7SG16 Ohmega 402 60

Distance Protection Relays

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

1 INTRODUCTION

The commissioning test verifies correct operation and connection of the relay within the protection scheme.

1.1 Equipment Required

Equipment Type.	Serial No.
500V Insulation Resistance Test Set.	
Two variable A.C. voltage sources with a means of varying the phase relationship between them e.g. phase shifting transformer. Ideally, a portable relay test set e.g. Doble, Omicron etc.	
Time interval meter.	
A.C. Voltmeters.	
Phase angle meter.	
D.C. supply with nominal voltage within the working range of the relay's D.C. auxiliary supply rating.	
D.C. supply with nominal voltage within the working range of the relay's D.C. status input rating.	
Continuity tester e.g. multimeter.	
Additional equipment for testing the communications channel : Portable PC with an electrical-to-optical RS232 converter and fibre optic connectors. A copy of Reydisp Evolution software installed on the PC to exercise the communications channel.	

1.2 Inspection

Check that the relay has not been physically damaged. Remove the relay from the case and check that the serial numbers of the relay, case and cover are all identical. Check also that the relay is the correct model and rating.

Ensure that all connections are secure and in accordance with the relay wiring diagram or the schematic diagram. Replace the relay back into the case and ensure that it is fully inserted. Ensure that the relay case is solidly bonded to a local earth point by checking the earthing connection to the case.

1.3 Applying Settings

Before applying settings to the relay, you should be familiar with the relay's menu system. Section 1 and Section 4 of the Technical Manual. 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, which can be used for pre-commissioning tests. See section 2 for a list of the relay default settings.

Settings can be entered into the relay using the keypad on the front of the relay or they can be sent to the relay, from a file, using a portable PC and Reydisp Evolution software package.

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

Note : when using setting groups it is important to remember that the relay need not necessarily be operating according to the settings which are currently being displayed. There is an "active setting group" on which the relay operates and an "edit/view setting group" which allows the settings in one group to be viewed and altered while protection continues to operate on a different unaffected group. The "active setting group" and the "edit setting group" are selected in the "System Configuration Menu".

1.3.1 Precautions

Before testing commences, the relay should be isolated from the voltage transformers in line with the local site procedures. The circuit breaker closing and alarm circuits should also be isolated where practical. Ensure that the correct d.c. auxiliary voltage is applied to the circuit. See the relevant schematic diagrams for the relay connections.

1.3.2 System Parameters

Enter the system Parameters in the table below;

VT Ratio	
CT Ratio	
Positive Sequence Line Angle	
Zero Sequence Line Angle	
Positive Sequence Line Impedance	
Zero Sequence Line Impedance	
Line Length	

2 GENERAL TESTS

2.1 Status Inputs

This test checks that the status input circuits are functioning correctly. The status input circuits should be energised in turn and observed to be operating using the instruments mode ‘Status Inputs’ display. A ‘1’ indicates that the status circuit is energised, a ‘0’ indicates that it is not.
Where practical operate the initiate condition of the status input, or failing this, connect the relevant D.C. voltage to the status input terminals to energise them:

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

INPUT	CHECKED	NOTES
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		
25		
26		
27		

Note: Status operating voltage need not be the same as the main energising voltage. For 110/125 volt or 220 /250 volt working, a standard status input, 48/54 volt rated will be supplied with external dropper resistor as follows:-

Nominal Voltage	Resistor Value; Wattage
110/125	2k7 ±5%; 2.5 W
220/250	8k2 ±5%; 6W

Checked
☐ OK

2.2 Output Relays

This test checks that the output relays are functioning correctly. The output relays should be energised in turn and the contacts should be checked for correct operation using a continuity tester. The output relays can be energised in a number of ways. The following is the recommended method:

Assign each output relay in turn to 'Relay Healthy' in the output relay menu. On pressing the ENTER key the output relay selected will be energised. Check with a continuity tester that the actual contacts have operated. De-select the output relay and check that the contact returns. Consult the schematic diagram or Relay Connections Diagram in the Technical Manual for terminal numbers.

Output Relay	**Type**
Relay 1-3	Change Over
Relay 4+	Normally Open

OUTPUT	CHECKED	NOTES
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		
25		
26		
27		
28		
29		

Note: when finished testing the output relays make sure that the 'Relay healthy' is re-assigned to the correct output relay given in the settings file.

Checked
☐ OK

3 MEASURING UNITS TESTS

3.1 Voltage Measurement

Apply A.C. voltage to each of the voltage input circuits of the relay using the A.C. variable voltage sources or portable relay test set. The relay should display the correct value of voltage, the value measured by the relay is displayed in the Instrument Menu; with ± 5% accuracy. The applied A.C. volts can be in the range of 5 – 220Vrms. Nominal voltage of 63.5V or 110V is recommended.

Checked
☐ OK

3.2 Current Measurement

Apply A.C. current to each current input circuit of the relay using a variable current source. The relay should display the correct value of current, the value measured by the relay is displayed in the Instrument Menu; with ± 5% accuracy.

Checked
☐ OK

4 MAIN PROTECTION

4.1 Distance Protection

4.1.1 Impedance Reach Test.

Set the distance scheme to the stepped time scheme and programme output relays accordingly.

4.1.1.1 Earth Fault Elements Test.

Check that the minimum impedance reach of the relay, on the line angle is as per the relay setting for Earth Faults.

Line Angle = ________ °

EF Comp Z0/Z1 Ratio = ________

EF Comp Z0 Angle = ________ °

Calculated Earth Fault Compensation Factor, K_N = $\frac{1}{3}\left(\frac{Z_0}{Z_1} - 1\right)$ = ________

If the test set incorporates automatic earth fault compensation ensure that this is configured correctly on the test set. Alternatively, if the test set has no automatic earth fault compensation then see Appendix A for details of how to measure the fault loop impedance. Record the impedance reach of each earth fault element in all zones in the table below.

Element	Relay Setting (Ω)	Fault Type	Measured Impedance (Ω)	% Error
Zone 1		A-E		
		B-E		
		C-E		
Zone 2		A-E		
		B-E		
		C-E		
Zone 3		A-E		
		B-E		
		C-E		
Zone 3 (Reverse)		A-E		
		B-E		
		C-E		

Ensure that the error does not exceed ± 5%, or ± 0.15 Ω, (whichever is larger)

Checked
☐ OK

4.1.1.2 Phase Fault Elements Test.

Check that the minimum impedance reach of the relay, on the line angle is as per the relay setting for Phase Faults.

If the test set incorporates automatic fault loop compensation, ensure that this is configured correctly on the test set. Alternatively, if the test set has no automatic fault loop compensation then see Appendix A for details of how to measure the fault loop impedance.

Element	Relay – Phase Fault Setting	Fault Type	Measured Impedance (Ω)	% Error
Zone 1		A-B		
		B-C		
		C-A		
Zone 2		A-B		
		B-C		
		C-A		
Zone 3		A-B		
		B-C		
		C-A		
Zone 3 (Reverse)		A-B		
		B-C		
		C-A		

Ensure that the error does not exceed ± 5%, or ±0.15 Ω, (whichever is larger)

Checked
☐ OK

4.1.2 Operating Time Test

Using a test set with a constant source impedance model, and an SIR of ≤30, apply phase faults and earth faults to the relay inside each of the zones of protection, on the line angle.

Check and record Zone 1, 2, 3 operating times for faults in the middle of reach zones.

Element	Time Delay Settings	Fault Type	Applied Impedance (Ω)	Measured Operating Time (ms)
Zone 1	Earth Fault =________ms	A-E		
		B-E		
		C-E		
	Phase Fault =________ms	A-B		
		B-C		
		C-A		
Zone 2	Earth Fault =________ms	A-E		
		B-E		
		C-E		
	Phase Fault =________ms	A-B		
		B-C		
		C-A		
Zone 3	Earth Fault =________ms	A-E		
		B-E		
		C-E		
	Phase Fault =________ms	A-B		
		B-C		
		C-A		

Check operating time is ≤ 50ms for SIR ≤30

Checked
☐ OK

4.2 Switch Onto Fault Feature.

SOTF ☐ ENABLED ☐ DISABLED

The SOTF feature can be used in either AC or DC mode. Indicate which mode is selected below:
SOFT MODE ☐ AC SOTF Carry out tests as per Section 4.2.1
☐ DC SOTF Carry out tests as per Section 4.2.2

4.2.1 AC SOTF

4.2.1.1 AC SOTF Operation (Zone 3 control).
Select the pre-fault time on the test set to zero. Initiate phase-to-earth and phase-to-phase faults outside zone 1. Record the operating times and indications in the table below. Ensure that the relay indicate the correct elements and a SOTF condition.

Fault Type	Measured Operating Time (ms)	Relay Indication	
A-E		☐ A-E	☐ SOTF
B-E		☐ B-E	☐ SOTF
C-E		☐ C-E	☐ SOTF
A-B		☐ A-B	☐ SOTF
B-C		☐ B-C	☐ SOTF
C-A		☐ C-A	☐ SOTF

4.2.1.2 AC Line Check Reset Time.
The AC line check is active for a short period after the breaker is closed.
With the pre-fault time set to 150ms, simulate a fault outside zone 1 but inside zone3.
Repeat this test with the pre-fault time set to 250ms.

Zone	Fault Type	Pre-fault time (ms)	Relay Indication
		150	☐ SOTF
		250	☐ Distance Trip

4.2.1.3 AC Line Check pick-up time.
The line must have been dead for a set time delay before the AC line check function is enabled. Using the test kit in a sequence mode, arrange the following sequence of states.

Setting of AC SOTF Pickup Delay = ____________ ms

STATE 1 [1 Second]	STATE 2 [AC Line Check Time delay]	STATE 3 [Turned off when relay trips
Nominal voltage.	Zero Voltage & Current on all phases.	Current on one phase to the nominal value.

Run this sequence of state with the State 2 time set to the AC SOTF Pickup delay minus 10%.
Repeat with the state 2 time set to set to the AC SOTF Pickup delay plus 10%.

State 2 Time	Relay Operation
	☐ SOTF
	☐ NO SOTF

4.2.2 DC SOTF (Status Input control).

Select the pre-fault time to 1 second.
Ensure that the status input CB Manual Close is low, then simulate a fault within Zone 3 and outside Zone 1. Record the trip time and indication.

Energise status input CB Manual Close, then repeat the test. Ensure that the fault is initiated within 400 ms of energisation of the status input

Status Input	Fault Type	Measured Operating Time (ms)	Relay Indication	
Low	A-E		□ A-E	□ TRIP
High	A-E		□ A-E	□ SOTF

Ensure that with the status input low the relay trips as normal (after the relevant time delay) and with the status input high, the relay trips instantaneously with a SOTF indication.

Checked
□ OK

4.3 Voltage Transformer Supervision VTS Tests.

VTS □ ENABLED □ DISABLED

4.3.1 Residual Voltage and Current detector.

Apply nominal voltage level on three phases and ramp down one of them until a VTS indication appears. Next, gradually increase the current on the same phase until the VTS indication drops off. Record these values in the "Measured pick-up level" column in the table below.

VTS Ires Level = ____________ A

VTS Vres Level = ____________ V

Calc. volts pick-up = [Vn] – [VTS Vres Level]= ____________________ V

Calc. Curr. Pick-up = [In]- [VTS Ires Level] = ____________________ A

Phase	Action	Calculated Pick-up level	Measured Pick-up level
A	Voltage to operate/reset	V	V
	Current to operate/reset	A	A
B	Voltage to operate/reset	V	V
	Current to operate/reset	A	A
C	Voltage to operate/reset	V	V
	Current to operate/reset	A	A

Ensure that the VTS picks up at the correct level.

Checked
□ OK

4.3.2 VTS blocking function.

The dynamic performance of the VTS scheme is checked using the state sequencer of the test set to simulate various conditions as follows.

STATE 1 [1 Second]	STATE 2 [1 Second]
Nominal Current & Voltage on all three phases	Zero Voltage on 2 phases, nominal voltage on third phase. Nominal balanced 3 phase Current on all three phases.

With the VTS blocking function enabled, the relay should be stable. If, however, the VTS blocking function is disabled, the protection should trip with the corresponding indication.

VTS Mode : VTS alarm only	TRIP	☐ OK
VTS Mode : VTS alarm and inhibit	NO TRIP	☐ OK

To prove the VTS blocking feature for phase faults, set up the following sequence using the test set.

STATE 1 [1 Second]	STATE 2 [1 Second]	STATE 3 [1 Second]
Nominal Current & Voltage on all three phases	Zero Volts on 2 phases Nominal PS Current on all three phases	Voltage as per State 2 Phase to phase fault current (180° phase difference)

In this case there will be no zero sequence current, although a fault has occurred. The relay will see residual voltage but no residual current and prevent tripping.

VTS Phase Fault Inhibit : Enable	NO TRIP	☐ OK
VTS Phase Fault Inhibit : Disable	TRIP	☐ OK

4.4 Power Swing Detector Tests.

Power Swing Detector ☐ ENABLED ☐ DISABLED

Power swing impedance based detector consists of two mho or quad zones. The outer zone is a replica of the inner zone multiplied by a specific factor set by a user. Before starting the tests, ensure that one of the relay LEDs is mapped to the Power Swing Alarm.

4.4.1 Power Swing Impedance Reach.

Apply a balanced three-phase condition with the impedance below the impedance setting of the inner zone. Gradually increase the impedance until the Power Swing Alarm operates. Record the minimum reach of the power swing detector, i.e. the reach of the inner zone. This should be repeated for the inner reverse reach where applicable.

Inner Zone Fwd Reach = ________ Ω

Inner Zone Rev Reach = ________ Ω

Element	Measured Impedance	% Error
Inner Zone Forward Reach		
Inner Zone Forward Reach		

Ensure that the percentage error does not exceed ± 5%

The outer reach of the Power Swing Detector zone is set by a multiplying factor. The actual outer reach is the inner reach multiplied by the PSD Outer multiplier.

PSD Outer multiplier = ________________

Outer Zone Fwd Reach = ________________ Ω

Outer Zone Rev Reach = ________________ Ω

Apply a balanced three-phase condition with the impedance above the impedance setting of the outer zone. Gradually decrease the impedance until the Power Swing Alarm operates. Record the maximum reach of the power swing detector, i.e. the reach of the outer zone. This should be repeated for the outer reverse reach where applicable.

Element	Measured Impedance	% Error
Outer Zone Forward Reach		
Outer Zone Forward Reach		

Ensure that the percentage error does not exceed ± 5%

Checked
☐ OK

4.4.2 Power swing transit timer.

Apply a balanced three-phase condition with the impedance between the inner and outer power swing detector zones. Measure the minimum time that the impedance must be in the Power Swing Detector region for a Power Swing Alarm to be initiated (indicated by LED). This will give the total time (transit time plus operating time) for the Power Swing Detector.
In the table below, note the Set PSD transit time on the relay and the actual time measured for this test. In the final column, calculate the operating time for the PSD element.

Set Transit Time (ms)	Measured Time(ms)	Calculated PSD Operation Time (ms)

4.4.3 Power swing blocking function.

In the table below tick the zones of protection that are blocked when a power swing occurs, and those which are not blocked.

Using the State sequencer, set up two states.

STATE 1. System impedance between the inner and outer zones of the Power Swing Detector.

STATE 2. System impedance within Zone 3.

This is repeated, altering state 2 to bring the impedance within Zone 1 and 2. Check that in zones which are blocked, the protection doesn't operate, and those which are not blocked the protection does operate.

	Unblocked	Blocked	Checked
Zone 1	□	□	□
Zone 2	□	□	□
Zone 3	□	□	□

5 AUXILIARY PROTECTION TESTS

5.1 Fault Locator

Enter Line Parameters in the table below;

Line Length, L = ____________ m

Line Impedance, Z_L = ____________ Ω

Line Angle, θ = ____________ °

The fault locator can be set to display location as percentage or distance. Apply two different type of fault at 50% of the total line impedance, and a further two faults at 100% of the total line impedance.

Fault Location	Fault Type	Expected Reading	Actual Reading	Error (%)
50 %				
50%				
100%				
100%				

Ensure that the error is less than ± 5% in each case.

Checked
☐ OK

5.2 High Set Overcurrent

HSOC ☐ ENABLED ☐ DISABLED

The high set overcurrent element will pick-up independently of the distance protection elements, when it detects a current above it's setting. Using the test set simulate a fault in zone with fault current lower than the HSOC setting. Repeat this gradually increasing the fault current until the HSOC detector picks up. Record the relay settings, the calculated pick-up level and the minimum operating level of the high set overcurrent relay below.

Nominal Current = ____________ A

High Set = ____________ x In

Calculated Pick-up[A]	Measured Pick-up[A]	Relay Operation	
		☐ Trip	☐HSOC

5.3 Stub Protection

STUB Protection □ ENABLED □ DISABLED

Ensure the "Enable Stub Prot'n" status input is de-energised and the Highset Overcurrent element is disabled. In the aux Protection menu ensure that the Stub Protection is enabled.

Energise the "Enable Stub Prot'n" status input and gradually increase the current applied to the relay. Record the level at which the element picks up, and the operating time of the element.

SP Level = ____________ x In (A)

SP Delay = ____________ Ms

Calculated Pick-up[A]	Measured Pick-up[A]	Operating Time (ms)	Relay Indication	
			□ Trip	□Stub Protection

5.4 Zone 2 Override.

Zone 2 Override □ ENABLED □ DISABLED

Ensure the Zone 2 Override Status Input is de-energised. Apply a Zone 2 Fault to the relay, and measure the trip time. Energise the Zone 2 Override Status Input and repeat the fault. Record the fault type, trip time and relay indication in the table below;

Status Input	Fault Type	Trip Time (ms)	Relay Indication
De-Energised			□ Zone 2 Trip
Energised			□ Zone 2 Override

6 END TO END TESTING

In cases where signalling is used in a distance protection scheme, end-to-end testing should be carried out in order to ensure that the relay and the signalling channel are working correctly.

The main difficulty presented by this type of test is the synchronisation between test equipment at the local and remote ends. It is not recommended to attempt to simulate faults at both ends of the line without identical test sets and some sort of synchronising system between them. Since such a test is difficult to set up, the recommended method of end-to-end testing is as follows.

6.1 Distance Scheme Tests.

Ensure that the signal received 1 output is mapped to an LED. With the signalling channel in service, initiate a zone 1 fault and check that the permissive signal is received at the remote end. This is indicated by operation of the assigned LED on the remote end relay.

Checked
☐ OK

Next, manually energise the signal send 1 signalling channel from the remote end. Simulate a zone 2 fault at the local end and ensure that the operating time of the local end relay is less than the zone 2 operating time, indicating that acceleration of the zone 2 element has occurred.

Fault	**Status Inputs**	**Expected Response**	**Relay Operation**
Zone 2	Remote end signal send 1 high.	Relay trips Zone 1	☐ OK
		Relay Autorecloses	☐ OK
		Signal sent – Channel 1	☐ OK

APPENDIX A

A.1 Fault Loop Compensation For Earth Faults

The relay is set in terms of positive sequence impedance. To calculate the actual fault loop impedance follow the steps below. Start by recording the relay settings;

Line Angle = ________________

EF Comp Z0/Z1 Ratio = ________________

EF Comp Z0 Angle = ________________

Calculated Earth Fault Compensation Factor, K_N = $\frac{1}{3}\left(\frac{Z_0}{Z_1} - 1\right)$ = ________________

Then calculate voltage, current and actual impedance using the formulae:

$V = IZ_1 (1 + K_N)$

Where Z1 is the positive sequence impedance (i.e. the relay setting)

Zone 1

Phase	Effective Impedance	Total Loop Impedance	Current Injected	Phase Angle	Voltage Injected	Phase Angle
A						
B						
C						

Zone 2

Phase	Effective Impedance	Total Loop Impedance	Current Injected	Phase Angle	Voltage Injected	Phase Angle
A						
B						
C						

Zone 3 (Fwd)

Phase	Effective Impedance	Total Loop Impedance	Current Injected	Phase Angle	Voltage Injected	Phase Angle
A						
B						
C						

Zone 3 (Rev)

Phase	Effective Impedance	Total Loop Impedance	Current Injected	Phase Angle	Voltage Injected	Phase Angle
A						
B						
C						

A.2 Fault Loop Compensation For Phase Faults

The relay is set in terms of positive sequence impedance. To calculate the actual fault loop impedance follow the steps below.

Calculate voltage from the formulae:

$V = 2IZ_1$

Where Z1 is the positive sequence impedance (i.e. the relay setting)

Zone 1

Phase	Effective Impedance	Total Loop Impedance	Current Injected	Phase Angle	Voltage Injected	Phase Angle
A						
B						
C						

Zone 2

Phase	Effective Impedance	Total Loop Impedance	Current Injected	Phase Angle	Voltage Injected	Phase Angle
A						
B						
C						

Zone 3 (Fwd)

Phase	Effective Impedance	Total Loop Impedance	Current Injected	Phase Angle	Voltage Injected	Phase Angle
A						
B						
C						

Zone 3 (Rev)

Phase	Effective Impedance	Total Loop Impedance	Current Injected	Phase Angle	Voltage Injected	Phase Angle
A						
B						
C						