

Current Differential Protection – SOLKOR-N – 7SG18

INTRODUCTION

The SOLKOR technique of current differential protection was developed by REYROLLE over 50 years ago, and has formed an important part of the product range ever since. It has now progressed into a microprocessor controlled, differential feeder protection system providing complete protection for overhead lines and cable feeders.

FEATURES

- Three pole, current differential protection with two stage bias characteristic.
- Intertripping from internal or external initiation.
- Three pole, phase fault overcurrent protection - IDMTL or DTL with highsets.
- Earth fault overcurrent protection - IDMTL or DTL with highsets.
- Overcurrent protection can be configured to operate as guard and/or back-up in case of communications failure.
- Communication loop-back test modes.
- Communication link supervision.
- Trip circuit supervision.
- Circuit breaker fail protection.
- Selectable 1A / 5A current inputs.
- Ratio correction for mis-matched line current transformer ratios.
- Ability to invert current inputs to assist in commissioning.
- Seven user-programmable output contacts.
- Up to nine user programmable status inputs with pick-up and drop-off timers.
- Stores last five fault records with a time stamp.
- Stores 500 time-stamped event records.
- Stores 5 waveform records.
- Data communications to IEC60870-5-103.
- End to End communications via electrical or Fibre Optic channels.
- Local and Remote Current Instruments

DESCRIPTION

Protection

Current Differential Protection

SOLKOR-N performs magnitude and phase angle comparison of currents at either end of the protected feeder, and operates for faults detected within the protected zone. The three pole, phase fault differential comparators each provide two bias slopes. The first stage of bias accommodates proportional measuring errors in the system. The second stage accommodates additional spill current caused by CT saturation at high fault levels.



Figure 1 below illustrates the differential protection operating characteristic.

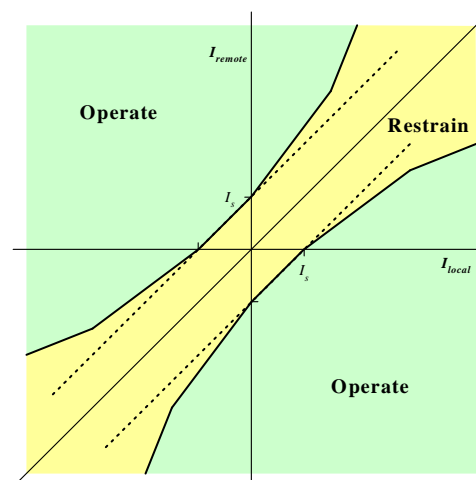


Figure 1 - Differential Protection Operating Characteristic

It is not necessary to have the same CT ratios at either end of a protected feeder, since ratio compensation is settable. It is also possible to invert the current inputs to aid in commissioning.

Backup Overcurrent Protection

In addition to the differential protection, SOLKOR-N provides comprehensive overcurrent protection for phase and earth faults, which provide back-up IDMTL and DTL characteristics in the event of a communications link failure.

Guard Relays

To add security to the differential scheme it is possible to designate any of the overcurrent elements as a guard element. The appropriate overcurrent element must then operate to allow the differential element to trip.

Intertripping

Three auxiliary signalling channels are provided for intertripping.

One internal intertrip dedicated to the differential protection. Two independent intertrips which can be used for either direct or permissive intertripping from an external source.

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 so block the trip. To overcome this, an internal intertrip signal is sent which can be used at the receive end to either override the guard so allowing the differential to trip, or, operate the trip contacts directly.

Protection Signalling Channels

Four types of protection signalling channel are provided as follows:

- RS485 level electrical link for distances up to 2km.
- Short range optical link for distances up to 15km (typical) using multimode fibres.
- Long range optical link for distances up to 49km (typical) using single mode fibres.
- RS232 link to external modem for electrical link up to 10km

Continuous protection signalling link supervision is provided. Two test modes are included to assist with commissioning the signalling link.

In loop test mode the local transmit and receive terminals can be connected together, allowing the SOLKOR-N to be tested in isolation.

Line test mode allows the integrity of the whole signalling channel to be checked. The SOLKOR-N commands the remote end to 'echo' all received data back to the local end. In line test mode, the remote differential protection is suspended.

The SOLKOR-N will automatically account for propagation delays in the signalling channel up to a maximum of 9.5ms. For delays in excess of 9.5ms a manual offset can be applied, with the actual delay falling within a 9.5ms window centred on the offset.

Fibre optic signaling interface connections are BFOC/2.5 (ST®) bayonet style connectors.

RS485 signalling interface uses screw terminals to suit 3/32" flat blade terminals. RS232 signalling interface for connection to the external pilot wire modem uses a male 9 pin D-type connector to suit the female connector on the end of the 1.9m long cable supplied with the pilot wire modem.

MONITORING

Trip circuit supervision

The trip circuit is monitored by a status input with the circuit breaker in both the open and close position. This is linked to an alarm and may be configured to operate an output relay.

Circuit breaker fail

The circuit breaker fail function may be triggered by a trip signal from the SOLKOR-N or from an external device. It operates by monitoring the line current following a trip signal and issues an alarm if the current does not stop within a specified time interval. This alarm can be used to operate an output contact to backtrip an upstream circuit

breaker. A further time delay enables another backtrip stage.

Circuit breaker operations counter

A circuit breaker operations count and a sum of I² count is provided. Alarm levels can be set which, when reached, can be used as the input to a condition-based maintenance regime.

I² counter

This can provide a measure of the contact erosion and be used for planning circuit breaker maintenance schedules.

Indications and Displays

The SOLKOR-N fascia includes 5 LEDs, providing the following indication:

- Protection Healthy (Green)
- Intertrip (Red) – an intertrip has been received
- I>Is (Yellow) – any algorithm detects current above setting
- Trip (Red) – the relay has issued a trip signal
- Signal Healthy (Green) – the signalling link is healthy

The following instruments are provided. If the SOLKOR-N is left untouched for 10 minutes it can display each instrument in turn.

- Local and remote end primary ammeters
- Local and remote end secondary ammeters
- Differential currents (secondary values)
- Differential starters
- Signalling link status
- General alarms
- Status inputs
- Output contacts
- Trip counter
- I² counter

SYSTEM DATA

Sequence of Event records

Up to 500 events are stored and time tagged to 1ms resolution. These are available via the communications.

Fault records

The last 5 fault records are available from the SOLKOR-N fascia with time and date of trip, measured quantities and type of fault.

Disturbance recorder

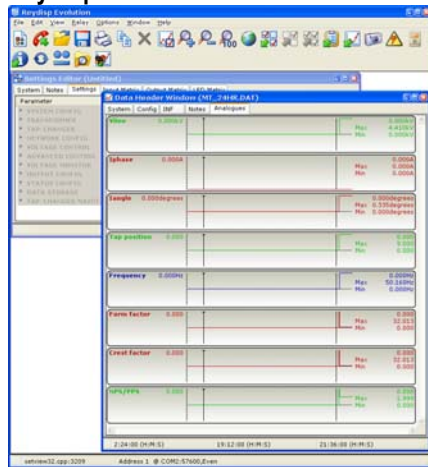
The waveform recorder may be triggered from a protection function or external input and has a configurable pre-fault trigger. Up to 5 fault waveforms may be stored with associated analogue and digital values.

Data Communications

A fibre-optic communications port is provided on the rear of the relay. This will be optimised for 62.5/125µm glass-fibre using BFOC/2.5 (ST@) bayonet-style connectors.

The SOLKOR-N uses IEC 60870-5-103 as its communications standard for relay interrogation.

ReyDisp Evolution



This support software is common to the entire range of REYROLLE numeric products. It provides the means for the user to apply settings to the SOLKOR-N, interrogate settings and retrieve events and disturbance waveforms from the SOLKOR-N.

TECHNICAL INFORMATION

Performance data to IEC 60255-3

Characteristic Energising Quantity

AC Current	Frequency
1A/5A	50Hz

Auxiliary Energising Quantity DC power supply

Nominal Voltage	Operating Range V dc
24, 30, 48 V	18 to 60
110, 220 V	88 to 280

DC status inputs

Nominal Voltage	Operating Range V dc
30, 34 V	18.0 to 37.5
48, 54 V	37.5 to 60.0
110, 125 V	87.5 to 137.5
220, 250 V	175.0 to 280.0

The status voltage need not be the same as the main energising voltage.

Electricity Association ESI48-4

The 30/34V and 48/54V inputs meet the requirements of ESI48-4 ESI 1. However, the 110/125V and 220/250V inputs will operate with a DC current of less than 10mA. If 110/125V or 220/250V inputs compliant with ESI48-4 ESI 1 are required, a SOLKOR-N with 48/54 V status can be supplied with external dropper resistors as follows:

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

Status Input Performance

Parameter	Value
Minimum DC current for operation (30/34V and 48/54V inputs only)	10 mA
Reset/Operate Voltage Ratio	≥ 90%
Typical response time	< 5 ms
Typical response time when used to energise an output relay contact	< 15 ms
Minimum pulse duration	40 ms

Each status input has an associated timer that can be programmed to give time delayed pick-up and time delayed drop-off. These timers have default settings of 20ms, thus providing immunity to an AC input signal. Status inputs will not respond to the following:

- 250V RMS 50/60 Hz applied for two seconds through a 0.1µF capacitor.
- 500 V RMS 50/60 Hz applied between each terminal and earth.

Discharge of a 10 µF capacitor charged to maximum DC auxiliary supply voltage.

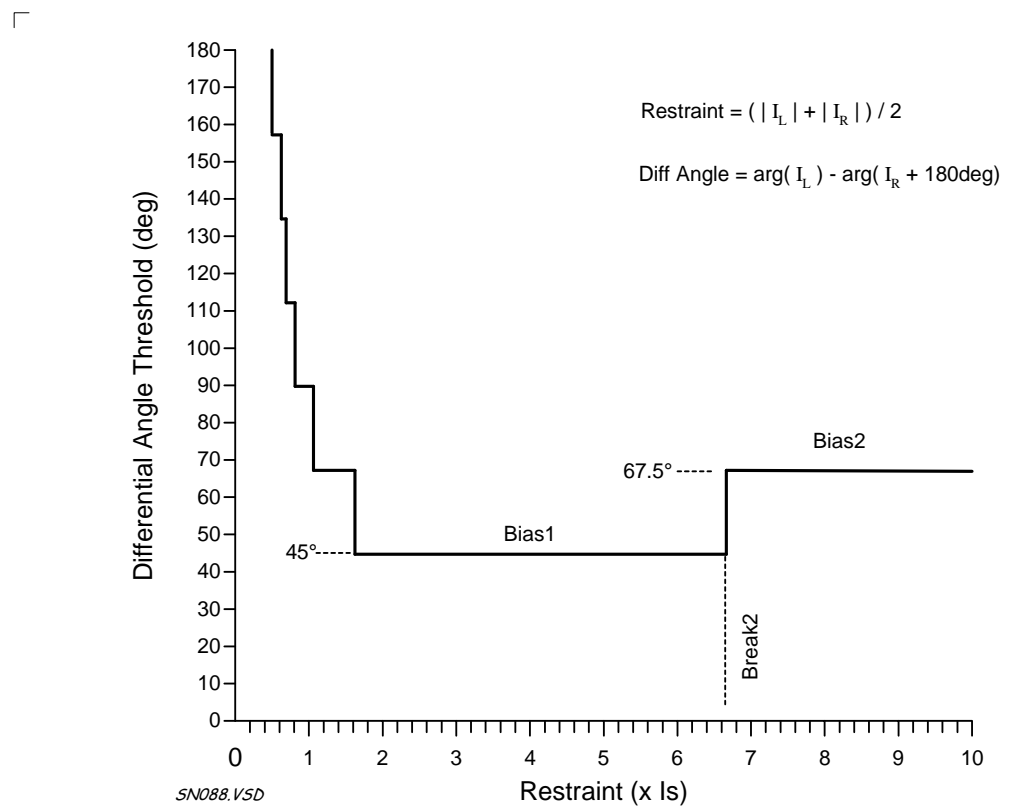
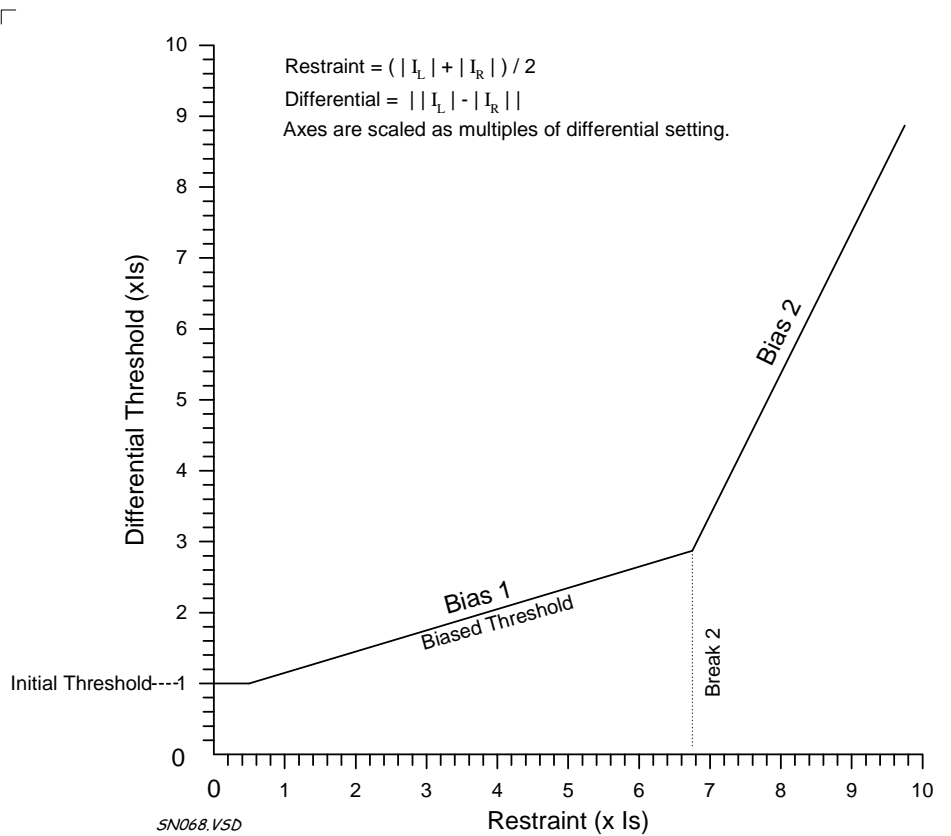
PROTECTION ELEMENTS

Current differential

Level	
Phase setting	0.10 to 2.50 I _n
Phase bias 1	20 to 70%
Phase bias 2	50 to 150%

Differential Element

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



The error limits on these diagrams are as follows:

Operate Levels	
Differential Magnitude – Initial Threshold	$\pm 10\%$ or $\pm 10\text{mA}$
Differential Magnitude – Biased Threshold (At low levels)	Biased threshold $\pm(10\%$ of Restraint) or $\pm 10\text{mA}$ For Restraint $<1.6\text{s}$ +ve limit – Biased threshold + 10% or +10mA -ve limit – Initial threshold -10% or -10mA
Differential Comparaitor Angle Threshold	$\pm 5^\circ$

Differential and Intertrip operate times are given by:

$$t = t_0 + t_d$$

Where

t_0 is the base operating time

t_d is the Differential Delay time

The base operating time depends on the communications bit rate.

Operate Times	
Differential base operate time ($I_{diff} > 10\text{Is}$)	$\leq 40\text{ms}$ (38400 baud) $\leq 50\text{ms}$ (19200 baud)
Differential Delay Time	$\pm 1\%$ or $\pm 10\text{ms}$

Overcurrent protection

Characteristic	
IDMTL (IEC)	Normal Inverse (NI), Very Inverse (VI), Extremely Inverse (EI), Long Time Inverse (LTI)
DTL	
No. of elements	1 Phase Fault + 1 Earth Fault
Level	
Settings	0.10 to 2.50 I _n
Accuracy	Operate: 105% of setting ± 4% or ± 10mA
	Reset: 95% of operate current
Repeatability	±1%
IDMTL delay	
Settings	0.025x to 1.600x
Accuracy	± 5% or ± 30 ms
Repeatability	± 1% or ± 5 ms
DTL delay	
Settings	0.00 to 20.00 sec
Accuracy	± 1% or ± 10 ms
Reset delay	
Settings	0 to 60 sec
Accuracy	± 1% or ± 10 ms
Repeatability	± 1% or ± 5 ms

Characteristic	DTL
No. of elements	3 Phase Fault + 3 Earth Fault
Level	
Settings	0.10 to 52.5 I _n
Accuracy	Operate: 100% of setting ± 5% or ± 10mA
	Reset: ≥ 95% of operate current
Repeatability	±1%
Delay	
Settings	0.00 to 20.00 sec
Accuracy	± 5 ms
Repeatability	± 1% or ± 5 ms

Circuit Breaker Failure

Operate Level

	Attribute	Value
I _s I _s I _{op}	Phase Fault setting Earth Fault setting Operate Level Reset Level	Off, 0.05, 0.1 ... 1.0 xI _n Off, 0.05, 0.1 ... 1.0 xI _n 100 % I _s ± 5% or 1% I _n 95 % I _{op} , ± 5% or 1 % I _n
	Repeatability	± 1%

Operate time

Characteristics	DTL
No. of Elements	2
Delay	
Settings	0.01 to 20.00 sec
Accuracy	+ 5ms
Repeatability	± 1%

GENERAL ACCURACY

Reference conditions

Parameter	Reference or Value
General	IEC 60255-3
Current Settings	100% of I _n
Time Multiplier	1.0
Current input (IDMTL)	2x to 30x I _s
Current Input (DTL)	5x I _s
Auxiliary Supply	Nominal
Frequency	50Hz
Ambient Temperature	20 °C

General Settings

Parameter	Value
Transient Overreach of Highset.Lowset (X/R =100)	≤ 5%
Disengaging Time ⁽¹⁾	< 42ms
Overshoot Time	< 40ms

(1)Output contacts have a minimum dwell time of 100ms, after which the disengage time is as above.

Accuracy Influencing Factors

Temperature

-10 °C to +55 °C	≤ 5% variation
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Frequency

47Hz to 52 Hz	Setting: ≤ 5% variation
	Operating time: ≤ 5% variation

Harmonic content

Frequencies to 550Hz	Setting: ≤ 5% variation
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THERMAL WITHSTAND

Continuous overload

Phase and Earth	3.0 xIn
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Limited period overload

3.5 x In	10 minutes
4.0 x In	5 minutes
5.0 x In	3 minutes
6.0 x In	2 minutes

Short term overload

Input	Maximum Current (A) for:			
	1 cycle	1 sec	2 sec	3 sec
5A Phase/Earth	2500	400	282	230
1A Phase/Earth	700	100	70.7	57.7

BURDENS

Current inputs

5A Phase/Earth	≤ 0.2VA	≤ 0.01
1A Phase/Earth	≤ 0.05VA	≤ 0.05

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

Auxiliary supply

Quiescent (Typical)	3W
Maximum	10W

OUTPUT CONTACTS

Contact rating to IEC 60255-0-2

Carry continuously	5 A AC or DC
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Make and carry

(limits: L/R 40ms and V 300 volts)

0.5 sec	20 A AC or DC
0.2 sec	30 A AC or DC

Break

(limits: ≤ 5A or ≤ 300 volts)

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

Minimum no. of operations	1000 at maximum load
Minimum recommended load	0.5W, limits 10mA or 5V

ENVIRONMENTAL

Temperature IEC 68-2-1/2

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

Humidity IEC 68-2-3

Operational Test	56 days at 40°C & 95% RH
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Transient overvoltage IEC 60255-5

Between all the terminals and earth or between any two independent circuits without damage or flashover	5 kV 1.2/50 µs 0.5 J
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Insulation IEC 60255-5

RMS levels for 1 minute

Between all terminals and earth	2.0 kV
Between independent circuits	2.0 kV
Across normally open contacts	1.0 kV

Immunity

Auxiliary DC supply IEC 60255-11

Allowable superimposed as components	≤ 12% of dc voltage
Allowable breaks/dips in supply (collapse to zero from nominal voltage)	≤ 20ms

High Frequency Disturbance IEC 60255-22-1 Class III

2.5kV, Longitudinal mode	≤ 3% variation
1.0kV, Transverse mode	

Electrostatic Discharge IEC 60255-22-2 Class III

8kV, Contact discharge	≤ 5% Variation
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Radio Frequency Interference IEC 60255-22-3

10V/m, 80 to 1000MHz	≤ 5% Variation
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Fast Transient IEC 60255-22-4 Class IV

4kV, 5/50ns, 2.5kHz, repetitive	≤ 3% Variation
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Conducted RFI IEC 60255-22-6

10 V, 0.15 to 8 MHz	≤ 5% Variation
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Emissions

Conducted limits IEC 60255-25

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

Radiated limits IEC 60255-25

Frequency Range	Limits at 10m Quasi-peak, dB(μV/m)
30 to 230 MHz	40
230 to 10000 MHz	47

Mechanical

Vibration (sinusoidal) IEC 60255-21-1 Class 1

0.5 gn, Vibration response	≤ 5% variation
1.0 gn, Vibration endurance	

Shock and Bump IEC 60255-21-2 Class 1

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

Seismic IEC 60255-21-3 Class 1

1 gn, Seismic Response	≤ 5% variation
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Mechanical Classification

Durability	In excess of 10 ⁶ operations
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SAMPLE SPECIFICATION

The feeder protection device shall integrate the following characteristics:

- Microprocessor device
- Current differential protection
- Guard relay
- Protection signalling supervision
- Backup overcurrent protection
- 1A and 5A current inputs on same device
- Trip circuit supervision
- Circuit breaker fail detection

Current Differential Protection

The current differential protection shall perform magnitude and phase angle comparison of currents, on a phase-by-phase basis, although tripping shall be three-phase.

The protection shall be capable of compensating for different CTs at each end of the feeder.

The protection shall be stable for through faults at high fault levels when the line CTs saturate.

Backup Overcurrent Protection

The backup three-phase overcurrent protection shall provide an IDMTL element and 3 DTL elements that will provide back-up protection for the event of a communications link failure.

Guard Relays

It will be possible to add an overcurrent guard to the differential protection to add security to the scheme.

Intertripping

The protection shall provide an intertrip facility capable of the following, as selected on the relay:

- a trip at the local end directly trips the circuit breaker at the remote end, or,
- a trip at the local end removes the need for a guard operation at the remote end, allowing tripping with a weak infeed.

Two additional intertrip channels shall be provided which allow external devices to directly trip remote

Testing

Testing facilities shall be provided that allow

- a single end to be tested in isolation,
- both ends to be tested together to ensure integrity of the communications link, and,
- both ends to be tested together to prove the directionality of the CTs

Signalling Channel

The protection shall use one of the following methods for signalling.

- RS485 electrical link using twisted-pair cable
- Optical-fibre link
- Electrical twisted pair using external modem

Continuous supervision of the protection signalling link shall be provided. The protection shall be capable of operating with propagation delays in the signalling channel varying up to 9.5ms.

Trip Circuit Supervision

The protection shall monitor the trip circuit when the circuit breaker is in both the open and closed position.

Circuit Breaker Fail

The protection shall provide have the ability to issue a backtrip in the event of circuit breaker failure, detected by the continued presence of current, rather than circuit breaker auxiliary switch position.

Indications

The protection shall provide indication of the following:

- Protection healthy
- Intertrip received
- Protection operating
- Trip
- Signalling channel healthy

Metering

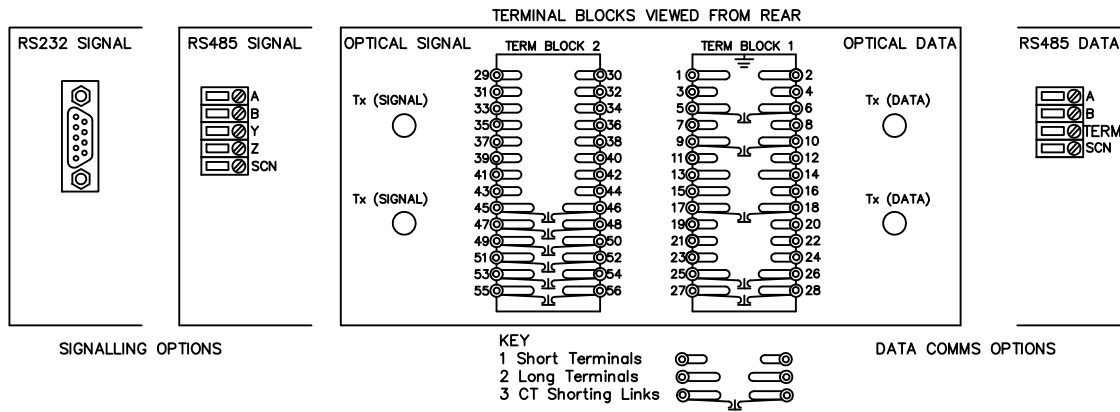
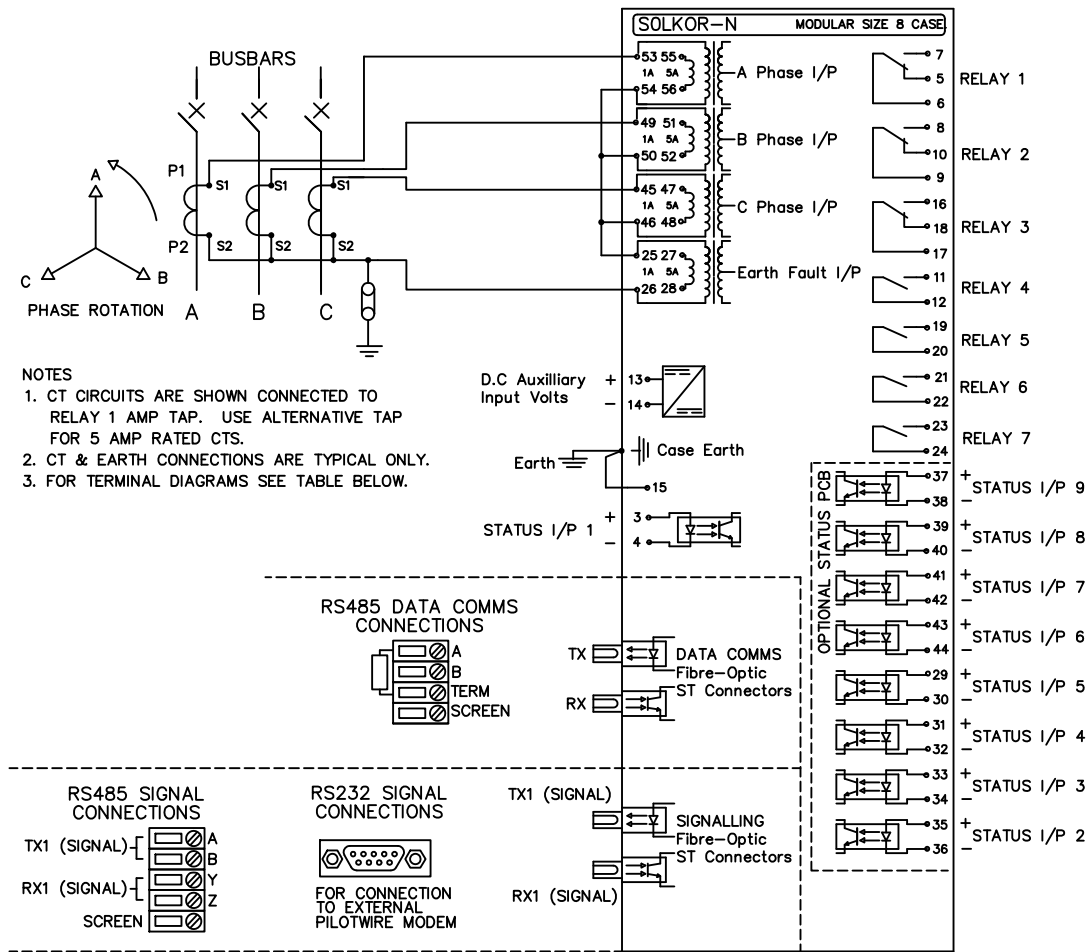
The device shall be capable of displaying the following measurements without user intervention:

- Local and remote end primary currents
- Local and remote end secondary currents
- Differential primary currents

Disturbance Recorder

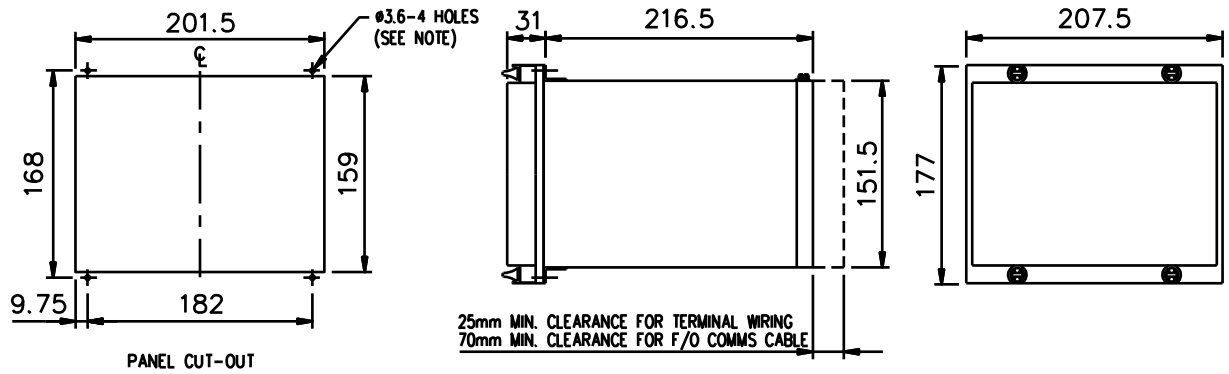
In the event of a trip the device shall record a disturbance record for a minimum of 1 second of the local and remote end currents, in primary amps.

TYPICAL CONNECTION DIAGRAM



Schematic diagram Solkor-N numeric current differential protection

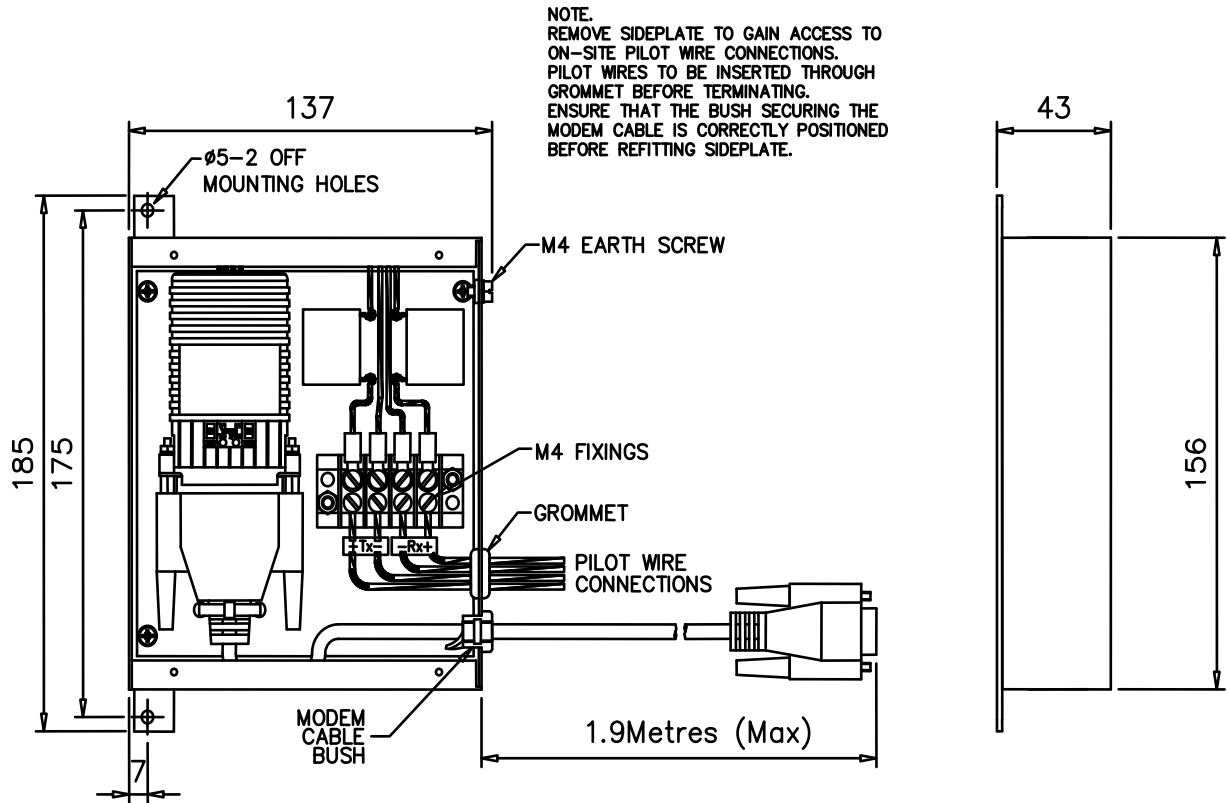
CASE



NOTE:

THE $\phi 3.6$ HOLES ARE FOR M4 THREAD FORMING (TRILOBULAR) SCREWS. THESE ARE SUPPLIED AS STANDARD AND ARE SUITABLE FOR USE IN FERROUS/ALUMINIUM PANELS 1.6mm THICK AND ABOVE. FOR OTHER PANELS, HOLES TO BE M4 CLEARANCE (TYPICALLY $\phi 4.5$) AND RELAYS MOUNTED USING M4 MACHINE SCREWS, NUTS AND LOCKWASHERS (SUPPLIED IN PANEL FIXING KIT).

Pilot Modem



NOTE:

REMOVE SIDEPLATE TO GAIN ACCESS TO ON-SITE PILOT WIRE CONNECTIONS. PILOT WIRES TO BE INSERTED THROUGH GROMMET BEFORE TERMINATING. ENSURE THAT THE BUSH SECURING THE MODEM CABLE IS CORRECTLY POSITIONED BEFORE REFITTING SIDEPLATE.

OUTLINE, PANEL DRILLING & ON-SITE PILOT WIRE CONNECTIONS FOR SOLKOR-N RS232 MODEM

Product description	Variants	Order No.
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SOLKOR-N

Line differential relay using direct fibre optic or metallic pilot wires for communication. Two terminal plain feeders only.

Relay type
Line differential

Protection options

Basic functionality

- 3-phase overcurrent (50/51)
- Earth-fault overcurrent (50N/51N)
- 3-Phase differential (with fixed settings) (87L)
- Trip circuit supervision (74TC)
- Circuit breaker fail (50BF)
- CT supervision
- External/Internal intertrip (96)

Basic functionality plus

- Variable differential settings

Protection signalling channel type

- RS485 electrical link (1200m)
- RS232 electrical to pilotwire link ²⁾
- 1300nm optical fibre link (0-16km) ³⁾
- 1300nm optical fibre link (49km) ³⁾

Auxiliary supply /binary input voltage

- 24/30/48 V DC auxiliary, 30 V DC/AC binary input
- 24/30/48 V DC auxiliary, 48 V DC/AC binary input
- 110/220 V DC auxiliary, 48 V DC/AC binary input ¹⁾
- 110/220 V DC auxiliary, 110 V DC/AC binary input
- 220 V DC auxiliary, 220 V DC/AC binary input

I/O range

- 1 Binary Inputs / 7 Binary Outputs (incl. 3 changeover)
- 9 Binary Inputs / 7 Binary Outputs (incl. 3 changeover)

Frequency

50Hz

Nominal current

1/ 5 A

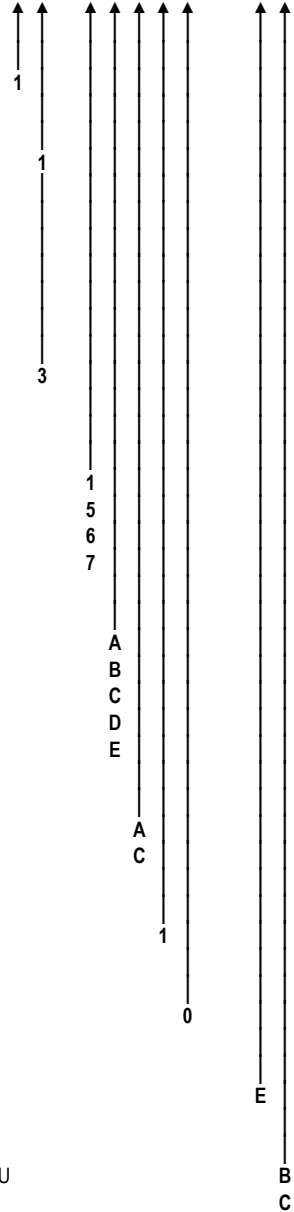
Housing size

Case size E8 (4U high)

Communication interface

- Fibre optic (ST-connector) / IEC 60870-5-103 or Modbus RTU
- RS485 interface / IEC 60870-5-103 or Modbus RTU

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1) High burden 110/125V & 220/250V binary inputs compliant with ESI48-4 ESI 1 available via external dropper resistors with 48V binary input version for 1 binary input and 110 V application, order resistor box VCE:2512H10066 in addition for 9 binary inputs and 110 V application, order resistor box VCE:2512H10064 in addition for 1 binary input and 220 V application, order resistor box VCE:2512H10068 in addition for 9 binary inputs and 220 V application, order two resistor boxes 2512H10067 in addition
Refer to website for application note about ESI48-4 compliance

2) Pilot wire modem (up to 10km) with RS232 interface in BOP mounting case is available for use with these models, order 7XG1210-1AA00-0AA0. Distance depends upon pilotwire parameters. Pilotwires must be screened twisted pair and two pairs are required for signalling

3) Fibre Optic communication requires a compatible pair of relays at both ends. If ordering for one end only please specify details of the other end, which may need to be upgraded to be compatible to the new delivery. Upgrade kits available under VCE:2646G10014K (0-16km) at 550 EUR and VCE:2646G10010K (49km) at 950 EUR. The kits will not be charged for if the old Fibre Optic modules are returned to the factory.

Qualifications

Siemens Protection Devices Limited operates a quality system accredited to ISO9001. **CE** Compliant to relevant EU Directives.

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