

7SG163 Ohmega 300 Series

7SG163 Protection Relay

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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.	
<i>Additional equipment for testing the communications channel :</i> 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 \pm 5%; 2.5 W
220/250	8k2 \pm 5%; 6W

Checked
<input type="checkbox"/> 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
<input type="checkbox"/> 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 $\pm 5\%$ accuracy. The applied A.C. volts can be in the range of 5 – 220Vrms. Nominal voltage of 63.5V or 110V is recommended.

Checked
<input type="checkbox"/> 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 $\pm 5\%$ accuracy.

Checked
<input type="checkbox"/> 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
<input type="checkbox"/> 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 $\pm 5\%$, or $\pm 0.15 \Omega$, (whichever is larger)

Checked
<input type="checkbox"/> 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 ≤ 50 ms for SIR ≤ 30

Checked
<input type="checkbox"/> 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		<input type="checkbox"/> A-E <input type="checkbox"/> SOTF
B-E		<input type="checkbox"/> B-E <input type="checkbox"/> SOTF
C-E		<input type="checkbox"/> C-E <input type="checkbox"/> SOTF
A-B		<input type="checkbox"/> A-B <input type="checkbox"/> SOTF
B-C		<input type="checkbox"/> B-C <input type="checkbox"/> SOTF
C-A		<input type="checkbox"/> C-A <input type="checkbox"/> 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	<input type="checkbox"/> SOTF
		250	<input type="checkbox"/> 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
	<input type="checkbox"/> SOTF
	<input type="checkbox"/> NO SOTF

4.2.2 DC Line Check (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 Time (ms)	Operating	Relay Indication
Low	A-E			<input type="checkbox"/> A-E <input type="checkbox"/> TRIP
High	A-E			<input type="checkbox"/> A-E <input type="checkbox"/> 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
<input type="checkbox"/> 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
<input type="checkbox"/> 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	<input type="checkbox"/>	OK
------	--------------------------	----

VTS Mode : VTS alarm and inhibit

NO TRIP	<input type="checkbox"/>	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	<input type="checkbox"/>	OK
---------	--------------------------	----

VTS Phase Fault Inhibit : Disable

TRIP	<input type="checkbox"/>	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 $\pm 5\%$

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 $\pm 5\%$

Checked
<input type="checkbox"/> 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	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Zone 2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Zone 3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

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 = _____ $^\circ$

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 $\pm 5\%$ in each case.

Checked
<input type="checkbox"/> OK

5.2 High Set Overcurrent

HSOC ENABLED DISABLED

The high set overcurrent element will pick-up independantly 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 I_n

Calculated Pick-up[A]	Measured Pick-up[A]	Relay Operation	
		<input type="checkbox"/> Trip	<input type="checkbox"/> HSOC

5.3 Sensitive Earth Fault (SEF).

SEF ENABLED DISABLED

Apply sensitive earth fault condition and measure the pick-up level of the SEF element.

SEF Pick-up		
Setting	Measured	Indication
		<input type="checkbox"/> SEF

Apply SEF conditions at double the setting current ($2 \times I_s$). Measure time between Application of SEF conditions and the SEF alarm operation, and the SEF trip operation.

Applied SEF (A)	SEF Alarm		SEF Trip	
	Setting	Measured	Setting	Measured

5.4 Overvoltage Protection.

OVERVOLTAGE PROT ENABLED DISABLED

There are two stages of overvoltage definite time delay protection, referred to as Alarm and Trip. Record operating values for each of them.

Overvoltage Alarm Level = _____ V
 Overvoltage Alarm Time = _____ ms
 Overvoltage Trip Level = _____ V
 Overvoltage Trip Time = _____ ms

Phase	Alarm		Trip	
	Level	Time	Level	Time
A				
B				
C				

Directional Earth Fault

DEF ENABLED DISABLED

The directional earth fault responds to residual current and voltage. The magnitude of the residual voltage is not important, as the relay only requires a minimal voltage level for its polarising signal – it can be set to a value of 10% of V_n for these tests. The phase angle referred to in these tests is the angle between residual current and voltage.

5.4.1 Sensitivity Test.

Set DEF into “Direct Trip” mode. Apply a balanced three-phase set of current and voltage to the relay. On top of this apply a residual voltage at 10% of V_n . Increase the residual current at the characteristic angle until DEF operates. Measure the operating threshold level.

Earth Fault Current		Relay Operation
Setting [A]	Measured[A]	
		<input type="checkbox"/> DEF

5.4.2 Directional Characteristic.

Set DEF into “Direct Trip” mode. Set directional characteristic into forward direction. Apply residual current at 2x setting and residual voltage at 10% of V_n to the relay at the angles shown in the table below. Confirm that the directional characteristic operates at the relay characteristic angle $\pm 85^\circ$.

Applied residual current = _____ A
 Applied residual voltage = _____ V

Phase Angle	Operation
+90°	<input type="checkbox"/> Stable
+80°	<input type="checkbox"/> DEF
0°	<input type="checkbox"/> DEF
-80°	<input type="checkbox"/> DEF
-90°	<input type="checkbox"/> Stable

5.4.3 DEF Operating Time.

Set the relay DEF mode back to DEF POR.

The DEF can operate in one of two ways;

Aided trip occurs when the local relay detects a DEF and receives a permissive signal from the remote end to indicate that the remote end relay has also detected a DEF condition – this causes a permissive trip.

Back-up trip occurs when a DEF condition is detected and remains on the system for longer than the DEF backup trip time.

Ensure that the Signal Receive 2 status input is low. Apply DEF conditions at one end only and measure the time taken for a back-up DEF trip. Next, energise the Signal Receive 2 status input. Repeat the test and measure the time taken for a permissive DEF trip. Record both times in the table below.

Sig Receive 2 Status Input	Nominal Time [ms]	Actual Time [ms]	Indication
High			<input type="checkbox"/> DEF Aided Trip
Low			<input type="checkbox"/> DEF

5.4.4 DEF Echo Send Signal - POR.

If the local circuit breaker is open when a permissive signal is received, the relay will “Echo” a permissive trip signal back to the remote end. Make sure that the status input for DEF CB Close is low. Energise the Signal Receive 2 input and measure the time for which Signal Send 2 is high.

DEF Echo Pulse Width Time (ms)	Measured time (ms)	Operation
		<input type="checkbox"/> Signal Send 2

5.4.5 DEF Current Reversal Guard Timer.

Set the test kit into a sequence mode. Energise “Signal Receive 2” and “CB DEF Close” status inputs. Two states are required.

STATE 1 Directional Earth Fault in the reverse direction

STATE 2 DEF in the forward direction and the current reversal reset time to the required value.

During state 2 the relay will trip after DEF Current Reversal Reset time.

DEF Current Reversal Reset (ms)	Measured time (ms)	Operation
		<input type="checkbox"/> DEF Aided Trip

5.5 Auto Reclose.

The relay incorporates an embedded three phase, single shot auto-reclosing feature which can be activated in "Auto-reclosing" menu. In order to test this feature, the test equipment must be arranged to run through a sequence of states to simulate the sequence of events which occur during an auto-reclose sequence.

The status of the auto-reclose sequence can be viewed in "Instruments" mode under "auto-reclose state" [it may be necessary to temporarily disable to fault locator to view all indications in this mode]. During a successful auto-reclosing sequence, the sequence of messages is as follows:

```

"IDLE"
"THREEPOLEDEADTIME"
"CBCLOSEPULSE"
"RECLAIM"
"IDLE"

```

5.5.1 Successful auto-reclosing.

Disable the synchronisation feature by selecting "Dead Line and Dead Bar" to "Enable" position. Then, switch "Auto-reclose" from "Out" to "In" position.

Arrange the test kit to run through the following states

STATE 1 [1 s].

Nominal Current, Nominal Voltage, Breaker Closed.

STATE 2 [100ms].

Single Phase Zone 1 fault, Breaker Closed.

STATE 3 [Until close pulse is issued].

Current zero, Voltage zero, Breaker open.

STATE 4 [1s].

Nominal Current, Nominal Voltage, Breaker Closed.

This sequence of events should initiate a successful auto-reclose sequence. Monitor the sequence of events and record auto-reclosing operating times from the relay interface -Reydisp.

AR Function	Measurement	Nominal Time[ms]	Actual Time[ms]
Dead Time	State 3 Time		
CB Close Pulse	CB Close Pulse Width		
Reclaim Time	From : A/R CB Close Pulse Reset To : A/R In Progress Reset		

5.5.2 Unsuccessful auto-reclosing.

The following are conditions under which auto-reclosing will not be successfully executed. Check for correct operation of the relay in each case.

Fault/Plant Condition	Relay Operation
Zone 2,3,4, trip	<input type="checkbox"/> No Auto Reclose
Blocking A/R status input high	<input type="checkbox"/> No Auto Reclose
3 Phase Fault	<input type="checkbox"/> Auto Reclose Lockout
Failure in opening a circuit breaker	<input type="checkbox"/> Auto Reclose Lockout
Failure in re-closing a circuit breaker	<input type="checkbox"/> Auto Reclose Lockout
Go direct into lock-out status input	<input type="checkbox"/> Auto Reclose Lockout

5.6 Synchronisation Check.

The check synchronisation feature is only used by the relay during synchronised auto reclosing, but it runs continuously. Thus the pick-up and drop-off levels can be measured easily. Set up the test set to apply voltages to the yellow phase line VT input and the synchronising VT input. Assign LEDs to Live Bar, Live Line and In Sync.

5.6.1 Live Line and Live Bar levels.

Note the relay settings below.

Bus Live	=	%
Bus Dead	=	%
Line Live	=	%
Line Dead	=	%

Start with the line voltage above the live line setting. Reduce the line voltage until the Live line LED goes out – this is the Measured dead line level setting. Then gradually increase this voltage until the LED lights again. This is the measured live line level – record this in the table below.

Plant	Measured Voltage		Percentage Voltage	
	Live [V]	Dead [V]	Live [V]	Dead [V]
Bus				
Line				

5.6.2 Angle Differential

Start the test with busbar voltage and line voltage at the same angle. Gradually increase the angle between them in the positive direction until the LED assigned to In Sync drops off. Repeat this test in the opposite direction. Record positive and negative phase angle differences in the table below.

Parameters	Relay Setting	Positive angle	Negative angle
Sync-Check	±	°	°
System Check	±	°	°

5.6.3 Frequency Slip

Start the test with busbar voltage and line voltage at the same angle, but a frequency differential greater than the relay Check Sync slip between them. This will cause the busbar voltage and the line voltage to slip relative to one another. Using the instruments mode bring up the Check Sync Line/Bus Phase Diff. Wait to see if the In Sync LED comes on when the voltages come into synchronism. If not gradually reduce the frequency difference until the LED assigned to In Sync comes on when the voltages are synchronised.

Parameters	Relay Setting	Positive Frequency Slip	Negative Frequency Slip
Sync-Check	±	°	°
System Check	±	°	°

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
<input type="checkbox"/> 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	<input type="checkbox"/> OK
		Relay Autorecloses	<input type="checkbox"/> OK
		Signal sent – Channel 1	<input type="checkbox"/> 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						