small metal tab on the left hand side of the input module rotate handle used for extraction until it is in a horizontal orientation. This is necessary so that the two PCB connectors on the underside of the current differential PCB do not catch the handle as the PCB is extracted.

Gently pull the faulty current differential PCB forward and out of the case.

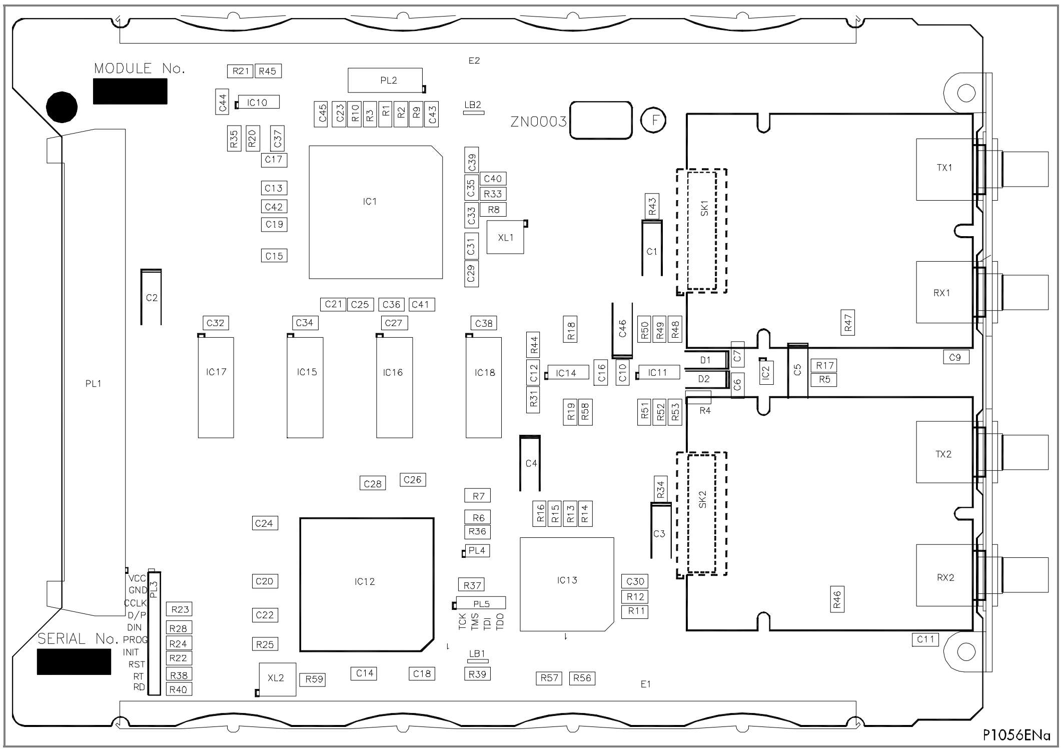

Figure 15 - Typical current differential board

To help identify that the correct board has been removed, Figure 15 illustrates the layout of the current differential board with dual fibre optic communications channels fitted. The current differential boards with a single communications channel (used in relays for two ended feeders where dual redundant communications channels are not required) use the same PCB layout but have less components fitted.

The replacement PCB should be carefully slid into the appropriate slot, ensuring that it is pushed fully back and the board securing screws are re-fitted.

Refit the fibre optic cable connections, ensuring that they are in the correct locations.

Refit the front panel using the reverse procedure to that given in section 9.3.1.2. After refitting and closing the access covers on size 60TE/80TE cases, press at the location of the hinge-assistance T-pieces so that they click back into the front panel moulding.

Once the relay has been reassembled after repair, it should be recommissioned in accordance with the instructions in sections 1 to 8 inclusive of this chapter.

9.3.2 P590 Interface Units

Should a P590 interface unit be found to have developed a fault it is recommended that the complete P590 module, together with a suitable case for protection, is returned to Schneider Electric, or an approved service centre, for repair. If a compatible spare P590 is available this can be installed until the faulted unit has been repaired.

The main reasons for fault finding to sub-assembly or component level not being recommended are:

Fault finding on printed circuit boards requires a knowledge of the P590 circuitry and specialised equipment.

The components used in manufacture are subjected to strict quality control procedures and in all cases have been selected for particular characteristics.

Metal Oxide Semiconductors (MOS) are used which require very careful handling to prevent damage from electrostatic discharges.

Damage can be caused to printed circuit board tracks and surrounding components unless extreme care is used when replacing faulty components.

Replacement of certain components will require the relay to be recalibrated.

Once the P590 has been replaced, it should be recommissioned in accordance with the instructions in sections 4.3 and 6 of this chapter.

9.4 Recalibration of the P540 Relay

Recalibration 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 recalibration 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 is carried out by the manufacturer, or entrusted to an approved service centre.

9.5 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.

Caution	**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.**

9.5.1 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.

9.5.2 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 4.2.3, ‘Date and Time’, can be performed.

9.5.3 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.

9.6 Cleaning

Caution **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 dampened 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.

10 COMMISSIONING TEST RECORD

10.1 Engineer Details

Date: ______________________ Engineer: ______________________

Station: ______________________ Circuit: ______________________

System Frequency: ______________________

10.2 Front Plate Information

Current differential protection relay	**P54_____**
Model number	
Serial number	
Rated current In	
Rated voltage Vn	
Auxiliary voltage Vx	

10.3 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.

Overcurrent test set	Model: Serial No:	
Optical power meter	Model: Serial No:	
Phase angle meter	Model: Serial No:	
Phase rotation meter	Model: Serial No:	
Insulation tester	Model: Serial No:	
Setting software:	Type: Version:	

		*Delete as appropriate
	Have all relevant safety instructions been followed?	Yes/No*
4	Product Checks	
4.1	With the relay de-energised	
4.1.1	Visual inspection	
	Relay damaged?	Yes/No*
	Rating information correct for installation?	Yes/No*
	Case earth installed?	Yes/No*
4.1.2	Current transformer shorting contacts close?	Yes/No/Not checked*
4.1.3	Insulation resistance >100MΩ at 500V dc	Yes/No/Not tested*
4.1.4	External Wiring	
	Wiring checked against diagram?	Yes/No*
	Test block connections checked?	Yes/No/na*
4.1.5	Watchdog Contacts (auxiliary supply off)	
	Terminals 11 and 12 Contact closed?	Yes/No*
	Contact resistance	_____Ω/Not measured*
	Terminals 13 and 14 Contact open?	Yes/No*
4.1.6	Measured auxiliary supply	_____V ac/dc*
4.2	With the relay energised	
4.2.1	Watchdog Contacts (auxiliary supply on)	
	Terminals 11 and 12 Contact open?	Yes/No*
	Terminals 13 and 14 Contact closed?	Yes/No*
	Contact resistance	_____Ω/Not measured*
4.2.3	Date and time	
	Clock set to local time?	Yes/No*
	Time maintained when auxiliary supply removed?	Yes/No*
4.2.4	Light emitting diodes	
	Alarm (yellow) LED working?	Yes/No*
	Out of service (yellow) LED working?	Yes/No*
	Trip (red) LED working?	Yes/No*
	All 8 programmable LEDs working?	Yes/No*

		*Delete as appropriate
4.2.5	Field supply voltage	
	Value measured between terminals 7 and 9	_____V dc
	Value measured between terminals 8 and 10	_____V dc
4.2.6	Input opto-isolators	
	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/na*
	Opto input 10 working?	Yes/No/na*
	Opto input 11 working?	Yes/No/na*
	Opto input 12 working?	Yes/No/na*
	Opto input 13 working?	Yes/No/na*
	Opto input 14 working?	Yes/No/na*
	Opto input 15 working?	Yes/No/na*
	Opto input 16 working?	Yes/No/na*
	Opto input 17 working?	Yes/No/na*
	Opto input 18 working?	Yes/No/na*
	Opto input 19 working?	Yes/No/na*
	Opto input 20 working?	Yes/No/na*
	Opto input 21 working?	Yes/No/na*
	Opto input 22 working?	Yes/No/na*
	Opto input 23 working?	Yes/No/na*
	Opto input 24 working?	Yes/No/na*
4.2.7	Output relays	
	Relay 1 Working?	Yes/No*
	Contact resistance	_____Ω/Not measured*
	Relay 2 Working?	Yes/No*
	Contact resistance	_____Ω/Not measured*
	Relay 3 Working?	Yes/No*
	Contact resistance	_____Ω/Not measured*
	Relay 4 Working?	Yes/No*
	Contact resistance (N/C)	_____Ω/Not measured*
	(N/O)	_____Ω/Not measured*
	Relay 5 Working?	Yes/No*
	Contact resistance (N/C)	_____Ω/Not measured*
	(N/O)	_____Ω/Not measured*
	Relay 6 Working?	Yes/No*
	Contact resistance (N/C)	_____Ω/Not measured*

			*Delete as appropriate
		(N/O)	_____Ω/Not measured*
Relay 7	Working?		Yes/No*
	Contact resistance	(N/C)	_____Ω/Not measured*
		(N/O)	_____Ω/Not measured*
Relay 8	Working?		Yes/No/na*
	Contact resistance		_____Ω/Not measured*
Relay 9	Working?		Yes/No/na*
	Contact resistance		_____Ω/Not measured*
Relay 10	Working?		Yes/No/na*
	Contact resistance		_____Ω/Not measured*
Relay 11	Working?		Yes/No*
	Contac t resistance	(N/C)	_____Ω/Not measured*
		(N/O)	_____Ω/Not measured*
Relay 12	Working?		Yes/No*
	Contact resistance	(N/C)	_____Ω/Not measured*
		(N/O)	_____Ω/Not measured*
Relay 13	Working?		Yes/No*
	Contact resistance	(N/C)	_____Ω/Not measured*
		(N/O)	_____Ω/Not measured*
Relay 14	Working?		Yes/No*
	Contact resistance	(N/C)	_____Ω/Not measured*
		(N/O)	_____Ω/Not measured*
Relay 15	Working?		Yes/No*
	Contact resistance	(N/C)	_____Ω/Not measured*
		(N/O)	_____Ω/Not measured*
Relay 16	Working?		Yes/No*
	Contact resistance	(N/C)	_____Ω/Not measured*
		(N/O)	_____Ω/Not measured*
Relay 17	Working?		Yes/No*
	Contact resistance	(N/C)	_____Ω/Not measured*
		(N/O)	_____Ω/Not measured*
Relay 18	Working?		Yes/No*
	Contact resistance	(N/C)	_____Ω/Not measured*
		(N/O)	_____Ω/Not measured*
Relay 19	Working?		Yes/No*
	Contact resistance	(N/C)	_____Ω/Not measured*
		(N/O)	_____Ω/Not measured*
Relay 20	Working?		Yes/No*
	Contact resistance	(N/C)	_____Ω/Not measured*
		(N/O)	_____Ω/Not measured*
Relay 21	Working?		Yes/No*

				*Delete as appropriate
		Contact resistance	(N/C)	_____Ω/Not measured*
			(N/O)	_____Ω/Not measured*
	Relay 22	Working?		Yes/No*
		Contact resistance	(N/C)	_____Ω/Not measured*
			(N/O)	_____Ω/Not measured*
	Relay 23	Working?		Yes/No*
		Contact resistance	(N/C)	_____Ω/Not measured*
			(N/O)	_____Ω/Not measured*
	Relay 24	Working?		Yes/No*
		Contact resistance	(N/C)	_____Ω/Not measured*
			(N/O)	_____Ω/Not measured*
	Relay 25	Working?		Yes/No*
		Contact resistance	(N/C)	_____Ω/Not measured*
			(N/O)	_____Ω/Not measured*
	Relay 26	Working?		Yes/No*
		Contact resistance	(N/C)	_____Ω/Not measured*
			(N/O)	_____Ω/Not measured*
	Relay 27	Working?		Yes/No*
		Contact resistance	(N/C)	_____Ω/Not measured*
			(N/O)	_____Ω/Not measured*
	Relay 28	Working?		Yes/No*
		Contact resistance	(N/C)	_____Ω/Not measured*
			(N/O)	_____Ω/Not measured*
	Relay 29	Working?		Yes/No*
		Contact resistance	(N/C)	_____Ω/Not measured*
			(N/O)	_____Ω/Not measured*
	Relay 30	Working?		Yes/No*
		Contact resistance	(N/C)	_____Ω/Not measured*
			(N/O)	_____Ω/Not measured*
	Relay 31	Working?		Yes/No*
		Contact resistance	(N/C)	_____Ω/Not measured*
			(N/O)	_____Ω/Not measured*
	Relay 32	Working?		Yes/No*
		Contact resistance	(N/C)	_____Ω/Not measured*
			(N/O)	_____Ω/Not measured*
4.2.8	Communication standard			K-Bus/Modbus/ IEC60870-5-103*/ DNP 3.0
	Communications established?			Yes/No*
	Protocol convertor tested?			Yes/No/na*

		*Delete as appropriate
4.3	Current Differential Fibre Optic Communications	
	Type of communications:	
	Channel 1	Dedicated fibre/ via P590*
	Channel 2	Dedicated fibre/ via P590*
4.3.1	Direct Fibre Communication	
	Communication working	Yes/No/na*
	Type of P590 interface:	
	Channel 1 unit	P59_____/na*
	Channel 2 unit	P59_____/na*
4.3..x.1	Visual Inspection (P590 units only)	
	Unit damaged?	
	Channel 1 unit	Yes/No/na*
	Channel 2 unit	Yes/No/na*
	Rating information correct?	
	Channel 1 unit	Yes/No/na*
	Channel 2 unit	Yes/No/na*
	Case earth installed?	
	Channel 1 unit	Yes/No/na*
	Channel 2 unit	Yes/No/na*

		*Delete as appropriate
4.3.x.2	Insulation resistance (P590 units only)	
	Channel 1 unit	Yes/No/Not tested/na*
	Channel 2 unit	Yes/No/Not tested/na*
4.3.x.3	External Wiring (P590 units only)	
	Wiring checked against diagram?	
	Channel 1 unit	Yes/No/na*
	Channel 2 unit	Yes/No/na*
4.3.x.4	Measured Auxiliary Supply (P590 units only)	
	Channel 1 unit	_____Vdc/ac/na*
	Channel 2 unit	_____Vdc/ac/na*
4.3.x.5	Light Emitting Diodes (P590 units only)	
	All LEDs working?	
	Channel 1 unit	Yes/No/na*
	Channel 2 unit	Yes/No/na*
4.3.x.6	Loopback Test	
	Signal strength received by P590	
	Channel 1 unit	_____dBm/na*
	Channel 2 unit	_____dBm/na*
	Signal strength transmitted by P590	
	Channel 1 unit	_____dBm/na*
	Channel 2 unit	_____dBm/na*
	Signal Strength within tolerance	Yes/No/na*
	Loopback test applied?	
	Channel 1 unit	Yes/No*
	Channel 2 unit	Yes/No/na*
	Communications working	Yes/No/na*
4.4.6	Synchronising signal	
	Channel 1	_____dBm/na*
	Channel 2	_____dBm/na*
	Channel 3	_____dBm/na*
	Channel 4	_____dBm/na*
	Signal Strength within tolerance	Yes/No/na*

			*Delete as appropriate
4.4.7	Connection to P595 or P596		
	Channel status correct?		Yes/No/na*
4.5.1	Current Inputs		
	Displayed Current		Primary/Secondary*
	Phase CT Ratio		_____ /na*
	Earth Fault CT Ratio		_____ /na*
	Mutual CT Ratio		_____ /na*
	Input CT	Applied value	Displayed value
	IA	_____A	_____A
	IB	_____A	_____A
	IC	_____A	_____A
	IN	_____A	_____A
4.5.2	Voltage Inputs		
	Displayed Voltage		Primary/Secondary*
	Main VT Ratio		_____ /na*
	C/S VT Ratio		_____ /na*
	Input VT	Applied value	Displayed value
	Va	_____V	_____V
	Vb	_____V	_____V
	Vc	_____V	_____V
	C/S Voltage	_____V/na*	_____V
5	Setting Checks		
5.1	Application-specific function settings applied?		Yes/No*
	Application-specific programmable scheme logic settings applied?		Yes/No/na*
5.2.1.2	Current Differential lower slope pickup		_____ A
5.2.1.3	Current Differential upper slope pickup		_____ A
5.2.2.1	Current Differential Phase A contact routing OK?		Yes/No
	Current Differential Phase A trip time		_____ s
5.2.2.2	Current Differential Phase B contact routing OK?		Yes/No
	Current Differential Phase B trip time		_____ s
5.2.2.3	Current Differential Phase C contact routing OK?		Yes/No
	Current Differential Phase C trip time		_____ s
	Average trip time, phases A, B and C		_____ s

		*Delete as appropriate
5.2.3.2	Distance Protection Zone 1 Reach OK?	Yes/No
5.2.3.3	Distance Protection Zone 2 Reach OK?	Yes/No
5.2.3.4	Distance Protection Zone 3 Reach OK?	Yes/No
5.2.4.1	Distance Protection Phase A contact routing OK?	Yes/No
	Distance Protection Phase A trip time	_____ s
5.2.4.2	Distance Protection Phase B contact routing OK?	Yes/No
	Distance Protection Phase B trip time	_____ s
5.2.4.3	Distance Protection Phase C contact routing OK?	Yes/No
	Distance Protection Phase C trip time	_____ s
	Average trip time, phases A, B and C	_____ s
5.2.5	Protection function timing tested?	Yes/No*
	Overcurrent type (set in cell (I>1 Direction))	Directional /Non-directional*
	Applied voltage	_____ V/na*
	Applied current	_____ A
	Expected operating time	_____ s
	Measured operating time	_____ s
5.3	Trip and auto-reclose cycle checked	
	3 pole cycle tested? (P542 only)	Yes/No/na*
5.4	Application-specific function settings verified?	Yes/No/na*
	Application-specific programmable scheme logic tested?	Yes/No/na*
6	End to End Tests	
6.1	Remove the loopback test	
	Communications alarms?	
	Channel 1	No/Yes*
	Channel 2	No/Yes/na*
	Loopback test removed?	
	Channel 1	Yes/No*
	Channel 2	Yes/No/na*
	All connections restored?	
	Channel 1	Yes/No*
	Channel 2	Yes/No/na*
	Application-specific settings applied?	
	Channel 1	Yes/No*
	Channel 2 (P592 & P593 only)	Yes/No/na*
	Cover replaced? (P590 units only)	
	Channel 1	Yes/No*
	Channel 2	Yes/No/na*

		*Delete as appropriate
6.2	Verify communications between relays	
	Optical port type	
	Channel 1	850nm/1300nm /1550nm*
	Channel 2	850nm/1300nm /1550nm/na*
	Signal strength received by P540	
	Channel 1	_____dBm/na*
	Channel 2	_____dBm/na*
	Signal strength transmitted by P540	
	Channel 1	_____dBm/na*
	Channel 2	_____dBm/na*
	Signal Strength within tolerance	Yes/No/na*
	Optical fibres reconnected?	
	Channel 1	Yes/No*
	Channel 2	Yes/No/na*
	Alarms reset?	Yes/No*
	Ch 1 Prop Delay	_____ms
	Ch 2 Prop Delay	_____ms/na*
	Ch1 1 No. Vald Mess	
	Ch1 No.Err Mess	
	Ch1 Errored / Valid	
	Ch1 Errored / Valid < 10^{-4}	Yes/No*
	Ch2 1 No.Vald Mess	
	Ch2 No.Err Mess	
	Ch2 Errored / Valid	
	Ch2 Errored / Valid < 10^{-4}	Yes/No/na*
7	On-load Checks	
	Test wiring removed?	Yes/No/na*
	Disturbed customer wiring re-checked?	Yes/No/na*
	On-load test performed?	Yes/No*
	Directionality test performed?	Yes/No/na*

			*Delete as appropriate
7.1	Confirm current and voltage transformer wiring		
7.1.1	Voltage Connections		
	Phase rotation correct?		Yes/No*
	Displayed Voltage		Primary/Secondary*
	Main VT Ratio		_____ /na*
	C/S VT Ratio		_____ /na*
	Voltages:	Applied value	Displayed value
	Va	_____ V	_____ V
	Vb	_____ V	_____ V
	Vc	_____ V	_____ V
	C/S Voltage	_____ V/na*	_____ V
7.1.2	Current connections		
	CT wiring checked?		Yes/No/na*
	CT polarities correct?		Yes/No*
	Displayed current		Primary/Secondary*
	Phase CT ratio		_____ /na*
	Earth fault CT ratio		_____ /na*
	Mutual CT ratio		_____ /na*
	Currents:	Applied value	Displayed value
	IA	_____ A	_____ A
	IB	_____ A	_____ A
	IC	_____ A	_____ A
	IN	_____ A/na*	_____ A/na*
7.2	Capacitive Charging Current		
	Measured capacitive charging current		
	‘A’ phase		_____ A
	‘B’ phase		_____ A
	‘C’ phase		_____ A
	(3105: GROUP 1 PHASE DIFF, Phase Is1)		
	Setting		_____ A

		*Delete as appropriate
7.3	Differential current checked?	Yes/ No*
7.4	Consistency of Current Transformer Polarity	
	Polarity at each end consistent?	
	'A' phase	Yes/No*
	'B' phase	Yes/No*
	'C' phase	Yes/No*
8	Final Checks	
	Test wiring removed?	Yes/No/na*
	Disturbed customer wiring re-checked?	Yes/No/na*
	Test mode disabled?	Yes/No*
	Circuit breaker operations counter reset?	Yes/No/na*
	Current counters reset?	Yes/No/na*
	Event records reset?	Yes/No*
	Fault records reset?	Yes/No*
	Disturbance records reset?	Yes/No*
	Alarms reset?	Yes/No*
	LED's reset?	Yes/No*
	Secondary front cover replaced?	Yes/No/na*

Commissioning Engineer

Customer Witness

Date

Date

11 SETTING RECORD

Note	*Each row of these setting records contains an entry which can be set by the Engineer. The relay database contains other items which record data. These data records are not programmable, so they are not listed here.*

11.1 Engineer Details

Date: ____________________ Engineer: ____________________

Station: ____________________ Circuit: ____________________

System Frequency: ____________________

11.2 Front Plate Information

Current Differential Protection Relay	P541 or P542
Model Number	
Serial Number	
Rated Current In	
Rated Voltage Vn	
Auxiliary Voltage Vx	

11.3 Setting Groups Used

	*Delete as appropriate
Group 1	Yes/No*
Group 2	Yes/No*
Group 3	Yes/No*
Group 4	Yes/No*

11.4 0000 - SYSTEM DATA

0001	Language	English/Francais/Deutsch/Espanol/РУССКИЙ/*
0002	Password	
0003	Sys Fn Links	
0004	Description	
0005	Plant Reference	
0006	Model Number	
0007	UNUSED	
0008	Serial Number	
0009	Frequency	
000A	Comms Level	
000B	Relay Address	
000C	Plant Status	

000D	Control Status	
000E	Active Group	
000F	UNUSED	
0010	CB Trip/Close	
0011	Software Ref. 1	
0012 to 001F	UNUSED	
0020	Opto I/P Status	
0021	Relay I/P Status	
0022	Alarm Status 1	
0023	UNUSED	
0050	Alarm Status 1 (copy of 0022)	
0051	Alarm Status 2	
0052	Alarm Status 3	
00D0	Access Level	
00D1	Password Control	Level 0/Level 1/Level 2*
00D2	Password Level 1	
00D3	Password Level 2	
00D4 to 00D8	UNUSED	

11.5 0100 - View Records

0100	VIEW RECORDS	
0101	Select Event	
0102	Menu Cell Ref	
0103	Time & Date	
0104	Event Text	
0105	Event Value	
0106	Select Fault	
0107	Faulted Phase	
0108	Start Elements	
0109	UNUSED	
010A	Trip Elements(1)	
010B	UNUSED	
010C	Fault Alarms	
010D	Fault Time	
010E	Active Group	
010F	System Frequency	
0110	Fault Duration	
0111	CB Operate Time	
0112	Relay Trip Time	
0113 to 0116	UNUSED	
0117	IA	
0118	IB	

0119	IC	
011A to 011C	UNUSED	
011D	IA local	
011E	IB local	
011F	IC local	
0120	IA remote 1	
0121	IB remote 1	
0122	IC remote 1	
0123	IA remote 2	
0124	IB remote 2	
0125	IC remote 2	
0126	IA Differential	
0127	IB Differential	
0128	IC Differential	
0129	UNUSED	
012A	IA Bias	
012B	IB Bias	
012C	IC Bias	
01F0	Select Maint	
01F1	Maint Text	
01F2	Maint Type	
01F3	Maint Data	
01FF	Reset Indication	

11.6 0200 - Measurements 1

0200	MEASUREMENTS 1	
0201	IA Magnitude	
0202	IA Phase Angle	
0203	IB Magnitude	
0204	IB Phase Angle	
0205	IC Magnitude	
0206	IC Phase Angle	
0207	IN Measured Mag	
0208	IN Measured Ang	
0209	IN Derived Mag	
020A	IN Derived Angle	
020B	UNUSED	
020C	UNUSED	
020D	I1 Magnitude	
020E	I2 Magnitude	
020F	I0 Magnitude	
0210	IA RMS	
0211	IB RMS	

0212	IC RMS	
0213 - 022C	UNUSED	
022D	Frequency	
022E - 0233	UNUSED	

11.7 0300 - Measurements 2

0300 - 0317	MEASUREMENTS 2	
0318	IA Fixed Demand	
0319	IB Fixed Demand	
031A	IC Fixed Demand	
031B - 031C	UNUSED	
031D	IA Roll Demand	
031E	IB Roll Demand	
031F	IC Roll Demand	
0320 - 0321	UNUSED	
0322	IA Peak Demand	
0323	IB Peak Demand	
0324	IC Peak Demand	
0325	Reset Demand	

11.8 0400 - Measurements 3

0400	MEASUREMENTS 3	
0401	IA local	
0402	IA Angle local	
0403	IB local	
0404	IB Angle local	
0405	IC local	
0406	IC Angle local	
0407	UNUSED	
0408	UNUSED	
0409	IA remote 1	
040A	IA Ang remote 1	
040B	IB remote 1	
040C	IB Ang remote 1	
040D	IC remote 1	
040E	IC Ang remote 1	
040F	UNUSED	
0410	UNUSED	
0411	IA remote 2	

0412	IA Ang remote 2	
0413	IB remote 2	
0414	IB Ang remote 2	
0415	IC remote 2	
0416	IC Ang remote 2	
0417	UNUSED	
0418	UNUSED	
0419	IA Differential	
041A	IB Differential	
041B	IC Differential	
041C	UNUSED	
041D	IA Bias	
041E	IB Bias	
041F	IC Bias	
0420	Thermal State	
0421	Reset Thermal	

11.9 0500 - Measurements 4

0500	MEASUREMENTS 4	
0501	Ch 1 Prop Delay	
0502	Ch 2 Prop Delay	
0503	Channel Status	
0503	UNUSED	
0504	Elapsed Time	
0505	Ch1 No.Vald Mess	
0506	Ch1 No.Err Mess	
0507	Ch1 No.Errored s	
0508	Ch1 No.Sev Err s	
0509	Ch1 No.Dgraded m	
050A	Ch2 No.Vald Mess	
050B	Ch2 No.Err Mess	
050C	Ch2 No.Errored s	
050D	Ch2 No.Sev Err s	
050E	Ch2 No.Dgraded m	
050F	Clear Statistics	
0511 - 14	UNUSED	

11.10 0600 - CB CONDITION

0601	CB Operations	
0602 to 0604	UNUSED	
0605	Total IA Broken	
0606	Total IB Broken	

0607	Total IC Broken	
0608	CB Operate Time	
0609	Reset CB Data	

11.11 0700 - CB CONTROL

0701	CB Control by	Disabled/Local/Remote/Local+Remote/Opto/ Opto+Local/Opto+Remote/Opto+Rem+Local*
0702	Close Pulse Time	
0703	Trip Pulse Time	
0704	UNUSED	
0705	Man Close Delay	
0706	CB Healthy Time	
0707	Check Sync Time	
0708	Lockout Reset	No/Yes*
0709	Reset Lockout by	User Interface/CB Close*
070A	Man Close RstDly	
070B	A/R Telecontrol	No Operation/Auto/Non-auto*
070C	Single Pole A/R	Disabled/Enabled*
070D	Double Pole A/R	Disabled/Enabled*
070E	A/R Status	Auto Mode/Non-auto Mode/Live Line*
070F	Total Reclosures	
0710	Reset Total A/R	
0711	CB Status Input	

11.12 0800 - DATE AND TIME

0801	IEC870 Time and Date	
0804	IRIG-B Sync	Disabled/Enabled*
0805	IRIG-B Status	Inactive/Active*
0806	Battery Status	Dead/Healthy*
0807	Battery Alarm	Disabled/Enabled*

11.13 0900 - CONFIGURATION

0901	Restore Defaults	
0902	Setting Group	Select via Menu/Select via Optos*
0903	Active Settings	Group 1/Group 2/Group 3/Group 4*
0904	Save Changes	
0905	Copy From	
0906	Copy To	
0907	Setting Group 1	Disabled/Enabled*
0908	Setting Group 2	Disabled/Enabled*
0909	Setting Group 3	Disabled/Enabled*

090A	Setting Group 4	Disabled/Enabled*
090B	Phase Diff	Disabled/Enabled*
090F	Opto Cntl	
0910	Overcurrent	Disabled/Enabled*
0912	Broken Conductor	Disabled/Enabled*
0913	Earth Fault	Disabled/Enabled*
0917	Thermal Overload	Disabled/Enabled*
0920	CB Fail	Disabled/Enabled*
0924	Auto-Reclose	Disabled/Enabled*
0925	Input Labels	Invisible/Visible*
0926	Output Labels	Invisible/Visible*
0928	CT & VT Ratios	Invisible/Visible*
0929	Record Control	Invisible/Visible*
092A	Disturb Recorder	Invisible/Visible*
092B	Measure't Setup	Invisible/Visible*
092C	Comms Settings	Invisible/Visible*
092D	Commission Tests	Invisible/Visible*
092E	Setting Values	Primary/Secondary*
092F	Control Inputs	
0935	Ctrl I/P Config	Invisible/Visible*
0936	Ctrl I/P Labels	Invisible/Visible*
0939	Direct Access	Disabled/Enabled*
09FF	LCD Contrast	

11.14 0A00 - CT AND VT RATIOS

0A07	Phase CT Primary	
0A08	Phase CT Secondary	
0A09	E/F CT Primary	
0A0A	E/F CT Secondary	

11.15 0B00 - RECORD CONTROL

0B01	Clear Events	
0B02	Clear Faults	
0B03	Clear Maint	
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*
0B0B	DDB 31- 0	

0B0C	DDB 63 - 32	
0B0D	DDB 95 - 64	
0B0E	DDB 127 - 96	
0B0F	DDB 159 - 128	
0B10	DDB 191 - 160	
0B11	DDB 223 - 192	
0B12	DDB 255 - 224	
0B13	DDB 287 - 256	
0B14	DDB 319 - 288	
0B15	DDB 351- 320	
0B16	DDB 383 - 352	
0B17	DDB 415 - 384	
0B18	DDB 447 - 416	
0B19	DDB 479 - 448	
0B1A	DDB 511 - 480	
0B1B	DDB 543 - 512	
0B1C	DDB 575 - 544	
0B1D	DDB 607 - 576	
0B1E	DDB 639 - 608	
0B1F	DDB 671 - 640	
OB20	DDB 703 - 672	
OB21	DDB 735- 704	
OB22	DDB 767 - 736	
OB23	DDB 799 - 768	
OB24	DDB 831 - 800	
OB25	DDB 863 - 832	
OB26	DDB 895 - 864	
OB27	DDB 927 - 896	
OB28	DDB 959 - 928	
OB29	DDB 991 - 960	
OB2A	DDB 1022 - 929	
OB30	Clear Dist Recs	

11.16 0C00 - DISTURB RECORDER

0C01	Duration	
0C02	Trigger Position	
0C03	Trigger Mode	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/Trigger L-H/Trigger H-L*
0C0E	Digital Input 2	
0C0F	Input 2 Trigger	No Trigger/Trigger L-H/Trigger H-L*
0C10	Digital Input 3	
0C11	Input 3 Trigger	No Trigger/Trigger L-H/Trigger H-L*
0C12	Digital Input 4	
0C13	Input 4 Trigger	No Trigger/Trigger L-H/Trigger H-L*
0C14	Digital Input 5	
0C15	Input 5 Trigger	No Trigger/Trigger L-H/Trigger H-L*
0C16	Digital Input 6	
0C17	Input 6 Trigger	No Trigger/Trigger L-H/Trigger H-L*
0C18	Digital Input 7	
0C19	Input 7 Trigger	No Trigger/Trigger L-H/Trigger H-L*
0C1A	Digital Input 8	
0C1B	Input 8 Trigger	No Trigger/Trigger L-H/Trigger H-L*
0C1C	Digital Input 9	
0C1D	Input 9 Trigger	No Trigger/Trigger L-H/Trigger H-L*
0C1E	Digital Input 10	
0C1F	Input 10 Trigger	No Trigger/Trigger L-H/Trigger H-L*
0C20	Digital Input 11	
0C21	Input 11 Trigger	No Trigger/Trigger L-H/Trigger H-L*
0C22	Digital Input 12	
0C23	Input 12 Trigger	No Trigger/Trigger L-H/Trigger H-L*
0C24	Digital Input 13	
0C25	Input 13 Trigger	No Trigger/Trigger L-H/Trigger H-L*
0C26	Digital Input 14	
0C27	Input 14 Trigger	No Trigger/Trigger L-H/Trigger H-L*
0C28	Digital Input 15	
0C29	Input 15 Trigger	No Trigger/Trigger L-H/Trigger H-L*
0C2A	Digital Input 16	
0C2B	Input 16 Trigger	No Trigger/Trigger L-H/Trigger H-L*
0C2C	Digital Input 17	
0C2D	Input 17 Trigger	No Trigger/Trigger L-H/Trigger H-L*
0C2E	Digital Input 18	
0C2F	Input 18 Trigger	No Trigger/Trigger L-H/Trigger H-L*
0C30	Digital Input 19	
0C31	Input 19 Trigger	No Trigger/Trigger L-H/Trigger H-L*
0C32	Digital Input 20	
0C33	Input 20 Trigger	No Trigger/Trigger L-H/Trigger H-L*
0C34	Digital Input 21	
0C35	Input 21 Trigger	No Trigger/Trigger L-H/Trigger H-L*
0C36	Digital Input 22	
0C37	Input 22 Trigger	No Trigger/Trigger L-H/Trigger H-L*

0C38	Digital Input 23	
0C39	Input 23 Trigger	No Trigger/Trigger L-H/Trigger H-L*
0C3A	Digital Input 24	
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*

11.17 0D00 - MEASURE'T SETUP

0D01	Default Display	3Ph+N Current/3Ph Voltage/Power/ Date and 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*
0D06	Fix Dem Period	
0D07	Roll Sub Period	
0D08	Num Sub Periods	
0D09	Distance Unit	Kilometres/Miles*
0D0A	Fault Location	Distance/Ohms/% of Line*
0D0B	Remote 2 values	Primary/Secondary*

11.18 0E00 - COMMUNICATIONS

0E01	RP1 Protocol	Courier/IEC870-5-103/Modbus/DNP3.0/UCA2*
0E02	RP1 Address	
0E03	RP1 InactivTimer	
0E04	RP1 Baud Rate	9600/19200/38400*
0E04	RP1 Baud Rate	
0E05	RP1 Parity	Odd/Even/None*
0E06	RP1 Meas Period*	

0E07	Physical Link	EIA(RS)485/Fibre Optic*
0E08	RP1 Time Sync	
0E09	Modbus IEC Time	Standard/Reverse/na*
0E0A	RP1 CS103 Blocking	Disabled/monitor blocking/Command blocking*
0E0C	RP1 Port Config	K Bus/ EIA485
0E0D	RP1 Comms Mode	IEC60860 FT1.2/10 bit no parity
0E0E	RP1 Baud Rate	9600/19200/38400 bits/s
0E80	REAR PORT2 (RP2)	
0E81	RP2 Protocol	
0E84	RP2 Card Status	
0E88	RP2 Port Config	EIA232/EIA485/K Bus*
0E8A	RP2 Comms Mode	IEC60870 FT1.2/10 bit no parity*
0E90	RP2 Address	
0E92	RP2 InactivTimer	
0E94	RP2 Baud Rate	9600/19200/38400 bits/s*

11.19 0F00 - COMMISSION TESTS

0F01	Opto I/P Status	
0F02	Relay O/P Status	
0F03	Test Port Status	
0F04	LED Status	
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/Blocked*
0F0E	Test Pattern	
0F0F	Contact Test	
0F10	Test LEDs	
0F11	Test Autoreclose	P542 only
0F12	Test Loopback	Disabled/Internal/External*
0F20	DDB 31 - 0	Binary Flag (32)
0F21	DDB 63 - 32	Binary Flag (32)
0F22	DDB 95 - 64	Binary Flag (32)
0F23	DDB 127 - 96	Binary Flag (32)
0F24	DDB 159 - 128	Binary Flag (32)
0F25	DDB 191 - 160	Binary Flag (32)
0F26	DDB 223 - 192	Binary Flag (32)
0F27	DDB 255 - 224	Binary Flag (32)
0F28	DDB 287 - 256	Binary Flag (32)

0F29	DDB 319 - 288	Binary Flag (32)
0F2A	DDB 351 - 320	Binary Flag (32)
0F2B	DDB 383 - 352	Binary Flag (32)
0F2C	DDB 415 - 384	Binary Flag (32)
0F2D	DDB 447 - 416	Binary Flag (32)
0F2E	DDB 479 - 448	Binary Flag (32)
0F2F	DDB 511 - 480	Binary Flag (32)
0F30	DDB 543 - 512	Binary Flag (32)
0F31	DDB 575 - 544	Binary Flag (32)
0F32	DDB 607 - 576	Binary Flag (32)
0F33	DDB 639 - 608	Binary Flag (32)
0F34	DDB 671 - 640	Binary Flag (32)
0F35	DDB 703 - 672	Binary Flag (32)
0F36	DDB 735 - 704	Binary Flag (32)
0F37	DDB 767 - 736	Binary Flag (32)
0F38	DDB 799 - 768	Binary Flag (32)
0F39	DDB 831 - 800	Binary Flag (32)
0F3A	DDB 863 - 832	Binary Flag (32)
0F3B	DDB 895 - 864	Binary Flag (32)
0F3C	DDB 927 - 896	Binary Flag (32)
0F3D	DDB 959 - 928	Binary Flag (32)
0F3E	DDB 991 - 960	Binary Flag (32)
0F3F	DDB 1022 - 992	Binary Flag (32)

11.20 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	

11.21 1100 - OPTO CONFIG

1101	Global Nominal V	
1101	Opto Input 1	
1102	Opto Input 2	
1103	Opto Input 3	
1104	Opto Input 4	
1105	Opto Input 5	
1106	Opto Input 6	
1107	Opto Input 7	
1108	Opto Input 8	
1109	Opto Input 9	
110A	Opto Input 10	
110B	Opto Input 11	
110C	Opto Input 12	
110D	Opto Input 13	
110E	Opto Input 14	
110F	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	
1180	Characteristic	Standard 60%-80%/50%-70%*

11.22 1200 - Control Inputs

1201	Ctrl I/P Status	

11.23 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	
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*
133D	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	
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	

11.24 2000 - I DIFF CONFIG

2001	Scheme Setup	3 Terminal/2 Terminal/Dual Redundant*
2002	Address	
2003	Address	
2004	Baud Rate	64kbits/s or 56kbits/s*
2005	Clock Source Ch1	Internal/External*
2006	Clock Source Ch2	Internal/External*
2007	Comm Delay Tol	
2008	Comm Fail Timer	
2009	Comm Fail Mode	Channel 1/Channel 2/Channel 1+2*
200A	Char Mod Time	
200B	I Cap Correction	Disabled/Enabled*
200C	Susceptance	
200D	Inrush Restraint	Disabled/Enabled*
200E	Vectorial Comp	Yy0 (0 deg)/Yd1 (-30 deg)/Yy2 (-60 deg)/ Yd3 (-90 deg)/ Yy4 (-120 deg)/Yd5 (-150 deg)/ Yy6 (180 deg)/ Yd7 (+150 deg)/ Yy8(+120 deg)/Yd9 (+90 deg)/Yy10 (+60 deg)/ Yd11 (+30 deg)/Ydy0 (0 deg)/Ydy6 (180 deg)*
200F	Ph CT Corr'tion	
2011	Re-Configuration	Three Ended/Two Ended (L&R1)/
2013	GPS Sync	Disabled/Enabled*
2014	Ch 2 Baud Rate	
2020	Comms Mode	Standard/IEEE C37.94*
2021	Ch1 N*64kbits/s	Auto/1/2/3/4/5/6/7/8/9/10/11/12*
2022	Ch2 N*64kbits/s	Auto/1/2/3/4/5/6/7/8/9/10/11/12*

11.25 2900 - CTRL 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 Input 11	
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	

11.26 GROUP PROTECTION SETTINGS

11.26.1 3100 - PHASE DIFF

Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
3101/ 3105	Phase Is1				
3102/ 3106	Phase Is2				
3103/ 3107	Phase k1				
3104/ 3108	Phase k2				
310A	Phase Time Delay				
310B	Phase TMS				
310C	Phase Time Dial				
310D	PIT Time				

Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
310E	ID High Set				

11.26.2 3500 - OVERCURRENT

Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
3501	I>1 Status				
3502	I>1 Function				
3503	UNUSED				
3504	I>1 Current Set				
3505	I>1 Time Delay				
3506	I>1 TMS				
3507	I>1 Time Dial				
3508	I>1 Reset Char				
3509	I>1 tRESET				
350A	I>2 Status				
350B	I>2 Function				
350C	UNUSED				
350D	I>2 Current Set				
350E	I>2 Time Delay				
350F	I>2 TMS				
3510	I>2 Time Dial				
3511	I>2 Reset Char				
3512	I>2 tRESET				
3513	I>3 Status				
3514	UNUSED				
3515	I>3 Current Set				
3516	I>3 Time Delay				
3517	I>3 Intertrip				
3518	I>4 Status				
3519	UNUSED				
351A	I>4 Current Set				
351B	I>4 Time Delay				
351C	I> Char Angle				
351D	I> Blocking				
351E to 3521	UNUSED				

11.26.3 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				

Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
3703	I2/I1 Time Delay				

11.26.4 3800 - EARTH FAULT

Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
3801	IN> Status				
3802	IN>1 Function				
3803	UNUSED				
3804	IN>1 Current Set				
3805	IN>1 Time Delay				
3806	IN>1 TMS				
3807	IN>1 Time Dial				
3808	IN>1 Reset Char				
3809	IN>1 tRESET				
380A	IN>2 Status				
380B	IN>2 Function				
380C	UNUSED				
380D	IN>2 Current Set				
380E	IN>2 Time Delay				
380F	IN>2 TMS				
3810	IN>2 Time Dial				
3811	IN>2 Reset Char				
3812	IN>2 tRESET				
3813	IN>3 Status				
3814	UNUSED				
3815	IN>3 Current Set				
3816	IN>3 Time Delay				
3817	IN>4 Status				
3818	UNUSED				
3819	IN>4 Current Set				
381A	IN>4 Time Delay				
381B	IN> Blocking				
381C to 3822	UNUSED				

11.26.5 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				

Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
3C05	Time Constant 2				

11.26.6 4500 - CB FAIL & I<

Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
4501	BREAKER FAIL				
4502	CB Fail 1 Status				
4503	CB Fail 1 Timer				
4504	CB Fail 2 Status				
4505	CB Fail 2 Timer				
4506	UNUSED				
4507	Ext Prot Reset				
4508	UNDER CURRENT				
4509	I< Current Set				
450A	UNUSED				
450B	ISEF< Current				
450C	BLOCKED O/C				
450D	Remove I> Start				
450E	Remove IN> Start				

11.26.7 4900 - AUTORECLOSE

Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
4901	UNUSED				
4902	Number of Shots				
4903 to 4907	UNUSED				
4908	Dead Time 1				
4909	Dead Time 2				
490A	Dead Time 3				
490B	Dead Time 4				
490C	490C Healthy Time				
490E	tReclaim Extend				
490F	Reclaim Time				
4910	4910 AR Inhibit Time				
4911 to 4912	UNUSED				
4913	Eff Maint Lock				
4914 to 4915	UNUSED				
4916	Trip 1 Main				
4917	Trip 2 Main				
4918	Trip 3 Main				

Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
4919	Trip 4 Main				
491A	Trip 5 Main				
491B to 4927	UNUSED				
4928	Phase Diff AR				
4929 to 492C	UNUSED				
492D	I1> AR				
492E	I2> AR				
492F	I3> AR				
4930	I4> AR				
4931	IN1> AR				
4932	IN2> AR				
4933	IN3> AR				
4934	IN4> AR				
4935 to 4946	UNUSED				

11.26.8 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				
4A0F	Opto Input 15				
4A10	Opto Input 16				
4A11 to 4A18	UNUSED				

11.26.9 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 to 4B20	UNUSED				

11.27 B700 - PSL Data

B700		
B701	Grp1 PSL Ref	ASCII Text (32 chars)
B702	Date/Time	IEC870 Date & Time
B703	Grp1 PSL ID	Unsigned Integer (32 bits)
B711	Grp2 PSL Ref	ASCII Text (32 chars)
B712	Date/Time	IEC870 Date & Time
B713	Grp2 PSL ID	Unsigned Integer (32 bits)
B721	Grp3 PSL Ref	ASCII Text (32 chars)
B722	Date/Time	IEC870 Date & Time
B723	Grp3 PSL ID	Unsigned Integer (32 bits)
B731	Grp4 PSL Ref	ASCII Text (32 chars)
B732	Date/Time	IEC870 Date & Time
33	Grp4 PSL ID	Unsigned Integer (32 bits)

11.28 BF00 - COMMS SYS DATA

BF01	Dist Record Cntrl Ref	Menu Cell(2)
BF02	Dist Record Extract Ref	Menu Cell(2)
BF03	Setting Transfer	Unsigned Integer
BF04	Reset Demand	None (Reset Menu Cell)
BF05	UNUSED	

BF06	Block Xfer Ref	Menu Cell(2)

Commissioning Engineer

Customer Witness

Date

Date

MAINTENANCE

CHAPTER 11

Date:	June 2011	
Products covered by this chapter:	P14x (P141, P142, P143, P144 & P145), P445, P44y (P443 and P446), P547, P54x (P543, P544, P545 & P546), P841, P842 and P846	
Hardware suffix:	P14x (P141, P142, P143, P144 & P145) P445 P44y (P443 and P446) P547 P54x (P543, P544, P545 & P546) P841 P842 P846	J J K K K K B J
Software version:	P14x (P141, P142, P143, P144 & P145) P445 P44y (P443 and P446) P547 P54x (P543, P544, P545 & P546) P841 P842 P846	43 35 & 36 0550 57 45 & 55 45 & 55 04 30
Connection diagrams:	P14x (P141, P142, P143, P144 & P145): 10P141/2/3/4/5xx (xx = 01 to 07) P445: 10P445xx (xx = 01 to 04) P44y: 10P44303 (SH 01 and 03) 10P44304 (SH 01 and 03) 10P44305 (SH 01 and 03) 10P44306 (SH 01 and 03) 10P44600 10P44601 (SH 1 to 2) 10P44602 (SH 1 to 2) 10P44603 (SH 1 to 2) P547: 10P54702xx (xx = 01 to 02) 10P54703xx (xx = 01 to 02) 10P54704xx (xx = 01 to 02) 10P54705xx (xx = 01 to 02)	P54x (P543, P544, P545 & P546): 10P54302xx (xx = 01 to 02) 10P54303xx (xx = 01 to 02) 10P54400 10P54402xx (xx = 01 to 02) 10P54403xx (xx = 01 to 02) 10P54502xx (xx = 01 to 02) 10P54503xx (xx = 01 to 02) 10P54600 10P54602xx (xx = 01 to 02) 10P54603xx (xx = 01 to 02) P841: 10P84100 10P84101 (SH 1 to 2) 10P84102 (SH 1 to 2) 10P84103 (SH 1 to 2) 10P84104 (SH 1 to 2) 10P84105 (SH 1 to 2) P842: 10P842xx (xx = 01 to 02) P846: 10P846xx (xx = 01 to 07)

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Notes:

1 MAINTENANCE PERIOD

It is recommended that products supplied by Schneider Electric receive periodic monitoring after installation. In view of the critical nature of protective and control equipment, and their infrequent operation, it is desirable to confirm that they are operating correctly at regular intervals.

Schneider Electric protection and control equipment is designed for a life in excess of 20 years.

MiCOM relays are self-supervizing and so require less maintenance than earlier designs. 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 equipment is functioning correctly and the external wiring is intact.

If the customer's organization has a preventative maintenance policy, the recommended product checks should be included in the regular program. Maintenance periods depend on many factors, such as:

- The operating environment
- The accessibility of the site
- The amount of available manpower
- The importance of the installation in the power system
- The consequences of failure

2 MAINTENANCE CHECKS

Although some functionality checks can be performed from a remote location by using the communications ability of the equipment, these are predominantly restricted to checking that the equipment, 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 equipment itself).

Warning **Before carrying out any work on the equipment, the user should be familiar with the contents of the Safety Guide or the Technical Data chapter of this Technical Manual and also the ratings on the equipment's rating label.**

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.

2.2 Opto-Isolators

The opto-isolated inputs can be checked to ensure that the equipment responds to energization by repeating the commissioning test detailed in the Commissioning chapter (*MiCOM/EN CM*).

2.3 Output Relays

The output relays can be checked to ensure that they operate by repeating the commissioning test detailed in the Commissioning chapter (*MiCOM/EN CM*)

2.4 Measurement Accuracy

If the power system is energized, the values measured by the equipment can be compared with known system values to check that they are in the approximate range that is expected. If they are, the analog/digital conversion and calculations are being performed correctly by the relay. Suitable test methods can be found in the Commissioning chapter (*MiCOM/EN CM*).

Alternatively, the values measured by the equipment can be checked against known values injected via the test block, if fitted, or injected directly into the equipment terminals. Suitable test methods can be found in the Commissioning chapter (*MiCOM/EN CM*). These tests will prove the calibration accuracy is being maintained.

3 METHOD OF REPAIR

If the equipment 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 Printed Circuit Boards (PCBs) should be replaced, as it is not possible to perform repairs on damaged PCBs. Therefore either the complete equipment module or just the faulty PCB (as identified by the in-built diagnostic software), can be replaced. Advice about identifying the faulty PCB can be found in the Troubleshooting chapter (*MiCOM/EN TS*).

The preferred method is to replace the complete equipment module 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 installed equipment due to limited access in the back of the cubicle and the 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. If the repair is not performed by an approved service center, the warranty will be invalidated.

Warning **Before carrying out any work on the equipment, the user should be familiar with the contents of the Safety Guide or the Technical Data chapter of this Technical Manual and also the ratings on the equipment's rating label.**

This should ensure that no damage is caused by incorrect handling of the electronic components.

3.1 Replacing the Complete Equipment IED/Relay

The case and rear terminal blocks have been designed to facilitate removal of the IED/relay should replacement or repair become necessary without having to disconnect the scheme wiring.

Warning	**Before working at the rear of the equipment, isolate all voltage and current supplies to the equipment.**

Note	*The MiCOM range has integral current transformer shorting switches which will close when the heavy duty terminal block is removed.*

1. Disconnect the equipment's earth, IRIG-B and fiber optic connections, as appropriate, from the rear of the device.

   There are two types of terminal block used on the equipment, medium and heavy duty, which are fastened to the rear panel using crosshead screws. These are shown in the Commissioning chapter (*MiCOM/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.*

2. Without exerting excessive force or damaging the scheme wiring, pull the terminal blocks away from their internal connectors.
3. Remove the screws used to fasten the equipment 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.

Warning	**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 equipment.**

4. Withdraw the equipment carefully from the panel, rack, etc. because it will be heavy due to the internal transformers.

To reinstall the repaired or replacement equipment, 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 equipment should be re-commissioned using the instructions in the Commissioning chapter (*MiCOM/EN CM*).

3.2 Replacing a PCB

Replacing PCBs and other internal components must be undertaken only by Service Centers approved by Schneider Electric. Failure to obtain the authorization of Schneider Electric after sales engineers prior to commencing work may invalidate the product warranty.

Warning	**Before removing the front panel to replace a PCB, remove the auxiliary supply and wait 5s for the capacitors to discharge.** **We strongly recommend that the voltage and current transformer connections and trip circuit are isolated.**

Schneider Electric support teams are available world-wide. We strongly recommend that any repairs be entrusted to those trained personnel. For this reason, details on product disassembly and re-assembly are not included here.

4 RE-CALIBRATION

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.

Warning	**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.**

5 CHANGING THE BATTERY

Each relay/IED 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/IED'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.

Warning	**Before carrying out any work on the equipment, the user should be familiar with the contents of the Safety Guide or the Technical Data chapter of this Technical Manual and also the ratings on the equipment's rating label.**

5.1 Instructions for Replacing the Battery

1. Open the bottom access cover on the front of the equipment.
2. Gently extract the battery from its socket. If necessary, use a small, insulated screwdriver to prize the battery free.
3. Ensure that the metal terminals in the battery socket are free from corrosion, grease and dust.
4. 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 3.6 V and safety approvals such as UL (Underwriters Laboratory), CSA (Canadian Standards Association) or VDE (Vereinigung Deutscher Elektrizitätswerke).*

5. 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.
6. Close the bottom access cover.

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'.

If further confirmation that the replacement battery is installed correctly is required, the commissioning test is described in the Commissioning chapter (*MiCOM/EN CM*), 'Date and Time', can be performed.

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 equipment is installed.

6 CLEANING

Warning	**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

CHAPTER 12

Date:	November 2011	
Hardware Suffix:	P14x (P141, P142, P143, P144 & P145) P24x (P241, P242 & P243) P341 P34x (P342, P343, P344, P345 & P346) P391 P445 P44y (P443 and P446) P547 P54x (P543, P544, P545 & P546) P64x (P642, P643 & P645): P841 P842 P846	J J (P241) & K (P242/P243) J J (P342) K (P343/P344/P345/P346) A (P391) A J K K K J (P642) & K (P643/645) K B J
Software Version:	P14x (P141, P142, P143, P144 & P145) P24x (P241, P242 & P243) P341 P34x (P342, P343, P344, P345 & P346) P391 P445 P44y (P443 and P446) P547 P54x (P543, P544, P545 & P546) P64x (P642, P643 & P645): P841 P842 P846	43 57 36 & 71 (with DLR) 36 36 35 & 36 0550 57 45 & 55 04 45 & 55 04 30
Connection Diagrams:	P14 (P141, P142, P143, P144 & P145): 10P141/2/3/4/5xx (xx = 01 to 07) P24x (P241, P242 & P243): 10P241xx (xx = 01 to 02) 10P24201 10P24301 P341: 10P341xx (xx = 01 to 12) P34x (P342, P343, P344, P345 & P346): 10P342xx (xx = 01 to 17) 10P343xx (xx = 01 to 19) 10P344xx (xx = 01 to 12) 10P345xx (xx = 01 to 07) 10P346xx (xx = 01 to 19) 10P391xx (xx = 01 to 02) P445: 10P445xx (xx = 01 to 04) P44y: 10P44303 (SH 01 and 03) 10P44304 (SH 01 and 03) 10P44305 (SH 01 and 03) 10P44306 (SH 01 and 03) 10P44600 10P44601 (SH 1 to 2) 10P44602 (SH 1 to 2) 10P44603 (SH 1 to 2)	P547: 10P54702xx (xx = 01 to 02) 10P54703xx (xx = 01 to 02) 10P54704xx (xx = 01 to 02) 10P54705xx (xx = 01 to 02) P54x: 10P54302 (SH 1 to 2) 10P54303 (SH 1 to 2) 10P54400 10P54404 (SH 1 to 2) 10P54405 (SH 1 to 2) 10P54502 (SH 1 to 2) 10P54503 (SH 1 to 2) 10P54600 10P54604 (SH 1 to 2) 10P54605 (SH 1 to 2) 10P54606 (SH 1 to 2) P64x: 10P642xx (xx = 01 to 10) 10P643xx (xx = 01 to 06) 10P645xx (xx = 01 to 09) P841: 10P841xx (xx = 01 to 02) 10P84100 10P841xx (xx = 01 to 03) P842: 10P842xx (xx = 01 to 02) P846: 10P846xx (xx = 01 to 07)

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Notes:

1 INTRODUCTION

Warning	**Before carrying out any work on the equipment, the user should be familiar with the contents of the Safety Guide or the Technical Data chapter of this Technical Manual and also the ratings on the equipment's rating label.**

The purpose of this chapter of the service manual is to allow an error condition on the relay to be identified so that appropriate corrective action can be taken.

If the relay has developed a fault, it should be possible in most cases to identify which relay module requires attention. The *Maintenance* chapter 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 chapter should be included.

2 INITIAL PROBLEM IDENTIFICATION

Consult Table 1 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. 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, 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, 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 Following text messages (in English) will be displayed if a fundamental problem is detected preventing the system from booting: Bus Fail address lines SRAM Fail data lines FLASH Fail format error FLASH Fail checksum Code Verify Fail These hex error codes relate to errors detected in specific relay modules: 0c140005/0c0d0000 0c140006/0c0e0000 Last 4 digits provide details on the actual error.	These messages indicate that a problem has been detected on the main processor board of the relay (located in the front panel). Input Module (inc. Opto-isolated inputs) Output Relay Cards Other error codes relate to problems within the main processor board hardware or software. It will be necessary to contact Schneider Electric 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.
5	Relay resets on completion of power up - record error code displayed	Error 0x0E080000, Programmable Scheme Logic (PSL) 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 PSL for feedback paths. Other error codes will relate to software errors on the main processor board, contact Schneider Electric.

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:	
		Bit	**Meaning**
		0	The application type field in the model number does not match the software ID
		1	The application field in the model number does not match the software ID
		2	The variant 1 field in the model number does not match the software ID
		3	The variant 2 field in the model number does not match the software ID
		4	The protocol field in the model number does not match the software ID
		5	The language field in the model number does not match the software ID
		6	The VT type field in the model number is incorrect (110V VTs fitted)
		7	The VT type field in the model number is incorrect (440V VTs fitted)
		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.

In the case of an RTD board failure, an alarm "RTD board fail" message is displayed, the RTD protection is disabled, but the operation of the rest of the relay functionality is unaffected.

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* *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, 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. If the protection element does operate, it will be necessary to check the PSL 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, 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 PSL. 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 PSL.

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 and the correct nominal voltage settings in any standard or custom menu settings. 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 is 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 that 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 steps to return an Automation product to us:

1. Get the Repair and Modification Authorization Form (RMA).

   A copy of the RMA form is shown at the end of this section.

2. Fill in the RMA form.

   Fill in only the white part of the form.

   Please ensure that all fields marked **(M)** are completed such as:

   Equipment model

   Model No. and Serial No.

   Description of failure or modification required (please be specific)

   Value for customs (in case the product requires export)

   Delivery and invoice addresses

   Contact details

3. 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 No

   Repair center address

   If required, an acceptance of the quote must be delivered before going to next stage.

4. 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.

Notes:

REPAIR/MODIFICATION RETURN AUTHORIZATION FORM

FIELDS IN GREY TO BE FILLED IN BY SCHNEIDER ELECTRIC PERSONNEL ONLY

Reference **RMA:** _____		Date:
Repair Center Address (for shipping)	**Service Type** ☐ Retrofit ☐ Warranty ☐ Paid service ☐ Under repair contract ☐ Wrong supply	LSC PO No.:
Schneider Electric - Local Contact Details Name: Telephone No.: Fax No.: 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 ☐	

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)** Part shipment accepted ☐ Yes ☐ No **OR** Full shipment required ☐ Yes ☐ No
Contact Name: Telephone No.: Fax No.: E-mail:	Contact Name: Telephone No.: Fax No.: 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 Schneider Electric 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

CHAPTER 13

Notes:

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Notes:

1 INTRODUCTION

This chapter describes the remote interfaces of the MiCOM relay in enough detail to allow integration within a substation communication network. As has been outlined in earlier chapters, the relay supports a choice of one of four protocols via the rear communication interface. This is in addition to the front serial interface and 2nd rear communications port, which supports the Courier protocol only.

The rear EIA485 (RS485) 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.

For each of the protocol options, the supported functions/commands will be listed together with the database definition. The operation of standard procedures such as extraction of event, fault and disturbance records, or setting changes, will also be described.

It should be noted that the descriptions contained within this chapter do not aim to fully detail the protocol itself. The relevant documentation for the protocol should be referred to for this information. This chapter serves to describe the specific implementation of the protocol in the relay.

1.1 Physical Connection

Two connection options are available for 1st rear communications port, either the rear EIA485 (RS485) port or an optional rear fibre optic port.

The Technical Data chater details the communication protocols that are supported on each interface.

1.2 Further Information

The following documentation should be referred to for a detailed description of the various protocols, command-sets and link descriptions.

R6509	K-Bus Interface Guide
R6510	IEC60870 Interface Guide
R6511	Courier Protocol
R6512	Courier User Guide

Modbus Serial Protocol Reference Guide - PI-MBUS-300 Rev. E

www.modbus.org

www.dnp.org

2 COURIER INTERFACE

2.1 Courier Protocol

Courier is a Schneider Electric communication protocol. The concept of the protocol is that a standard set of commands are used to access a database of settings and data within the relay. This allows a master to be able to communicate with different slave devices. The application-specific aspects are contained within the database rather than the commands used to interrogate it, i.e. the master does not need to be pre-configured.

The same protocol can be used via four physical links K-Bus, EIA485 (RS485), an optional fibre optic port (Version 30 software or later) and EIA232 (RS232).
K-Bus is based on EIA485 (RS485) voltage levels with HDLC FM0 encoded synchronous signalling and its own frame format. The K-Bus twisted pair connection is unpolarised, whereas the EIA485 and EIA232 interfaces are polarised.
The EIA232 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 EIA485 voltage levels it is a synchronous HDLC protocol using FM0 encoding. It is not possible to use a standard EIA232 to EIA485 converter to convert IEC60870-5 FT1.2 frames to K-Bus. Nor is it possible to connect K-Bus to an EIA485 computer port. A protocol converter, such as the KITZ101, should be employed for this purpose.

2.2 Front Courier Port

The front EIA232 (RS232) 9 pin port supports the Courier protocol for one to one communication. The EIA232 port is actually compliant to EIA574; the 9-pin version of EIA232, see www.tiaonline.org . 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:

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.

2.3 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.*

2.4 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.

The Relay Menu Database document 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)

2.5 Setting Changes

(See R6512, Courier User Guide - Chapter 9)

Courier provides two mechanisms for making setting changes, both of these are supported by the relay. Either method can be used for editing any of the settings within the relay database.

2.5.1 Method 1

This uses a combination of three commands to perform a settings change:

Enter Setting Mode	Checks that the cell is settable and returns the limits
Preload Setting	Places a new value to the cell, this value is echoed to ensure that setting corruption has not taken place, the validity of the setting is not checked by this action.
Execute Setting	Confirms the setting change, if the change is valid then a positive response will be returned, if the setting change fails then an error response will be returned.
Abort Setting	This command can be used to abandon the setting change.

This is the most secure method and is ideally suited to on-line editors as the setting limits are taken from the relay before the setting change is made. However this method can be slow if many settings are being changed as three commands are required for each change.

2.5.2 Method 2

The Set Value command can be used to directly change a setting, the response to this command will be either a positive confirm or an error code to indicate the nature of a failure. This command can be used to implement a setting more rapidly then the previous method, however the limits are not extracted from the relay. This method is most suitable for off-line setting editors such as MiCOM S1, or for the issuing of pre-configured (SCADA) control commands.

2.5.3 Relay Settings

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.

2.5.4 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.

2.6 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.

2.6.1 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.

2.6.2 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)

2.6.3 Event Format

The Send Event command results in the following fields being returned by the relay:

- Cell Reference
- Timestamp
- Cell Text
- Cell Value

The relay menu database document, 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.

2.6.4 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 250 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.

2.7 Disturbance Record Extraction

The disturbance records are stored in uncompressed format and can be extracted either manually or automatically 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.

2.8 Programmable Scheme Logic (PSL) 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 PSL 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 uses the rear EIA485 (RS485) port (or for software version 30 or later an optional rear fibre 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)

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.

Table 1 - Response codes

3.4 Register Mapping

The relay supports these 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 relay menu database document.

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. Alarm 30011 Relays 30723 Optos 30725 Protection events - Like the Relay and Opto addresses this will map onto the Modbus address of the appropriate DDB status register depending on which bit of the DDB the change occurred. These will range from 30727 to 30785. For Platform events, Fault events and Maintenance events the default is 0.
Event Index	30111	1	This register will contain the DDB ordinal for protection events or the bit number for alarm events. The direction of the change will be indicated by the most significant bit; 1 for 0 - 1change and 0 for 1 - 0 change.

Event Description	Modbus Address	Length	Comments
Additional Data Present	30112	1	0 means that there is no additional data 1 means fault record data can be read from 30113 to 30199 (number of registers depends on the product) 2 means maintenance record data can be read from 30036 to 30039

Table 2 - Event Description, Modbus Address, Length and Comments

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: b0 - Out of service b1 - Minor Self Test Failure b2 - Event b3 - Time Synchronization b4 - Disturbance b5 - Fault b6 - Trip b7 - Alarm b8 to b15 - Unused A ‘1’ on b4 indicates the presence of a disturbance.
3x00800	No of stored disturbances	Indicates the total number of disturbance records currently stored in the relay, both extracted and 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 ‘No of stored disturbances’ value to calculate a value for manually selecting records.

MODBUS Register	Name	Description
4x00250	Manual disturbance record selection register	This register is used to manually select disturbance records. The values written to this cell are an offset of the unique identifier value for the oldest record. The offset value, which ranges from 0 to the No of stored disturbances - 1, is added to the identifier of the oldest record to generate the identifier of the required record.
4x00400	Record selection command register.	This register is used during the extraction process and has a number of commands. These are: b0 - Select next event b1 - accept event b2 - Select next disturbance record b3 - Accept disturbance record b4 - Select next page of disturbance data b5 - Select data file
3x00930 - 3x00933	Record time stamp	These registers return the timestamp of the disturbance record.
3x00802	No of registers in data page.	This register informs the master station of the number of registers in the data page that are populated.
3x00803 - 3x00929	Data page registers	These 127 registers are used to transfer data from the relay to the master station. They are 16-bit unsigned integers.
3x00934	Disturbance record status register	The disturbance record status register is used during the extraction process to indicate to the master station when data is ready for extraction. See next table.
4x00251	Data file format selection	This is used to select the required data file format. This is reserved for future use.

Note *Register addresses are provided in reference code + address format. E.g. 4x00001 is reference code 4x, address 1 (which is specified as function code 03, address 0x0000 in the MODBUS specification).*

Table 3 - Interface registers

The Disturbance Record status register will report one of the following values:

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.

Table 4 - Disturbance Record status register

3.6.2 Extraction Procedure

The following procedure will be used to extract disturbances from the relay. The procedure is split into four sections:

- Selection of a disturbance - Either manually or automatically
- Extraction of the configuration file
- Extraction of the data file
- 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 1. The manual method of extraction does not allow for the acceptance of disturbance records.

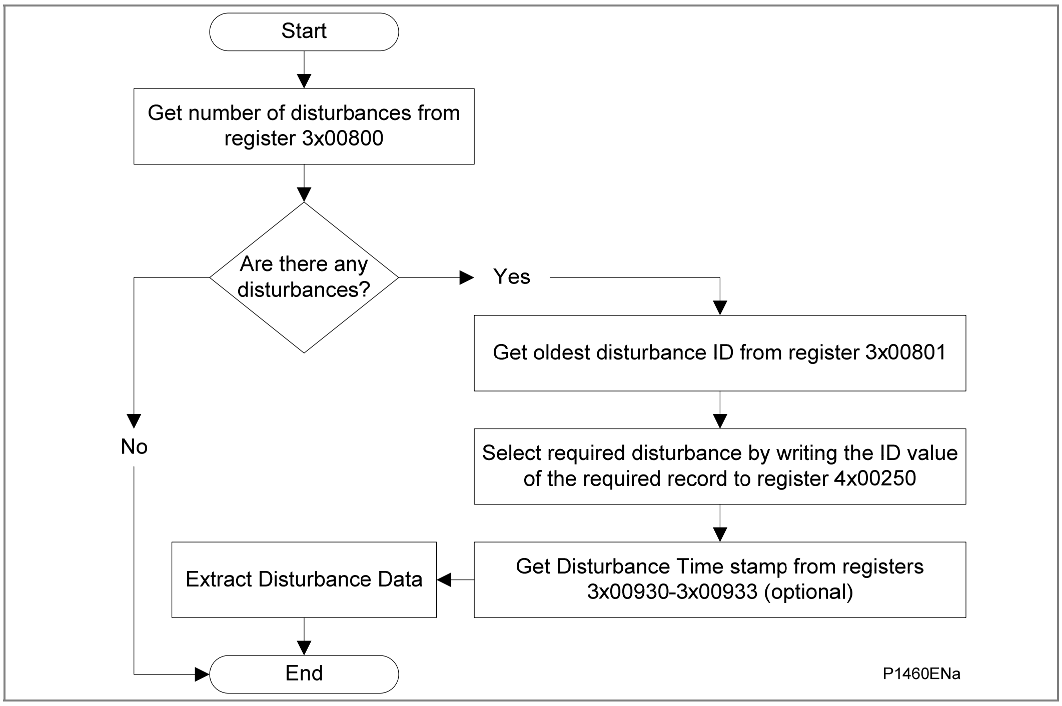

Figure 1 - Manual selection of a disturbance record

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 2. This also shows the acceptance of the disturbance record once the extraction is complete.

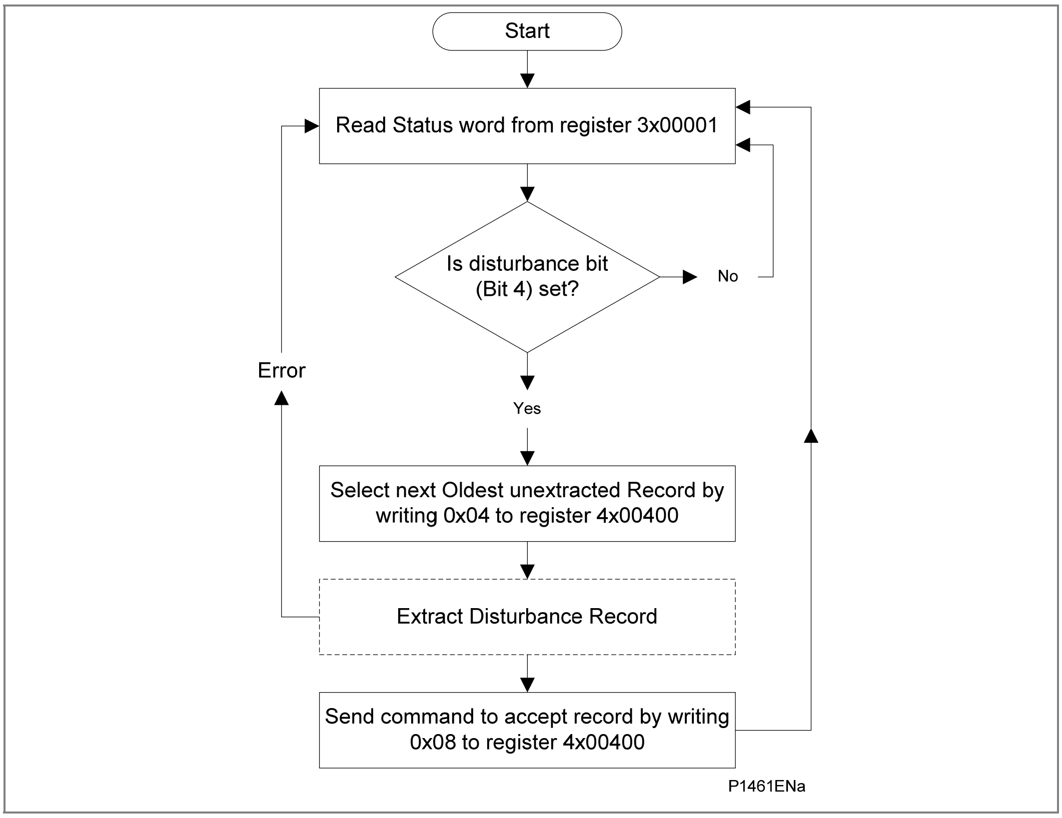

Figure 2 - Automatic selection of a disturbance - option 1

3.6.2.4 Automatic Extraction Procedure - Option 2

The second method that can be used for automatic extraction is shown in Figure 3. This also shows the acceptance of the disturbance record once the extraction is complete:

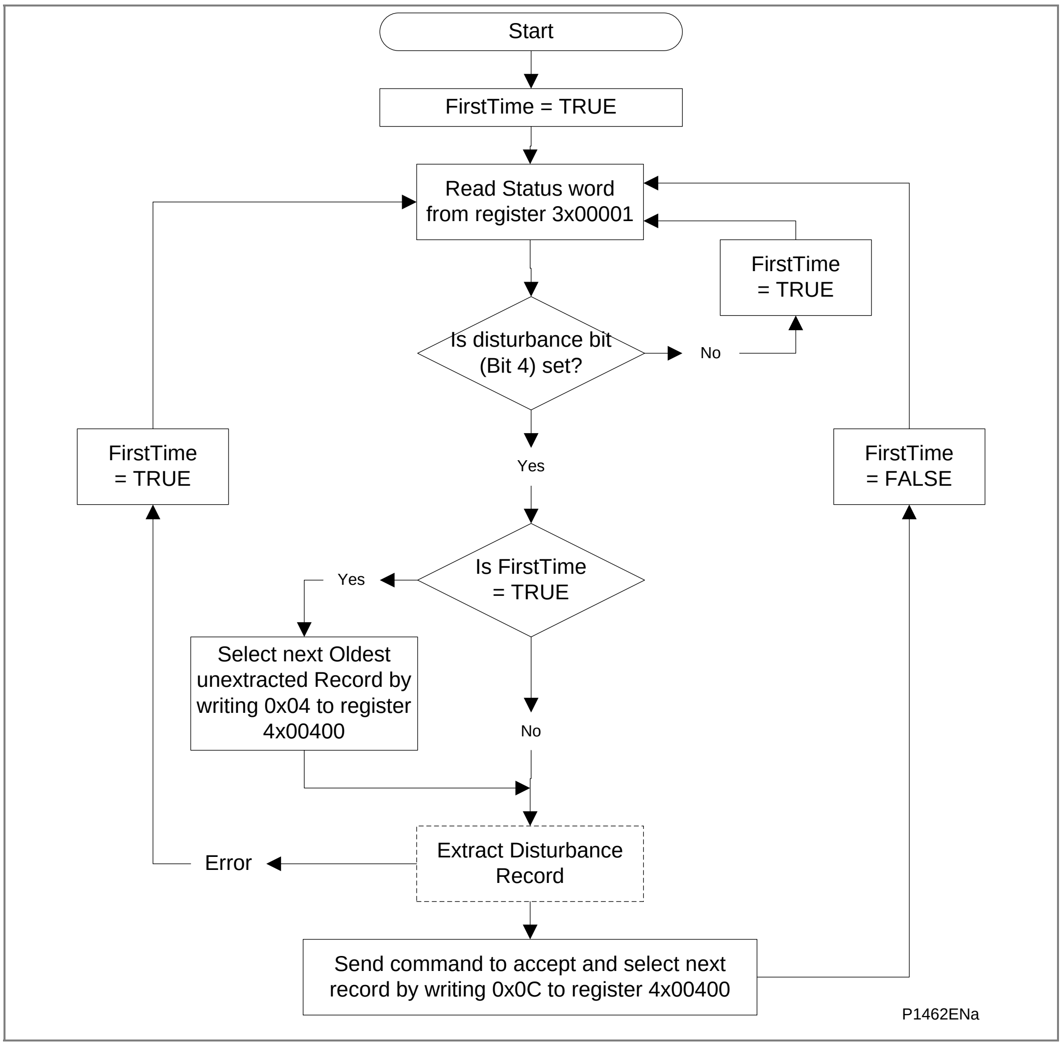

Figure 3 - Automatic selection of a disturbance - option 2

3.6.3 Extracting the Disturbance Data

The extraction of the disturbance record, as in Figure 1, Figure 2 and Figure 3, is a two-stage process that involves extracting the configuration file first and then the data file. Figure 4 shows how the configuration file is extracted from the relay:

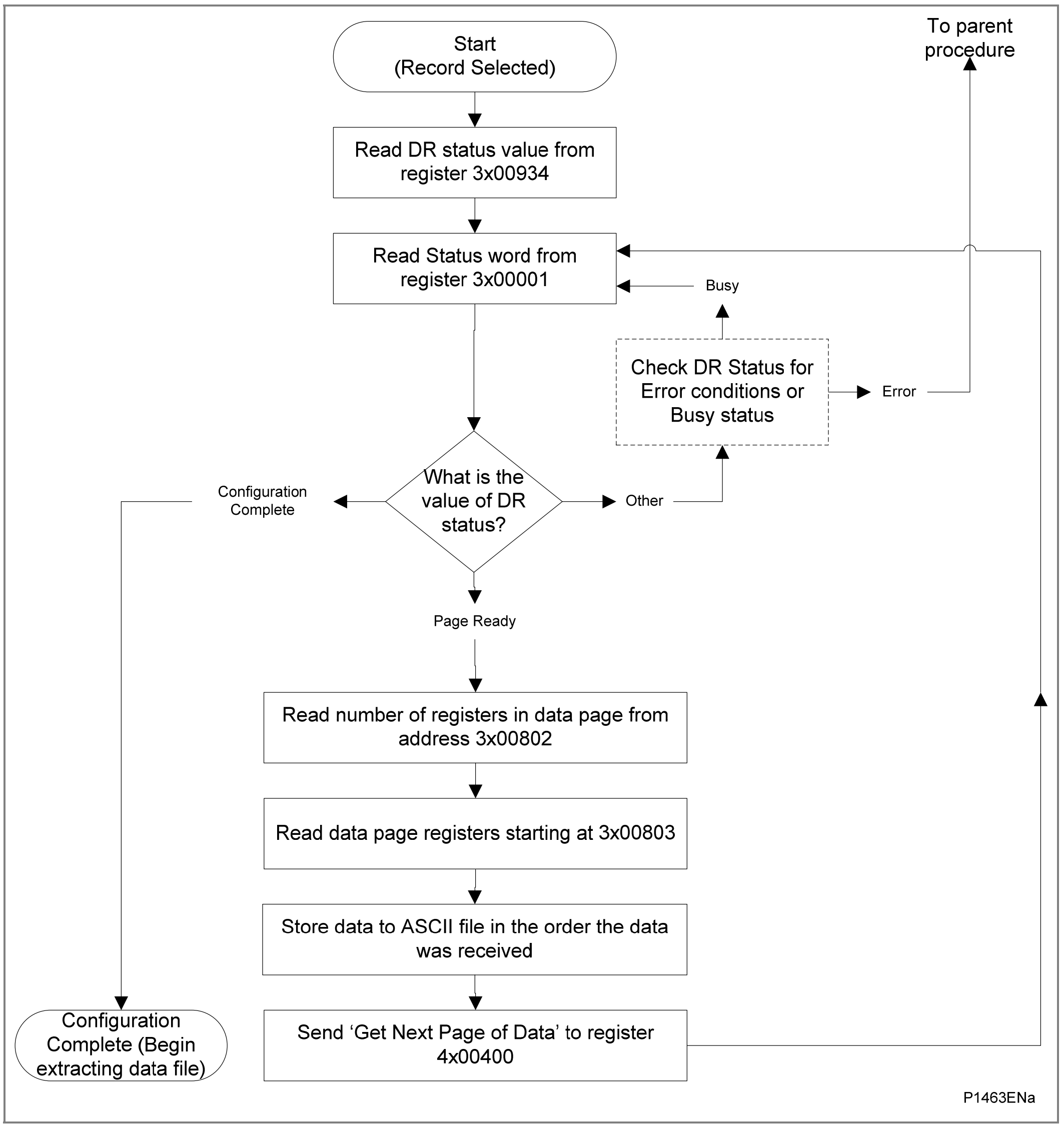

Figure 4 - Extracting the COMTRADE configuration file

Figure 5 shows how the data file is extracted:

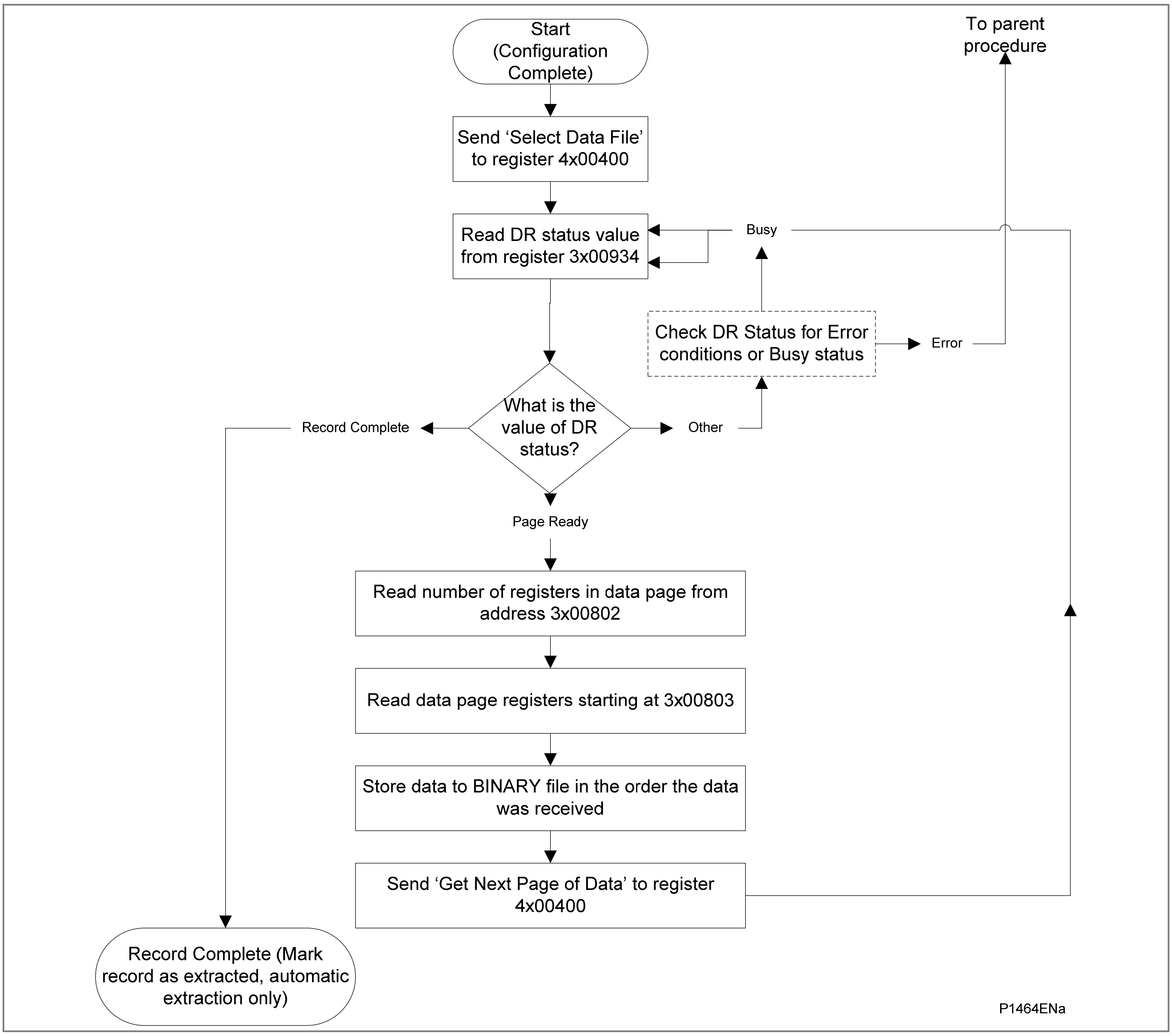

Figure 5 - Extracting the COMTRADE Binary Data File

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.

3.6.4 Manual Selection

Each disturbance record has a unique identifier which increments for each stored record and resets at a value of 65535. The following registers can be used to determine the identifiers for the stored records

- 30800 - The number of stored disturbance records
- 30801 - The identifier for the oldest stored record

A record can be selected by writing the required record identifier to register 40250. It is possible to read the timestamp of the selected record and in this way produce a chronological list of all the stored records.

3.6.5 Automatic Extraction

The Modbus master station can determine the presence of unread disturbance records by polling register 30001 (G26 data type). When the disturbance bit of this register is set, disturbance records are available for extraction. To select the next disturbance record, write a value of 4 to register 40400 (G18 data type). Once the disturbance record data has been read by the master station this record can be marked as having been read by writing a value of 8 to register 40400.

3.6.6 Record Data

The timestamp for a record selected using either of the above means can be read from registers 30390 to 30393.

The number of pages required to extract a record will depend on the configured size of the record.

When a record is first selected, the first page of data will be available in registers 30803 to 30929. (The number of registers required for the current page can be read from register 30802. It will have a value of 127 for all but the last page in the record). Once the first page has been read, the next page can be selected by writing a value of 5 to register 40400. If this action is performed after the last page for the disturbance record has been selected an illegal value error response will be returned. This error response can be used by the Modbus master to indicate that the last page of the disturbance record has been read.

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 menu database. 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 data-type is used for record time-stamps and for time-synchronisation

The structure of the data type is shown in Table 5 and is compliant with the IEC60870-5-4 "Binary Time 2a" format.

	Bit position							
Byte	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 5 - G12 Date & time data type structure.

The seven bytes of the structure are packed into four 16-bit registers. Two packing formats are provided: *standard* and *reverse*. The prevailing format is selected by register 4x306 or for software 30 onwards via the G238 setting in the "Date and Time" menu column.

The *standard* packing-format is the default and complies with the IEC60870-5-4 requirement 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.

The *reverse* packing-format is the exact byte transmission order reverse of the *standard* format. That is, the null (zero) byte is sent as the high-order byte of the first register and byte 7 as the register's low-order byte. The second register's high-order byte contains byte 6 and byte 5 in it's low order byte.

The principal application of the *reverse* format is for date-time packet-format consistency when a mixture of MiCOM Px20, Px30, and Px40 series products are being used. This is especially true when there is a requirement for broadcast time synchronisation with a mixture of such MiCOM products.

The data type provides only the year of century value; the century must be deduced. Simplistically the century could be imposed as 20 for applications not dealing with dates stored in this format from the previous (20th) century. Alternatively, the century can be 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.
3. 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. (Note that the value of the summertime bit does not affect the time displayed by the product.)

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 product. It is up to the end user to determine the time zone used by the product. Normal practice is to use UTC (Universal Co-ordinated Time), which avoids the complications with daylight saving time-stamp correlations.

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 relay menu database 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×110,000V/110 = 10,000,000. The overall value of the G29 register set is 64 × 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:

- Initialisation (Reset)
- Time Synchronisation
- 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 EIA485 (RS485) port or an optional rear fibre optic port. Should the fibre optic port be fitted the selection of the active port can be made via the front panel menu or the front Courier port.

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 Initialisation

Whenever the relay has been powered up, or if the communication parameters have been changed a reset command is required to initialise 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 relay menu database.

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 Synchronisation

The relay time and date can be set using the time synchronisation feature of the IEC60870-5-103 protocol. The relay will correct for the transmission delay as specified in IEC60870-5-103. If the time synchronisation message is sent as a send/confirm message then the relay will respond with a confirm. Whether the time-synchronisation message is sent as a send confirm or a broadcast (send/no reply) message, a time synchronisation Class 1 event will be generated/produced.

If the relay clock is being synchronised 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 synchronised internal clock.

4.4 Spontaneous Events

Events are categorised using the following information:

- Function Type
- Information number

The IEC60870-5-103 profile in the relay menu database 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 relay menu database.

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 analogue value.

4.7 Commands

A list of the supported commands is contained in the relay menu database. 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 INTERFACE

5.1 DNP3 Protocol

The DNP3 protocol is defined and administered by the DNP Users Group. Information about the user group, DNP3 in general and the protocol specifications can be found on their Internet site:

www.dnp.org

The descriptions given here are intended to accompany the device profile document which is included in the relay menu database, P54x/EN MD/H53. The DNP3 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 implementation for the relay. This is the standard format DNP3 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. The relay operates as a DNP3 slave and supports subset level 2 of the protocol, plus some of the features from level 3.

DNP3 communication uses the EIA485 (RS485) rear communication port or for software 30 onwards an optional fibre optic 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 Menu Setting

The settings shown below are available in the menu for DNP3 in the ‘Communications’ column.

Setting	Range	Description
Remote Address	0 - 65534	DNP3 address of relay (decimal)
Baud Rate	1200, 2400, 4800, 9600, 19200, 38400	Selectable baud rate for DNP3 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

Table 6 - DNP3 Menu Settings

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 point data. These can be used to cross-reference to the DDB definition list which is also found in the relay menu database. 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 which can be operated via DNP3. 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 relay menu database and execute the command once for either command. The other fields are ignored (queue, clear, trip/close, in time and off time).

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 Analogue Input

Object 30, analogue 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 analogue 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	*All object 30 points are reported as secondary values in DNP3 (with respect to CT and VT ratios).*

5.7 DNP3 Configuration Using MiCOM S1

A PC support package for DNP3 is available as part of the Settings and Records module of MiCOM S1. The S1 module allows configuration of the relay's DNP3 response. The PC is connected to the relay via a serial cable to the 9-pin front part of the relay - see chapter 1, Introduction. 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 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 data is displayed on a three tabbed screen, one screen each for object1, 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 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 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 analogue 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 SECOND REAR COMMUNICATIONS PORT (COURIER)

Relays with Courier, Modbus, IEC60870-5-103 or DNP3 protocol on the first rear communications port have the option of a second rear port, running the Courier language. The second port is designed typically for dial-up modem access by protection engineers/operators, when the main port is reserved for SCADA communication traffic. Communication is via one of three physical links: K-Bus, EIA485(RS485) or EIA232(RS232). The port supports full local or remote protection and control access by MiCOM S1 software.

When changing the port configuration between K-Bus, EIA485 & EIA232 it is necessary to reboot the relay to update the hardware configuration of the second rear port.

There is also provision for the EIA485 & EIA232 protocols to be configured to operate with a modem, using an IEC60870 10 bit frame.

Port Configuration	Valid communication protocol
K-Bus	K-Bus
EIA232	IEC60870 FT1.2, 11bit frame IEC60870,10 bit frame
EIA485	IEC60870 FT1.2, 11bit frame IEC60870, 10 bit frame

Table 7 - Port configurations and valid communication protocols

If both rear communications ports are connected to the same bus, care should be taken to ensure their address settings are not the same, to avoid message conflicts.

The second rear communications port is functionally the same as detailed in section 2 for a Courier rear communications port, with the following exceptions:

6.1 Event Extraction

Automatic event extraction is not supported when the first rear port protocol is Courier, Modbus or CS103. It is supported when the first rear port protocol is DNP3.

6.2 Disturbance Record Extraction

Automatic disturbance record extraction is not supported when the first rear port protocol is Courier, Modbus or CS103. It is supported when the first rear port protocol is DNP3.

6.3 Connection to the Second Rear Port

The second rear Courier port connects via the 9-way female D-type connector (SK4) in the middle of the card end plate (in between IRIG-B connector and lower D-type). The connection is compliant to EIA574.

For IEC60870-5-2 over EIA232 and for K-bus or IEC60870-5-2 over EIA485

Pin	For IEC60870-5-2 over EIA232	For K-bus or IEC60870-5-2 over EIA485
	Connection	**Connection ***
1	No Connection	
2	RxD	
3	TxD	
4	DTR #	EIA485 - 1 (+ ve)
5	Ground	
6	No Connection	
7	RTS #	EIA485 - 2 (- ve)
8	CTS #	
9	No Connection	

*Note *   All other pins unconnected.*

Note # - These pins are control lines for use with a modem

Notes   Connector pins 4 and 7 are used by both the EIA232and EIA485 physical layers, but for different purposes. Therefore, the cables should be removed during configuration switches.
For the EIA485 protocol an EIA485 to EIA232 converter will be required to connect a modem or PC running MiCOM S1, to the relay. A Schneider Electric CK222 is recommended.
EIA485 is polarity sensitive, with pin 4 positive (+) and pin 7 negative (-).
The K-Bus protocol can be connected to a PC via a KITZ101 or 102.

Table 8 - IEC60870-5-2 over EIA232 and K-bus or IEC60870-5-2 over EIA485

6.4 SK5 Port Connection

The lower 9-way D-type connector (SK5) is currently unsupported. Do not connect to this port.

Notes:

SYMBOLS AND GLOSSARY

CHAPTER SG

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Notes:

1 ACRONYMS AND ABBREVIATIONS

Term	Description
<	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)
A	Ampere
AA	Application Association
AC / ac	Alternating Current
ACSI	Abstract Communication Service Interface
ACSR	Aluminum Conductor Steel Reinforced
ALF	Accuracy Limit Factor
AM	Amplitude Modulation
ANSI	American National Standards Institute
AR	Auto-Reclose.
ARIP	Auto-Reclose In Progress
ASCII	American Standard Code for Information Interchange
ATEX	ATEX is the Potentially Explosive Atmospheres directive 94/9/EC
AUX / Aux	Auxiliary
AWG	American Wire Gauge
BAR	Block Auto-Reclose signal.
BCD	Binary Coded Decimal
BCR	Binary Counter Reading
BDEW	Bundesverband der Energie- und Wasserwirtschaft | Startseite (i.e. German Association of Energy and Water Industries)
BMP	BitMaP – a file format for a computer graphic
BOP	Blocking Overreach Protection - a blocking aided-channel scheme.
BPDU	Bridge Protocol Data Unit
BRCB	Buffered Report Control Block
BRP	Beacon Redundancy Protocol
BU	Backup: Typically a back-up protection element
C/O	A ChangeOver contact having normally-closed and normally-open connections: Often called a “form C” contact.
CB	Circuit Breaker
CB Aux.	Circuit Breaker auxiliary contacts: Indication of the breaker open/closed status.
CBF	Circuit Breaker Failure protection
CDC	Common Data Class
CF	Control Function
Ch	Channel: usually a communications or signaling channel
Check Synch	Check Synchronizing function
CLIO	Current Loop Input Output: 0-1 mA/0-10 mA/0-20 mA/4-20 mA transducer inputs and outputs CLI = current loop input - 0-1 mA/0-10 mA/0-20 mA/4-20 mA transducer input CLO = current loop output - 0-1 mA/0-10 mA/0-20 mA/4-20 mA transducer output
CIP	Critical Infrastructure Protection standards

Term	Description
CLK / Clk	Clock
Cls	Close - generally used in the context of close functions in circuit breaker control.
CMV	Complex Measured Value
CNV	Current No Volts
CPNI	Centre for the Protection of National Infrastructure
CRC	Cyclic Redundancy Check
CRP	Cross-network Redundancy Protocol
CRV	Curve (file format for curve information)
CRx	Channel Receive: Typically used to indicate a teleprotection signal received.
CS	Check Synchronism.
CSV	Comma Separated Values (a file format for database information)
CT	Current Transformer
CTRL	Control - as used for the Control Inputs function
CTS	Current Transformer Supervision: To detect CT input failure.
CTx	Channel Transmit: Typically used to indicate a teleprotection signal send.
CUL	Canadian Underwriters Laboratory
CVT	Capacitor-coupled Voltage Transformer - equivalent to terminology CCVT.
DAU	Data Acquisition Unit
DC	Data Concentrator
DC / dc	Direct Current
DCC	An Omicron compatible format
DCE	Data Communication Equipment
DDB	Digital Data Bus within the programmable scheme logic: A logic point that has a zero or 1 status. DDB signals are mapped in logic to customize the relay's operation.
DDR	Dynamic Disturbance Recorder
DEF	Directional Earth Fault protection: A directionalized ground fault aided scheme.
df/dt	Rate of Change of Frequency
df/dt>1	First stage of df/dt protection
DFT	Discrete Fourier Transform
DG	Distributed Generation
DHCP	Dynamic Host Configuration Protocol
DHM	Dual Homing Manager
DHP	Dual Homing Protocol
Diff	Differential protection.
DIN	Deutsches Institut für Normung (German standards body)
Dist	Distance protection.
DITA	Darwinian Information Typing Architecture
DLDB	Dead-Line Dead-Bus : In system synchronism check, indication that both the line and bus are de-energised.
DLLB	Dead-Line Live-Bus : In system synchronism check, indication that the line is de-energised whilst the bus is energised.
DLR	Dynamic Line Rating
DLY / Dly	Time Delay
DMT	Definite Minimum Time

Term	Description
DNP	Distributed Network Protocol
DPWS	Device Profile for Web Services
DSP	Digital Signal Processor
DST	Daylight Saving Time
DT	Definite Time: in the context of protection elements: An element which always responds with the same constant time delay on operation. Abbreviation of “Dead Time” in the context of auto-reclose:
DTD	Document Type Definition
DTOC	Definite Time Overcurrent
DTS	Date and Time Stamp
EF or E/F	Earth Fault (Directly equivalent to Ground Fault)
EIA	Electronic Industries Alliance
ELR	Environmental Lapse Rate
EMC	ElectroMagnetic Compatibility
ENA	Energy Networks Association
ER	Engineering Recommendation
ESD	Electrostatic Discharge
FAA	Ageing Acceleration Factor: Used by Loss of Life (LOL) element
FFail	A field failure (loss of excitation) element: Could be labeled 40 in ANSI terminology.
FFT	Fast Fourier Transform
FIR	Finite Impulse Response
FLC	Full load current: The nominal rated current for the circuit.
FLT / Flt	Fault - typically used to indicate faulted phase selection.
Fn or FN	Function
FPGA	Field Programmable Gate Array
FPS	Frames Per Second
FTP	File Transfer Protocol or Foil Twisted Pair
FWD, Fwd or Fwd.	Indicates an element responding to a flow in the “Forward” direction
Gen Diff	A generator differential element: Could be labeled 87G in ANSI terminology.
Gen-Xformer Diff	A generator-transformer differential element: Could be labeled 87GT in ANSI terminology.
GIF	Graphic Interchange Format – a file format for a computer graphic
GND / Gnd	Ground: used in distance settings to identify settings that relate to ground (earth) faults.
GOOSE	Generic Object Oriented Substation Event
GPS	Global Positioning System
GRP / Grp	Group. Typically an alternative setting group.
GSE	General Substation Event
GSSE	Generic Substation Status Event
GUESS	Generator Unintentional Energization at StandStill.
GUI	Graphical User Interface
HMI	Human Machine Interface

Term	Description
HSR	High-availability Seamless Ring
HTML	Hypertext Markup Language
I	Current
I/O	Input/Output
I/P	Input
IANA	Internet Assigned Numbers Authority
ICAO	International Civil Aviation Organization
ID	Identifier or Identification. Often a label used to track a software version installed.
IDMT	Inverse Definite Minimum Time. A characteristic whose trip time depends on the measured input (e.g. current) according to an inverse-time curve.
IEC	International Electro-technical Commission
IED	Intelligent Electronic Device - a term used to describe microprocessor-based controllers of power system equipment. Common types of IEDs include protective relaying devices, load tap changer controllers, circuit breaker controllers, capacitor bank switches, recloser controllers, voltage regulators, etc.
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IIR	Infinite Impulse Response
Inh	An Inhibit signal
Inst	An element with Instantaneous operation: i.e. having no deliberate time delay.
IP	Internet Protocol
IRIG	InterRange Instrumentation Group
ISA	International Standard Atmosphere
ISA	Instrumentation Systems and Automation Society
ISO	International Standards Organization
JPEF	Joint Photographic Experts Group – a file format for a computer graphic
L	Live
LAN	Local Area Network
LCD	Liquid Crystal Display: The front-panel text display on the relay.
LD	Level Detector: An element responding to a current or voltage below its set threshold.
LDOV	Level Detector for Overvoltage
LDUV	Level Detector for Undervoltage
LED	Light Emitting Diode: Red or green indicator on the front-panel.
LLDB	Live-Line Dead-Bus : In system synchronism check, indication that the line is energized whilst the bus is de-energized.
Ln	Natural logarithm
LN	Logical Node
LoL	A Loss of Load scheme, providing a fast distance trip without needing a signaling channel.
LPDU	Link Protocol Data Unit
LPHD	Logical Physical Device
MC	MultiCast
MCB	Miniature Circuit Breaker
MIB	Management Information Base
MICS	Model Implementation Conformance Statement

Term	Description
MIDOS	Modular Integrated DrawOut System
MMF	Magneto-Motive Force
MMS	Manufacturing Message Specification
MRP	Media Redundancy Protocol
MU	Merging Unit
MV	Measured Value
N	Neutral
N/A	Not Applicable
N/C	A Normally Closed or “break” contact: Often called a “form B” contact.
N/O	A Normally Open or “make” contact: Often called a “form A” contact.
NERC	North American Reliability Corporation
NIST	National Institute of Standards and Technology
NPS	Negative Phase Sequence
NVD	Neutral voltage displacement: Equivalent to residual overvoltage protection.
NXT	Abbreviation of “Next”: In connection with hotkey menu navigation.
O/C	Overcurrent
O/P	Output
OCB	Oil Circuit Breaker
OID	Object IDentifier
Opto	An Optically coupled logic input. Alternative terminology: binary input.
OSI	Open Systems Interconnection
PCB	Printed Circuit Board
PCT	Protective Conductor Terminal (Ground)
PDC	Phasor Data Concentrator
Ph	Phase - used in distance settings to identify settings that relate to phase-phase faults.
PICS	Protocol Implementation Conformance Statement
PMU	Phasor Measurement Unit
PNG	Portable Network Graphics – a file format for a computer graphic
Pol	Polarize - typically the polarizing voltage used in making directional decisions.
POR	A Permissive OverReaching transfer trip scheme (alternative terminology: POTT).
PRP	Parallel Redundancy Protocol
PSB	Power Swing Blocking, to detect power swing/out of step functions (ANSI 78).
PSL	Programmable Scheme Logic: The part of the relay’s logic configuration that can be modified by the user, using the graphical editor within MiCOM S1 Studio software.
PSlip	A Pole slip (out of step - OOS) element: could be labeled 78 in ANSI terminology.
PT	Power Transformer
PTP	Precision Time Protocol
PUR	A Permissive UnderReaching transfer trip scheme (alternative terminology: PUTT).
Q	Quantity defined as per unit value
R	Resistance
R&TTE	Radio and Telecommunications Terminal Equipment

Term	Description
RBAC	Role Based Access Control
RCA	Relay Characteristic Angle - The center of the directional characteristic.
REB	Redundant Ethernet Board
REF	Restricted Earth Fault
Rev.	Indicates an element responding to a flow in the “reverse” direction
RMS / rms	Root mean square. The equivalent a.c. current: Taking into account the fundamental, plus the equivalent heating effect of any harmonics.
RP	Rear Port: The communication ports on the rear of the IED
RS232	A common serial communications standard defined by the EIA
RS485	A common serial communications standard defined by the EIA (multi-drop)
RST or Rst	Reset generally used in the context of reset functions in circuit breaker control.
RSTP	Rapid Spanning Tree Protocol
RTD	Resistance Temperature Device
RTU	Remote Terminal Unit
Rx	Receive: Typically used to indicate a communication transmit line/pin.
SBS	Straight Binary Second
SC	Synch-Check or system Synchronism Check.
SCADA	Supervisory Control and Data Acquisition
SCL	Substation Configuration Language
SCU	Substation Control Unit
SEF	Sensitive Earth Fault Protection
Sen	Sensitive
SHM	Self-Healing Manager
SHP	Self Healing Protocol
SIR	Source Impedance Ratio
SLA	Service Level Agreement
SMV	Sampled Measured Values
SNTP	Simple Network Time Protocol
SOA	Service Oriented Architecture
SOAP	Simple Object Access Protocol
SOC	Second of Century
SOTF	Switch on to Fault protection. Modified protection on manual closure of the circuit breaker.
SP	Single pole.
SPAR	Single pole auto-reclose.
SPC	Single Point Controllable
SPDT	Single Pole Dead Time. The dead time used in single pole auto-reclose cycles.
SPS	Single Point Status
SQRT	Square Root
SSL	Source Impedance Ratio
STP	Shielded Twisted Pair or Spanning Tree Protocol
SV	Sampled Values
SVC	Sampled Value Model
SVM	Sampled Value Model

Term	Description
TAF	Turbine Abnormal Frequency
TCP	Transmission Control Protocol
TCS	Second of Century
TCS	Trip Circuit Supervision
TD	Time Dial. The time dial multiplier setting: Applied to inverse-time curves (ANSI/IEEE).
TE	Unit for case measurements: One inch = 5TE units
THD	Total Harmonic Distortion
TICS	Technical Issues Conformance Statement
TIFF	Tagged Image File Format – a file format for a computer graphic
TLS	Transport Layer Security protocol
TMS	Time Multiplier Setting: Applied to inverse-time curves (IEC)
TOC	Trip On Close (“line check”) protection. Offers SOTF and TOR functionality.
TOR	Trip On Reclose protection. Modified protection on autoreclosure of the circuit breaker.
TP	Two-Part
TUC	Timed UnderCurrent
TVE	Total Vector Error
Tx	Transmit
UDP	User Datagram Protocol
UL	Underwriters Laboratory
UPCT	User Programmable Curve Tool
UTC	Universal Time Coordinated
V	Voltage
VA	Phase A voltage: Sometimes L1, or red phase
VB	Phase B voltage: Sometimes L2, or yellow phase
VC	Phase C voltage: Sometimes L3, or blue phase
VCO	Voltage Controlled Overcurrent element
VDEP OC>	A voltage dependent overcurrent element: could be a voltage controlled or voltage restrained overcurrent element and could be labeled 51V in ANSI terminology.
VDR	Voltage Dependant Resistor
V/Hz	An overfluxing element, flux is proportional to voltage/frequency: could be labeled 24 in ANSI terminology.
Vk	IEC knee point voltage of a current transformer.
VT	Voltage Transformer
VTS	Voltage Transformer Supervision: To detect VT input failure.
WAN	Wide Area Network
Xformer	Transformer
XML	Extensible Markup Language
XSD	XML Schema Definition

Table 1 - Acronyms and abbreviations

2 COMPANY PROPRIETARY TERMS

Symbol	Description
Courier	Schneider Electric’s proprietary SCADA communications protocol
Metrosil	Brand of non-linear resistor produced by M&I Materials Ltd.
MiCOM	Schneider Electric’s brand of protection relays

Table 2 - Company-proprietary terms

3 ANSI TERMS

ANSI no.	Description
3PAR	Three pole auto-reclose.
3PDT	Three pole dead time. The dead time used in three pole auto-reclose cycles.
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
64R	Rotor earth fault protection
64S	100% stator earth (ground) fault protection using a low frequency injection method.

Table 3 - ANSI abbreviations

ANSI no.	Function	Description
Current Protection Functions		
50/51	Phase overcurrent	Three-phase protection against overloads and phase-to-phase short-circuits.
50N/51N	Earth fault	Earth fault protection based on measured or calculated residual current values: • 50N/51N: residual current calculated or measured by 3 phase current sensors
50G/51G	Sensitive earth fault	Sensitive earth fault protection based on measured residual current values: • 50G/51G: residual current measured directly by a specific sensor such as a core balance CT
50BF	Breaker failure	If a breaker fails to be triggered by a tripping order, as detected by the non-extinction of the fault current, this backup protection sends a tripping order to the upstream or adjacent breakers.
46	Negative sequence / unbalance	Protection against phase unbalance, detected by the measurement of negative sequence current: • sensitive protection to detect 2-phase faults at the ends of long lines • protection of equipment against temperature build-up, caused by an unbalanced power supply, phase inversion or loss of phase, and against phase current unbalance
46BC	Broken conductor protection	Protection against phase imbalance, detected by measurement of I2/I1.
49RMS	Thermal overload	Protection against thermal damage caused by overloads on machines (transformers, motors or generators). The thermal capacity used is calculated according to a mathematical model which takes into account: • current RMS values • ambient temperature • negative sequence current, a cause of motor rotor temperature rise
Re-Closer		
79	Recloser	Automation device used to limit down time after tripping due to transient or semipermanent faults on overhead lines. The recloser orders automatic reclosing of the breaking device after the time delay required to restore the insulation has elapsed. Recloser operation is easy to adapt for different operating modes by parameter setting.
Directional Current Protection		
67N/67NC type 1 and 67	Directional phase overcurrent	Phase-to-phase short-circuit protection, with selective tripping according to fault current direction. It comprises a phase overcurrent function associated with direction detection, and picks up if the phase overcurrent function in the chosen direction (line or busbar) is activated for at least one of the three phases.

ANSI no.	Function	Description
67N/67NC	Directional earth fault	Earth fault protection, with selective tripping according to fault current direction. Three types of operation: • Type 1: the protection function uses the projection of the I0 vector • Type 2: the protection function uses the I0 vector magnitude with half-plane tripping zone • Type 3: the protection function uses the I0 vector magnitude with angular sector tripping zone
67N/67NC type 1	Directional current protection	Directional earth fault protection for impedant, isolated or compensated neutral systems, based on the projection of measured residual current.
67N/67NC type 2	Directional current protection	Directional overcurrent protection for impedance and solidly earthed systems, based on measured or calculated residual current. It comprises an earth fault function associated with direction detection, and picks up if the earth fault function in the chosen direction (line or busbar) is activated.
67N/67NC type 3	Directional current protection	Directional overcurrent protection for distribution networks in which the neutral earthing system varies according to the operating mode, based on measured residual current. It comprises an earth fault function associated with direction detection (angular sector tripping zone defined by 2 adjustable angles), and picks up if the earth fault function in the chosen direction (line or busbar) is activated.
Directional Power Protection Functions		

32P	Directional active overpower	Two-way protection based on calculated active power, for the following applications:
		• active overpower protection to detect overloads and allow load shedding
		• reverse active power protection:
		  • against generators running like motors when the generators consume active power
		  • against motors running like generators when the motors supply active power

32Q/40	Directional reactive overpower	Two-way protection based on calculated reactive power to detect field loss on synchronous machines: • reactive overpower protection for motors which consume more reactive power with field loss • reverse reactive overpower protection for generators which consume reactive power with field loss.
Machine Protection Functions		
37	Phase undercurrent	Protection of pumps against the consequences of a loss of priming by the detection of motor no-load operation. It is sensitive to a minimum of current in phase 1, remains stable during breaker tripping and may be inhibited by a logic input.

48/51LR/14	Locked rotor / excessive starting time	Protection of motors against overheating caused by:
		• excessive motor starting time due to overloads (e.g. conveyor) or insufficient supply voltage.
		The reacceleration of a motor that is not shut down, indicated by a logic input, may be considered as starting.
		• locked rotor due to motor load (e.g. crusher):
		  • in normal operation, after a normal start
		  • directly upon starting, before the detection of excessive starting time, with detection of locked rotor by a zero speed detector connected to a logic input, or by the underspeed function.

66	Starts per hour	Protection against motor overheating caused by:
		• too frequent starts: motor energizing is inhibited when the maximum allowable number of starts is reached, after counting of:
		  • starts per hour (or adjustable period)
		  • consecutive motor hot or cold starts (reacceleration of a motor that is not shut down, indicated by a logic input, may be counted as a start)
		• starts too close together in time: motor re-energizing after a shutdown is only allowed after an adjustable waiting time.

ANSI no.	Function	Description
50V/51V	Voltage-restrained overcurrent	Phase-to-phase short-circuit protection, for generators. The current tripping set point is voltage-adjusted in order to be sensitive to faults close to the generator which cause voltage drops and lowers the short-circuit current.
26/63	Thermostat/Buchholz	Protection of transformers against temperature rise and internal faults via logic inputs linked to devices integrated in the transformer.
38/49T	Temperature monitoring	Protection that detects abnormal temperature build-up by measuring the temperature inside equipment fitted with sensors: • transformer: protection of primary and secondary windings • motor and generator: protection of stator windings and bearings.
Voltage Protection Functions		
27D	Positive sequence undervoltage	Protection of motors against faulty operation due to insufficient or unbalanced network voltage, and detection of reverse rotation direction.
27R	Remanent undervoltage	Protection used to check that remanent voltage sustained by rotating machines has been cleared before allowing the busbar supplying the machines to be re-energized, to avoid electrical and mechanical transients.
27	Undervoltage	Protection of motors against voltage sags or detection of abnormally low network voltage to trigger automatic load shedding or source transfer. Works with phase-to-phase voltage.
59	Overvoltage	Detection of abnormally high network voltage or checking for sufficient voltage to enable source transfer. Works with phase-to-phase or phase-to-neutral voltage, each voltage being monitored separately.
59N	Neutral voltage displacement	Detection of insulation faults by measuring residual voltage in isolated neutral systems.
47	Negative sequence overvoltage	Protection against phase unbalance resulting from phase inversion, unbalanced supply or distant fault, detected by the measurement of negative sequence voltage.
Frequency Protection Functions		
81O	Overfrequency	Detection of abnormally high frequency compared to the rated frequency, to monitor power supply quality. Other organizations may use 81H instead of 81O.
81U	Underfrequency	Detection of abnormally low frequency compared to the rated frequency, to monitor power supply quality. The protection may be used for overall tripping or load shedding. Protection stability is ensured in the event of the loss of the main source and presence of remanent voltage by a restraint in the event of a continuous decrease of the frequency, which is activated by parameter setting. Other organizations may use 81L instead of 81U.
81R	Rate of change of frequency	Protection function used for fast disconnection of a generator or load shedding control. Based on the calculation of the frequency variation, it is insensitive to transient voltage disturbances and therefore more stable than a phase-shift protection function. **Disconnection** In installations with autonomous production means connected to a utility, the “rate of change of frequency” protection function is used to detect loss of the main system in view of opening the incoming circuit breaker to: • protect the generators from a reconnection without checking synchronization • avoid supplying loads outside the installation. **Load shedding** The “rate of change of frequency” protection function is used for load shedding in combination with the underfrequency protection to: • either accelerate shedding in the event of a large overload • or inhibit shedding following a sudden drop in frequency due to a problem that should not be solved by shedding.
Dynamic Line Rating (DLR) Protection Functions		

ANSI no.	Function	Description
49DLR	Dynamic line rating (DLR)	Protection of overhead lines based on calculation of rating or ampacity to dynamically take into account the effect of prevailing weather conditions as monitored by external sensors for: • Ambient Temperature • Wind Velocity • Wind Direction • Solar Radiation

Table 4 - ANSI descriptions

4 CONCATENATED TERMS

Term
Undercurrent
Overcurrent
Overfrequency
Underfrequency
Undervoltage
Overvoltage

Table 5 - Concatenated terms

5 UNITS FOR DIGITAL COMMUNICATIONS

Unit	Description
b	bit
B	Byte
kb	Kilobit(s)
kbps	Kilobits per second
kB	Kilobyte(s)
Mb	Megabit(s)
Mbps	Megabits per second
MB	Megabyte(s)
Gb	Gigabit(s)
Gbps	Gigabits per second
GB	Gigabyte(s)
Tb	Terabit(s)
Tbps	Terabits per second
TB	Terabyte(s)

Table 6 - Units for digital communications

6 AMERICAN VS BRITISH ENGLISH TERMINOLOGY

British English	American English
…ae…	…e…
…ence	…ense
…ise	…ize
…oe…	…e…
…ogue	…og
…our	…or
…ourite	…orite
…que	…ck
…re	…er
…yse	…yze
Aluminium	Aluminum
Centre	Center
Earth	Ground
Fibre	Fiber
Ground	Earth
Speciality	Specialty

Table 7 - American vs British English terminology

7 LOGIC SYMBOLS AND TERMS

Symbol	Description	Units
&	Logical “AND”: Used in logic diagrams to show an AND-gate function.	
Σ	“Sigma”: Used to indicate a summation, such as cumulative current interrupted.	
τ	“Tau”: Used to indicate a time constant, often associated with thermal characteristics.	
ω	System angular frequency	rad
<	Less than: Used to indicate an “under” threshold, such as undercurrent (current dropout).	
>	Greater than: Used to indicate an “over” threshold, such as overcurrent (current overload)	
o	A small circle on the input or output of a logic gate: Indicates a NOT (invert) function.	
1	Logical “OR”: Used in logic diagrams to show an OR-gate function.	
ABC	Clockwise phase rotation.	
ACB	Anti-Clockwise phase rotation.	
C	Capacitance	A
df/dt	Rate of Change of Frequency protection	Hz/s
df/dt>1	First stage of df/dt protection	Hz/s
F<	Underfrequency protection: Could be labeled 81-U in ANSI terminology.	Hz
F>	Overfrequency protection: Could be labeled 81-O in ANSI terminology.	Hz
F<1	First stage of under frequency protection: Could be labeled 81-U in ANSI terminology.	Hz
F>1	First stage of over frequency protection: Could be labeled 81-O in ANSI terminology.	Hz
f_{max}	Maximum required operating frequency	Hz
f_{min}	Minimum required operating frequency	Hz
f_n	Nominal operating frequency	Hz
I	Current	A
I$\wedge$	Current raised to a power: Such as when breaker statistics monitor the square of ruptured current squared ($\wedge$ power = 2).	An
I’f	Maximum internal secondary fault current (may also be expressed as a multiple of In)	A
I<	An undercurrent element: Responds to current dropout.	A
I>>	Current setting of short circuit element	In
I>	A phase overcurrent protection: Could be labeled 50/51 in ANSI terminology.	A
I>1	First stage of phase overcurrent protection: Could be labeled 51-1 in ANSI terminology.	A
I>2	Second stage of phase overcurrent protection: Could be labeled 51-2 in ANSI terminology.	A
I>3	Third stage of phase overcurrent protection: Could be labeled 51-3 in ANSI terminology.	A
I>4	Fourth stage of phase overcurrent protection: Could be labeled 51-4 in ANSI terminology.	A
I0	Earth fault current setting Zero sequence current: Equals one third of the measured neutral/residual current.	A
I1	Positive sequence current.	A
I2	Negative sequence current.	A
I2>	Negative sequence overcurrent protection (NPS element).	A
I2pol	Negative sequence polarizing current.	A
I2therm>	A negative sequence thermal element: Could be labeled 46T in ANSI terminology.	
IA	Phase A current: Might be phase L1, red phase.. or other, in customer terminology.	A
IB	Phase B current: Might be phase L2, yellow phase.. or other, in customer terminology.	A
IC	Phase C current: Might be phase L3, blue phase.. or other, in customer terminology.	A
Idiff	Current setting of biased differential element	A

Symbol	Description	Units
If	Maximum secondary through-fault current	A
If max	Maximum secondary fault current (same for all feeders)	A
If max int	Maximum secondary contribution from a feeder to an internal fault	A
If Z1	Maximum secondary phase fault current at Zone 1 reach point	A
Ife	Maximum secondary through fault earth current	A
IfeZ1	Maximum secondary earth fault current at Zone 1 reach point	A
Ifn	Maximum prospective secondary earth fault current or 31 x I> setting (whichever is lowest)	A
Ifp	Maximum prospective secondary phase fault current or 31 x I> setting (whichever is lowest)	A
I_m	Mutual current	A
IM64	InterMiCOM64.	
IMx	InterMiCOM64 bit (x=1 to 16)	
I_n	Current transformer nominal secondary current. The rated nominal current of the relay: Software selectable as 1 amp or 5 amp to match the line CT input.	A
IN	Neutral current, or residual current: This results from an internal summation of the three measured phase currents.	A
IN>	A neutral (residual) overcurrent element: Detects earth/ground faults.	A
IN>1	First stage of ground overcurrent protection: Could be labeled 51N-1 in ANSI terminology.	A
IN>2	Second stage of ground overcurrent protection: Could be labeled 51N-2 in ANSI terminology.	A
Inst	An element with “instantaneous” operation: i.e. having no deliberate time delay.	
I/O	Inputs and Outputs - used in connection with the number of optocoupled inputs and output contacts within the relay.	
I/P	Input	
Iref	Reference current of P63x calculated from the reference power and nominal voltage	A
IREF>	A Restricted Earth Fault overcurrent element: Detects earth (ground) faults. Could be labeled 64 in ANSI terminology.	A
IRm2	Second knee-point bias current threshold setting of P63x biased differential element	A
Is	Value of stabilizing current	A
IS1	Differential current pick-up setting of biased differential element	A
IS2	Bias current threshold setting of biased differential element	A
I_{SEF}>	Sensitive earth fault overcurrent element.	A
Isn	Rated secondary current (I secondary nominal)	A
Isp	Stage 2 and 3 setting	A
Ist	Motor start up current referred to CT secondary side	A
K	Dimensioning factor	
K_1	Lower bias slope setting of biased differential element	%
K_2	Higher bias slope setting of biased differential element	%
K_e	Dimensioning factor for earth fault	
km	Distance in kilometers	
K_{max}	Maximum dimensioning factor	
K_{rpa}	Dimensioning factor for reach point accuracy	
K_s	Dimensioning factor dependent upon through fault current	
K_{ssc}	Short circuit current coefficient or ALF	
K_t	Dimensioning factor dependent upon operating time	
kZm	The mutual compensation factor (mutual compensation of distance elements and fault locator for parallel line coupling effects).	

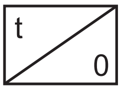
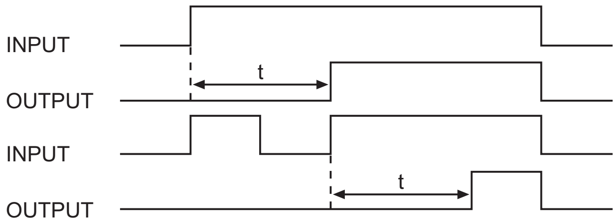
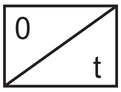
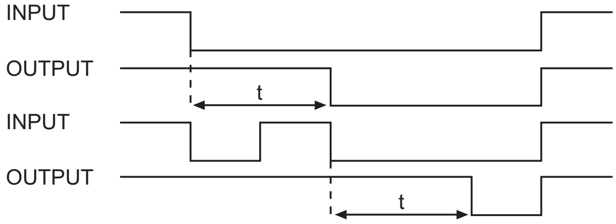
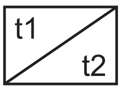
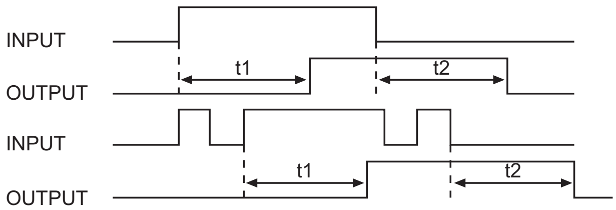
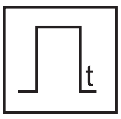
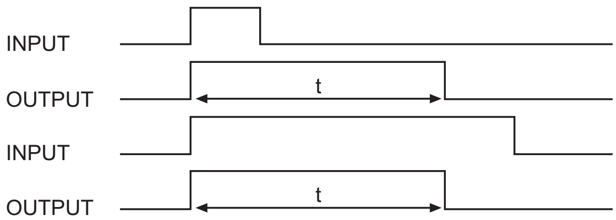
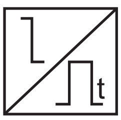
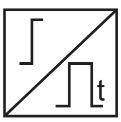
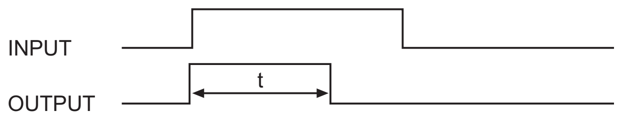
Symbol	Description	Units
kZN	The residual compensation factor: Ensuring correct reach for ground distance elements.	
L	Inductance	A
m1	Lower bias slope setting of P63x biased differential element	None
m2	Higher bias slope setting of P63x biased differential element	None
mi	Distance in miles.	
N	Indication of “Neutral” involvement in a fault: i.e. a ground (earth) fault.	
-P>	A reverse power (W) element: could be labeled 32R in ANSI terminology.	
P>	An overpower (W) element: could be labeled 32O in ANSI terminology.	
P<	A low forward power (W) element: could be labeled 32L in ANSI terminology.	
P1	Used in IEC terminology to identify the primary CT terminal polarity: Replace by a dot when using ANSI standards.	
P2	Used in IEC terminology to identify the primary CT terminal polarity: The non-dot terminal.	
P_n	Rotating plant rated single phase power	W
PN>	Wattmetric earth fault protection: Calculated using residual voltage and current quantities.	
Q<	A reactive under power (VAr) element	
R	Resistance (Ω)	Ω
R< or 64S R<	A 100% stator earth (ground) fault via low frequency injection under resistance element: could be labeled 64S in ANSI terminology.	
R Gnd.	A distance zone resistive reach setting: Used for ground (earth) faults.	
R Ph	A distance zone resistive reach setting used for Phase-Phase faults.	
Rct	Secondary winding resistance	Ω
Rl	Resistance of single lead from relay to current transformer	Ω
Rr	Resistance of any other protective relays sharing the current transformer	Ω
Rrn	Resistance of relay neutral current input	Ω
Rrp	Resistance of relay phase current input	Ω
Rs	Value of stabilizing resistor	Ω
Rx	Receive: typically used to indicate a communication receive line/pin.	
S<	An apparent under power (VA) element	
S1	Used in IEC terminology to identify the secondary CT terminal polarity: Replace by a dot when using ANSI standards.	
S2	Used in IEC terminology to identify the secondary CT terminal polarity: The non-dot terminal. Also used to signify negative sequence apparent power, S2 = V2 x I2.	
S2>	A negative sequence apparent power element, S2 = V2 x I2.	
t	A time delay.	
t’	Duration of first current flow during auto-reclose cycle	s
T1	Primary system time constant	s
TF	Through Fault monitoring	
tfr	Auto-reclose dead time	s
Thermal I>	A stator thermal overload element: could be labeled 49 in ANSI terminology.	
Thru/TF	Through Fault monitoring	
tIdiff	Current differential operating time	s
Ts	Secondary system time constant	s
Tx	Transmit: typically used to indicate a communication transmit line/pin.	
V	Voltage.	V
V<	An undervoltage element: could be labeled 27 in ANSI terminology	V

Symbol	Description	Units
V<1	First stage of undervoltage protection: Could be labeled 27-1 in ANSI terminology.	V
V<2	Second stage of undervoltage protection: Could be labeled 27-2 in ANSI terminology.	V
V>	An overvoltage element: could be labeled 59 in ANSI terminology	V
V>1	First stage of overvoltage protection: Could be labeled 59-1 in ANSI terminology.	V
V>2	Second stage of overvoltage protection: Could be labeled 59-2 in ANSI terminology.	V
V0	Zero sequence voltage: Equals one third of the measured neutral/residual voltage.	V
V1	Positive sequence voltage.	V
V2	Negative sequence voltage.	V
V2>	A negative phase sequence (NPS) overvoltage element: could be labeled 47 in ANSI terminology.	
$V2_{pol}$	Negative sequence polarizing voltage.	V
V_A	Phase A voltage: Might be phase L1, red phase.. or other, in customer terminology.	V
V_B	Phase B voltage: Might be phase L2, yellow phase.. or other, in customer terminology.	V
V_C	Phase C voltage: Might be phase L3, blue phase.. or other, in customer terminology.	V
Vf	Theoretical maximum voltage produced if CT saturation did not occur	V
Vin	Input voltage e.g. to an opto-input	V
V_k	Required CT knee-point voltage. IEC knee point voltage of a current transformer.	V
VN	Neutral voltage displacement, or residual voltage.	V
VN>	A residual (neutral) overvoltage element: could be labeled 59N in ANSI terminology.	V
V_n	Nominal voltage	V
Vn	The rated nominal voltage of the relay: To match the line VT input.	V
VN>1	First stage of residual (neutral) overvoltage protection.	V
VN>2	Second stage of residual (neutral) overvoltage protection.	V
VN3H>	A 100% stator earth (ground) fault 3rd harmonic residual (neutral) overvoltage element: could be labeled 59TN in ANSI terminology.	
VN3H<	A 100% stator earth (ground) fault 3rd harmonic residual (neutral) undervoltage element: could be labeled 27TN in ANSI terminology.	
Vres.	Neutral voltage displacement, or residual voltage.	V
Vs	Value of stabilizing voltage	V
V_x	An auxiliary supply voltage: Typically the substation battery voltage used to power the relay.	V
WI	Weak Infeed logic used in teleprotection schemes.	
X	Reactance	None
X/R	Primary system reactance/resistance ratio	None
Xe/Re	Primary system reactance/resistance ratio for earth loop	None
Xt	Transformer reactance (per unit)	p.u.
Y	Admittance	p.u.
Z	Impedance	p.u.
Z<	An under impedance element: could be labeled 21 in ANSI terminology.	
Z0	Zero sequence impedance.	
Z1	Positive sequence impedance.	
Z1	Zone 1 distance protection.	
Z1X	Reach-stepped Zone 1X, for zone extension schemes used with auto-reclosure.	
Z2	Negative sequence impedance.	
Z2	Zone 2 distance protection.	
ZP	Programmable distance zone that can be set forward or reverse looking.	

Symbol	Description	Units
Zs	Used to signify the source impedance behind the relay location.	
Φal	Accuracy limit flux	Wb
Ψr	Remanent flux	Wb
Ψs	Saturation flux	Wb

Table 8 - Logic Symbols and Terms

8 LOGIC TIMERS

Logic symbols	Explanation	Time chart
	Delay on pick-up timer, t	
	Delay on drop-off timer, t	
	Delay on pick-up/drop-off timer	
	Pulse timer	
	Pulse pick-up falling edge	
	Pulse pick-up raising edge	

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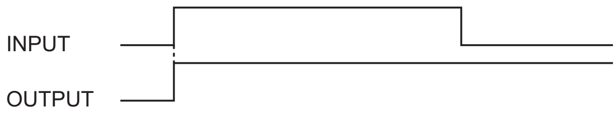
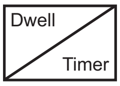
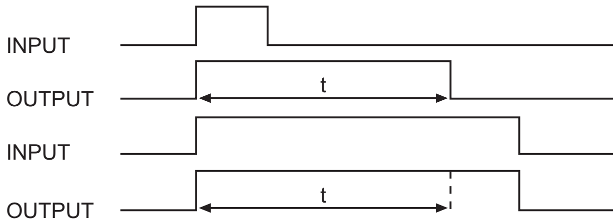
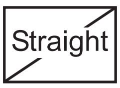
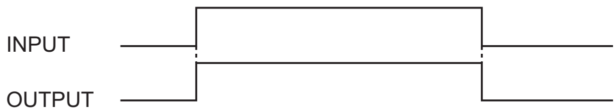
<tr><th>Logic symbols</th><th>Explanation</th><th>Time chart</th></tr>
<tr><td></td><td>Latch</td><td></td></tr>
<tr><td></td><td>Dwell timer</td><td></td></tr>
<tr><td></td><td>Straight (non latching):
Hold value until input reset signal</td><td></td></tr>
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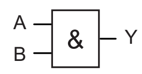
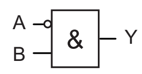
Table 9 - Logic Timers

9 LOGIC GATES

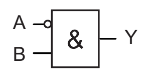
AND GATE



IN		OUT
0	1	0
0	1	0
0	1	0
1	0	0
1	1	1

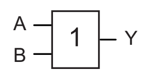


IN		OUT
A	B	Y
0	0	0
0	1	1
1	0	0
1	1	0

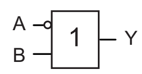


IN		OUT
A	B	Y
0	0	1
0	1	1
1	0	1
1	1	0

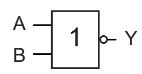
OR GATE



IN		OUT
A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

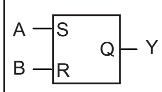


IN		OUT
A	B	Y
0	0	1
0	1	1
1	0	0
1	1	1

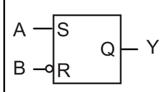


IN		OUT
A	B	Y
0	0	1
0	1	0
1	0	0
1	1	0

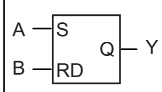
R - S FLIP-FLOP



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



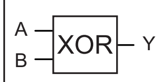
A	B	QN	QN+	Active Mode
0	0	0		Hold Mode
		1	0	Reset
0	1			Hold Mode
1	0	-	-	Inhibit Mode
0	1	0	1	Set
		1		Hold Mode



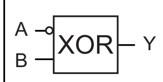
* RD = Reset Dominant

A	B	QN	QN+	Active Mode
0	0			Hold Mode
0	1			0
1	0	0	1	Set
		1		Hold Mode
1	1			0

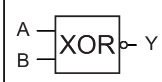
EXCLUSIVE OR GATE



IN		OUT
A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0

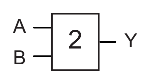


IN		OUT
A	B	Y
0	0	1
0	1	0
1	0	0
1	1	1

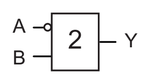


IN		OUT
A	B	Y
0	0	1
0	1	0
1	0	0
1	1	1

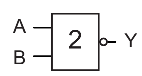
MULTI INPUT GATE



IN		OUT
A	B	Y
0	0	0
0	1	0
1	0	0
1	1	1

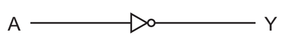


IN		OUT
A	B	Y
0	0	0
0	1	1
1	0	0
1	1	0



IN		OUT
A	B	Y
0	0	1
0	1	1
1	0	1
1	1	0

NOT GATE



Inverter (NOT)

IN	OUT
A	Y
0	1
1	0

Figure 1 - Logic Gates

Notes:

INSTALLATION

CHAPTER 15

Notes:

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1 RECEIPT, HANDLING, STORING AND UNPACKING

1.1 Receipt of Relays

Protective relays, although generally of robust construction, require careful treatment prior to installation on site. 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 Schneider Electric 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 1.3 of this chapter gives more information about the storage of relays.

1.2 Handling of Electronic Equipment

Caution **Before carrying out any work on the equipment, the user should be familiar with the contents of the Safety Guide (SFTY/4L M/G11) or later issue, or the Safety and Technical Data chapters of this Technical Manual and also the ratings on the equipment's rating label.**

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 which, although not always immediately apparent, will reduce the reliability of the circuit. This is particularly important to consider where the circuits use Complementary Metal Oxide Semiconductors (CMOS), as is the case with these relays.

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 it's 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 analogue 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 which is at the same potential as yourself.

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 aforementioned British Standard document.

1.3 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. The action of the de-humidifier crystals will be impaired if the bag is exposed to ambient conditions and may be restored by gently heating the bag for about an hour prior to replacing it in the carton.

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 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.

1.4 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.

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. This particularly applies to installations which are being carried out at the same time as construction work.

2 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 cut-outs and hole centres. This information can also be found in the product publication.

Secondary front covers can also be supplied as an option item to prevent unauthorised changing of settings and alarm status. They are available in sizes 40TE (GN0037 001) and 60TE (GN0038 001). Note that the 60TE cover also fits the 80TE case size of the relay.

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 is positioned on the right-hand side of the relay (or relays) with which it is associated. This minimises the wiring between the relay and test block, and allows the correct test block to be easily identified during commissioning and maintenance tests.

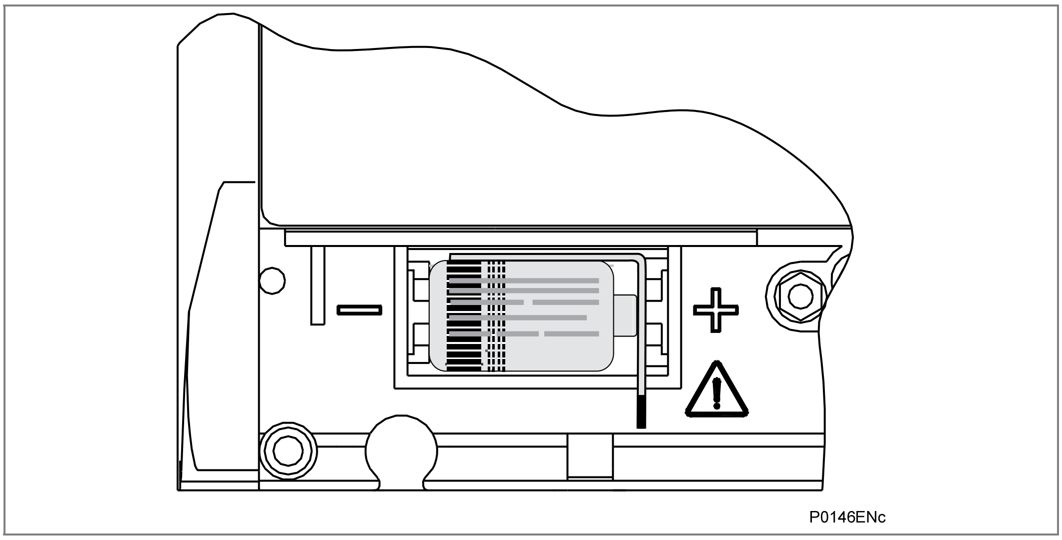


Figure 1 - Location of battery isolation strip

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. This will prevent unnecessary battery drain during transportation to site and installation. 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.

2.1 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 (19”) 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 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.*

Once the tier is complete, the frames are fastened into the racks using mounting angles at each end of the tier.

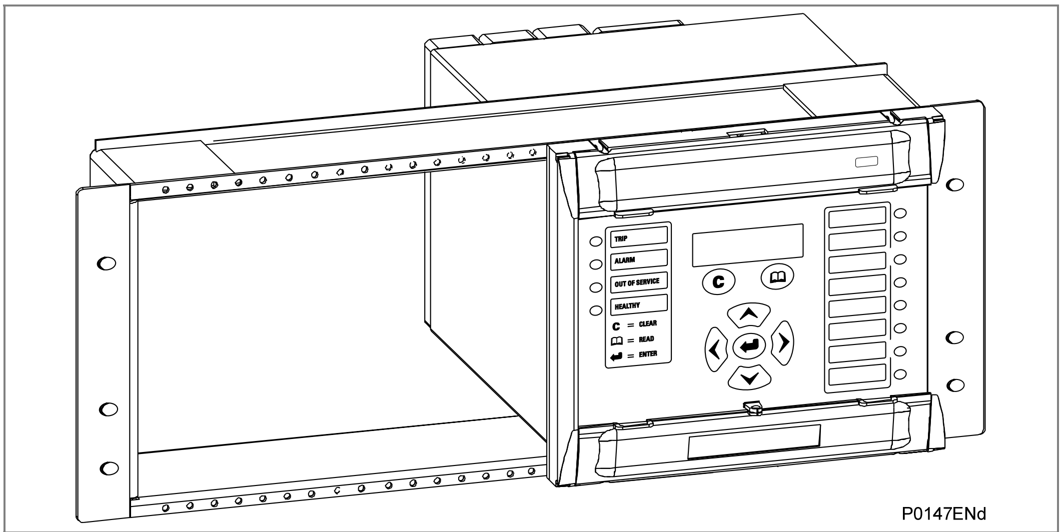


Figure 2 - Rack mounting of relays

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.

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 001
10TE	GJ2028 002
15TE	GJ2028 003
20TE	GJ2028 004
25TE	GJ2028 005
30TE	GJ2028 006
35TE	GJ2028 007
40TE	GJ2028 008

Table 1 - Blanking plates

2.2 Panel Mounting

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 cut-out in the panel, it is advised that they are mechanically grouped together horizontally and/or vertically to form rigid assemblies prior to mounting in the panel.

Note	*It is not advised 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 BS EN60529 IP52, it will be necessary to fit a metallic sealing strip between adjoining relays (Part no GN2044 001) and a sealing ring selected from Table 2 around the complete assembly.

Width	Single tier	Double tier
10TE	GJ9018 002	GJ9018 018
15TE	GJ9018 003	GJ9018 019
20TE	GJ9018 004	GJ9018 020
25TE	GJ9018 005	GJ9018 021
30TE	GJ9018 006	GJ9018 022
35TE	GJ9018 007	GJ9018 023
40TE	GJ9018 008	GJ9018 024
45TE	GJ9018 009	GJ9018 025
50TE	GJ9018 010	GJ9018 026
55TE	GJ9018 011	GJ9018 027
60TE	GJ9018 012	GJ9018 028
65TE	GJ9018 013	GJ9018 029
70TE	GJ9018 014	GJ9018 030
75TE	GJ9018 015	GJ9018 031
80TE	GJ9018 016	GJ9018 032

Table 2 - IP52 sealing rings

Further details on mounting MiDOS relays can be found in publication R7012, “MiDOS Parts Catalogue and Assembly Instructions”.

3 RELAY WIRING

This section serves as a guide to selecting the appropriate cable and connector type for each terminal on the MiCOM relay.

3.1 Medium and Heavy Duty Terminal Block Connections

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, Schneider Electric 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 colour
ZB9124 901	0.25 – 1.65mm2 (22 – 16AWG)	Red
ZB9124 900	1.04 – 2.63mm2 (16 – 14AWG)	Blue
ZB9124 904	2.53 – 6.64mm2 (12 – 10AWG)	Uninsulated*
* To maintain the terminal block insulation requirements for safety, an insulating sleeve should be fitted over the ring terminal after crimping.		

Table 3 - M4 90° crimp ring terminals

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.

3.2 EIA(RS)485 Port

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:	0.5mm2 per core
Screen:	Overall braid, PVC sheathed

3.3 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.

3.4 EIA(RS)485 Port

Short term connections to the EIA(RS)485 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 Introduction (P54x/EN IT) chapter details the pin allocations.

3.5 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. The Introduction (P54x/EN IT) chapter details the pin allocations.

3.6 Earth Connection

Every relay must be connected to the local 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. 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 per wire. If a greater cross-sectional area is required, two parallel connected wires, each terminated in a separate ring terminal at the relay, or a metal earth bar could be used.

Note	*To prevent any possibility of electrolytic action between brass or copper earth conductors and the rear panel of the relay, precautions should be taken to isolate them from one another. This could be achieved in a number of ways, including placing a nickel-plated or insulating washer between the conductor and the relay case, or using tinned ring terminals.*

3.7 Protection Communication Channel Connections

A number of communications options are available as shown in Table 4 together with the appropriate optical fibre. All terminations are BFOC 2.5 connectors (ST).

Communication option	Optical Fibre
850nm multi-mode	50/125µm or 62.5/125µm
1300nm multi-mode	50/125µm or 62.5/125µm
1300nm single-mode	9/125µm
1550nm single-mode	9/125µm

Table 4 - Communications options

4 P590 SERIES INSTALLATION

MiCOM P59x series interface units 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 cut-outs and hole centres. This information can also be found in the P59x publication.

The P59x series interface units should be mounted in close proximity to the telecommunications equipment with which it is intended for use. Ideally this will be in the same or an adjacent cubicle.

4.1 External Connections

The external connections are shown on diagrams 10P59101, 10P59201 & 10P59301 and in the External Connection Diagram chapter (P54x/EN CO). The connections can be broken down into four groups.

4.1.1 Auxiliary supply connections

It is recommended that wire with a minimum cross section of $1.5mm^2$ be used.

The recommended external protective fuse for the auxiliary DC supply of the P59x series interface units is:

2 Amp HRC (High Rupture Capacity) GE Red Spot type NIT or TIA;

or

if a UL recognised fuse is required, 2A time delay Gould type AJT2.

Caution **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**

4.1.2 Telecommunications equipment connections

4.1.2.1 P591 – G.703 Connections

ITU-T G.703 electrical connections to the P591 interface unit are via the terminal blocks on the rear of the device. The G.703 signals are isolated by pulse transformers to 1kV. Since the G.703 signals are only ±1V magnitude, the cable connecting the P591 unit and the multiplexer must be properly screened against electromagnetic noise and interference. The interface cable should consist of pairs of 24AWG (19/0.12mm), twisted and shielded, and have a characteristic impedance of about 120 ohms.

The choice of grounding depends on the local codes and practices.

It is recommended that the interface cable shield is connected to the multiplexer frame ground. The cable may be connected to the MiCOM P591 case earth if no earth loop current is expected.

4.1.2.2 P592 – V.35 Connections

ITU-T V.35 electrical connections to the P592 interface unit are made via a standard female 34 pin ‘M’ block connector on the rear of the device. Since the V.35 signals are either of ±0.55V or ±12V magnitude, the cable connecting the P592 unit and the multiplexer must be properly screened against electromagnetic noise and interference.

The interface cable should consist of pairs of 24AWG (19/0.12mm), twisted and shielded, and have a characteristic impedance of about 100 ohms. The choice of grounding depends on the local codes and practices.

It is recommended that the interface cable shield is connected to the multiplexer frame ground. The cable may be connected to the MiCOM P592 case earth if no earth loop current is expected.

4.1.2.3 P593 – X.21 Connections

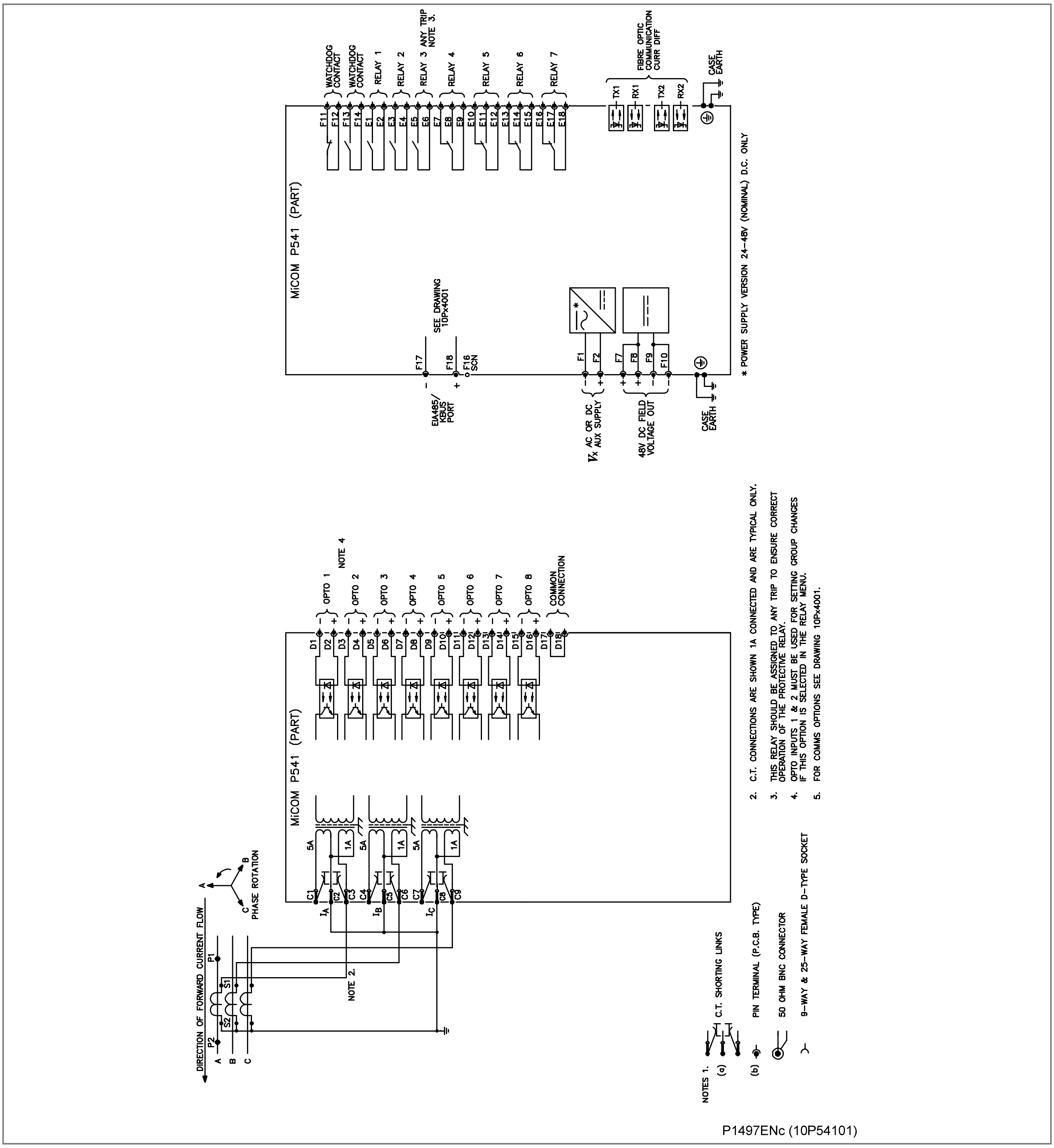
ITU-T X.21 electrical connections to the P593 interface unit are made via a standard male 15 way D-subminiature connector. The use of twisted pairs of 24 AWG (19/0.12mm) stranded cable, foil shielded, with drain wire is recommended. Due to the similarities between RS449 and X.21, the P593 may also be suitable for connection to RS449/RS422 equipment.

4.1.3 Protection Communication Channel Connections

The P59x unit is connected to the P540 relay using 850nm multi-mode optical fibre type 50/125µm or 62.5/125µm and fitted with BFOC 2.5 connectors (ST).

5 EXTERNAL CONNECTION DIAGRAMS

5.1 10P54101 - Current Differential Relay (40TE) with Mag Inrush Restraint and 3-pole tripping only and no VT connections



P1497ENc (10P54101)

Figure 3 - 10P54101 - Current Differential Relay (40TE) with Mag Inrush Restraint and 3-pole tripping only and no VT connections

5.2 10P54201 - Current Differential Relay (60TE) with Mag Inrush Restraint and 3-pole tripping only, Auto-Reclose and no VT connections

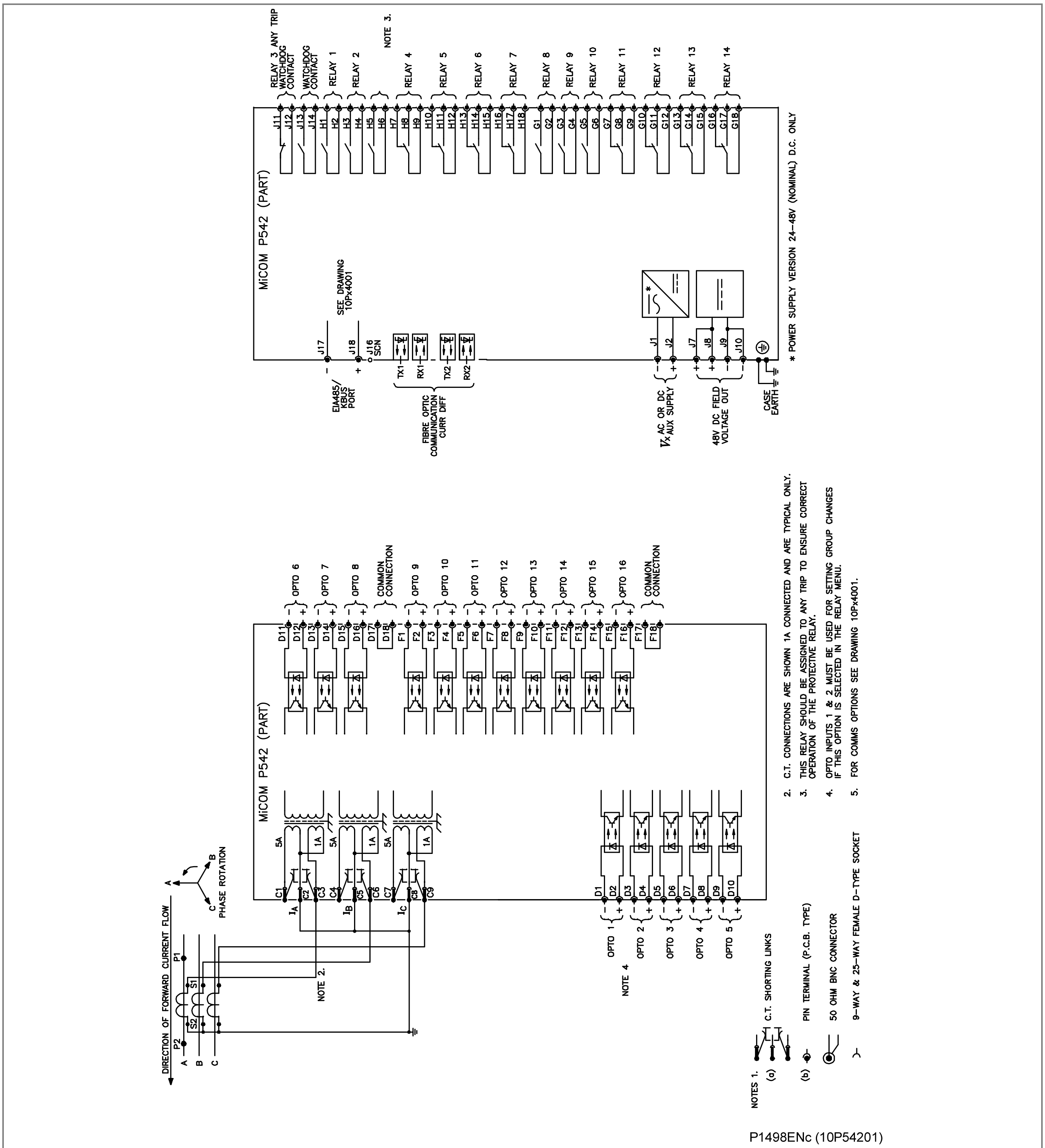
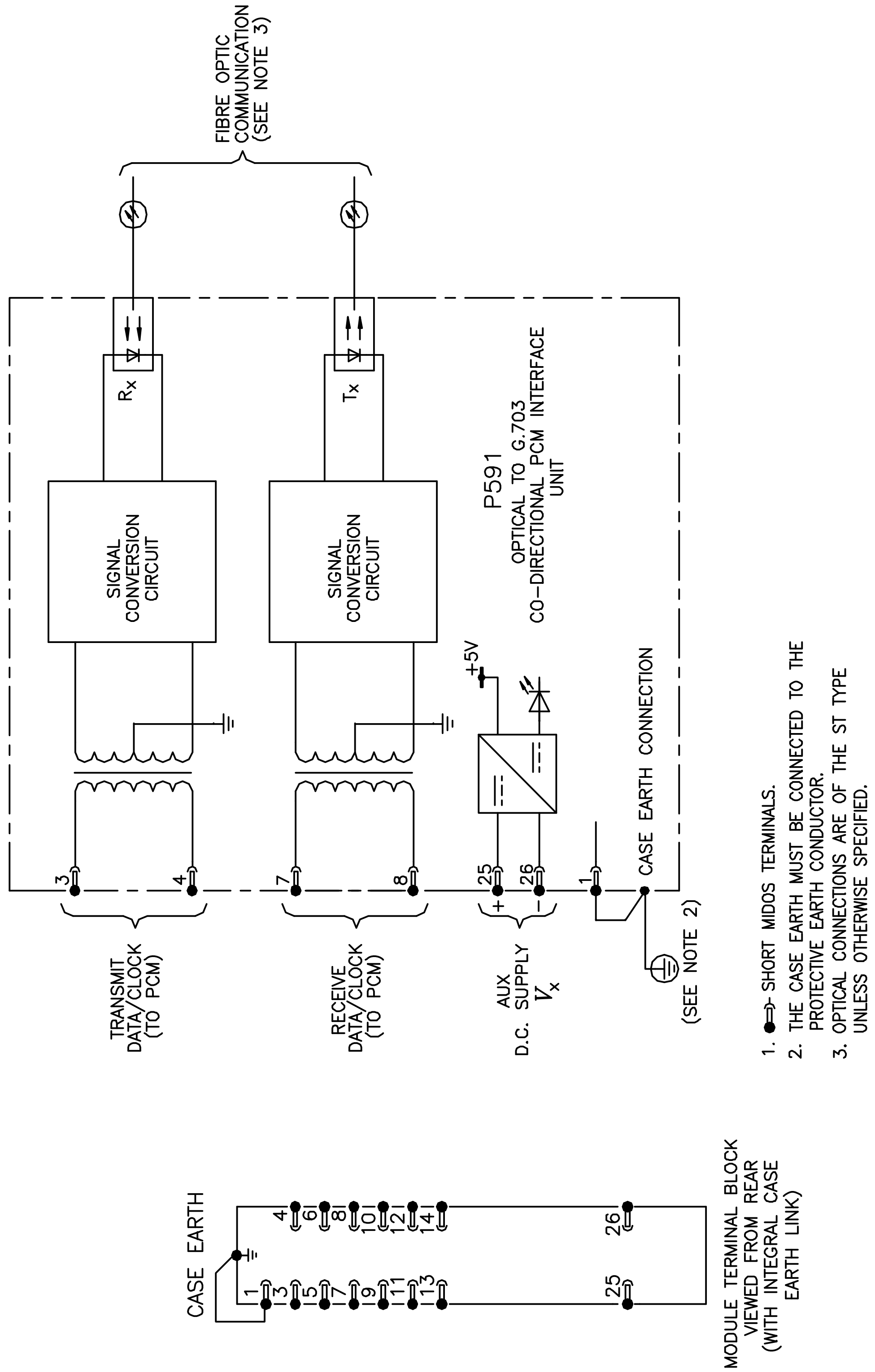


Figure 4 - 10P54201 - Current Differential Relay (60TE) with Mag Inrush Restraint and 3-pole tripping only, Auto-Reclose and no VT connections

5.3 10P59101 - Optical to G703 Co-Directional PCM Interface Unit P591



P1510ENb (10P59101)

Figure 5 - 10P59101 - Optical to G703 Co-Directional PCM Interface Unit P591

5.4 10P59201 - Optical to V.35 Communication Interface P592

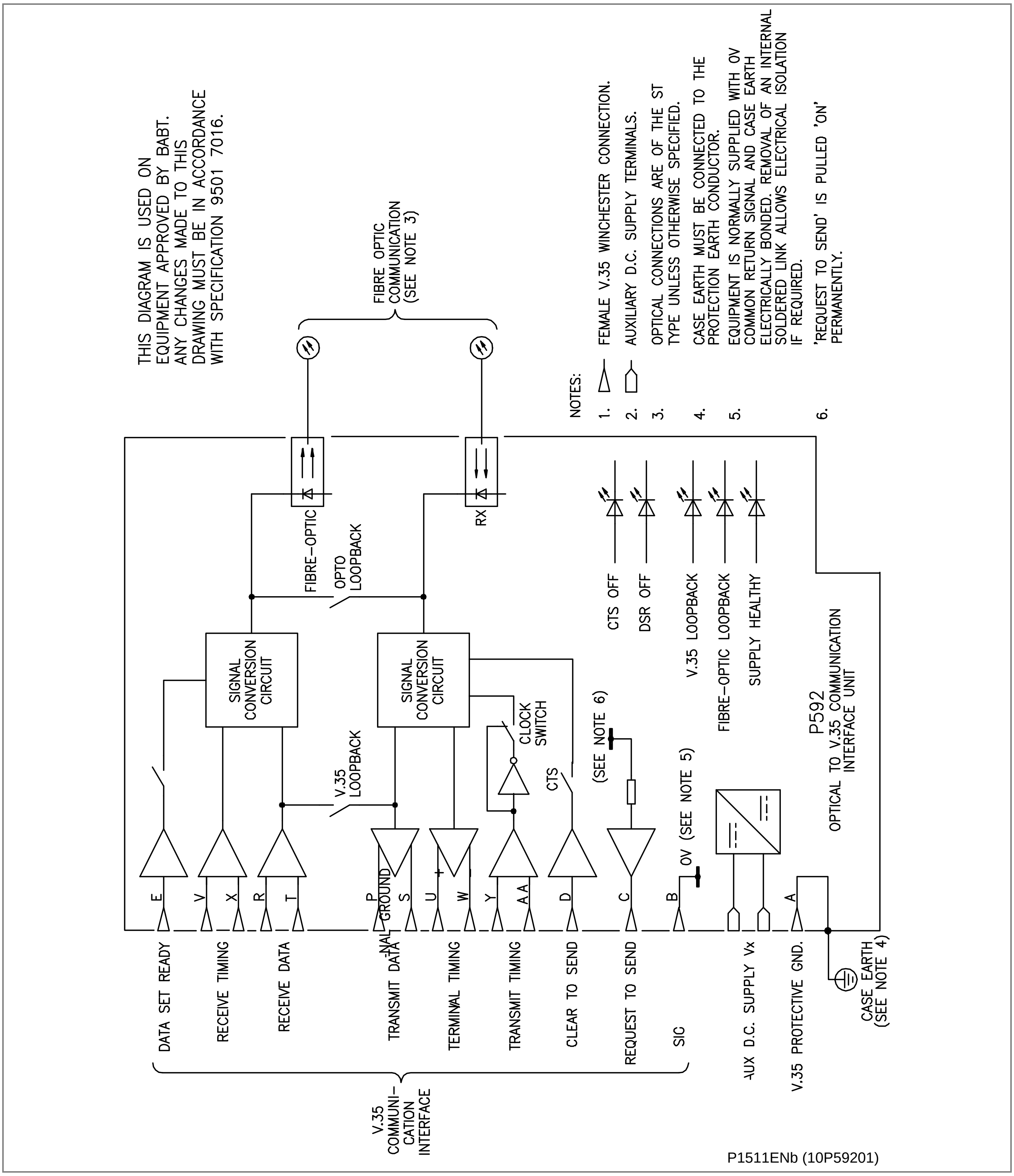


Figure 6 - 10P59201 - Optical to V.35 Communication Interface P592

5.5 10P59301 - Optical to X.21 Communication Interface P593

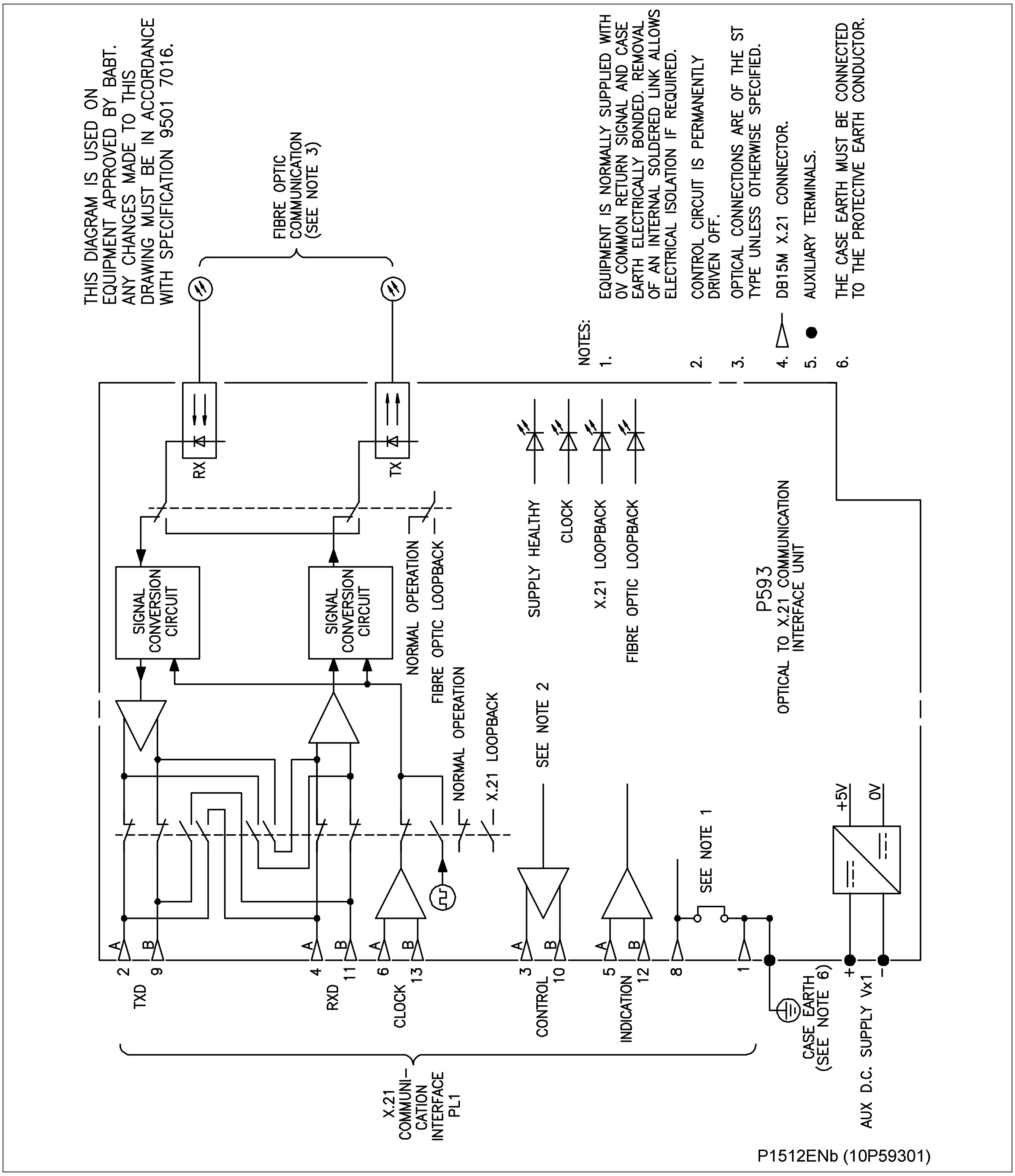


Figure 7 - 10P59301 - Optical to X.21 Communication Interface P593

VERSION HISTORY

CHAPTER 16

Notes:

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Notes:

1 VERSION HISTORY AND COMPATIBILITY

Software Version		Hard-ware Suffix	Original Date of Issue	Description of Changes	S1 Compa-tibility	Technical Document-ation
Major	Minor					
01	A	A	Feb 2000	First release to production.	V1.07 or later	TG8613A
02	A	A	Mar 2000	PSB. Three settings added to set Zone 6 to increase flexibility. Protection Address. Universal Address added. SEF & EF. Polarising voltage setting range increased. Thermal. Setting range increased. Trip Conversion Logic. 3 DDB signals added to simplify logic for users. Distance. Min polarising voltage increased to prevent tripping for close up three phase faults. Check Sync. Angle measurement improved. PSB. Text for Power Swing indication improved. Include pole discrepancy logic to P543. Remove DDB elements for Neutral Diff. Modify IEC870 Test Mode operation. Susceptance setting corrected.	V1.08 or later	TG8613B
03	A	A	May 2000	German text changed. Spanish text changed. Changes to DDB names & properties. Improvements in autoreclose and reset from lockout code. Changes to pole dead & Trip Conversion Logic. Changes to P544 circuit breaker fail logic. Added DDB for CS103 Test Mode. Not recommend upgrading to 03B software or later.	V1.09 or later	TG8613B
03	B	A	Feb 2002	All builds released for maintenance upgrades. Resolved possible reboot caused by Disturbance Recorder. Resolved possible reboot caused by invalid modbus requests. Resolved a loss of measurements (column 3 & 4) problem that can occur in 3 terminal applications. Problem whereby MiCOM S1 could only set group 1 line length corrected. Fixed capacitive charging current compensation in P544. Corrected P544 display of Phase C current phase angle. IDMT curve improvements. Removed rounding error in tp calculation. Menu dependence using ripple bit corrected. Directional / non direction Earth Fault changes. Battery Fail Alarm improvement. Power measurements read over modbus corrected. Improving read key functionality in the presence of alarms. Prevented software errors from clearing event log.	V1.09 or later	TG8613B
04	A	A	Aug 2000	Trip conversion logic moved from internal fixed logic to PSL	V1.10 or later	TG8613B
04	B	A	Mar 2001	Only P543 CS103 builds released. Improvements to the CS103 time synchronization.	V1.10 or later	TG8613B
04	C	A	Jun 2001	Only P543 CS103 builds released. Based on 04B. Resolved a loss of measurements (columns 3 & 4) problem that can occur in 3 terminal applications.	V1.10 or later	TG8613B
04	D	A	Jun 2001	Only P543 CS103 build released. Based on 04C. Prevents a reboot on power-up when battery is removed	V1.10 or later	TG8613B

Software Version		Hard-ware Suffix	Original Date of Issue	Description of Changes	S1 Compa-tibility	Technical Document-ation
Major	Minor					
05	B	A	Oct 2000	Includes DNP3.0. Courier Bay Module compatibility modification. Modbus Bay Module compatibility modification. Distance – Z3 selectable forward / reverse. Spanish text corrected. Menu dependencies improved. Modbus reading of fault location corrected. RDF file modified. Directional / non direction Earth Fault directionality improvements . Some modbus address changed. Requirement to use relays 8, 9 & 10 for Trip A, B & C removed. Modbus communication when used with140 harmonised. Battery Fail Alarm improvement. Blocking negative sign for fault location for close-up faults. Power measurements read over modbus corrected. Modbus status register reports disturbance records incorrectly following power up cycle. Recommend upgrading to 05G software or later, or 05H+ for modbus	V2.0 or later	TG8613B
05	E	A	Jun 2001	Improvements to measurements 3 and 4 columns for three terminal applications. Not recommend upgrading to 05G software or later, or 05K or later	V2.0 or later	TG8613B
05	F	A	Sep 2001	All builds released to production. Based on 05E software. Problem whereby MiCOM S1 could only set group 1 line length correct. Fixed capacitive charging current compensation in P544. Corrected P544 display of Phase C current phase angle. IDMT curve improvements. Removed rounding error in tp calculation. Fixed problems caused by changes to DNP3 address. Recommend upgrading to 05K or later	V2.0 or later	TG8613B
05	G	A	Jan 2002	Resolved possible reboot caused by Disturbance Recorder. Problem in modbus build which could cause a reboot. Not recommend upgrading to 05K or later	V2.0 or later	TG8613B
05	H	A	Jan 2002	Resolved possible reboot caused by invalid modbus requests. Not recommend upgrading to 05K or later	V2.0 or later	TG8613B
05	I	A	Oct 2002	Correct the format used to display frequency over the modbus interface. Not recommend upgrading to 05K or later	V2.0 or later	TG8613B
05	J	A	Nov 2002	Resolved incorrect operation of C Diff Failure Alarm in 3 terminal schemes. Correct operation of Capacitive Charging Current Compensation in 3 terminal schemes. Resolved problem with resample timer on microprocessor. Not recommend upgrading to 05K or later	V2.0 or later	TG8613B
05	K	A	Feb 2003	Resolved problem with IEC60870-5-103 time synchronisation	V2.0 or later	TG8613B
05	L	A	Jan 2004	Maintenance Release based on 05K (not formally released). Prevents compressed disturbance recorder stalling. Prevent a maintenance record when reading from an inaccessible modbus register	V2.0 or Later	TG8613B
05	M	A	Jun 2004	Maintenance Release based on 05L. Improved Self-checking of Analogue data acquisition. Improved self checking of SRAM. Reception of modbus frame improved. Rejection of spurious messages injected onto RS485 network improved. Permissive Intertrip in dual redundant schemes corrected	V2.0 or Later	TG8613B

Software Version		Hard-ware Suffix	Original Date of Issue	Description of Changes	S1 Compa-tibility	Technical Document-ation
Major	Minor					
11	A	B	Sep 2001	GPS synchronisation for P545 & P546. Flexible intertripping. Event Optimisation & Filtering. Watt Hour Measurement Change. Addition of digital opto filtering control. Increase in protection signalling address to 20. DDB increased in size to 1022. Support for universal optos (Model number suffix B). Internal loopback added. Restore defaults now restores DNP3 cells correctly. Prevent non DNP3 builds generating fatal error when S1 request DNP3 upload. Modbus enabling/disabling of IRIG-B improved. Courier/modbus event bit functionality corrected. Rear port address setting improvement. Improving read key functionality in the presence of alarm. Prevented software errors from clearing event log. Unextracted Disturbance records now set the courier status flag on power up. Added support for modbus function code 7. Corrected the modbus status bit 0. Changes to OTEV bit in the Status of Fault in IEC60870-5-103. PSL version history reference identifier added. Reset LEDs DDB name change. Change to line length of fault locator. Control inputs added. Changes to capacitive charging current compensation in P544 & P546. Minor changes to IDMT characteristics. Added a 1s drop off timer to C Diff inhibit. Changed max value of Char mod timer to 2s Increased number of PSL timers to 16 (all models). Added a setting to P543/5 AR to select which edge of trip initiates AR. Added 3 DDB signals to block distance. Removed force 3 pole trip DDB. DNP & modbus address are compatible but there are several new ones. Software is not compatible with previous software (signalling message). Distance. Directional line now inclined at –30 degrees and +150 degrees on polar plot (previously perpendicular to line impedance angle). Power swing blocking. Unblocking for faults during power swing now selectable in PSL (default uses I2 unblocking to match phase 1). Power swing blocking logic improved. Enhancements to IEC60870-5-103 builds to add disturbance recorder, private codes and monitor blocking. Not recommend upgrading to software 11G or later	V2.03 or later	P54x/EN x/D11
11	B	B	Oct 2001	Modified the co-processor start-up routine to work with alternative types of SRAM. Improved response to a CS103 poll class 1 when monitor blocked was active. Resolved a time alignment problem which resulted in C Diff failure Alarms being raised. Corrected some modbus address for P545 & P546. Fixed a problem with the relays response to modbus commands read coils and read inputs. Fixed an incorrect response to a DNP3.0 command. Not recommended upgrading to 11G or later	V2.03 or Later	P54x/EN x/D11
11	C	B	Dec 2001	Voltage and power measurements in CS103 build now marked as invalid. Fixed a problem in P544 & P546 where the SEF current measurement was incorrect when set to 1A & 60Hz. Not recommended upgrading to software 11G or later	V2.03 or later	P54x/EN x/D11

Software Version		Hard-ware Suffix	Original Date of Issue	Description of Changes	S1 Compa-tibility	Technical Document-ation
Major	Minor					
11	D	B	Jan 2002	Resolved possible reboot caused by Disturbance Recorder. Resolved possible reboot caused by invalid modbus requests. Resolved problem when internal loopback was selected with external clocks. Resolved a problem which caused the loss of IEC60870-5-103 class 1 messages. Not recommended upgrading to 11G or later	V2.03 or later	P54x/EN X/D11
11	E	B	Oct 2002	Resolved incorrect operation of C Diff Failure Alarm in 3 terminal schemes. Correct operation of Capacitive Charging Current Compensation on 3 terminal schemes. Resolved problem which caused short duration GPS Failure Alarms. Recommended upgrading to 11G or later	V2.03 or later	P54x/En x/D11
11	F	B	Feb 2003	Resolved several problems related to the IEC 60870-5-103 protocol. Resolved problem with resample timer on microprocessor. Corrected the format used to display frequency over the modbus interface. Not recommended upgrading to 11G or later.	V2.03 or later	P54x/EN x/D11
11	G	B	May 2003	Changes to clock recovery circuits to improve operation with mutliplexers. PSL logic for user defined intertrips corrected P545 & P546. Permissive intertrip in dual redundant schemes corrected. Prevented unwanted Comms Delay Alarms	V2.03 or later	P54x/EN x/D11
11	H	B	Sept 2003	Prevents compressed disturbance recorder stalling. Prevents CS103 reporting more non-compressed disturbance records than actually present.	V2.03 or later	P54x/EN x/D11
11	I	B	Oct 2004	All builds released to production. Based on 11G software. Improved Self-checking of Analogue data acquisition. Differential Intertrip in IEC60870-5-103 reported with correct FAN. SRAM self checking added to co-processor board. Reception of modbus frame improved. Rejection of spurious messages injected onto RS485 network improved. Improved self checking of SRAM. Fixed an incorrect response of the summertime time bit in IEC60870-5-103 protocol. Prevented incorrect behaviour of P545/P546 when one relay is energised when there is noise on the signalling channel. Status of local GPS reported incorrectly in dual redundant schemes. Setting “Char Mod Time” was missing on P541- P544. Prevent a maintenance record when reading from an inaccessible modbus register. Prevents relay crashing when phase 2 software used with phase 1 optos. Cell 0709 now replies OK Change	V2.03 or Later	P54x/EN x/D11

Software Version		Hard-ware Suffix	Original Date of Issue	Description of Changes	S1 Compa-tibility	Technical Document-ation
Major	Minor					
12	B	B	Mar 2002	2nd Rear Communications supported. Alarms increased to 64 with user programmable alarms. Enhancements and corrections to CS103. Suppression of certain events in power up. French language text improvements. Prevent a maintenance record when reading from an inaccessible modbus register. Setting “Char Mod Time” was missing on P541-P544. Cell 0709 corrected. Does not have Maximum pre-trigger time for Disturbance recorder in IEC870-103-5 builds reduced, to allow extraction via rear port. Resolved incorrect operation of C Diff Failure Alarm in 3 terminal schemes. Correct operation of Capactive Charging Current Compensation in 3 terminal schemes Resolved problem which caused short duration GPS Failure Alarms. Resolved problem selecting setting via optos. Resolved a Circuit Breaker Lockout problem. Corrected the thermal measurement displayed when thermal protection is disabled. Failure Alarms. Resolved problem selecting setting via optos. Resolved a Circuit Breaker Lockout problem. Corrected the thermal measurement displayed when thermal protection is disabled. Spanish text for user defined alarms contained an extra letter. Blocked overcurrent elements now generate events. Correct DNP3 operation of object 10. Resolved problem with P541 & P542 IEC60870-5-103 builds not running. Resolved a problem with IEC60870-5-103 class 1 polling. Resolved a problem with IEC60870-5-103 ASDU2 events which occurred prior to a start event. Correct the format used to display frequency over the modbus interface. Resolved problem related to incorrect CB trip/close commands via Modbus being accepted when not selected. Resolved a problem which prevented protection setting being saved after control and support setting had been saved. Corrected the saving of Fault Locator settings in groups 2, 3, 7, 4 when made via user interface. Added object 10 to DNP3 class 0 poll. Corrected the way DNP3 handled the season bit in the time & date. Not Recommended upgrading to 12D or later	V2.05 or later	P54x/EN x/E21
12	C	B	Mar 2003	Resolved several problems related to the IEC 60870-5-103 protocol. Resolved problem with resample timer on microprocessor. Improved self diagnostics relating to input module clock. Modified courier block transfer mechanism so it can handle more than 255 blocks. Intermittent loss of data from 2nd rear comms port corrected. PSL logic for user defined intertrips corrected P545 & P546. Permissive Intertrip in dual redundant schemes corrected. Not recommended upgrading to 12D or later	V2.05 or later	P54x/EN x/E21
12	D	B	Jun 2003	Changes to clock recovery circuits to improve operation with multiplexers. Prevented unwanted Comms Delay Alarms	V2.05 or later	P54x/EN x/E21
12	E	B	Sept 2003	Prevents compressed disturbance recorder stalling. Correction to operation of Reset Relays / LEDs opto. Prevents CS103 reporting more non-compressed disturbance records than actually present.	V2.05 or later	P54x/EN x/E21
12	F	B	Jun 2004	Not released to production. Supplied to one customer. Based on 12E software. Improved Self-checking of Analogue data acquisition. Differential Intertrip in IEC60870-5-103 reported with correct FAN	V2.05 or Later	P54x/EN x/E21

Software Version		Hard-ware Suffix	Original Date of Issue	Description of Changes	S1 Compa-tibility	Technical Document-ation
Major	Minor					
12	G	B	Oct 2004	All builds released to production. Based on 12E software. Improved Self-checking of Analogue data acquisition. Differential Intertrip in IEC60870-5-103 reported with correct FAN. SRAM self checking added to co-processor board. Reception of modbus frame improved. Rejection of spurious messages injected onto RS485 network improved. Improved self checking of SRAM. Fixed an incorrect response of the summertime time bit in IEC60870-5-103 protocol. Prevented incorrect behaviour of P545/P546 when one relay is energised when there is noise on the signalling channel. Status of local GPS reported incorrectly in dual redundant schemes	V2.05 or Later	P54x/EN x/E21
13	A	B	April 2004	All builds released to production. Based on 12E software. Control inputs enhancements including non-volatile, latched, pulsed and support for DNP3 pulsed. Enhanced DNP3. Distance Residual compensation angle range extended. Display of number of good messages via modbus is corrected. Prevented DNP3 time sync causes relay to reboot when IRIG-B is active. Improved self-checking of analogue data acquisition. Improved self-checking of SRAM. Added TRIP & ALARM to modbus status word. Addition of MODBUS only setting to allow transmission of IEC time format in reverse IEC byte order. Reception of modbus frame improved. Rejection of spurious messages injected onto RS485 network improved. Handling of FAN in IEC60870-5-103 improved. Differential Intertrip in IEC60870-5-103 reported with correct FAN	V2.10 or later	P54x/EN x/E21
13	B	B	Aug 2004	All builds released to production. Based on 13A software. SRAM self checking added to co-processor board. Fault location & cumulative broken current measurements reported over dnp3. Accuracy of modbus time sync improved. Invalid modbus register 4x00966 removed. Reception of modbus frame improved	V2.10 or Later DNP3 files different to 13A	P54x/EN x/E21
13	C	B	Oct 2004	All builds released to production. Based on 13B software. Resolved a problem relating to co-processor SRAM checking. Fixed an incorrect response of the summertime time bit in IEC60870-5-103 protocol. Prevented incorrect behaviour of P545/P546 when one relay is energised when there is noise on the signalling channel. Status of local GPS reported incorrectly in dual redundant schemes	V2.10 or Later DNP3 files different to 13A	P54x/EN x/E21

Software Version		Hard-ware Suffix	Original Date of Issue	Description of Changes	S1 Compa-tibility	Technical Document-ation
Major	Minor					
20	E	G	Oct 2002	All builds released to production – runs on phase 2 processor board. Based on 12B. UCA2 option added. Added Fault Location . Added TRIP and ALARM to modbus status word. Distance direction setting added. Distance residual compensation angle range extended. Password status indicated on DDBs. Improvements to Autoreclose. Alarms increased to 96. Russian text added. Disturbance recorder sampling rate increased to 24 samples per cycle and changed to non compressed design. IDMT IEEE curves corrected. Corrected the response to courier SEND EVENT. Improved self diagnostics relating to input module clock. Removed the setting for IEC60870-5-103 over fibre when hardware not present. Resolved problem related to CB trip/close commands via Modbus being accepted when not selected. Corrected the saving of Fault locator settings in groups 2, 3, 7, 4 when made via user interface. Added object 10 to DNP3 class 0 poll. Corrected the way DNP3 handled the season bit in the time & date. Enhanced Check Synchronisation feature. Control inputs enhancements including non-volatile, latched, pulsed and support for DNP3 pulsed. Resolved several problems related to the IEC60870-5-103 protocol. Resolved problem with resample timer on microprocessor. Improved self diagnostics relating to input module clock. PSL logic for user defined intertrips corrected P545 & P546. Operation of manual reset alarms corrected. CB Control via hot keys. Changes to clock recovery circuits to improve operation with multiplexers. Prevented unwanted Comms Delay Alarms. Alarms handled better in CS103 GI. Time synchronisation via opto added. Platform Alarms copied to DDB. Correction to operation of Reset Relays / LEDs opto. Backup protection run if co-processor fails to start up on power on. Correction to cell OB25	V2.09 or later	P54x/EN x/F32
20	F	G	Feb 2004	Release to production. UCA2: Increase Max. pending requests & Max. Connected clients . Enhanced DNP3. Prevented DNP3 time sync causes relay to reboot when IRIG-B is active. Corrected cause of transmission which may be returned for “fault location”. Prevents relay rebooting during EMC ANSI Fast transient and IEC high frequency. A number of bug fixes relating to CPU2	V2.09 or later	P54x/EN x/F32

Software Version		Hard-ware Suffix	Original Date of Issue	Description of Changes	S1 Compa-tibility	Technical Document-ation
Major	Minor					
20	G	G	Jun 2004	Release to production. Prevented repeated downloads of GSL files without Ethernet card restart rebooting Ethernet card. Correction to uploading of Disturbance Records over UCA2. Corrected operation of ethernet card link LED for 10 Base-FL. Closed UCA2 association after 'dirty' client disconnection. Made UAC2 Disturbance Record directory service compatible with PACiS. Improved Self-checking of Analogue data acquisition. Handling of FAN in IEC60870-5-103 improved. Differential intertrip in IEC60870-5-103 reported with correct FAN. Prevented C Diff Fail alarm occurs before Signaling Fail alarm for loss of communications. Improved self checking of SRAM	V2.09 or later	P54x/EN x/G42
20	H	G	Oct 2005	Release to Production. Based on 20G software. SRAM self checking added to co-processor board. Fixed an incorrect response of the summertime time bit in IEC60870-5-103 protocol. Prevented incorrect behaviour of P545/P546 when one relay is energised when there is noise on the signalling channel. Status of local GPS reported incorrectly in dual redundant schemes. Accuracy of modbus time sync improved. Fixed an incorrect response of the summertime time bit in IEC60870-5-103 protocol. Prevented Ethernet card restarting after approximately 20 hours when no connection made. Improvements to time sync for Courier, CS103 and DNP3. Invalid modbus register 4x00966 removed	V2.09 or later	P54x/EN x/G42
20	I	G	Nov 2004	Release to Production. Based on 20G software. Display of No. Valid messages on LCD corrected. Operation of CB Maintenance alarm corrected. Corrections to allow Extended Courier characters to be used in string setting cells for Courier and Modbus. Corrected default display of neutral current for 5A CTs. Prevented a reboot for modbus versions during event extraction when messages where close together. Correction to prevent the 2nd rear comms locking up	V2.09 or later	P54x/EN x/G42

Software Version		Hard-ware Suffix	Original Date of Issue	Description of Changes	S1 Compa-tibility	Technical Document-ation
Major	Minor					
30	C	J	Nov 2004	Released to production, Based on 20G. Interface to Optical Multiplexer (IEEE standard C37.94). SRAM checking in Co-processor. Dual range optos. AREVA Livery & software changes. Extended Residual angle in fault locator to match Distance. Rename GOOSE signals in line with P443. Add virtual signals, control inputs & user alarms to DR in line with P443. Relay settings shall be stored in FLASH EEPROM instead of EEPROM memory. Extend Range of Time Dial to line up with P140. Accuracy of modbus time sync improved. Invalid modbus register 4x00966 removed. Improvements to time sync for Courier, CS103 and DNP3. Addition of MODBUS only time and Date format setting to common Courier settings for access from the other interfaces. Vector group compensations for YY2 and YY10 corrected. Prevented Ethernet card restarting after approximately 20 hours when no connection made. Prevented incorrect behaviour of P545/P546 when one relay is energised when there is noise on the signalling channel. Courier, Modbus & DNP3 communications over Fibre added. Display of No. Valid messages on LCD corrected. Operation of CB Maintenance alarm corrected. Some text in autoreclose column made consistent with that in overcurrent column. Improvements to VTS and Autoreclose in single pole tripping applications. Corrections to allow Extended Courier characters to be used in string setting cells for Courier and Modbus. Fixed an incorrect response of the summertime time bit in IEC60870-5-103 protocol. Corrected reporting of local GPS fail in dual redundant schemes. Corrected default display of neutral current for 5A CTs. Prevented a reboot for dnp3 versions when control & support settings are changed rapidly. Prevented a reboot for modbus versions during event extraction when messages where close together. Correction to prevent the 2nd rear comms locking up. Changes to co-processor start-up to eliminate a timing problem	V2.11 or Later	P54x/EN x/H53
30	D	J	Dec 2004	Released to Production, Based on 30C. Improvements to operation when subjected to multiple communication switches when operating in non-GPS mode.	V2.11 or Later	P54x/EN x/H53
30	D	J	Aug 2012	Previously this was issued as two separate manuals, namely: Operation Guide (P54x/EN O/H53) and Technical Guide (P54x/EN T/H53). These have been combined into a new single volume Technical Manual (P54x/EN M/H53) which only covers P541 and P542 products. Some information has been transferred between chapters (mainly between chapters 1. Introduction and 3. Getting Started). Some chapters have been renamed - for details, please see Chapter 1. Additional material has been added to chapter 7. Programmable Scheme Logic. Data has been copied from the Relay Menu Database (P54x/EN MD/H53) into chapter 4. Settings. Generic chapters (which are used across several MiCOM products) have been used to replace some chapters (Safety Information, 11. Maintenance, 12. Troubleshooting and 14. Symbols & Glossary). Information relating only to Product Numbers P543, P544, P546. P546 & P594 has been removed from this manual.	V2.11 or Later	P54x/EN M/H53

Table 1 - Version history

2 SETTING FILE AND RELAY SOFTWARE VERSION

Setting File Software Version	Relay Software Version												
	01	02	03	04	05	07	11	12	13	14	15	20	30
01	✓	×	×	×	×	×	×	×	×	×	×	×	×
02	×	✓	×	×	×	×	×	×	×	×	×	×	×
03	×	×	✓	1	×	×	×	×	×	×	×	×	×
04	×	×	×	✓	2	2	×	×	×	×	×	×	×
05	×	×	×	×	✓	✓	×	×	×	×	×	×	×
07	×	×	×	×	✓	✓	×	×	×	×	×	2	×
11	×	×	×	×	×	×	✓	✓	2	2	×	2	×
12	×	×	×	×	×	×	✓	✓	2	2	×	2	×
13	×	×	×	×	×	×	✓	✓	✓	2	×	2	×
14	×	×	×	×	×	×	×	×	×	✓	×	×	×
15	×	×	×	×	×	×	×	×	×	×	✓	×	×
20	×	×	×	×	×	×	×	×	×	×	×	✓	3
30	×	×	×	×	×	×	×	×	×	×	×	×	✓

1 Compatible except for Disturbance recorder digital channel selection.
2 Additional functionality added such that's setting files from earlier software versions will need additional settings to be made.
3 Compatible except for Disturbance recorder digital channel selection & settings for additional functionality will be missing.

Table 2 - Setting File and Relay Software Version

3 PSL FILE AND RELAY SOFTWARE VERSION

PSL File Software Version	Relay Software Version												
	01	**02**	**03**	**04**	**05**	**07**	**11**	**12**	**13**	**14**	**15**	**20**	**30**
01	✓	×	×	×	×	×	×	×	×	×	×	×	×
02	×	✓	×	×	×	×	×	×	×	×	×	×	×
03	×	×	✓	×	×	×	×	×	×	×	×	×	×
04	×	×	×	✓	×	×	×	×	×	×	×	×	×
05	×	×	×	×	✓	1	×	×	×	×	×	×	×
07	×	×	×	×	×	✓	×	×	×	×	×	×	×
11	×	×	×	×	×	×	✓	✓	✓	×	×	1	1
12	×	×	×	×	×	×	×	✓	✓	×	×	1	1
13	×	×	×	×	×	×	×	×	✓	×	×	1	1
14	×	×	×	×	×	×	×	×	×	✓	×	×	×
15	×	×	×	×	×	×	×	×	×	×	✓	×	×
20	×	×	×	×	×	×	×	×	×	×	×	✓	1
30	×	×	×	×	×	×	×	×	×	×	×	×	✓
1	Additional DDBs were added such that PSL files from earlier software versions will not be able to access them.												

Table 3 - PSL File and Relay Software Version

4 MENU TEXT FILE SOFTWARE VERSION AND RELAY SOFTWARE VERSION

Menu Text File Software Version	Relay Software Version												
	01	02	03	04	05	07	11	12	13	14	15	20	30
01	✓	×	×	×	×	×	×	×	×	×	×	×	×
02	×	✓	×	×	×	×	×	×	×	×	×	×	×
03	×	×	✓	×	×	×	×	×	×	×	×	×	×
04	×	×	×	✓	×	×	×	×	×	×	×	×	×
05	×	×	×	×	✓	✓	×	×	×	×	×	×	×
07	×	×	×	×	✓	✓	×	×	×	×	×	×	×
11	×	×	×	×	×	×	✓	×	×	×	×	×	×
12	×	×	×	×	×	×	×	✓	×	×	×	×	×
13	×	×	×	×	×	×	×	×	✓	×	×	×	×
14	×	×	×	×	×	×	×	×	×	✓	×	×	×
15	×	×	×	×	×	×	×	×	×	×	✓	×	×
20	×	×	×	×	×	×	×	×	×	×	×	✓	×
30	×	×	×	×	×	×	×	×	×	×	×	×	✓
Menu text remains compatible within each software version but is NOT compatible across different versions.													

Table 4 - Menu Text File Software Version and Relay Software Version

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Publisher: Schneider Electric

Publication: P54x/EN M/H53 Software Version: 30 Hardware Suffix: J

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