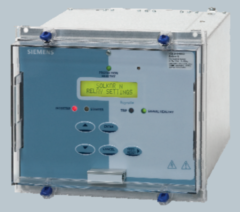

Reyrolle
Protection
Devices

7SG18 Solkor N

Numeric Differential Protection

Answers for energy

SIEMENS

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Technical Manual Chapters

7SG18 Solkor N

Numeric Differential Protection

Document Release History

This document is issue 2010/02. The list of revisions up to and including this issue is:
Pre release

2010/02	Document reformat due to rebrand

Software Revision History

19/04/2005	2646H80006R5	

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Reference Material

[1] - REYDISP EVOLUTION : is a PC based relay support package which allows local or remote access to relays for uploading settings, downloading event and disturbance records, reading real-time data and allowing control of plant. The package is available and is compatible with these relays.

[2] - INFORMATIVE COMMUNICATIONS INTERFACE : a report detailing all aspects of the communications protocol used in these relays is available from Siemens. The report reference is 434TM05B.

List of Symbols

I_L	Local current
I_R	Remote current
I_S	Differential Current setting
Ires	Restraint current
I_D	Differential current
ThsM	Differential magnitude threshold
ThsA	Differential angle threshold
B_2	Bias Break Point (defines beginning bias slope 2)
S_1	Bias slope 1
S_2	Bias slope 2

1 Introduction

This series of Current Differential relays are numerical, multi-function devices, which have been designed to be applied for the protection of two terminal overhead line and cable feeders. The relay may be used on generation, transmission, distribution or industrial power systems. The end to end signal can be via several types of fibre-optic, RS485 cable or twisted pair pilotwire.

This series of Current Differential relays are part of the comprehensive range of Argus-platform based numeric relays. These relays have extensive control functions, which are supplemented by advanced metering, data storage and fibre optic communications. Supervisory and self-monitoring features give added confidence to the user as well as reduced maintenance and down time. A menu-based interface gives user-friendly access to relay settings, meters and operational data.

The relay includes backup over current and earth fault protection. The relay may be set to have this backup protection in service permanently or only when a protection signal disturbance is detected by the relay.

The relay conforms to the relevant IEC 60255 standards.

Current differential elements:

In principle, current differential protection works by monitoring currents entering and leaving the protected zone. On a healthy feeder, these should be equal and opposite (assuming current flow out of a terminal to be negative). Any difference equates to current lost within the protected zone. Fault conditions generally cause high differential currents. Low levels of differential current can exist on a healthy feeder caused by capacitive current shunted off along its length, or low-level tapped loads. Generally, the difference between a fault current and any standing differential is large. Also, a large step change occurs in differential current as a fault crosses the zone boundary defined by the geographic location of the line CTs. An internal fault can therefore be detected accurately with a Go / No-Go detector which does not require great accuracy in its self.

This protection is designed to work within the limitations of an asynchronous digital communication channel for its end-to-end current information exchange. As such, the protection has to work with low data rates. This involves minimising the content of each current sample and minimising the rate at which they are transmitted, consistent with acceptable protection performance.

Intertripping elements:

The relay has three independent intertripping channels. One of the intertrip channels is an internal intertrip channel and is dedicated to the differential protection. The other two channels are external intertrip channels and are independent of the differential protection. These may be used for inhibits, intertrips, operation tripping or protection signals used in distance protection schemes.

The transmission or reception of an intertrip command can be inhibited by the use of a status input.

Overcurrent elements:

The relay has three phase fault and one earth fault overcurrent characteristic elements.

These elements have a programmable pick-up level, characteristic, time multiplier and time delay and can be inhibited via a status input or when the protection signalling channel is healthy. The programmable characteristics consist of four IDMTL (inverse definite minimum time lag) curves, NI, VI, EI, LTI, and one DTL (definite time lag) timer.

These elements may be assigned as guard relays for the differential protection. For the majority of applications the use of over current and earth fault guards is not recommended as the relay automatically supervises the protection signalling channel and automatically blocks the differential protection when its loss is detected. For longer feeders the instantaneous over current may be used to trip very fast for close up internal phase faults. Its use and setting will depend upon the relative feeder and source impedances.

Lowset elements:

The relay has three phase fault lowset and one earth fault lowset elements. These elements have a programmable pick-up level and time delay and can be inhibited via a status input or when the protection signalling channel is healthy.

These elements can also be assigned as guard relays for the differential protection.

Highset elements:

The relay has six Phase Fault (P/F) and two Earth Fault (E/F) Highset elements. These are grouped and designated as follows:

Highset 1 comprising 3 PF + 1 EF

Highset 2 comprising 3 PF + 1 EF

These elements have a programmable pick-up level and time delay and can be inhibited via a status input or when the protection signalling channel is healthy.

These elements may also be assigned as guard relays for the differential protection. These lowest and highest elements may be set as instantaneous or definite time delayed (DTL).

2 Hardware Description

2.1 General

All types of these relays share common hardware components and modules with the Argus range. The design for the mechanical arrangement of the relays has been carefully chosen to provide a high level of EMI screening using multi-layer PCB's with ground planes, RFI suppression components and earthed metal screens. The internal arrangement has been divided into noisy and quiet areas in order to improve noise immunity and reduce RFI emissions. The only direct connection from the quiet components to the external environment is via the optical serial communications interface, which is immune to radiated or conducted interference.

2.2 Output Relays

The relays have 7 physical output contacts that are fully user configurable and can be programmed to operate from any or all of the protection functions. In addition, a watchdog feature within the relay can be mapped to any of the output relays. The normally closed contact of one of the three changeover outputs is generally required for this.

All output relays are of the same design, all capable of handling direct circuit breaker-tripping duty.

In addition to the physical output contacts, a virtual output contact is provided for use as a guard relay. This allows any element to control the guard function of the relay and does not require any external wiring to the relay.

In their normal mode of operation, output relays, including the virtual guard relay, will remain energised for a minimum user programmable delay. By default this is 100msec. If required, however, outputs can be programmed to operate as latching relays. These latched outputs can be reset by either pressing the TEST/RESET button, by energising a status input, or by sending an appropriate IEC60870-5-105 communications command.

A trip test feature is provided to exercise the output contacts.

For a list of terminal numbers and their usage see Table 1.

2.3 Status Inputs

Standard four pole relays have 1 status input. An expansion card can provide an extra 8 status inputs giving a total of 9.

All status inputs are fully user programmable and each has a pick-up and drop-off timer. These timers allow software filtering to be applied, which provides security in the presence of any induced A.C. voltages in the external wiring. The default pickup timer of 20ms provides extra immunity to a.c. pickup on dc scheme wiring. If high-speed operation is required, then the pick-up delay should be set to zero.

Each of the status inputs can be programmed to perform one of the following functions:

- Initiate the External Inter-trip.
- Provide Trip Circuit Supervision
- Inhibit operation of any one or more protection functions.
- Select an alternative settings group.
- Trigger storage of a waveform record.
- Synchronise the real-time clock.
- Reset latched output relays.
- Energise an output relay.
- Raise a user definable alarm string that is scrolled across the LCD display.

Additionally, each status input can have its operating logic inverted with the Status Invert feature. This allows normally open or normally closed contacts to drive the status inputs.

For a list of terminal numbers and their usage see Table 1.

2.4 Self Monitoring

The relay incorporates a number of self-monitoring features. Each of these features can initiate a controlled reset sequence, which can be used to generate an alarm output. In addition, the Protection Healthy LED will give visual indication.

A watchdog timer continuously monitors the microprocessor and the relay program memory is continuously checked for data corruption using a cyclic redundancy check (CRC) routine. The internal voltage supply rails are also continuously supervised and the microprocessor is reset if any of the rails are detected outside their working ranges. Any failure is detected in sufficient time for the microprocessor to shut down in a safe and controlled manner.

2.5 Measuring Principles

The input phase currents to the relay are passed through current transformers, which step down the phase currents to levels suitable for the electronic input stage of the relay. The transformers have balanced outputs which are lowpass filtered and fed into a differential amplifier. This provides excellent common mode and high frequency noise rejection. The single ended output from the differential amplifier feeds into a switched gain amplifier and then into an Analogue to Digital Converter (ADC) for sampling. The switched gain adjusts the signal level to give optimum sampling resolution, and increases the effective dynamic range of the ADC.

The main current measuring algorithm for the differential protection is a Discrete Fourier Transform (DFT). This extracts the fundamental power frequency component and attenuates d.c. and harmonic components. The DFT output is not a sine wave, but a pair of scalar (d.c.) signals representing a phasor in terms of its quadrature Real and Imaginary components. Phasor Magnitude and Angle are derived from these using trigonometrical relationships. The DFT uses 16 samples per cycle over a one-cycle moving window.

The main current measuring algorithm for the overcurrent protection is an RMS calculation, again using 16 samples per cycle over a one-cycle moving window.

All relays are fully calibrated during manufacture using an accurate current source. Calibration coefficients are stored in EEPROM and are used by the processor to compensate for any inaccuracies in the input stage, which have been introduced by the analogue circuits. Errors in magnitude and phase are eliminated using this method.

3 Protection Functions

3.1 Differential Element

This relay uses a combination of both phase and magnitude differential comparison to determine operation.

The differential element takes a sampled version of the instantaneous current waveform as its local input and compares it with a corresponding current from the remote end. The signal is converted to magnitude and angle information for comparison

The relay is a biased differential protection, whereby the differential threshold is increased with increasing load to accommodate any measuring and CT errors. The bias is a compromise between accommodating errors and spill currents on one hand, while retaining sensitivity to genuine faults on the other. Some of the largest sources of error result in angular errors (e.g. Communications delay, sample synchronisation, capacitive current) whereas low level fault currents tend to be in phase with any through current. Separate limits for angle and magnitude difference allow larger angular errors to be accommodated without sacrificing sensitivity.

A block diagram for a single phase of the differential protection is shown in Figure 1. Differential comparison is performed at each end of the feeder, so an identical algorithm runs in the remote relay. The relay performs a pole by pole magnitude and angle comparison using three separate algorithms, one per phase. A full cycle DFT is used to measure the instantaneous current waveform which gives outputs for magnitude and angle. This phasor information is used in the local differential comparator. An identical copy of the local measurement is sent to the remote end. For transmission, magnitude and angle values are compressed to reduce the number of bits required per sample. At the receiving end the values are expanded back to their original scale. Magnitude compression inherently clips its signal at a maximum limit. The consequence to the protection is linear differential comparison at low fault levels, turning to phase comparison at high fault levels. Since this protection works on each phase individually, the stability angle can be larger than phase comparison schemes using a single summated relaying quantity.

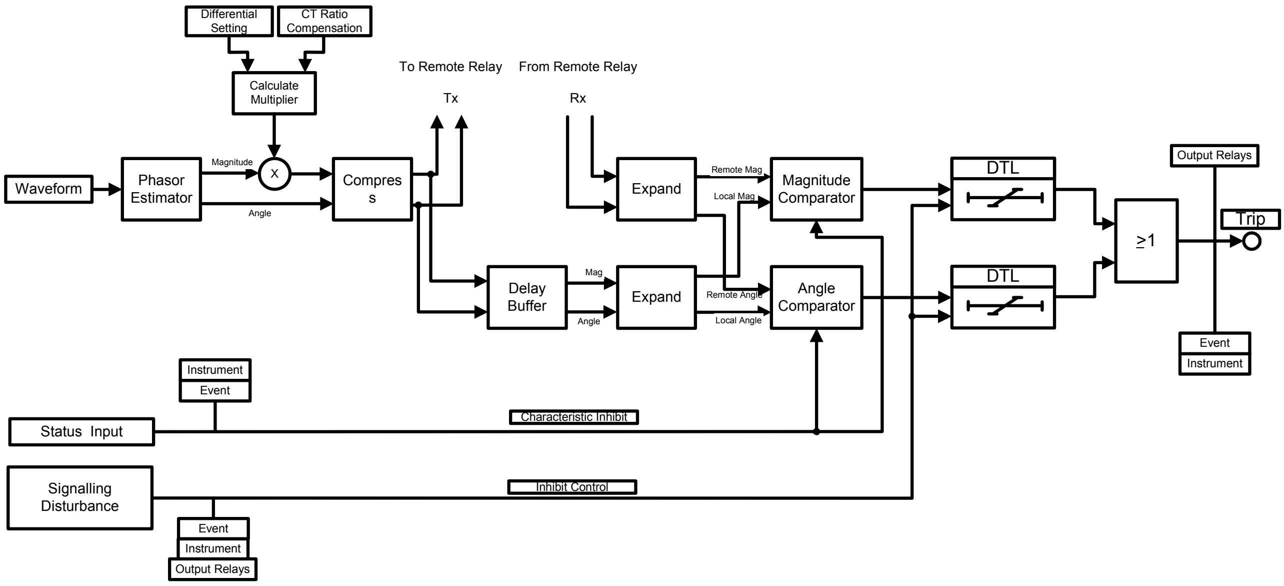


Figure 1 – Differential Protection Element (1 Phase)

The local signal path goes through the same compression / expansion (companding) process as the transmitted path, so that when local and remote currents are compared balance is maintained.

Separate magnitude and angle comparators compare the local and remote phasors and make a tripping decision based on how closely matched they are. For operation, either magnitude *or* angle must exceed the relevant differential threshold.

To improve security in the presence of communication disturbances, CT saturation, or other transient errors, the final tripping decision is based on the comparator's decision made over several samples. A counter is incremented if the comparator operates and decrements if not. If the cumulative count exceeds a set target, the trip command is issued. This target is user selectable allowing a trade-off between security and operate time for onerous conditions such as excessive CT saturation.

If a communications error condition is detected an error signal is raised. As a safeguard against corrupted data causing an unwanted trip, the differential protection count is held on a fleeting occurrence, or reset on a prolonged occurrence.

3.1.1 End To End Synchronisation

The DFTs on each relay work to a common time base. This is achieved by numbering the ADC samples at each end and synchronising them in time. The DFTs at each end start their reference cycles at the same sample number, hence at the same instant.

Transmitted samples are subject to delay inherent in the communication channel, buffering, etc. In addition to synchronising at source, it is also important that the correct samples are matched up for comparison at the receiving end.

When data is transmitted, a sample number goes with it. A copy is stored locally, also tagged with the same sample number. At the receiving end, the sample number associated with the received data is used to retrieve the corresponding local sample from a history buffer. Comparison is therefore done on sets of data originating at the same time, irrespective of transmission delays etc (See Figure 1).

3.1.2 Differential Operation

For operation the following conditions must be met:

The difference between local and remote magnitudes must exceed the magnitude differential threshold.

or

The difference between local and the inverted remote angle must exceed the Angle differential threshold.

Expressed mathematically:

$$|I_L| - |I_R| \geq Ths_M$$

or

$$\arg(I_L) - \arg(I_R + 180°) \geq Ths_A$$

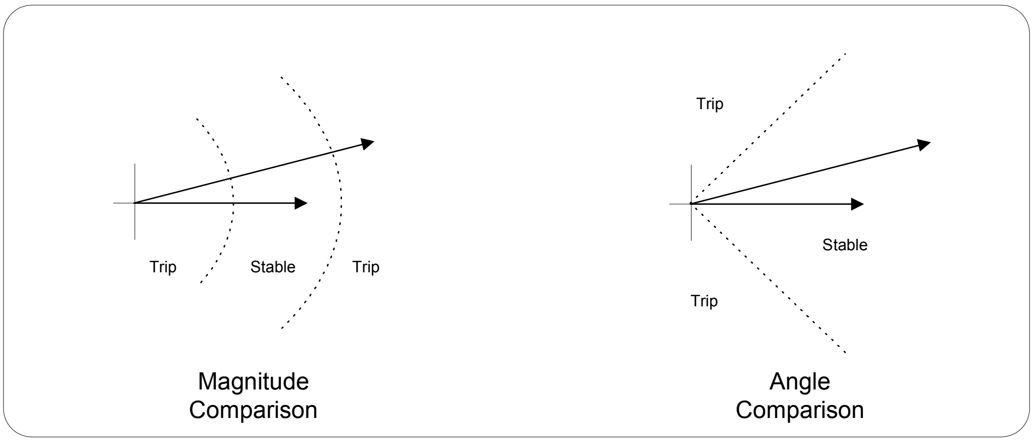


Figure 2 – Magnitude and Angle Comparison

A point of convention: The stable condition shown in the diagrams corresponds to two phasors superimposed, i.e. the reference phasor is in the centre of the stable area. Normal convention regards currents flowing *into* the protected zone as having the same sign, so a balanced (stable) condition has equal and *opposite* currents. If the remote current is taken as reference, then the reference phasor shown in the centre of the stable area is -R.

3.1.3 Biasing

Both magnitude and angle comparators are biased so the overall stable area on the polar plane increases with current magnitude. The same restraining quantity is used for both, derived from the mean scalar current.

$$I_{res} = \left(|I_L| + |I_R| \right) / 2$$

A multi-stage bias is used giving thresholds as follows:

Magnitude Threshold: The operating threshold is given by the equation:

$$\begin{aligned} Ths_M &= I_S & &\text{for } I_{res} < 0.5I_S \\ &= I_S + S_1(I_{res} - 0.5I_S) & &B_2 > I_{res} \geq 0.5I_S \\ &= I_S + S_1(B_2 - 0.5I_S) + S_2(I_{res} - B_2) & &I_{res} \geq B_2 \end{aligned}$$

This is shown graphically in Figure 3. The first stage of bias accommodates proportional errors in the system to maintain a stability margin at least equal to the original differential setting. The second stage of bias accommodates any additional differential current caused by the likes of CT saturation at higher current levels.

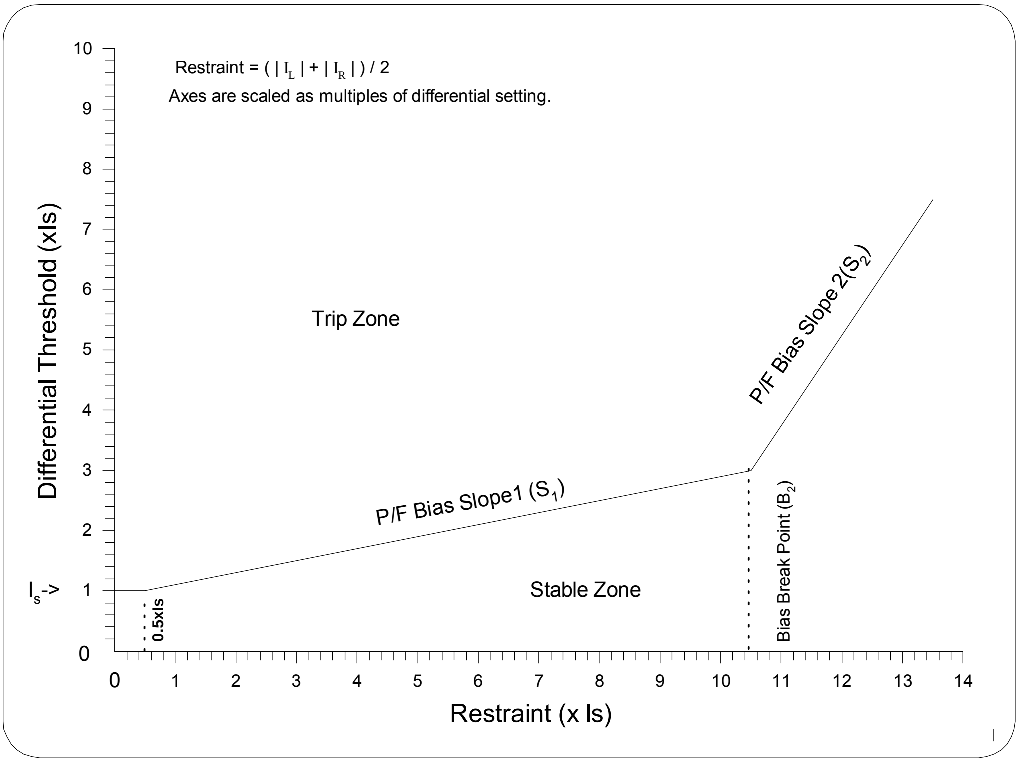


Figure 3 – Magnitude Comparator Bias Characteristic

Settings:

I_S = P/F Differential Setting **S_1 = P/F Bias Slope 1 Setting**

S_2 = P/F Bias Slope 2 Setting **B_2 = Bias Break Point Setting**

Angle Threshold: The operating threshold is given by the equation:

$$Ths_A = \pm 180° \qquad \text{for } I_{res} < 0.5 I_S$$
$$= \pm 45 + Shaping \qquad B2 > I_{res} \geq 0.5 I_S$$
$$= \pm 67.5° \qquad I_{res} \geq B_2$$

Figure 4 shows the bias characteristic graphically. The lowest level of currents for which the protection can correctly operate, result in a restraint of 0.5 Is. Phasor angle measurement becomes inaccurate at very low levels and near zero it can swing full circle. The angle comparator is therefore turned off for restraint current below 0.5Is by giving it a threshold greater than ±180° (i.e. ±200°). Above this, the angle threshold is set to accommodate phase shifts caused by sample synchronisation errors, data compression and whatever margin is required by power system conditions etc. At high current levels, the angular threshold is opened up to accommodate additional phase shifts caused by CT saturation.

Relay software Revision 4 code released in July 2004, altered the phase angle comparator to a shaped characteristic to allow more sensitive differential settings to be used on long cable feeders and hence improve fault detection.

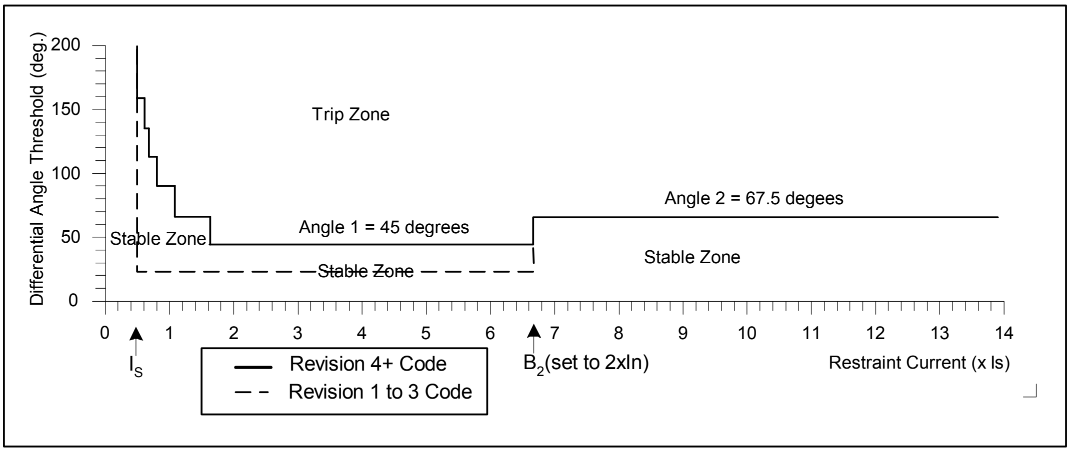


Figure 4 – Angle Comparator Bias Characteristic

Polar diagrams resulting from the combination of these two characteristics are illustrated in Figure 5.

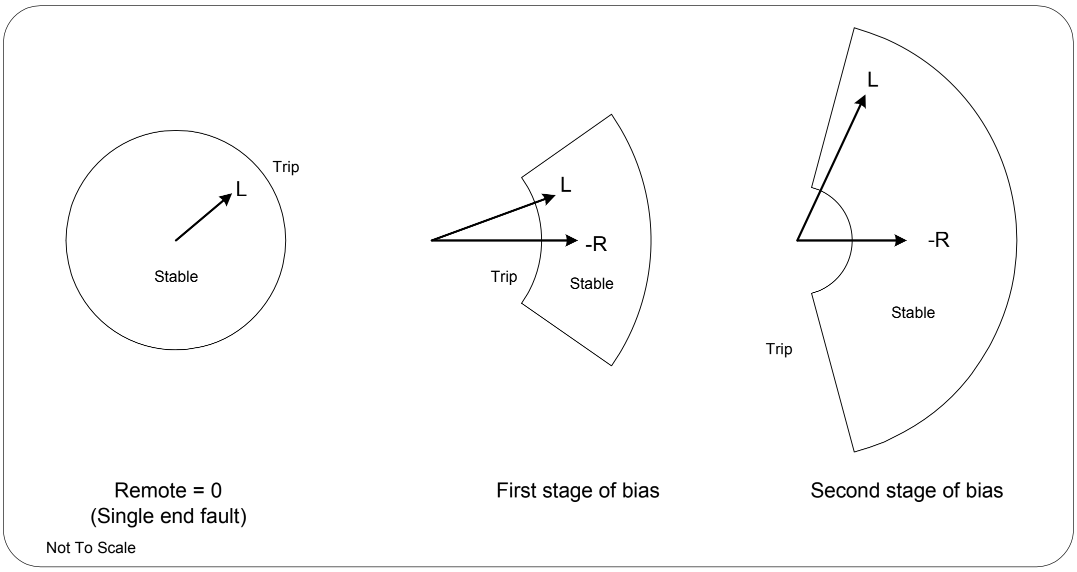


Figure 5 – Overall Polar Characteristic

3.1.4 Trip Decision Processing

If a threshold is exceeded a counter is incremented, otherwise it is decremented. This occurs at each pass of the algorithm. If the count exceeds a set value a trip signal is issued. The trip is made on the outcome of a number of successive comparisons. The output from the magnitude and phase comparitors at each stage, are "OR" gated to assist with tripping with arcing and evolving faults.

This decision period is user adjustable via the "Differential Delay" setting. This is set to zero in most cases. The Differential delay may be used if concern of CB breaking capacity may be compromised, to allow the dc offset component in the fault current to subside, before a trip signal is sent.

The trip decision process can be interrupted in two ways if an alarm or error signal is raised elsewhere:

1) The count can be frozen, i.e. present comparisons are effectively ignored but previous ones retained.

2) The count can be reset, i.e. previous comparisons are dumped and present ones ignored.

The algorithm is processed every 5 ms, therefore each count adds 5 ms to the protection operating time. The overall operating time also includes the response time of the DFT, communications delay, output contacts and any delay incurred transferring data to and from various processor modules in the hardware.

3.1.5 Supervision of the Protection Signalling Channel

The relay software includes several types of error checking (such as scew and parity) in the frames sent and received. The relay provides complete supervision of the channel, and will instantaneously block the differential elements if frames cannot be synchronised due to a loss of the channel for a severed fibre or broken wiring.

This feature may be checked by removing the signalling medium to both relays and applying a simulated internal fault after the Signal Healthy LED has commenced flashing on both relays. The Signal Alarm output contact can be used to indicate a fault in the channel to a remote point. This feature removes the need for over current and earth fault guard elements to supervise a differential trip.

3.2 Intertripping Elements

3.2.1 Internal Intertrip

The internal intertrip is used to ensure both ends of a feeder are cleared if the differential protection is used with a guard qualifying its trip output. (A guard is used when additional security is required, usually against false tripping under difficult communication conditions.) If an internal fault is fed largely from one end, the differential comparators at *both* ends operate identically, but the guard at the low current end may not pick up and the trip will be blocked at this end.

To ensure tripping at both ends, an intertrip is sent if both Differential AND Guard operate. At the receive end, the intertrip output can operate any user selected contact. The additional security provided by the guards is still present as the intertrip only sends if a differential is detected coincidentally with a large current.

3.2.2 External Intertrip

Two external inter-trip channels are provided. These channels are of the Direct Intertrip (Transfer Trip) type and are independent of the differential protection. They are driven from mapped status inputs. At the receiving end, the intertrip output follows the state of the sending end status input. The outputs can independently operate any user selected contact.

An external intertrip can be configured as a permissive type intertrip by connecting its output contact in series with an instantaneous overcurrent contact. Intertrip output is therefore blocked unless local current is present.

3.2.3 Intertrip Operation

When either an internal or external intertrip send command is raised the appropriate bits for that intertrip are set in the data message frame.

After the message has passed security checks at the receive end, a counter is incremented whenever these bits are detected. If the count exceeds a predetermined target value, an intertrip output is issued. This way, making the tripping decision on a number of received messages enhances the system security.

Each intertrip channel has its own count, which also serves as the intertrip delay timer. The target value determines the intertrip delay time, subject to a minimum value required to ensure adequate security. The target values on the two external intertrip timers are derived from the user setting "Ext Intertrip Delay". The target value on the internal intertrip timer is derived from the user setting “Differential Delay”, so it takes on the same delay as the differential element.

3.3 Overcurrent Characteristic Elements

The main overcurrent element can operate with either an Inverse Definite Minimum Time Lag (IDMTL) or a Definite Time Lag (DTL) characteristic. Four IDMT curves are available:

Normal Inverse	(NI)
Very Inverse	(VI)
Extremely Inverse	(EI)
Long Time Inverse	(LTI)

The IDMT algorithms operate correctly for developing faults where current varies with time.

Intermittent or flashing faults are detectable by applying a delayed reset to the overcurrent timer.

These elements can be inhibited using either status inputs or when the protection signalling communications channel is healthy.

There are 3 phase fault overcurrent elements and 1 earth fault overcurrent element.

The output of the element can also be used as a guard relay for the differential protection.

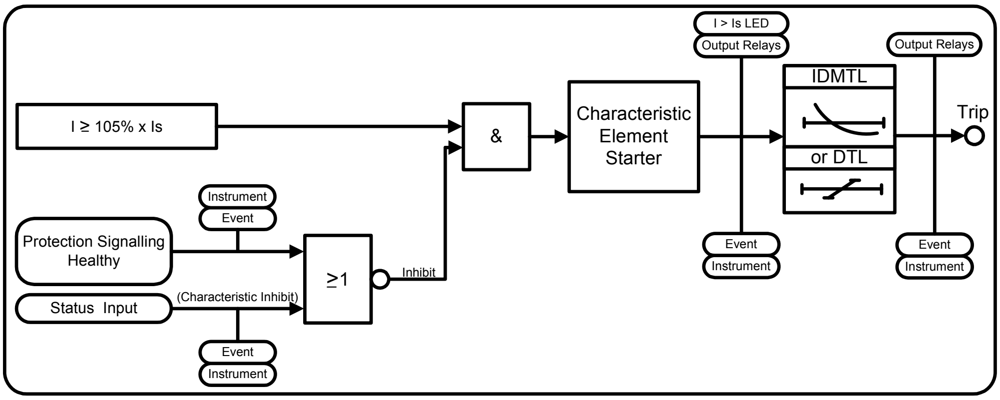


Figure 6 – Overcurrent Characteristic Element

3.4 Lowset Elements

There are three Phase Fault (PF) lowest elements and one Earth Fault (EF) lowset element. These elements have programmable pick-up levels and time delays. They can be inhibited via a status input or when the protection-signalling channel is healthy.

The lowset element consists of a shaped instantaneous starter characteristic followed by a DTL. The instantaneous outputs are designed for transient free operation where high values of system X/R are experienced.

The output of the element can also be used as a guard relay for the differential protection.

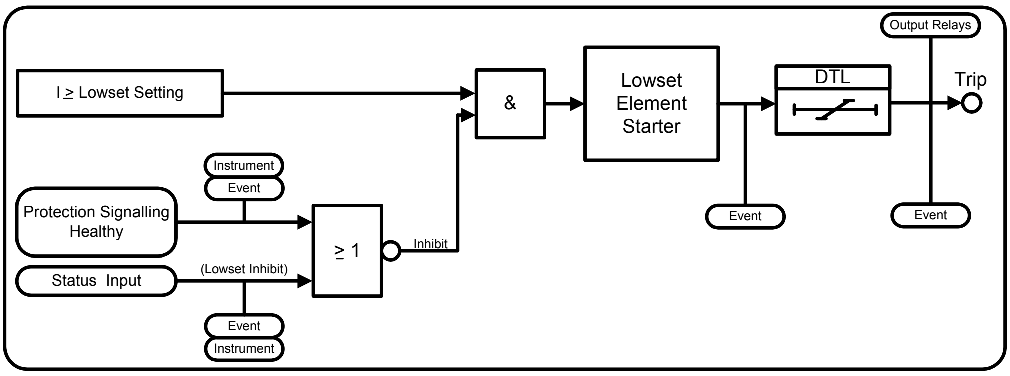


Figure 7 - Lowset Element

3.5 Highset 1 & Highset 2 Elements

There are two sets of Highset elements. Each set comprises three PF Highset elements and one EF Highset element. These have programmable pick-up levels and time delays. They can be inhibited via a status input or when the protection signalling channel is healthy.

All Highset 1 and Highset 2 elements consist of a shaped instantaneous starter characteristic followed by a DTL. The instantaneous outputs are designed for transient free operation where high values of system X/R are experienced. Highset 1 and Highset 2 are independent from one another.

The output of the elements can also be used as a guard relay for the differential protection

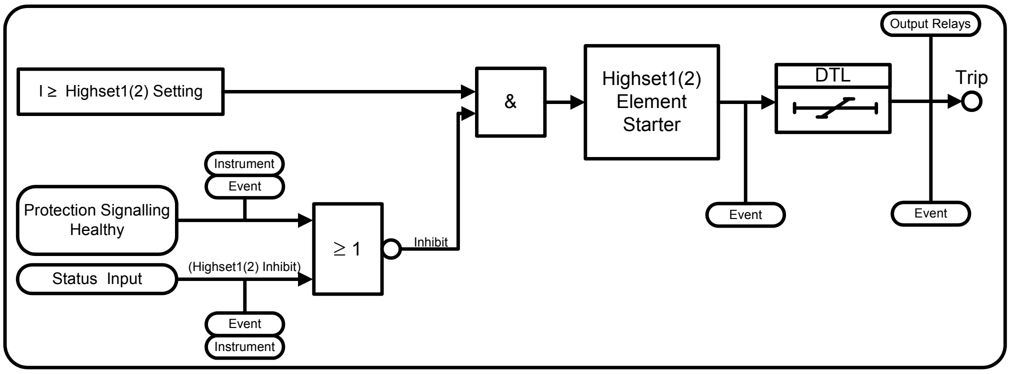


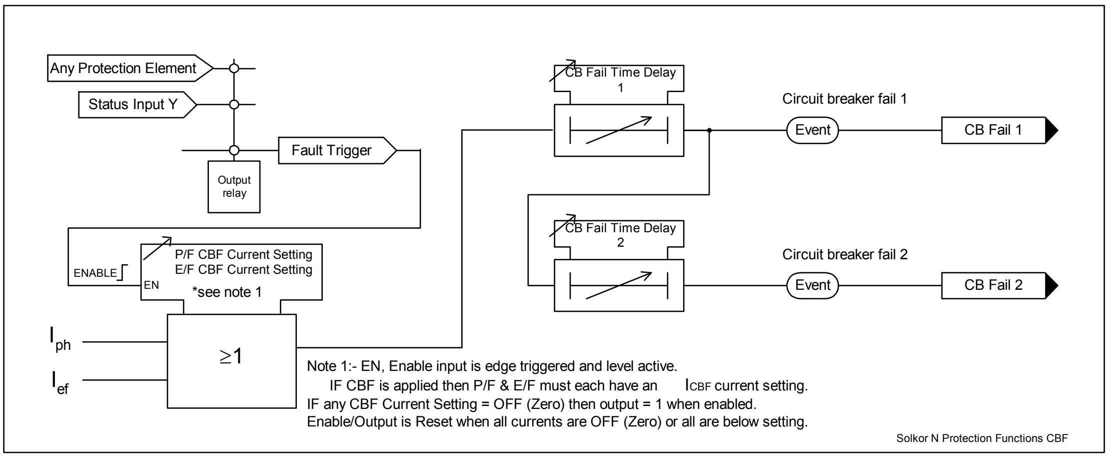
Figure 8 – Highset 1 and Highset 2 Element

3.6 Guard Relay operation

Any of the Highset and Lowset elements may be assigned as guard relays. Generally these guard elements are not required for this relay, as the Signal Loss Detection will block the differential elements if a break in the protection signal channel causes an loss of frame synchronism.

3.7 Circuit Breaker Fail

A two-stage circuit breaker fail timer is provided. CBF timer 1 begins to run following a trip output from any one of the protection algorithms and issues a back-trip output if current is still above setting. CBF timer 2 then begins to run and issues a second back-trip output. The correct operation of the CF Fail depends upon all trip outputs being assigned as “Fault Triggers” in the Wavefrom storage menu. As an additional check the CB Fail Level detectors Provide a means of checking the continuation of the fault current.



An externally triggered CBF initiate, for instance from an external SEF relay, requires a Status input to be mapped to as “Fault Trigger” allocated output contact. When this output operates the CBF level detectors are Enabled.

Figure 9 – Circuit Breaker Fail

3.8 Trip Circuit Supervision

A trip circuit supervision feature is provided within the relay. The relay can monitor its own trip circuit(s) by configuring any one of its status inputs using the ‘Trip Circuit Fail’ setting and connecting the status input(s) into the trip circuit. Indication is then given instantaneously of ‘Trip Circuit Fail’ should a fault be detected and this display also identifies which input has detected the fault. Since the status inputs can be programmed to operate output contacts, an alarm can be also generated from the trip circuit supervision feature.

3.9 CT Supervision

This feature provides detection for a CT becoming disconnected from the relay due to loose or broken wiring. It operation depends upon the relay detecting a one or more phase currents being below the CT Supervision Pickup level and at least one being above for the set CT Supervision time delay setting. If the load is high enough at the point where the CT becomes detached from the relay the magnitude comparator will trip. If a CT supervision elements operates without the load being high enough to operate the relay, a method of blocking the differential protection at both ends of the feeder is possible using one of the external intertrip channels.

3.10 External Tripping

Any status input can be programmed to receive a trip signal from another device. The status input should firstly be mapped to the trip output contact in the Output Configuration Menu, so that energisation of the status input results in a trip signal being issued. If the same trip contact is specified in the ‘Fault trigger’ setting then the relay will switch to the fault data mode and indicate that an external trip has occurred.

4 Other Features

4.1 Circuit Breaker Maintenance

The $\sum I^2$ feature and the trip counter provide circuit breaker condition monitoring. Alarm outputs with programmable settings are available from both features.

All of this information is accessed either from the relay front panel or via the IEC60870-5-103 communications interface.

The values of current used for the $\sum I^2$ are those measured at the time of issuing a trip signal. A $\sum I^2$ is generated for each phase element and the highest value is used for alarm and display purposes.

It is also possible to initiate the $\sum I^2$ algorithm from an external tripping device via a status input if required.

Note: both the trip count and $\sum I^2$ count can be reset when viewing the appropriate instrument screen by pressing the TEST/RESET button.

4.2 Metering

Real time measurements and data are available at the fascia (in “Instrument Mode”) through the metering functions or via the auxiliary communications interface. The following displays are available:

- Primary local RMS currents for IA, IB, IC and IE
- Secondary local RMS currents for Ia, Ib, Ic and Ie
- Primary remote RMS currents for IA, IB, IC and IE
- Secondary remote RMS currents for Ia, Ib, Ic and Ie
- Differential current magnitudes for Ia, Ib and Ic
- Output relay status
- Digital input status
- Trip circuit status
- General alarm screen
- Trip counter
- $\sum I^2$ counter
- Circuit breaker status
- Number of waveforms recorded
- Number of events stored
- Date - displayed in DD/MM/YY format
- Time - displayed in HH:MM:SS format
- Overcurrent characteristic information for phase and earth poles
- Differential characteristic information for phase poles
- Protection signalling communications channel status
- Protection signalling delay

Note: the instrument displays are updated as often as the software routines can service them, however the RMS current measurands have a response time of approximately 500msec.

Figure 10 shows the display menu structure from where the available instruments can be accessed. Note that pressing the ⇨ Test/Reset key can clear three of the instruments, the Trip Counter, Waveforms and Events.

4.3 Data Storage

Details of relay operation are recorded in three forms, namely Waveform records, Event records and Fault Data records. All records are time and date tagged by a real time clock which maintains the time even when the relay is de-energised [see Note below]. Time and date can be set either via the relay fascia using appropriate commands in the System Config menu or via the IEC60870-5-103 communications interface. In the latter case, relays connected in a network can be synchronised by a global time sync command.

Alternatively, synchronising pulses can be received via a status input. To use this feature one of the status inputs has to be assigned to the 'Clock Sync' feature in the Status Config menu. Additionally the 'Clock Sync Period' setting in the System Config menu should be set to either 'seconds' or 'minutes'. If 'seconds' are selected then the energisation of the selected status input will result in the clock being synchronised to the nearest second with the milliseconds set to zero. If 'minutes' are selected then the clock is synchronised to the nearest minute with both seconds and milliseconds set to zero.

Note: the real-time clock, waveform records and event records are all maintained, in the event of loss of auxiliary d.c. supply voltage, by the backup storage capacitor. This capacitor has the ability to maintain the charges on the real-time clock IC and the SRAM memory device for typically 2-3 weeks time duration. This time, however, is influenced by factors such as temperature and the age of the capacitor and could be shorter.

4.3.1 Waveform Records.

The waveform record feature stores analogue and digital information for the current inputs, status inputs and output relays. The waveform record is 1.0 second long with a sampling resolution of 16 samples per cycle. The recorder feature has the ability to store records for the previous five trip operations of the relay. These are labelled 1-5 with 1 being the most recent record.

The waveform recorder can be triggered in the following ways:

- Via the waveform trigger status input signal.
- From any element trip operation, including, overcurrent, differential and intertrip elements.
- From a disturbance on the protection signalling communications channel.
- Via the IEC60870-5-103 communications interface.

The waveform recorder has a settable pre-fault triggering capability.

4.3.2 Event Records

The event recorder feature allows the time tagging of any change of state (event) of the relay. As an event occurs the actual event condition is logged as a record along with a time and date stamp to a resolution of 5ms. There is capacity for a maximum of 500 event records to be stored in the relay and when the event buffer is full, any new record will over-write the oldest. The following events are logged:

- Change of setting (though not the actual setting change). Also indication of which group of settings is active.
- Change of state of each output relay.
- Change of state of each status Input.
- Change of state of any of the protection functions of the relay.
- Protection signalling disturbances and alarms.
- Trip indication reset
- Trip test.
- Trip supply failure.

For a full list of all the events available see 6 Event Codes.

4.3.3 Fault Data Records

When issuing a trip output under fault conditions, the relay will illuminate the Trip LED, store a fault record and display the fault indication screen. The fault indication screen displays a summary of the fault data record, giving immediate, easily understood information on what has occurred. It displays date (DD/MM), time (HH:MM:SS) and the poles which were picked up when the trip signal was issued e.g.

25/04 17:25:51 **TRIP A B C**

This display is held until the TEST/RESET button is pressed, upon which the LED will turn off and any latched output relays are reset. The relay enters ‘Fault Data Display Mode’ at which point the fault indication screen is replaced by a more detailed scrolling fault data display. This shows the date and time of fault and for each pole the elements that were picked up and the currents measured at the time of trip. Elements in angled brackets, <>, caused the trip e.g.

FAULT 1 25/04/00 17:25:51.5400 G1, IA= 10.00xIn <DIFF> IDMTL LS, IB= 0.00xIn, IC = 0.00xIn, IE = 10.00xIn HS1 HS2, INTERTRIPS=Remote Int

FAULT 1
<< Fault Data >>

The fault record is viewed in the ‘Fault Data Display Mode’ of the menu system and can be viewed again at a later date. The relay will store the last 5 fault records, which are numbered 1-5, with 1 being the most recent record. To view them, scroll down using the ⇩ button.

Depending upon the relay application, some of the protection elements may not be used for tripping purposes but for alarm purposes. In these cases it would be undesirable for the relay to light the Trip LED and give fault indication. It is therefore necessary to define a ‘Fault’ for the cases where a trip is issued. A ‘Fault Trigger’ setting exists in the Data Storage Menu, which allows a fault condition to be defined by selecting any combination of output relays as tripping outputs. The Trip LED and the fault record storage will be triggered when any of the selected output relays are energised. Note that a trip output can still be generated even if the fault trigger setting is not used, though no trip indication will be given.

Fault records are stored in non-volatile memory.

4.4 Protection Signalling Communications Channel

End to end protection signalling can employ any of the following communication circuit options:

See Performance Specification for the available communication channels.

4.5 Communications

IEC60870-5-103 or MODBUS RTU protocols are available as a user selectable setting.

A fibre optic communication port is provided which gives superior EMC performance or an optional RS485 electrical connection is available. For communication with the relay via a PC (personal computer) a user-friendly software package, REYDISP EVOLUTION [1], is available to allow transfer of the following:

- Relay Settings
- Waveform Records
- Event Records
- Close Data Records
- Instrument and meters
- Control Functions

Communications operation is described in detail in Section 4 of this manual.

4.6 General Alarm Screens

An independent display function provides up to five alarm messages, each of which may be programmed by the user to display a message associated with an external alarm.

Within the System Config Menu, each alarm message can be text edited by the user to display up to 13 characters. Also, each alarm can be user mapped to any status input, via the Status Config Menu, so that on energisation of that input the associated alarm message is automatically displayed. Where more than one General Alarm is raised then the display will scroll right to left to show all energised screens sequentially, with screens separated by a ‘+’ sign. If required, more than one alarm may be mapped to a single status input, allowing long messages to be displayed.

The message will appear on the LCD for the duration of the time that the status input is energised.

General Alarms
<< Alarm1 + Al<<

4.7 Default Instrument Screens

The menu presentation of the various instruments allows the user to view a single screen at a time. However, for in-service use, it is desirable that a small number of high interest, user selectable, screens are presented automatically by default without user intervention. The instrument screens of interest to the user e.g. those required to be presented to a visiting engineer for record purposes can be selected by the user by pressing **ENTER** when viewing the required screen. On pressing **ENTER** a ‘Screen Set As Default’ message will be flashed up and a ‘□’ will appear at the top right of that screen. The ‘□’ indicates that a screen is a ‘default screen’. To de-select a default screen, simply press **ENTER** while on that particular screen and a ‘Screen Cleared As Default’ message will be flashed up. The ‘□’ symbol will be cleared.

Differential a □
0.00

If no keys have been pressed for a pre-determined time the relay will jump to the default instrument display regardless of where the menu system has been left by the user. It will then scroll through each of the selected default instruments and remain on each for 5 seconds. The main timer which sets the time to elapse before the relay goes into the default instruments mode is found in the System Config Menu. This is the Default Screen Timer setting and it can be set to a range of values from 10 seconds to 1 hour. See relay settings, Section 3 of this manual.

If any General Alarm is raised, then the general alarm screen will be presented in the default screen sequence. The general alarm screen, which has a scrolling display, will present one pass of its display message.

Any key press while in the default screen sequence will result in a return to the ‘Relay Identifier’ screen at the top of the menu structure.

4.8 Multiple Settings Groups.

The relay provides eight alternative setting groups, making it possible to edit one group while the relay protection algorithms operate using another ‘active’ group. An indication of which group is being viewed is given by the ‘Gn’ character in the top left of the display. The relay can then be switched from one group of settings to another to suit alterations in the power system configuration. Changeover will occur within 35ms.

A change of group can be achieved either locally at the relay fascia, remotely via an IEC60870-5-103 communication interface command or by energisation of a status input. In the case of the latter method, the ‘Settings Group Select’ setting is used to configure any one (or more) of the status inputs to select a settings group. The selected group is then made active if the status input is energised and remains active for as long as the input remains energised. Changing setting groups must ensure the differential settings for a pair of relays remain identical at all times. Therefore changes to the differential settings must only be done with no load current on the feeder.

4.9 Password Feature

The programmable password feature enables the user to enter a 4 character alphanumeric code to secure access to the relay settings. The relay is supplied with the password set to ‘NONE’ which means that the password feature is not activated. Once a password has been entered then it will be required thereafter to change settings. It can, however, be de-activated by using the password to gain access and by resetting it back to ‘NONE’.

As soon as the user attempts to change a setting the password is requested before any setting alterations are allowed. Once the password has been validated, the user is ‘logged on’ and any further changes can be made without re-entering the password. If no more changes are made within 1 hour then the user will automatically be ‘logged off’, re-enabling the password feature.

Note that the password validation screen also displays a numerical code. If the password is lost or forgotten, this code can be communicated to Siemens by authorised personnel, and the password can be retrieved.

5 User Interface

The user interface is designed to provide a user-friendly method of entering settings and retrieving data from the relay. The relay fascia includes a 16 character by 2 line, backlit, liquid crystal display (LCD), 5 light emitting diodes (LED) and 5 push buttons. Figure 11 shows a relay fascia.

5.1 Liquid Crystal Display

The liquid crystal display is used to present settings, instrumentation and fault data in a textual format.

To conserve power the display backlighting is turned off if no push buttons are pressed for 5 minutes. After one hour the whole display is de-activated except if the display is left in the 'Instruments Mode' where it will remain visible permanently so that instruments can be displayed continuously. Also, if any default instruments have been selected then the display will not power down, only the backlight will turn off. Once the backlight is turned off, any following keypress will turn the backlight on without changing the display.

5.2 LED Indications

The following indications are provided:

- **Protection Healthy – Green LED (flashes with fault).**

This LED is solidly illuminated to indicate that DC volts have been applied to the relay and that the relay is operating correctly. If the internal relay watchdog detects a permanent fault then this LED will continuously flash. If this LED is not lit, then the dc supply to the relay or its' power supply has failed

- **Intertrip – Red LED (latched).**

This LED indicates that an intertrip has occurred. This may be generated from either the internal intertrip or one of the external intertrip channels.

- **I > Is – Yellow LED (self resetting).**

This LED indicates that any pole is picked up and is measuring current above one of the IDMTL / DTL characteristic current settings. Visually this is equivalent to an induction disk relay starting to turn.

- **Trip – Red LED (latched).**

This LED indicates that a trip as defined by the user has occurred. Such a trip may be issued by any of the relay's protection functions. Only the operation of outputs set as "Fault Triggers" in the Waveform Storage Menu will illuminate this LED.

- **Signal Healthy – Green LED (flashes with comms disturbance).**

This LED is solidly illuminated to indicate that the protection signalling communications channel is in synchronism, and is operating correctly and error free. If a disturbance is detected on the signalling communications channel then this LED will flash. A permanent fault detected on the communications channel will cause this LED to flash continuously.

5.3 Keypad

Five pushbuttons are used to control the functions of the relay. They are labelled ⇧ ⇩ ⇨ **ENTER** and **CANCEL**. Note that the ⇨ button is also labelled **TEST/RESET**.
When the relay front cover is in place only the ⇩ and ⇨buttons are accessible. This allows only read access to all the menu displays. It is not possible to change settings.

5.4 Navigating the Menu System

The display menu structure is shown in Figure 10. This diagram shows the three main modes of display, which are the Settings Mode, Instruments Mode and the Fault Data Mode.

On relay start up the user is presented with a default relay identifier,

SOLKOR N **Factory Settings**

which shows that the relay has been set with the standard factory default settings. The top line of the LCD can be changed to some user-definable identifier or code if preferred.

Pressing the ⇨key on this display initiates an LED test. Pressing ⇩ at this display allows access to the three display modes that are accessed in turn by pressing the ⇨key.

The ‘Settings Mode’ contains 9 setting sub-menu’s. These hold all of the programmable settings of the relay in separate logical groups. The sub-menu’s are accessed by pressing the ⇨ key. This enters the sub-menu and presents a list of all the settings within that sub-menu. Pressing the ⇩ key scrolls through the settings until after the last setting in the group the next sub-menu is presented. Access to this group is via the same method as before. If a particular sub-menu is not to be viewed then pressing the ⇩ key will skip past that particular menu and present the next one in the list. Note that all screens can be viewed even if the password is not known. The password only protects against unauthorised changes to settings.

While viewing an editable screen pressing the **ENTER** key allows the user to change the displayed data. The editable field will be indicated by a flashing character(s). Pressing ⇧ or ⇩ scrolls through the available setting values or, pressing the ⇨key moves right through the edit fields. Note that all settings can be incremented or decremented using the ⇧ or ⇩ keys and they all wrap-around so that to go from e.g. a setting minimum value to the maximum value it is quicker to press the ⇩ key, rather than scroll up through every setting. Also, to facilitate quicker setting changes an acceleration feature is available which if ⇧ or ⇩ are depressed and held, then the rate of scrolling through the setting values increases.

If **CANCEL** is pressed during a setting change operation the original setting value is restored and the display is returned to the normal view mode.

If changes are made to the setting value then pressing **ENTER** disables the flashing character mode and displays the new setting value. This is immediately stored in non-volatile memory.

Note: the relay exhibits a method of hiding settings which are not relevant to a particular customer scheme which is known as setting dependencies. Some settings are dependant on others being enabled and if a function is not enabled then associated settings are not displayed e.g. if the P/F Lowset is not required then set,

Gn P/F Lowset Setting to OFF; the following associated setting will not be displayed;

Gn P/F Lowset Delay,

Also hidden are all associated output relays options and status input inhibits.

There are many examples of setting dependencies and care must be taken to ensure a function is enabled before looking for other associated settings which otherwise would be hidden.

The ‘Instruments Mode’ contains a list of instruments. Pressing the ⇩ key scrolls down through the list of instruments and pressing ⇧ scrolls up through them. For more information on the relay’s instruments see Section 4.2.

The ‘Fault Data Mode’ can contain a maximum of 5 fault records. These are accessed in the same way as the other display modes. For more information on the fault record displays see 4.3.3 Fault Data Records

For a complete list of all possible settings see Section 3 – of this manual. This section also shows all setting ranges and factory default values, as well as including a brief description of each setting function.

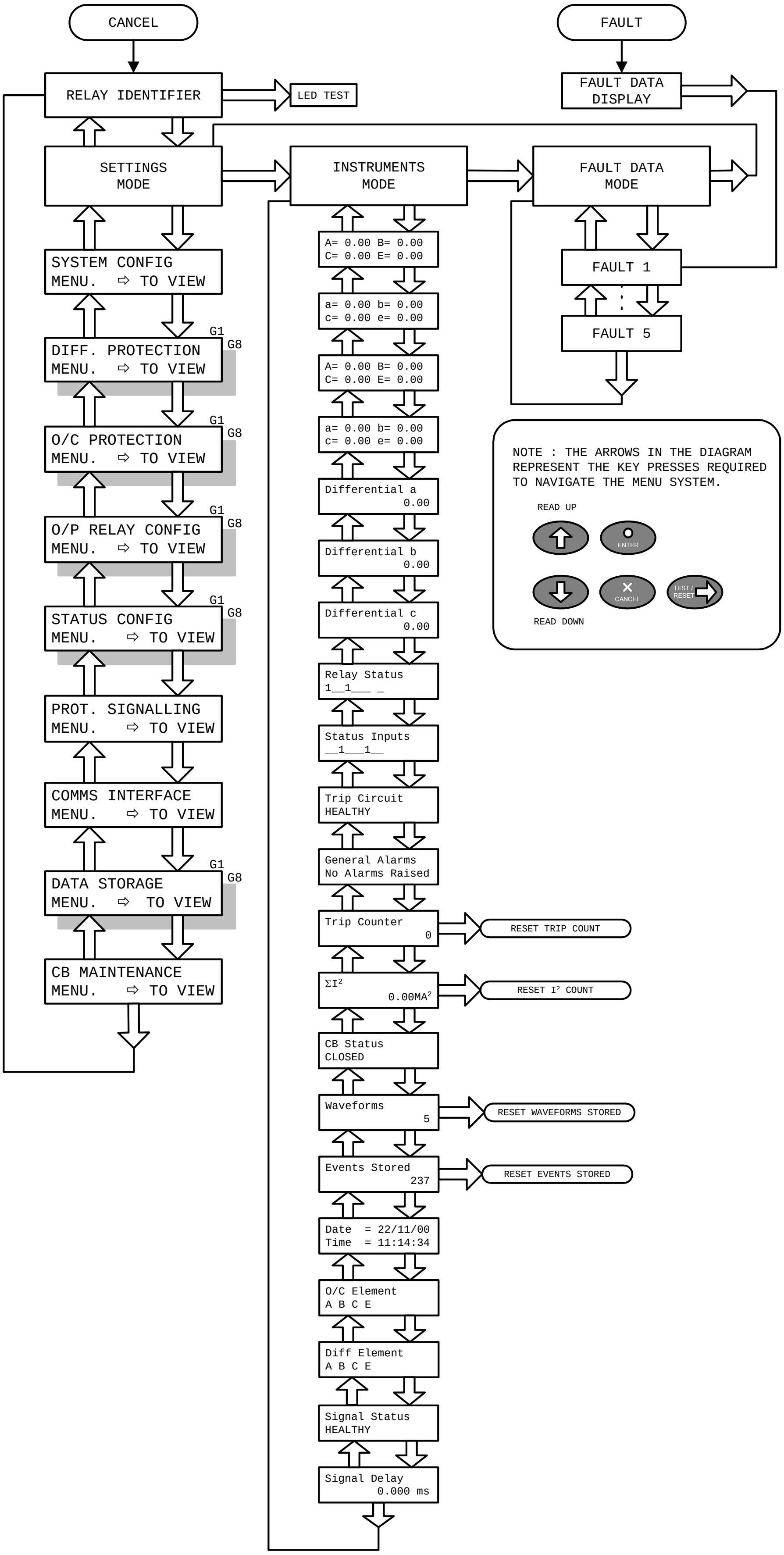


Figure 10 - Display Menu Structure

Figure 11 –Relay Fascia

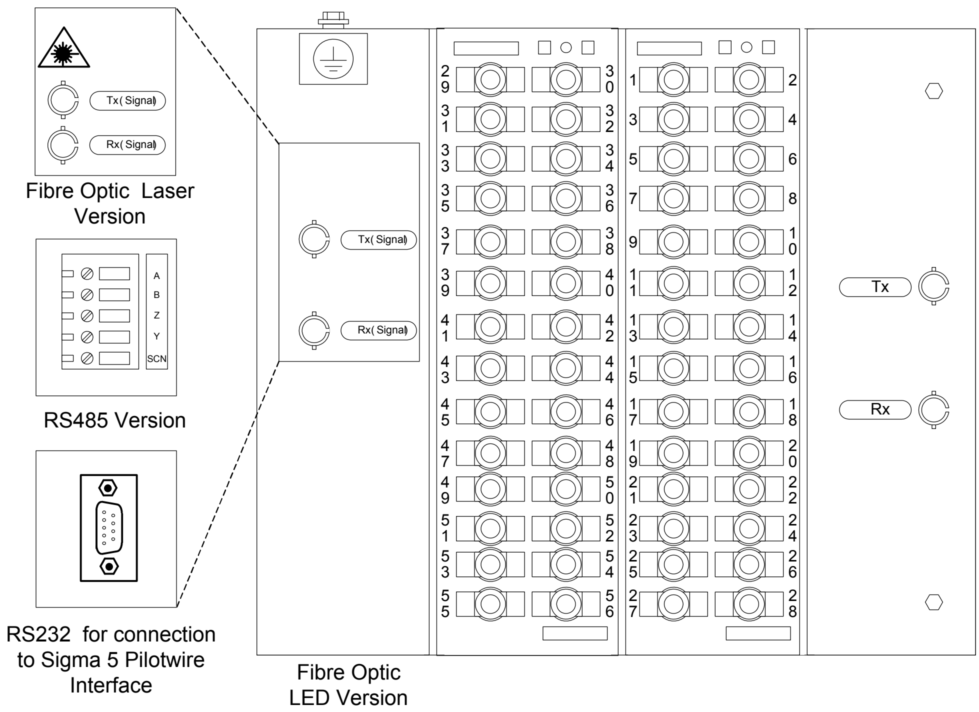


Figure 12 –Rear View

Block	Function		Terminal	Terminal		Function
Terminal Block 1	Not Used	–	**1**	**2**	–	Not Used
	Status Input 1	(+)	**3**	**4**	(–)	Status Input 1
	Relay 1 (N/C)	–	**5**	**6**	–	Relay 1 (COM)
	Relay 1 (N/O)	–	**7**	**8**	–	Relay 2 (N/O)
	Relay 2 (COM)	–	**9**	**10**	–	Relay 2 (N/C)
	Relay 4 (N/O)	–	**11**	**12**	–	Relay 4 (N/O)
	Aux. Volts	(+)	**13**	**14**	(–)	Aux. Volts
	Earth	(⏚)	**15**	**16**	–	Relay 3 (N/O)
	Relay 3 (COM)	–	**17**	**18**	–	Relay 3 (N/C)
	Relay 5 (N/O)	–	**19**	**20**	–	Relay 5 (N/O)
	Relay 6 (N/O)	–	**21**	**22**	–	Relay 6 (N/O)
	Relay 7 (N/O)	–	**23**	**24**	–	Relay 7 (N/O)
	Earth 1A CT	Start	**25**	**26**	Finish	Earth 1A CT
	Earth 5A CT	Start	**27**	**28**	Finish	Earth 5A CT
Terminal Block 2	Status Input 5	(+)	**29**	**30**	(–)	Status Input 5
	Status Input 4	(+)	**31**	**32**	(–)	Status Input 4
	Status Input 3	(+)	**33**	**34**	(–)	Status Input 3
	Status Input 2	(+)	**35**	**36**	(–)	Status Input 2
	Status Input 9	(+)	**37**	**38**	(–)	Status Input 9
	Status Input 8	(+)	**39**	**40**	(–)	Status Input 8
	Status Input 7	(+)	**41**	**42**	(–)	Status Input 7
	Status Input 6	(+)	**43**	**44**	(–)	Status Input 6
	C Phase 1A CT	Start	**45**	**46**	Finish	C Phase 1A CT
	C Phase 5A CT	Start	**47**	**48**	Finish	C Phase 5A CT
	B Phase 1A CT	Start	**49**	**50**	Finish	B Phase 1A CT
	B Phase 5A CT	Start	**51**	**52**	Finish	B Phase 5A CT
	A Phase 1A CT	Start	**53**	**54**	Finish	A Phase 1A CT
	A Phase 5A CT	Start	**55**	**56**	Finish	A Phase 5A CT

Table 1 - Connection

6 Event Codes

IEC 60870-5-103

The relay has four groups of event codes with function codes 160 (IEC60870 overcurrent), 164 (Reyrolle overcurrent), 192 (IEC60870 line differential), and 196 (Reyrolle line differential). The event codes are shown in Table 2 to

Table 5.

The General Interrogation column indicates those events that are returned in a general interrogation sequence.

The type column determines the type of frame used (type 1 = Absolute time stamp, type 2 = Relative time stamp, type 5 = Initialisation).

The General Command column indicates which commands can be issued to the relay via the IEC60870-5-103 frame ASDU20.

The Measurand column indicates which measurands are returned via the IEC60870-5-103 ASDU4 frame. A private ASDU9 frame is also used to return the four local and remote currents.

All events are time stamped to a resolution of 1ms. There can be a maximum of 500 events stored in the event buffer as per the Argus range of relays.

EVENT	CODE	GENERAL INTERROGATION	TYPE	MEASURAND (ASDU4)	GENERAL COMMANDS (ASDU 20)	EVENT	CODE	GENERAL INTERROGATION	TYPE	MEASURAND (ASDU4)	GENERAL COMMANDS (ASDU 20)
A-O/C starter	64	•	2			Circuit breaker fail 1	85		2		
B-O/C starter	65	•	2			P/F-general HS trip	91		2		
C-O/C starter	66	•	2			E/F-general HS trip	93		2		
E-O/C starter	67	•	2								

Table 2 - IEC60870 Overcurrent Event Codes (Function code 160)

EVENT	CODE	GENERAL INTERROGATION	TYPE	MEASURAND (ASDU4)	GENERAL COMMANDS (ASDU 20)	EVENT	CODE	GENERAL INTERROGATION	TYPE	MEASURAND (ASDU4)	GENERAL COMMANDS (ASDU 20)
A-lowset starter	1		2			E-HS1 trip	16		2		
B-lowset starter	2		2			A-HS2 trip	17		2		
C-lowset starter	3		2			B-HS2 trip	18		2		
E-lowset starter	4		2			C-HS2 trip	19		2		
A-lowset trip	5		2			E-HS2 trip	20		2		
B-lowset trip	6		2			A-HS1 starter	26		2		
C-lowset trip	7		2			B-HS1 starter	27		2		
E-lowset trip	8		2			C-HS1 starter	28		2		
A-delayed trip	9		2			E-HS1 starter	29		2		
B-delayed trip	10		2			A-HS2 starter	30		2		
C-delayed trip	11		2			B-HS2 starter	31		2		
E-delayed trip	12		2			C-HS2 starter	32		2		
A-HS1 trip	13		2			E-HS2 starter	33		2		
B-HS1 trip	14		2			Circuit breaker fail 2	39		2		
C-HS1 trip	15		2								

Table 3 - Private Overcurrent Event Codes (Function code 164)

EVENT	CODE	GENERAL INTERROGATION	TYPE	MEASURAND (ASDU4)	GENERAL COMMANDS (ASDU 20)	EVENT	CODE	GENERAL INTERROGATION	TYPE	MEASURAND (ASDU4)	GENERAL COMMANDS (ASDU 20)
Reset FCB	2		5			Input4	30	•	1		
Reset CU	3		5			Trip circuit fail	36	•	1		
Start/Restart	4		5			Signalling Disturbed	39	•	1		
Power On	5		5			Alarm	47	•	1		
LEDs reset	19		1		•	A-Diff Starter	64	•	2		
Test Mode	21	•	1			B-Diff Starter	65	•	2		
Settings changed	22	•	1			C-Diff Starter	66	•	2		
Setting G1 selected	23	•	1		•	General trip	68		2		
Setting G2 selected	24	•	1		•	A-general trip	69		2		
Setting G3 selected	25	•	1		•	B-general trip	70		2		
Setting G4 selected	26	•	1		•	C-general trip	71		2		
Input1	27	•	1			General Starter	84	•	2		
Input2	28	•	1			CB Status	128		1		
Input3	29	•	1								

Table 4 - IEC60870 Line Differential Event Codes (Function code 192)

EVENT	CODE	GENERAL INTERROGATION	TYPE	MEASURAND (ASDU4)	GENERAL COMMANDS (ASDU 20)	EVENT	CODE	GENERAL INTERROGATION	TYPE	MEASURAND (ASDU4)	GENERAL COMMANDS (ASDU 20)
Data lost	0		1			Output2	52	•	1		•
Internal Intertrip Sent	2		2		•	Output3	53	•	1		•
Internal Intertrip Received	3		2			Output4	54	•	1		•
External Intertrip 1 Sent	4		2		•	Output5	55	•	1		•
External Intertrip 1 Received	5		2			Output6	56	•	1		•
External Intertrip 2 Sent	6		2		•	Output7	57	•	1		•
External Intertrip 2 Received	7		2			Trip count alarm	70	•	1	•	
External Trip	8		2			CB maintenance alarm	71	•	1	•	
A-Diff Trip	9		2			Waveform stored	80		1		•
B-Diff Trip	10		2			Remote control interrupted	81		1		
C-Diff Trip	11		2			E/F-general trip	92		2		
Remote Test Mode	21	•	1			General alarm 1	121	•	1		
Setting G5 selected	35	•	1		•	General alarm 2	122	•	1		
Setting G6 selected	36	•	1		•	General alarm 3	123	•	1		
Setting G7 selected	37	•	1		•	General alarm 4	124	•	1		
Setting G8 selected	38	•	1		•	General alarm 5	125	•	1		
Input5	45	•	1			General alarm 6	126	•	1		
Input6	46	•	1			General alarm 7	127	•	1		
Input7	47	•	1			General alarm 8	128	•	1		
Input8	48	•	1			General alarm 9	129	•	1		
Input9	49	•	1			Ends In Synch	130	•	1		
Output1	51	•	1		•	P/F Guard	131	•	1		•

Table 5 – Private Line Differential Event Codes (Function code 196)

7SG18 Solkor N

Numeric Differential Protection

Document Release History

This document is issue 2010/02. The list of revisions up to and including this issue is:

Pre release

2010/02	Document reformat due to rebrand

Software Revision History

Contents

Table of Figures

1 General

The relay complies with the relevant clauses in the following specifications: -

- IEC 60255 – 3
- IEC 60255 – 13

Note: References to Is refer to the current setting for the characteristic being discussed.

2 Characteristic Energizing Quantity

Rated Current (In)	1A / 5A

Rated Frequency (f_N)	Operating Range
50 Hz	47Hz to 52Hz

3 Auxiliary Energizing Quantity

3.1 DC Power Supply

Nominal Voltage (V_{aux})	Operating Range
24, 30, 48V	18V to 60V dc
110, 220V	88V to 280V dc

3.2 DC Status Inputs

Nominal Voltage	Operating Range
30 / 34	18V to 37.5V
48 / 54	37.5V to 60V
110 / 125	87.5V to 137.5V
220 / 250	175V to 280V

Note: the status voltage need not be the same as the power supply voltage. For 110/125V or 220/250V working, use a standard 48/54V status input with a dropper resistor as follows: -

3.3 Status Input External Resistances

Nominal Voltage	Resistor Value (Wattage)
110 / 125V	2k7 ± 5% ; (2.5W)
220 / 250V	8k2 ± 5% ; (6.0W)

Optional versions of status input are available for direct connection of 110V and 220V dc. These do not comply with ESI 48-4 and will operate with a DC current of less than 10mA (see Section 5.6)

4 Accuracy Reference Conditions

General	IEC 60255 –3 IEC 60255 –13
Current input for IDMTL	2x to 30x Is
Current input for DTL	5x Is
Auxiliary Supply	Nominal
Frequency	50.0 Hz
Ambient Temperature	20°C

5 Accuracy & Performance

Accuracy in this section is specified at reference conditions.

5.1 Differential Element

The Magnitude and Angle of the currents are compared in separate comparators. Typical operating threshold characteristics are shown in Figure 1 and

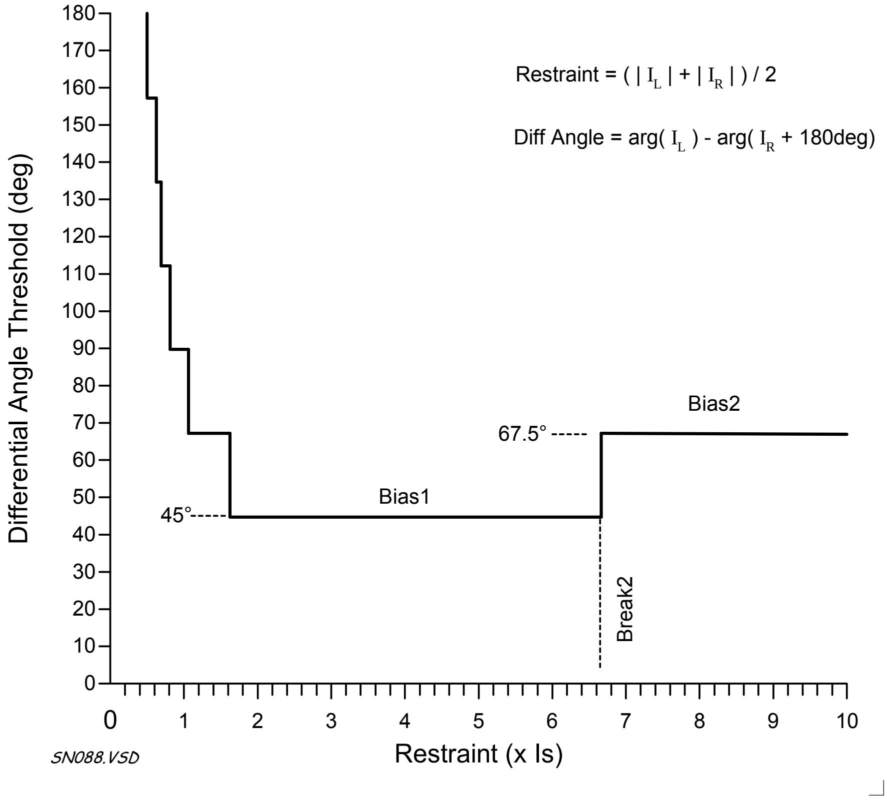


Figure 2. The error limits on these are as follows:

Operate levels	
Differential Magnitude - Initial Threshold	±10% or ±10mA
Differential Magnitude - Biased Threshold (At low levels)	Biased threshold ±(10% of Restraint) or ±10mA For Restraint <1.6Is +ve limit:- Biased threshold +10% or +10mA -ve limit:- Initial threshold -10% or -10mA
Differential Comparitor Angle Threshold	±5°

Differential and Intertrip operate times are given by:

t = t0 + td

where

t0 is the base operating time.
td is the Differential Delay time.

The base operating time depends on the communications bit rate.
Figure 3 shows typical Differential operating times at 38400.

Operate Times	
Differential base operate time (Idiff > 10 Is)	≤ 40ms (38400 baud) ≤ 55ms (19200 baud)
Differential Delay time	±1% or ±10ms

5.2 Intertrip Element

Intertrip Element	
Intertrip base operate time	≤ 50ms (38400 baud) ≤ 65ms (19200 baud)
Intertrip Delay	±1% or ±10ms

5.3 Lowset, Highset1, Highset2 Instantaneous/DTL Elements

Lowset Element	
Pickup / Dropoff levels	
Operate Level	Setting ±5% or ±10mA
Reset Level	≥ 95% of operate level
Repeatability	±1%
Operate Time	
Operate Time See Figure 4 for operate time.	±1% or ±10ms
Repeatability	±1% or ±5ms

5.4 Overcurrent Characteristic Elements

IDMTL / DTL Characteristic	
Pickup / Dropoff levels	
Operate Level	105% of setting ±4% or ±10mA
Reset Level	≥ 95% of operate level
Repeatability	±1%
IDMTL Operate Time (NI, VI, EI, LTI)	
Starter Time See Figure 5 for starter operate time.	±5%
Operate times are calculated as follows: $t = \frac{K}{\left(\frac{I}{Is}\right)^{\alpha} - 1} \times Tm$ where I = fault current Is = current setting Tm = time multiplier and for NI K = 0.14, α = 0.02 for VI K = 13.5, α = 1.00 for EI K = 80.0, α = 2.00 for LTI K = 120.0, α = 1.00 See Figure 6 for IDMTL operate curves.	±5% or ±30ms
Reset Time	±1% or ±10ms
Repeatability	±1% or ±5ms
DTL Operate Time	
Starter Time	±5%
Operate Time	±1% or ±10ms
Reset Time	±1% or ±10ms
Repeatability	±1% or ±5ms

5.5 Circuit Breaker Fail Elements

Pickup / Dropoff levels	
Operate Level	Setting ±5% or ±10mA
Reset Level	≥ 95% of operate level
Repeatability	±1%
Operate Time	
Operate Time	±1% or ±10ms
Repeatability	±1% or ±5ms
Reset Time	
Reset Time	Typically 25ms (20 to 0.9 x setting) Accuracy ±1% or ±10ms
Repeatability	±1% or ±5ms

5.6 Status Inputs

Each status input has associated timers that can be programmed to give time delayed pick-up and time delayed drop-off. The timers have default settings of 20 ms for pick-up and 0ms for drop-off, thus providing immunity to an AC input signal.

Minimum operating current	10mA
Reset/Operate Voltage Ratio	≥ 90%
Response time (Pickup delay set to 0ms)	< 5ms

Status inputs will not respond to the following:

- 250V r.m.s. 50/60Hz applied for two seconds through a 0.1uF capacitor.
- 500V r.m.s. 50/60Hz applied between each input terminal and earth.
- 10uF capacitor discharged from maximum DC auxiliary voltage.

The inputs meet the requirements of ESI 48-4.
(Apart from the optional low current versions that operate direct from 110V and 220V.)

6 Accuracy General

Transient Overreach of Highsets and Lowset for X/R = 100	≤ -5%
Disengaging Time	< 42ms
Overshoot Time	< 40ms

Note: Output contacts can be programmed to have a minimum dwell time (the default is 100ms), after which the disengaging time is as above.

7 Accuracy Influencing Factors

For conditions other than reference conditions, the following applies.

Factor	Range	Additional Error
Temperature	-10°C to +55°C	0%
Frequency	47Hz to 52Hz	
Differential setting		≤ 5%
Differential timing		≤ 1%
Overcurrent setting		≤ 1%
Overcurrent timing		≤ 1%
Ripple on DC supply (IEC 60255-11)	≤ 12% of DC voltage	0%
Break in DC supply (IEC 60255-11)	≤ 20 ms	0%

8 Thermal Rating

Phase & Earth Inputs

Duration	1A Tap	5A Tap
Continuous	3.0A	15A
10 min	3.5A	16.5A
5 min	4.0A	20A
3 min	5.0A	25A
2 min	6.0A	30A
3 sec	57.5A	230A
2 sec	70.7A	282A
1 sec	100A	400A
1cycle	700A	2500A

9 Burdens

Current Inputs

	AC Burden	Impedance
1A tap @ 1A	≤ 0.05VA	≤ 0.05 Ω
5A tap @ 5A	≤ 0.2VA	≤ 0.01 Ω

Note: Burdens and impedances are measured at nominal current rating.

Power Supply

	DC Burden
Quiescent (Typical)	7 Watts
Max	11 Watts

10 Output Contacts

Contact rating to IEC 60255-0-20.

Carry

Continuous	5A ac or dc

Make and Carry

(limit L/R ≤ 40ms and V ≤ 300 volts)

For 0.5 sec	20A ac or dc
For 0.2 sec	30A ac or dc

Break

(limit ≤ 5A or ≤ 300 volts)

ac resistive	1250VA
ac inductive	250VA @ PF ≤ 0.4
dc resistive	75W
dc inductive	30W @ L/R ≤ 40 ms 50W @ L/R ≤ 10 ms

Minimum number of operations	1000 at maximum load
Minimum recommended load	0.5W, limits 10mA or 5V

11 Protection Signalling

Transmission type	Asynchronous
Data rate	19200 bps, 38400 bps
Protocol	Asynchronous, 11bit characters including start, stop, parity.
Data Frame	10 character frame including start flag, end flag, checksum. Based on IEC 60870-5-1. Characters in a data frame are transmitted with no intentional gaps but a received gap of up to 1 bit can be tolerated
Hamming distance	4
Connection	Point to point
Max permissible jitter	<10μs at 19200 bps <5μs at 38400 bps
Max permissible delay	37.5 ms end to end

Channel propagation delay is automatically compensated for if it falls within one of the pre-selected bands in the protection settings.

Delays in each direction should be identical, or as near identical as possible. Any difference results in a phase error of 9 deg/ms on a 50Hz waveform, which must be accommodated in the protection's stability margin.

Delays in each direction must fall within the same setting band for auto compensation.

Interface Options

Interface	**TX budget**	**Max Range**
Fibre Optic 1300nm long range model	20dB	Typically from 0 to 49km using typical 9/125μm singlemode fibre*
	26dB	Typically from 5km to 15km using typical 62.5/125μm multimode fibre*
Fibre Optic 1300nm short range model	20dB	Typically from 0 to 15km using typical 62.5/125μm multimode fibre*
Electrical 4 wire RS485		< 1.2km
Metallic twisted pair pilots		< Typically 8km for 0.8mm sq pilotwire(dependant on pilot type-R&C) – see Table below.

* Based on fibre attenuations: -

62.5/125μm multimode 3.5dB/km
9/125μm single mode 0.3dB/km
Assumes no joins in the fibre, but includes a 3dB safety margin.
Actual losses for specific application should be calculated using cable manufacturers data or by direct measurement using specialised equipment. Refer to the Applications Guide section of this manual.

Typical Range Limits for Screened Twisted Pair Pilotwires

Cross Sectional Area	**Approximate Range**
0.4mm sq	4km
0.5mm sq	5km
0.6mm sq	6km
0.7mm sq	7km
0.8mm sq	8km
0.9mm sq	9km
1.0mm sq and above	10km

The combination of pilotwire resistance (R) and inter-core capacitance (C) should not exceed a RC product of 300,000 nF ohms. The value of R is the resistance for a single wire between pilotwire modems at either end of the feeder. The value of C is the inter-core capacitance a pair of pilot wires. The pilotwires should be earthed at both ends at the pilot wire terminations to limit. The relay and pilotwire modems should be earthed separately in the relay panel. This above range limits includes a suitable safety margin as the communications drop out occurs at about 340,000nF ohms.

12 Environmental Withstand

12.1 General

Temperature - IEC 60068- 2-1/2

Operating range	-10°C to +55°C
Storage range	-25°C to +70°C

Humidity - IEC 60068- 2-3

Operational test	56 days at 40°C and 95% RH

Transient Overvoltage – IEC 60255-5

Between all terminals and earth or between any two independent circuits without damage or flashover	5kV 1.2 / 50µs 0.5J

Insulation - IEC 60255-5

Between all terminals and earth	2.0kV rms for 1 min
Between independent circuits	2.0kV rms for 1 min
Across normally open contacts	1.0kV rms for 1 min

12.2 Immunity

High Frequency Disturbance -
IEC 60255-22-1 Class III

	Variation
2.5kV Common (Longitudinal) Mode	≤ 5%
1.0kV Series (Transverse) Mode	≤ 5%

Electrostatic Discharge -
IEC 60255-22-2 Class III

	Variation
6kV contact discharge	≤ 5%
8kV air discharge (to fascia)	≤ 5%

Radio Frequency Interference -
IEC 60255-22-3 Class III

	Variation
80MHz to 1000MHz, 10V/m	≤ 5%

Fast Transient – IEC 60255-22-4 Class IV

	Variation
4kV 5/50ns 2.5kHz repetitive	≤ 5%

Conducted RFI – IEC 60255-22-6

	Variation
0.15 to 1000MHz - 10V	≤ 5%

12.3 Emissions

Radiated Limits – IEC 60255-25

Frequency Range	Limits at 10m Quasi-peak dB (µV/m)
30 to 230MHz	40
230 to 1000MHz	47

Conducted Limits – IEC 60255-25

Frequency Range	Limits dB (µV)	
	Quasi-peak	Average
0.15 to 0.5MHz	79	66
0.5 to 30MHz	73	60

12.4 Mechanical

Vibration (Sinusoidal) – IEC 60255-21-1 Class 1

		Variation
Vibration response	0.5gn	≤ 5%
Vibration endurance	1.0gn	≤ 5%

Shock and Bump – IEC 60255-21-2 Class 1

		Variation
Shock response	5 gn 11ms	≤ 5%
Shock withstand	15 gn 11ms	≤ 5%
Bump test	10 gn 16ms	≤ 5%

Seismic – IEC 60255-21-3 Class 1

		Variation
Seismic Response	1gn	≤ 5%

Mechanical Classification

Durability	In excess of 10^6 operations

Qualification
Product :- CE compliant to all relevant EU directives.
Quality Systems :- accredited to ISO 9001

13 Characteristics

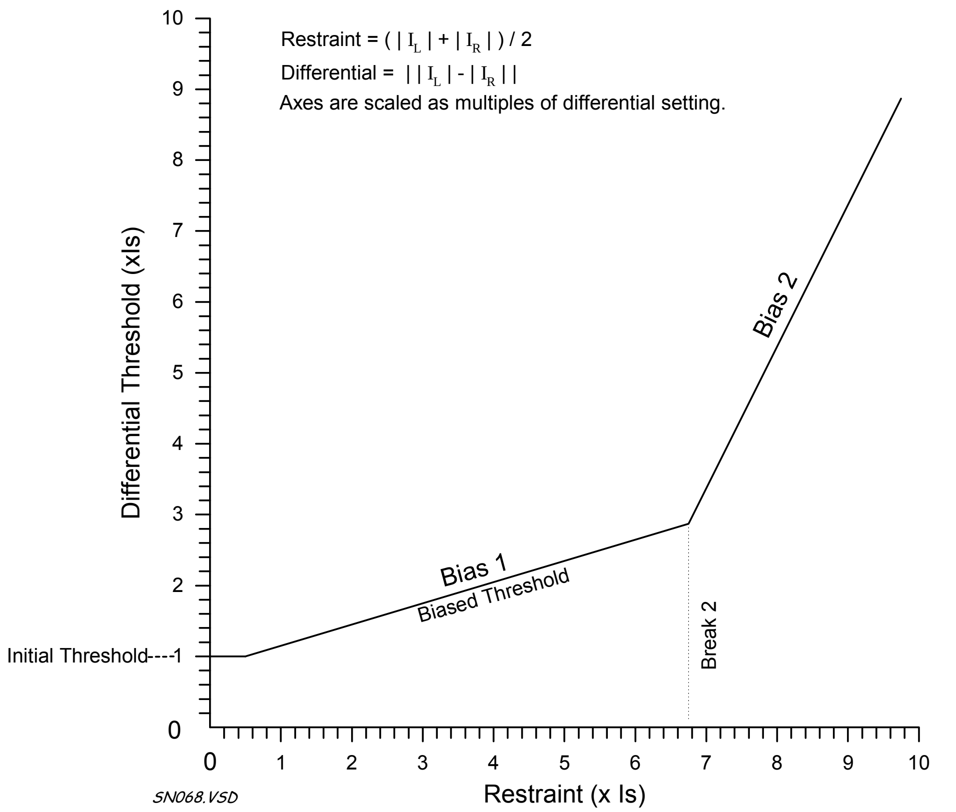


Figure 1 – Differential Threshold (Magnitude)

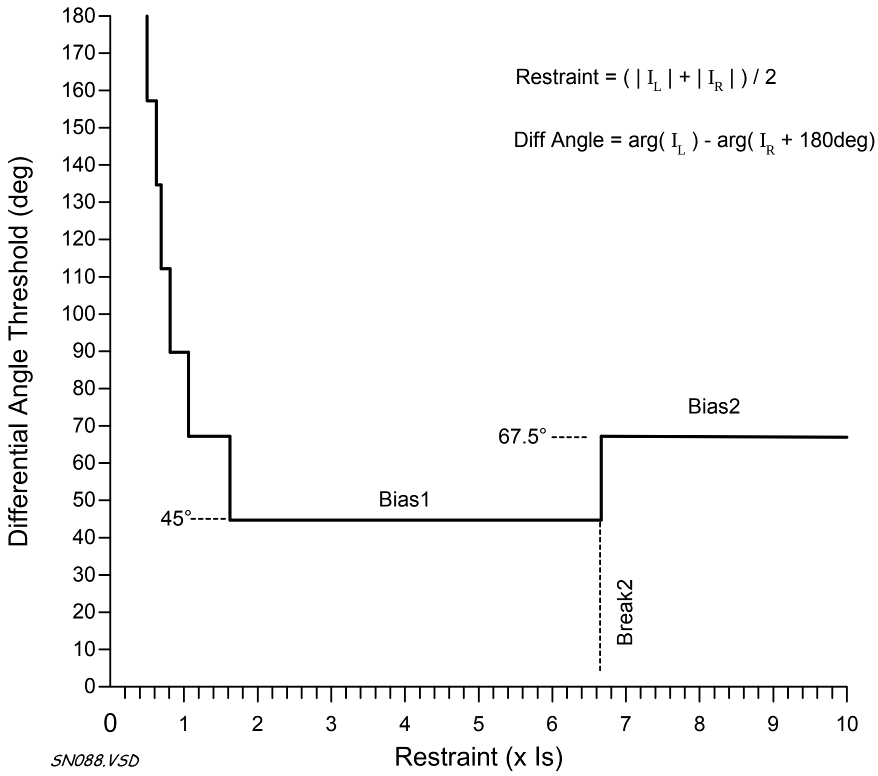


Figure 2 – Differential Threshold (Angle)

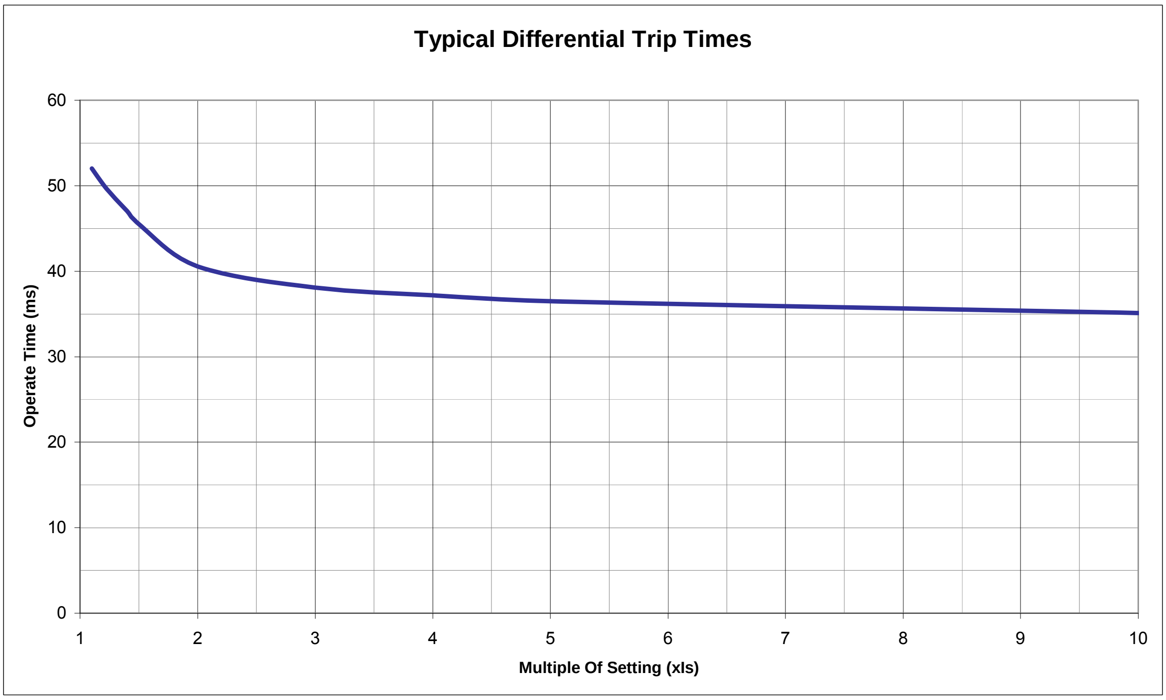


Figure 3 – Typical Differential Trip Times @ 38400 baud

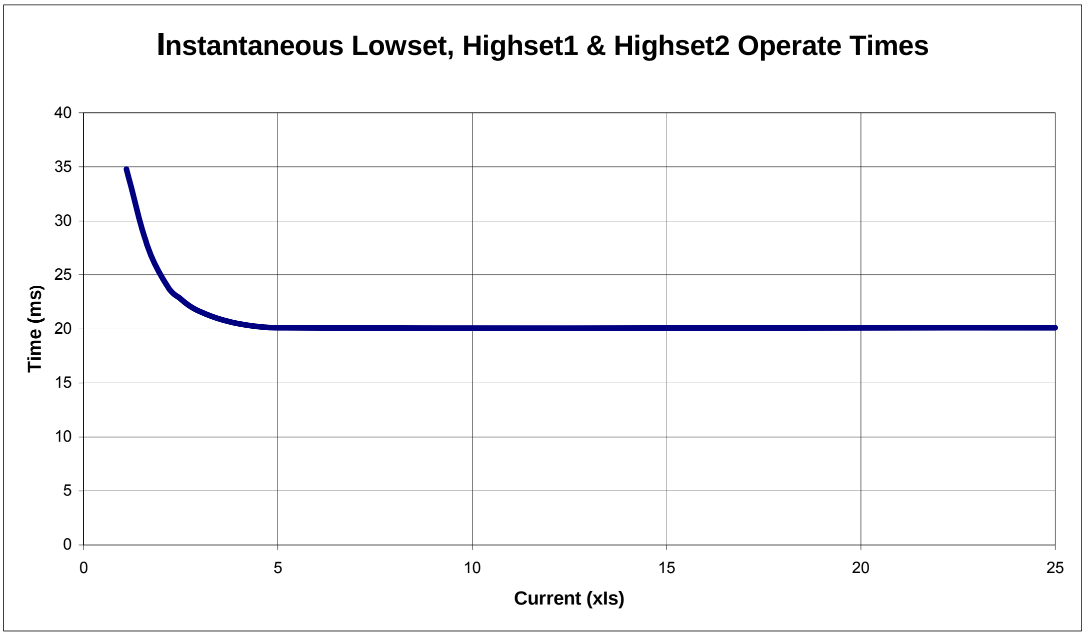


Figure 4 – Instantaneous Lowset, Highset1 & Highset2 Operate Times

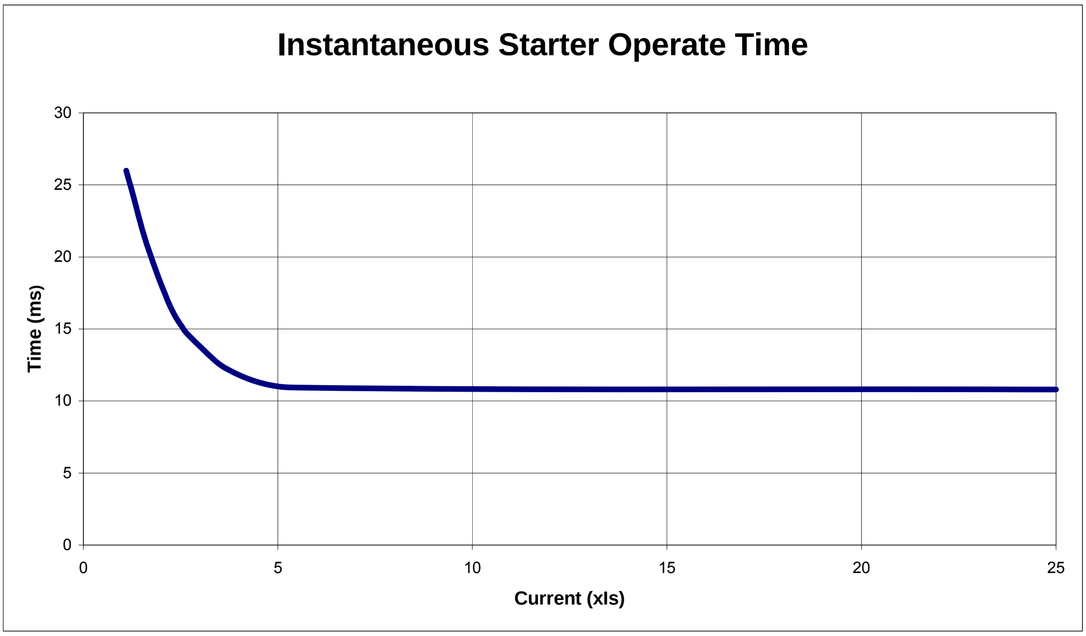


Figure 5 – Overcurrent Starter Operate Time

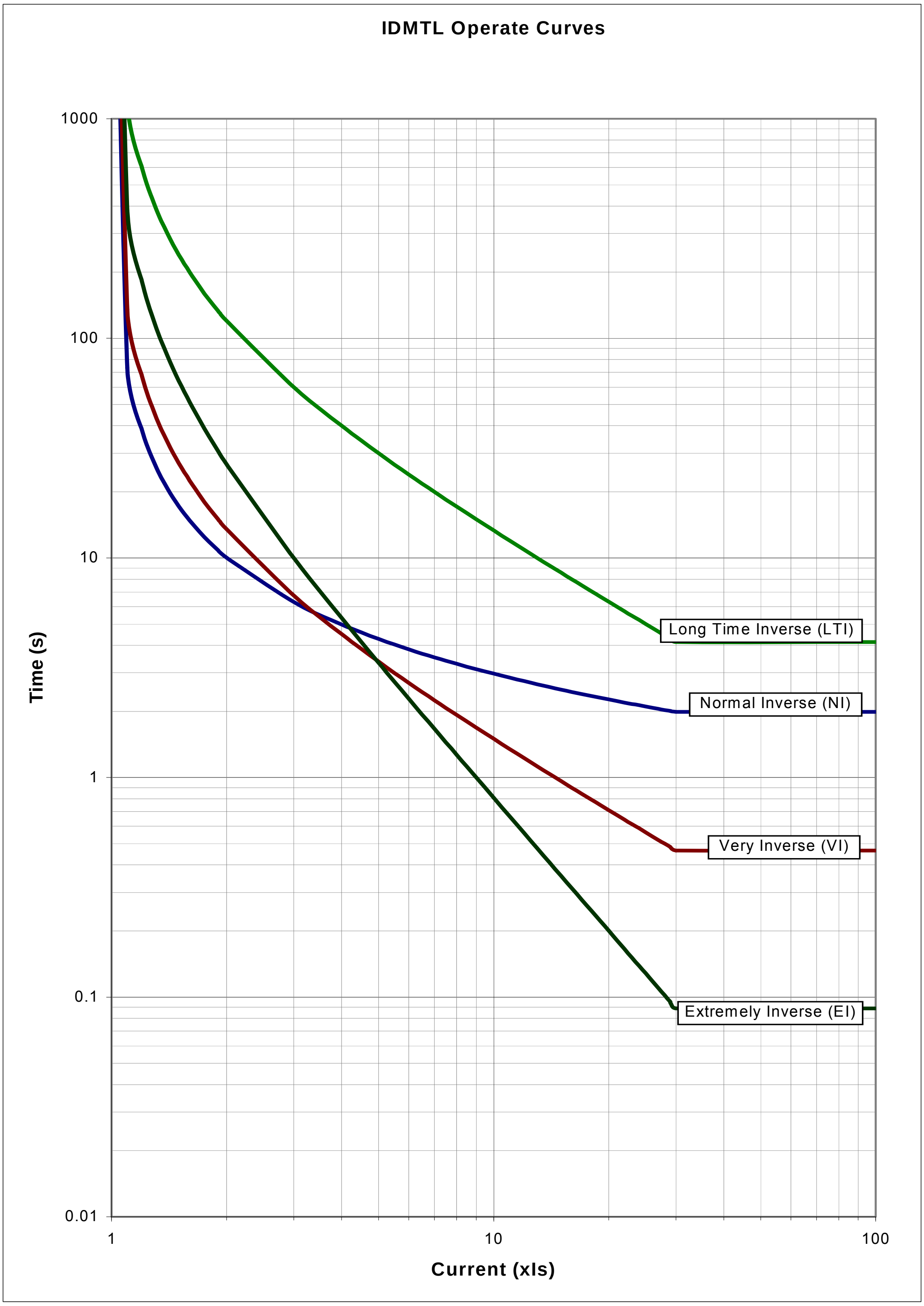


Figure 6 – IDMTL Overcurrent Characteristic (Time Multiplier = 1)

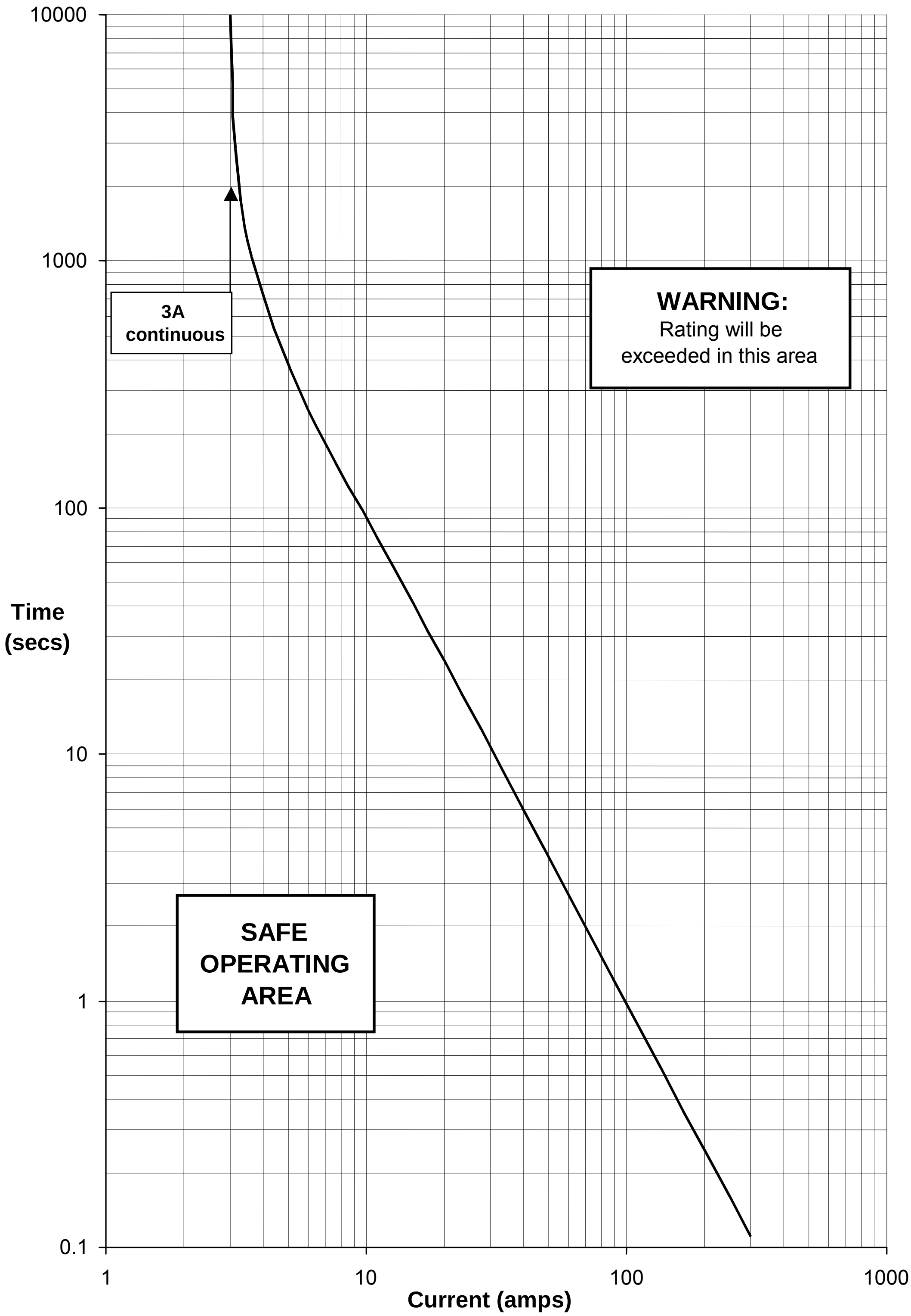


Figure 7 – Thermal Rating for 1A Relay

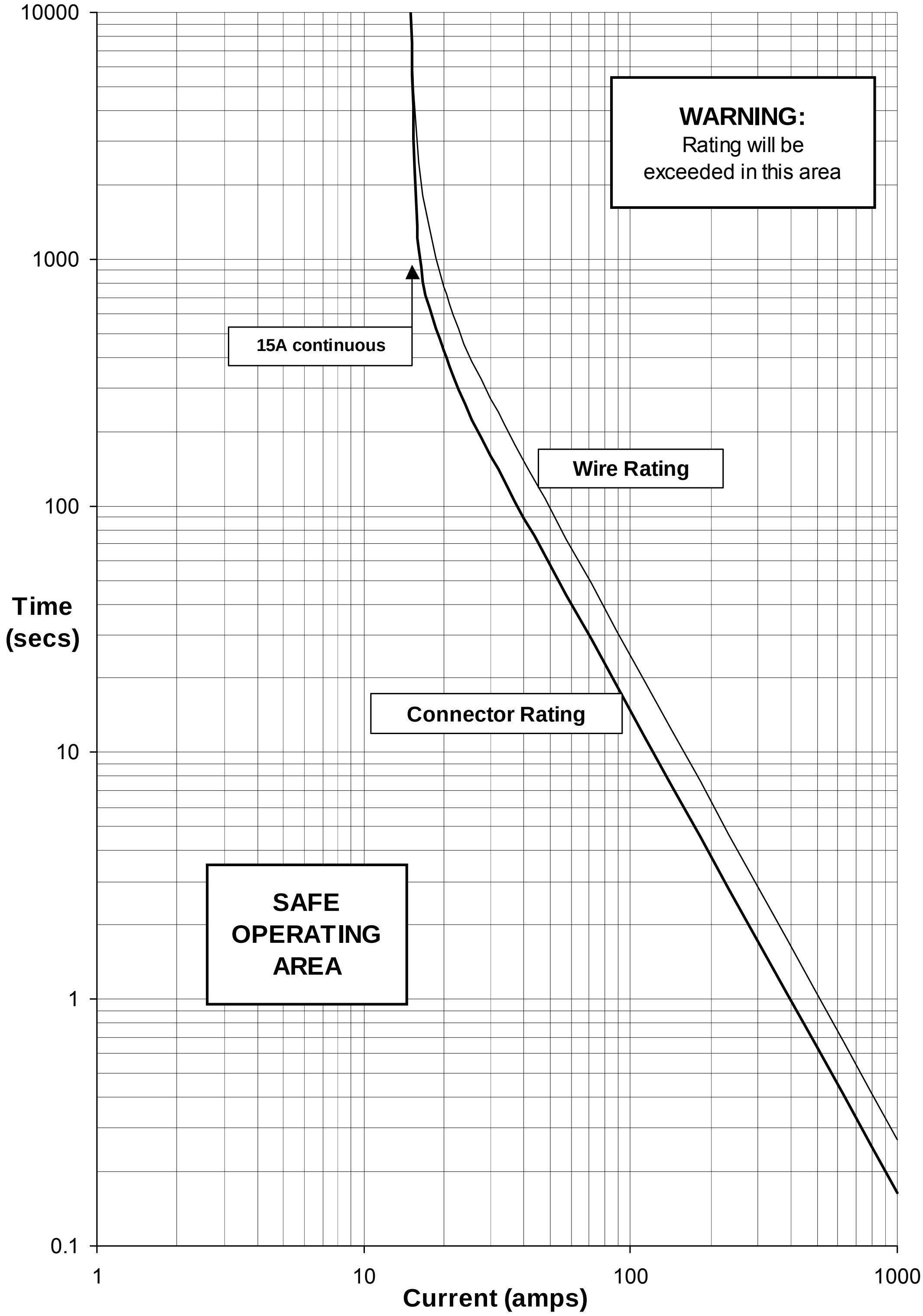


Figure 8 – Thermal Rating for 5A Relay

7SG18 Solkor N

Numeric Differential Protection

Document Release History

This document is issue 2010/02. The list of revisions up to and including this issue is:
Pre release

2010/02	Document reformat due to rebrand

Software Revision History

19/04/2005	2646H80006R5	

Contents

1 System Config Menu

SETTING	RANGE	DEFAULT
Active Settings Group *selects the settings group that the relay will act upon*	G1-G8	G1
Settings Group Edit/View *selects the settings group to be displayed on the LCD*	G1-G8	G1
Copy Group *allows the contents of one settings group to be copied completely to another group. Note that Copy Group will not allow the copying of a group onto the currently active group*	From G1-G8 to G1-G8	From G1-G2
Local P/F Rating *sets the local relay's phase fault current CT rating*	1A, 5A	1A
Local E/F Rating *sets the local relay's earth fault current CT rating*	1A, 5A	1A
Local P/F CT Ratio *sets the local relay's phase input CT ratio so that local primary currents can be displayed*	5 to 10000 step 5 : 1 or 5	300:1
Local E/F CT Ratio *sets the local relay's earth input CT ratio so that local primary currents can be displayed*	5 to 10000 step 5 : 1 or 5	300:1
Remote P/F Rating *sets the remote relay's phase fault current CT rating*	1A, 5A	1A
Remote P/F CT Ratio *sets the remote relay's phase input CT ratio so that remote primary currents can be displayed*	5 to 10000 step 5 : 1 or 5	300:1
Current Display *sets the display mode to use for the relay*	xIn, PRIMARY, SECONDARY	xIn
Set Identifier *allows a 16 character alphanumeric code or unique identification reference to be entered for the relay*	Up to 16 alphanumeric characters	SOLKOR N
Set Alarm 1 *allows a 13 character alphanumeric string to be entered for the General Alarm screen. It will be displayed on energisation of the ALARM 1 status input*	Up to 13 alphanumeric characters	ALARM 1
Set Alarm ..n *as Alarm 1. There are a maximum of 9 alarms available in the relay*	Up to 13 alphanumeric characters	ALARM n
Calendar – Set Date *sets the current date in DD/MM/YY format*	DD/MM/YY	01/01/00
Clock - Set Time *sets the current time in HH/MM/SS format. Note that only hours and minutes can be set. The seconds default to zero on pressing the ENTER key*	HH:MM:SS	00:00:00
Clock Sync. From Status *sets the period of synchronisation of the clock to the nearest second or minute. The synchronisation occurs on energisation of the Clock Sync. status input*	Seconds or Minutes	Minutes
Default Screen Timer *sets the time delay after which, if no key presses have been detected, the relay will begin to poll through any screens which have been selected as default instrument screens*	10sec, 60sec, 5min, 1hour	5 min
Change Password *allows a 4 character alphanumeric code to be entered as the password. Note that the display shows a password dependent encrypted code on the second line of the display*	4 alphanumeric characters	NONE

2 Diff. Protection Menu

SETTING	RANGE	DEFAULT
Gn P/F Diff. Setting* *sets the current setting for the differential element*	0.10 – 2.50xIn step 0.05xIn	0.30xIn
Gn P/F Bias Slope 1* *sets the first bias slope for the differential element*	20%, 30%, 50%, 70%	30%
Gn P/F Bias Slope 2* *sets the second bias slope for the differential element*	50%, 100%, 150%	150%
Gn Bias Break Point* *sets the bias slope break point identifying the point where the characteristic changes from bias slope 1 to bias slope 2*	0.50xIn – 20.00xIn step 0.10xIn	2.00xIn
Gn Differential Delay *sets the trip time for the differential element and the internal intertrip*	0.000s – 0.200s step 0.005s 0.210s – 1.000s step 0.010s 1.100s – 10.000s step 0.100s	0.0s
P/F CT Ratio Correction *enables a CT ratio correction to be set when the local and remote relays are connected to different CTs.*	0.50 – 1.00 step 0.01	1.00
Remote P/F Ratio Correction *enables a CT ratio correction to be set when the local and remote relays are connected to different CTs.*	0.50 – 1.00 step 0.01	1.00
Gn Internal Intertrip *enables / disables internal intertrips*	ON, OFF	OFF
Gn Int Intertrip Delay *Sets the trip time for the internal intertrip elements*	0.000s – 0.05s step 0.005s	0.000s
Gn External Intertrip *enables / disables external intertrips*	ON, OFF	ON
Gn Ext Intertrip Delay *Sets the trip time for the external intertrip elements*	0.000s – 0.200s step 0.005s 0.210s – 1.000s step 0.010s 1.100s – 10.000s step 0.100s	0.000s

3 O/C Protection Menu

SETTING	RANGE	DEFAULT
Gn P/F Charact. Setting *sets the phase fault overcurrent characteristic protection pick-up level*	OFF 0.10xIn – 2.50xIn step 0.05xIn	1.00xIn
Gn P/F Charact. *sets the phase fault overcurrent characteristic*	NI, VI, EI, LTI, DTL	NI
Gn P/F Charact. Time Mult *sets the phase fault time multiplier to use for the characteristics NI, VI, EI, LTI*	0.025 – 1.600 step 0.025	1.000
Gn P/F Charact. Delay *sets the phase fault time delay to use for the characteristic DTL*	0.00s – 20.00s step 0.01s	5.00s
Gn P/F Lowset Setting *sets phase fault lowset pick-up level*	OFF 0.10xIn – 2.50xIn step 0.05xIn 3.0xIn – 52.5xIn step 0.5xIn	1.00xIn
Gn P/F Lowset Delay *sets phase fault lowset time delay*	0.00s – 20.00s step 0.01s	0.00s
Gn P/F Highset1 Setting *sets phase fault highset 1 pick-up level*	OFF 0.10xIn – 2.50xIn step 0.05xIn 3.0xIn – 52.5xIn step 0.5xIn	10.00xIn
Gn P/F Highset1 Delay *sets phase fault highset 1 time delay*	0.00s – 20.00s step 0.01s	0.00s
Gn P/F Highset2 Setting *sets phase fault highset 2 pick-up level*	OFF 0.10xIn – 2.50xIn step 0.05xIn 3.0xIn – 52.5xIn step 0.5xIn	OFF

*These settings are fixed at the default values shown above on the fixed differential setting relay. Variable differential settings type relays are normally ordered. The differential settings on a pair of relay protecting a feeder MUST be identical at all times.

SETTING	RANGE	DEFAULT
Gn P/F Highset2 Delay *sets phase fault highset 2 time delay*	0.00s – 20.00s step 0.01s	0.00s
Gn E/F Charact. Setting *sets the earth fault overcurrent characteristic protection pick-up level*	OFF 0.10xIn – 2.50xIn step 0.05xIn	1.00xIn
Gn E/F Charact. *sets the earth fault overcurrent characteristic*	NI, VI, EI, LTI, DTL	NI
Gn E/F Charact. Time Mult *sets the earth fault time multiplier to use for the characteristics NI, VI, EI, LTI*	0.025 – 1.600 step 0.025	1.000
Gn E/F Charact. Delay *sets the earth fault time delay to use for the characteristic DTL*	0.00s – 20.00s step 0.01s	5.00s
Gn E/F Lowset Setting *sets earth fault lowset pick-up level*	OFF 0.10xIn – 2.50xIn step 0.05xIn 3.0xIn – 52.5xIn step 0.5xIn	1.00xIn
Gn E/F Lowset Delay *sets earth fault lowset time delay*	0.00s – 20.00s step 0.01s	0.00s
Gn E/F Highset1 Setting *sets earth fault highset 1 pick-up level*	OFF 0.10xIn – 2.50xIn step 0.05xIn 3.0xIn – 52.5xIn step 0.5xIn	10.00xIn
Gn E/F Highset1 Delay *sets earth fault highset 1 time delay*	0.00s – 20.00s step 0.01s	0.00s
Gn E/F Highset2 Setting *sets earth fault highset 2 pick-up level*	OFF 0.10xIn – 2.50xIn step 0.05xIn 3.0xIn – 52.5xIn step 0.5xIn	OFF
Gn E/F Highset2 Delay *sets earth fault highset 2 time delay*	0.00s – 20.00s step 0.01s	0.00s
Gn CB Fail Time Delay1 *sets the first time delay for Circuit Breaker fail*	OFF 0.01s – 20.00s step 0.01s	OFF
Gn CB Fail Time Delay2 *sets the second time delay for Circuit Breaker fail*	OFF 0.01s – 20.00s step 0.01s	OFF
Gn P/F CB Fail Setting *sets over current CB Fail level*	OFF 0.10xIn – 1.00xIn step 0.05xIn	OFF
Gn E/F CB Fail Setting *sets earth fault CB Fail level*	OFF 0.10xIn – 1.00xIn step 0.05xIn	OFF
Gn CT Failure Setting *sets CT Failure level*	OFF 0.10xIn – 1.00xIn step 0.05xIn	OFF
Gn CT Failure Delay *sets delay for CT Failure*	0.00s – 20.00s step 0.01s	1 sec
Gn Relay Reset Delay *sets the overcurrent reset characteristic*	INST 1s – 60s step 1s	INST

4 O/P Relay Config Menu

SETTING	RANGE	DEFAULT
Gn Prot. Healthy *sets the output relay operated by the relay(s) watchdog monitor. An output relay with a changeover or normally closed contact should be used for this function (contact open when healthy)*	RL1..RL7	RL1
Gn P/F Diff. *sets the output relay(s) operated by the phase fault differential protection*	RL1..RL7	RL4
Gn P/F Starter *sets the output relay(s) operated by the phase fault overcurrent characteristic starter*	RL1..RL7, GPF[1]	None
Gn P/F Charact. *sets the output relay(s) operated by the phase fault overcurrent characteristic*	RL1..RL7, GPF[1]	None
Gn P/F Lowset *sets the output relay(s) operated by the phase fault lowset*	RL1..RL7, GPF[1]	None
Gn P/F Highset1 *sets the output relay(s) operated by the phase fault highset 1*	RL1..RL7, GPF[1]	None

[1] **GPF** – **G**uard for **P**hase **F**ault differential. This is a virtual output relay that is used as a guard for the phase fault differential protection. See section 1 – Description of Operation for more information regarding this functionality.

SETTING	RANGE	DEFAULT
Gn P/F Highset2 *sets the output relay(s) operated by the phase fault highset 2*	RL1..RL7, GPF[1]	None
Gn E/F Starter *sets the output relay(s) operated by the earth fault overcurrent characteristic starter*	RL1..RL7, GPF[1]	None
Gn E/F Charact. *sets the output relay(s) operated by the earth fault overcurrent characteristic*	RL1..RL7, GPF[1]	None
Gn E/F Lowset *sets the output relay(s) operated by the earth fault lowset*	RL1..RL7, GPF[1]	None
Gn E/F Highset1 *sets the output relay(s) operated by the earth fault highset 1*	RL1..RL7, GPF[1]	None
Gn E/F Highset2 *sets the output relay(s) operated by the earth fault highset 2*	RL1..RL7, GPF[1]	None
Gn Remote Int. iTrip *sets the output relay(s) operated by a remote internal intertrip*	RL1..RL7, GPF[1]	None
Gn Remote Ext. iTrip1 *sets the output relay(s) operated by a remote external intertrip 1*	RL1..RL7, GPF[1]	None
Gn Remote Ext. iTrip2 *sets the output relay(s) operated by a remote external intertrip 2*	RL1..RL7, GPF[1]	None
Gn Status 1 *sets the output relay(s) operated by Status Input 1 energisation*	RL1..RL7, GPF[1]	None
Gn Status ..n *Sets the output relays operated by the other status inputs (if fitted)*	RL1..RL7, GPF[1]	None
Gn CB Fail 1 *sets the output relay(s) operated by the first circuit breaker failure delay*	RL1..RL7, GPF[1]	None
Gn CB Fail 2 *sets the output relay(s) operated by the second circuit breaker failure delay*	RL1..RL7, GPF[1]	None
Gn CT Failure *sets the output relay(s) operated by the CT failure delay*	RL1..RL7, GPF[1]	None
Gn Counter Alarm *sets the output relay(s) operated by the Trip Counter Alarm function*	RL1..RL7, GPF[1]	None
Gn Sum of I^2 Alarm *sets the output relay(s) operated by the Sum of I^2 CB Alarm function*	RL1..RL7, GPF[1]	None
Gn Power On Count. *sets the output relay(s) operated by a Power On Counter*	RL1..RL7	None
Gn Signal Dist. *sets the output relay(s) operated by a signalling disturbance*	RL1..RL7	None
Gn Signal Alarm *sets the output relay(s) operated by the signalling alarm*	RL1..RL7	None
Gn Signal Test *sets the output relay(s) operated when in either Loop Test or Line Test modes*	RL1..RL7	None
Gn Hand Reset *sets the output relay(s) which are to stay latched after operation. These can be reset via the fascia, a status input, or a communications command*	RL1..RL7, GPF[1]	None
Gn Min O/P Energise Time *sets the minimum length of time any output relay can be energised for*	100ms – 500ms step 50ms	100ms

5 Status Config Menu

SETTING	RANGE	DEFAULT
Settings Group Select *sets the status input(s) required to select a settings group to become the active settings group. Note that the lower the number of status input, the higher precedence that it has e.g. Status 1 will take precedence over all the rest*	S1..Sn (each status can be set from 1-8 to select active group 1-8)	None
Inverted Inputs *sets the status input(s) required to be inverted. Any function assigned to an inverted input becomes active when the input is de-energised*	S1..Sn	None
Gn P/F Diff. Inhibit *sets the status input(s) which will inhibit the phase fault differential characteristic*	S1..Sn	None

[1] **GPF** – **G**uard for **P**hase **F**ault differential. This is a virtual output relay that is used as a guard for the phase fault differential protection. See section 1 – Description of Operation for more information regarding this functionality.

SETTING	RANGE	DEFAULT
Gn P/F Charac. Inhibit *sets the status input(s) which will inhibit the phase fault overcurrent characteristic*	S1..Sn, SIG[1]	None
Gn P/F Lowset Inhibit *sets the status input(s) which will inhibit the phase fault lowset*	S1..Sn, SIG[1]	None
Gn P/F Highset1 Inhibit *sets the status input(s) which will inhibit the phase fault highset 1*	S1..Sn, SIG[1]	None
Gn P/F Highset2 Inhibit *sets the status input(s) which will inhibit the phase fault highset 2*	S1..Sn, SIG[1]	None
Gn E/F Charac. Inhibit *sets the status input(s) which will inhibit the earth fault overcurrent characteristic*	S1..Sn, SIG[1]	None
Gn E/F Lowset Inhibit *sets the status input(s) which will inhibit the earth fault lowset*	S1..Sn, SIG[1]	None
Gn E/F Highset1 Inhibit *sets the status input(s) which will inhibit the earth fault highset 1*	S1..Sn, SIG[1]	None
Gn E/F Highset2 Inhibit *sets the status input(s) which will inhibit the earth fault highset 2*	S1..Sn, SIG[1]	None
Gn External iTrip1 *sets the status input(s) which will send an external intertrip 1 to the remote relay*	S1..Sn	None
Gn External iTrip2 *sets the status input(s) which will send an external intertrip 2 to the remote relay*	S1..Sn	None
Gn Receive iTrip Inhibit *sets the status input(s) which will inhibit the receival of intertrip commands*	S1..Sn	None
Gn Send iTrip Inhibit *sets the status input(s) which will inhibit the transmission of intertrip commands*	S1..Sn	None
Gn CB Open *sets the status input(s) for detecting if the circuit break is open*	S1..Sn	None
Gn CB Closed *sets the status input(s) for detecting if the circuit break is closed*	S1..Sn	None
Gn Trip Circuit Fail *sets the status input(s) which will be used within the Trip Circuit Monitoring scheme*	S1..Sn	None
Gn Waveform Trig *sets the status input(s) which, on energisation, will cause a waveform record to be stored*	S1..Sn	None
Gn Sum of I^2 Update *sets the output relay(s) which, on energistaion, will update the ΣI^2 counter*	S1..Sn	None
Gn Reset Flag & Outputs *sets the status input(s) which, on energisation, will reset the Trip LEDs and any latched output relays*	S1..Sn	None
Gn Clock Sync. *sets the status input(s) which, on energisation, will synchronise the real time clock to the nearest second or minute*	S1..Sn	None
Gn ALARM 1 *sets the status input(s) which, on energisation, will cause the Alarm 1 message to be displayed on the LCD*	S1..Sn	None
Gn ALARM ..n	S1..Sn	None
Gn Status 1 P/U Delay *sets the delay period to be applied to the pick-up of Status Input 1*	0.00s – 2.00s step 0.01s 2.10s – 20.00s step 0.10s 21s – 300s step 1s 360s – 3600s step 60s 3900s – 14400s step 300s	0.02s
Gn Status 1 D/O Delay *sets the delay period to be applied to the drop-off of Status Input 1*	As above	0.00s
Gn Status n P/U Delay	As Status 1	0.02s
Gn Status n D/O Delay	As Status 1	0.00s

[1] **SIG** – **SIG**nalling healthy. This is a virtual status input that is used for inhibiting elements if the signalling channel is healthy. See section 1 – Description of Operation for more information regarding this functionality.

6 Prot. Signalling Menu

SETTING	RANGE	DEFAULT
Local Address *sets the local address for the signalling channel. This setting will indicate what the remote relay's address should be set to.*	0 – 31 step 1	0
Baud Rate *sets the signalling channel baud rate*	19200, 38400	38400
Signalling Delay *sets the signalling channel delay. This is used to compensate for delays in the transmit and received paths for the signalling channel*	0.000ms – 9.375ms 9.375ms – 18.750ms 18.750ms – 28.125ms 28.125ms – 37.500ms	0 – 9.375ms
Signal Alarm Timeout *sets a time delay the signalling channel has to be unhealthy before issuing a permanent alarm*	1s – 60s step 1s	5s
Signal Test Mode *puts the relay(s) into test mode to help aid commissioning.* *Loop test mode is used to test one relay and requires the Rx to be looped backed into the Tx of the same relay.* *Line test mode is used to test the signalling channel between two relays. When line test mode is entered the remote relay will echo all data back and will not function as a differential relay.*	OFF LOOP TEST LINE TEST	OFF
Signalling Port *enables or disables the protection signalling channel. Before the two relays will communicate this setting must be enabled.*	DISABLED, ENABLED	DISABLED

7 Comms Interface Menu

SETTING	RANGE	DEFAULT
Comms Protocol *Sets the communications protocol to be used.*	IEC60870-5-103, MODBUS-RTU	IEC60870-5-103
Class 2 Update Period *Sets the time interval between successive updates of Class 2 Measurands.*	0s – 60s step 1s	15s
IEC Class 2 Scaling *Sets the level as a multiple of nominal current at which a Class 2 measurand is automatically generated.*	1.2x, 2.4x	1.2x
Comms Baud Rate *sets the required communications Baud Rate for IEC60870-5-103 and MODBUS-RTU*	75, 110, 150, 300, 600, 1200, 2400, 4800, 9600, 19200	19200
Comms Parity *selects whether a parity check is transmitted with the comms data for IEC60870-5-103 and MODBUS-RTU*	NONE, EVEN	EVEN
Relay Address *sets the required address of a particular relay within a network for IEC60870-5-103 and MODBUS-RTU*	0 – 254	0
Line Idle *sets the required communications line idle sense for fibre optic sytems. RS485 requires that this setting is set to OFF.*	LIGHT ON, LIGHT OFF	LIGHT OFF
Data Echo *enables Data Echo which is necessary for use with relays connected in a ring for IEC60870-5-103. RS485 or MODBUS-RTU requires that this setting is set to OFF.*	OFF / ON	OFF

8 Data Storage Menu

SETTING	RANGE	DEFAULT
Gn Fault Trigger *sets the output relay(s) which are connected as trip outputs for the purpose of giving trip information and storing fault records*	RL1..RLn	4
Gn Waveform Trig *selects which functions trigger a waveform record (STA = status input)*	STA, DIF, O/C, iTp, SIG	STA + DIF + O/C + iTp
Gn Waveform Pre-trigger *selects which functions trigger a waveform record*	OFF, 10%-100% step 10%	70%
Demand Window Type *selects how the maximum demand is measured*	OFF, ROLLING, FIXED	OFF

SETTING	RANGE	DEFAULT
Demand Window *selects the period over which the maximum demand is measured*	5-50 mins, step 5 mins. 90–300 mins, step 30 mins. 360-1440 mins., step 60 mins.	15 minutes
Clear All Waveforms *clears all the waveform records stored. Note that this can also be done at the instruments display*	NO, YES (Confirmation required)	NO
Clear All Events *clears all the event records stored. Note that this can also be done at the instruments display*	NO, YES (Confirmation required)	NO
Clear All Faults *clears all the fault data records stored*	NO, YES (Confirmation required)	NO

9 CB Maintenance Menu

SETTING	RANGE	DEFAULT
Trip Counter Reset *resets the Trip Counter to zero*	NO, YES (Confirmation required)	NO
Trip Counter Alarm *sets a target value for which an alarm output will be given when the value is reached*	OFF 1 – 999 step 1	OFF
Sum I^2 Reset *resets the CB Duty ΣI^2 to zero*	NO, YES (Confirmation required)	NO
ΣI^2 Alarm *sets a target value for which an alarm output will be given when theCB Duty Sum ΣI^2 value is reached*	OFF 10 – 100 step $1MA^2$ 200 – 20000 step $100MA^2$ 21000 – 100000 step $1000MA^2$	OFF
Power on Count Alarm *Allows a set number of relay power ups to produce an alarm*	OFF, 999	OFF
Phase A Reversal *allows phase A current input to be reversed. This is equivalent to swapping the wiring connected to the phase A current input*	OFF, ON	OFF
Phase B Reversal *allows phase B current input to be reversed. This is equivalent to swapping the wiring connected to the phase B current input*	OFF, ON	OFF
Phase C Reversal *allows phase C current input to be reversed. This is equivalent to swapping the wiring connected to the phase C current input*	OFF, ON	OFF
Earth Reversal *allows the earth current input to be reversed. This is equivalent to swapping the wiring connected to the earth fault current input*	OFF, ON	OFF
Manual Intertrip *allows a manual intertrip to be sent to the remote relay*	OFF, Internal iTrip, External iTrip1, External iTrip2	OFF
O/P Test *allows any combination of output relays to be energised. This is achieved by selecting one of the output settings defined in the O/P Relay Config Menu. Note that the relay is energised after 10 seconds have elapsed and is energised for the minimum output relay energise time*	Any output relay option	OFF

7SG18 Solkor N

Numeric Differential Protection

Document Release History

This document is issue 2010/02. The list of revisions up to and including this issue is:
Pre release

2010/02	Document reformat due to rebrand

Software Revision History

19/04/2005	2646H80006R5	

Contents

Table of Figures

Glossary

Baud Rate	See *bits per second*.
Bit	The smallest measure of computer data.
Bits Per Second (BPS)	Measurement of data transmission speed.
Data Bits	A number of *bits* containing the data. Sent after the *start bit*.
Half-Duplex Asynchronous Communications	Communications in two directions, but only one at a time.
Full-Duplex Asynchronous Communications	Communications in two directions, both at the same time.
Hayes 'AT'	Modem command set developed by Hayes Microcomputer products, Inc.
Master Station	See *primary station*.
Modem	MOdulator / DEModulator device for connecting computer equipment to a telephone line.
Parity	Method of error checking by counting the value of the bits in a sequence, and adding a parity bit to make the outcome, for example, even.
Parity Bit	*Bit* used for implementing parity checking. Sent after the *data bits*.
Primary Station	The device controlling the communication.
PSTN	Public Switched Telephone Network
RS232C	Serial Communications Standard. Electronic Industries Association Recommended Standard Number 232, Revision C.
Secondary Station	The device being communicated with.
Slave Station	See *secondary station*.
Start Bit	*Bit* (logical 0) sent to signify the start of a byte during data transmission.
Stop Bit	*Bit* (logical 1) sent to signify the end of a byte during data transmission.

1 Introduction

The relay has two communications channels:

1 Protection Communication Channel used to exchange power system current and other protection information between relays at each end of the protected feeder. The type of connection may be one of three types. The three types are: One pair of ST (RX&TX) type ports for various types of Fibre Optic ports; a four wire RS485 terminal or RS232 nine pin D type for connection to a Pilotwire Modem.

2 Auxiliary Communication Channel used to set, control and interrogate the relay and extract captured fault records. This may be either two wire RS485 or Fibre optic

The auxiliary communications channel can use either an IEC 60870-5-103 compliant protocol or MODBUS-RTU protocol, which allows the relay to communicate with a portable computer or a host computer in a SCADA scheme. The end to end protection communications uses a protocol based on IEC60870-5-103, but is a propriety protocol.

Access to the relay via the auxiliary communications port requires appropriate software in the interrogating computer, such as Reydisp Evolution. This software uses IEC60870-5-103 and therefore the relay must be set with this protocol active during setting and commissioning.

2 Protection Signalling Channel

2.1 Connection Specification and Relay Settings

This section defines the connection medium used for the protection signalling channel.

The settings for the protection signalling channel can be found in the PROT. SIGNALLING MENU.

2.1.1 General

The relays work in pairs, one at each end of a protected zone or feeder, connected via the protection communications channel. This could be a direct end-to-end connection as shown in Figure 1 or it could be routed through a multiplexer as shown in Figure 2. The physical connection to the relay can be either electrical or optical, allowing twisted pair sections to be employed between the relay and multiplexer.

2.1.2 Recommended cable

The type of cables recommended for the various interface options are given in the table below. Details of transmission distances and signal budgets are given in the Performance Specification.

See Performance Specification for the available communication channels.

No other types of media are suitable for use with the protection signalling channel.

2.1.3 Connection Method

The relays are connected pairs consisting of a local end and a remote end. These pairs may be connected directly together (see figure 1) or through a digital multiplexer such as the UMUX 1500 from RFL Electronics Inc (see figure 2). The third connection method using RS 485 is shown in figure 3. A fourth type is connection over two pairs of screened twisted pilot wires.

The following table specifies the options available for communication between relays.

Transmitter Type	Wire/Fibre Type	Typical Attenuation Limits	Launch Power	Receive Power	Typical Distance
Electrical RS-485	Belden 9842 twisted pair		-	-	0-2km
Electrical Screened Twisted Pair Pilotwire	Various	Total Pilotwire Resistance and Intercore Capacitance Product <300,000nFohms	Requires Externally mounted RS232 to Pilotwire Modem, 19200 Baud only		0-10km **
Fibre Optic 1300nm Short Range	62.5/125µm multimode	-1.5dB at 1300nm per km of FO.	-10dB	-30dB	0-15km*
Fibre Optic 1300nm Long Range	9/125µm single mode	-0.35dB at 1300nm per km of FO.	-10dB	-30dB	0-49km*
	62.5/125µm multimode	-1.5dB at 1300nm per km of FO.	-7dB	-30dB	5-15km*

* assumes FO splices every 4km of -0.05dB to - 0.1db each, but includes a 3dB safety margin for relay connector losses etc, based on minimum output levels. Typical distances may be greater. Loss estimates should be calculated for individual application studies using cable manufacturers data or measured after installation using specialised equipment.

Note all Fibre Optic type relays have a maximum Receive Power limit of -9dB, above which the input saturates.

The long range relays have the 1300nm transmitter set to have a launch power set to this level when a 9µm singlemode fibre is connected. When a 62.5µm multimode fibre is connected to the long range device the launch power will be above this level and therefore have a minimum as well as a maximum distance limit. The Launch power can be calibrated downwards at the rear of the relay using a suitable Fibre Optic Meter to allow the Signalling to become healthy.

The short range device is set to a launch power of -9dB when a 62.5µm fibre is connected and therefore are not restricted by a minimum length.

** maximum length of pilotwire connection is dependent on cable properties. See Section 5 - Applications.

2.1.4 Transmission Method

Full duplex asynchronous communications is employed. The protocol is based on IEC60870-5-103 and uses frames assembled from individual characters. Each character consists of 11 bits:

1 start, 8 data, 1 parity, 1 stop.

Each frame consists of 10 characters:

1 Start flag, 7 Data, 1 Check sum, 1 End flag.

2.1.5 Transmission Rate (Baud Rate Setting)

Baud rates of 38400 and 19200 bits per second (BPS) are provided. Wherever possible use 38400 bps as this gives faster operate times. Use 19200 bps with external communications equipment (e.g. multiplexers) that do not support 38400 bps. When the signalling channel is non-standard and may introduce more noise than normal, a 19200 bps will provide more immunity. When using the relay with screened twisted pilotwires via the Pilotwire modem, the Protection Signalling baud rate **must be set to 19,200.**

2.1.6 Local Address Setting

The protection signalling address of the relay can be set to a value of between 0 and 31. The remote relay's address must be set so that the sum of both addresses is 31. I.e. if the local relay has an address of 5 then the remote relay's address must be set to 26. The lowest number in a pair is assigned as the master relay.

2.1.7 Propagation Delay

The protection can accommodate propagation delay up to the maximum specified in the Performance Specification. The Go and Return delays should be near identical, preferably to within 0.5 ms of each other.

3 IEC60870-5-103 Interrogation Channel

3.1 Connection Specification and Relay Settings

This section defines the connection medium as defined by IEC60870-5-103. Appendix B shows some typical communication connections.

The settings for the IEC60870-5-103 interrogation channel can be found in the COMMS INTERFACE MENU.

3.1.1 Recommended cable

Selection of fibre optic cable is critical. Fibres should be terminated with BFOC/2.5 (ST®) bayonet-style connectors. With this type of connector the recommended cable is 62.5 / 125μm glass fibre. This offers superior performance over SMA type connectors in terms of better coupling to the fibre and therefore has lower losses.

No other types of cable are suitable for use with the relays.

3.1.2 Connection Method

The relays can be connected in either a Star or Ring fibre-optic communications network. If star connected then a passive fibre optic hub must be used. A lower cost option is the ring configuration where the relays are 'daisy chained.' That is, the transmit output of the first relay is connected to the receive input of the second relay, and so on until the ring is complete.

Communication to the ring may be achieved either locally in the substation or remotely via the Public Switched Telephone Network (PSTN). If remote communication is desired, then additional modem equipment must be installed.

Reydisp Evolution is a PC based software package providing capability for both local and remote communication. It provides features such as download of disturbance and event records, upload of relay settings, real-time monitoring of measurands and remote control of plant.

3.1.3 Transmission Method

The transmission method is Half Duplex serial asynchronous transmission. In IEC60870-5-103 the line idle state is defined as Light ON. This can alternatively be selected as Light OFF in the Communications Interface menu of the relay if required for use with alternate hardware (See Section 3.1.5).

3.1.4 Transmission Rate

Rates of 19200, 9600, 4800, 2400, 1200, 600, 300, 150, 110 and 75 bits per second (BPS) are provided. Only 19200 and 9600 BPS are standard in IEC60870-5-103, the additional rates are provided for local or modem communications. The 19,200 BPS setting is normally used.

3.1.5 Line Idle Setting

The line idle setting can be set to be either ON or OFF and the setting must be compatible with the device connected to the relay. The IEC60870-5-103 standard defines a line idle state of Light On. If the device the relay is connected to does not have a compatible fibre-optic port then a suitable electrical to optical converter is required to connect it to a standard RS232C electrical interface. A suitable converter is the Sigma 4 type, which is available from Siemens.

Alternative converters are the Reyrolle Dual RS232 Port (Sigma 3) or Reyrolle Passive Fibre-Optic Hub (Sigma 1).

1. The Sigma 3 Dual RS232 port provides a fibre-optic interface to a relay and two RS232 ports. The RS232 system port is typically connected to a control system while the second port is a local port. When the local port is in use the system port is automatically disabled. The Sigma 3 has an internal link to switch between line idle Light ON or Light OFF. The default configuration is Light OFF.
2. The Sigma 1 Passive Fibre-Optic Hub provides fibre-optic interfaces for up to 29 relays. It has a fibre-optic port to the control system and multiple relay connections. Each of the 30 fibre-optic ports can be configured for either Light ON or Light OFF operation. Default for all is OFF.

3.1.6 Parity Setting

IEC60870-5-103 defines the method of transmission as using EVEN Parity. However, in some instances an alternative may be required. This option allows the parity to be set to NONE.

3.1.7 Address Setting

The IEC60870-5-103 address of the relay must be set to a value between 1 and 254 inclusive before any communication can take place. Setting the address to zero disables communications to the relay, although if it is in an optical ring it will still obey the Data Echo setting. All relays in an optical ring must have a unique address. Address 255 is reserved as a global broadcast address.

3.2 Modems

The communications interface has been designed to allow data transfer via modems. However, IEC60870-5-103 defines the data transfer protocol as an 11 bit format of 1 start, 1 stop, 8 data and 1 parity bit which is a mode most commercial modems do not support. High performance modems, for example, Sonix (now 3Com), Volante and MultiTech Systems MT series will support this mode but are expensive. For this reason a parity setting (see section 2.6) to allow use of easily available and relatively inexpensive commercial modems has been provided. The downside to using no parity is that the data security will be reduced slightly and the system will not be compatible with true IEC60870 control systems.

3.2.1 Connecting a modem to the relay(s)

The RS232C standard defines devices as being either Data Terminal Equipment (DTE) e.g. computers, or Data Communications Equipment (DCE) e.g. modems. To connect the modem to a relay requires a fibre-optic to electrical connector and a Null Terminal connector that switches various control lines. The fibre-optic converter is then connected to the relay in the following manner:

Fibre-Optic Converter	Relay Connection
Tx	**Rx**
Rx	**Tx**

3.2.2 Setting the Remote Modem

Most modems support the basic Hayes ‘AT’ command format, though different manufacturers can use different commands for the same functions. In addition, some modems use DIP switches to set parameters while others are entirely software configured. Before applying the following settings it is necessary to return the modem to its factory default settings to ensure that it is in a known state.

The remote modem must be configured as Auto Answer, which will allow it to initiate communications with the relays. Auto answer usually requires 2 parameters to be set. One switches auto answer on and the other, the number of rings after which it will answer. The Data Terminal Ready (DTR) settings should be forced on which tells the modem that the device connected to it is ready to receive data. The parameters of the modem’s RS232C port need to be set to match those set on the relay i.e. baud rate and parity to be the same as the settings on the relay, and number of data bits to be 8 and stop bits 1.

Note: although it may be possible to communicate with the modem at e.g. 19200bps, it may not be possible to transmit at this rate over the telephone system which may be limited to 14400. A baud rate setting needs to be chosen which is compatible with the telephone system. Since 14400 is not available in the relay, the next lowest rate, 9600, would have to be used.

Since the modem needs to be transparent, simply passing on the data sent from the controller to the device and vice versa, the error correction and buffering must be turned off. In addition if possible force the Data Carrier Detect (DCD) setting to ON as the fibre-optic converter will use this control line.

Finally these settings should be stored in the modem’s memory for power on defaults.

3.2.3 Connecting to the remote modem

Once the remote modem is configured correctly it should be possible to dial into it using the standard configuration from a local PC. As the settings on the remote modem are fixed, the local modem should negotiate with it on connecting and choose suitable matching settings. If it does not, however, set the local modem to mimic the settings of the remote modem described above.

3.3 Support Software

Reydisp Evolution is a PC based software package that provides access to the relay from a computer via the auxiliary communication channel. Its salient features are:

- Download, display and analysis of fault records and event records.
- Upload relay settings.
- Real-time measurements.
- Remote control of plant.

4 Introduction – Modbus RTU

This section describes how to use the Modbus Interface with a compliant control system. For further information regarding the interface, reference should be made to the Argus Modbus implementation report 434/TIR/14 available on website www.siemens.com.
The same communications interface is used to provide control system connections.
The relay complies with the physical requirements of Modbus using fibre-optics or an RS485 interface.

4.1 Medium

The communicating medium is optical fibre or electrical RS485. The device communicating with the Argus should have an interface optimised for 62.5/125 μm glass fibre-optics, or RS485 electrical connection.

4.2 Sigma Fibre-optic to RS232 Converters

See previous section 3

4.3 Recommended cable

Selection of fibre-optic cable is important. Fibres must be terminated with ST™ (BFOC/2.5) connectors. The recommended type is 62.5/125μm glass fibre. Communication distances over 1 km are achievable using this type of fibre.
The RS485 electrical interface can be connected using 120 ohm screened twisted pair wire i.e. Belden 9841 or equivalent.

4.4 Network Topology

Fibre optical communication networks can be connected singularly or in a star configuration. Modbus does not support a fibre optic ring configuration.
RS485 electrical connection can be used in a single or multi-drop configuration. The last device must be terminated correctly.
Appendix B illustrates typical network arrangements.

4.5 Settings

Communication parameters of Communications Interface:**Comms Baud Rate**, Communications Interface:**Comms Parity** and Communications Interface**: Line Idle** should match those of the communicating device.

4.6 Baud Rate

Rates of **19200**, **9600**, **4800**, **2400**, **1200**, **600**, **300**, **150**, **110** and **75** bits per second are provided.
The Communications Interface:**Comms Baud Rate** setting should match that of the communicating device,

4.7 Comms Parity

The Communications Interface:**Comms Parity** setting allows parity of **Even** or **None** to be selected. This setting should match that of the communicating device.

4.8 Relay Address

Each relay on a network must have a unique address, between **1** and **247**, as set by the Communications Interface: **Relay Address** setting. A relay with the default address of **0** will not be able to communicate. The actual number of devices will be limited to 32 devices on any one RS485 connection. Note that the setting range available on the relay is 0-254 to suit IEC60870-5-103 but only 0-247 apply to Modbus-RTU.

4.9 Line Idle

If the communication medium is fibre-optic the Communications Interface**: Line Idle** setting defines the quiescent state. When set as **Light On** binary '0' is represented by light on, binary '1' is represented by light off and vice versa for **Light Off** mode. While in **Light On** mode and the device is not communicating it maintains the **Light On** mode to allow breaks in the cable to be detected. These potential breaks would not be detected when the device mode is set to **Light Off**.
This must be set to **OFF** when connected to the RS485 electrical connection.

4.10 Data Echo

All relays must have the Communications Interface:**Data Echo** setting to **OFF for Modbus-RTU**.

APPENDIX A – PROTECTION SIGNALLING COMMUNICATION CONNECTIONS

Figures 1 to 5 illustrate a number of methods of connecting the protection signalling communications channel.

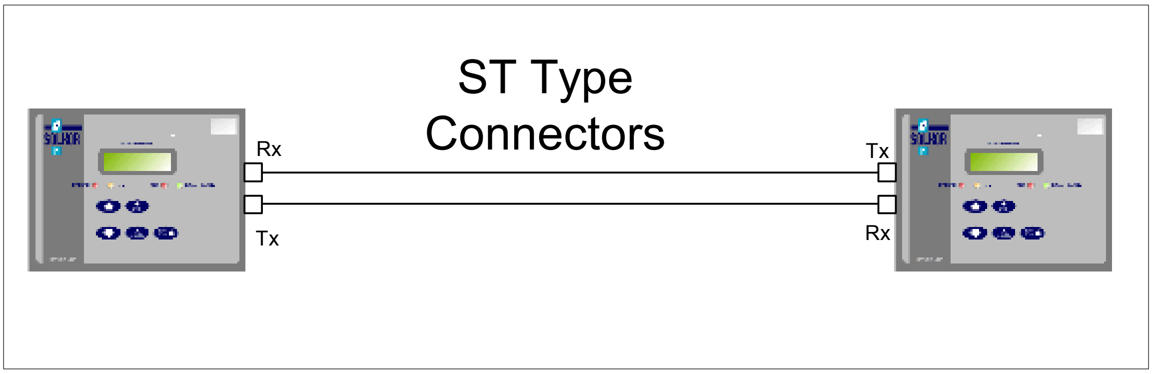


Figure 1 – Fibre Optic Signalling Connections

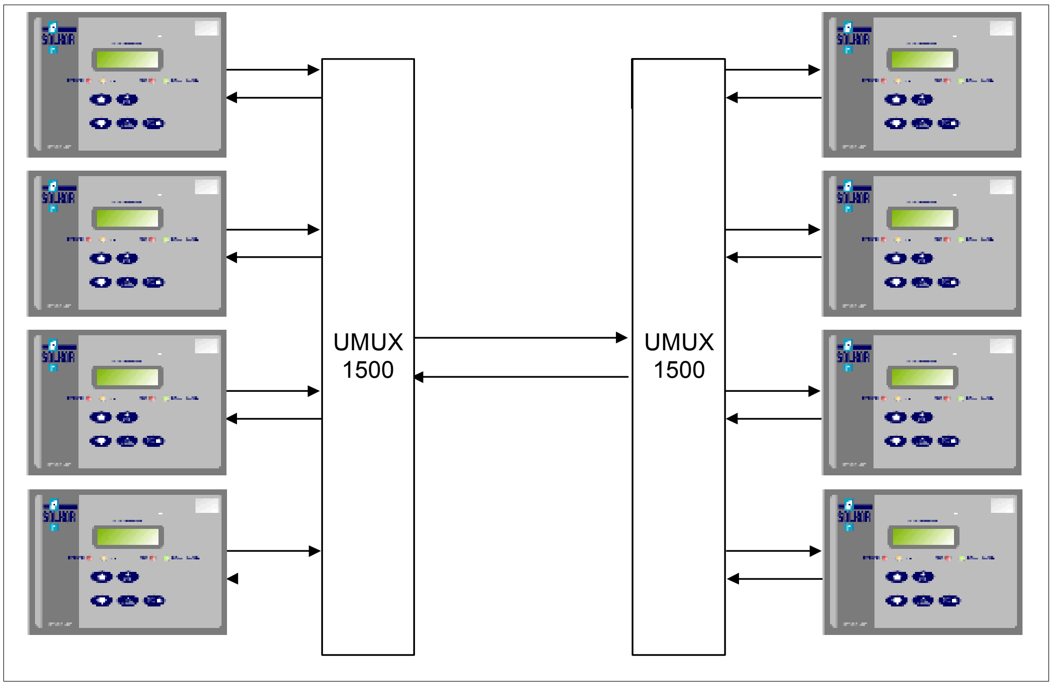


Figure 2 - Multiplexer Signalling Communications Configuration

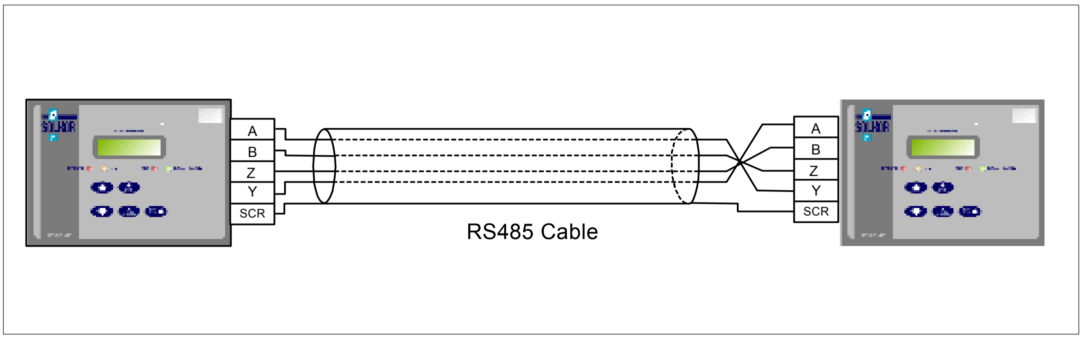


Figure 3 - RS485 Signalling Cable Connections

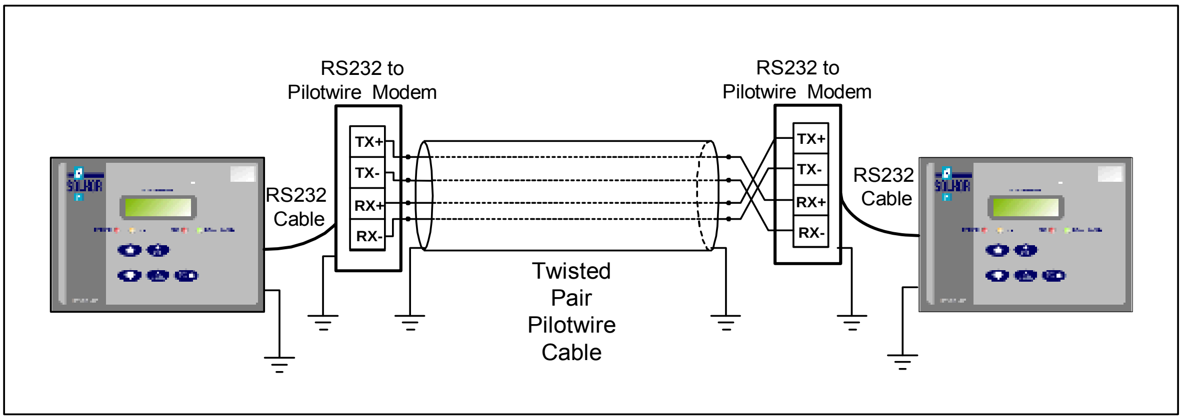


Figure 4 - Pilotwire Signalling Cable Connections

As shown above the pilot wires should be earthed at both ends, at the substation pilot wire terminations. The relay and Pilotwire Modem must be earthed separately at the relay panel. The Protection Signalling Baud Rate of the relay must be set to 19,200 when using pilot wire. The Pilotwire Modem has a mounting bracket that may be altered to suite the available panel space.

The Pilot wire modem is internally panel mounted.

APPENDIX B – IEC60870-5-103 COMMUNICATION CONNECTIONS

Figures 5 to 11 illustrate a number of methods of connecting relays in communications networks.

(Note that in the case of the optical ring configuration (figure 9 & 10), the Data Echo feature must be switched ON in the communications settings menu of the relay. In all other cases this setting should be set to OFF).

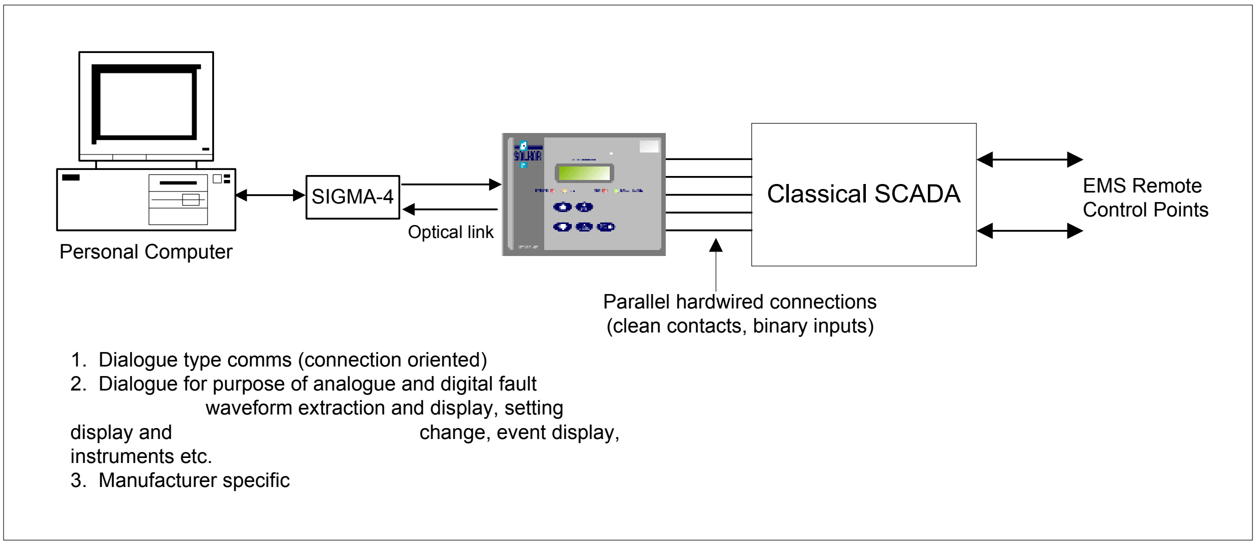


Figure 5 - Basic Fibre Optic Data Communications Configuration

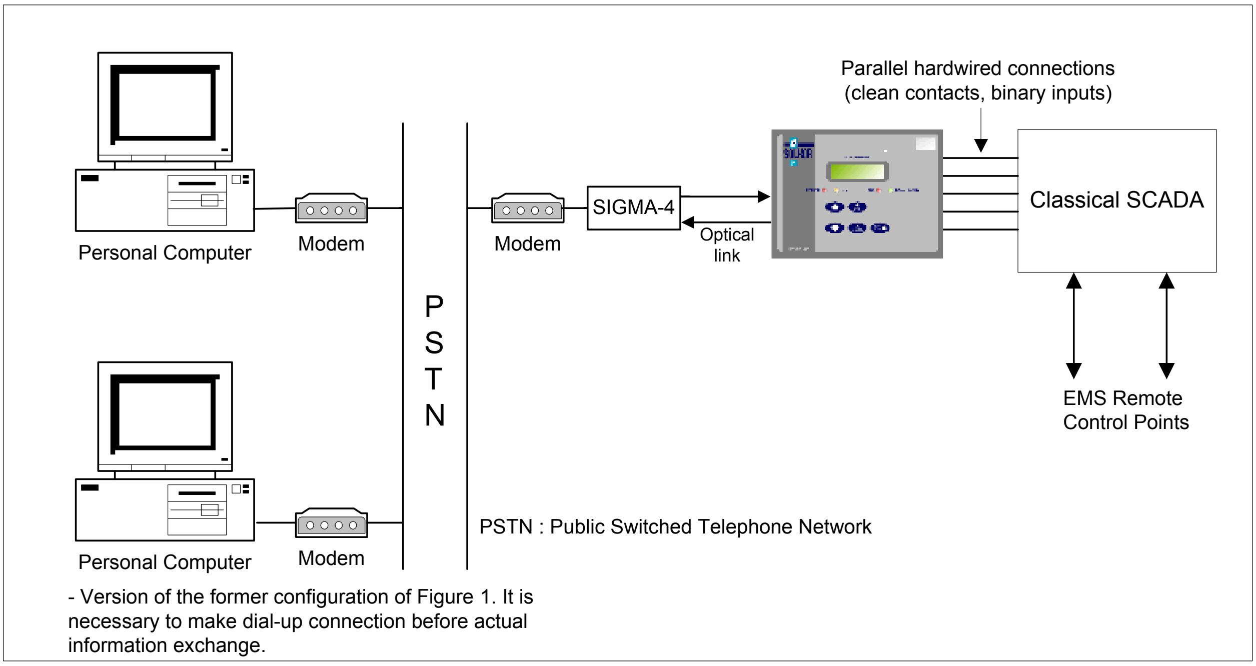


Figure 6 – Fibre Optic Data Communications Configuration (Remote)

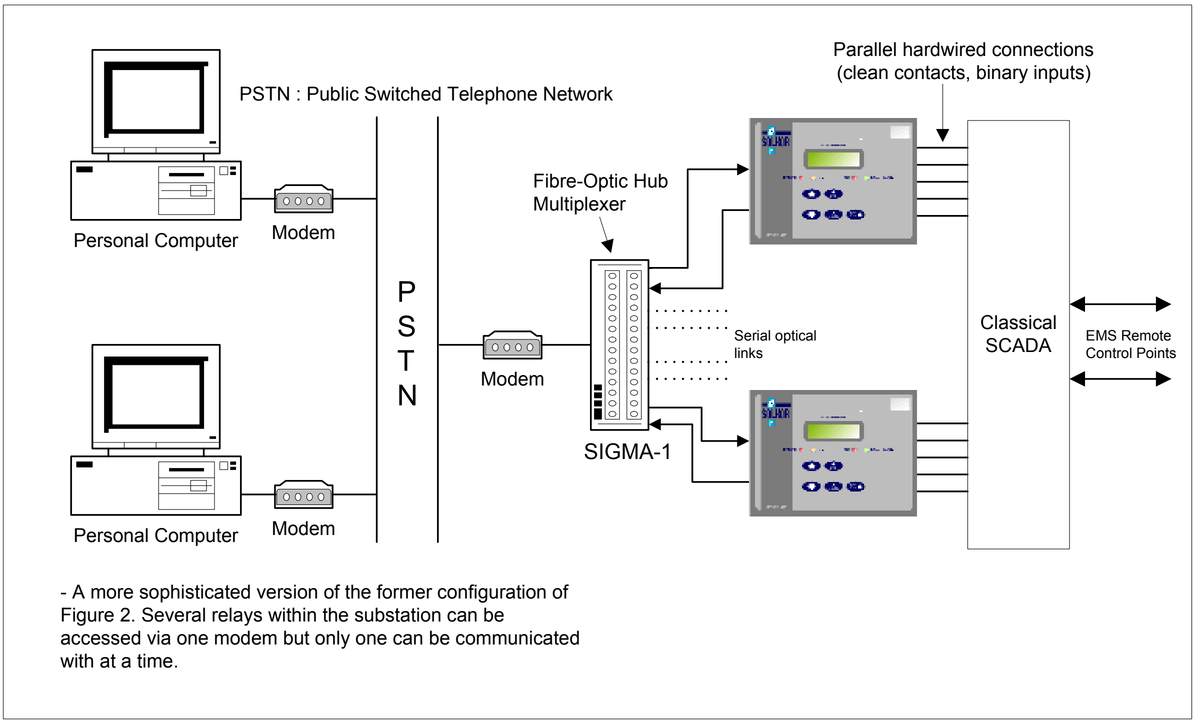


Figure 7 - Star Type Configuration (Multiplexer)

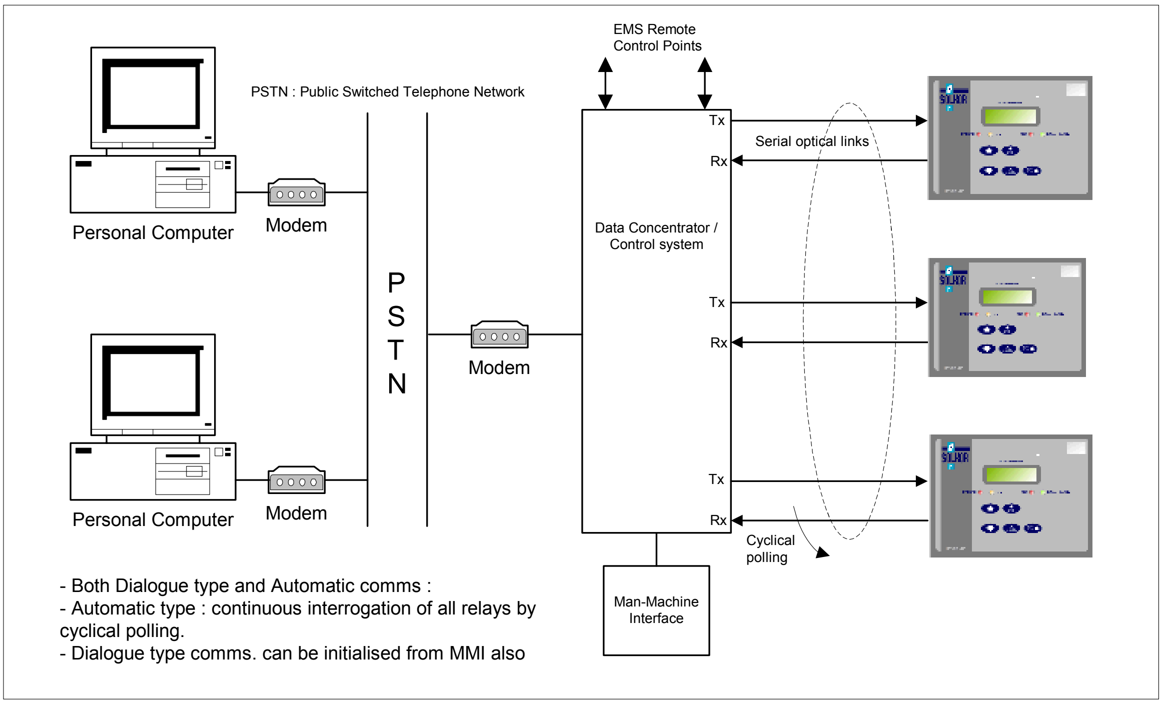


Figure 8 - Data Concentrator Configuration

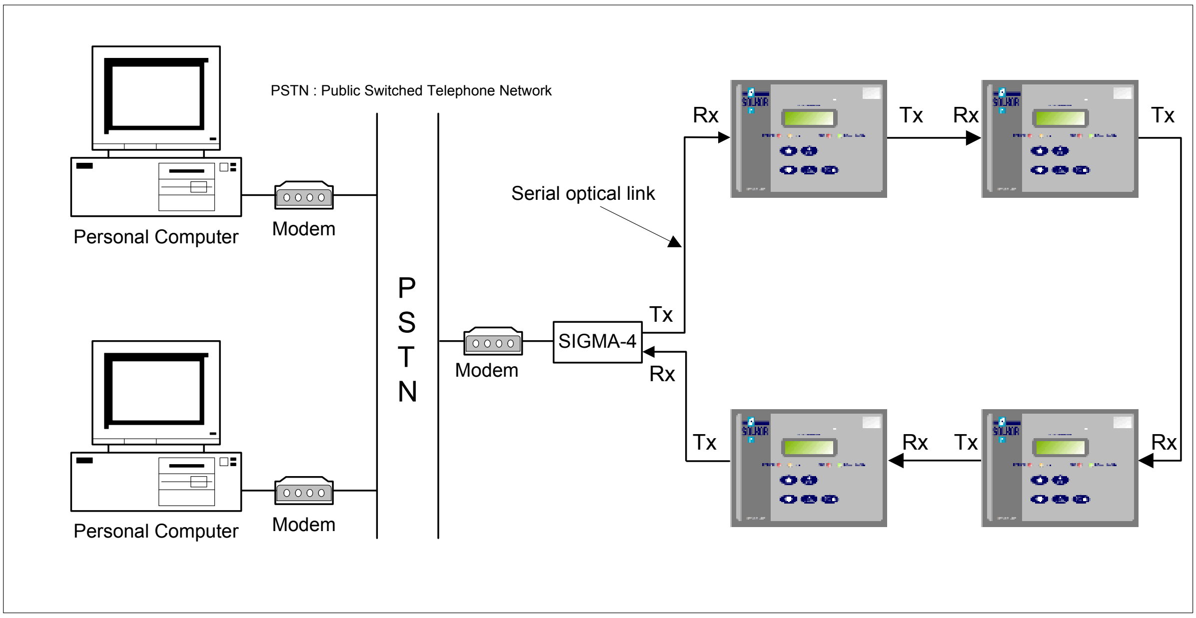


Figure 9 - Optical Ring Configuration (Data Echo - On)

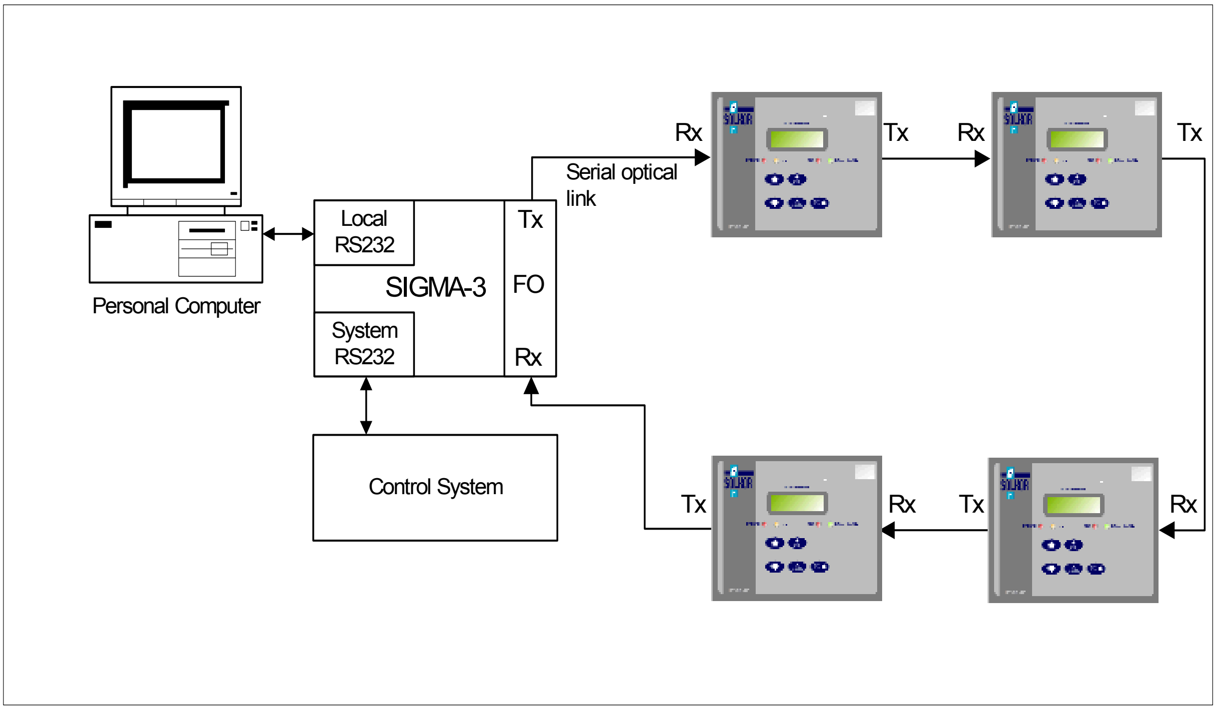


Figure 10 - Configuration using the Sigma 3 – Dual Port RS232 Device

Up to 254 relays may be connected in the above Fibre Optic ring.

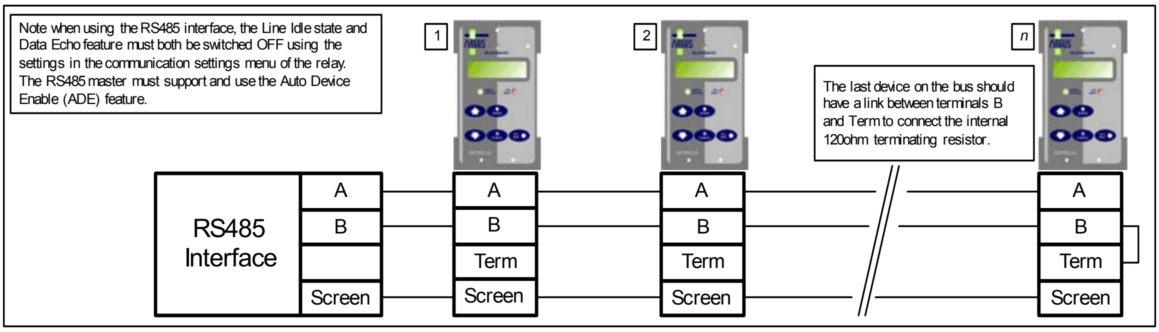


Figure 11 – Data Communication using the Two wired RS485 Interface

Up to 31 similar relays can be connected on the RS485 multi-drop bus per main interface.

7SG18 Solkor N

Numeric Differential Protection

Document Release History

This document is issue 2010/02. The list of revisions up to and including this issue is:
Pre release

2010/02	Document reformat due to rebrand

Software Revision History

19/04/2005	2646H80006R5	

Contents

Figures

Reference Material

[1] – REYDISP EVOLUTION: is a PC based relay support package which allows local or remote access to relays for uploading and downloading settings, down loading waveform, event and fault records, reading real time instruments and plant control. This software is a MS Windows^{TM} based package, and is compatible with Solkor N, Argus and Modular II Reyrolle numerical relays. This package is very useful tool for commissioning and setting relays, as it saves time. The use of Reydisp Evolution is covered in the communications section of this manual.

[2] – INFORMATIVE COMMUNICATIONS INTERFACE: is a report detailing all aspects of the IEC 870-5-103 communications protocol used by the Solkor N, Argus and Modular II products available from Siemens Protection Devices Limited. This manual is very useful when interfacing the relay protocol to the control system protocol for remote access and control.

[3] – REYROLLE COMMUNICATIONS MANUAL: is a report detailing the methods of how relays supplied by Siemens Protection Devices Ltd can be connected together to realise communications access to the relays. This report covers the configuration, type and interface equipment required for remote and local access.

1 Introduction

This relay is a numerical current differential relay providing unit protection of a cable or over head line feeder. It has all of the usual features of such a device such as remote communications, waveform and event recording.

It uses two concurrent phase and amplitude comparators on each of the three phases to detect internal faults. It can employ several common types of direct protection communications link.

- Several types of Direct Fibre Optic to 70km
- Multiplexed
- RS485 Four Wire Cable to 1.5km
- Screened Twisted Pair Pilotwire to 10km

The relays can be applied to the following circuit types:

- Two Terminal Cable Feeders.
- Two Terminal Overhead Line Feeders.
- Two Terminal Hybrid or Mixed Cable/Overhead line Feeders

The speed of operation is 30 to 40ms for normal feeder faults such as lightening strikes and cable sealing end flashovers. The operate time will suit applications for sub-transmission and distribution feeder protection. When the relay is set to 38.4K baud

The relay provides the following functions:

- Current Differential using independent phase angle and magnitude comparison for each phase current.
- IDMTL and DTL Backup Over Current and Earth Fault
- Differential Guard elements
- Protection Signal Channel Supervision
- External and Internal initiated Inter-tripping/Protection Signalling
- Trip Circuit Supervision
- CT Ratio Correction
- Circuit Breaker Fail
- CT Supervision
- User definable Alarms
- Communications for Remote Access of Relay Data via IEC-60870-5-103 or Modbus Protocols
- Waveform, Event and Maximum Demand Recording.

The typical end to end protection signalling length limitations, for direct connection between relays are indicated in the Performance Specification, for each type of the direct protection communication channel. A fibre optic loss budget calculation should be considered for any prospective application. An example is shown in this manual section.

One of the above types of communication medium must be specified at the time of order.

The Fibre Optic or RS485 type signal may also be multiplexed using a high speed MUX device.

The specification of the fibre optic and RS485 cable can be found in Section 4 – Communications Interface of this manual.
The communications output type may be changed easily, as the send and receive module can be removed from the case and changed.

The maximum length of the Cable Feeder that can be protected with a pilot wire type output is primarily dependant upon the pilot wire resistance and inter-core capacitance. A larger diameter pilot wire will allow greater feeder lengths to be covered. The Twisted pilots must have an earthed screen to limit any induced interference. The drop out pilot wire resistance and capacitance product is approximately 340,000 nano-Farad ohms. The limits for the communications range, as set out in the Section 4 Communications of this Technical Manual are based on approximately 250,000 nano-Farad ohms to allow for a safety margin for tolerances. An absolute limit on the length of pilot wire that may be used with the pilotwire modem is 300,000 nano-farad ohms.

The relay requires two pairs of screened conductors when used over pilotwires. Where conventional circulating protection using two or three wire connection is used, such as with Solkor A, B, R or Rf, the inter-tripping pilots may be utilised, this relay has a two internal, supervised, inter-trip channels.

2 General Information

2.1 Relay External Connections

The relay should be connected to a three-phase set of CT's at either end of the protected zone. Typical connections are shown in Figures 6 (Fibre Optic), Figure 7 (RS485 Cable) and Figure 8 (Screened Twisted Pair Metallic Pilotwire). These connections provide the facility to provide backup over current and earth fault protection, as well as current differential. Figure 8 details the CT connections for the relays at either end of the feeder. The Protection Signalling connection diagram for fibre optics, RS485 cable and Pilotwire interface can be found at the end of Section 4 – Communication Interface.

The auxiliary DC supply voltage of the relay must be specified at time of order. The user may choose from two power supplies. One is rated from 18 to 60V DC and is suitable for 24V, 30V, or 50 V systems. The other is rated from 88V to 280V DC, and is suitable for 110V or 220V systems. If ac voltage is used to power the relays, the instantaneous peak voltage must not exceed the maximum DC voltage, i.e. 60V for the first power supply and 280V for the other.

The rating of status inputs can be either 30V, 50V, 110V or 220V. Refer to Sections 2 – Performance Specification of this manual, for their range of operating voltage.

The relay is supplied with seven output contacts and either one or nine status inputs. The status inputs can be programmed to any of the relay elements. The output relays consist of 4 normally open and 3 change over contacts.

2.2 Current Differential - Fixed or Optional Variable Settings

The relay can be ordered in two variants, it can have fixed or variable differential settings.

If relays are ordered for the protection of plain feeder circuit current differential on medium voltage distribution networks, or where personnel are inexperienced in setting numerical differential protection, a fixed setting relay may be the most appropriate choice.

Generally the Variable Settings version affords more flexibility when applying the relay to a variety circuits. The circuits may vary in terms of length or type (overhead line, cable or hybrid). Where there is a mis-match of CT ratios or rating, the variable setting relay is also recommended. Eight settings groups are included in the variable setting relay. Relays can be converted from fixed to variable differential type if setting problems occur by software upgrade.

Refer to Section 3 - Relay Settings for the range of settings available. The variable setting version of the relay is supplied with the default settings as set out in Section 3.

3 Current Transformer Requirements

The two primary criteria to be met when specifying current transformers (C.T.) for use with the relay are C.T. ratio and kneepoint voltage. The CT connections and polarity are shown at the end of this section.

3.1 Current Transformer Ratio Selection

The first criterion is to select a CT ratio to step the primary rated current of the protected circuit down to approximately a relay nominal current of 1A or 5A. Ratios should be chosen to provide the relay with about rated current at full feeder rating. As a general comment, 1A secondary rated CT's are superior to 5A, for all types of protection relays, as they are less prone to saturation. Where possible 1A rated CT's are recommended, however the relay does have 1A and 5A rated CT terminals.

The relay settings can then be chosen to allow the use of sensitive settings. The relay can be connected with 1A rated CT's at one end and 5A rated CT's at the other end. CT ratio correction is provided in the range of 0.5 to 1.0 to cater for retrofit applications whereby the c.t. ratio at one end may have a different ratio to that at the other. This setting operates on the secondary level of current from the line CT's. The setting range of the CT ratio correction factor of 0.5 to 1.0 must be taken into account when considering protection of a circuit with different CT ratio's.

Example of Applying CT Ratio Correction

A feeder circuit rated at 600A and maximum anticipated load of 600A has a line CT ratio of 600/1 at one end and 800/5 at the other end. The ratio correction would be set to 600/800 = 0.75 on the relay connected to the 600/1 CT, and 800/800 = 1.0 on the other relay. Each relay has 1A and 5A inputs for connection to the C.T.'s, allowing for example 600/1A at one end of the feeder circuit and 800/5A at the other.

3.2 Current Transformer Class/Rating

The second criterion is the specification of the c.t. class/rating. The relay is a relatively sensitive biased current differential relay and therefore, to ensure stability for high values of through fault current (ie high multiples of the rated current) a class PX c.t. to IEC 60044 is recommended.

A class PX ensures a guaranteed turns ratio, maximum excitation current, minimum knee-point (or saturation) voltage and maximum secondary wiring resistance. With an appropriate design specification for ratio and class PX, the relay can be set sensitively without concern for false operation for a through fault.

The following formula for establishing a class PX knee-point voltage design is based on the relay settings for the fixed setting variant, (or the defaults of the variable setting models) and the settings are listed below. This c.t. specification is also suitable for any settings which are less sensitive than those listed.

The CT requirements may be altered by selection of any one of three relay Bias Break Point settings. A lower Bias Break Point setting will lower the CT requirements.

The following page contains formulae that may be used to select appropriate CT kneepoint voltages. The CT e.m.f. is chosen to allow the protection to be stable for the worst case through fault.

3.3 CT Formulae

The minimum kneepoint voltage of the CT's is dependant on the settings used:

With Bias Slope 2 = 150% and Bias Break Point = 2 x I_N

$$Vk = \left(0.6 + 0.05\frac{X}{R}\right) \times IFm \times Rs \quad for \quad \frac{X}{R} \leq 18$$

$$Vk = \left(1.5 + 0.3\left(\frac{X}{R} - 18\right)\right) \times IFm \times Rs \quad for \quad 18 < \frac{X}{R} \leq 25$$

$$Vk = \left(3.6 + 0.08\left(\frac{X}{R} - 25\right)\right) \times IFm \times Rs \quad for \quad \frac{X}{R} > 25$$

With Bias Slope 2 = 150% and Bias Break Point = 1 x I_N

$$Vk = 1 \times IFm \times Rs \quad for \quad \frac{X}{R} \leq 15$$

$$Vk = \left(1.0 + 0.13\left(\frac{X}{R} - 15\right)\right) \times IFm \times Rs \quad for \quad 15 < \frac{X}{R} \leq 30$$

$$Vk = \left(2.95 + 0.033\left(\frac{X}{R} - 30\right)\right) \times IFm \times Rs \quad for \quad \frac{X}{R} > 30$$

With Bias Slope 2 = 150% and Bias Break Point = 0.5 x I_N

$$Vk = 1 \times IFm \times Rs \quad for \quad \frac{X}{R} \leq 20$$

$$Vk = \left(1.0 + 0.135\left(\frac{X}{R} - 20\right)\right) \times IFm \times Rs \quad for \quad 20 < \frac{X}{R} \leq 30$$

$$Vk = \left(2.35 + 0.029\left(\frac{X}{R} - 30\right)\right) \times IFm \times Rs \quad for \quad \frac{X}{R} > 30$$

where,

V_k - is the knee point voltage of the CT defined as the point where a 10% increase in excitation voltage produces a 50% increase in magnetising or excitation current.
X/R - is the system reactance to resistance ratio for a three phase **through** fault on the protected feeder.
I_{FM} - is the **f**eeder **m**aximum primary three phase **through** fault current referred to the secondary side.
R_S - is the total resistive burden of the **s**econdary circuit, including CT secondary winding, relay phase input and lead loop resistance.

The above formulae include a minimum safety margin in excess of 120%. This may be utilised if the CT's calculated above are loo large to fit in the Circuit Breaker chamber. Therefore a 120% reduction may be made to the above minimum kneepoint requirements. This margin is present, as the above expressions were based on tests using the saturation e.m.f (Esat) level of the CT. As the kneepoint voltage (Vk) of the CT is a measurable constant, this was instead of Esat in the expression above. Esat is always at between 120% and 160% of the kneepoint voltage Vk and therefore reducing the Vk calculated above by up to 20% is valid.

The above expressions are derived from system conjunctive tests and power system simulations. The lower the Bias Break Point setting becomes the greater the level of saturation that may be tolerated as is shown in the following figure. This must be offset against fault sensitivity for load bias that may continue during an internal earth fault on resistance earthed power systems.

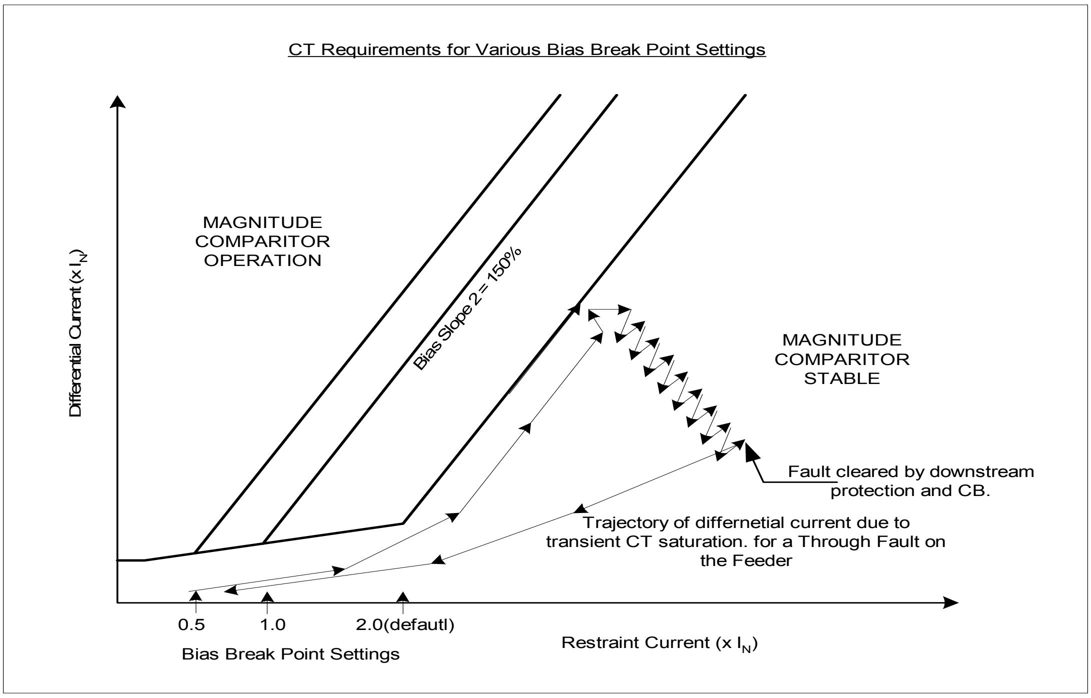


Figure 1 – Relay Amplitude for CT Saturation for an external Phase Fault.

The above demonstrates that decreasing the Bias Break Point (B_2) setting has the affect of lowering the Minimum CT requirements. The reduction in Bias Break Point setting must be balanced against making sure the relay will operate for load bias due to arc resistance and non-effectively earth systems for single end fed internal faults.

For example if the system was resistance earthed and an earth fault occurred on a cable at a very high load a Bias Break Point of 0.5 may not be suitable. A typical example for setting the relay with a resistance earthed power system is given later.

4 Determining Current Transformer Requirements

There are four parameters that must be established before the minimum CT kneepoint voltage can be specified for a particular circuit. This assumes the Bias Slope 2 setting is set to its default of 150%. For all applications of the relay this setting should be set to 150%.

- Bias Breakpoint Setting.
- Maximum Three Phase Fault Through Fault Level.
- X/R of the through Fault.
- Estimation of the total secondary resistance

The process of specifying the CT kneepoint voltage required is done in three steps:

4.1.1 Step 1 - Determine the Bias Break Point Setting

As discussed above the Bias Breakpoint setting is established by examining the earth fault sensitivity required to detect the minimum internal earth fault. The relay settings are selected so that the relay measures this fault to be in the operate region. This setting should be set as low as possible to lower CT requirements and add stability for through faults.

As a general guideline, cable feeders used on power systems with solidly earthed neutrals allow for lower Bias Breakpoint Setting of 0.5 to 1 x In to be selected. Cable and all overhead line feeders that are resistively earthed may require a setting of 1.0 to 2.0 xIn, in order to detect the minimum earth fault, as some load bias will also be measured during the fault. The Bias Break Point setting should therefore be set as low as possible, but should be set to attempt to allow tripping of the minimum earth fault on the feeder. This compromise between lowered CT requirements for through phase faults and detection of low level internal earth faults with load bias dictate the best setting to adopt.

4.1.2 Step 2 - Determine the Fault Level and X/R Ratio of a Through Fault

This maximum level for a three phase **through fault** can be calculated if the source and feeder primary resistance (R) and reactance (X) values are known. Sometimes only the source fault level at the busbars will be known. The system primary time constant can also be used to calculate the source X /R ratio, as the time constant (X/R) = 2π x f x L / R.

The maximum through fault and maximum X/R ratio cannot occur simultaneously as one counter acts the other. Therefore it is not technically sound to use both the circuit breaker breaking capacity and maximum system X/R simultaneously when calculating the CT requirements. If the source X/R is at a maximum the external fault level will tend towards a minimum.

System Voltage (kV)	Source - Transient Current Multiple(TCM) X/R x Fault Level (kA)
33 and Below	500
66	600
132	700
275	900
400	1000

The above TCM limits are the extremes taken from the system data contained in international power system standards. The above figures can be used for all circuits, except for circuits where the feeder protected by the relays is fed from a busbar source with several directly connected (i.e. no step up transformer) generators, such as at 11kV. In this case the source TCM may exceed the above limits, and such circuit will need careful consideration for the CT's requirements.

For example at the 132kV busbar, the source X/R is considered to be 50 and the circuit breaker has a fault current breaking capacity of 40kA, this produces a TCM of 2000. This value is not practical for a through fault on any power system, so the practical maximum limit of 700 is imposed.

The maximum source fault level and X/R can then be calculated. The two cases are studied separately. The first considers the maximum source X/R and the second the maximum fault level.

Example

Case1 – Maximum Source X/R

The source fault level to use in the CT calculations = 700 / 50 = 14kA.

Therefore a check of each feeder should be done with an X/R of 50 and a fault level of 14kA.

Case 2 – Maximum Fault Level

The source X/R to use with the maximum source fault level = 700 / 40 = 17.5

The second case should be done with an X/R of 17.5 and a fault level of 40kA

For the above example the three phase fault level may be quoted in MVA instead of kA. In this case, the fault current can be calculated by using:

3Phase Fault MVA / (Rated Voltage Line Voltage x root 3)

System positive sequence impedance information is required in order to accurately estimate both values. Otherwise the Appendix 2 include in this Technical Manual can be used to estimate the values required. The calculation process needs to evaluate the following:

X/R used in CT equation = $(X_S + X_F) / (R_S + R_F)$

The source reactance (X_S) and resistance (R_S) will be fixed, but the feeder reactance (X_F) and resistance (R_F) will increase with the length of the circuit. This means the line impedance dominating the over all X/R for the external fault as the circuit length increases.

Several sources feeding the busbar will have the affect of magnifying the feeder impedance. For example four transformers feeding the busbar in parallel will have affect of keeping the source X/R (=X/4 / R/4) at around 40 to 50, but means the effect of the feeder impedance is magnified by a factor of 4, in dominating the overall X/R of the feeder external phase fault.

4.1.3 Step 3 – Estimate of Total Resistance of the CT Secondary Circuit

The lead loop resistance may be estimated by examining the cable run. For 2.5mm square multi-cores used with a one ampere secondary nominal rating, the resistance is approximately 7.4 ohms per km. For 4mm square multi-core the resistance is about 4.6 ohms per km. The CT secondary winding resistance and relay phase input burden should be added to this.

The relay burden is 0.05 ohms when using one ampere rated CT's and relay inputs.

The relay burden is 0.01 ohms when using one ampere rated CT's and relay inputs.

$\mathbf{R_S}$ = CT Secondary Winding Resistance + Relay Phase Input + Lead Loop Resistance

$\mathbf{R_S} = (R_{CT} + R_{PH} + R_{LL})$

4.1.4 Example CT Requirement - Solidly Earthed 10km 132kV Feeder

The cable feeder is 10 km in length and uses single core 630mm square cables. The 132kV power system is solidly earthed and has a minimum internal earth fault level of 15000 amperes and the cable circuit has a rating of 840 amperes. The CT ratio is chosen to be 1000/1A. Cables rated at 132kV have earthed sheaths and are cross bonded. All internal feeder faults will therefore be earth faults.

As shown later the P/F Differential setting should be chosen so that the minimum internal earth fault level is detected. Where the power system is non-effectively earthed such as resistance or reactance type earthing, the load current will continue during the fault. The load current will have an effective of biasing the relay towards stability. Setting the differential protection for non-effectively earthed systems is covered in 5.5.2.

In this case, as the system is solidly earthed, and the cables are cross bonded to earth at each substation and cable joint all internal earth faults will be large. The fault current will almost exclusively return to the source via the cable sheathed, which will cancel most of the induction effect of the fault current.

The minimum earth fault level is estimated to be not less than 15,000 amperes, are the minimum setting of 0.5 x I_N can be chosen. This level of earth fault will always produce a large differential current and a fast and definite relay operation. If the circuit were resistance or reactance earthed a higher setting would be required.

Differential Current = 15000/1000A = 15 x I_N, Bias Current = (15 + 0) / 2 = 7.5 x I_N. This fault would appear in the operate region of the bias characteristic at a percentage slope of approximately 200%.

If we assume the total secondary resistance is 5 ohms, then the Vk requirement can be established.

The cable feeder is fed from a busbar with a three phase fault level of 40kA and a maximum X/R of 50. As explained earlier these two extremes cannot occur together as they would compromise the circuit breaker breaking capacity. The above Transient Current Multiples are used to limit the parameters used to practical maximum values. The maximum TCM of 700 is applied to 132kV systems. The parameters to use for each of the two cases were calculated previously to be:

Case 1 – CT required with a maximum X/R of 50 and a fault level of 14kA.

Case 2 – CT required with a maximum fault level of 40kA and an X/R of 17.5.

The CT's are 1000/1A and have a secondary winding resistance of 4 ohms. The lead loop resistance (R_{LL}), CT secondary winding resistance and relay phase input resistance of 0.05 oms, must be added together to find the total circuit resistance of the secondary circuit (R_S).

The cable has a characteristic impedance of X = -j 0.1277 ohms per km, and R = 0.039 ohms per km. The charging current for this type of cable is 8 amperes per km.

Example calculation

Case 1: Source X/R=50 FL=14kA **Case 2: Source X/R=17.5 FL=40kA**

I_F = 14kA, X/R=50 **I_F=40kA, X/R=17.5**

Z_S = 132,000 / (√3 x 14,000) = 5.443 ohms. Z_S = 132,000 / (√3 x 40,000) = 1.905 ohms.

As the busbar X/R is known for both cases the X and R components of the source impedance may be found.

X_S=Cos(Tan^{-1}(1/X/R))xZ_S=-j5.442 ohms X_S=Cos(Tan^{-1}(1/X/R))xZ_S=-j1.9046 ohms

R_S=Sin(Tan^{-1}(1/X/R))xZ_S=0.109 ohms R_S=Sin(Tan^{-1}(1/X/R))xZ_S = 0.0381 ohms

Cable Impedance = 0.39 – j1.277 ohms Cable Impedance = 0.39 – j1.277 ohms

Total Impedance = 0.499 – j6.719ohms Total Impedance = 0.4281 – j3.1816 ohms

The X/R for external fault = 13.46 The X/R for external fault = 8.91

Z_T = √(0.499^2 + 6.719^2) = 6.737ohms Z_T = √(0.4281^2 + 3.1816^2) = 3.210 ohms

External Fault Level = 132kV / (root 3 x Z_T)
= 11,312 A

External Fault Level = 132kV / (root 3 x Z_T)
= 23,741 A

Both Cases should be considered when arriving at the CT minimum e.m.f. requirements

The X/R= ranges from 8.91 to 13.46. The through fault level ranges from 11.312 to 23.741A.

As the bias break point is being set to 0.5 xIN the following CT formula is applicable:

$$Vk = 1 \times IFm \times Rs \qquad for \quad \frac{X}{R} \leq 20$$

CT Requirements:

Case 1: Source X/R=50 FL=14kA **Case 2: Source X/R=17.5 FL=40kA**

Vk ≥ 1 x 11312/1000 x (R_{LL} + R_{PH} + R_{CT}) Vk ≥ 1 x 23741/1000 x (R_{LL} + R_{PH} + R_{CT})

From the above, Case 2 requirements are more onerous and should be use to calculate the Vk minimum required.

CT's for Substation A:

Vk ≥ 1 x 23741/1000 x (1.95+0.05+5)

Vk ≥ 167 volts

CT's for Substation B:

Vk ≥ 1 x 23741/1000 x (3.5+0.05+5)

Vk ≥ 203 volts

The above figures are recommended for the relay, however the safety margin of 20% may be used if CT core size makes fitting the CT into the switchgear chamber difficult. In the above example the absolute lower limits would be:

Vk ≥ 167 / 1.2 = 140 volts Vk ≥ 203 / 1.2 = 170 volts

This 20% reduction is attributable to the fact the CT formulae were based on the saturation emf (e_{sat}). The e_{sat} of a CT is always ≥ 120 % of the CT kneepoint voltage. The relay would still remain stable for these CT kneepoint voltages as there are other safety margins built into the formulae.

These additional safety margins are:

- The CT requirements was based on three phase fault levels, therefore only the single core run between the relay and CT needed to be considered as the lead burden. The formulae used included the full lead loop resistance.

- The CT core was induced with a one Tesla of remnant flux prior to the fault being applied.

- The fault inception point was set at zero degrees, which produces the largest dc offset in the primary fault current and the highest dc transient flux requirement in the CT core. Most short circuit faults occur at between fourty-five and ninety degrees.

On solidly earthed systems the earth fault level can exceed the phase fault level by up to a factor of 1.2. However the X/R of the earth fault will always be less than the three phase fault as the return path via the earth/sheath is mainly resistive. This will reduce any dc offsets in the primary fault current for an earth fault. It is therefore it is sufficient to consider three phase faults only.

The above figures demonstrate the feeder impedance reduces the CT minimum requirements as the feeder length increases. The Feeder reactance and resistance will become more dominant as the feeder length increases. This is shown graphically for the 132kV cable feeder used in the example.

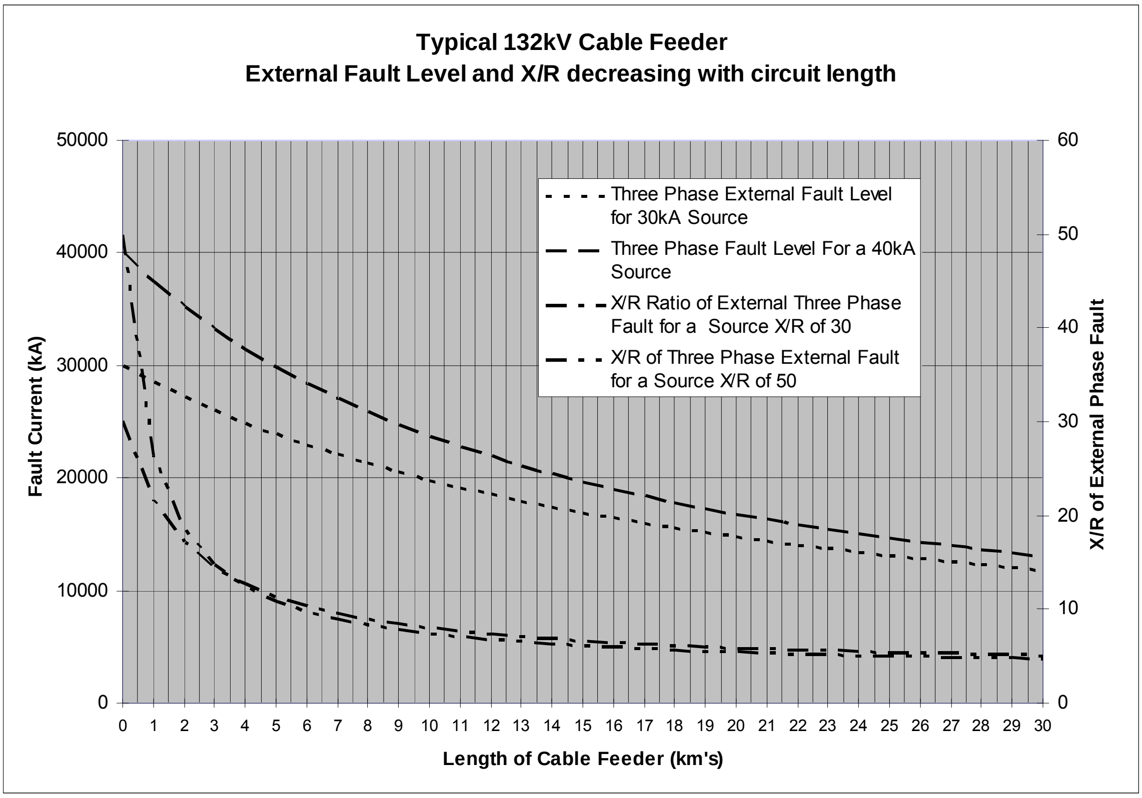


Figure 2 – Fault Level and X/R reducing with feeder length.

The above shows the X/R ratio of feeder through fault current is less than half the source X/R when the cable exceeds only 3km's in length. The fault level also reduces with increasing length and may allow the use of an instantaneous high set over current element for longer feeders. This may be set to provide fast tripping for close up faults, if say a flexible earth clamp was inadvertently left connected when the circuit is energised.

4.1.5 Fault Level and X/R for a Phase Through Fault

Combinations of X/R and Fault level will rarely exceed a maximum of 1000 on any power system. This is because a high X/R will tend to reduce the fault level. System X/R and fault level therefore have an inverse relationship. In the above example the source reactance (Xs) and resistance (Rs) are calculated and additional feeder reactance (X_F) and resistance (R_F) are added as the feeder length increases, to arrive at the profile shown above.

Therefore using the Maximum Breaking capacity of the CB and maximum system X/R together is not technically valid as the both of these values cannot occur at the same time. If one of these parameters is at a maximum the other tends towards its minimum value. This is why a limit is imposed on the product of these two parameters. These limits are the maximum practical case possible.

The circuit type also affects the CT requirements. Cables have much lower X/R ratios than over head lines and therefore tend to dominate as feeder length increases.

Cables in particular will reduce the through fault X/R ratio, as they have small X/R ratios in the 5 to 0.3 range. Higher voltage single phase cables tending towards the higher figure and lower voltage trifoil cable tend towards the lower end of this range. If the cable feeder is longer than a few miles then it is fairly safe to use the X/R of the cable. Using more then one cable per phase will of course reduce this affect and increase charging current. In all cases it is better to calculate the X/R and fault level of the through fault if the data is available. Where multiple sources are present to feed the fault this has a magnifying affect in reducing the overall X/R of the external fault as the feeder circuit impedance will dominate.

A spreadsheet is available to allow easy calculation of the CT kneepoint voltage required for a particular application of the relay.

5 Fibre Optic Losses

The main factors limiting transmission distances with fibre-optics are:

- Transmitter launch power
- Attenuation, based on light frequency, fibre material and fibre diameter
- Number of intermediate connectors and splices
- Receiver sensitivity

The light power at the receiver must be above the sensitivity of the receiver in order that effective communication can occur.

The sensitivity of the fibre optic receiver is -30dB.

The launch power of the fibre optic transmitter is as follows:

Relay Type	Fibre Type	Launch Power
Long Range device	Single-mode fibre	-10dB
Long Range device	Multi-mode fibre	-7dB
Short Range device	Multi-mode fibre	-10dB

Typical attenuation for 1300nm:

Fibre Type	Loss (dB/km)
9µm Single mode Glass	0.3
62.5µm Multi-mode Glass	1.2

Consult fibre manufacturers data for actual values

Fibre cables are supplied on reels of finite length which may necessitate additional jointing. Jointing losses should be allowed for to suit this limitation, for example one additional splice every 4km.

Typical losses at connectors are 0.5-1.0dB each. This allows for normal age related deterioration. Consult manufacturers data for actual values

Typical Splice losses are <0.3dB.

A 3dB safety margin is usually allowed after the budget calculation is performed.

Individual applications should be assessed using actual manufacturers data.

Following installation the actual losses should be measured for each fibre using a calibrated light source and meter and the measured values compared to the calculated estimate before the relay is applied.

The following table can be used to record budget calculations:

A	Launch power	dB
B	Fibre Type	
C	Loss (dB/km)	dB/km
D	Length	km
E	Total fibre loss (CxD)	dB
F	No. of Splices	
G	Loss at each splice	dB
H	Total loss at splices (FxG)	dB
I	No. of connectors	
J	Loss per connector	dB
K	Total loss at connectors (IxJ)	dB
L	Total losses (E+H+K)	dB
M	Receive power budget (A-L)	dB
N	Safety Margin	dB
O	Device Receive Sensitivity	dB

6 Relay Functions & Settings

6.1 Current Differential Protection

The current differential elements have separate phase angle and current magnitude comparators. The current differential magnitude comparator has four settings; P/F differential (I_S), Bias Slope 1 (S_1), Bias Break Point (B_2) and Bias Slope 2 (S_2). The relay operates by comparing the magnitude and phase of the local and remote relay currents. The characteristics and equations are shown in Figure 3. The differential algorithm is phase segregated and will produce a trip for the operation of any of the three phase differential elements.

It is imperative that the relay differential settings and software revisions are identical for each pair of relays protecting a feeder at all times. The Software Revision can be checked by pressing and holding the [TEST/RESET] and [CANCEL] pushbutton simultaneously, when the relay displaying its identifier at the top of the menu structure. The Software Revision number installed is scrolled across the LCD.

Advice on setting the differential elements for various types of circuits and earthing methods are covered later. But a summary of the technical aspects to consider is listed.

P/F Differential - this setting defines the minimum sensitivity of the internal fault that the protection can detect. This setting also defines the bias current that the phase angle comparator becomes active. The phase angle comparator is active when the bias current measured by a pair of relay is greater than half of this setting. A lower setting can normally be used on. The feeder charging current must be assessed when defining the lowest setting that could be applied to a feeder.

Bias Slope 1- this is used to allow the relay to detect lower level internal earth faults. It will generally be selected to 20% for resistance earthed power systems and 30% for solidly earthed power systems.

Bias Slope 2 – this setting is used to accommodate some saturation of the CT's caused by through phase faults on the feeder. This setting should always be selected to 150%.

Bias Break Point – this setting as a multiple of rated current, defines where Slope 1 ends and Slope 2 begins. This setting is critical as it defines the CT formula to use and the ability of the relay to detect earth faults on resistance earthed networks. A lower setting makes the relay more stable for through faults but may compromise earth fault detection. Non-effectively earthed power systems will tend to require a higher setting than solidly earthed power systems, as some load will tend to continue to flow during the earthed. This will provide extra bias to the relays and shift the fault point towards a more stable position.

The following page illustrates the relay differential characteristics and settings.

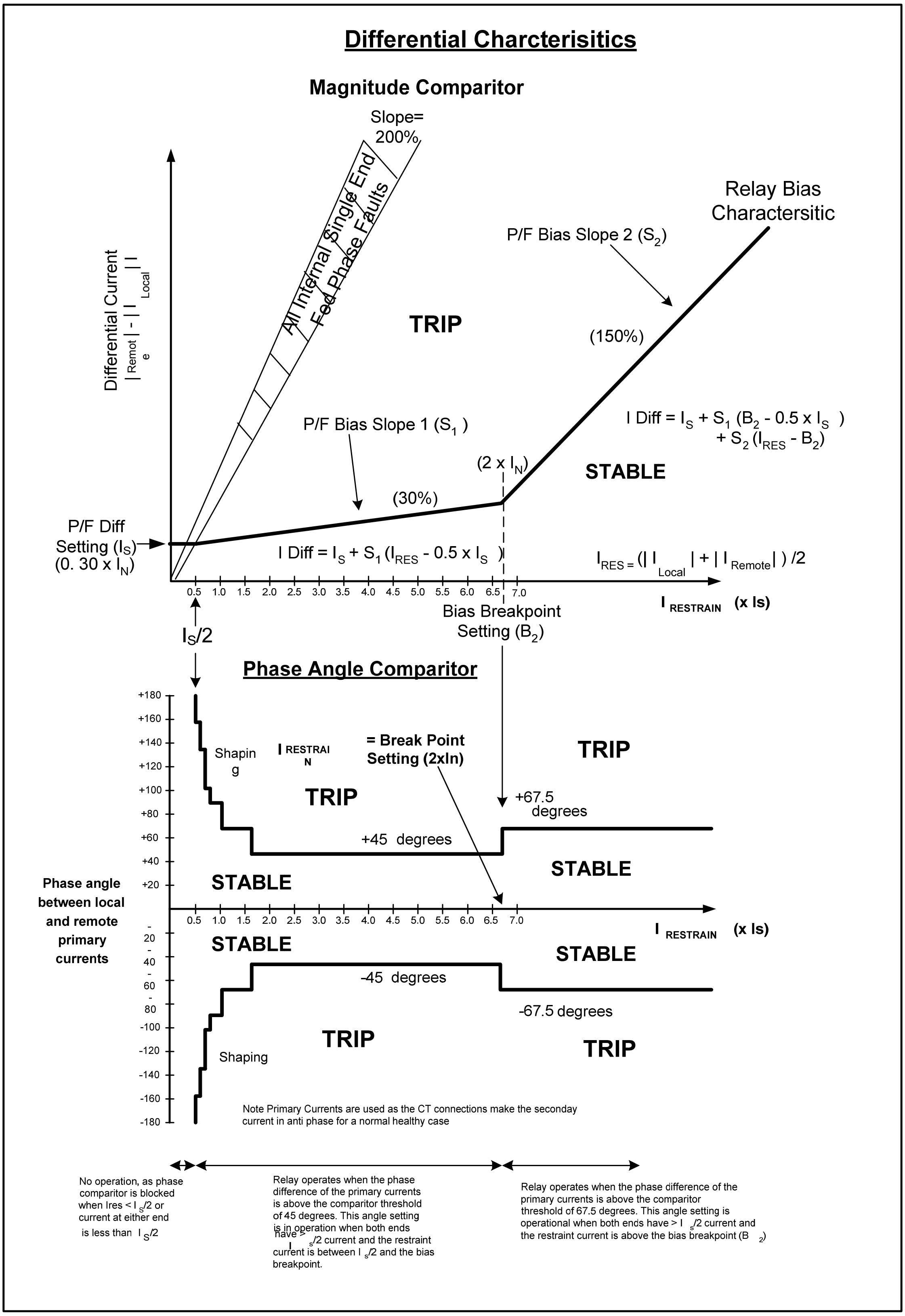


Figure 3 – Relay Magnitude and Phase Angle Comparators (Revision 4 and above)

6.2 Backup Over current and Earth Fault

The relay provides one IDMTL (inverse definite minimum time lag) inverse curve and three instantaneous or DTL (definite time lag) elements, for both phase and earth faults. The DTL elements are named Highset 1, Highset 2 and Lowset in the relay OC PROTECTION menu. The P/F or E/F Characteristic settings can be selected to Normal inverse, long-time inverse, extremely inverse and very inverse IDMTL curves or to DTL.

Any of these elements can be set to be in service permanently, or only when the end to end protection signal becomes corrupted, i.e. when differential protection is no longer possible. To use any of the elements in this way, scroll down to the Status Input menu and select the element required to be inhibited by the signal healthy. The elements can be inhibited by any of the status inputs, plus the virtual input of the state of signal healthy (SIG) seen on the relay display screen at the end of the binary string. Setting the SIG input to ‘1’ means the element is inhibited by a healthy signal.

These elements can be set and used as guard relays for the differential protection, ie the differential protection will only operate and trip when the local relay current exceeds the guard element setting(s).

The IDMTL/DTL elements can be set to grade with relays or fuses up and down-stream of the protected feeder. In most applications, the selection of relay IDMTL characteristics will be dictated by the type of curve used on the over current and earth fault protection relays on the source and load side of this relay. Usually normal inverse curves are selected for grading between relays. Extremely Inverse curves type C to IEC 255 are often used on H.V. transformer circuits, since this type of curve grades with L.V. fuses or moulded case circuit breakers. The setting applied to the earth fault elements must consider residual current caused by charging current under normal load and under fault conditions.

6.3 Differential Guard Elements

When overcurrent and earth fault elements are allocated as a “guard” to the differential elements, the feeder current must exceed the guard level(s) before a differential trip is allowed. Other relay functions such as inter-trip, status inputs, circuit breaker fail may be used as differential guard relays. The guard elements are allocated in the O/P RELAY CONFIG menu. Setting the virtual relay output GPF (guard phase fault differential) to 1 in the output setting string enables the guard feature.

The differential elements are automatically blocked if a protection signaling disturbance occurs; i.e. a discrete guard element does not have to be set to ensure stability.

6.4 Protection Signalling

The relay provides two separate external signalling channels. These can be used for externally initiated inter-tripping or for signalling from another protection, such as a permissive or blocking signal required by distance protection schemes. The use of this differential protection with a distance relay is a cost-effective method of protecting a circuit. It provides dual main protections (operating on different principles and hardware), inter-tripping, signalling and backup over current protection.

The protection/intertrip signal is initiated by a contact on the external device, wired to energise one or more of the status inputs. The operating time is approximately 50ms from energising the local relay status input to closing the output contact of the remote relay. The reset time is approximately 45ms.

6.5 Intertripping

Provision for both Internally and Externally initiated intertripping is included in the relay. The relay is provided with an intertrip LED to signal the operation of this function. The intertrip LED on the receive relay, is always illuminated, for both external and internal type intertrips. The relay at the send end, only illuminates its own intertrip LED flag, if the intertrip is initiated from its own protection elements, i.e. it is an internal intertrip. This assists in determining where the external intertrip was originated. The internal and external intertripping can be enabled or disabled in the DIFF. PROTECTION MENU. Either type of inter-tripping can be selected to ON or OFF in this menu.

a) Externally Initiated Intertipping

The external inter-tripping can be initiated by energising a relay Status Input. The status input(s) used for this purpose, must be assigned as External Intertrips (iTrip1&2) in the STATUS CONFIG setting menu. The output relay(s) assigned to trip the circuit breaker, of the remote end relay must be allocated in the [Remote Ext. itrip1&2]

of the O/P RELAY CONFIG menu. The operate time of the external intertrip, from energising the status input to closure of the remote output contact, is 50ms, ie if no pickup delay is applied to the status input. As mentioned previously, **the external intertrip must be selected to ON** in the DIFF. PROTECTION relay menu.

b) Internally Initiated Intertripping
The Internal inter-tripping may be used when over current and earth fault elements are used as guard relays and fault current can only be fed from one end of the feeder. The differential element of the relay at the end of the feeder with no fault infeed will not trip, as the guard element(s) will prevent operation. The relay sensing fault current will trip on differential, as the guard levels will be exceeded. This relay can send an internal inter-trip signal to the other relay and force a trip of the other relay.

The internal inter-trip must be set to ON in the DIFF. PROTECTION relay menu, and trip outputs allocated.

6.6 Circuit Breaker Fail (CBF) Protection

This type of protection function is designed to ensure a fault current is cleared even if the local circuit breaker fails to trip and remove the fault. For this reason it is also called local backup protection.

The CBF function may use either internal protection elements or external relay outputs to initiate the circuit breaker fail logic.

Internally Initiated CBF

The relay incorporates an internal two-stage circuit breaker fail feature. The sequence of the internal CBF logic is as follows.

An internal protection element picks up and operates its output contact(s) to trip the circuit breaker. If the circuit breaker fails to open, the protection algorithm pickup and the output contact closure will both continue for as long as the fault current continues to flow. The output relay(s) closure and pickup of the protection algorithm are both monitored. The output contacts used to trigger the internal CBF logic **MUST** be allocated as Fault Triggers in the DATA STORAGE menu. This is necessary to differentiate the use of output contacts used for alarms and trips.

Additionally the relay has over current and earth fault CBF level detectors that may be used to give additional security to the CBF scheme. If the level detectors are required both must be set. If one or both the CB Fail detectors are set to OFF the additional level detector check is not implemented.

The level detectors are triggered by three conditions:

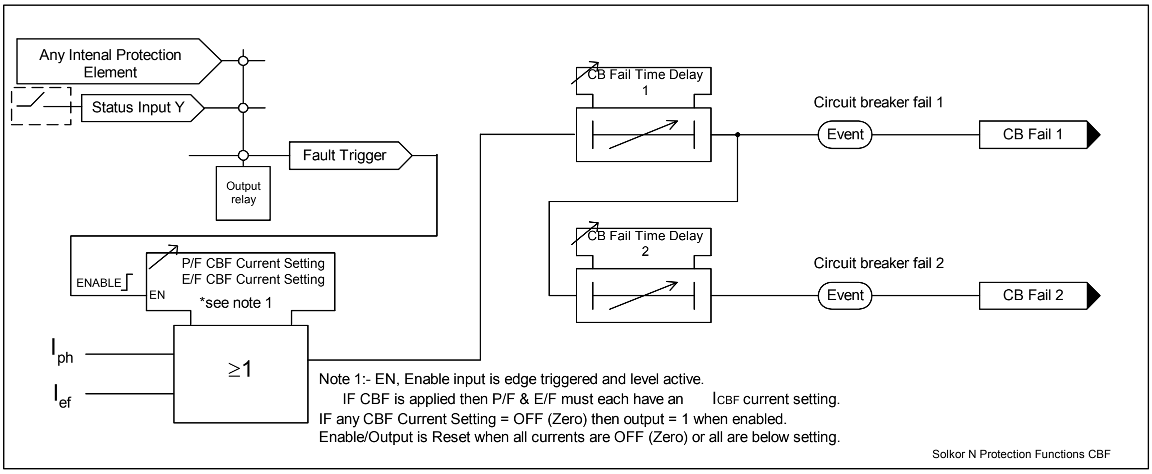
Protection element timing out
An output allocated as a Fault Trigger has operated
The pick up level of one the CBF level detectors is exceeded.

This combination of a relay algorithm that has not reset following an output contact closure and optionally the level detector being exceeded will start the definite time lag feature designated “CB Fail 1”. This function can be programmed to energise an output relay when the CB Fail 1 time delay has elapsed.

The contacts of CB Fail 1 element can be employed to energise a second trip coil on the feeder circuit breaker or to trip another circuit breaker - typically an incoming breaker. The timing out of the CB Fail 1 timer starts a second time lag feature designated “CB Fail 2”. If the trip outputs already initiated do not stop the current flow through the relay, another output relay can be programmed in the output matrix to trip a further breaker e.g. a bus section circuit breaker. The timers should be set to operate in 50ms plus the longest C.B. tripping time. The 50ms time allows for operating and reset times of the internal relay elements. The circuit breaker fail feature can also be used to implement multi-stage tripping.

Externally Initiated CBF
A conventional circuit breaker fail relay is usually initiated by main protection trip relay(s). CB Fail current detectors monitor if fault current is removed and allow the CBF timer(s) to run. When these timer(s) have expired the scheme will initiate repeat and/or back tripping. This relay can be employed to provide the c.b. fail function in this manner by employing a status input, initiated by an external trip output. This status input is mapped to operate an output relay. This output relay must also be allocated as a “Fault Trigger”.

Two stage timing via dedicated output contacts can then be employed for repeat or back tripping as required. The CB Fail logic is shown in the diagram below.



6.7 User Defined Alarms

These alarms allow flagging of the operation of external protection on the relay LCD display. The waveform recording of the relay can also be triggered.
For example, operation of a cable low oil pressure detector could be wired to a status input of the relay. This could be used to display “Low Cable Oil Pressure” alarm on the relay lcd display.

This is programmed into the relay by assigning a relay Status Input as Alarm 1, in the STATUS CONFIG menu and naming Set Alarm 1 as “Low Cable Oil Pressure”, in the SYSTEM CONFIG menu.

If the external device is initiated by a fault and trips the feeder (eg Bucholz protection on an in-zone power transformer), the status input can also be programmed to initiate the waveform storage to assess if fault current was flowing.

6.8 Trip Circuit Supervision

The relay provides trip circuit supervision for up to nine trip circuits. The trip circuit supervision scheme is implemented using the relay status inputs. The status input is held energised and monitors the continuity of current through the input. The supervision is in service with the circuit breaker in the open and closed positions. Figure 5 at the back of this Section shows how the scheme is connected. The relay displays ‘Trip Cct Fail’ on it’s LCD when a trip circuit becomes unhealthy.

To be compliant with the ESI48-4 ESI1 Trip Circuit Supervision standard a 30 or 48V rated input must be used with an external dropper resistor.

6.9 CT Supervision

The relay provides supervision of the CT’s connected to the relay. It is used to produce an alarm if the connection between relay and one or more CT’s is broken. The function does not block operation of the differential protection. If the load level is above the relay P/F Differential Setting, when the CT wiring becomes open circuit, then the relay will still trip.

The feeder circuit must be loaded for the CT supervision element to operate. The CT Supervision element must have a time delay applied to allow external faults to be cleared before the CT supervision times out. A typical setting would be 0.1 x I_N and 5 to 10 seconds time delay.

The function will give an alarm after the set time delay if the current measured on one or two phases falls below the setting whilst at least one other phase remains above the setting, and remains so for the set time delay. This function may be disabled by applying a setting of OFF.

Where single pole reclosing is applied either the function must be set to OFF or the time delay set longer than the longest dead time plus a margin.

6.10 Waveform, Fault and Event Records

The relay has three types of information provided to help investigate relay operation. The waveform recorder is an oscillograph of a.c. current waveforms, r.m.s. values of local and remote currents, state of differential elements and state of status input and output relays. The waveform recorder displays both local and remote currents to determine differential operation.

The sine waves shown by the Waveform Records are instantaneous samples, i.e. the peak level of current. The relay uses the r.m.s. value of current to determine operation. The r.m.s. value of current, may be estimated from the peak value by dividing the peak value on a sine wave by $\sqrt{2}$. The waveform recorder, can be configured to be automatically triggered by operation of starter elements, differential, over current and earth fault, inter-trip, and signal unhealthy (ST+DF+OC+iTp+SIG) in the DATA STORAGE - Waveform Trigger menu. The waveform can be set with a pre-trigger, to capture the fault currents before the relay trip occurred.

The waveform recorder can be triggered from a relay status input or from Reydisp Evolution. This can be used to trigger a hard copy of the commissioning tests carried out. The waveforms can be printed out and used to form part of the Commissioning Test Report.

The Fault Recorder is used to display operation of any of the relay elements on the front of the relay via the LCD. The fault record is scrolled across the LCD, and displays the pickup value and the elements that have operated. To trigger the fault recorder the Fault Trigger output relays must be set and the Waveform Trigger must be set. For example, if an over current element is meant to trigger the Fault Recorder and is allocated to use output relay 2 (RL2), the Waveform Trigger Menu must include OC and the relay 2 must be allocated as a Fault Trigger in the DATA storage menu.

The Event Records is a list of time stamped pick-up, drop-off and operation status of the relay algorithms. This is particularly useful, in determining the sequence of events that led to a relay operation, and the cause of the trip. It does not have to be set as it continuously records any events. Five hundred events are recorded with a time stamped accuracy of 1ms.

6.11 Relay Settings Groups

The variable settings version of the relay has eight Settings Groups. The fixed setting relay does not have settings groups.

The active Settings Group can be changed manually via the front pushbuttons, Reydisp Evolution, or remotely via the relay communications. It can also be changed automatically by energising a relay status input. Care must be taken to ensure the differential elements are stable if settings at either end are different. Advice can be provided on request, if an application requires this feature to be used.

6.12 Trip and Intertrip Tests

The settings in the CB maintenance menu can be used to do trip and intertrip tests.

The trip test allows the local circuit breaker to be tested and the intertrip test allows the remote CB to be tested. The settings to do these tests are found in the CB maintenance menu. The trip test has a ten second delay before closure of the selected trip contacts to allow personnel to vacate the vicinity of the circuit breaker.

7 Differential Protection Settings For Feeder Circuits

The relay was developed to provide protection for two ended sub-transmission and distribution feeders. The relay combines current differential feeder protection with back-up over current and earth fault protection suitable for these feeders. The fibre optic, RS485 and twisted pair pilotwire connections to the relay are shown in figures 6, 7 and 8. The relay is only suitable for two ended feeders.

There are various primary circuit types each requiring specific considerations.

These include:

- Plain poly-phase Tri-foil cable Feeders.
- Phase segregated, single phase cables Feeders.
- Overhead line feeders.
- A Feeder with a mixture of the above.

Each of these configurations is discussed below.

Special consideration is also given to earth fault protection provided by the relay for different network designs with respect to the method of grounding. The feeder charging current will have the most impact on the minimum differential setting that may be chosen.

7.1 Capacitive Charging Current – Cable and Hybrid Feeders

Significant Charging currents are to be expected on cable or hybrid (a mix of cable and over head line) feeder circuits. Pure overhead line feeders will not have significant charging currents and will not generally affect the lowest differential setting that may be chosen. The cable charging current will increase linearly with circuit length. The capacitive charging current is at leading power factor to the feeder load current and has the affect of causing a phase and magnitude difference to arise between the current measured at each end of the feeder. This normal steady state difference in currents will have an impact on the minimum differential settings that may be used.

The relay must be set with a P/F Differential setting that must be minimum multiple of the steady state charging current. The steady state charging current may be calculated from the cable data and the circuit length. This multiple of charging current is necessary to accommodate transient charging current, steady state charging current and rises in phase to neutral voltages during system faults. As the relay design was developed an effort was made to improve the relay sensitivity to allow resistive earth faults to be detected. Later releases of code allowed lower differential settings to be used.

The phase angle comparator was altered in Release 4 of the relay code. This was done to allow the relay differential protection to be set to improve sensitivity by allowing the relay to be set to a lower multiple of steady state charging current. This enhancement also improves relay stability for lightly loaded circuits.

The minimum initial setting that can be selected on the relay depends upon the revision of software installed on the relay. Revision 3 or earlier requires the following minimum sensitivities to be selected:

The recommended figures are in terms of a multiple of the steady state feeder charging current (Ic).

Minimum P/F Differential Setting recommended for Relays with Revision 1 to 3 code(prior to July 2004):

Feeder Type and System Earth Method	**Pure Cable Feeder**	**Hybrid Feeder (OHL+Cable)**	**Pure OHL Feeder**
Solidly Earthed	**8 x Ic**	**14 x Ic**	**14 x Ic**
Resistance Earthed	**14 x Ic**	**14 x Ic**	**14 x Ic**
Reactance Earthed	**14 x Ic**	**14 x Ic**	**14 x Ic**
Isolated	**14 x Ic**	**14 x Ic**	**14 x Ic**

Revision code 4 or later allows the relay to be set more sensitively as the comparison of the tables above and below demonstrate.

Minimum P/F Differential Setting recommended for Revision 4 (released July 2004) code with or later are:

Feeder Type and System Earth Method	**Pure Cable Feeder**	**Hybrid Feeder (OHL+Cable)**	**Pure OHL Feeder**
Solidly Earthed	**2.5 x Ic**	**4 x Ic**	**4 x Ic**
Resistance Earthed	**4 x Ic**	**4 x Ic**	**4 x Ic**
Reactance Earthed	**5 x Ic**	**5 x Ic**	**5 x Ic**
Isolated	**5 x Ic**	**5 x Ic**	**5 x Ic**

A significant transient charging current will flow a cable feeder is first energised. The relay digital filtering is designed to remove almost all of this transient current. The frequency of this current tends to be a high multiple of power system frequency. Therefore the steady state charging current only need to be considered when selecting the differential setting.

The revision of the relay software installed, may be found moving to the top of the menu structure to display the relay identifier and holding the [Cancel] and [Test/Reset] pushbuttons depressed or by selecting [Relay] [Information][Get System Information] in Reydisp Evolution. If the setting file for the relay is saved, open the .set file in Reydisp Evolution, clicking on the Info (***i)*** tab at the top right hand corner of the “Settings Editor” window. The Software Revision should now be displayed in the “Settings Source Information” window.

If relays with installed code of Revision 1 to 3 do not provide enough sensitivity, the latest revision may be downloaded. Note a pair of relays must have identical software installed and differential settings selected at all times.

These above figures include provision for transient increases in healthy phase charging current during external earth faults on non-effectively earthed power systems.

Some typical Examples of Cable Charging Currents are given in the Table below:

Voltage	**Charging current per km**
3.3	**0.2 to 0.7**
6.6	**0.5 to 1.6**
11	**0.7 to 2.4**
22	**1.1 to 3.2**
33	**1.3 to 3.5**
66	**4 to 7.5**
132	**5 to 11**
220	**10 to 20**
400	**15 to 30**

The above figures are for single cables only. Where two cables per phase are used the feeder charging current will double. The highest charging current figure at the top end of the range are for the largest cross-sectional area single core cables and for small diameter three core cables at the bottom of the table. If the charging current is not known the top figure in the range may be used with confidence, as it will tend to over estimate the feeder charging current and set the relay to a more stable differential setting.

The above table should only been used as a worst case estimate. For optimum relay settings the differential setting to select, should be based a multiple on the true charging current or susceptance of the cable.

7.2 Plain Poly Phase Cable Feeders

This type of cable is usually used at 33kV and below. The reactance of these cables tends to be low as the phase currents tend to cancel in each cable. The X/R of the external fault to use in the CT formula will tends towards the cable X/R if the cable exceeds 2 to 3 km. This assists in reducing the CT requirements.

7.3 Phase Segregated Single Phase Cable Feeders

The major difference between this type of circuit and poly-phase cable circuits, is that the transient and steady state charging current will be higher. The charging current will rise with rated voltage and the length of the circuit. The variable setting relay is recommended for this type of circuit, as it offers the flexibility to cope with a variable level of charging current. The P/F differential setting must be set above the charging current on the feeder. The waveform recorder in the relay can be used to assess the magnitude of charging current. The method is covered in part 4.4 of this section of the manual. Several Cables per phase may be used and this may increase overall charging current by a multiple of a single cable.

The P/F Differential should be set as per the recommendations in 6.1.

The cable X/R will reduce the external fault X/R to a significant extent is the cable is more than a few kilometres in length.

7.4 Overhead Line Feeder

The relay is suitable for protecting circuits of this type. The settings can be set more sensitively than for cable feeders as charging current is much lower. The P/F differential setting may need to be set towards the lower settings of 10% to 20% to cover arc resistance and/or resistively earthed neutral. The Slope 1 Setting should also be set to 20% and the Bias Break Point may need to be set to 1.0, 1.5 or 2.0 to allow for load current flow during the internal earth fault. The Bias Break Point will usually have to be set higher for overhead lines, than for cable circuits, to allow for load bias during a high resistance earth fault on the feeder.

Where twisted pair pilotwire connection is used for protection signalling, and the circuit is an overhead line, the consideration of the induced voltage onto the pilotwires becomes important. Please contact Customer Services for applications advice.

7.5 Earth Fault Sensitivity

The method adopted for earthing the power system network will determine the amount of fault current available to operate the differential elements. As mentioned above care must be taken when assessing the best combination of settings to use.

Network feeder circuits of the type that this relay is likely to be applied on, eg 3kV to 150kV, may operate with their neutral points either solidly earthed (typical for the 150 kV end of the range), unearthed (often employed in the middle range of distribution voltage ratings) and impedance earthed at the lower end.

This must be considered when selecting and applying the relay, as outlined below:

7.5.1 Solid or Effective Neutral Earthing

Solid earthing will normally result in earth fault levels of a similar magnitude or just above the three phase faults. Low impedance earthed generators are normally designed to allow fault current of the order of magnitude of the source incoming circuit rating, typical values being in the range of 100-1600 amps.

In either case, solid or low impedance, the standard basic relay, with fixed or variable settings should provide adequate sensitivity for earth faults. Both the differential and the back-up non-unit protection will provide sensitive protection.

For low impedance earthed networks it is only necessary to ensure that the current transformer primary rating and ratio is compatible with the earth fault current, or is of a lower value.

Example: maximum fault current – 800 amp
c.t ratio ≤ 800/1 (or 5)

For low impedance earthed networks it is recommended that the differential sensitivity be no more than 80% of the minimum earth fault current. The relay with variable differential settings should allow this to be met.

7.5.2 High Impedance and Resistance Earthed Neutrals

This method is often employed in medium voltage power system, where the fault current in each source neutral is limited to a low value, for reasons of safety and to limit fault damage.

The fault current may be of the order of 100 to 1000 amps.

In this type of network, with feeders typically rated 400-800 amps and c.t ratios chosen appropriately, eg 800/400/1 or 5 amp, the earth fault current may not be sufficient to operate relay models from the basic range. The minimum relay setting is 10% of nominal current rating for both the differential (ie variable setting models) and back-up protection.

The relay set at it's minimum setting of 10% would be satisfactory provided that the primary equivalent fault current is at least 4 x the relay operating current. This is based on the recommendation of a maximum operating current of 25% given above. This allows for factors such as fault limitation by arcing earths, c.t. error and the relay's bias characteristic.

For transformer feeders, an earth fault part way into the transformer winding would result in a much lower proportion of maximum fault current. For Delta windings this is usually acceptable, whereas for star connected windings a separate more sensitive restricted earth fault protection is normally provided.

For plain feeders, acceptable settings to apply to the relay are as follows:

Example: Maximum earth fault from one source = 40 amps
C.t. ratio ≤ 100/1 (or 5 amp)

Relay settings
P/F Differential (I_S) = 0.10 x I_N
Bias slope 1 (S_1) = 20%
Bias slope 2 (S_2) = 150%
Bias Break Point (B2) = 2.0 x I_N

Example - 33kV Earth Fault on Resistance Earthed Cable Feeder

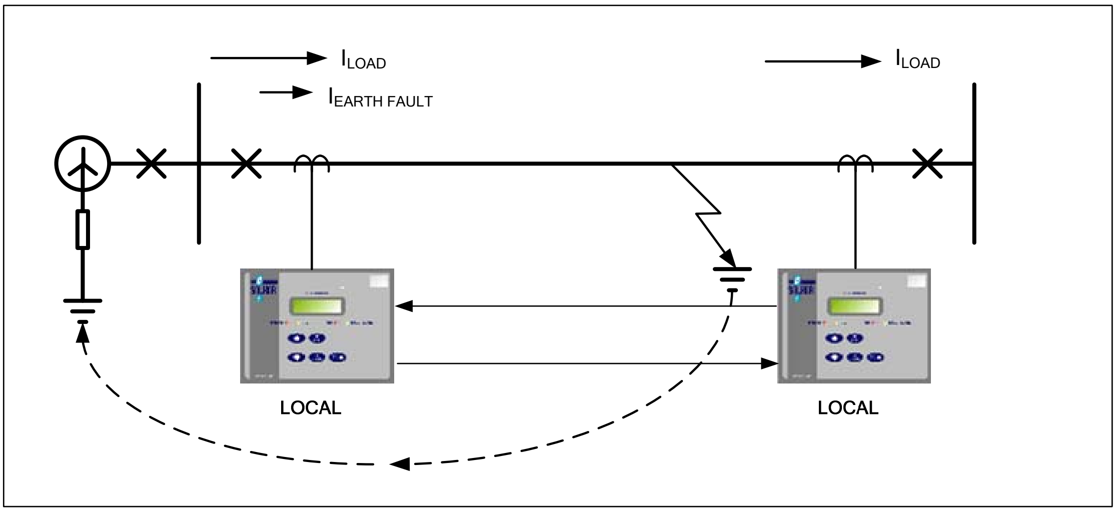


Figure 4 – Earth Fault with load bias for Resistance Earthed System

Circuit Parameters:

33kV Cable Length	= 7km
Load prior to Fault inception	= 700A.
Load during Earth Fault	≈ 600A
Circuit Rating	= 800A
CT Ratio	= 1000/1A
Maximum Feeder Earth Fault level	= 800A (two transformers)
Minimum Feeder Earth Fault Level	= 400A (one transformer)
Charging Current per cable	= 4.5A per km

At the fault point the phase to neutral voltage may not fall significantly and therefore load current will continue to flow through the radial cable to the load during the earth fault. The load will usually reduce, but the full circuit rating is used to calculate the fault position on the relay bias characteristic, as this will test the relay setting for the worst case. At one end of the feeder only the load current will be measured. At the other end the load and the superimposed fault current will flow.

As the system is radial the phase comparator will generally not operate as the fault current and load is often of a very similar power factor. Therefore it is essential the relay is set to ensure this minimum earth fault level is detected by the magnitude comparator.

Secondary Currents under Fault conditions:

For a minimum earth fault of 400 amps, the currents measured by the relays at either end of the feeder will be:

Local End = 600 amps + 400 amps = 1000 amps / 1200 = 0.833 amps

Remote End = 600 amps / 1200= 0.500 amps

Restraint or Bias Current = (0.833 + 0.500) / 2 = 0.666A

Differential Current = 0.833 - 0.500 = 0.333A

The measured relay point is therefore 0.333A differential current at bias current 0.666A.

This can be compared graphically with the relay default P/F Diff. Setting of 0.3xIn and 30% Slope.

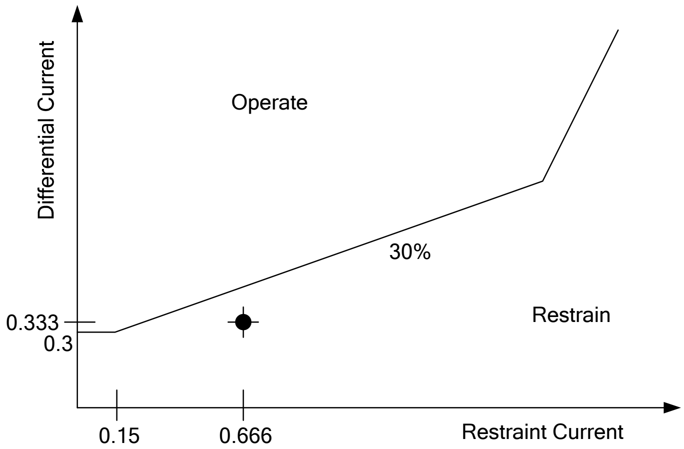


Figure 5 – Setting of P/F Diff. Setting for Load Bias

It is clear that the relay will not operate for this fault. To detect this level of fault the relay P/F Differential and/or Slope 1 setting must be reduced.
This setting must be set in excess of the multiple of steady state charging current required by the relay to ensure stable operation. For relays with shaped phase angle comparators (Revision 4 and above) the required minimum limit is 4 x Ic, where Ic is the steady state cable charging current of the feeder.

Cable Charging Current:

The P/F Differential Setting > 4 x charging current [Resistance Earthed System]

The secondary charging current can be estimated to be: 7km x 4.5A x 1/1200 = 0.0263 A

P/F Differential Setting > 4 x 0.0263A / rated current = 0.106 x I_N

The relay should be set to the next highest Differential Setting of 0.15 x I_N

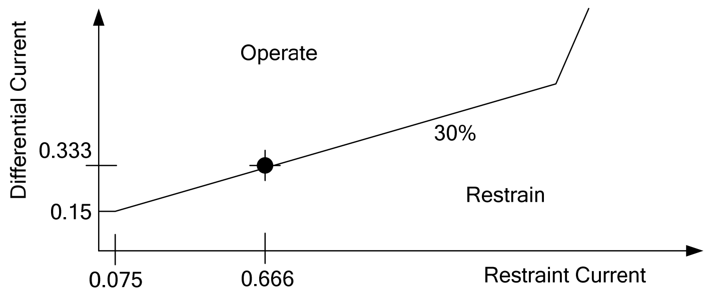


Figure 6 – Setting of Bias Slope for Load Bias

Shown graphically it is clear that it would be advantageous to reduce the bias slope. The next setting below 30% is the minimum of 20%.

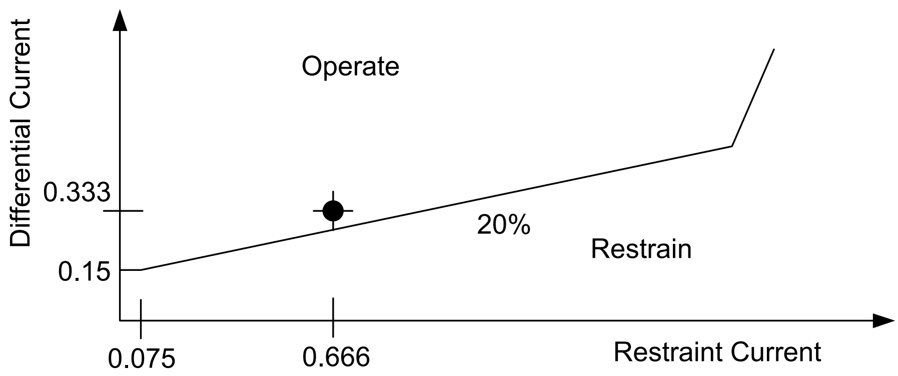


Figure 7 – Settings for correct Load Bias

To allow operation of the relay for this minimum earth fault the Bias Break Point must be set to 1.0 x I_N or above. A setting of 1 x I_N, rather than 1.5 x I_N, would be selected as this help lower the CT requirements. The Figure below shows the effect of settings applied for detecting earth faults on resistance earthed systems. It also shows the fault point for the above example:

Where the relay is used on interconnected systems and the fault current is fed from both ends of the feeder (double end fed) the phase comparator will generally operate.

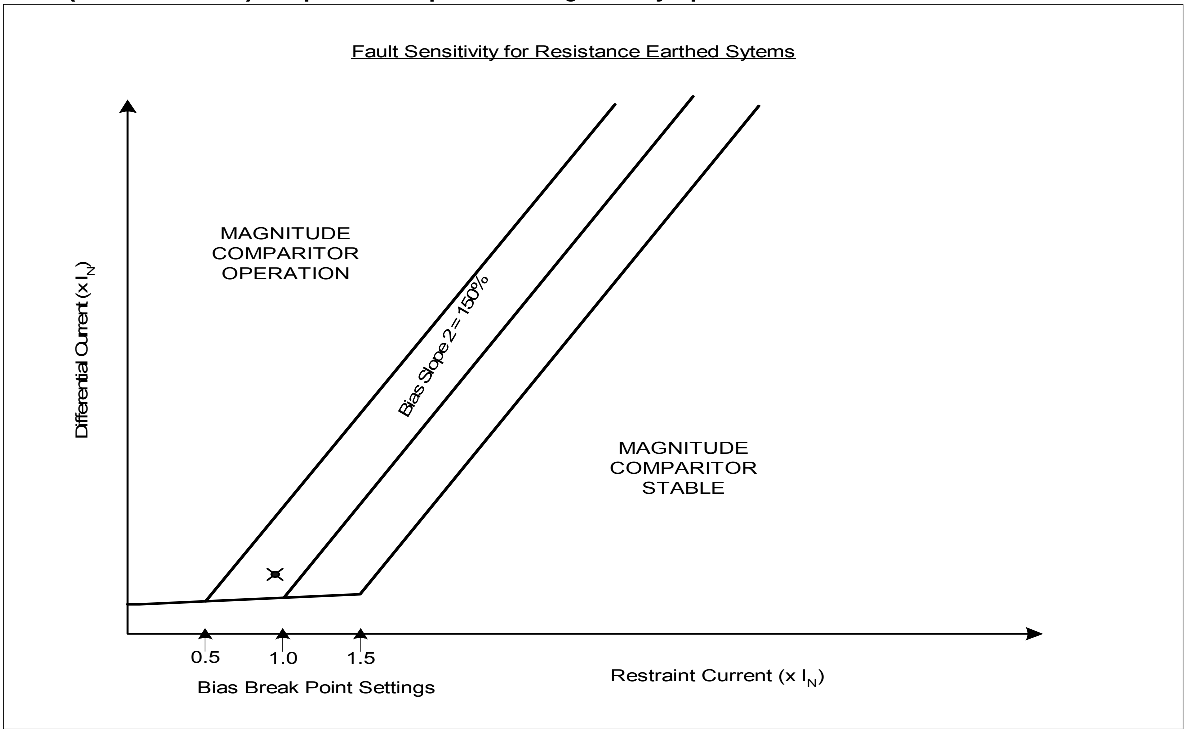


Figure 8 – Setting of Bias Break Point for Load Bias

Figure 9 to 11 shows typical values chosen for the P/F Differential, Bias Slope 1 and Bias Break Point settings to allow an earth fault with some load biasing to be detected. Three typical relay settings used for resistance earthed systems are shown graphically, to assist with selecting appropriate settings.

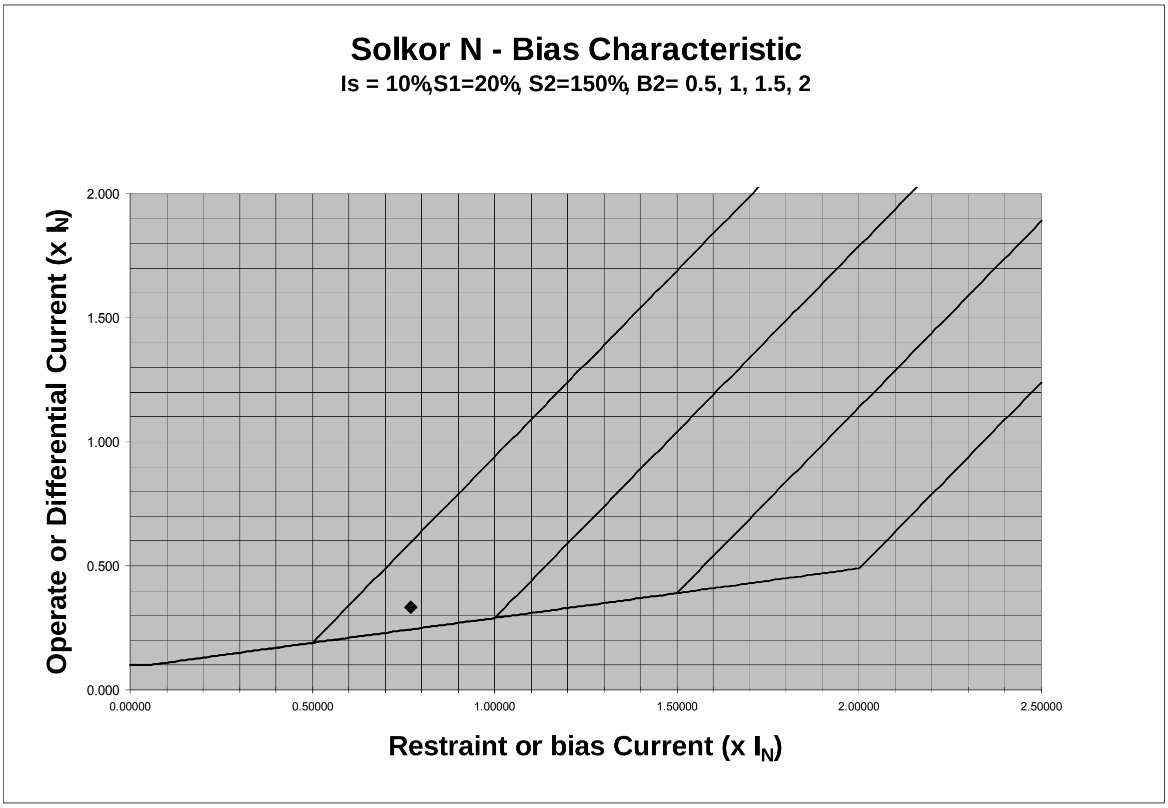


Figure 9– 10% P/F Differential and Bias Break Point of 0.5, 1.0, 1.5 and 2.0.

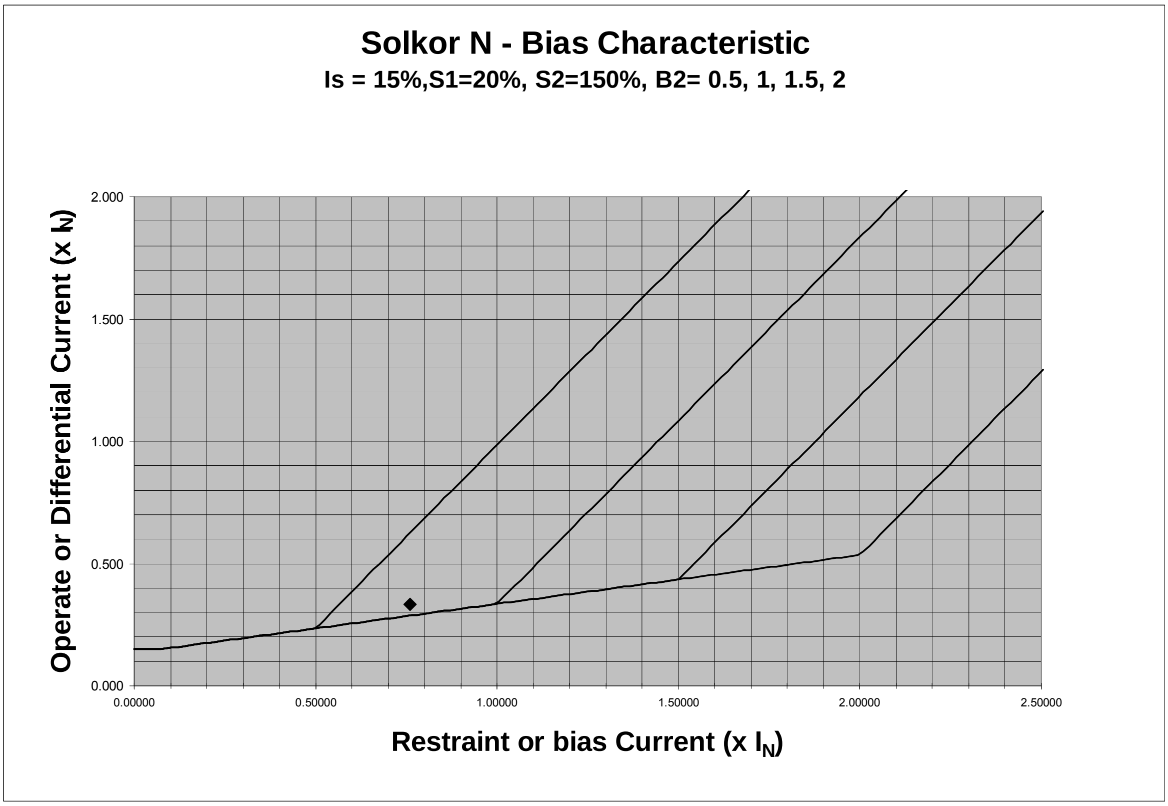


Figure 10 – 15% Differential and Bias Break Point of 0.5, 1.0, 1.5 and 2.0.

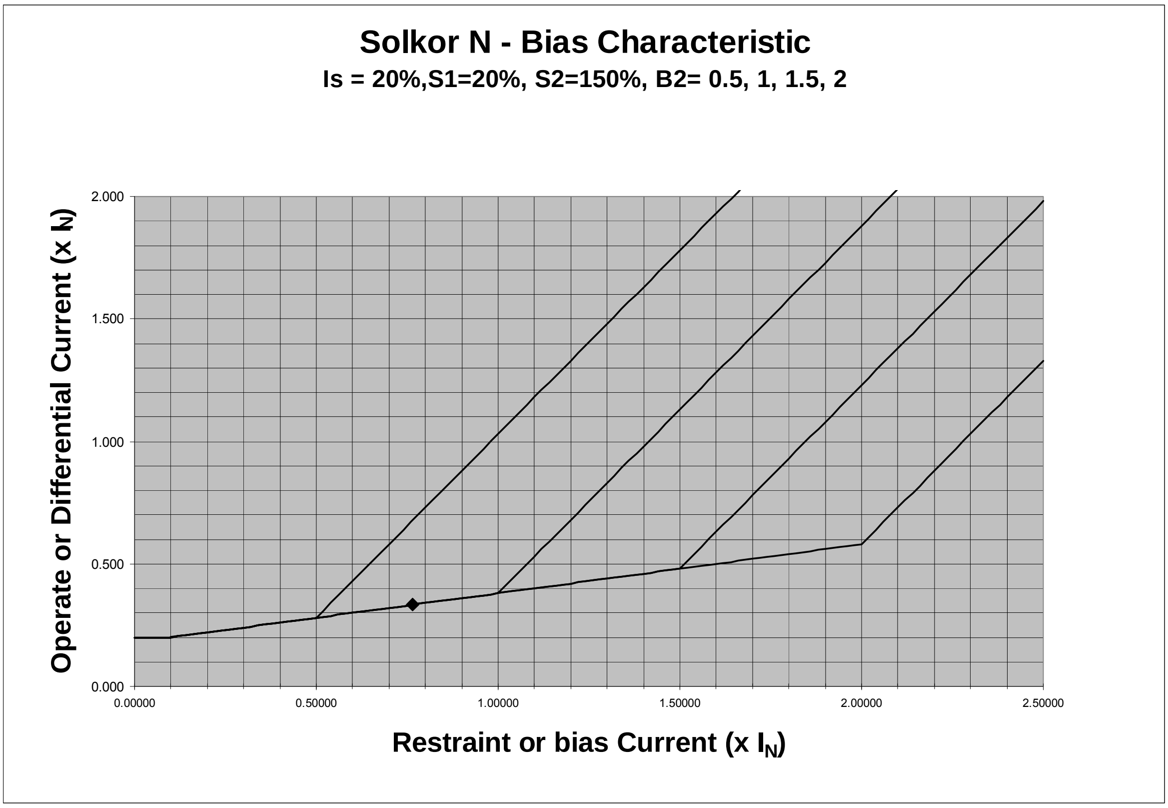


Figure 11 – 20% Differential and Bias Break Point of 0.5, 1.0, 1.5 and 2.0.

7.5.3 Isolated (unearthed) and Reactance Earthing

For these networks, the intention is to ensure that an earthed live conductor does not result in any significant fault current and minimise interruptions to supply. Utility networks of this type do not normally include discriminating protection as a first level, e.g. whilst the network is earthed via a Peterson Coil (reactance earthing).

Often the earth fault position is found by applying a short to the neutral reactance after a time delay. If the fault is within the protected zone of the relay then the device would then trip. Often systems with this type of earthing will have “pecking” type faults that may lead to problems in grading different types of over current and earth fault relays. XLPE cable circuits typically have pecking faults where the arc is extinguished and the fault re-seals.

The reset of the relays may become out of step as the pulses of fault current usually are not long enough to allow relays to time out, and eventually this will often lead to loss of grading. Where circuits have pilot wires often this grading problem may be over come by the use of this relay type.

For industrial networks, employing the isolated network neutral philosophy, it is usually intended that discriminating protection be employed if possible. This type of protection employs the detection of zero sequence fault current resulting from network cable capacitance, employing a core balance c.t., and zero sequence voltage from a neutral displacement voltage transformer winding, in combination, to establish the position of a fault.

During the period where the system is earthed via a variable neutral reactance, the fault current pulse is usually long enough for this relay type to provide satisfactory earth fault protection on such a network. After the neural control time delay has expired and the reactance earthed system becomes solidly earthed, the relay will operate and trip the faulted circuit.

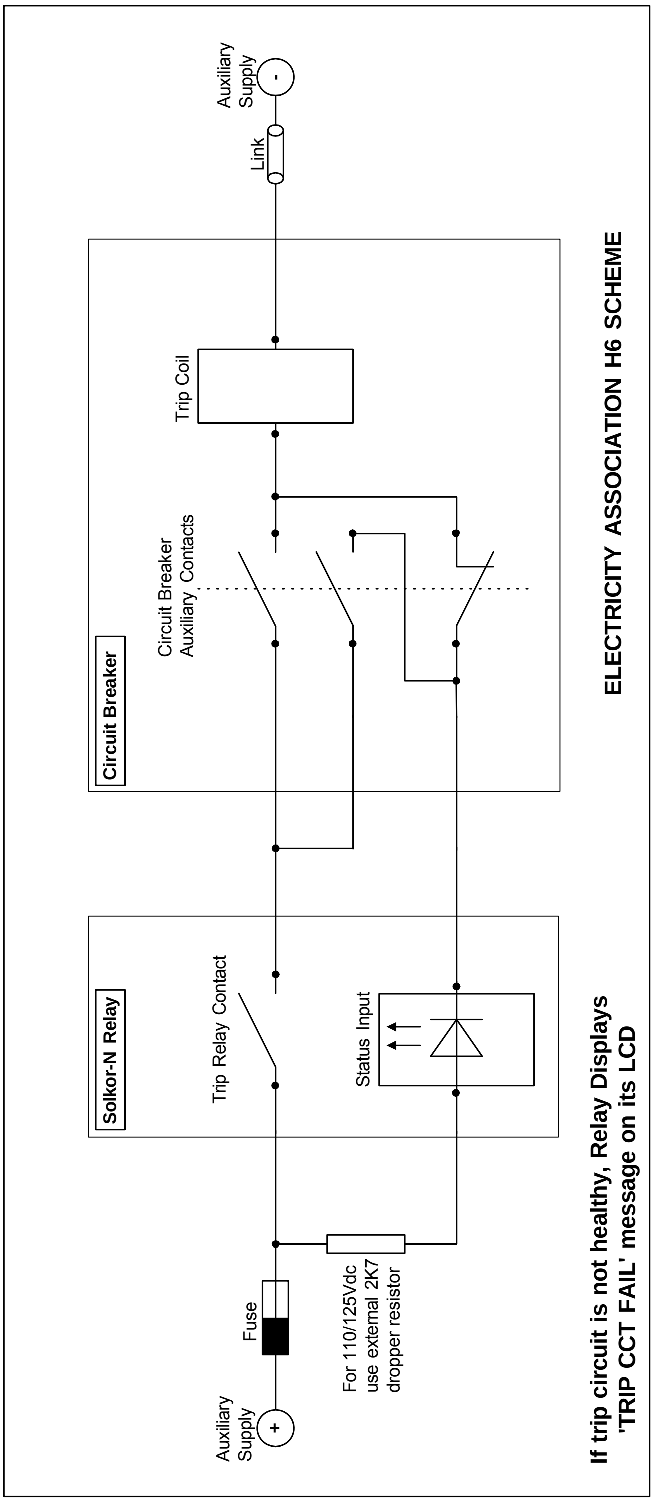


Figure 12 – Trip Circuit Supervision Connections

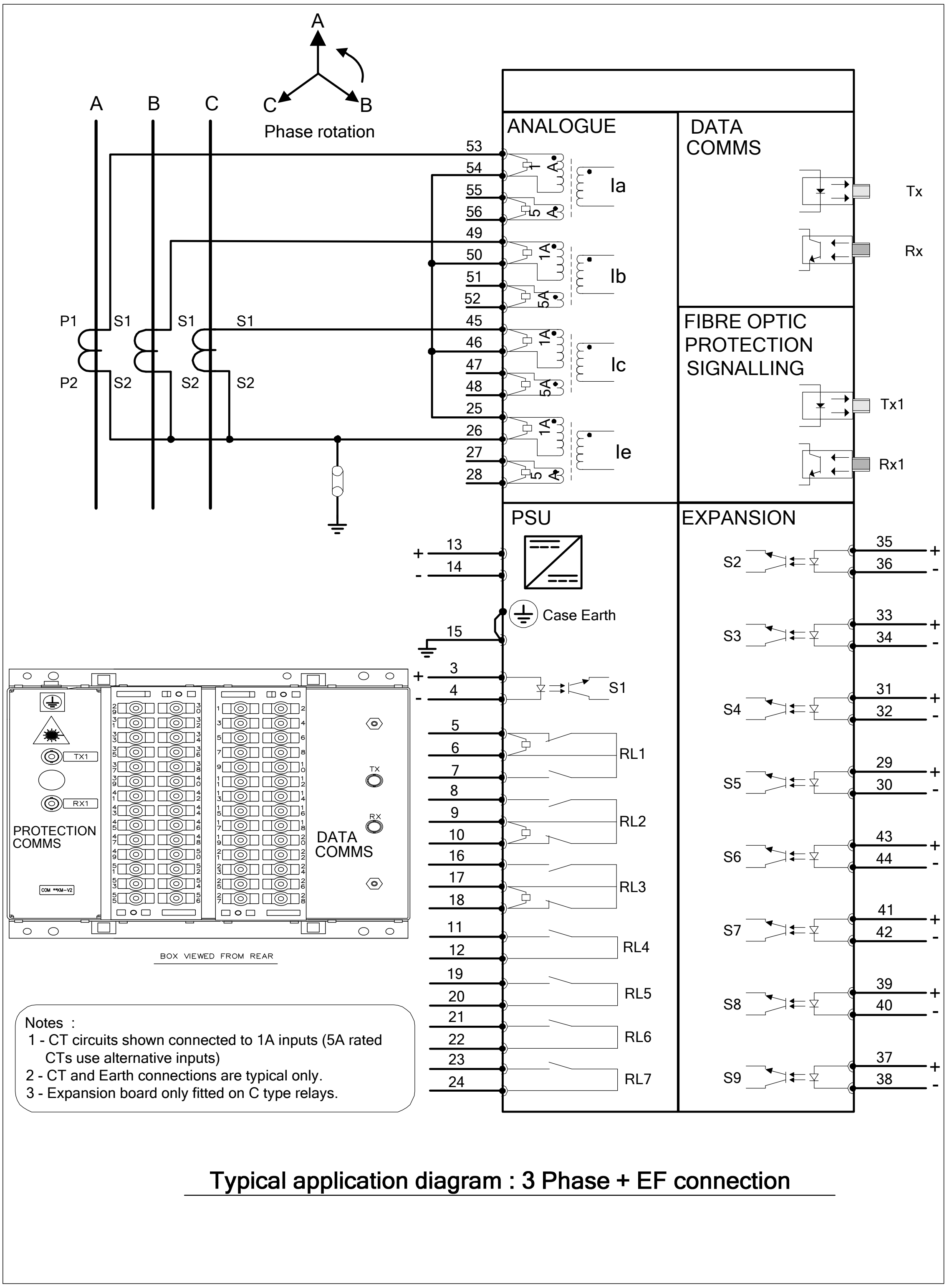


Figure 13 – Relay Connections for Fibre Optic

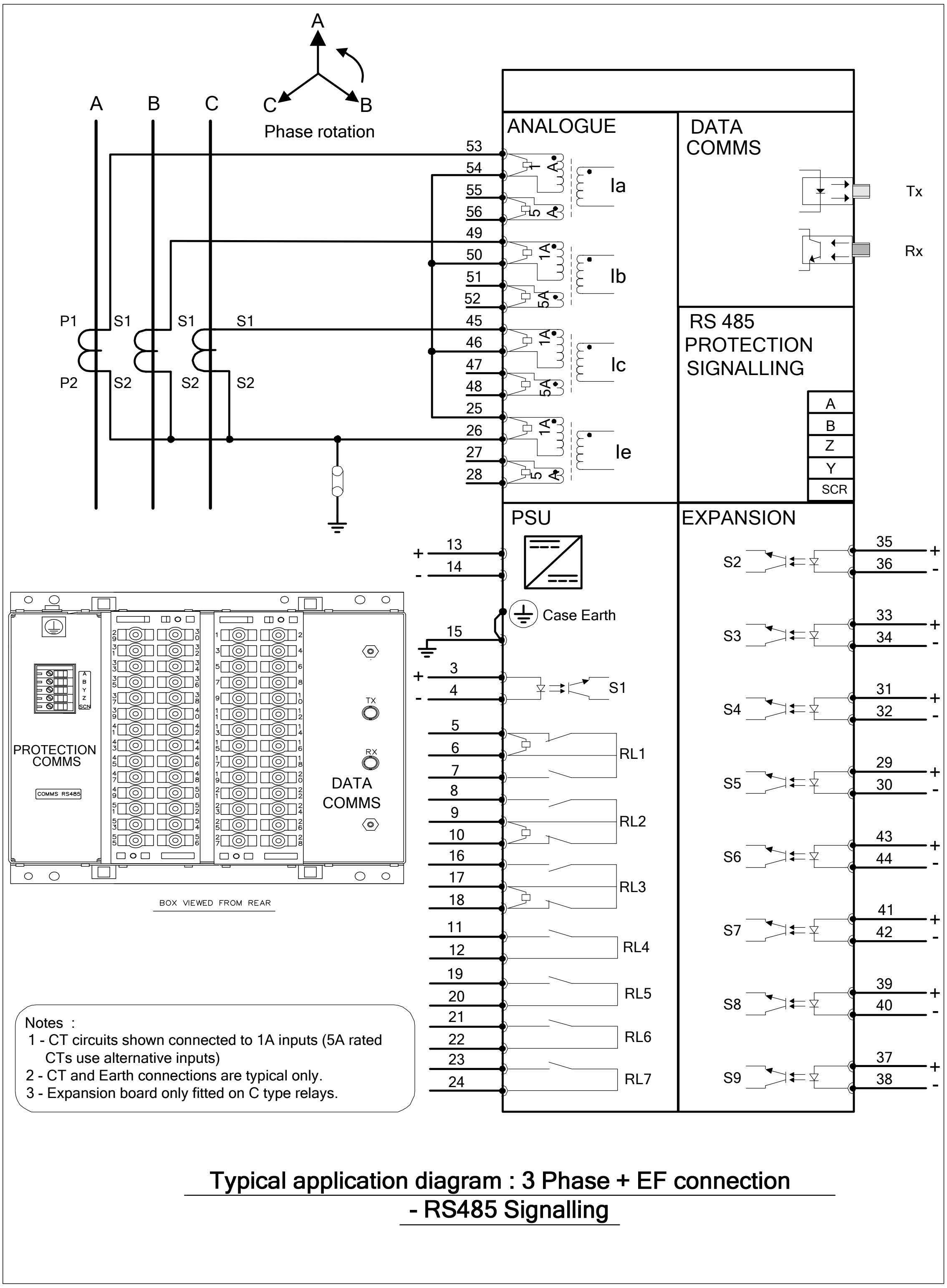


Figure 14 – Relay connections for RS485 Cable

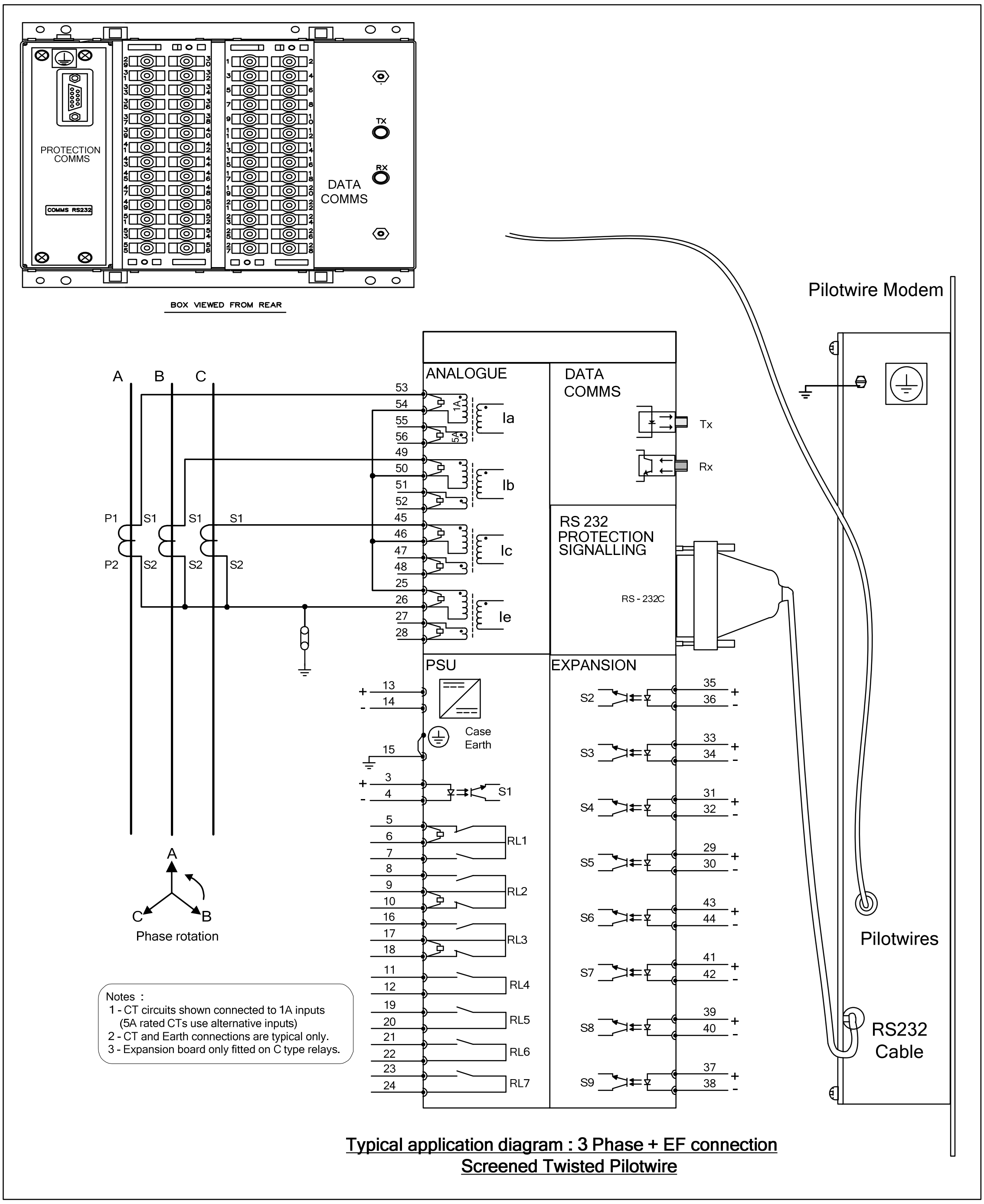


Figure 15 – Relay Connections for Screened Twisted Pair Metallic Pilotwires

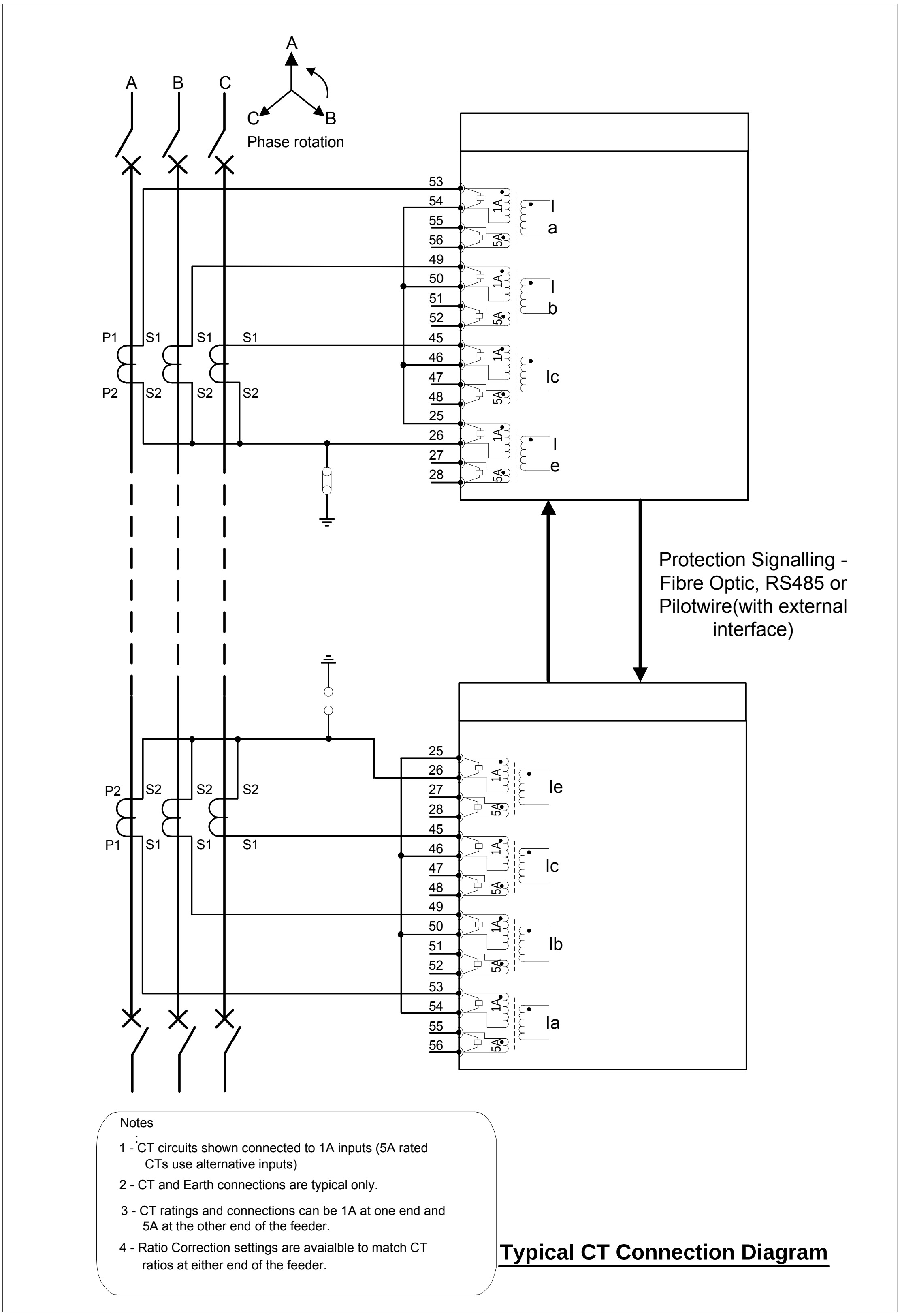


Figure 16 - Typical CT Connection Diagram

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Document Release History

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Pre release

2010/02	Document reformat due to rebrand

Software Revision History

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Figures

1 Unpacking, Storage And Handling

On receipt, remove the relay from the container in which it was received and inspect it for obvious damage. Check that the relay is the correct model number and the rating information is correct. It is recommended that the relay is not removed from the case. To prevent the possible ingress of dirt, the sealed polythene bag should not be opened until the relay is to be used. If damage has been sustained a claim should immediately be made against the carrier and Siemens should be informed.

When not required for immediate use the relay should be returned to its original carton and stored in a clean, dry place. The relay contains static sensitive devices, which are susceptible to damage due to static discharge and for this reason it is essential that the correct handling procedure is followed. The relays' electronic circuits are protected from damage by static discharge when it is housed in its case. When it has been withdrawn from the case, static handling procedures should be observed.

- Before removing the relay from its case the operator must first ensure that he is at the same potential as the relay by touching the case.
- The relay must not be handled by any of the relay terminals on the rear of the chassis.
- Relays must be packed for transport in an anti-static container.
- Ensure that anyone else handling the relays is at the same potential as the relay.

As there are no user serviceable parts in the relay, then there should be no requirement to remove any modules from the chassis. If any modules have been removed or tampered with, then the guarantee will be invalidated. Siemens reserves the right to charge for any subsequent repairs.

2 Recommended Mounting Position

The relay uses a liquid crystal display (LCD) which displays setting and metering information. It has a viewing angle of ± 70º and an internal back light. The recommended viewing position is at eye level.

The relay should be mounted onto the circuit breaker or panel at a level which allows the user easiest access to the relay functions.

3 Relay Dimensions

The relay is supplied in an Epsilon size E8 case. Mechanical diagrams of the case dimensions and panel cut-out requirements are shown in Figure 1.

4 Fixings

4.1 Crimps

Amp Pidg or Plasti Grip Funnel entry ring tongue

Size	AMP Ref	Reyrolle Ref
0.25-1.6mm^2	342103	2109E11602
1.0-2.6mm^2	151758	2109E11264

4.2 Panel Fixing Screws

Kit – 2995G10046 comprising:

- Screw M4 X10TT 2106F14010 – 4 off
- Lock Washers 2104F70040 – 4 off
- Nut M4 2103F11040 – 4 off

Note Two Mounting screws for the Pilot wire Interface are not supplied as this is mounted inside the protection panel. The Pilot wire modem has two 5mm diameter holes on a mounting bracket - see figure 2.

4.3 Communications

The communications connection types supplied are:

IEC60870-5-103 Communication Interface

BFOC/2.5 (ST®) bayonet-style connectors – 2 per relay.

Protection Signalling Communication Interface

Any one of the following internal communication interfaces may be supplied with the relay.

RS485 Cable - Screen twisted pair electrical link - 5 way screw terminal – 1 per relay.

RS232C and Pilot wire Modem - 4 way screw to 1.9m RS232 cable – 1 per relay.

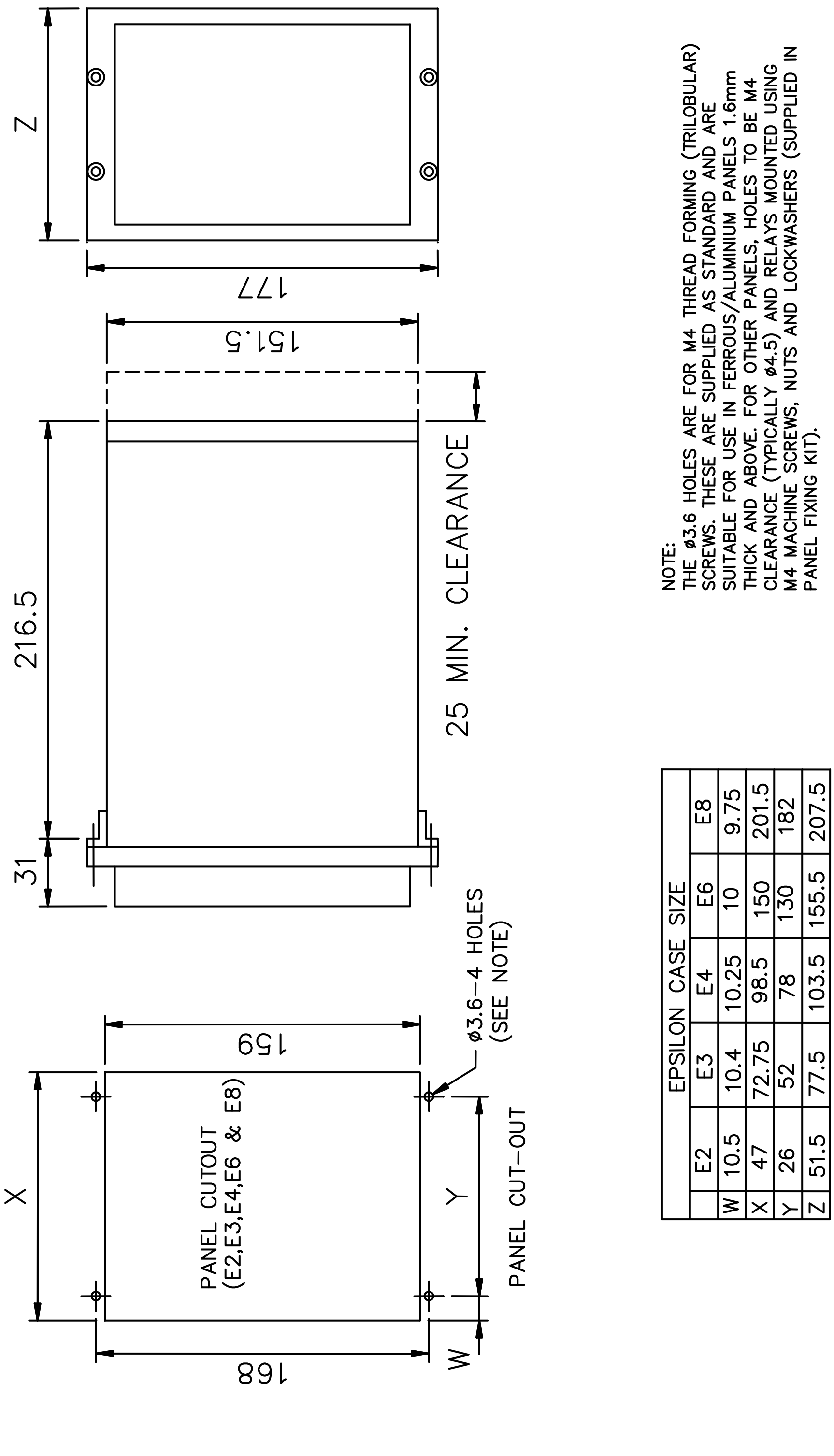
1300nm LED Multimode optical fibre link - BFOC/2.5 (ST®) bayonet-style connectors – 2 per relay.

1300nm LED Single mode optical fibre link - BFOC/2.5 (ST®) bayonet-style connectors – 2 per relay.

(Refer to Section 4 of this manual – Communications Interface).

5 Ancillary Equipment

The relay can be interrogated locally or remotely by making connection to the fibre optic terminals on the rear of the relay. For local interrogation a portable PC with a fibre to RS232 modem (Sigma 4) is required. The PC must be capable of running Microsoft Windows Ver 3.1 or greater, and it must have a standard RS232 port in order to drive the modem. For remote communications more specialised equipment is required. Refer to Section 4 of this manual – Communications Interface.



	EPSILON CASE SIZE				
	E2	E3	E4	E6	E8
W	10.5	10.4	10.25	10	9.75
X	47	72.75	98.5	150	201.5
Y	26	52	78	130	182
Z	51.5	77.5	103.5	155.5	207.5

Figure 1 - Overall Mounting Dimensions (E8 size Case)

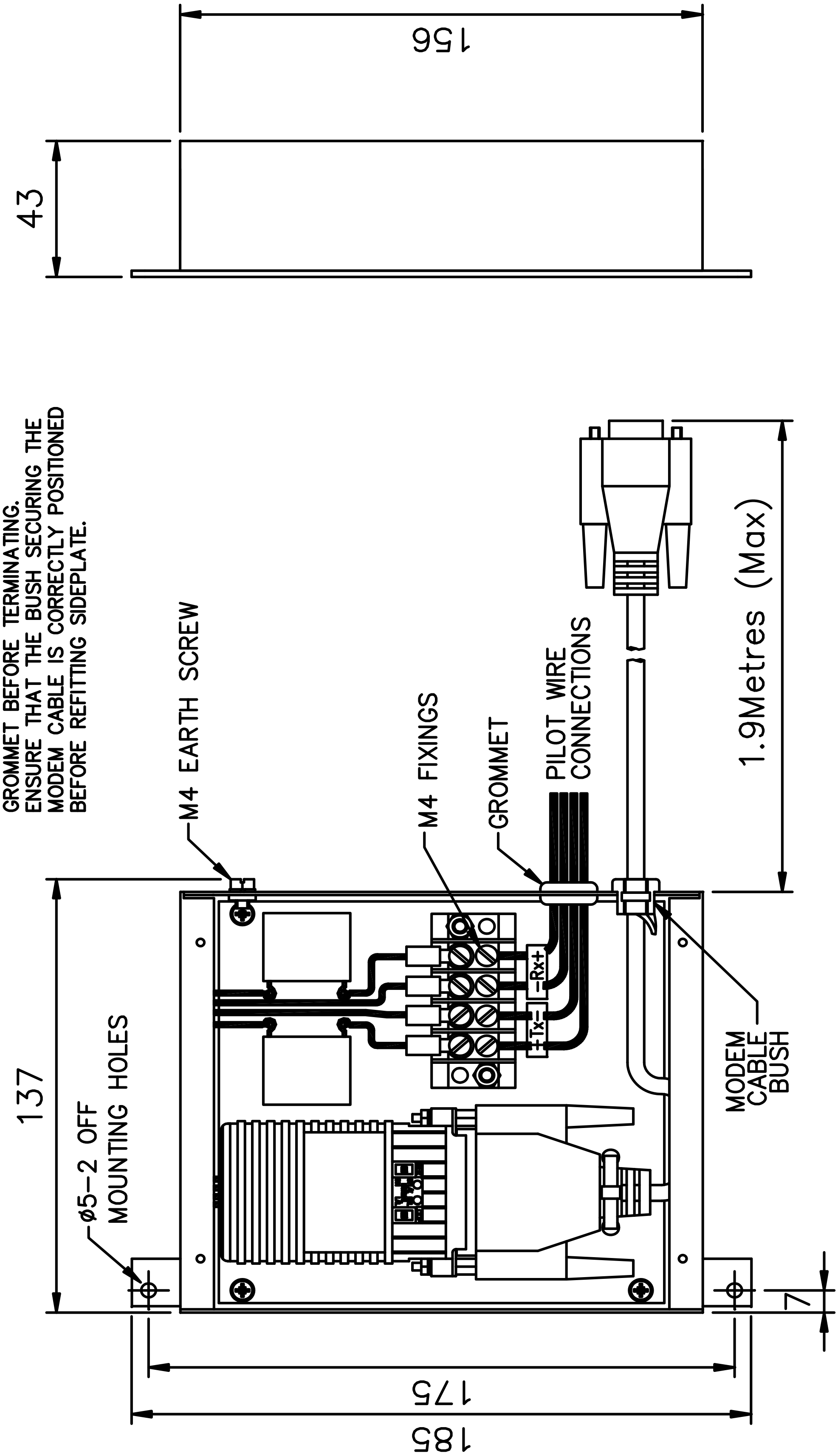


Figure 2 - Mounting Dimensions of Pilotwire Modem

The pilot wire connections are shown in Section 4 – Communications Interface.

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Software Revision History

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1 Required Test Equipment

- 500V Insulation resistance test set.
- Variable single or three phase secondary injection current source rated at greater than 10A. The amplitude must be adjustable.
- Time interval meter.
- Primary injection equipment up to circuit rating.
- A d.c. supply with nominal voltage within the working range of the relay's d.c. auxiliary supply rating.
- A d.c. supply with nominal voltage within the working range of the relay's d.c. status input rating. Additional equipment for testing the communications channel:
- Portable PC with Reydisp Evolution v4.02 (or later) installed, pair of ST type fibre optics, Sigma 4 RS232/FO converter and RS232 lead. Alternative is USB to RS232 converter.
- Test Plugs suitable for panel mounted test sockets.

It is recommended the facilities afforded by Reydisp Evolution Software be used for relay setting and commissioning. Relays can be programmed and final settings applied, then saved as a setting file, before altering the settings during commissioning. These can then be downloaded back into the relays before the circuit is put back into service. See Section 2 of this manual for equipment required.

Settings file can be compared using Reydisp Evolution Software. This is done by opening two settings files to be compared and then selecting [Relay] [File compare]. Any differences are highlighted in a different colour.

2 Inspection

Ensure that all connections are tight and in accordance with the relay wiring diagram and the scheme diagram. Check the relay is correctly programmed and the relay is fully inserted into the case. Refer to the Description of Operation for programming the relay.

3 Applying Settings

The relay settings for the particular application should be applied before any secondary testing occurs. If they are not available then the relay has default settings that can be used for pre-commissioning tests. Note the tripping and alarm contacts must be programmed correctly before any scheme tests are carried out. See the Relay Settings section of this manual for the default values and settings advice.

The relay features eight alternative settings groups. In applications where more than one settings group is to be used, it may be necessary to test the relay in more than one configuration.

When using settings groups, it is important to remember that the relay need not necessarily be operating according to the settings currently displayed. There is an 'active settings group' on which the relay will operate, and a separate selection for 'edit/view settings group' which is visible on the display. The displayed Settings Group can be altered. This allows the settings in one group to be altered while the protection continues to operate on a different unaffected group. The 'active settings group' and the 'edit settings group' are selected in the 'System Configuration Menu'. The differential setting of a pair of relays, at either end of the feeder must remain identical at all times.

Elsewhere in the settings menu, the settings can be altered in the different groups. Each Settings Group is indicated by the symbols G1, G2 etc. in the top left of the display. Some settings are common to all groups, but all the protection settings can be set to different values. It is important to set the differential settings identically on each pair of relays.

4 Precautions

Before testing commences the equipment should be isolated from the current transformers and the CT's short circuited in line with the local site and safety procedures. The tripping and alarm circuits should also be isolated where practical. Busbar CT's should be shorted where necessary, to avoid primary injection operating busbar protection.

Ensure the correct auxiliary supply voltage and polarity is applied to the relay. See the relevant scheme diagrams for the relay connections.

5 Insulation Tests

Connect together all of the C.T. terminals and measure the insulation resistance between these terminals and all of the other relay terminals connected together and to earth.

Connect together the terminals of the DC auxiliary supply circuit and measure the insulation resistance between these terminals and all of the other relay terminals connected together and to earth.

Connect together the terminals of the DC status input circuits and measure the insulation resistance between these terminals and all of the other relay terminals connected together and to earth.

Connect together the terminals of the output relay circuits and measure the insulation resistance between these terminals and all of the other relay terminals connected together and to earth. Satisfactory values for the various readings depend upon the amount of wiring concerned. Where considerable multi-core wiring is involved a reading of 2.5 to 3.0 megohms can be considered satisfactory. For short lengths of wiring higher values can be expected. A value of 1.0 megohm or less should not be considered satisfactory and should be investigated for insulation damage.

Remove temporary connections.

6 Injection Tests

It is imperative that the relay differential settings and software revisions are identical at all times, for each pair of relays protecting the feeder. The Software Revision can be checked by pressing [TEST/RESET] and [CANCEL] pushbuttons simultaneously, when the relay is displaying its identifier at the top of the menu structure. The Revision information is scrolled across the LCD. The latest Software code revision is R5 to which relays may be upgraded, to improve sensitivity for feeders with significant charging current.

6.1 Secondary Injection Tests

Select the required relay configuration and settings for the application. Note that the relay may be connected as either a 1A or 5A rated device. The user should check this before commencing secondary testing.

Reydisp Evolution software can be used to prepare a setting file to download into the relay, prior to commissioning. It is often useful to download the file again, at the end of the tests prior to putting the circuit into service.

It is important that relay elements are tested individually, as spurious results may be recorded if more than one element operates from an injection. Some functional elements may need to be set to 'OFF' or some may need to have pickup and time delay settings to be increased, to avoid simultaneous operation of relay functions.

6.1.1 Current Differential

It is only necessary to test the relay operation at the settings to be used. Apply the settings to the relay in accordance to the requirements for the circuit and scheme.

The differential elements can be tested for accuracy of current magnitude comparison with the relays in three different configurations:

a) Normal - with healthy communications between relays
b) Loop Test Mode – Single relay test without communications
c) Line Test Mode – Single relay test with communications.

The relays at both ends of the feeder should be tested using **one** of these modes. The injection will test the relay accuracy at differential setting (I_S). The differential pickup level should be approximately the Phase Fault differential setting applied to the relays. The results can be recorded in **Table 1** of the Sample Test Record below.

Note: Phase angle comparison cannot be tested by secondary injection. Refer to 6.2 – Primary Injection and load tests below.

a) Normal Connection

This test requires both relays to be powered up, settings applied and healthy communications channel. Inject single phase or three phase current into the current inputs of each relay in turn. Slowly increase the current until the TRIP LED (red) operates and record the pick-up current in **table 1** of the Sample Test Record at the end of his section. The remote relay will also operate on current differential as the relay can operate for a single end fed fault. Reduce the current and record the drop off level.

Check that all pick-up current levels are measured within 100% ± 10% for 1A rated inputs, and 100% ± 15% for 5A rated inputs, of the applied setting. Check that the reset levels are ≥95% of the measured pick-up value.

The stability of the differential protection system can only be checked when primary load current is applied, refer to item 6.3 below.

b) Loop Test Mode
A single relay can be tested on its own in this mode. To select this mode, press the [Down] arrow button on the relay until the PROTECTION SIGNALLING MENU appears, and select the Signal Test Mode to LOOP TEST using [ENTER] and [UP]/[DOWN] arrow keys.

The relay can be tested by connecting a single fibre optic between the Tx to the Rx ports on one relay. In this mode, the relay will test as a single end relay, as the received signal is ignored. Inject Current into the relay as above and record the pickup and drop-off values of current. Using this method it is only possible to check the P/F Differential Setting and perform a local end trip test.

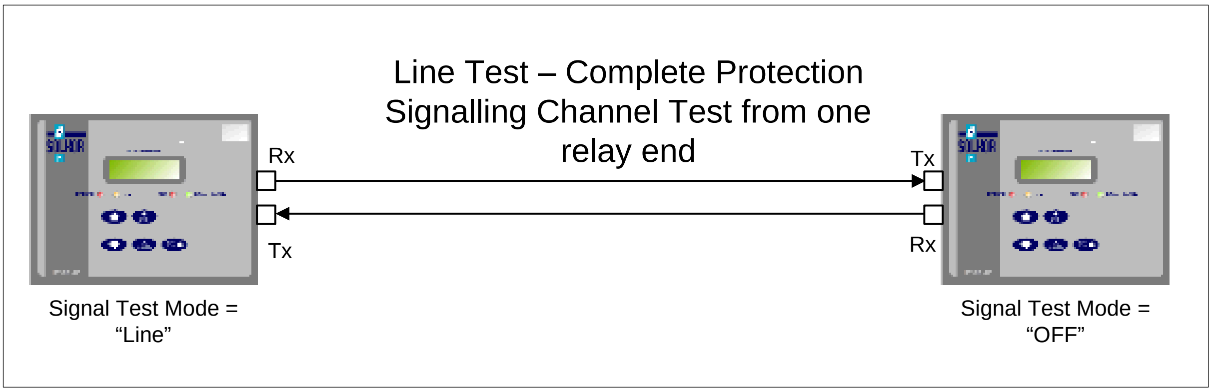
The phase angle comparator cannot be tested using this method.

c) Line Test Mode
If the communications path exists and both relays are capable of being powered up, this method may be used. The whole communications channel can be checked from the Signal Healthy LED. It will be held illuminated if it is healthy. If an end to end communications problem exists, the Signal Healthy LED will flash constantly.

Connect relays at either end to the communications channel.

Set the relay required to be tested into LINE TEST mode, in the PROTECTION SIGNALLING MENU. Only one relay must be put in LINE TEST MODE at a time, as this enables a complete test of the signal path from one end of the feeder.

The relay in LINE TEST MODE can now be tested as in the LOOP TEST MODE, i.e. injection will simulate a single end fed fault. The pickup and drop-off accuracy of the differential elements of the relay in LINE TEST can performed in a similar way to the Loop test above. Only the relay injected will operate.



6.1.2 IDMTL/DTLOver Current and Earth Fault Pick-up and Reset

This test checks the accuracy of the pick-up and drop-off levels of the settings applied.

Inject single phase current into one of the current inputs. Slowly increase the current until the I>Is LED (yellow) operates and record the pick-up current in **Table 2** of the Sample Test Record. Reduce the current until the LED goes out, and record this as the reset level. Repeat this test for each current input.

Check that all pick-up current levels are measured within 105% ± 4% of the applied setting. Check that the reset levels are ≥95% of the measured pick-up value.

Note: Depending upon the applied settings a trip could occur if the current is on for longer than the relay operating time. This may be undesirable while measuring pick-up and reset levels. The fault trigger setting (in the data storage menu) can be used to disable trip indication temporarily during this test. Alternatively the Low and High Set elements can be temporarily turned off, in order to prevent unwanted instantaneous operations.

6.1.3 Overcurrent and Earth Fault IDMTL/DTL Timing Characteristics

This test checks the accuracy of the time delay characteristic (IDMTL/DTL) applied. Select the relay current setting, characteristic and time multiplier setting as required, and then inject a level of current which is a multiple of the relay setting.

The correct output contact must be programmed for the phase fault and earth fault elements. A time interval meter must be connected to the correct terminals. The timer should be started by the source and stopped by the trip contacts. Each current input should be tested. A secondary injection timing test circuit is illustrated in **Figure 1**.

The table below shows theoretical values for each characteristic curve with a time multiplier of 1.0. Record the actual results in **Table 3** of the Sample Test Record and check that the measured times lie within ±5% of the theoretical ones.

Curve	2X Is	5 X Is	10 X Is	20 X Is
NI	10.03	4.28	2.97	2.27
EI	26.67	3.33	0.81	0.20
VI	13.50	3.38	1.50	0.71
LTI	120.00	30.0	13.33	6.32
DTL	*	*	*	*

Timing characteristic (Time in seconds) *User setting

A specific operate times at set multiple of pickup, can be calculated using the IDMTL equations found in Section 2- Performance Specification.

6.1.4 Overcurrent and Earth Fault Lowset and HighSets – (DTL or Instantaneous Elements)

Two highsets and one lowset are available and any one of these instantaneous/DTL characteristics may be required depending on the application. The following tests should be applied to the functions in use.

The low/high set under test should be programmed to operate an output contact. That contact can then be monitored to detect operation of the protection.

Programme the current setting for the low/high set characteristic to the required level, and set its time delay to 0.00 sec. Inject a level of current below the setting of the relay, then increase the current until the output contact operates. Record the pick-up level of these elements in **Table 4, 5 or 6** and confirm that in each case it occurs within ±5% of the applied setting.

For high levels of current the thermal limit of the relay must not be exceeded. Refer to the performance specification for the relay which defines the thermal limits.

To test the operating time, a current of 5 times setting should be applied and the required time delay set on the relay. Output contacts for the high/low set must be programmed and a time interval meter connected to the correct terminals.

The timer should be started by the source and stopped by the High/Low set contacts. Each phase should be tested. For testing above this level then care must be taken to ensure that the test equipment has the required rating and stability and the relay is not stressed beyond its thermal limit.

Record the results in **Tables 7, 8 and 9** and confirm that the measured delays are within ±5% of the set values.

6.1.5 Circuit Breaker Fail (CBF)

The CBF feature works by looking at the reset of the protection element(s) that have operated, allocated fault triggers to distinguish between alarm and trip outputs and an optional level detector on each of the relay poles. The level detector check may also be switched off.

Internally Initiated CBF
The 2-stage internal circuit breaker failure feature should be tested if it is being used, otherwise the CBF time delay 1 & 2 should be set to OFF. If only one of the stages is to be used then only CBF delay 1 need be tested.

In order to test both stages of the CBF feature then the two CBF delays should be programmed to operate output contacts other than the main trip output. They should also be programmed with their appropriate delays.

CBF delay 1 starts timing out when the main trip output operates and a protection element remains operated, indicating a fault current is still flowing. After timing out, it generates a trip output of its own and also initiates CBF delay 2 which subsequently generates a final trip output.

Note both Phase and Earth CBF Level detectors must be set to allow them to be incorporated into the CBF logic.

Connect the main trip output to start a time interval meter. Connect the output from CBF delay 1 to stop both the timer and the current source. Inject current of 2x setting into any pole and record the first CBF time delay in **Table 10**.

Connect the CBF delay 1 output to start the time interval meter. Connect the output from CBF delay 2 to stop both the timer and the current source. Inject current of 2x setting into any pole and record the second CBF time delay.

Check that the measured delays are within ±5% of the set values.

External Initiated CBF
The 2-stage external circuit breaker failure feature should be tested if required by the application. If only one of the stages is to be used then only one of the DTL elements (used as the CBF 1 detector) need be tested.

In order to test both stages of the CBF feature then the two DTL elements used should be programmed to operate output contacts other than the main trip output. They should also be programmed with their appropriate delays.

CBF delay 1 DTL element is initiated by voltage being applied to its assigned status input to allow the DTL element to measure and time out. After timing out, it generates a trip output of its own. The second DTL element used for CBF delay 2 is usually set to the same current pickup and inhibited by the same status input, but has a longer time delay applied and separate trip output(s) allocated.

Connect the main trip output to start a time interval meter. Connect the output from CBF delay 1 to stop both the timer and the current source. Inject current of 2x setting into any pole and record the first CBF time delay in **Table 11**. The inverted status input used to block operation of the DTL elements must be energised to allow the DTL elements to operate.
Connect the DTL (CBF) delay 1 output to start the time interval meter. Connect the output from DTL (CBF) delay 2 to stop both the timer and the current source. Inject current of 2x setting into any pole and record the second CBF time delay.

Check that the measured delays are within±5% of the set values.

The pickup and drop-off of the CBF level detectors may be tested by operating the element with a ramp up or down of the injected current.

6.1.6 Status Inputs
The operation of the status input(s) can be monitored on the ‘status input’ display when in Instruments Mode. Apply the required supply voltage to the status input and check for correct operation. Repeat for the other status inputs if the expanded relay with 9 status inputs is ordered.

Depending on the application, the status inputs may be programmed to perform a number of functions, and these may need to be tested individually. Such functions are alarms and waveform recording from other external protection devices, such as Buchholz.

Status inputs may be inverted to allow testing without applying and energising voltage.

See **Table 12** to record test results.

6.1.7 Output Relays

All relay models have seven output relays, three of which have change-over contacts; the remaining four have normally open contacts. Each contact can be tested individually by the trip test feature or they can be checked during commissioning by testing the feature to which they are assigned. See **Table 13** to record test results.

6.2 Primary Injection Tests

Primary injection tests are important, to check the ratio and polarity of the current transformers as well as the secondary wiring. Alternatively on load tests may be conducted to speed to up test procedure.

Use the circuit shown in **Figure 2** to check the current transformer ratio and the c.t. phase to earth connections. Inject a current of sufficient magnitude for the relay ammeters to display. These values should be compared with the ammeters connected in series with the relay.

The secondary current is: $Is = \frac{\text{Primary current}}{\text{C. T. ratio}}$

Use the circuit shown in **Fig. 3** to check the current transformer ratio and the C.T. phase to phase connections.

Record the results in **Table 14**.

6.3 End to end Signalling

Healthy end to end signalling will illuminate the SIGNAL HEALTHY LED permanently. A flashing LED indicates a fault in the end to end signalling.

The SIGNAL HEALTHY LED of both relays should be checked, as they are independent of each other.

The relays monitor the incoming received signal for noise or interruption. Differential protection is blocked if the signal to noise ratio exceeds a set value or the channel is lost.

The state of the signal healthy LED can be recorded in **Table 15**.

6.4 On-Load Tests

The phase angle comparator must be tested using load current. The test undertaken (Test 1 or Test 2) is depending upon the level of load current flowing in the feeder at the time of the test. The level of load current can be checked via the restraint current measurement in the Instruments mode. The levels of load, restraint and differential currents should be recorded in **Table 16**. One of the following tests should be performed to test the phase angle comparator. Which of these two tests to do, will depend upon the restraint (feeder load) current flowing at the time of the test:

(i) **Test 1** – If restraint current is greater than the P/F Differential Setting /2
(ii) **Test 2** - If the load current is less than P/F Differential Setting /2

The test procedure is as follows:

Close both circuit breakers at either end of the feeder to permit load current to flow. Both relays should be stable and the “Signal Healthy” LED on both relays should be permanently illuminated, i.e. not flashing.

Test 1 – Where Load Current is High

This test applies when the load current is high enough to ensure that the restraint current is higher than half of “P/F Differential” setting. The restraint current is the average of the load current measured at each end. Since these two values are normally the same (eg, unless there are significant values of in-zone capacitance current or load current of a small auxiliary power transformer in the protected zone), then the restraint current will equal the load current.

If this load current is higher than half the P/F Differential current setting there is sufficient current to ensure the phase angle comparator is not blocked.

The load current at the local end and the remote end can both be read from either relay using the Instrument display. This allows the restraint current to be established.

Positive operation of the phase angle comparator can be checked as follows and this test could provide an on-load trip test:

With the relays connected normally and load current flowing the relay should be stable and minimum differential current displayed on the instruments.

Reversing the CT connections will cause the relays to become unstable and they will issue a trip signal. High levels of differential current can be observed on the instruments.

- The "CT Reversal" setting in the relay's "CB Maintenance" setting menu is employed to swing the current vector on one relay by 180° and thus operate the phase angle comparator function.

- Use the [ENTER], [⇩] and [⇧] pushbuttons or Reydisp Evolution to change the "CT Reversal" setting from "OFF" to "ON".

Note: When the [ENTER] pushbutton is pressed to initiate the CT reversal of 180°, the trip output will be initiated immediately! CT reversal can then be turned back to the OFF setting. See **Table 17** to record test results.

Often this test is conducted to operate the trip relay only, without tripping the feeder, by removal of the CB Trip - Fuse and Link. For this test, the relay will be in permanent trip state. The relay does not accept setting changes when in the tripped state, as the relay trip operation takes priority over implementing setting changes. To revert the relay to its normal state, change the CT reversal setting(s) to normal and select "Update Changed Setting" in the Relay Menu of Reydisp Evolution. Then remove the relay supply by extracting either its supply fuse or link, to power the relay down. Immediately after the LCD powers down, power the relay up by re-inserting the fuse or link. The setting change will then be implemented to and the CT reversal removed (set to OFF) to allow the relay to reset.

Test 2 – Where Load Current is Low

This test applies when the restraint current is below the P/F differential settings /2. At this level of load current the Phase angle comparator is blocked and as a result the relays will remain stable.

The phase comparator will be blocked if the restraint current (which is approximately equal to the load current for on-load testing) is less than half of the "P/F Differential" setting.

The connections are correct if the relay indicates an increase in differential current when the CT reversal applied to one relay only. The CT Reversal Setting is found in the CB Maintenance Menu. In this state, the differential current should be approximately double the restraint current. The differential current should increase significantly when CT reversal is implemented. Check the differential and restraint currents for all three phases.

The CT Reversal" is implemented as described in Test No 1 above. See **Table 18** to record test results. The CT reversal should then be de-selected.

If load current levels measured by the relay are very low then settings may have to be altered to allow the increase in differential currents to be registered, when the CT reversal is applied. An angle measurement cut-off is applied at the following levels if either the Local or Remote current is less than the following levels:

P/F Differential Setting Selected	Secondary Current Required to activate CT Reversal	
	Relay 1 Ampere Rated Inputs used (mA)	Relay 5 Ampere Rated Inputs used (mA)
0.10 x In	13	60
0.15 x In	15	70
0.20 x In	16	75
0.25 x In	20	95
0.30 x In	21	113
0.35 x In	29	136
0.40 x In	30	137
0.45 x In	35	158
0.50 x In	40	172

If load levels are very low set both relays to the minimum P/F Differential of 0.1 x In. As indicated above the minimum levels are 13mA for 1A and 60mA for 5A terminals. If 5A CT's are used and the secondary current is below 60mA, the check for an increase in differential current may be carried out by temporarily connecting the 5A CT wiring to the 1A relay input terminals.

Test Waveform Records

The Reydisp Evolution software program can be employed to trigger waveform storage to provide a record of these tests. A snapshot of the load current can be taken for both of the above tests and in the case of Test No 1 the trip record can also be taken.

Waveform storage can be triggered either by the trip initiation (i.e. Test No 1) or by energising a status input which has been programmed to trigger a waveform record (i.e. Test No 2). These records can be used as part of the protection commissioning report for the relay under test. When the relay is balanced the phase angle difference on each phase, as displayed on the waveform record should be 8 ±2.

7 Trip And Intertrip Tests

The relays have settings to allow:
1. A local trip test or
2. An intertrip test of both relays

7.1 Local Trip Test

This can be activated through the fascia pushbuttons on the Reydisp Evolution Software. Select the [CB Maintenance Menu] and scroll down into O/P test. Select the output relays used to initiate circuit breaker tripping on pressing the enter pushbutton to activate the setting the relay will wait 10 secs before the closing the selected output contacts. This 10 secs delay is used to allow personnel to vacate the vicinity of the CB before it opens.

7.2 Manual Intertrip Test

Either a simulated internal intertrip or external intertrip can be simulated by selection of settings. Again the [ENTER] pushbutton to activate this setting will initiate this test.

Record the Trip and Intertrip Test results in **Table 19.**

Note: These tests do not require any current in the relay.

8 Putting Into Service

After tests have been performed satisfactorily the relay should be put back into service as follows:

Remove all test connections.

Where possible, the relay settings should be down-loaded to a computer and a printout of the settings produced. This should then be compared against the required settings. The Reydisp Evolution Software can compare settings files automatically. To do this open the two settings files for comparison and select [Relay] [Compare Settings]. Select one file to compare to the other and select [Compare]. Differences are highlighted in colour.

It is important that the correct settings group is active if more than one group has been programmed.

Replace all fuses and links.

9 Sample Test Records

RECORD OF COMMISSIONING TESTS RESULTS

Substation Name:

Feeder Name:

Date Tested:

INSULATION TEST RESULTS **M Ohms**

Between Relay a.c. current inputs and earth	
Between Relay power supply terminals and earth	
Between Relay status inputs and earth	
Between Relay output contacts and earth	

SECONDARY INJECTION TESTS

Differential Protection

Substation Name - end A:

Mode of Test : Normal/ Loop Test/Line Test (delete where appropriate)

Substation Name - end B:

Mode of Test : Normal/ Loop Test/Line Test (delete where appropriate)

Level of Restraint current = $I_S/2$

Differential Current

Current Input	P/F differential Setting	Measured Pick-up	*Pick-up Error(±10% of 100% Max)	Measured Reset	Reset (≥95% of pick-up)
Phase A					
Phase B					
Phase C					

Table 1 – Differential Pick-up/Reset Results

*This accuracy tolerance is for 1A rated inputs used on both relays. Note the pickup error for 5A inputs or where 1A and 5A inputs are used is 15%.
Table 1. Differential Pick-up/Reset Results

Overcurrent and Earth Fault Protection

Current Input	Pick-up Setting	Measured Pick-up	Pick-up Error (±4% of 105%)	Measured Reset	Reset (≥95%) of pick-up)
Phase A					
Phase B					
Phase C					
E/F					

Table 2 - Characteristic Pick-up/Reset Results

Current Input	Characteristic (NI, VI, EI, LTI, DTL)	2xIs		5xIs		10xIs		20xIs	
		Delay	Error (±5%)	Delay	Error (±5%)	Delay	Error (±5%)	Delay	Error (±5%)
Phase A									
Phase B									

Phase C									
E/F									

Table 3 - Timing Characteristic Results

Current Input	Lowset Setting	Measured Pick-up	Error (±5% setting)
Phase A			
Phase B			
Phase C			
E/F			

Table 4 - Lowset Setting Results

Current Input	Highset 1 Setting	Measured Pick-up	Error (±5% of setting)
Phase A			
Phase B			
Phase C			
E/F			

Table 5 - Highset 1 Setting Results

Current Input	Highset 2 Setting	Measured Pick-up	Error (±5% of setting)
Phase A			
Phase B			
Phase C			
E/F			

Table 6 - Highset 2 Setting Results

Current Input	Lowset Delay Setting	Measured Delay	Error (±5% of setting)
Phase A			
Phase B			
Phase C			
E/F			

Table 7 - Lowset Timing Results

Current Input	Highset 1 Delay Setting	Measured Delay	Error (±5% of setting)
Phase A			
Phase B			
Phase C			
E/F			

Table 8 - Highset 1 Timing Results

Current Input	Highset 2 Delay Setting	Measured Delay	Error (±5% of setting)
Phase A			
Phase B			
Phase C			
E/F			

Table 9 - Highset 2 Timing Results

CBF Delay	Delay Setting	Measured Delay	Error (±5% of setting)
Delay 1			
Delay 2			

Table 10 - Circuit Breaker Fault Timing Results

CBF Delay	Delay Setting	Measured Delay	Error (±5% of setting)
Delay 1			
Delay 2			

Table 11 – External Circuit Breaker fault Timing Results

CBF Level Detectors	PU Setting	PU Measured	Error (±5% of setting)
Phase A			
Phase B			
Phase C			
E/F			

Table 12 – External Circuit Breaker fault Timing Results

Status Inputs

S/I No	1	2*	3*	4*	5*	6*	7*	8*	9*
Tested OK (✓)									

Table 13 – Status Input Test Results   * - Applicable Yes/No

Output Relays

Relay Reference	RL1	RL2	RL3	RL4	RL5	RL6	RL7
Operation Confirmed (✓)							

Table 14 – Output Contact Test Results

Primary Injection

Phase Injected	Primary Current	Secondary Current			
		A	B	C	N
A-B				Nil	Nil
B-C		Nil			Nil
B-E		Nil		Nil	

Table 15 – Primary Injection Results

Signal Healthy LED Indication

Green LED illuminated constantly	Signal Healthy	
Green LED flashing	Signal unhealthy	

Table 16 – Protection Signalling Test Results

If Signal unhealthy, investigate protection signalling path.

On Load Tests

Substation A -	
Substation B -	

Instruments Display

Phase	Measured Load Current (x I_N) (Sec Amps)	Restraint Current displayed by relay at Substation A (Sec Amps)	Restraint current displayed by relay at Substation B (Sec Amps)	Differential Current Displayed S/S end A (Sec Amps)	Differential Current displayed S/S end B (Sec Amps)
A					
B					
C					

Table 17 – Record of Load, Restraint and Differential Currents

The differential current shown on the instruments display should be less than 15% of the local and remote restraint currents.

If the calculated restraint current is less than the P/F Bias Setting /2, proceed to Test 2. If the restraint current is greater than the P/F Bias Setting /2, proceed to Test 1.

Test 1 – Phase Comparison Test – medium to high feeder load current

P/F Differential Setting (Sec Amps)	
Restraint Current (Sec Amps)	
CT Reversal – OFF	No trip – Yes/No
***CT Reversal – ON**	Relay Trip – Yes/No
CT Reversal – OFF	Relay Reset – Yes/No
Waveform record obtained	Yes/No

Table 18 – Comparator test results with feeder load current > P/f Bias Setting /2

***Note, for correct operation, when the CT reversal is activated both relays operate.

Test 2 – Phase Comparison trip Blocked – low feeder load current

P/F Differential Setting (Sec Amps)	
Restraint Current (Sec Amps)	
CT Reversal – OFF	No trip – Yes/No
*CT Reversal – ON	Relay Trip – Yes/No
CT Reversal – OFF	Relay Reset – Yes/No
Waveform record obtained (eg from status input initiation)	Yes/No

Table 19 – Comparator tests with feeder load current< P/F Bias Setting/2.

*Note for correct operation, when setting the CT reversal to ‘ON’ the relay should NOT trip.

Manual Trip and Intertrip Tests

Internal iTrip (✓ - OK)			
External iTrip 1 (✓ - OK)			
External iTrip 2 (✓ - OK)			
Trip Test	**Output Contacts Tested->**		**(✓ - ok)**

Table 20 – Record of Manual Trip and Inter-trip tests

Test Result - Approval Signatures

The above Results are a true reflection of the test measurements taken, and the protections scheme is considered fit for service.

Witnessing Engineer: **Date:**

Company:

Commissioning Engineer: **Date:**

Company

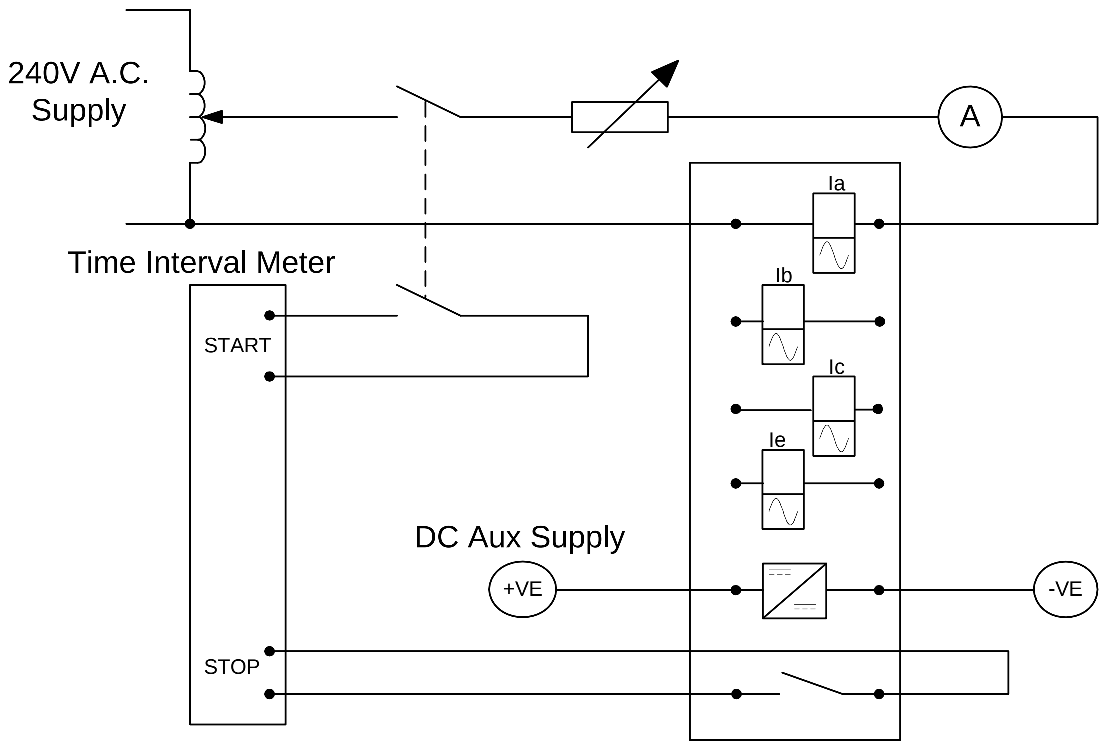


Figure 1 - Secondary Injection Test Circuit

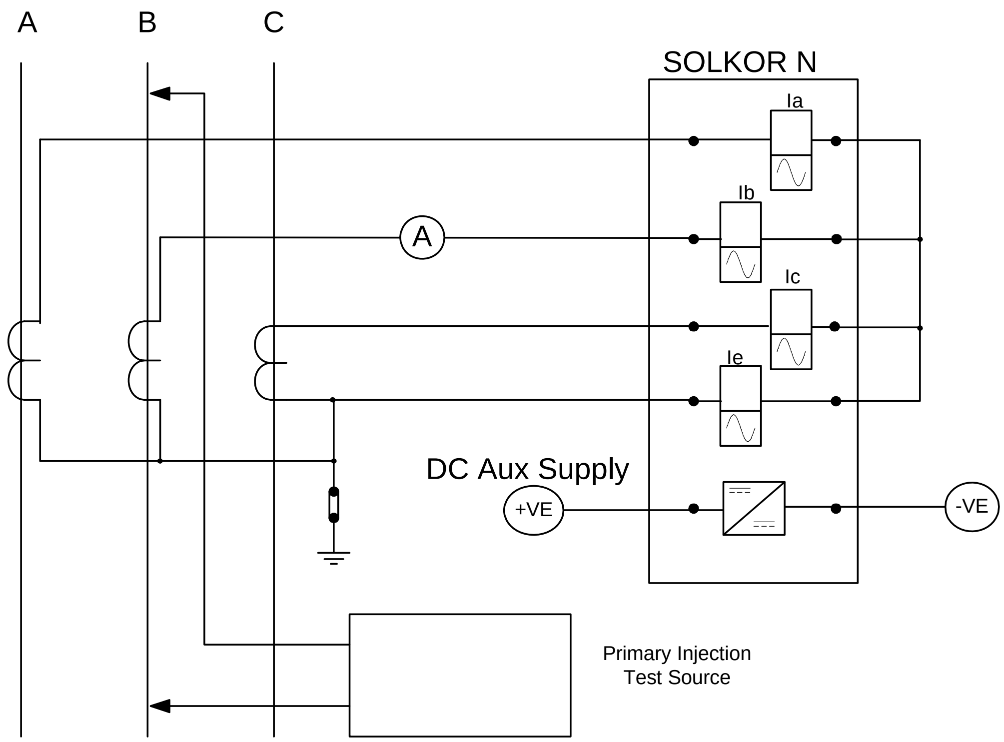


Figure 2 - Phase to Earth Primary Injection Test Circuit

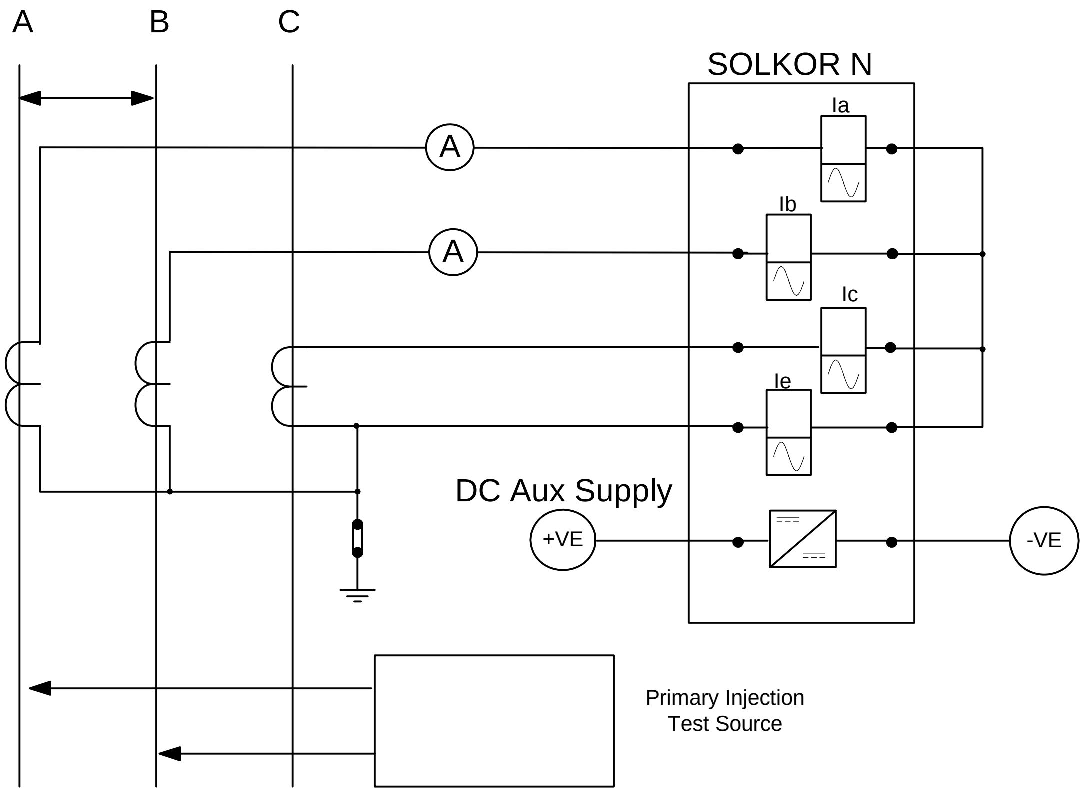


Figure 3 - Phase to Phase Primary Injection Test Circuit

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Pre release

2010/02	Document reformat due to rebrand

Software Revision History

19/04/2005	2646H80006R5	

Contents

1 Maintenance Instructions

The relay is a maintenance free relay, with no user serviceable parts. During the life of the relay it should be checked for operation during the normal maintenance period for the site on which the product is installed. It is recommended the following tests are carried out:

1. Visual inspection of the metering display (every year)
2. Operation of output contacts (every 2 years)
3. Secondary injection of each element (every 5 years)

The revision of the relay software installed, may be found moving to the top of the menu structure to display the relay identifier and holding the [Cancel] and [Test/Reset] pushbuttons depressed or by selecting [Relay] [Information][Get System Information] in Reydisp Evolution. If the setting file for the relay is saved, open the .set file in Reydisp Evolution, clicking on the Info (***i)*** tab at the top right hand corner of the “Settings Editor” window. The Software Revision should now be displayed in the “Settings Source Information” window.

2 Defect Report Form

Form sheet for repairs and returned goods (fields marked with * are mandatory fields)

Sender:

*** Name, first name:**	Complete phone number (incl. country code):	Complete fax number (incl. country code):
Email address:	*** Org-ID and GBK reference:**	*** AWV:**

*** Order-/ reference-no (choosing at least 1 option):**

Order-no for repair:	order-/ delivery note-no for return of commission failure:	Beginning order-no for credit note demand:

Information concerning the product and its use:

*** Order Code (MLFB):**	Firmware version: V	*** Serial number:**	
* Customer:	Product was in use approximately since:	Station/project:	Hotline Input no.:
Customer original purchase order number:	Delivery note number with position number:	Manufacturer:	

*** Type of order (choosing at least 1 option):**

☐ Repair
☐ Upgrade / Modification to …
☐ Return of commission failure
☐ Warranty repair
☐ For collection
☐ Credit Note
☐ Quotation (not repair V4 and current products! See prices in PMD)

Type of failure:

☐ Device or module does not start up
☐ Sporadic failure
☐ Permanent failure
☐ Repeated breakdown
☐ Mechanical problem
☐ Knock sensitive
☐ Temperature caused failure
☐ Failure after firmware update
☐ Overload
☐ Transport damage
☐ Failure after ca ☐ hrs in use

Error description:

☐ Display message:
(use separated sheet for more info)

☐ Active LED messages:

☐ Faulty Interface(s), which?
☐ Wrong measured value(s), which?
☐ Faulty input(s)/output(s), which?

***Detailed error description** (please refer to other error reports or documentation if possible):

*** Shall a firmware update be made during repair or mechanical upgrade of protective relays? (choosing at least 1 option)**

☐ Yes, to most recent version
☐ No
☐ Yes, actual parameters must be reusable

repair report:

☐ Yes, standard report (free of charge)
☐ Yes, detailed report (charge: 400EUR)

Shipping address of the repaired/upgraded product:

Company, department

Name, first name

Street, number

Postcode, city, country

Date, Signature

Please contact the Siemens representative office in your country to obtain return instructions.

E D EA MF TCC 6 release from 11/2009

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Software Revision History

APPENDIX

Attached are Setting Configuration Sheets, which can be photocopied and used to store a record of a relay's settings and general Notes Pages, for customer use.

GENERAL INFORMATION
Relay Type :
Article Number :
Serial Number :
Date :
Station :
Circuit :

The following Setting Menu Tables are for **SETTINGS GROUP G**

SYSTEM CONFIGURATION MENU

SETTING	RANGE	SET VALUE
Active Settings Group	G1-G8	
Power System Frequency	50 / 60 Hz	
Local P/F Rating	1A, 5A	
Local E/F Rating	1A, 5A	
Local P/F CT Ratio	5 to 10000 : 1 or 5	
Local E/F CT Ratio	5 to 10000 : 1 or 5	
Remote P/F Rating	1A, 5A	
Remote P/F CT Ratio	5 to 10000 : 1 or 5	
Current Display	xIn, PRIMARY, SECONDARY	
Set Identifier	Up to 16 alphanumeric characters	
Set Alarm 1	Up to 13 alphanumeric characters	
Set Alarm 2	Up to 13 alphanumeric characters	
Set Alarm 3	Up to 13 alphanumeric characters	
Set Alarm 4	Up to 13 alphanumeric characters	
Set Alarm 5	Up to 13 alphanumeric characters	
Set Alarm 6	Up to 13 alphanumeric characters	
Set Alarm 7	Up to 13 alphanumeric characters	
Set Alarm 8	Up to 13 alphanumeric characters	
Set Alarm 9	Up to 13 alphanumeric characters	
Calendar – Set Date	DD/MM/YY	
Clock - Set Time	HH:MM:SS	
Clock Sync. From Status	Seconds or Minutes	
Default Screen Timer	10sec, 60sec, 5min, 1hour	
Change Password	4 alphanumeric characters	

DIFF. PROTECTION MENU		
SETTING	**RANGE**	**SET VALUE**
Gn P/F Diff. Setting	0.10 – 2.50xIn step 0.05xIn	
Gn P/F Bias Slope 1	20%, 30%, 50%, 70%	
Gn P/F Bias Slope 2	50%, 100%, 150%	
Gn Bias Break Point	0.50xIn – 20.00xIn step 0.10xIn	
Gn Differential Delay	0.000s – 0.200s step 0.005s 0.210s – 1.000s step 0.010s 1.100s – 10.000s step 0.100s	
P/F CT Ratio Correction	0.50 – 1.00 step 0.01	
Gn Internal Intertrip	ON, OFF	
Gn External Intertrip	ON, OFF	
Gn Ext Intertrip Delay	0.000s – 0.200s step 0.005s 0.210s – 1.000s step 0.010s 1.100s – 10.000s step 0.100s	
Gn Internal Intertrip	ON, OFF	

O/C PROTECTION MENU		
SETTING	**RANGE**	**SET VALUE**
Gn P/F Charact. Setting	0.10xIn – 2.50xIn step 0.05xIn	
Gn P/F Charact.	NI, VI, EI, LTI, DTL	
Gn P/F Charact. Time Mult	0.025 – 1.600 step 0.025	
Gn P/F Charact. Delay	0.00s – 20.00s step 0.01s	
Gn P/F Lowset Setting	OFF, 0.10xIn – 2.50xIn step 0.05xIn 3.0xIn – 52.5xIn step 0.5xIn	
Gn P/F Lowset Delay	0.00s – 20.00s step 0.01s	
Gn P/F Highset1 Setting	OFF, 0.10xIn – 2.50xIn step 0.05xIn 3.0xIn – 52.5xIn step 0.5xIn	
Gn P/F Highset1 Delay	0.00s – 20.00s step 0.01s	
Gn P/F Highset2 Setting	OFF, 0.10xIn – 2.50xIn step 0.05xIn 3.0xIn – 52.5xIn step 0.5xIn	
Gn P/F Highset2 Delay	0.00s – 20.00s step 0.01s	
Gn E/F Charact. Setting	0.10xIn – 2.50xIn step 0.05xIn	
Gn E/F Charact.	NI, VI, EI, LTI, DTL	
Gn E/F Charact. Time Mult	0.025 – 1.600 step 0.025	
Gn E/F Charact. Delay	0.00s – 20.00s step 0.01s	
Gn E/F Lowset Setting	OFF, 0.10xIn – 2.50xIn step 0.05xIn 3.0xIn – 52.5xIn step 0.5xIn	
Gn E/F Lowset Delay	0.00s – 20.00s step 0.01s	
Gn E/F Highset1 Setting	OFF, 0.10xIn – 2.50xIn step 0.05xIn 3.0xIn – 52.5xIn step 0.5xIn	
Gn E/F Highset1 Delay	0.00s – 20.00s step 0.01s	
Gn E/F Highset2 Setting	OFF, 0.10xIn – 2.50xIn step 0.05xIn 3.0xIn – 52.5xIn step 0.5xIn	
Gn E/F Highset2 Delay	0.00s – 20.00s step 0.01s	
Gn CB Fail Time Delay1	OFF, 0.01s – 20.00s step 0.01s	
Gn CB Fail Time Delay2	OFF, 0.01s – 20.00s step 0.01s	
Gn P/F CB Fail Setting	0.10xIn – 1.00xIn step 0.05xIn	
Gn E/F CB Fail Setting	0.10xIn – 1.00xIn step 0.05xIn	
Gn CT Failure Setting	OFF, 0.10xIn – 1.00xIn step 0.05xIn	
Gn CT Failure Delay	0.00s – 20s step 0.01s	
Gn Relay Reset Delay	INST, 1s – 60s step 1s	

O/P RELAY CONFIG MENU		
SETTING	**RANGE**	**SET VALUE**
Gn Prot. Healthy	RL1..RL7	
Gn P/F Diff.	RL1..RL7	
Gn P/F Starter	RL1..RL7, GPF	
Gn P/F Charact.	RL1..RL7, GPF	
Gn P/F Lowset	RL1..RL7, GPF	
Gn P/F Highset1	RL1..RL7, GPF	
Gn P/F Highset2	RL1..RL7, GPF	
Gn E/F Starter	RL1..RL7, GPF	
Gn E/F Charact.	RL1..RL7, GPF	
Gn E/F Lowset	RL1..RL7, GPF	
Gn E/F Highset1	RL1..RL7, GPF	
Gn E/F Highset2	RL1..RL7, GPF	
Gn Remote Int. iTrip	RL1..RL7, GPF	
Gn Remote Ext. iTrip1	RL1..RL7, GPF	
Gn Remote Ext. iTrip2	RL1..RL7, GPF	
Gn Status 1	RL1..RL7, GPF	
Gn Status 2	RL1..RL7, GPF	
Gn Status 3	RL1..RL7, GPF	
Gn Status 4	RL1..RL7, GPF	
Gn Status 5	RL1..RL7, GPF	
Gn Status 6	RL1..RL7, GPF	
Gn Status 7	RL1..RL7, GPF	
Gn Status 8	RL1..RL7, GPF	
Gn Status 9	RL1..RL7, GPF	
Gn CB Fail 1	RL1..RL7, GPF	
Gn CB Fail 2	RL1..RL7, GPF	
Gn Counter Alarm	RL1..RL7, GPF	
Gn Sum of I^2 Alarm	RL1..RL7, GPF	
Gn Power on Count.	RL1..RL7	
Gn Signal Dist.	RL1..RL7	
Gn Signal Alarm	RL1..RL7	
Gn Signal Test	RL1..RL7	
Gn Hand Reset	RL1..RL7, GPF	
Gn Min O/P Energise Time	100ms – 500ms step 50ms	

STATUS CONFIG MENU		
SETTING	**RANGE**	**SET VALUE**
Settings Group Select	S1..S9 (Note : special setting where each status can be set from 1-8 to select active group 1-8)	
Inverted Inputs	S1..S9	
Gn P/F Diff. Inhibit	S1..S9	
Gn P/F Charac. Inhibit	S1..S9, SIG	
Gn P/F Lowset Inhibit	S1..S9, SIG	
Gn P/F Highset1 Inhibit	S1..S9, SIG	
Gn P/F Highset2 Inhibit	S1..S9, SIG	
Gn E/F Charac. Inhibit	S1..S9, SIG	
Gn E/F Lowset Inhibit	S1..S9, SIG	
Gn E/F Highset1 Inhibit	S1..S9, SIG	
Gn E/F Highset2 Inhibit	S1..S9, SIG	

STATUS CONFIG MENU		
SETTING	**RANGE**	**SET VALUE**
Gn External iTrip1	S1..S9	
Gn External iTrip2	S1..S9	
Gn Receive iTrip Inhibit	S1..S9	
Gn Send iTrip Inhibit	S1..S9	
Gn CB Open	S1..S9	
Gn CB Closed	S1..S9	
Gn Trip Circuit Fail	S1..S9	
Gn Waveform Trigger	S1..S9	
Gn Sum of I^2 Update	S1..S9	
Gn Reset Flag and Outputs	S1..S9	
Gn Clock Sync.	S1..S9	
Gn ALARM 1	S1..S9	
Gn ALARM 2	S1..S9	
Gn ALARM 3	S1..S9	
Gn ALARM 4	S1..S9	
Gn ALARM 5	S1..S9	
Gn ALARM 6	S1..S9	
Gn ALARM 7	S1..S9	
Gn ALARM 8	S1..S9	
Gn ALARM 9	S1..S9	
Gn Status 1 P/U Delay	0 – 2.00 sec step 10ms 2.10 – 20.00 sec step 100ms 21 – 300 sec step 1 sec 360 – 3600 sec step 60 sec 3900 – 14400 sec step 300 sec	
Gn Status 1 D/O Delay	As above	
Gn Status 2 P/U Delay	As above	
Gn Status 2 D/O Delay	As above	
Gn Status 3 P/U Delay	As above	
Gn Status 3 D/O Delay	As above	
Gn Status 4 P/U Delay	As above	
Gn Status 4 D/O Delay	As above	
Gn Status 5 P/U Delay	As above	
Gn Status 5 D/O Delay	As above	
Gn Status 6 P/U Delay	As above	
Gn Status 6 D/O Delay	As above	
Gn Status 7 P/U Delay	As above	
Gn Status 7 D/O Delay	As above	
Gn Status 8 P/U Delay	As above	
Gn Status 8 D/O Delay	As above	
Gn Status 9 P/U Delay	As above	
Gn Status 9 D/O Delay	As above	

PROT. SIGNALLING MENU		
SETTING	**RANGE**	**SET VALUE**
Local Address	0 – 31 step 1	
Baud Rate	19200, 38400	
Signalling Delay	0.000ms – 9.375ms 9.375ms – 18.750ms 18.750ms – 28.125ms 28.125ms – 37.500ms	
Signal Alarm Timeout	1s – 60s step 1s	
Signal Test Mode	OFF, LINE TEST, LOOP TEST	
Signalling Port	DISABLED, ENABLED	

COMMS INTERFACE MENU		
SETTING	**RANGE**	**SET VALUE**
Comms Baud Rate	75, 110, 150, 300, 600, 1200, 2400, 4800, 9600, 19200	
Comms Parity	NONE, EVEN	
Relay Address	0 – 254	
Line Idle	LIGHT ON, LIGHT OFF	
Data Echo	OFF / ON	

DATA STORAGE MENU		
SETTING	**RANGE**	**SET VALUE**
Gn Fault Trigger	RL1..RL7	
Gn Waveform Trig	STA, DIF, O/C, iTp, SIG	
Gn Waveform Pre-trigger	OFF, 10%-100% step 10%	
Demand Window Type	OFF, ROLLING, FIXED	
Demand Window	5-50 mins, step 5 mins 90-300 mins, step 30 mins 360-1440 mins, step 60 mins	

CB MAINTENANCE MENU		
SETTING	**RANGE**	**SET VALUE**
Trip Counter Alarm	OFF, 1 – 999 step 1	
Sum I^2 Alarm	OFF 10 – 100 step $1MA^2$ 200 – 20000 step $100MA^2$ 21000 – 100000 step $1000MA^2$	
Power on Count Alarm	OFF, 999	
Phase A Reversal	OFF, ON	
Phase B Reversal	OFF, ON	
Phase C Reversal	OFF, ON	
Earth Reversal	OFF, ON	
Manual Intertrip	OFF, Internal iTrip, External iTrip, External iTrip2	

7SG18 Solkor N

Numeric Differential Protection

Document Release History

This document is issue 2010/02. The list of revisions up to and including this issue is:

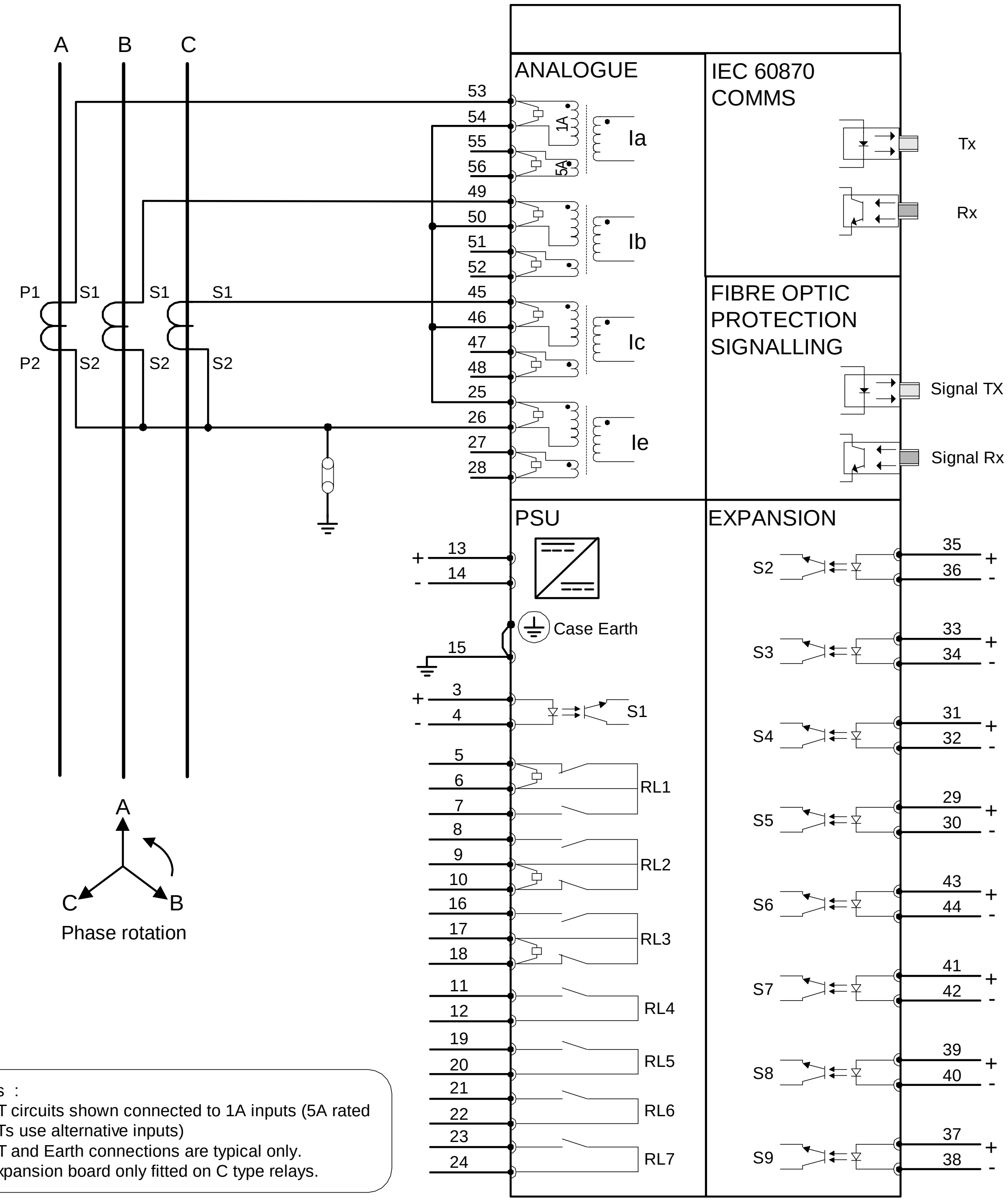
Pre release

2010/02	Document reformat due to rebrand

Software Revision History

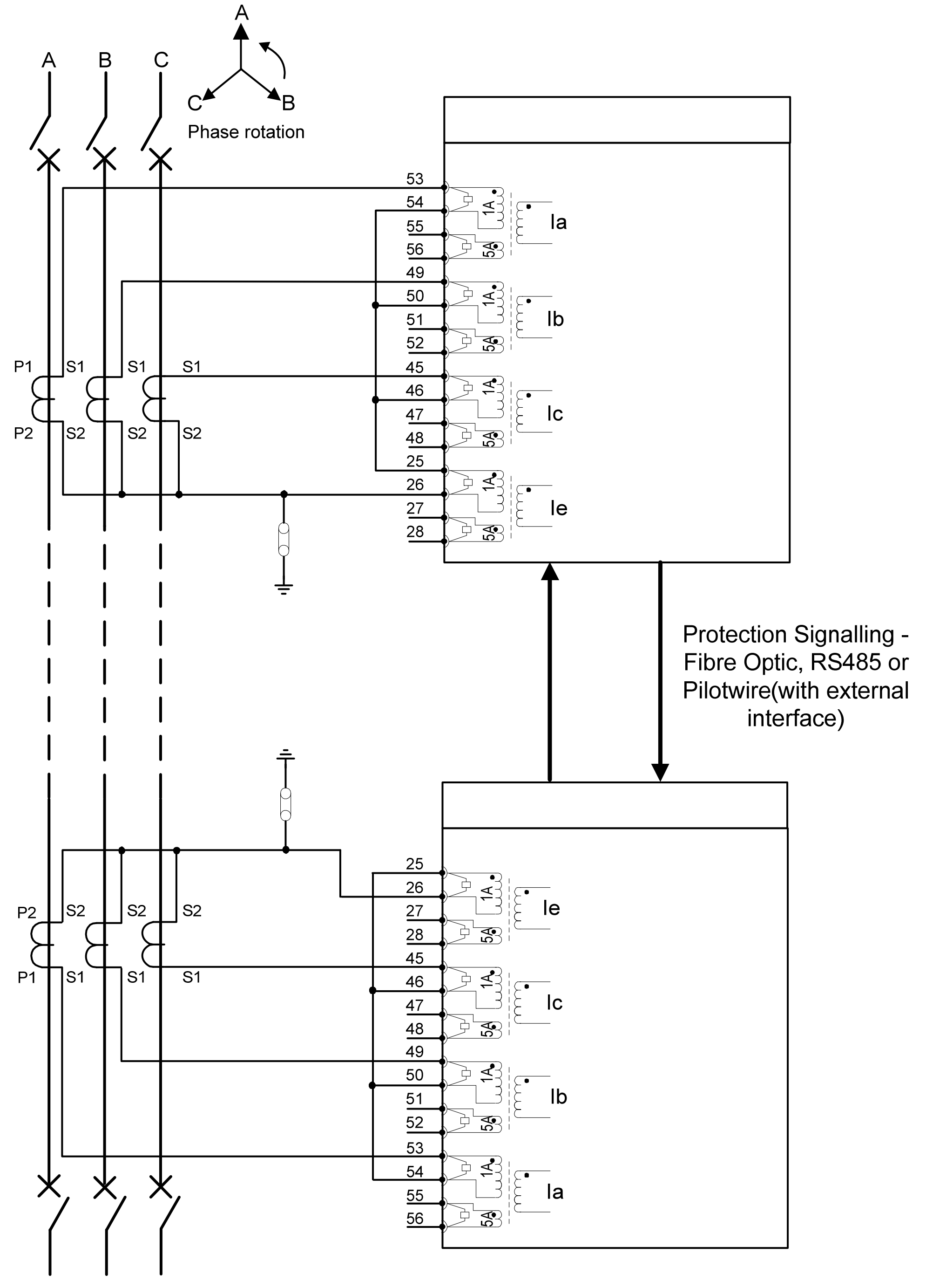
19/04/2005	2646H80006R5	

Contents



Notes :
1 - CT circuits shown connected to 1A inputs (5A rated CTs use alternative inputs)
2 - CT and Earth connections are typical only.
3 - Expansion board only fitted on C type relays.

Typical application diagram : 3 Phase + EF connection



Notes

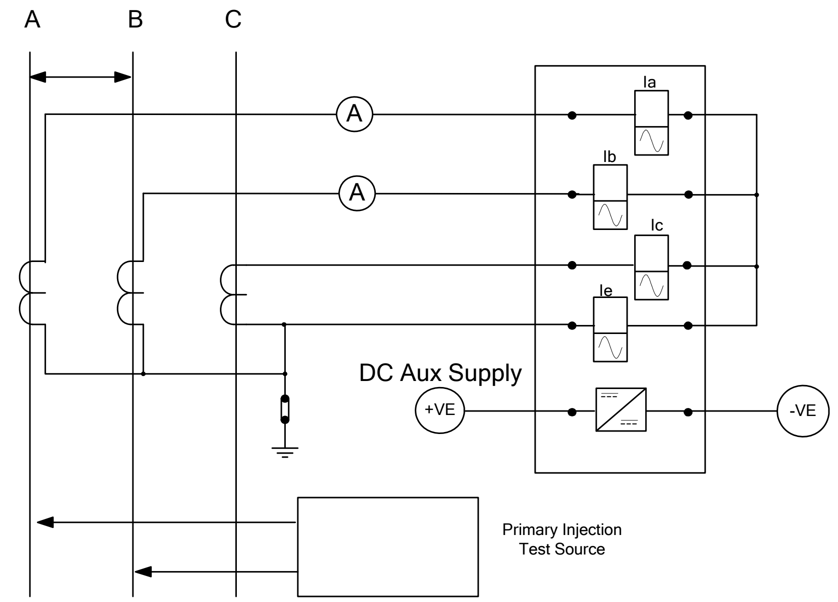
1 - CT circuits shown connected to 1A inputs (5A rated CTs use alternative inputs)

2 - CT and Earth connections are typical only.

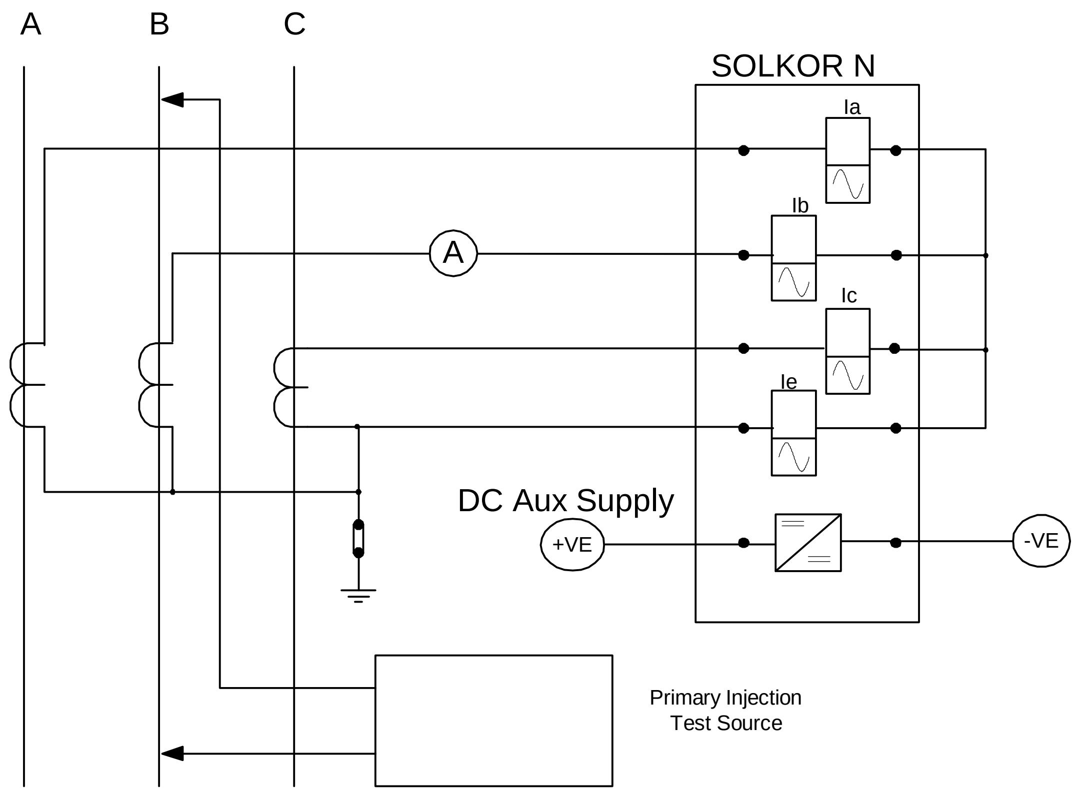
3 - CT ratings and connections can be 1A at one end and 5A at the other end of the feeder.

4 - Ratio Correction settings are avaialble to match CT ratios at either end of the feeder.

Typical CT Connection Diagram



Phase to Phase Primary Injection Test Circuit



Phase to Earth Primary Injection Test Circuit

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