Application Paper **AP013002EN**

Effective January 2024
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Field testing instructions and application guide for ground fault and Maintenance Mode protection systems utilizing Eaton Magnum PXR and Power Defense SB circuit breakers

Contents

Powering Business Worldwide

Overview of testing

Overall system selectivity and performance of integral ground fault protection equipment can be field tested by using the primary current injection method or with the secondary injection method. When first installed to meet the NEC® requirements for the primary method of testing, the following rules must be followed:

1. Tests are to be conducted by qualified personnel.
2. All sources of power must be de-energized or disconnected from the switchgear.
3. Loads must be disconnected from the switchgear when testing feeder breaker ground fault. If only the mains or ties are to be tested, all feeder breakers must be open.
4. A single-phase high-current power supply with a minimum of 300 A at approximately 2.5 V capability is required. Flexible cables rated for over 1200 A or equal to the current that will be applied will also be required.
5. For testing purposes only, when using a primary single-phase current source to test low-level ground fault current settings, the manufacturer recommends the use of an auxiliary power source to power the trip unit. When the single-phase test current is low, it may appear as if the trip unit does not respond until the current is well above the set value, leading the tester to believe there is an error in the trip unit when there is none. The reason this occurs is that the single-phase test current is not a good simulation of the normal three-phase current power system. If three phases had been flowing, the trip unit would have been powered sufficiently. Use a power adapter module connected to the trip unit micro-USB input or supply +24 Vdc auxiliary power to the input connections through the secondary terminals for correct trip unit performance when single-phase tests are made.
6. On four-wire systems, check to ensure that there are no additional grounds on the feeder breaker neutral conductors.
7. When testing with a primary injection high-current power supply, it should be calibrated and checked with an oscilloscope for accuracy, consistency, and absences of any "beat" level drifting as seen in the **Figure 1** waveform. The tested current level should be chosen above the pickup level to make sure the current is not causing a pickup/dropout/pickup condition. This condition can cause longer trip times.

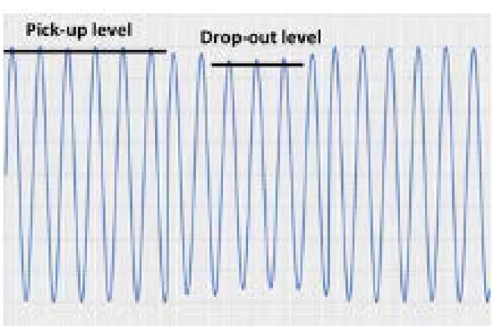


Figure 1. Example of unstable test current regulation

Primary injection current testing—important general issues

1. Insufficient current through enough poles to power the electronics. When testing for ground fault (GF), and the breaker does not have auxiliary power on the trip unit, it is advisable to put a current through the other two poles to power up the trip unit electronics, as shown in **Figure 2**.

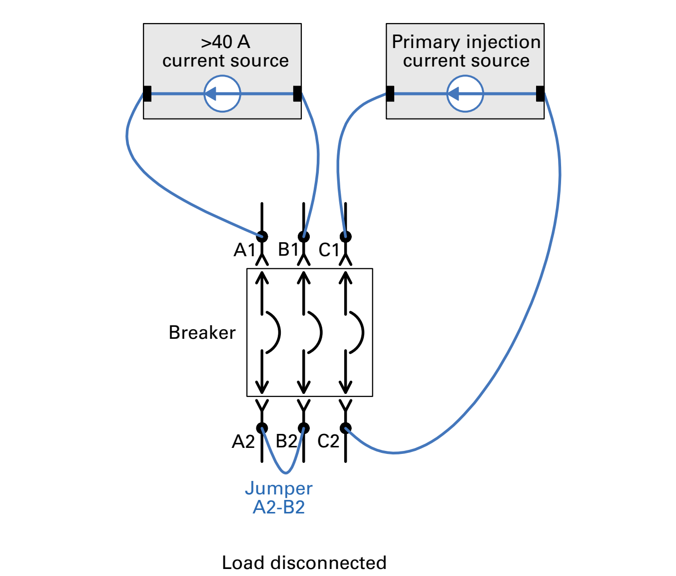


Figure 2. Power in A-B phases and test current in phase C

2. GF causing tripping before expected phase trip time or phase causing tripping before expected GF time. See TD013172EN for time/current curves.
3. Zone selective interlocking (ZSI) causing tripping before expected time. If ZSI is enabled in the trip unit and the breaker is in the disconnected or withdrawn position for testing, the ZSI input to output terminals C19–C21 need to have a jumper between them or ZSI can be disabled in the trip unit.
4. Thermal memory can cause a faster trip time when multiple tests are performed. The thermal memory function can be disabled, or the tester should wait a minimum of 5 minutes between tests.
5. The size of the cable used to test during primary injection is important. Undersized cable and higher resistance can cause voltage drops and lead to improper test levels.
6. The neutral sensor orientation and wiring is important for correct residual sensing operation. See IL0131154EN for neutral sensor installation and selection in trip unit menus. If neutral sensing is not needed in your application, the CT selection should be made (this is the factory default setting). If Rogowski is selected and no coil is connected, false current readings and possibly trips will occur.

7. A primary circuit resistance test is performed on all Eaton low-voltage air circuit breakers as part of the production test program. This test is performed on the breaker immediately after the breaker has been completely assembled and just prior to shipping. At this moment, there is minimal oxidation on the contacts. After the breaker is shipped and before it is energized, there is no control of the environments that the breaker is exposed to during this period and oxidation or corrosion can build up on the contacts thus affecting the results of a primary circuit resistance test. When performing a primary circuit resistance test in the field, the instantaneous primary injection testing must be performed first. In addition to the instantaneous primary injection testing, the breaker should be operated several times to allow the contact wiping action under rated current to remove the buildup of oxidation or corrosion on the contacts through the opening process. A digital low-resistance ohmmeter (DLRO) or a millivoltmeter used with a primary current injection test set can measure primary circuit resistance. Record the results for comparison when this test is performed in the future. Gross changes of millivolt drop may indicate a problem such as loose bolted joints or corroded contacts. This test shall be performed with a 24 V or less direct current power supply capable of supplying at least 100 Adc. The following may cause primary circuit resistance to increase:
    - Chemical contamination, dirt particles, or oxidation of the surfaces of main contacts
    - Loose electrical connections
    - Mechanical damage on the surfaces of conductors and contacts
8. Eaton states levels and tolerances on the time current curve (TCC) for short-circuit protection that are based on two- or three-phase testing results. The circuit breakers are subjected to tests using full voltage and current to achieve the stated times and levels on the TCC, which power system engineers can use for their coordination studies. Testing with one phase at these high current levels, with low voltage, can lead to different results. Single-phase testing at these high currents causes unbalanced magnetic fields inside the circuit breaker versus testing with multiple phases. These unbalanced magnetic fields can cause the trip unit to measure the fault current lower than the actual current and therefore require a higher current to go over the pickup level set on the trip unit. A way to counteract this effect is to loop the current back up the adjacent phase as shown in **Figure 6**.

Special considerations for double-wide circuit breaker applications

For ANSI circuit breaker ratings 4000 A and above, the Magnum™ PXR and Power Defense™ SB (PD-SB) circuit breakers are designed in a double-wide configuration. The circuit breaker is configured with two poles and buses for each phase and neutral. If the neutral is used and is external to the circuit breaker, then there should be a current sensor on the neutral for residual ground fault protection. If there are two buses, then there should be a neutral sensor on each. For this application, Eaton recommends the use of current transformer (CT) neutral sensors so that the current sources can be paralleled to get the correct current signal to the circuit breaker trip unit. Rogowski sensors can be used as neutral sensors in standard applications but are not recommended for split neutral bus applications except in four-pole circuit breakers. When external Rogowski sensors are used, the output signals are low voltage and need to have special wiring considerations. **Figure 3** shows the two types of neutral sensors: CT neutral sensor Catalog No. MSCNCT and Rogowski sensor Catalog No. NRMPN.

When testing a double-wide circuit breaker with a single-phase current source, the field of the current can "bleed" into the adjacent phases, causing a reduction in the value of the current sensed as shown in **Figure 4**. The field loss can be compounded when testing double-wide circuit breakers because of the two separate phase connections that need to be made as shown in **Figure 5**. A way to counteract the effect of the loss of field is to loop the current back up the adjacent phase as shown in **Figure 6**.

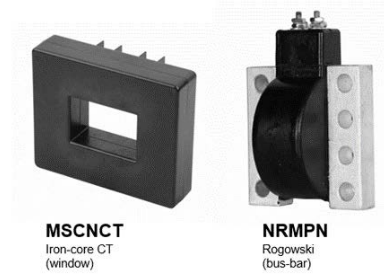


Figure 3. CT and Rogowski neutral sensors

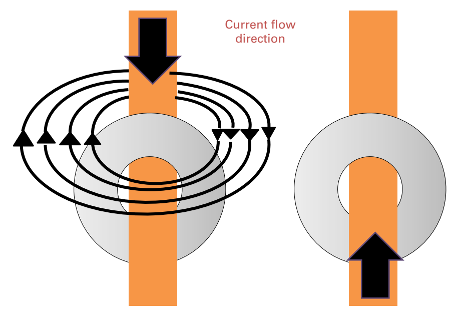


Figure 4. Single-phase current field effect

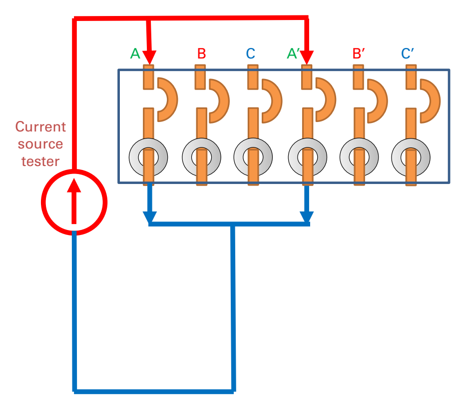


Figure 5. Double-wide single-phase test

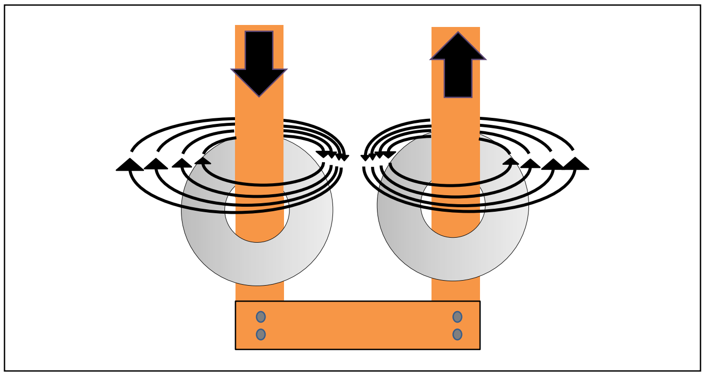


Figure 6. Looping current between phase

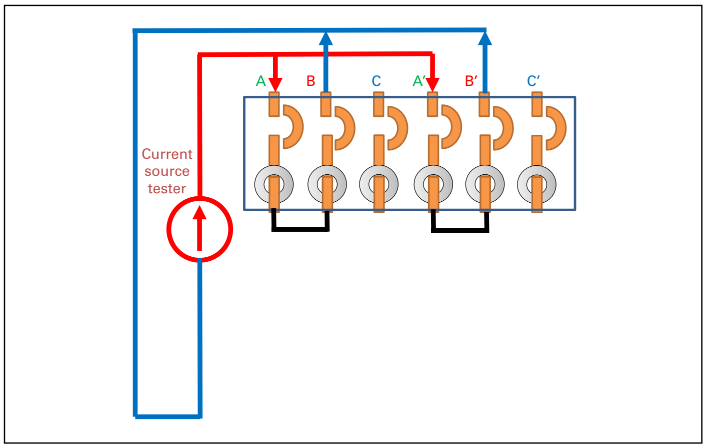


Figure 7. Loop testing for double-wide circuit breaker

Ground fault testing

NEC 230.95(c)

The 2020 National Electrical Code® makes the following statement regarding ground fault conformance testing:

"The ground fault protection system shall be performance tested when first installed. This testing shall be conducted by a qualified person(s) using a test process of primary current injection, in accordance with instructions that shall be provided with the equipment. A written record of this testing shall be made and shall be available to the authority having jurisdiction."

This document is intended to provide instructions for conformance testing of ground fault systems utilizing type Magnum PXR and PD-SB circuit breakers. Although the most common system variations are specifically illustrated, they are also used to form the basis for more complex systems. These instructions may be applied, accordingly, on these systems as well. Refer to order-specific drawings to determine the actual ground fault system supplied.

⚠ DANGER

DO NOT ATTEMPT TO TEST THIS EQUIPMENT WHILE IT IS ENERGIZED. DEATH OR SEVERE PERSONAL INJURY CAN RESULT. TURN OFF ALL POWER TO THIS EQUIPMENT AND CHECK FOR THE PRESENCE OF VOLTAGE BEFORE TESTING.

Table 1. GF pickup values for Magnum PXR and PD-SB circuit breakers

Ground fault settings for I_n current ratings					
	Pickup settings in amperes ①				
	Minimum 0.2	PXR 25 Setpoints range increments 0.1x			Maximum 1.0
Installed I_n current rating	PXR 20 Setpoints				
	0.2	0.4	0.6	0.8	1.0
200	50	60	70	80	200
250	63	75	88	100	250
300	75	90	105	120	300
400	100	120	140	160	400
600	150	180	210	240	600
800	200	240	280	320	800
1000	250	300	350	400	1000
1200	300	360	420	480	1200
1600	300	360	420	480	1200
2000	300	360	420	480	1200
2500	300	360	420	480	1200
3000	300	360	420	480	1200
3200	300	360	420	480	1200
4000	300	360	420	480	1200
5000	300	360	420	480	1200

① Tolerances on pickup levels are +10% of values shown. Shown in the shaded area is how the trip unit clips the maximum setting to 1200 A to meet the NEC code limit.

Ground fault sensing methods

The Magnum PXR and PD-SB circuit breakers and trip units are capable of three different methods of detecting ground fault current. The most common scheme is the residual method. This method measures the current in all three phases and neutral conductor (if the neutral is used). The vector sum of the currents produces a value for the ground current. The source ground method measures the value of current that is flowing in the ground point of the incoming source transformer. The Zero Sequence method uses a transformer sensor that has all three phases and neutral (if used) pass through the window of the transformer. The magnetic fields are vectorially summed and the output of the secondary winding is the value of the ground current.

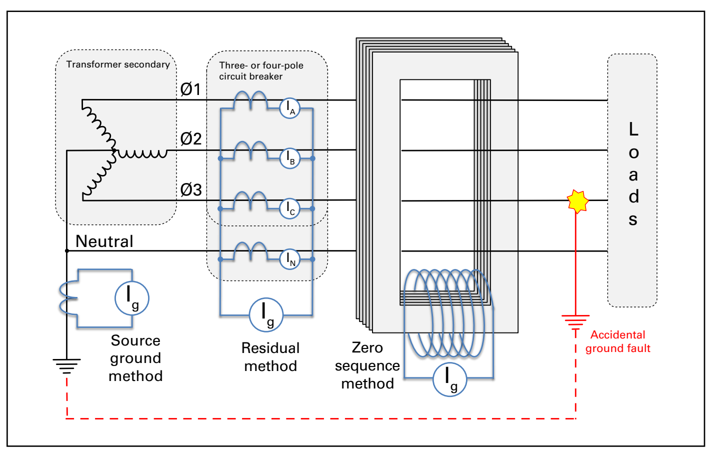
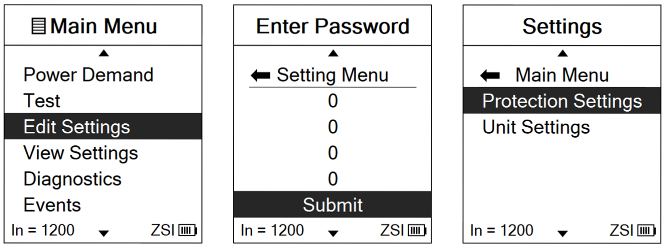
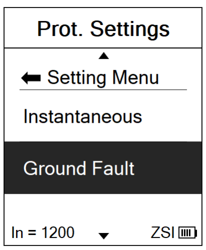


Figure 8. Three methods of determining ground fault current

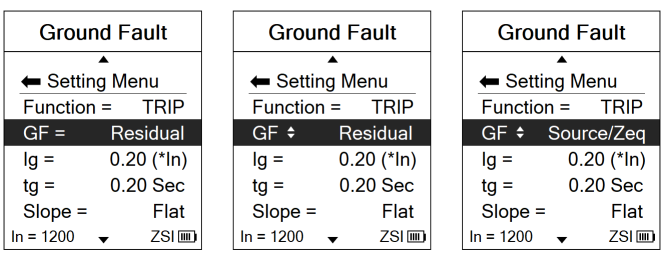
PXR 25 display screen images for programming ground fault protection

The PXR 25 screens are shown although they are similar or the same to the PXR 20 screens. From the Edit Settings selection, press the Enter button and enter the password (factory default is 0000) needed to access the Settings selection. Next, select the Protection Settings menu by highlighting it and pressing Enter. Then step to the Ground Fault selection and press Enter to edit the setting.





Step to the GF setting and press Enter to edit the setting. The Up or Down Arrow buttons will cycle between the residual and source ground / zero sequence selections. Pressing the Enter button will return the setpoint to the non-edit mode and save the selection to memory.



ZSI ground fault testing

Under a ground fault condition, the downstream breaker will send a restraining signal to the upstream breaker.

This signal tells the upstream breaker to begin timing (assuming the fault current is above its pickup settings). The downstream breaker should then clear the fault. If the downstream breaker fails to trip, the upstream breaker will then finish its time out and clear the fault condition.

If the fault condition is located between the upstream breaker and the downstream breaker, the downstream breaker will not sense the fault and no restraining signal will be sent. The upstream breaker will then trip at its minimum time band, regardless of the time delay setting. The pickup and time delay settings on the main, tie, and feeder breakers must be selectively coordinated.

Secondary injection testing using PXPM

All the PXR trip units should be powered up when testing. Their green status LED should be flashing.

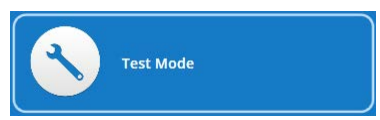
This procedure requires the use of PXPM for secondary injection testing. The PXPM software can be downloaded ① at the site: **Eaton.com/PXPM**.

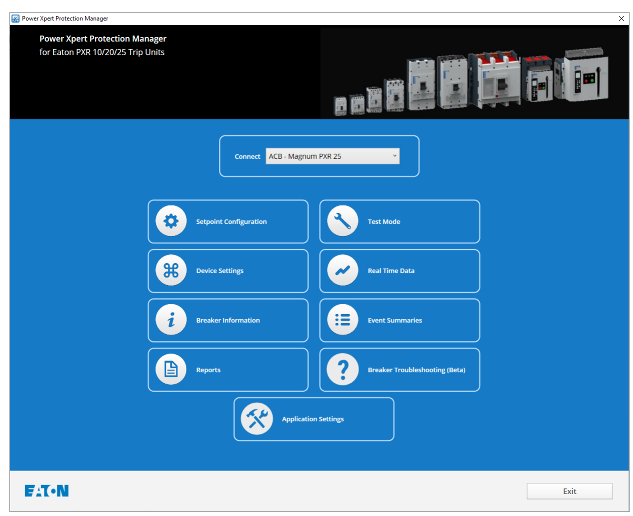
The PXR trip units have a built-in secondary injection test circuit that allows for a hardware test to verify the sensing and processing functions of the trip unit.

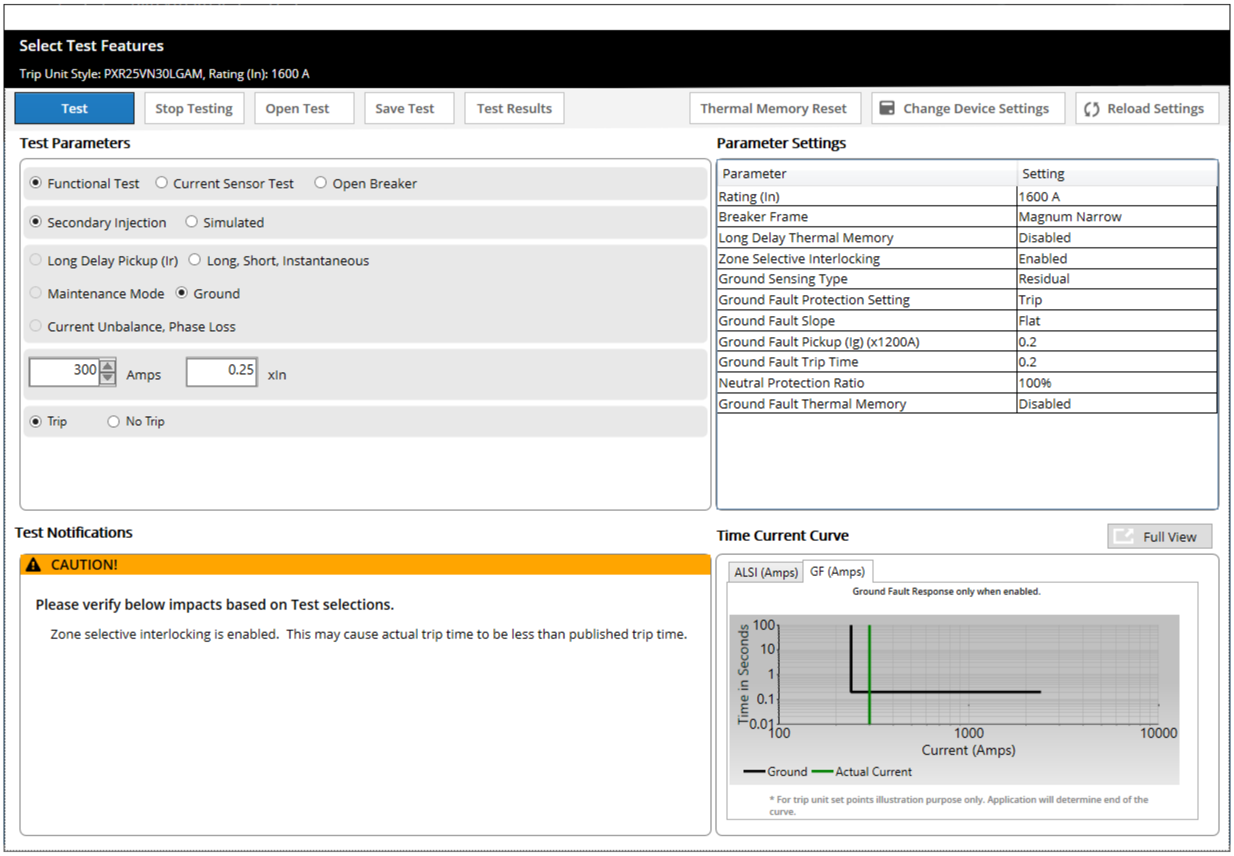
Once the PXPM software is downloaded onto a computer that is connected to the trip unit via a micro USB cable, testing can start.

The example screen below shows a graph of the ground fault protection settings and a current (green vertical line at 300 A) that is chosen as the test value. Make sure the test current is at least 110% of the pickup value. The settings are shown in the upper right side of the screen so that they can be used to verify the black lines in the graph. After the testing is finished, there will be an option to generate a report from PXPM of the tests and setpoints used.

① The PXPM software program is a free download. The first five testing sessions are free. A license needs to be purchased for additional testing sessions.







Example of a PXPM secondary injection GF test

PXR trip unit field testing of ground zone interlocking using PXPM software

The following is a general procedure to check the zone interlocking functions and wiring. Primary injection is not required for this test. Drawout breakers must be in the Test or Connected position. The breakers must not be energized except for control power.

ZSI features in the PXR trip units

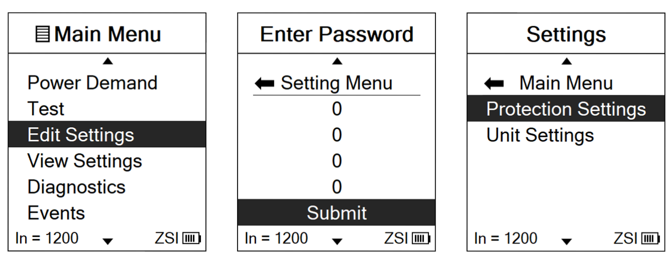
ZSI is standard on all PXR trip units.

Programmable, the ZSI feature can be programmed ON or OFF in each trip unit. When the trip unit has ZSI enabled (ON), the letters "ZSI" will appear on the bottom of the trip unit display. When ZSI disabled (OFF), there is no need to add the "self-interlock" jumper on the terminal block that was needed for Digitrip™ style trip units.

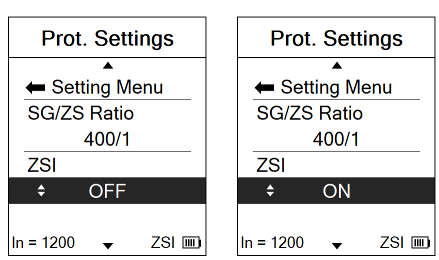
The check mark symbol appears when a ZSI input signal is received. This √ symbol will appear on the bottom of the trip unit display next to the letters ZSI. This symbol will stay on the display until the RESET button is pressed or the trip unit has lost all control power.

PXR 25 display screen images to program enable/disable ZSI

The PXR 25 screens are shown below; however, they are similar to or the same as the PXR 20 screens. From the Edit Settings selection, press Enter and enter the password needed to access the Settings selection. Next, select the Protection Settings menu by highlighting it and pressing Enter.



Step to the ZSI selection and press Enter. Once the ZSI setting is selected, the Up or Down Arrow buttons will cycle between the OFF (disable) or ON (enable) ZSI selections. Pressing the Enter button will return the setpoint to the non-edit mode and save the selection to memory.



Test 1—self interlocked feeders

Verify each feeder breaker trips with time delay when self-interlocked.

Push the reset button on the trip unit to clear the display of any √ mark. Use PXPM from a laptop with the USB cable plugged into the trip unit to initiate a GF test of that breaker. The breaker should trip with the full time delay. The self-interlock jumper will send the zone output signal to the zone input. The trip unit will read the input and set the √ mark on the display. Verify the mark and time delay that PXPM records to confirm a passed test. Push the reset button to clear √ on the display. Test each feeder breaker and verify that delayed tripping occurs and the zone input signal was recognized.

Note: Self-interlocking is defined as the feeder breaker having a jumper installed on secondary contacts C21 and C19. When this jumper is installed, it allows the ground fault time delay to operate at the trip unit setting. Without this jumper, the ground fault time delay will always revert to an immediate trip of 0.075 s or less at 60 Hz, regardless of the trip unit delay setting. The self-interlocked jumpers should only be on the furthest downstream breakers in the interlocked zone scheme.

Test 2—no delay on upstream breakers (Normally mains and ties)

Verify that each upstream breaker will trip with no time delay (75 ms or less), which are not self-interlocked and are not receiving a restraint signal from a downstream breaker.

Push the reset button on the trip unit to clear the display of any √ mark. Use PXPM from a laptop with the USB cable plugged into the trip unit to initiate a GF test of that breaker. The breaker should trip without any intentional time delay (75 ms or less). The circuit breaker should not be self-interlocked and the √ mark should not appear on the display. Verify that there is no mark and the time delay that PXPM records and confirms a passed test. Test each main and tie breaker and verify that the fast tripping occurs and the zone input signal was not recognized. Repeat the test for each upstream breaker.

Test 3—delayed trip on upstream breakers (Normally mains and ties)

Verify that without a restraint signal sent by a downstream breaker that an upstream breaker does time delay before tripping.

Push the reset button on the trip unit to clear the display of any √ mark. Install a self-interlocked jumper between terminals C21 and C19 on the terminal block. Then use PXPM from a laptop with the USB cable plugged into the trip unit to initiate a GF test of that breaker. The breaker should trip with the full time delay. The self-interlock jumper will send the zone output signal to the zone input.

The trip unit will read the input and set the √ mark on the display. Verify the mark and time delay that PXPM records to confirm a passed test. Push the reset button to clear √ on the display. Test each upstream breaker and verify that delayed tripping occurs and the zone input signal was recognized.

Test 4—verifying ZSI wiring

Verify that each upstream breaker and feeder breaker see the correct zone interlock signal to verify the integrity of the wiring.

Figure 9 shows an example of the feeder 11 breaker being tested using PXPM. Start the test by pushing the reset button on each trip unit to clear the display of any √ marks. Use PXPM from a laptop with the USB cable plugged into the trip unit to initiate the test.

The test can be done with a Short Delay protection or Ground Fault protection test because they both have ZSI capability. In this example, a laptop with PXPM is connected to feeder 11 and is tested above 4000 A of secondary injection current to simulate a fault above its Short Delay pickup setting. The feeder 11 trip unit shows a checkmark because it is self-interlocked. The Main 1 breaker shows a checkmark because it has received the ZSI input restraining signal.

Feeders 12 and 13 are in the same zone as feeder 11 and should not see the fault because the simulated fault is only on feeder 11. Feeder 12 should not see the ZSI input signal and does not show a checkmark, which is correct. Feeder 13 does show a checkmark. Further inspection will find that feeder 13 has its input and output signals wired incorrectly.

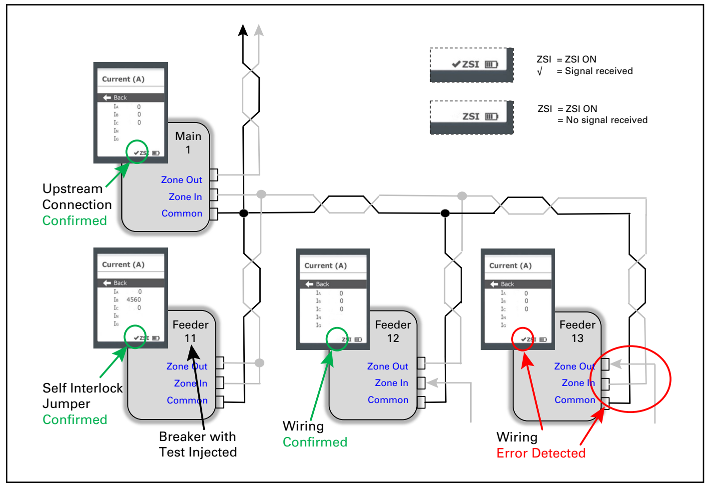


Figure 9. ZSI wire testing example

Repeat the test for each downstream feeder breaker to verify.

Primary injection test procedures for residual ground fault systems

Test procedures

Feeder breakers—three-wire—residual ground fault

⚠ DANGER

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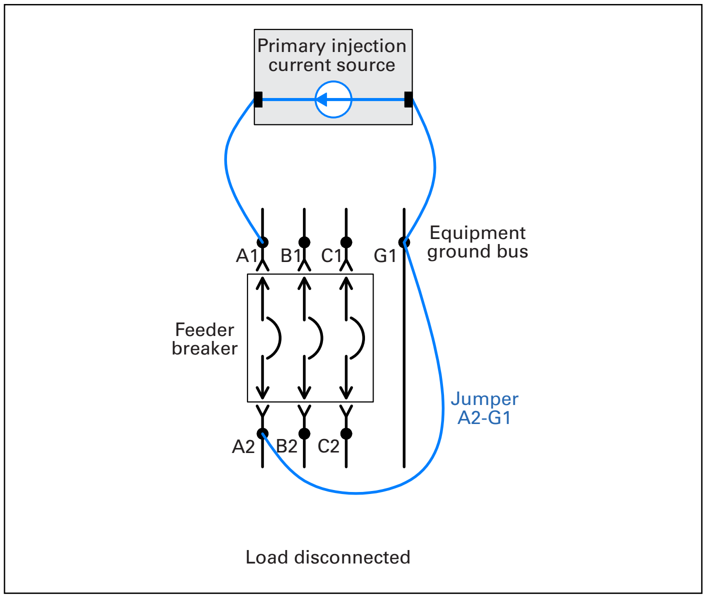

Figure 10. Three-line diagram with phase A test connections

Breaker status feeder	Apply single-phase current to	Install jumper from	Results	Remarks
Closed	A1 and G1	A2 and G1	Feeder times out and trips	

Repeat the above test for "B" phase and "C" phase.

Note: If the above test does not pass, check that the incoming lines and loads are disconnected and that the test power supply and jumper connections are correct. If breaker is used in a ZSI application (not shown), either install a jumper from C19 to C21 or disable ZSI during testing.

Feeder breakers—four-wire—residual ground fault

⚠ DANGER

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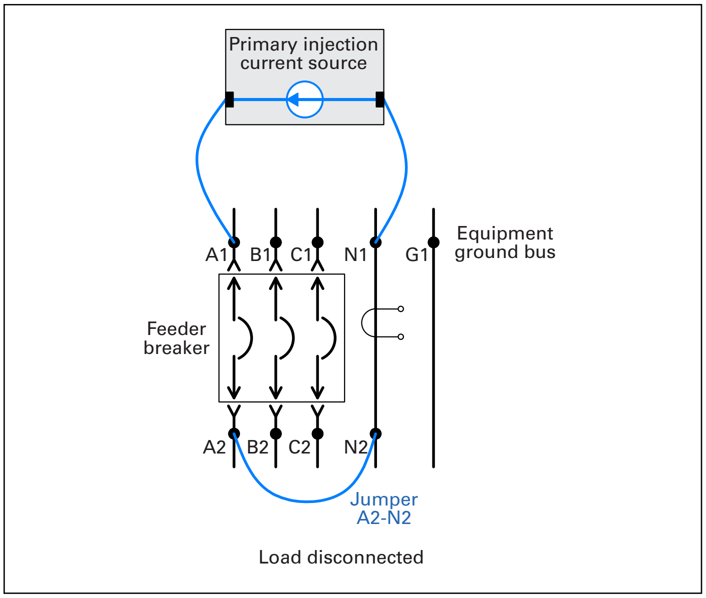


Figure 11. Three-line diagram with phase A no trip test connections

Feeder breaker status	Apply single-phase power to	Install jumper from	Results	Remarks
Closed	A1 and N1	A2 and N2	No trip	Polarity check for neutral sensor (see IL0131154EN for neutral sensor installation)
Closed	A1 and G1	A2 and G1	Feeder times out and trips	

Repeat the above test for "B" phase and "C" phase.

Note: If the above test does not pass, check that the incoming lines and loads are disconnected and that the test power supply and jumper connections are correct. If breaker is used in a ZSI application (not shown), either install a jumper from C19 to C21 or disable ZSI during testing.

Main breakers—three-wire—residual ground fault

⚠ DANGER

DO NOT ATTEMPT TO TEST THIS EQUIPMENT WHILE IT IS ENERGIZED. DEATH OR SEVERE PERSONAL INJURY COULD RESULT. TURN OFF ALL POWER SUPPLYING THIS EQUIPMENT AND CHECK FOR VOLTAGE BEFORE TESTING.

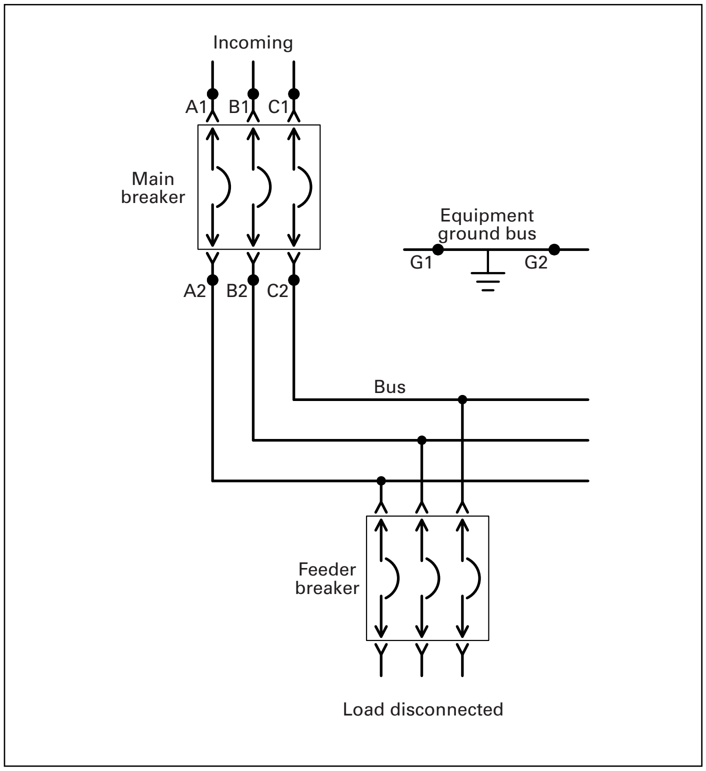


Figure 12. Three-line diagram indicating test points

Breaker status		Apply single-phase power to	Install jumper from	Results	Remarks
52-1	Feeder				
Closed	Open	A1 and G1	A2 and G2	Main 52-1 times out and trips	

Repeat the above test for "B" phase and "C" phase.

Note: If the above test does not pass, check that the incoming lines and loads are disconnected and that the test power supply and jumper connections are correct. If breaker is used in a ZSI application (not shown), either install a jumper from C19 to C21 or disable ZSI during testing.

Main breakers—four-wire—residual ground fault

⚠ DANGER

DO NOT ATTEMPT TO TEST THIS EQUIPMENT WHILE IT IS ENERGIZED. DEATH OR SEVERE PERSONAL INJURY COULD RESULT. TURN OFF ALL POWER SUPPLYING THIS EQUIPMENT AND CHECK FOR VOLTAGE BEFORE TESTING.

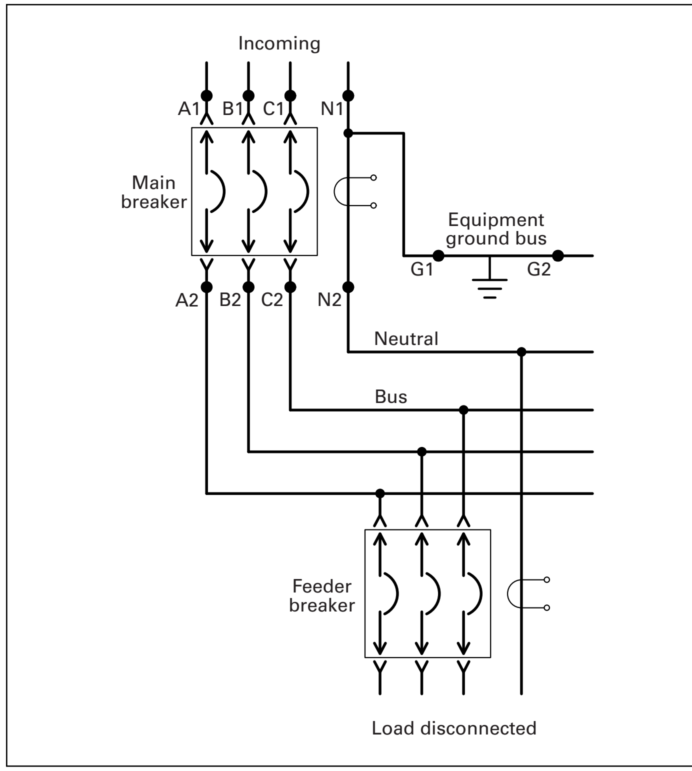


Figure 13. Three-line diagram indicating test points

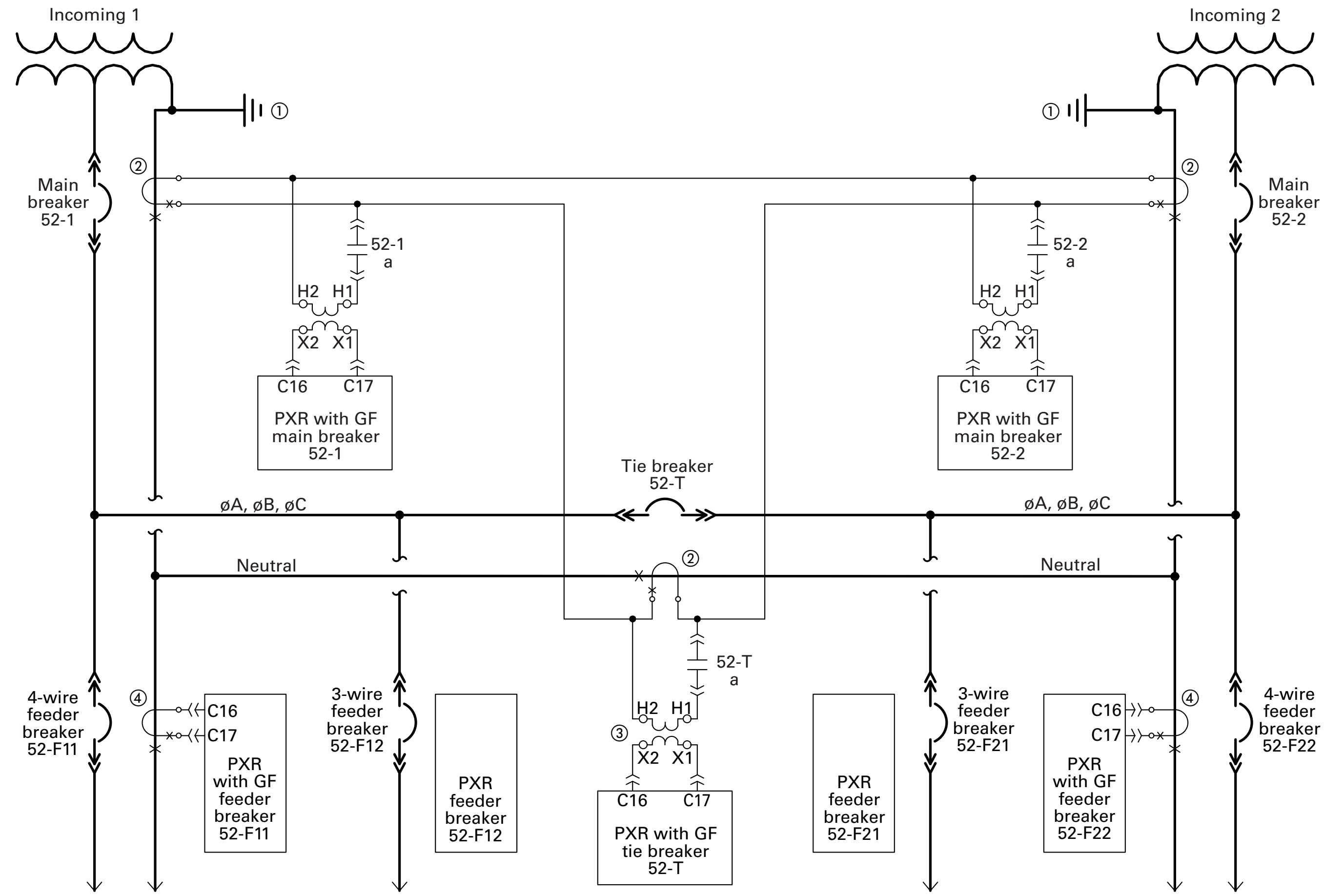
Breaker status		Apply single-phase power to	Install jumper from	Results	Remarks
52-1	Feeders				
Closed	Open	A1 and N1	A2 and N2	No trip	Polarity check for neutral sensor (see IL0131154EN for neutral sensor installation)
Closed	Open	A1 and G1	A2 and G2	Main 52-1 times out and trips	

Repeat all of the above tests for "B" phase and "C" phase, except neutral sensor polarity check is only required on one phase.

Note: If the above test does not pass, check that the incoming lines and loads are disconnected and that the test power supply and jumper connections are correct. If breaker is used in a ZSI application (not shown), either install a jumper from C19 to C21 or disable ZSI during testing.

Primary injection test procedures for double-ended modified partial differential ground fault systems

Typical double-ended four-wire system with partial differential residual ground fault



① No other grounding of the neutral bus should be made downstream from these two points. To do so will defeat protection.

② Use CT type neutral sensor Catalog No. MSCNCT, sized for all breaker ratings. Double-wide breakers can use a single neutral sensor or two neutral sensors mounted and wired in parallel.

③ Isolation transformer (1:1 equivalent ratio) required for modified partial differential ground fault.

④ Use either CT type neutral sensor Catalog No. MSCNCT or Rogowski type neutral sensor Catalog No. NRMPN, sized for all breaker ratings. Double-wide breakers can use a single neutral sensor of either type or two CT type sensors mounted and wired in parallel. PXR trip unit must be programmed for appropriate neutral sensor type in the settings.

⑤ If breaker is used in a ZSI application (not shown), either install a jumper from C19 to C21 or disable ZSI during testing.

Figure 14. Typical modified partial differential ground fault scheme for switchgear

Test procedure: double-ended, four-wire, with partial differential design with Magnum PXR or PD-SB

⚠ DANGER

DO NOT ATTEMPT TO TEST THIS EQUIPMENT WHILE IT IS ENERGIZED. DEATH OR SEVERE PERSONAL INJURY COULD RESULT. TURN OFF ALL POWER SUPPLYING THIS EQUIPMENT AND CHECK FOR VOLTAGE BEFORE TESTING.

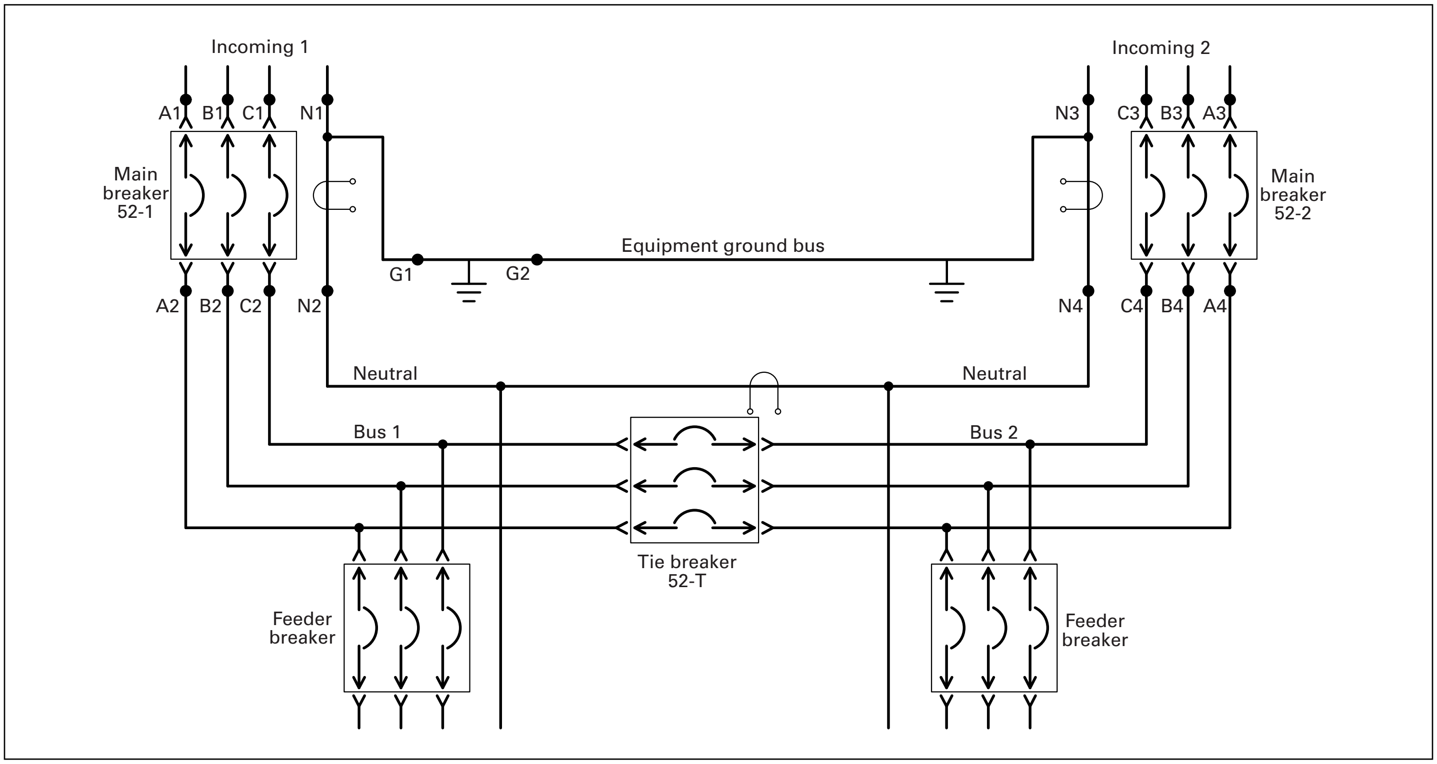


Figure 15. Three-line diagram for partial differential scheme

Test number	Breaker status 52-1	52-T	52-2	Feeders	Apply single-phase power to	Install jumper from	Results	Remarks
1	Closed	Open	Closed	Open	A1 and N1	A2 and N2	No trip	Polarity check for main 52-1 neutral sensor (see IL0131154EN for neutral sensor installation)
2	Closed	Closed	Open	Open	A1 and N1	A4 and N4	No trip	Polarity check for tie 51-T neutral sensor (see IL0131154EN for neutral sensor installation)
3	Closed	Open	Closed	Open	A3 and N3	A4 and N4	No trip	Polarity check for main 52-2 neutral sensor (see IL0131154EN for neutral sensor installation)
4	Closed	Open	Closed	Open	A1 and N1	A2 and G2	Main 52-1 trips	
5	Closed	Closed	Open	Open	A1 and N1	A4 and G2	Tie 52-T trips	If main 52-1 and tie 52-T have the same ground fault settings, main 52-1 may trip instead of tie 52-T
6	Closed	Open	Closed	Open	A3 and N3	A4 and G2	Main 52-2 trips	
7	Open	Closed	Closed	Open	A3 and N3	A2 and G2	Tie 52-T trips	If main 52-2 and tie 52-T have the same ground fault settings, main 52-2 may trip instead of tie 52-T

Repeat all of the above tests for “B” phase and “C” phase.

Note: If the above test does not pass, check that the incoming lines and loads are disconnected and that the test power supply and jumper connections are correct. If breaker is used in a ZSI application (not shown), either install a jumper from C19 to C21 or disable ZSI during testing.

Application notes for source ground / zero sequence transformer designs

The source ground / zero sequence ground fault protection method with the Magnum PXR and PD-SB circuit breakers has many combinations of current protection levels that can be achieved.

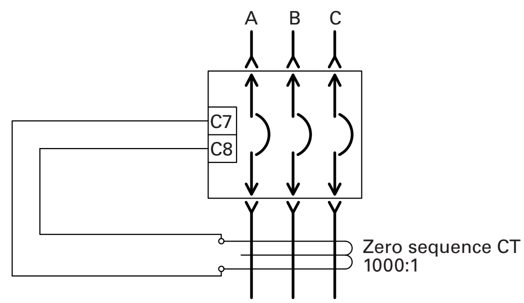
When the PXR trip unit is programmed to perform source ground / zero sequence ground fault protection, the trip unit will measure the current at breaker terminal inputs C7–C8 for the ground current. The input current on those terminals must only be from iron core current transformers and not from Rogowski coil sensors. The trip unit will look for 100 mA of current as the one per unit, which is the value in **Table 2** right column labeled as a multiple of 1.0.

Table 2. Ground fault pickup settings

		Ground fault pickup settings in amperes				
		Minimum	PXR 25 setpoint multiple			Maximum
		0.2	Range increments 0.1x			1.0
		PXR 20 setpoint multiple				
Physical CT combination	PXR ratio setting	0.2	0.4	0.6	0.8	1.0
1200:1 + 10:1	1200:1	240	480	720	960	1200
1000:1 + 10:1	1000:1	200	400	600	800	1000
800:1 + 10:1	800:1	160	320	480	640	800
400:1 + 10:1	400:1	80	160	240	320	400
4000:1	400:1	80	160	240	320	400
200:1 + 10:1	200:1	40	80	120	160	200
100:1 + 10:1	100:1	20	40	60	80	100
1000:1	100:1	20	40	60	80	100
50:1 + 10:1	50:1	10	20	30	40	50
500:1	50:1	10	20	30	40	50
25:1 + 10:1	25:1	5	10	15	20	25
250:1	25:1	5	10	15	20	25
10:1 + 10:1	10:1	2	4	6	8	10
100:1	10:1	2	4	6	8	10

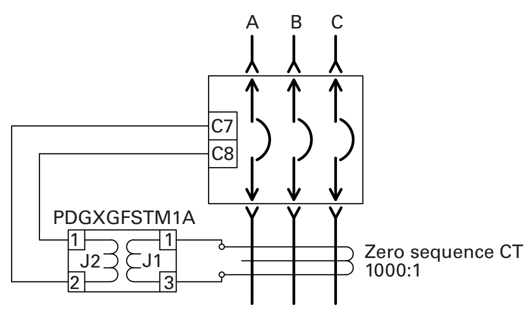
Table 2 shows current transformers with ratios of 100:1, 250:1, 500:1, 1000:1, and 4000:1. These transformers can be used without a secondary 10:1 transformer but their effective ratio is 10 times smaller. This is because the trip unit is looking for 0.1 A of current as the one per unit current instead of 1 A. Therefore, a 4000:1 transformer will have an effective ratio of 400:1. The effective 400:1 is what should be programmed into the trip unit for the source ground / zero sequence (SG/ZS) ratio setting as shown in the 5th row from the top in **Table 2**. Another example is **Figure 16** that shows a 1000:1 transformer being directly connected to the circuit breaker terminals C7–C8. The effective ratio will be 100:1.

Figure 17 shows how to use a 10:1 transformer module to create a straight ratio combination. The module is Eaton Catalog No. PDGXGFSTM1A. In this example, the 1000:1 transformer has the module connected to its secondary. Therefore, at 1000 A on the primary of the zero sequence transformer, the 1 A secondary is reduced to 0.1 A one per unit of current to the input of the circuit breaker and trip unit. The trip unit ratio setting in this example would be programmed for 1000:1 as shown in the second row from the top of **Table 2**. Other combinations are available as shown in the table. As low as 10 A for one per unit of current is available to provide a minimum ground fault protection setting at a 2 A level. More information on the 10:1 secondary transformer module can be found in instruction leaflet IL012309EN.



1000:1 transformer used to obtain a 100:1 effective ratio; programmed in the trip unit as 100:1

Figure 16. Zero sequence 100:1 scheme

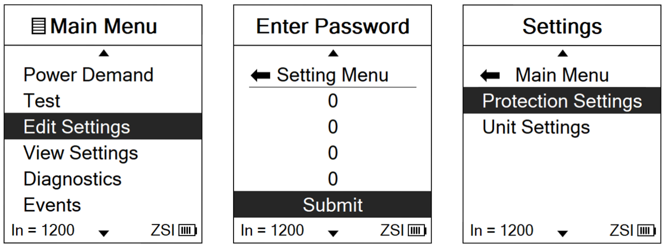


1000:1 transformer used with a 10:1 secondary transformer to obtain a 1000:1 effective ratio; programmed in the trip unit as 100:1

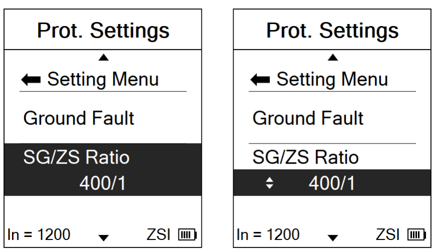
Figure 17. Zero sequence 1000:1 scheme

PXR 25 display screen images to select SG/ZS transformer ratio

The PXR 25 screens are shown below; however, they are similar to or the same as the PXR 20 screens. From the Edit Settings selection, press the Enter button and enter the password needed to access the Settings selection. Next, select the Protection Settings menu by highlighting it and pressing Enter.



Step to the SG/ZS Ratio setting and press the Enter button to edit the setting. The Up or Down Arrow buttons will cycle between the SG/ZS Ratio selection settings. Pressing the Enter button will return the setpoint to the non-edit mode and save the selection to memory. If the setting cannot be changed from the N/A (not applicable) setting, then the previous Ground Fault protection setting was programmed to be Residual and not Source/ZSeq.



Possible Ratio Settings
10:1
25:1
50:1
100:1
200:1
400:1
800:1
1000:1
1200:1

Primary injection test procedures for source ground or zero sequence ground fault systems

Test procedures

Three-wire system—zero sequence ground fault

⚠ DANGER

DO NOT ATTEMPT TO TEST THIS EQUIPMENT WHILE IT IS ENERGIZED. DEATH OR SEVERE PERSONAL INJURY COULD RESULT. TURN OFF ALL POWER SUPPLYING THIS EQUIPMENT AND CHECK FOR VOLTAGE BEFORE TESTING.

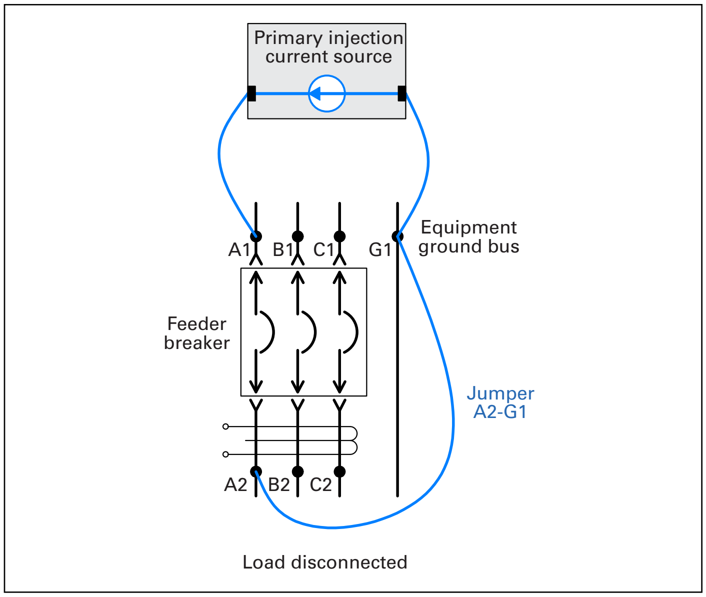


Figure 18. Three-line diagram with phase A test connections

Breaker status	Apply single-phase current to	Install jumper from	Results	Remarks
Closed	A1 and G1	A2 and G1	Breaker times out and trips	

Repeat the above test for "B" phase and "C" phase.

Note: If the above test does not pass, check that the incoming lines and loads are disconnected and that the test power supply and jumper connections are correct. If breaker is used in a ZSI application (not shown), either install a jumper from C19 to C21 or disable ZSI during testing.

Four-wire system—zero sequence ground fault

⚠ DANGER

DO NOT ATTEMPT TO TEST THIS EQUIPMENT WHILE IT IS ENERGIZED. DEATH OR SEVERE PERSONAL INJURY COULD RESULT. TURN OFF ALL POWER SUPPLYING THIS EQUIPMENT AND CHECK FOR VOLTAGE BEFORE TESTING.

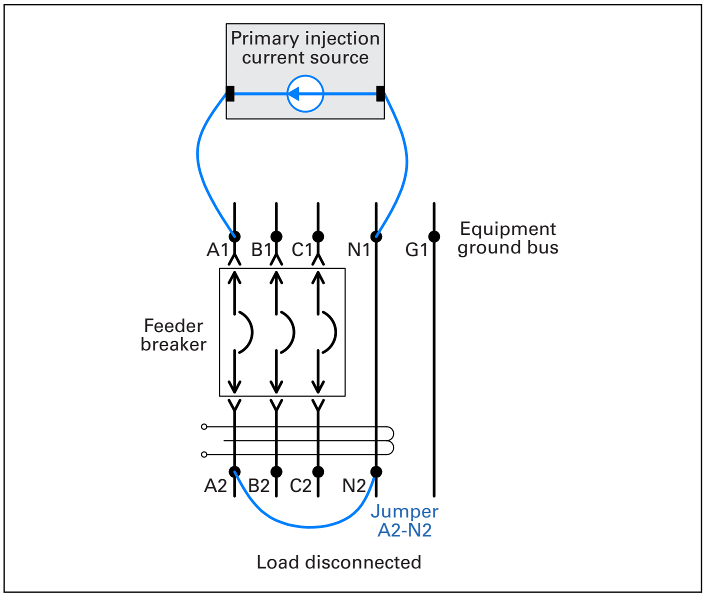


Figure 19. Three-line diagram with phase A no trip test connections

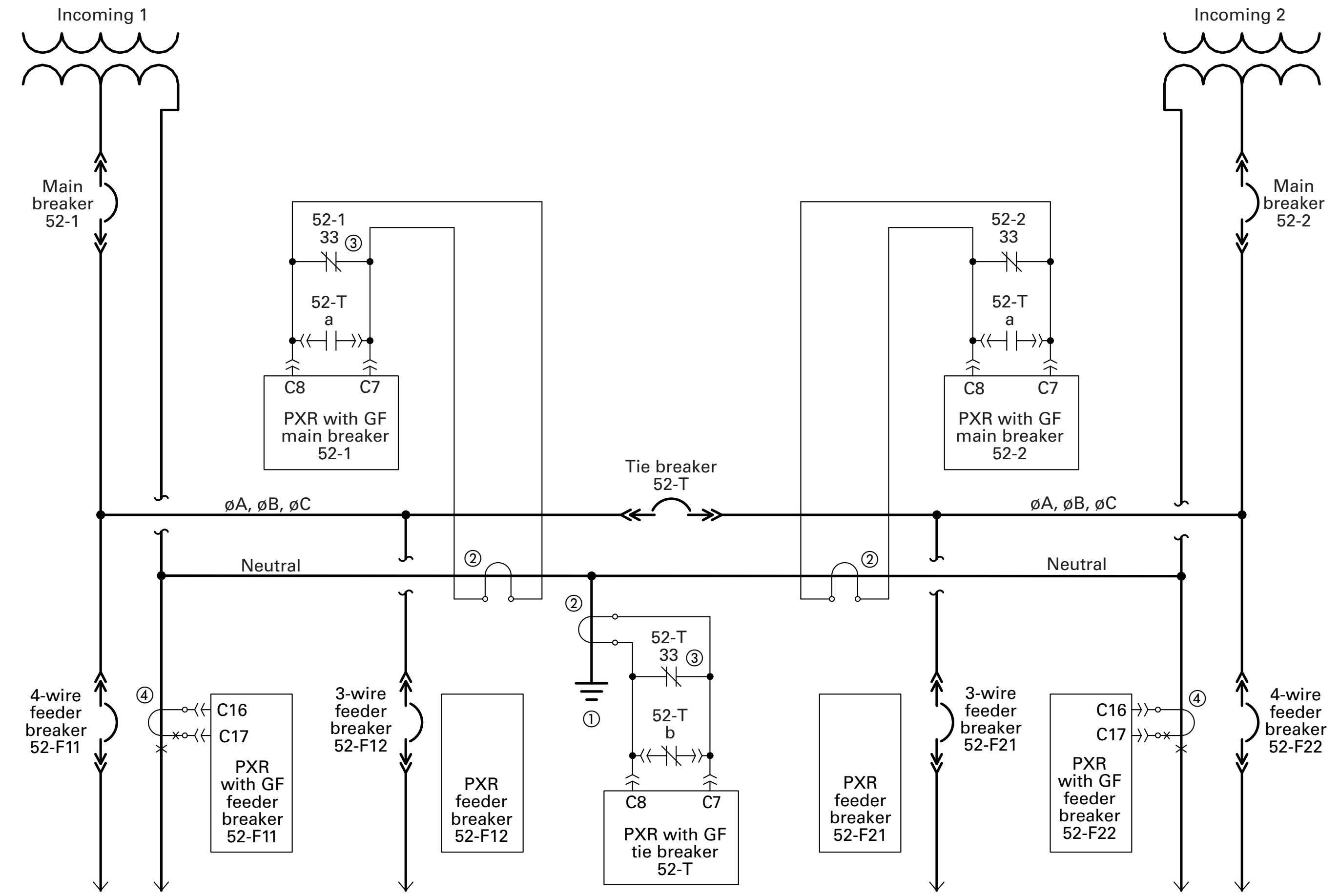
Breaker status	Apply single-phase power to	Install jumper from	Results	Remarks
Closed	A1 and N1	A2 and N2	No trip	
Closed	A1 and G1	A2 and G1	Breaker times out and trips	

Repeat the above test for "B" phase and "C" phase.

Note: If the above test does not pass, check that the incoming lines and loads are disconnected and that the test power supply and jumper connections are correct. If breaker is used in a ZSI application (not shown), either install a jumper from C19 to C21 or disable ZSI during testing.

Primary injection test procedures for double-ended source ground fault systems

Typical double-ended four-wire system single-point grounding “T” connection



① No other grounding of the neutral bus should be made. To do so will defeat protection.

② The neutral CT should be selected based on application requirements. Refer to **Table 2** for available ratios. PXR trip unit must be programmed for Source/ZSeq in the settings. Trip unit reads the magnitude of the sensor output but not the direction (not polarity sensitive).

③ Cell switch contact only applies to drawout breakers. If fixed-mounted breakers are used, this contact is eliminated.

④ Use either CT type neutral sensor Catalog No. MSCNCT or Rogowski type neutral sensor Catalog No. NRMPN, sized for all breaker ratings. Double-wide breakers can use a single neutral sensor of either type or two CT type sensors mounted and wired in parallel. PXR trip unit must be programmed for appropriate neutral sensor type in the settings.

⑤ If breaker is used in a ZSI application (not shown), either install a jumper from C19 to C21 or disable ZSI during testing.

Figure 20. Typical single-point ground fault scheme for switchgear

Test procedure: double-ended, four-wire, single-point grounding "T" connection with Magnum PXR or PD-SB

⚠ DANGER

DO NOT ATTEMPT TO TEST THIS EQUIPMENT WHILE IT IS ENERGIZED. DEATH OR SEVERE PERSONAL INJURY COULD RESULT. TURN OFF ALL POWER SUPPLYING THIS EQUIPMENT AND CHECK FOR VOLTAGE BEFORE TESTING.

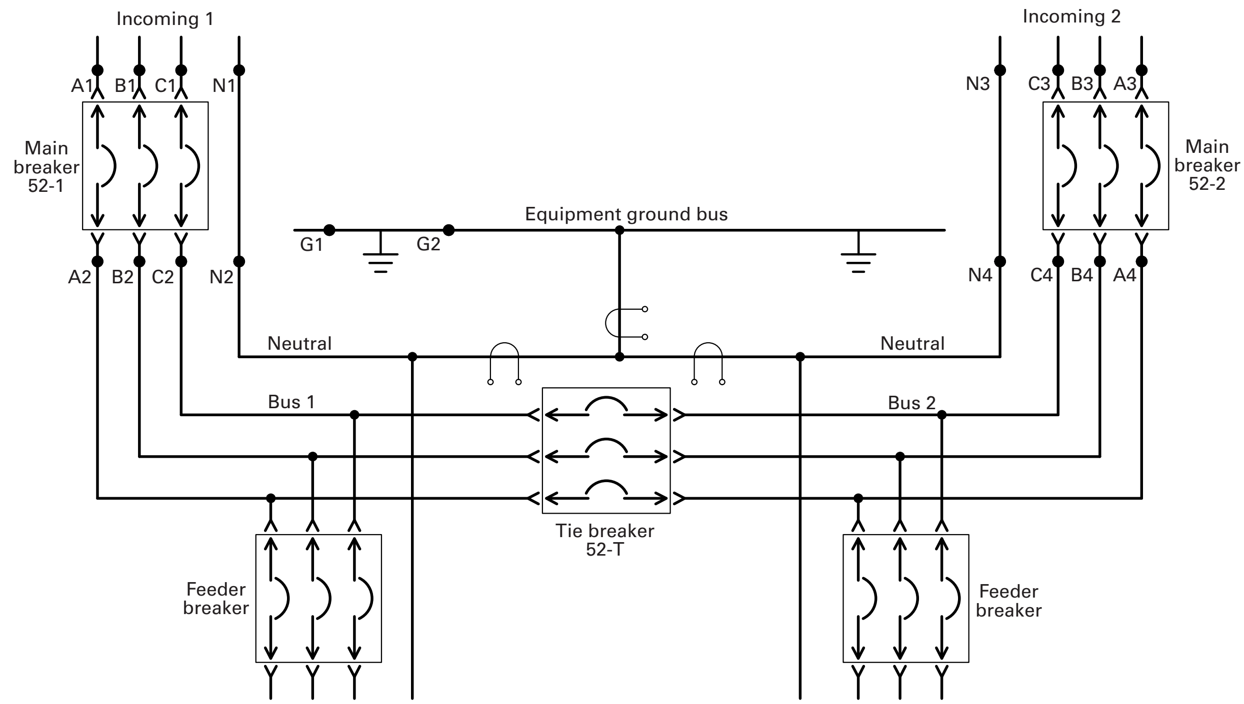


Figure 21. Three-line diagram for single-point ground scheme

Test number	Breaker status 52-1	52-T	52-2	Feeders	Apply single-phase power to	Install jumper from	Results	Remarks
1	Closed	Open	Closed	Open	A1 and N1	A2 and G2	Main 52-1 trips	If no trip, check trip unit is programmed for Source/ZSeq
2	Closed	Closed	Open	Open	A1 and N1	A2 and G2	Tie 52-T trips, then main 52-1 trips	If no trip, check trip unit is programmed for Source/ZSeq
3	Closed	Closed	Open	Open	A1 and N1	A4 and G2	Tie 52-T trips	If no trip, check trip unit is programmed for Source/ZSeq
4	Closed	Open	Closed	Open	A3 and N3	A4 and G2	Main 52-2 trips	If no trip, check trip unit is programmed for Source/ZSeq
5	Open	Closed	Closed	Open	A3 and N3	A4 and G2	Tie 52-T trips, then main 52-2 trips	If no trip, check trip unit is programmed for Source/ZSeq
6	Open	Closed	Closed	Open	A3 and N3	A2 and G2	Tie 52-T trips	If no trip, check trip unit is programmed for Source/ZSeq

Repeat all of the above tests for "B" phase and "C" phase.

Note: If the above test does not pass, check that the incoming lines and loads are disconnected and that the test power supply and jumper connections are correct. If breaker is used in a ZSI application (not shown), either install a jumper from C19 to C21 or disable ZSI during testing.

Ground fault test record form

Test date	Circuit breaker no.	Results	Tested by

Ground fault test record should be retained by those in charge of the building's electrical installation to be available to the authority having jurisdiction.

Maintenance Mode testing

The Magnum PXR and PD-SB Maintenance Mode protection, Arcflash Reduction Maintenance System™, is designed to meet the requirements in the National Electrical Code 240.87 Arc Energy Reduction.

There are many arc reduction protection techniques that were developed by manufacturers to reduce the energy caused by an accidental arc flash event. Several of the techniques use high-speed trigger mechanisms that when triggered must be replaced like testing a fuse. The 2020 National Electrical Code makes the exception for Maintenance Mode arc energy reduction system testing and allows the protection to be tested using the manufacturer's instructions, which can include secondary injection methods.

NEC 240.87(c) performance testing

"The arc energy reduction protection system shall be performance tested by primary current injection testing or another approved method when first installed on site. This testing shall be conducted by a qualified person(s) in accordance with the manufacturer's instructions. A written record of this testing shall be made and shall be available to the authority having jurisdiction. Informal note: some energy reduction protection systems cannot be tested using a test process of primary injection due to either the protection method being damaged, such as with the use of fuse technology or because current is not the primary method of arc detection."

This document is intended to provide instructions for conformance testing of the Maintenance Mode system utilizing type Magnum PXR and PD-SB circuit breakers. These instructions may be applied, accordingly, on these systems. Refer to specific drawings for the system to determine the actual maintenance system options wired for the system you have.

⚠ DANGER

DO NOT ATTEMPT TO TEST THIS EQUIPMENT WHILE IT IS ENERGIZED. DEATH OR SEVERE PERSONAL INJURY CAN RESULT. TURN OFF ALL POWER TO THIS EQUIPMENT AND CHECK FOR THE PRESENCE OF VOLTAGE BEFORE TESTING.

Overall system performance of the integral Arcflash Reduction Maintenance System Maintenance Mode protection can be field tested by using the secondary current injection method using the Eaton PXPM software. Alternatively, the primary injection method can be used but there are limitations as explained in section Alternative Primary Injection Testing.

1. Tests are to be conducted by qualified personnel.
2. The incoming line or source transformer must be disconnected from the switchgear.
3. Loads must be disconnected from the switchgear when testing circuit breakers. If only the breakers with Maintenance Mode are to be tested, all other breakers and feeder breakers must be open.

Alternative primary injection testing

The Magnum PXR or PD-SB with Arcflash Reduction Maintenance System protection can be tested with primary injection techniques. It is recommended that a low protection current pickup level setting, such as 2.5X, be selected. This avoids the need for high currents and large heavy cables. Short connections to the breakers should be utilized.

There can be differences in the single-phase primary injection tests to the Time Current Curve data that is based on three-phase testing.

Maintenance Mode application

There are rare occasions that maintenance on a power system needs to be performed although the power system cannot be shut down because of critical loads. If the power cannot be turned off and an accidental short circuit should occur, it is well documented how the arcing energy from that short circuit can cause loss of life, injury, burns, and equipment damage. Eaton developed a special protection circuit that, when enabled, provides a fast-acting trip of the circuit breaker when a short circuit is detected. Tripping the circuit breaker very fast reduces the arcing time, which reduces the arc energy that happens during this event. This protection circuit is separate from the standard Long, Short, Instantaneous, and Ground (LSIG) protection. The Arcflash Reduction Maintenance System Maintenance Mode protection overlaps the LSIG protection, which redundantly operates in the background as shown in **Figure 22**.

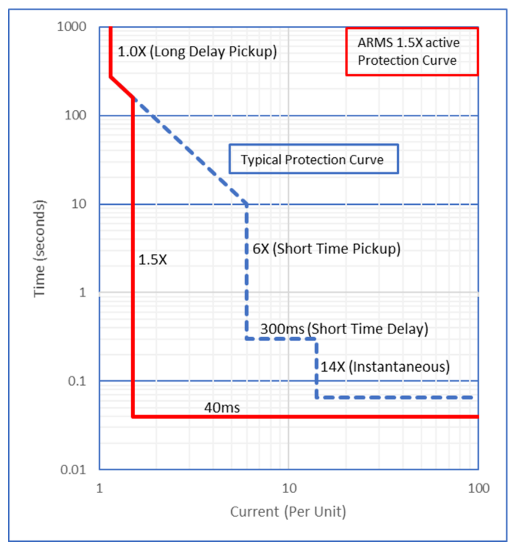


Figure 22. Example LSI curve with Arcflash Reduction Maintenance System curve

Maintenance Mode settings

The Eaton arc energy reduction protection system provides the user with the ability to set a pickup setting on the overcurrent protection level. It takes time to calculate a true rms value of the fault current, therefore, the arc energy reduction circuit is a peak detecting circuit to provide the fastest tripping time of the circuit breaker. When the power system is connected to a critical load and users want to avoid shutdown, it is recommended that a power system study is performed so common scenarios, like inrush current from a motor load, can be taken into account with the trip settings. If a systems study is done on the loads and there could be a motor startup inrush current while the Maintenance Mode is active, the trip level of the Maintenance Mode can be adjusted from a low of 1.5x up to 10x times the circuit breaker rating (I_n) current to ride out this inrush. If the trip level is extended to the maximum pickup and the fault is over that level, the time difference is not that significant. As shown in **Figure 23**, the time taken to detect the fault level is between when the electronics power up and the trip actuator is energized.

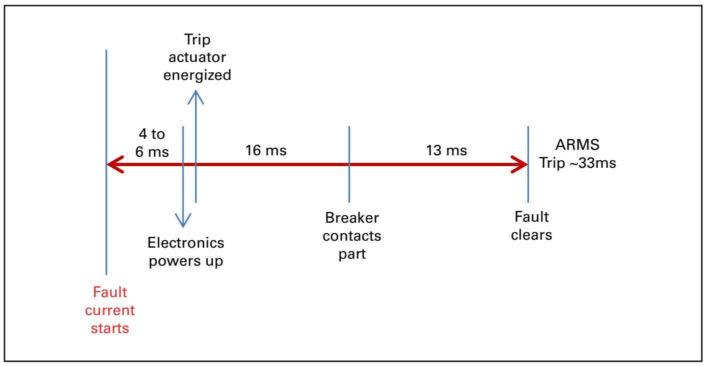
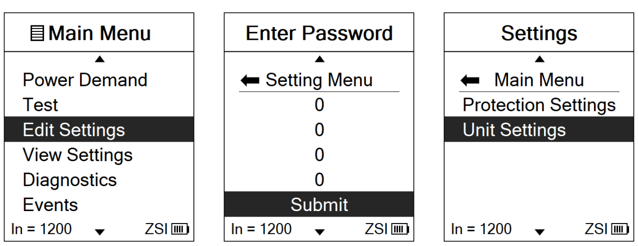


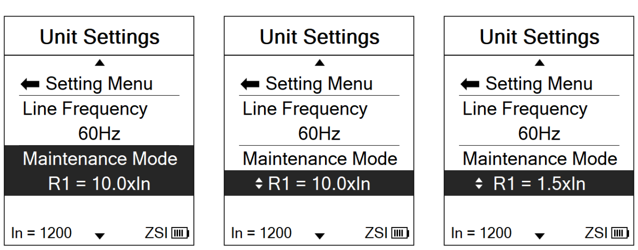
Figure 23. Typical arc reduction protection timing

PXR 25 display screen images to program Maintenance Mode pickup level

The PXR 25 screens are shown below; however, they are similar to or the same as the PXR 20 screens. From the Edit Settings selection, press the Enter button and enter the password needed to access the Settings selection. Next, select the Unit Settings menu by highlighting it and pressing the Enter button. Then, step to the Maintenance Mode selection.

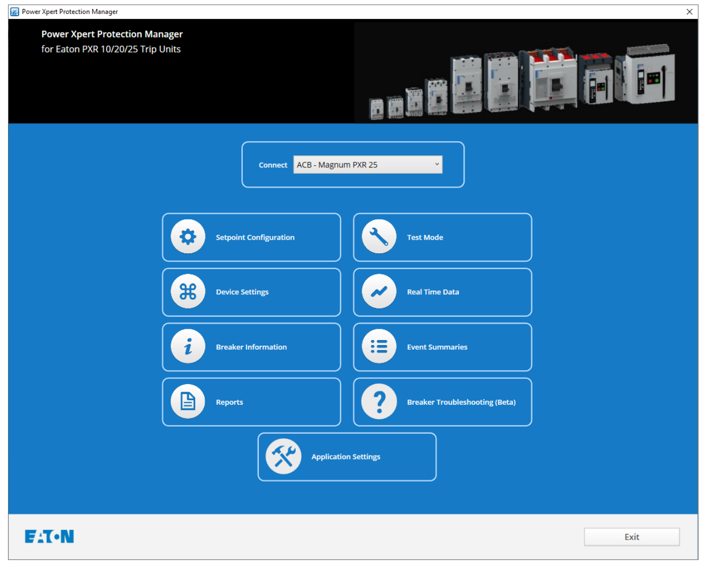


With the Maintenance Mode setting highlighted, press the Enter button and the setpoint can be edited using the Up and Down arrows. Pressing the Enter button will return the setpoint to the non-edit mode and save the selection to memory.



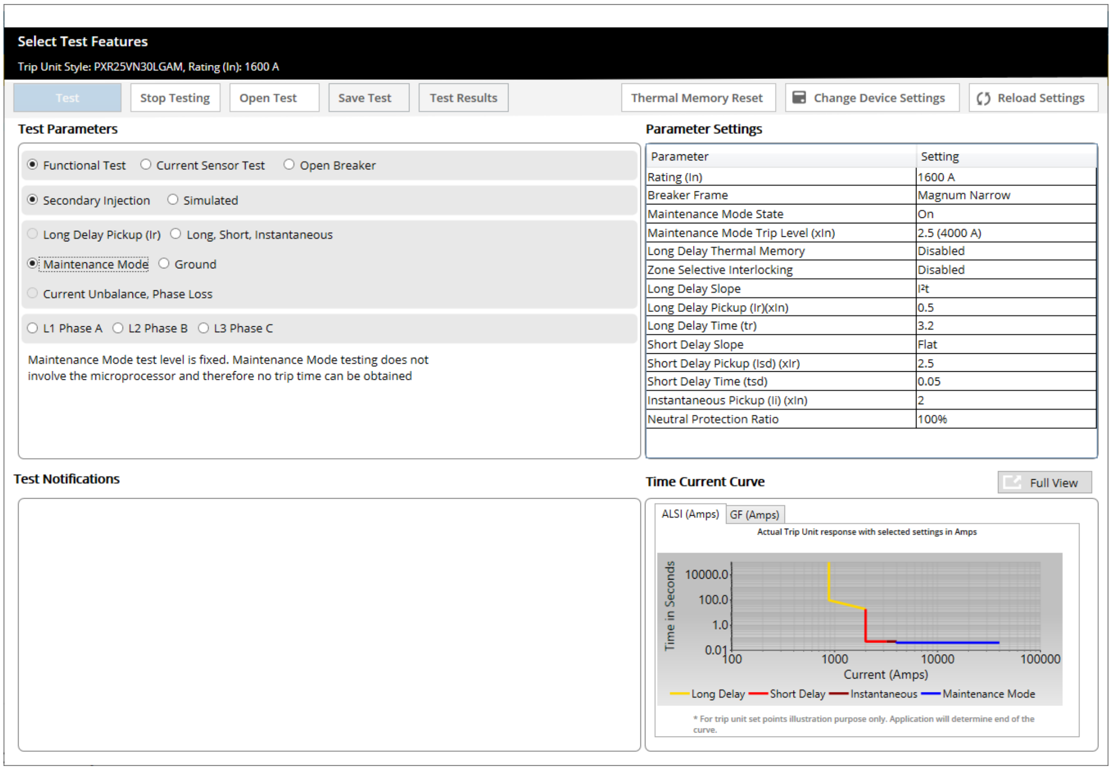
Using PXPM to perform a Maintenance Mode test

With the USB cable connected to the computer and the PXR trip unit, start the PXPM software. When the home screen comes up as shown below, check that the software has recognized the trip unit in the connected box in the middle of the screen. If it hasn't been recognized, then the software will display "No Device" and ask if you want to Enter Simulation Mode. Check the cable and connections. Many times, the USB cable used is only a charging cable with +5 V and GND connections and no communications capability.

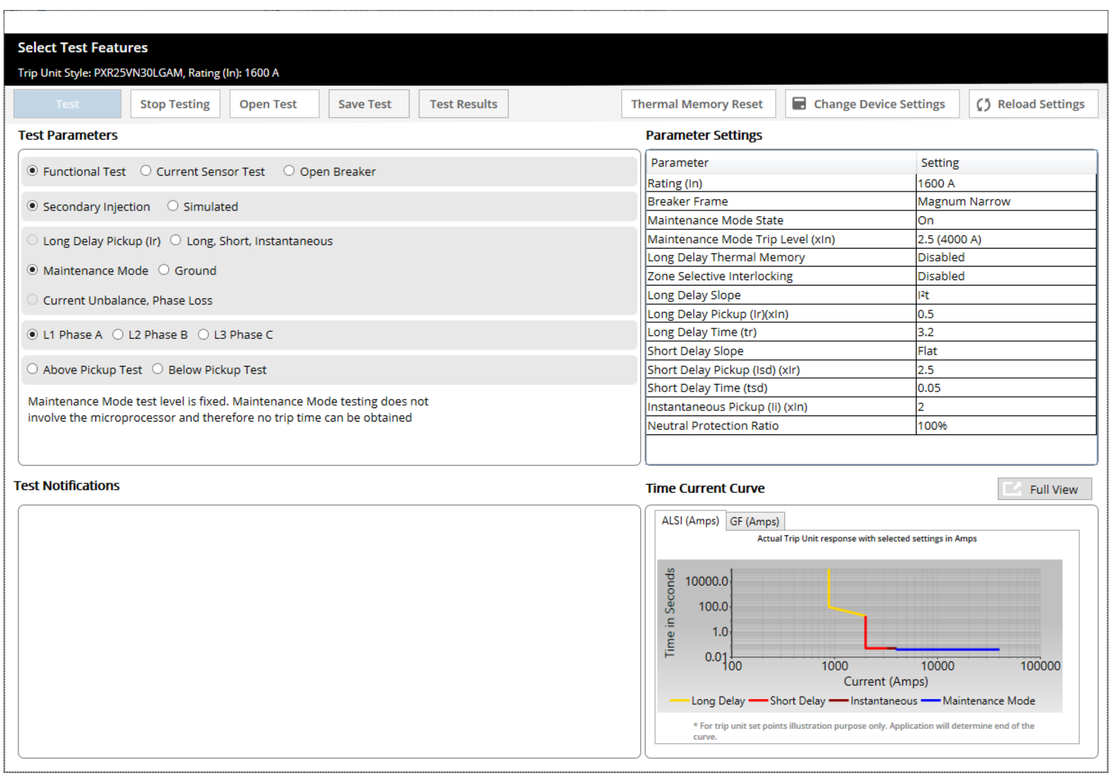


Click on the Test Mode box to bring up the testing screens.

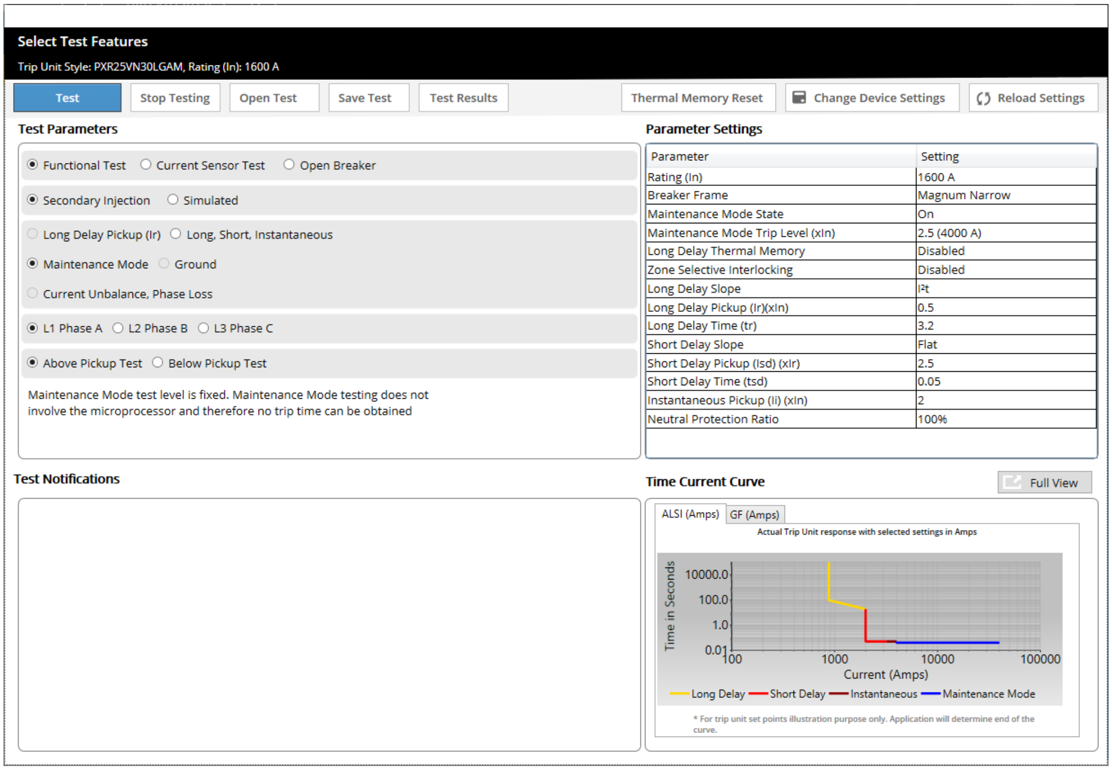
Select the Functional Test, Secondary Injection, and Maintenance Mode options. If the Maintenance Mode option is grayed out, check to ensure that Maintenance Mode is turned on.



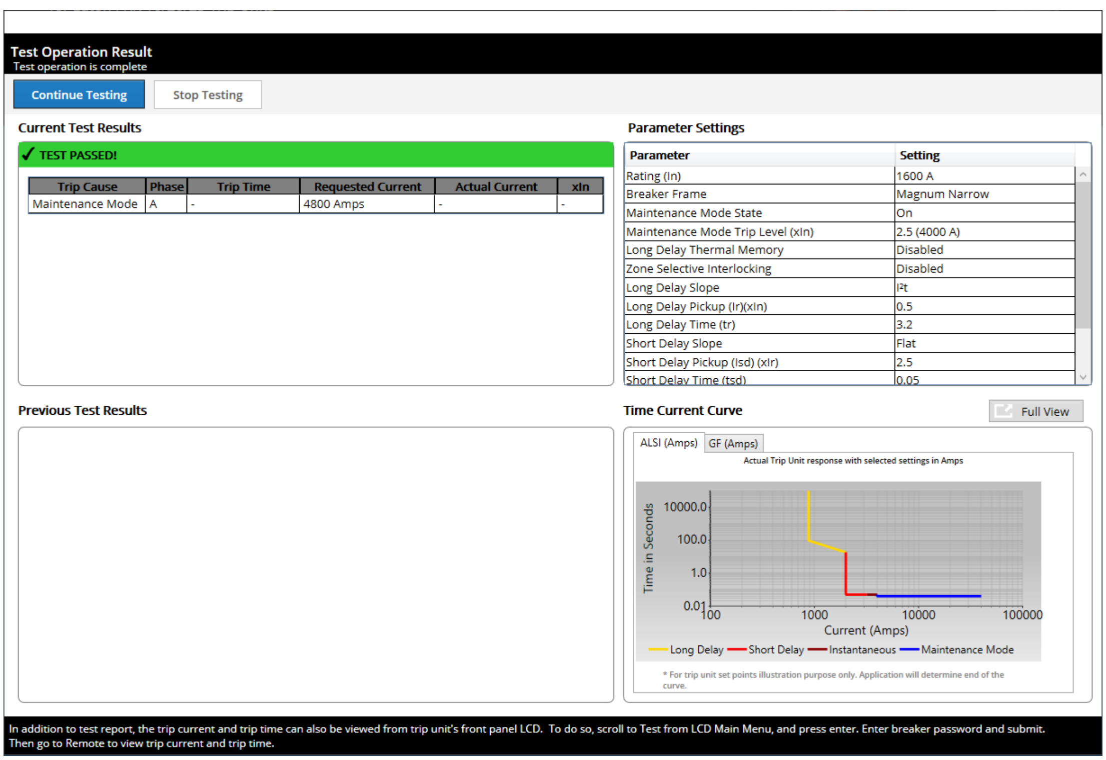
You can then decide which phase of the secondary inputs to the trip unit that you want to test.



Next, you can decide if you want to perform a trip or no trip test. The software asks if the test current should be above pickup (trip test) or below pickup (no trip test). As the note says in the screen, that the Maintenance Mode circuit is separate from the main protection processor and no trip time is recorded to be displayed in PXPM. If you pick Below Pickup Test, the PXPM software will pick a value of current below the pickup. For example, if the Arcflash Reduction Maintenance System trip setting is 2.5x, the software will choose 2x current for the below pickup value. Once the test is set up, click Test at the top left of the window.



After the test runs, a screen displays the results. From here you can select Continue Testing to return to the test screen and run additional tests, or you can select Stop Testing to close out of the test window.



When testing is complete, a test report can be generated by selecting Generate Report from the Final Setting Adjustments window, or by selecting Reports from the PXPM home screen.

Final Setting Adjustments

Exit Testing | Generate Report | Change Device Settings | Reload Settings | Continue Testing

Below is a chart of the Parameters and Settings. The "As Found" Settings that were captured before testing began are listed for your convenience. Please make any necessary changes to the settings. Choosing Exit Testing will capture these settings. These settings will be located in the test report as the as the "As Left" settings.

Choose Generate Report in order to save the test data.If you choose Exit Testing you can generate a test report for tests performed in current test cycle from the main screen using the Report button.

Highlighted values indicate a difference between the "As Found" setting and the existing "As Left" setting.

Parameter	As Found	As Left
Rating (In)	1600 A	1600 A
Maintenance Mode State	Off	Off
Maintenance Mode Trip Level (xIn)	2.5	2.5
Line Frequency	60 Hz	60 Hz
Reverse Feed Breaker	Forward	Forward
Language Setting	English	English
Long Delay Thermal Memory	Disabled	Disabled
Zone Selective Interlocking	Disabled	Disabled
Long Delay Slope	I^2t	I^2t
Long Delay Pickup (Ir)(xIn)	0.5	0.5
Long Delay Time (tr)	3.2	3.2
Highload 1 (xIr) (LED Blinking)	73 %	73 %
Highload 2 (xIr) (LED Solid)	105 %	105 %
Short Delay Slope	Flat	Flat
Short Delay Pickup (Isd) (xIr)	2.5	2.5
Short Delay Time (tsd)	0.05	0.05
Instantaneous Pickup (Ii) (xIn)	2	2
Ground Sensing Type	NA	Residual
Ground Fault Protection Setting	Off	Trip
Ground Fault Slope	NA	Flat
Ground Fault Pickup (Ig) (x1200A)	NA	0.2
Ground Fault Trip Time	NA	0.2
Neutral Protection Ratio	100%	100%

EATON Powering Business Worldwide

Power Xpert Protection Manager for PXR 10/20/25 Trip Units - Test Report

Created: 10/4/2023 10:22:06 AM

Protection / Configuration Settings #1

Parameter	Setting	Parameter	Setting	Parameter	Setting
Maint. Mode	Off	HL1	73 %	GST	Residual
MM Trip Level	2.5	HL2	105 %	GF Setting	Trip
LDTM	Disabled	SDS	Flat	GFS	Flat
LDS	I^2t	SDPU	2.5	GFPU	0.2
LDPU	0.5	SDT	0.05	GFT	0.2
LDT	3.2	INST	2	GFTM	Disabled
NPR	100%	ZSI	Disabled		

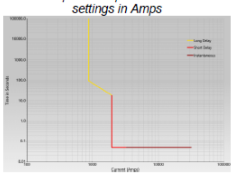
Motor Settings #1

Parameter	Setting	Parameter	Setting
Over Voltage	Off / 180 V / 1 S	Under Voltage	Off / 60 V / 1 S
Voltage Unbalance	Off / 5 % / 1 S	Current Unbalance	Off / 5 % / 1 S
Reverse Power	Off / 1 KW / 1 S	Phase Loss	Off / 1 S

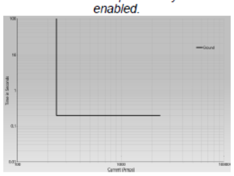
Maintenance Mode Test Results #1

Test Settings				Test Results	
Phase	Current(Amps)	Multiple	Type	Cause	Result
A	4800	3.00 xIn	Above Pickup	Maintenance Mode	Passed

Actual Trip Unit response with selected settings in Amps



Ground Fault Response only when enabled.



** For trip unit set points illustration purpose only. Application will determine end of the curve.*

Alternatively, the test can be recorded in the sample test report forms at the end of this document.

Arc energy reduction test record form

Test date	Circuit breaker no.	Results	Tested by

The Arcflash Reduction Maintenance System Mode test record should be retained by those in charge of the building's electrical installation to be available to the authority having jurisdiction.

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