INSTRUCTIONS

Ground fault protection systems

Performance testing

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General information

The circuit diagrams included in this manual are for illustration of typical applications and are not intended as constructional information. Although reasonable care has been taken in their preparation to assure their technical correctness, no responsibility is assumed by ABB for any consequences of their use.

The devices and arrangements disclosed herein may be covered by patents of ABB or others. Neither the disclosure of any information herein nor the sale of devices by ABB conveys any license under patent claims covering combinations of devices with other devices or elements.

In the absence of any express written agreement to the contrary, ABB assumes no liability for patent infringement arising out of any use of the devices or elements by any purchaser of devices or others.

Purpose
The purpose of this publication is to provide instructions for testing ground fault protection (Ground fault protection) systems in ABB low-voltage equipment.

These instructions are for use with equipment manufactured by ABB, in accordance with the National Electrical Code, Section 230-95.

NEC 230-95(c) reads as follows:
(c) The ground-fault protection system shall be performance tested when first installed on site. 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.

Instructions applicable to

Equipment	ReliaGear SB and LV SG
Circuit breakers	Power, insulated case, and molded case circuit breakers with EntelliGuard TU and and Ekip Dip and Touch/Hi-Touch trip units.
Fusible switch	HPCII with integral ground fault tripping
Ground fault relays & sensors	Ground-Break System or similar ground fault relays and sensors (CT's) used to trip any circuit breaker or switch with a shunt trip.

Testing by qualified personnel
Performance testing of the ground fault protection system should be undertaken only by qualified personnel. Particularly in the tests requiring the use of a high-current test set, it is usually necessary to obtain the services of a qualified testing organization. ABB's Maintenance and Field Services organization is qualified and equipped to provide this testing service.

Checklist for ground fault performance testing

Problems that may be encountered that can prevent proper GROUND FAULT PROTECTION operation	How to check for this condition
On 3-phase 4-wire systems, the neutral conductor should not have additional grounding connections made downstream from the main bonding jumper which must be located in the service entrance section. (Refer to NEC 250-23). This condition may cause loss of sensitivity in sensing ground fault current.	By visual inspection. By measurement of resistance between neutral conductor and ground bus. In the high-current tests this condition may be the cause if it takes over 150% of ground fault current setting to initiate tripping.
Neutral sensor in residual sensor arrangements or with integral Ground fault trip circuit breaker may be installed with incorrect polarity with respect to the associated phase sensors. This will cause false tripping by reading balanced load current as imbalanced and interpreting the error slgnal as a fault situation.	By visual inspection. In the high-current testing the "no-trip" tests will detect this condition.
Neutral conductor in a load circuit must pass through a zero-sequence sensor in the same direction as the phase conductors. Unbalanced signals cause false tripping.	
When a given circuit is monitored by a zero-sequence sensor, none of the conductors shall be omitted from passing through the sensor. Unbalanced signals cause false tripping.	
An equipment bonding or grounding conductor must not be passed through the window of a ground fault sensor. This will cause cancellation of error signals, and will prevent ground fault tripping when it is needed.	Inspect load cables and grounding connections between conduits and the switchboard ground bus. The grounding connections must not pass through a zero-sequence sensor with phase and neutral wires.
The ground fault protection may be rendered inoperable by damaged wiring or devices, blown or missing control fuses, or lack of tripping power when supplied from a remote source.	If the high-current tests do not produce expected tripping, check for control power at transformers, at fuses, and at relays.

Testing methods

General
There are two alternate test methods for evaluating ground fault protection (Ground fault protection) systems - by using simulated fault current or by high-current primary injection. Both test methods are applicable to ground-fault relay systems, but only the high-current primary injection method can be used to test a system with integral ground-fault trip circuit breakers.

If it is acceptable to the local inspection authorities, ground fault relay systems may be tested by the simulated fault current testing method combined with a thorough visual inspection. Otherwise, it will be necessary to use the high-current primary injection test method.

Ground fault protection testing with simulated fault current
In the simulated fault current method, a simulated fault current is generated by a coil around a window-type sensor or by means of a separate test winding in the sensor. When the monitor panel sends a small current through the test winding, it produces a secondary current in the sensor which the relay responds to as if it were caused by a primary current of 1600 amperes.

In an equivalent method which can be used with any window-type sensor supplying a ground fault relay, a number of turns of wire are wrapped around the sensor core, such as twenty turns of #14 wire. A current of approximately 125 percent of the pickup setting of the relay divided by the number of turns is passed through the wire to simulate the ground-fault current. By setting the relay pickup to the low end of the range, the test current may be kept to a minimum.

Testing with simulated fault current provides a means of demonstrating the operation of the sensor, relay and shunt trip and the adequacy of the control power supply. In addition to these items, the ground fault protection system must be checked to confirm that neutral ground points are located correctly with respect to sensors, that sensor polarities are correct when several are connected in parallel, and that conductors which pass through a sensor window all run in the same direction. If done thoroughly by a qualified person, a visual inspection can confirm that these items have been taken care of correctly.

The importance of supplementing simulated fault current testing with an adequate inspection is emphasized when one realizes that the first five items on the items on the checklist, from the previous page, are problems that can NOT be detected by simulated fault current testing alone.

Ground fault protection testing by high-current primary injection

The high-current injection test method may be used to test ground fault protection systems with either ground fault relays or integral ground fault trips on circuit breakers. With relays, it is an alternative to simulated fault-current testing supplemented by inspection. We recommend it as the best way to test the performance of ground fault protection systems with relays.

Integral ground fault protection in circuit breakers can be system-tested only by using the high-current injection test method. The internal electronics of these circuit breakers can be checked out with the Ekip TT or Ekip T&P for the Emax 2 and/or Tmax Xt circuit breakers. These sets are not suitable for making system tests, however.

High-current testing of ground fault protection systems consists of injecting full-scale current into the equipment phase and neutral conductors to duplicate the flow of ground fault current under various conditions. The testing equipment required includes a high-current supply capable of delivering up to 1000 amperes or more at 2.5 volts, or similar.

By using the lower ground fault current pickup settings on relays and circuit breakers or switches, the current required to trip can be kept to a minimum, such as 300 or 400 amperes or less. If inspection authorities require tests at full ground fault protection setting, a current supply capable of delivering 1200 amperes or more may be needed.

Connect the current supply as shown in the diagrams on the following pages, using flexible welding cable such as No. 2 AWG. Also connect jumpers between the points indicated in the tables accompanying the same referenced diagrams.

Ground fault protection in three-wire equipment

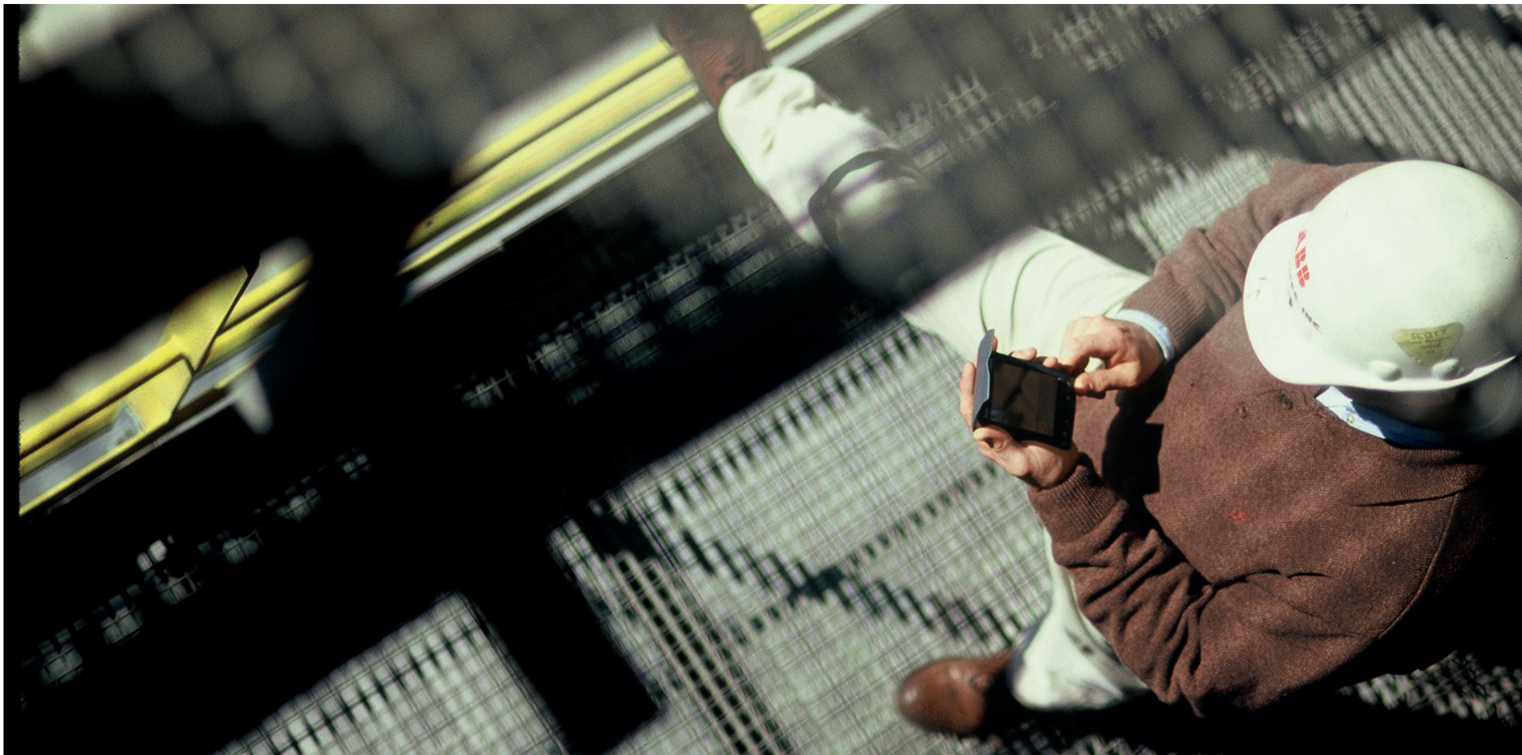
Ground fault protection can be provided for 3-wire and 4-wire equipment fed from a solidly grounded 4-wire supply, wye or delta. NEC Article 250-23(b) requires that whenever a service is derived from a grounded neutral system, the grounded neutral conductor must be brought into the service entrance equipment, and bonded to the equipment enclosure and ground bus, even if the grounded conductor is not needed for the load supplied by the service. This is required to provide a low-impedance ground fault current return path to the neutral to assure operation of the overcurrent device.

Test diagrams for systems with ground fault relays

Figure	Description
1	Main circuit breaker with ground fault relay and ground return sensor
2	Main circuit breaker with ground fault relay and zero-sequence sensor arrangement
3	Main circuit breaker with ground fault relay and residual sensor arrangement
4	Feeder circuit breaker with ground fault Relay and zero- sequence sensor arrangement
5	Ground fault relay protection on normal and emergency main circuit breakers interlocked for automatic throwover
6	Ground fault relay protection on normal and emergency main circuit breakers with automatic transfer switch (3-pole)
7	Double-ended substation - (transformers not individually grounded) Single-point ground and ground fault relays
8	Double-ended equipment - (both sources grounded) Modified differential scheme with ground fault relays.

Test notes

1. All tests are for 3-phase, 4-wire unless noted as 3-phase 3-wire.
2. Notes on diagrams referring to tripping at ground fault setting are intended to imply nominal values. Consistent tripping may require 125% of pickup settings, and good time-delay figures may be obtained only at 150% and higher.
3. WARNING In all the illustrations the source transformer(s) must be deenergized when applying and using the test current.
4. A temporary source of control power (usually 120 VAC) will be needed for operation of ground-break relays and shunt trip devices.



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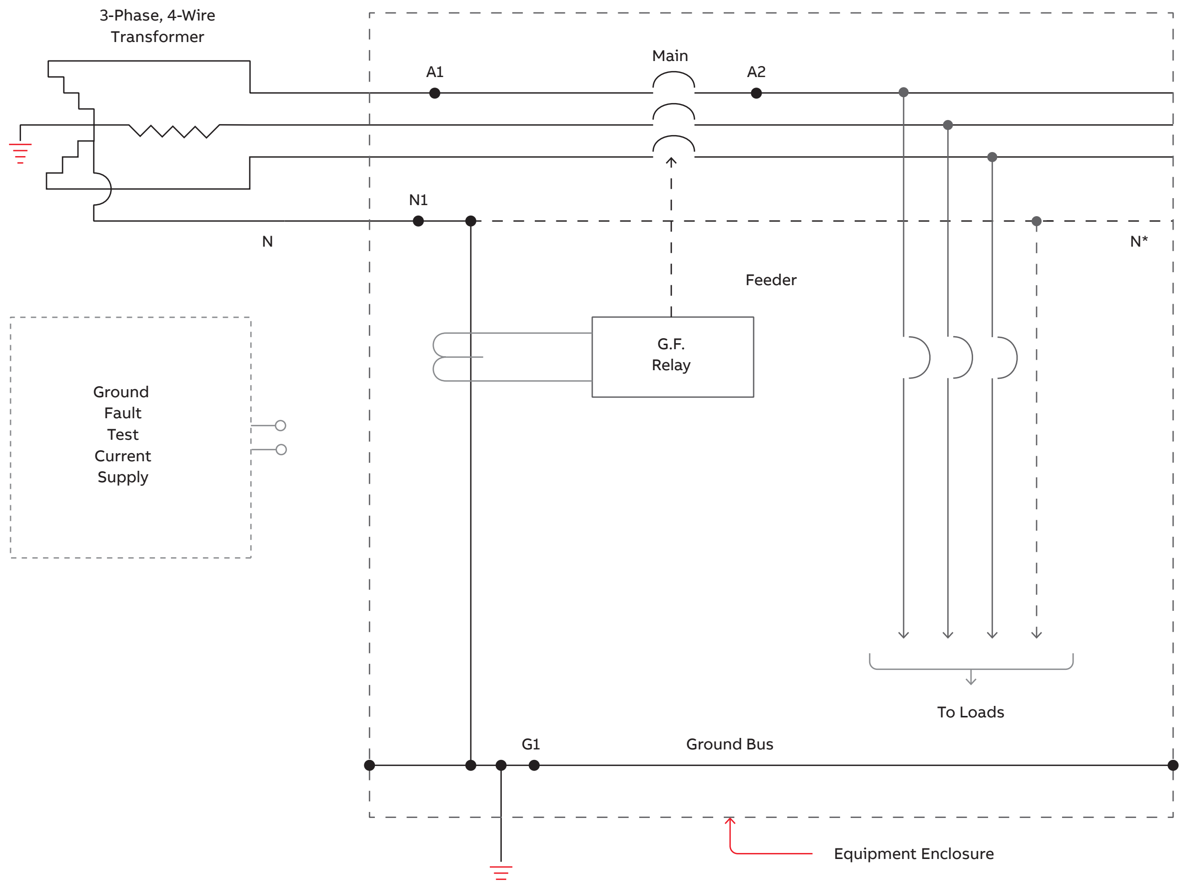
01
Main circuit breaker with ground fault relay and ground-return sensor



Test no.	Connect test current supply to points	Connect jumper between points	Results expected	Comments
1-1	A1 and N1	A2-G 1	Main circuit breaker should trip	Confirms continuity of ground path from ground bus to neutral

* In 3-wire equipment the load neutral is not furnished.

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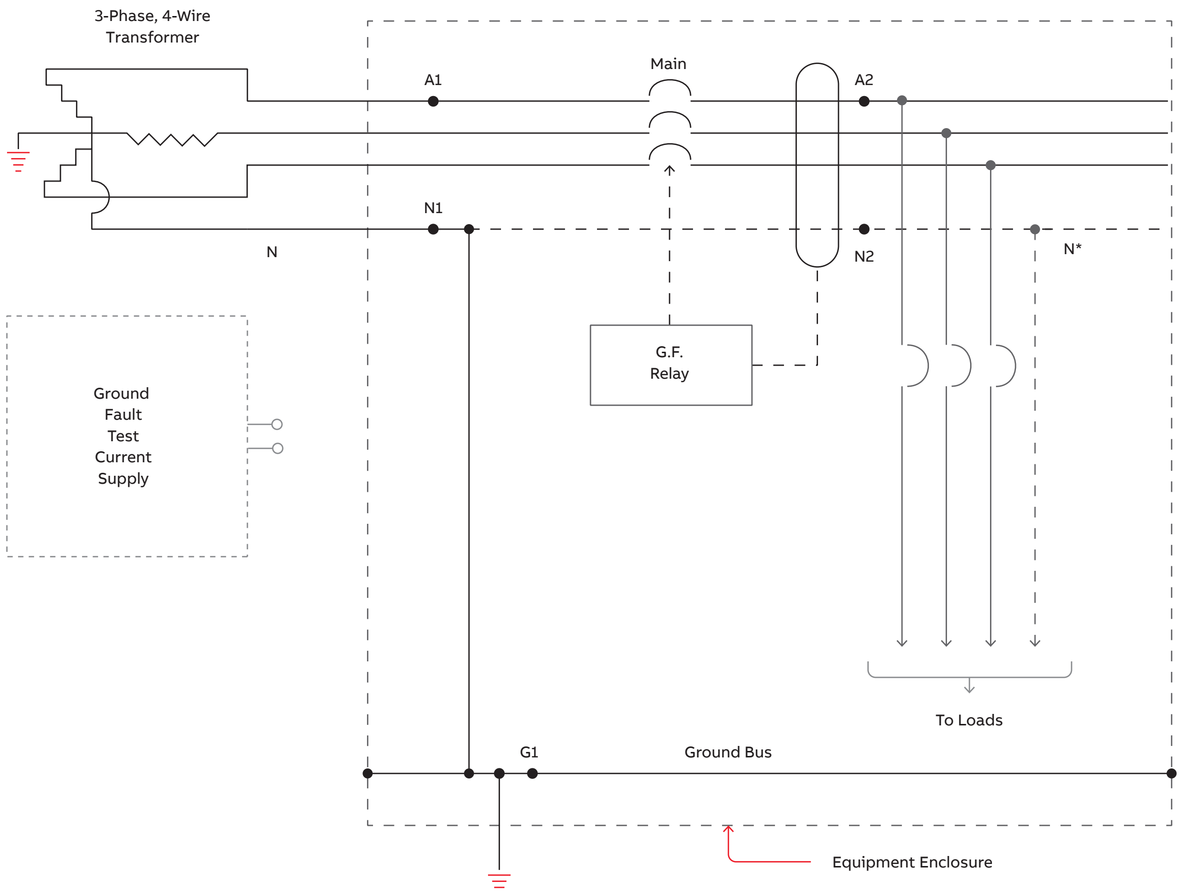
02
Main circuit breaker with ground fault relay and zero-sequence sensor arrangement



Test no.	Connect test current supply to points	Connect jumper between points	Results expected	Comments
2-1	A1 and N1	A2-N2	Main circuit breaker shpold not trip	Confirms that neutral and phase conductors go through sensor and in same direction
2-2	A1 and N1	A2-GI	Main circuit breaker should trip	Confirms continuity of ground path from ground bus to neutral

NOTE: It is not necessary to repeat the tests for each phase if a visual inspection confirms that all phases go through the sensor window.
* In 3-wire equipment the load neutral is not furnished. Omit Test 2-1.

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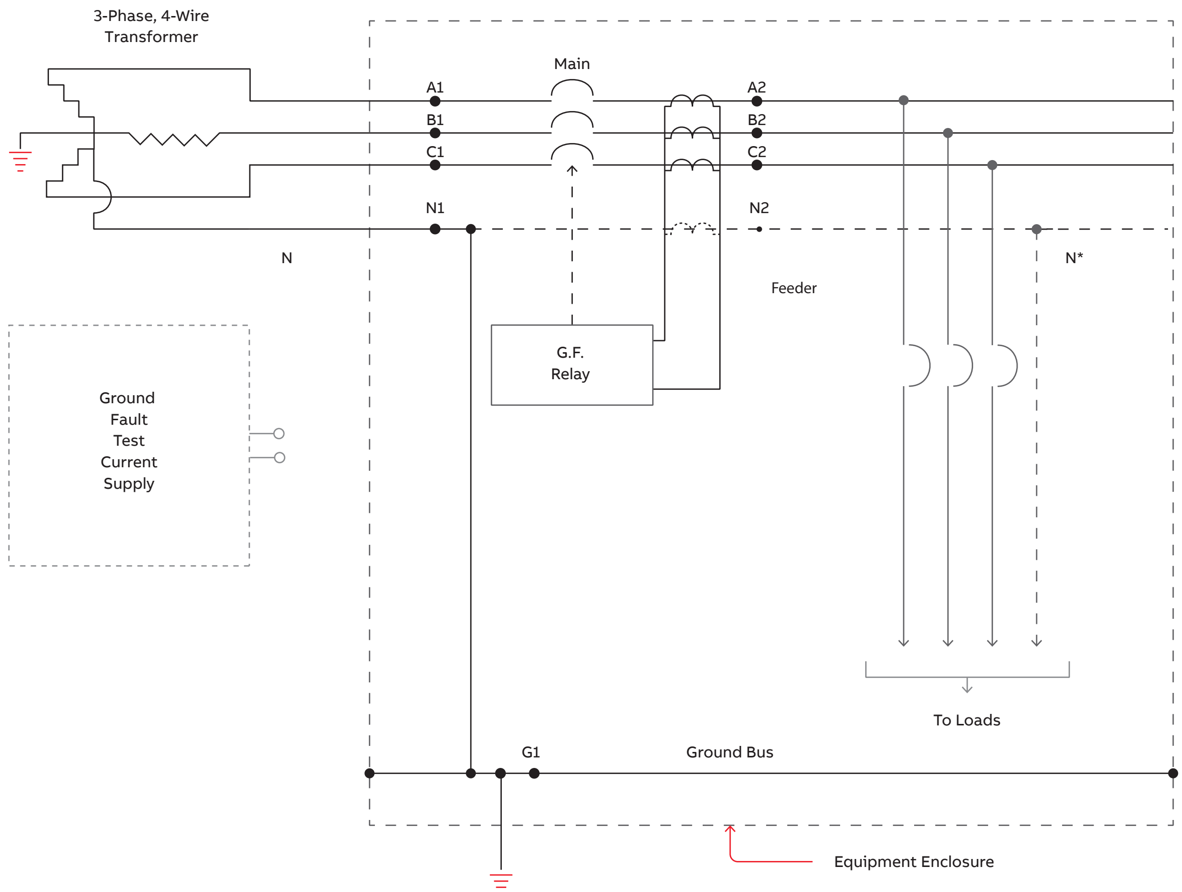
03
Main circuit breaker with ground fault relay and residual sensor arrangement



Test no.	Connect test current supply to points	Connect jumper between points	Results expected	Comments
3-1	A1 and N1 B1 and N1 C1 and N1	A2-N2 B2-N2 C2-N2	Circuit breaker should not trip	Confirms correct polarity of sensor connections
3-2	A1 and N1 B1 and N1 C1 and N1	A2-G1 B2-G1 C2-G1	Circuit breaker should trip	Confirms continuity of ground path from ground bus to neutral

* In 3-wire equipment, the load neutral and neutral sensor are not furnished. Omit Test 3-1.

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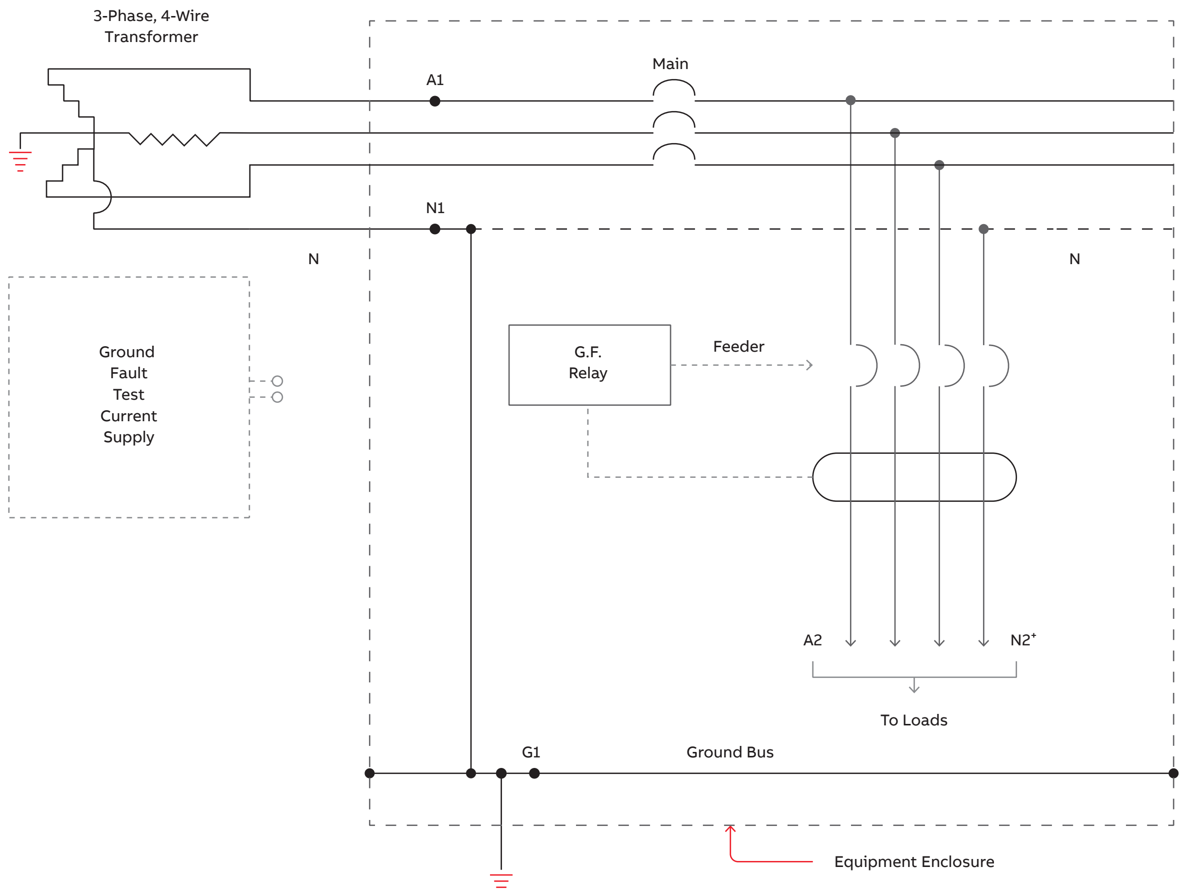
04
Feeder circuit breaker with ground fault relay and zero-sequence sensor arrangement



Test no.	Connect test current supply to points	Connect jumper between points	Results expected	Comments
4-1	A1 and N1	A2-N2	Circuit breaker should not trip	Confirms correct polarity of sensor connections
4-2	A1 and N1	A2-G1	Circuit breaker should trip	Confirms continuity of ground path from ground bus to neutral

NOTE: It is not necessary to repeat the tests for each phase if a visual inspection confirms that all phases go through the sensor window.
* On 3-wire equipment, the neutral conductor is not furnished. Omit Test 4-1.

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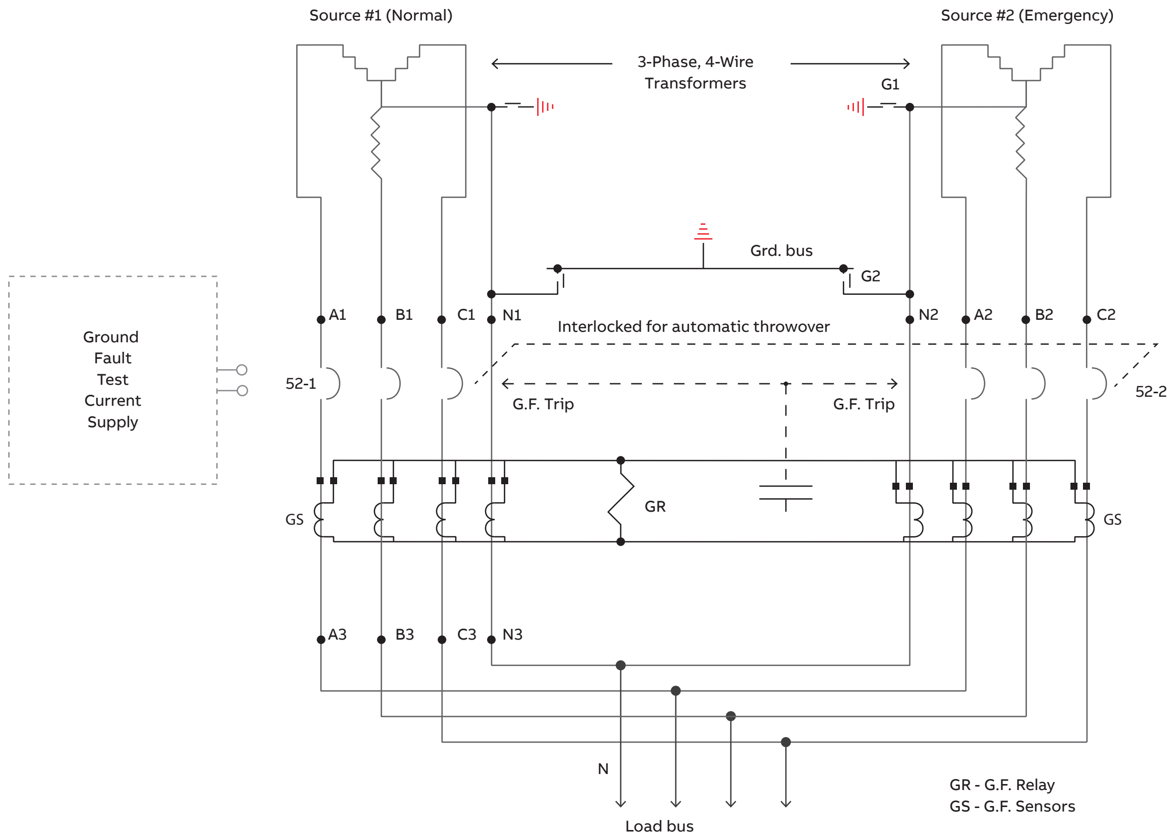
05
Ground fault relay protection on normal and emergency main circuit breakers interlocked for automatic throwover on 3-phase 4-Wire system



Test no.	Connect test current supply to points	Connect jumper between points	During the test disconnect ground from neutral at points	Results expected	Comments
5-1	A1 and N1 B1 and N1 C1 and N1	A3-N3 B3-N3 C3-N3	G1 and G2 G1 and G2 G1 and G2	Circuit breaker 52-1 should not trip	Confirms correct polarity of sensor connections.
5-2	A2 and N2 B2 and N2 C2 and N2	A3-N3 B3-N3 C3-N3	G1 and G2 G1 and G2 G1 and G2	Circuit breaker 52-2 should not trip	
5-3	A2 and N2 B2 and N2 C2 and N2	A3-N1 B3-N1 C3-N1	G1 and G2 G1 and G2 G1 and G2	Circuit breaker 52-2 should trip	Confirms operation when ground return path is through neutral from most distant ground.
5-4	A1 and N1 B1 and N1 C1 and N1	A3-N2 B3-N2 C3-N2	G1 and G2 G1 and G2 G1 and G2	Circuit breaker 52-1 should trip	

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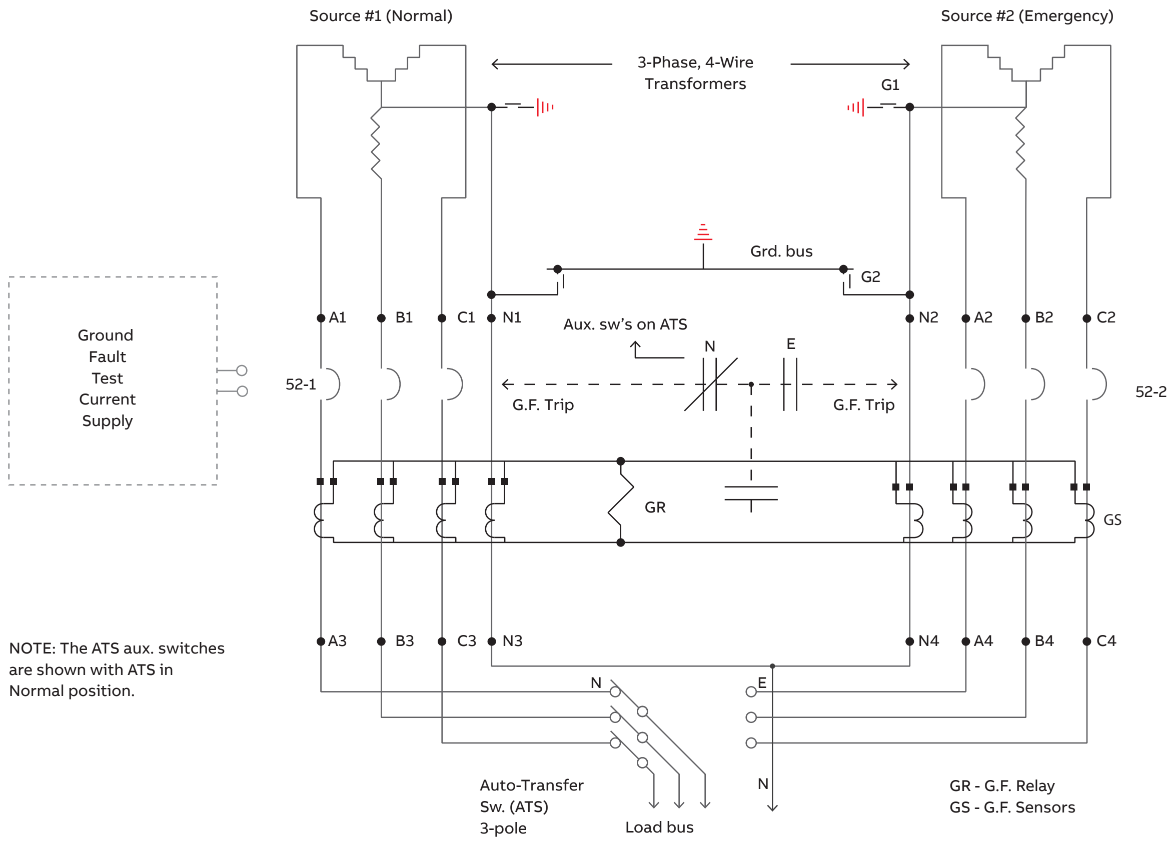
06
Ground fault relay protection on normal and emergency main circuit breakers with automatic transfer switch (3-pole) on 3-phase 4-wire system



Test no.	Transfer switch position	Connect test current supply to points	Connect jumper between points	During the test disconnect ground from neutral at points	Results expected	Comments
	N	A1 and N1	A3-N3	G1 and G2	Circuit breaker	
	N	B1 and N1	B3-N3	G1 and G2	52-1 should not	
6-1	N	C1 and N1	C3-N3	G1 and G2	trip	
	E	A2 and N2	A4-N4	G1 and G2	Circuit breaker	Confirms correct
	E	B2 and N2	B4-N4	G1 and G2	52-2 should not	polarity of sensor
6-2	E	C2 and N2	C4-N4	G1 and G2	trip	connections.
	E	A2 and N2	A3-N1	G1 and G2		
	E	B2 and N2	B3-N1	G1 and G2	Circuit breaker	Confirms operation
6-3	E	C2 and N2	C3-N1	G1 and G2	52-2 should trip	when ground return
	N	A1 and N1	A3-N2	G1 and G2		path is through
	N	B1 and N1	B3-N2	G1 and G2	Circuit breaker	neutral from most
6-4	N	C1 and N1	C3-N2	G1 and G2	52-1 should trip	distant ground.

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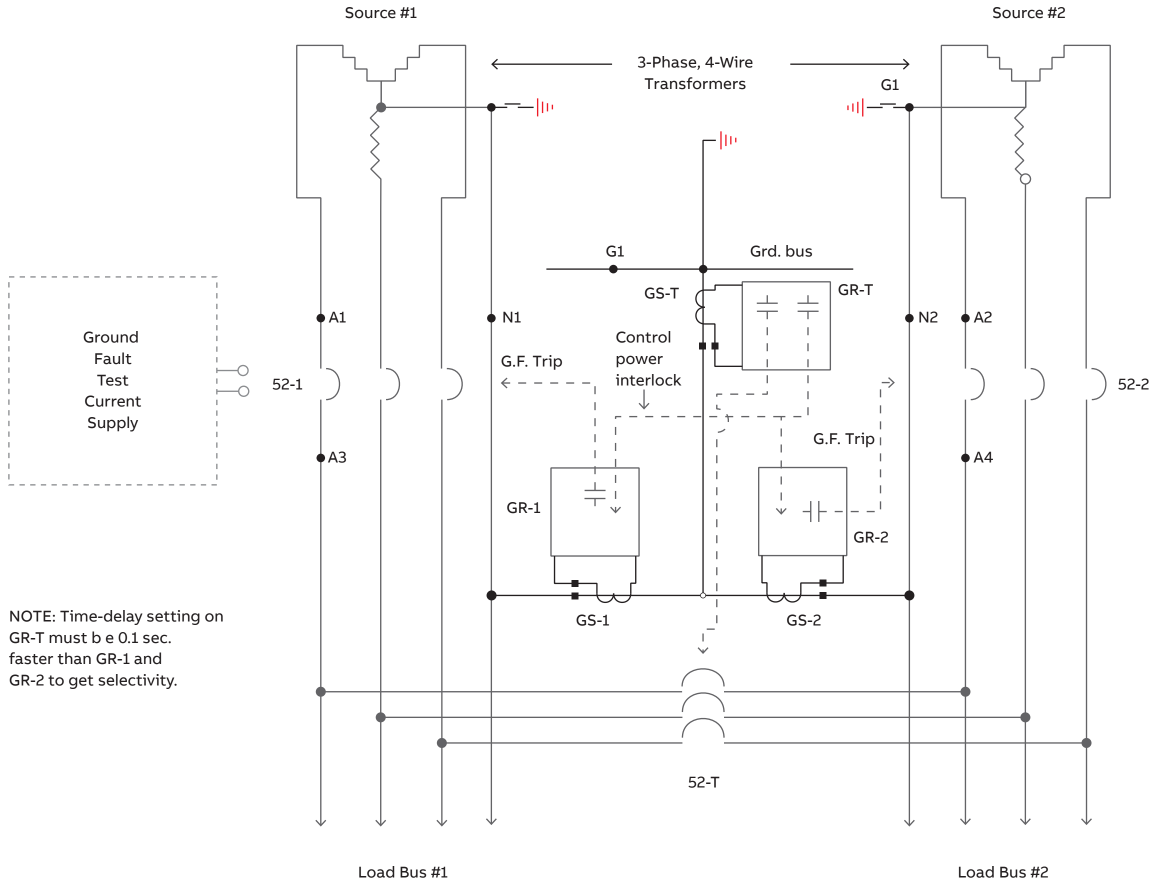
07
Double-ended substation (transformers not individually grounded) with single-point ground and ground fault Relays on 3-phase 4-wire system



Test no.	Connect test current supply to points	Connect jumper between points	Circuit breakers Open (O) or Closed (C) 52-1	52-T	52-2	Results expected	Comments
7-1	A1 and N1	A3-G1	C	O	C	Circuit breaker 52-1 should trip	52-1 trips for a ground fault on load bus #1
7-2	A2 and N2	A4-G1	C	O	C	Circuit breaker 52-2 should trip	52-2 trips for a ground fault on load bus #2
7-3	A2 and N2	A3-G1	O	C	C	Circuit breaker 52-T should trip and circuit breaker 52-2 should not trip (see note).	52-T trips for a ground fault on load bus #1, fed from source #2
7-4	A1 and N1	A4-G1	C	C	O	Circuit breaker 52-T should trip and circuit breaker 52-1 should not trip (see note).	52-T trips for a ground fault on load bus #2, fed from source #1

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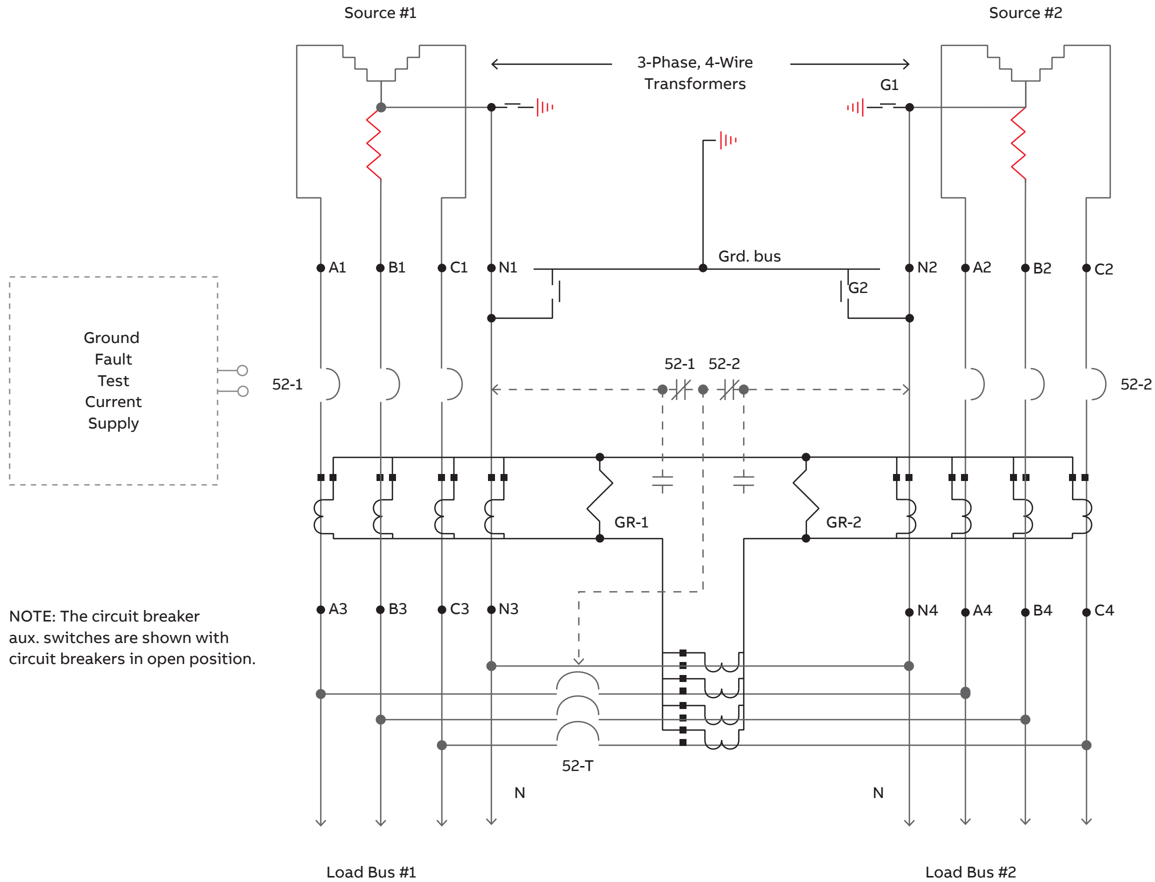
08
Double-ended equipment (both sources grounded) using modified differential scheme with ground fault relays on 3-phase 4-Wire system



Test no.	Connect test current supply to points	Connect jumper between points	During the test disconnect ground from neutral at points	Circuit breakers Open (O) or Closed (C) 52-1	52-T	52-2	Results expected	Comments
	A1 and N1	A4-N4	G1 and G2	C	C	O	Circuit breaker	
	B1 and N1	B4-N4	G1 and G2	C	C	O	52-1 and 52_T	
8-1	C1 and N1	C4-N4	G1 and G2	C	C	O	should not trip.	
	A2 and N2	A4-N4	G1 and G2	O	C	C	Circuit breaker	Confirms correct
	B2 and N2	B4-N4	G1 and G2	O	C	C	52-2 should	polarity of sensor
8-2	C2 and N2	C4-N4	G1 and G2	O	C	C	not trip	connections
	A2 and N2	A4-N1	G1 and G2	O	C	C	Circuit breaker	52-2 trips for a
	B2 and N2	84-N1	G1 and G2	O	C	C	52-2 should	ground fault on
8-3	C2 and N2	C4-N1	G1 and G2	O	C	C	trip	load bus #2
	A1 and N1	A3-N2	G1 and G2	C	C	O	Circuit breaker	52-1 trips for a
	B1 and N1	B3-N2	G1 and G2	C	C	O	52-1 should	ground fault on
8-4	C1 and N1	C3-N2	G1 and G2	C	C	O	trip	load bus #1
	A1 and N1	A4-N2	G1 and G2	C	C	O	Circuit breaker	52-T trips for a
	B1 and N1	B4-N2	G1 and G2	C	C	O	52-T should	ground fault on
8-5	C1 and N1	C4-N2	G1 and G2	C	C	O	trip	load bus #2

Test diagrams for systems with integral ground fault protection

Figure	Description
9	Neutral sensor polarity markings
10	Main circuit breaker with integral ground fault protection
11	Feeder circuit breaker with integral ground fault protection
12	Integral ground fault protection on main and tie circuit breakers of doubleended equipment - 3-Phase, 4-Wire

Neutral sensor polarity markings
In the accompanying integral ground fault protection circuit diagrams the neutral sensors are depicted using conventional current transformer symbols. The equivalent polarity markings for VersaTrip, SelecTrip, SST and Micro VersaTrip integral trip sensors are shown in the figure below.

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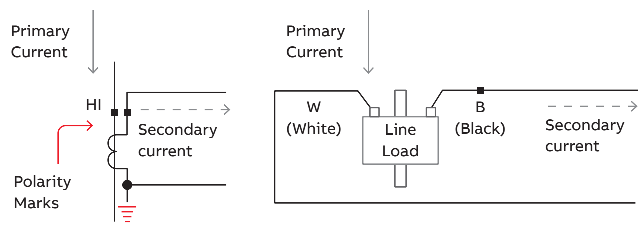
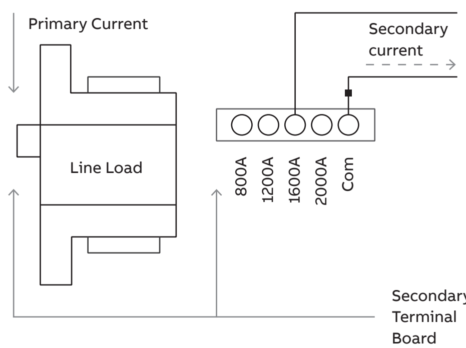
09
This diagram shows the equivalent polarity markings for neutral sensors that are not marked like conventional current transformers



HI is primary polarity marking.
XI is secondary polarity marking.
"LINE" end is equivalent of HI marking.
"BLACK" terminal is equivalent of XI marking.
"LINE" end is equivalent of HI marking.
"COM" terminal is equivalent of XI marking.



Note:
WARNING: In all the illustrations the source transformer(s) must be deenergized when applying and using the test current.

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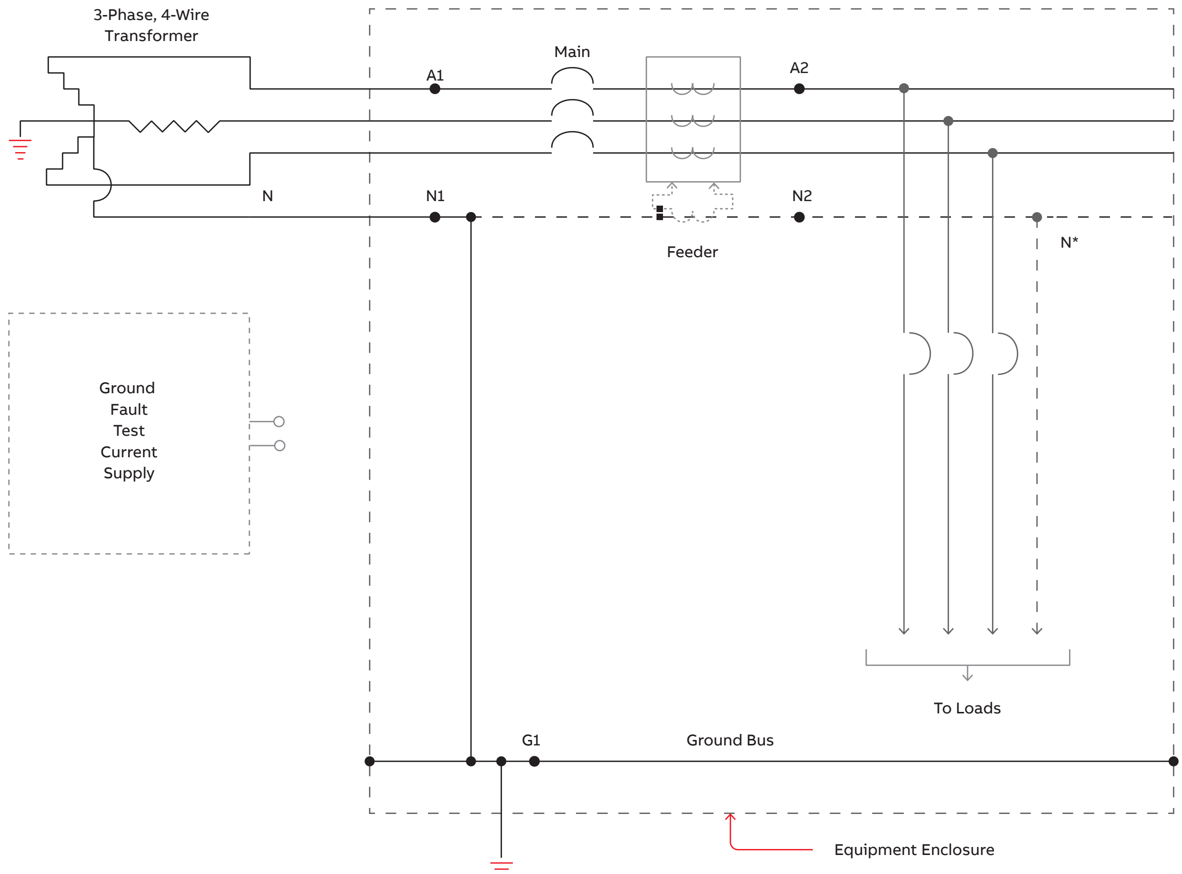
10
Main circuit breaker with integral ground-fault protection - 3-Phase, 4-wire



Test no.	Connect test current supply to points	Connect jumper between points	Results expected	Comments
10-1	A1 and N1	A2-N2	Circuit breaker should not trip	This confirms that polarity and ampere rating of the neutral sensor match those of the phase sensors in the circuit breaker.
10-2	A1 and N1	A2-G1	Circuit breaker should trip at ground fault setting.	Confirms continuity of ground path from ground bus to neutral

* In 3-wire equipment the load neutral is not furnished. Omit Test 10-1.

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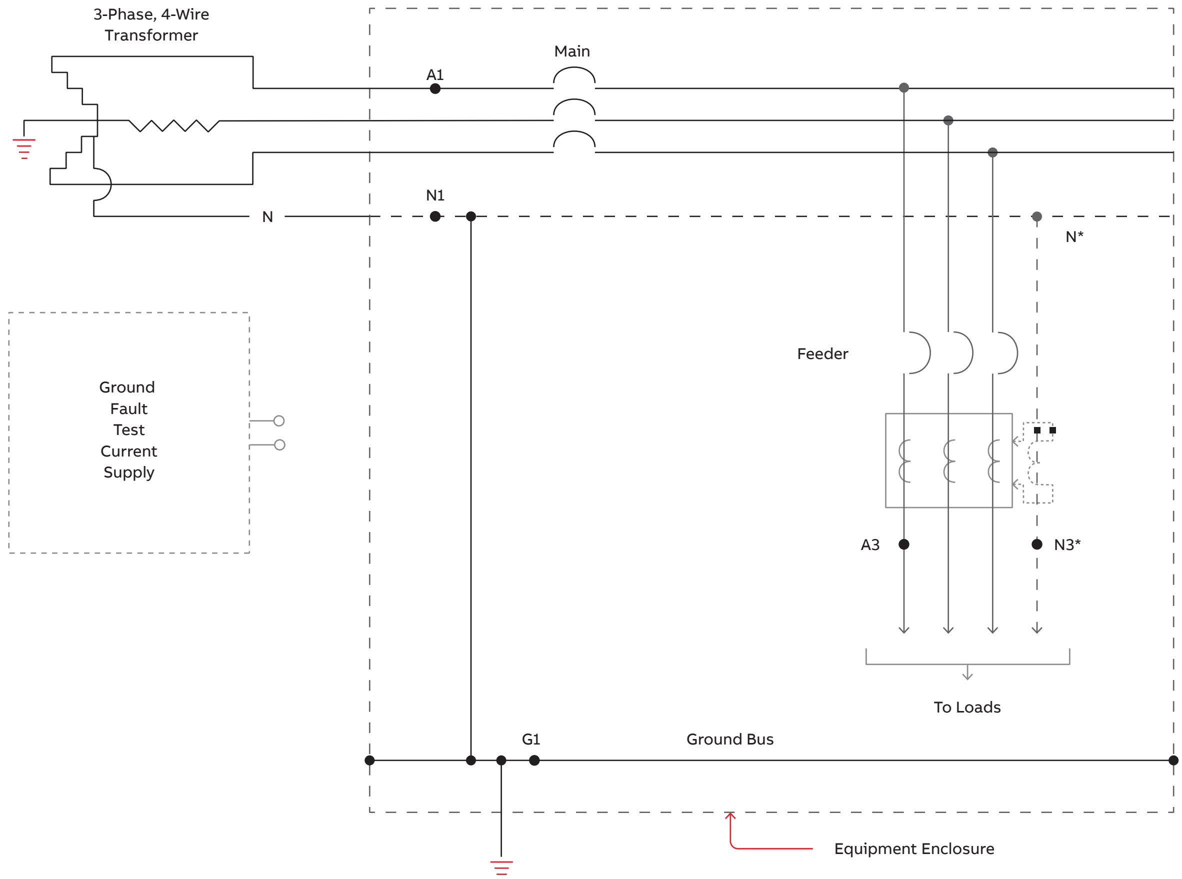
11
Feeder circuit breaker with integral ground-fault protection - 3-Phase, 4-wire



Test no.	Connect test current supply to points	Connect jumper between points	Results expected	Comments
11-1	A1 and N1	A3-N3	Circuit breaker should not trip	This confirms that polarity and ampere rating of the neutral sensor match those of the phase sensors in the circuit breaker.
11-2	A1 and N1	A3-G1	Circuit breaker should trip at ground fault setting.	Confirms continuity of ground path from ground bus to neutral

* On 3-wire feeders the neutral conductor and neutral sensor are not furnished. Omit Test 11-1.

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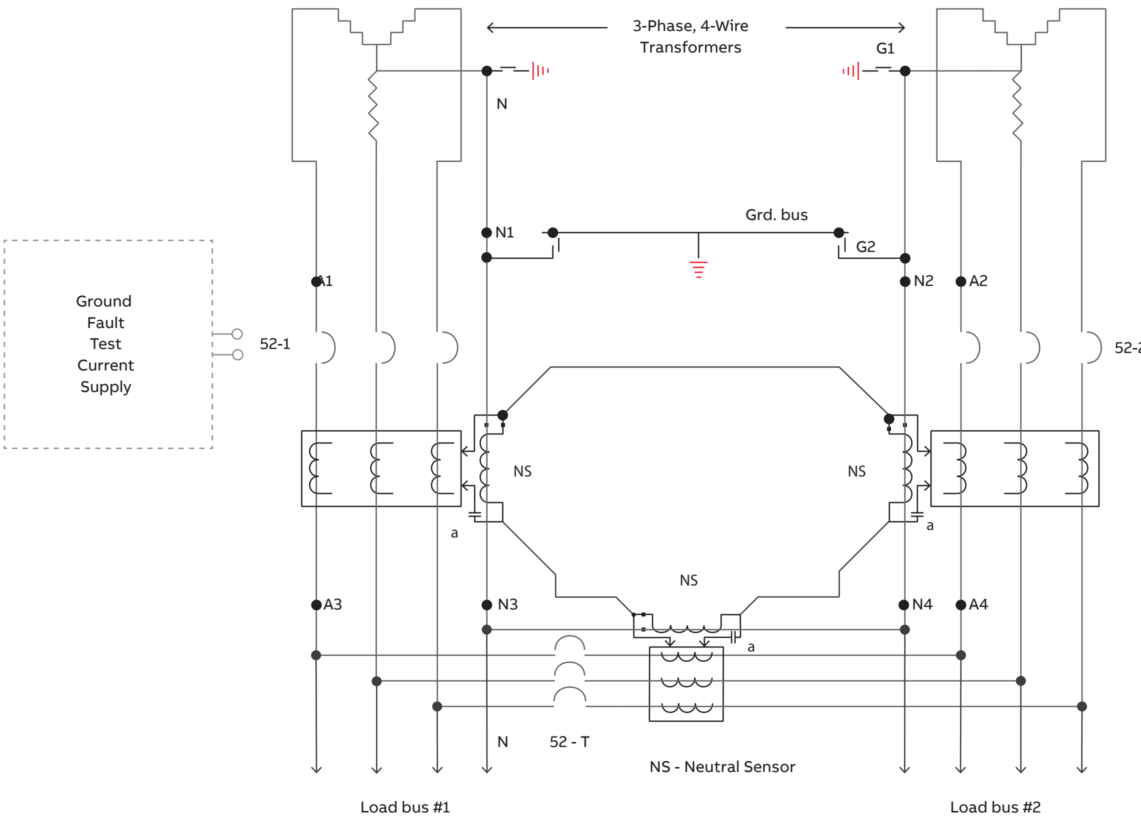
12
Integral ground fault protection on main and tie circuit breakers of Double-ended equipment - &phase, 4-wire



Test no.	Connect test current supply to points	Connect jumper between points	During the test disconnect ground from neutral at points	Circuit breakers Open or Closed 52-1	52-T	52-2	Results expected	Comments
12-1	A1 and N1	A4-N4	G1 and G2	C	C	O	Circuit breakers 52-1 and 52-T should not trip	
12-2	A2 and N2	A4-N4	G1 and G2	O	C	C	Circuit breaker 52-2 should not trip	Confirms that sensor polarity is correct
12-3	A2 and N2	A4-N1	G1 and G2	O	C	C	Circuit breaker 52-2 should trip	52-2 trips for a ground fault on load bus #2
12-4	A1 and N1	A3-N2	G1 and G2	C	C	O	Circuit breaker 52-1 should trip	52-1 trips for a ground fault on load bus #1
12-5	A1 and N1	A4-N2	G1 and G2	C	C	O	Circuit breaker 52-T should trip	52-T trips for a ground fault on load bus #2

Ground fault protection with ground fault relays
Performance test record

This test form should be retained by those in charge of the building's electrical installation in order to be available to the authority having jurisdiction.

ABB Order/Requisition No. ______________________
Customer Name ______________________
Location ______________________
Order No. ______________________

Equipment

☐ ReliaGear SB

☐ ReliaGear LV SG

☐ Other ______________________

Rating:
Volts ______________________
Phase ______________________
Wire ______________________
Amps ______________________
Hz ______________________

Ground fault protection

Circuit breaker (or switch) tripped by ground fault relay:

Function: ☐ Main ☐ Feeder

Circuit No ______________________
Type: ______________________

☐ Drawout ☐ Stationary

Rating (Amps):
Frame ______________________
Trip ______________________

Equipment arrangement

☐ Single-source

☐ Double-ended

☐ Unit-Substation

☐ Transforrner(s) remote from equipment.

☐ Other (explain) ______________________

Ground fault relay and accessories

☐ Ground-break System

☐ Other (explain)

Relay Cat. No. Pickup Range (Amps)
____

Sensor (C.T.) Cat. No.
____

Monitor Panel (if used) Cat. No
____

Sensor arrangement

- [ ] Ground-return Type
- [ ] Residual (sensor on each phase).
- [ ] Zero-sequence (all conductors thru one window).

Double-ended:

- [ ] Single-Point Ground Scheme
- [ ] Modified-Differential Scheme

Additional Description (if needed) ______________________

____

____

Test record

Test number	Ground fault relay setting: Pickup (Amps)	Ground fault relay setting: Delay (Sec.)	Test Current (Amps)	Tripping results: BkrISw. Trip?	Tripping results: Measured Time For Bkr/Sw. to Open

Conclusions

The test results are satisfactory. ______________________

The test results are not satisfactory. ______________________

(Explain) ______________________

____

____

____

Tests performed by: ______________________

Test Set Used: ______________________

Test Date: ______________________

Witnessed By ______________________

Ground fault protection with integral ground fault trips on circuit breaker
Performance test record

This test form should be retained by those in charge of the building's electrical installation in order to be available to the authority having jurisdiction.

ABB Order/Requisition No. ______
Customer Name ______
Location ______
Order No. ______

Equipment

- ☐ ReliaGear SB
- ☐ ReliaGear LV SG
- ☐ Other ______

Rating:
Volts ______
Phase ______
Wire ______
Amps ______
Hz ______

Equipment arrangement

- ☐ Single-source
- ☐ Double-ended
- ☐ Unit-Substation
- ☐ Transforrner(s) remote from equipment.
- ☐ Other (explain) ______

Ground fault protection

Circuit breaker tripped by integral ground fault trips:

Function: ☐ Main ☐ Feeder

Circuit No ______
Type: ______

☐ Drawout ☐ Stationery

Rating (Amps):
Frame ______
Sensor/Tap ______
3-Wire ______
4-Wire ______

Trip Type:
- ☐ EntelliGuard TU
- ☐ Ekip Dip
- ☐ Ekip Touch
- ☐ Ekip Hi-Touch

Additional Description (if needed) ______

—
Test record

	Ground fault Relay setting		Test	Tripping results	
Test number	Pickup (Amps)	Delay (Sec.)	Current (Amps)	Bkr/Sw Trip?	Measured Time For Bkr/Sw. to Open

Conclusions
The test results are satisfactory. ______
The test results are not satisfactory. ______
(Explain) ______

Tests performed by: ______
Test Set Used: ______
Test Date: ______
Witnessed By ______

ABB Inc.
305 Gregson Drive
Cary, NC 27511 USA
abb.com/contacts

abb.com/lowvoltage

1VAL386401-HT Rev B July 2023