Bulletin 14-6-6
Ground fault protection
Rules 14-102

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Scope

1) Requirements for ground fault protection
2) Ground fault protection design schemes
    a) Zero sequence sensing
    b) Ground strap sensing
3) Ground fault protection for circuits
    a) Power supply connection for ground fault protective systems

1) Requirements for ground fault protection

Rule 14-102 requires ground fault protection be provided to de-energize all normally ungrounded conductors of a circuit that faults to ground, where one of the following circuit characteristics exists in solidly grounded systems:

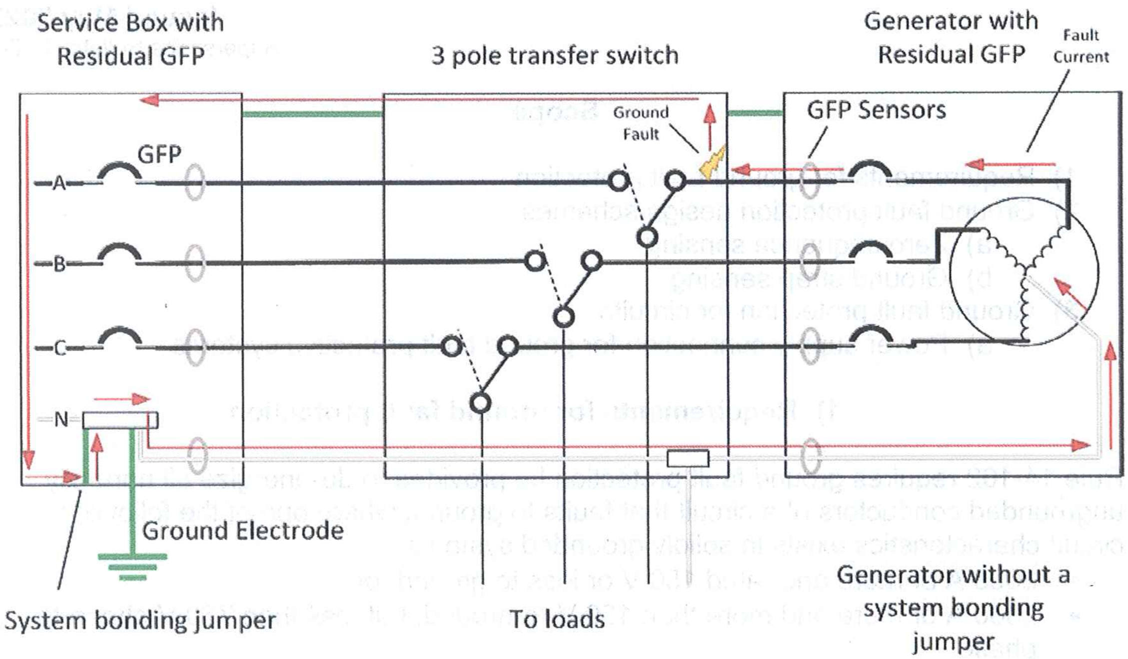
- 2000 A or more and rated 150 V or less to ground; or
- 1000 A or more and more than 150 V-to-ground, but less than 750 V phase-to-phase.

Notes:

1) Rule 14-102 applies to only solidly grounded systems.
2) Diagram 3 of The Ontario Electrical Safety Code (OESC) shows a variety of ultimate points of conductor de-energization in the event of a ground fault.
3) Ground fault relays are usually factory-set at the lowest current and shortest time settings available, to ensure against unnecessary equipment damage during early stages of construction. These settings should be adjusted to the intended values prior to final commissioning of the equipment and may be found in the co-ordination study.
4) Where the neutral conductor of any system is interconnected at any point with that of another system, and ground fault protection is required, the point(s) at which the system bonding jumper is installed may impact the functionality of the ground fault protection scheme. This can occur when the neutral of a standby or emergency source is interconnected to the neutral of a supply authority system. It can also occur when the neutral of two or more separately derived systems terminate at a common tie point. Diagram B1 is an example where the generator neutral is interconnected with the supply authority neutral and the wrong type of ground fault protection has been selected for the application. The generator is equipped with a residual ground fault protection scheme. When the generator is running and a ground fault occurs, ground fault current will return along the bonding system, through the system bonding jumper in the service box onto the generator neutral. This would appear as a balanced condition to the ground fault

protection equipment and the generator will continue to run, supplying the fault. This will not be compliant with Rule 14-102 5).

Diagram B1 – Example of a Non-Compliant Ground Fault Protection Scheme



1) Although there are ground fault protection schemes that function correctly when multiple sources with interconnected neutrals incorporate more than one system bonding jumper, when installed outside of a single piece of equipment this type of installation may cause objectionable current in violation with Rules 10-100 and 10-500.
2) The grounded conductor of a supply authority system or a separately derived system is to have no other connection to non-current carrying parts on the line and load side of the point where it is grounded (Rules 10-210 and 10-212). This is often overlooked when a new source is added to an existing system and the new neutral is interconnected with the existing. To ensure such considerations have been addressed in the design of the ground fault protection scheme, designers must not only consider that a new piece of equipment is equipped with ground fault protection, but the system will function as intended when it is integrated with an electrical installation.
3) It is the responsibility of the installer to ensure there is no other connection between the grounded system conductor and any equipment enclosure or connection to ground downstream in the building distribution system. This can inhibit the function of the ground fault protection scheme and is also not permitted by Rules 10-212 and 10-214.

Some common design items that may affect the performance of a ground fault protection scheme are:

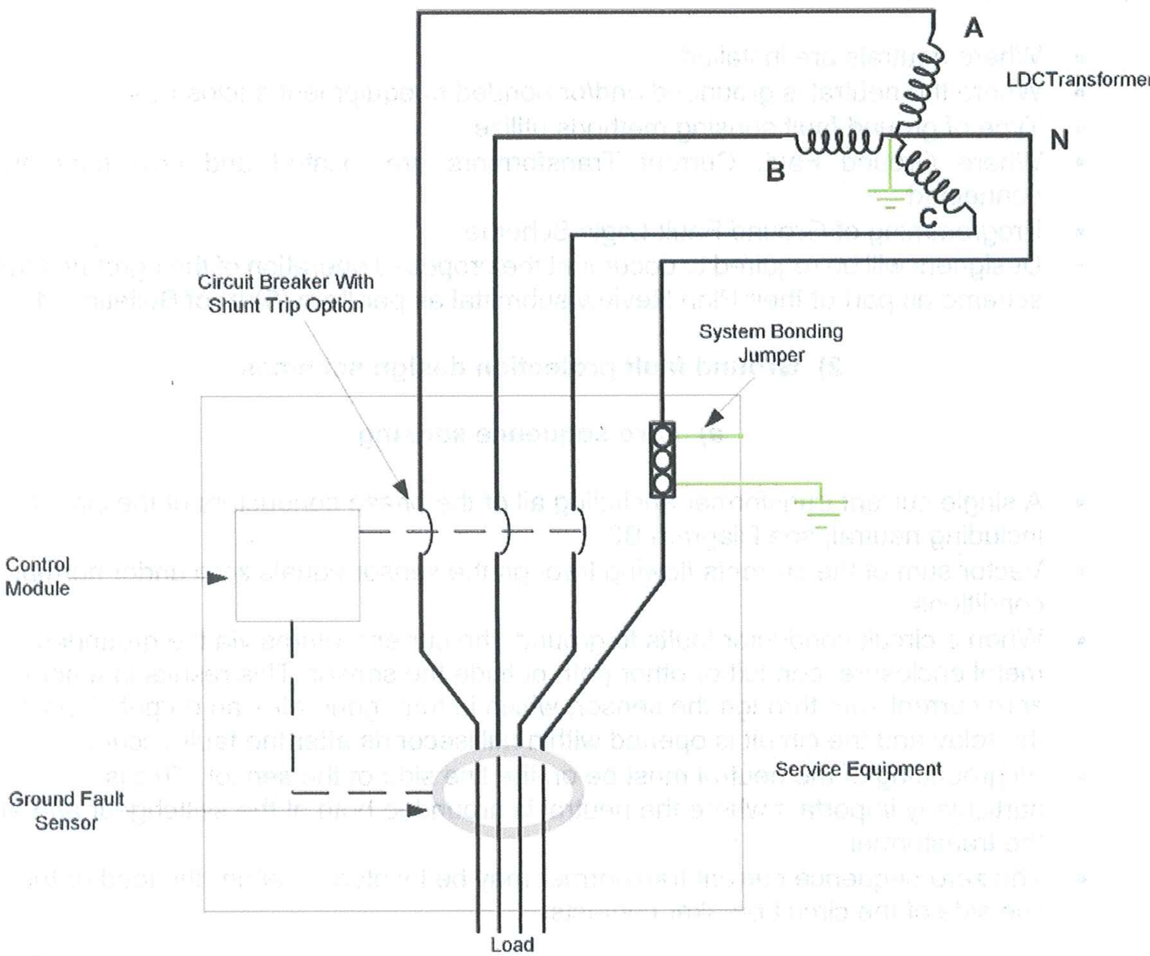
- Where neutrals are installed
- Where the neutral is grounded and/or bonded to equipment enclosures
- Type of ground fault sensing methods utilize
- Where Ground Fault Current Transformers are located and how they are connected
- Programming of Ground Fault Logic Scheme
- Designers will be required to document the proposed operation of their ground fault scheme as part of their Plan Review submittal as per Item (5)(a) of Bulletin 2-11-*

2) Ground fault protection design schemes

a) Zero sequence sensing

- A single current transformer encircling all of the phase conductors of the circuit including neutral, see Diagram B2.
- Vector sum of the currents flowing through the sensor equals zero under normal conditions.
- When a circuit conductor faults to ground, the current returns via the grounded metal enclosure, conduit or other path outside the sensor. This results in a non-zero current sum through the sensor, which in turn, generates an output signal to the relay and the circuit is opened within milliseconds after the fault occurs.
- All grounding of the neutral must be on the line side of the sensor. This is particularly important where the neutral is grounded both at the switchgear and at the transformer.
- The zero-sequence current transformer may be located on either the load or the line side of the circuit breaker contacts.

Diagram B2 - Zero sequence sensing

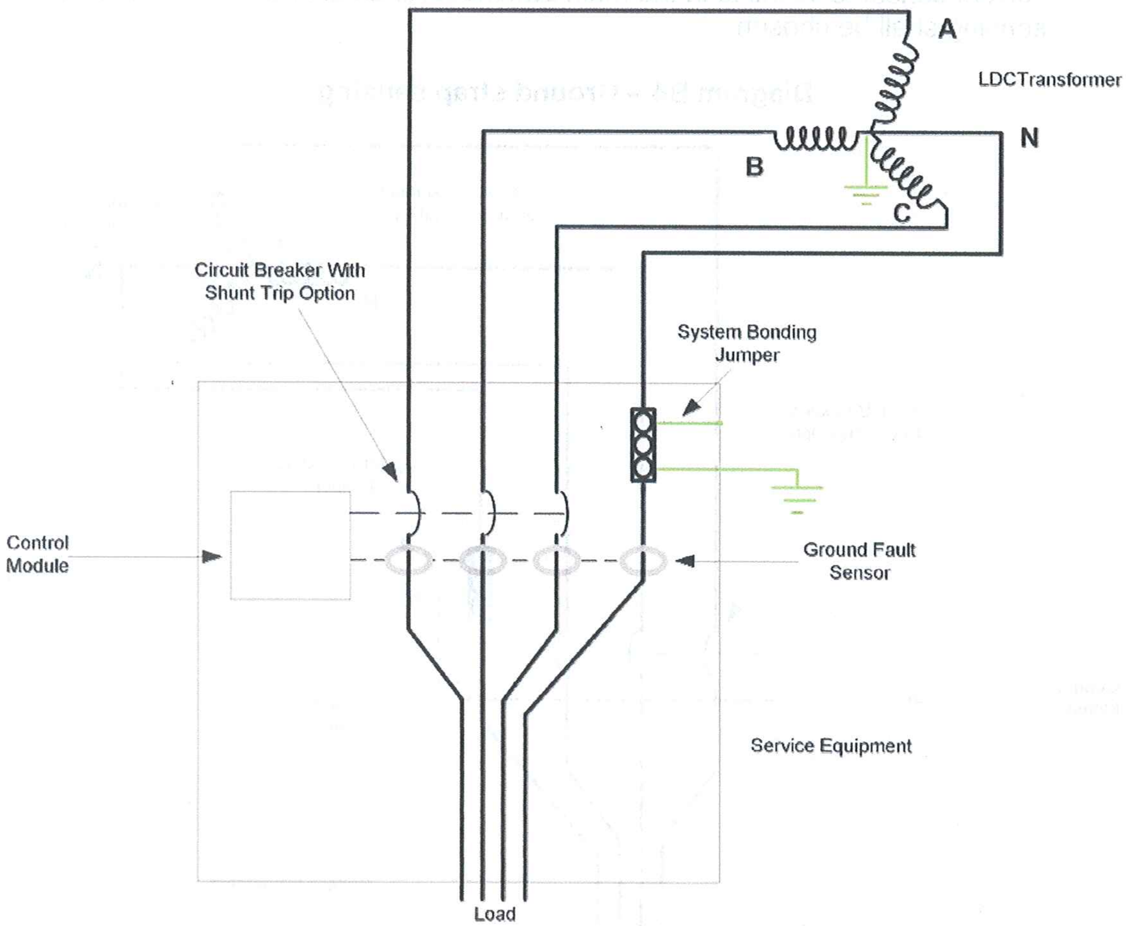


Notes to Diagram B2:

1) Current transformer encircles all phase conductors and neutral.
2) The sensor does not encircle equipment-grounding bus.
3) The grounding of the system and the neutral connection to the enclosure at the service are to be on the supply side (ahead) of the sensors.

A residually connected ground fault protection system is a form of zero-sequence sensing. The difference being, this system utilizes a number of current transformers, instead of one. The vectoral sum of the phase currents and the neutral current are monitored using separate current transformers and a ground relay (See Diagram B3). Again note the similarity to zero sequence, the grounding points must be on the supply side (ahead) of the sensors (current transformers).

Diagram B3 – Residually–connected ground fault protection system

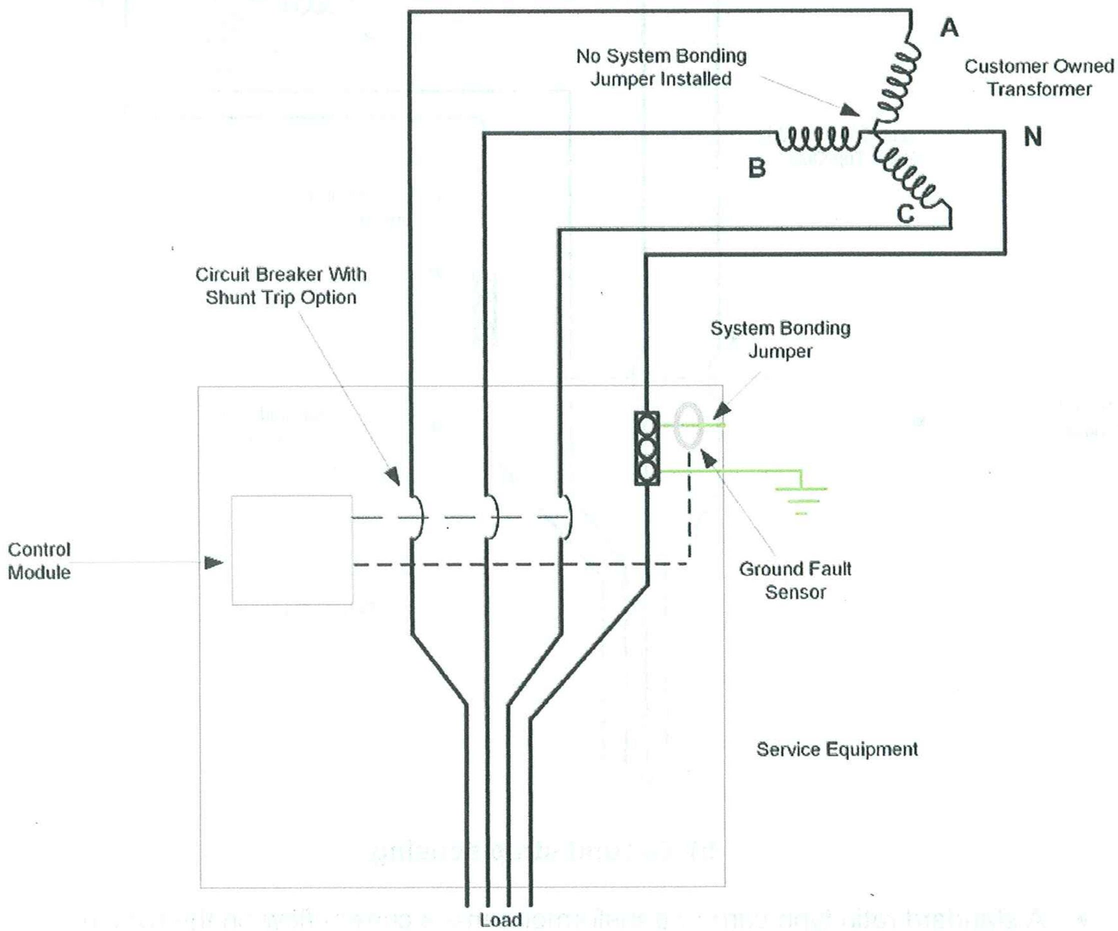


b) Ground strap sensing

- A standard ratio type current transformer senses current flow on the system bonding jumper or “ground strap” that connects the frame or grounding bus of the switchboard to the neutral.
- A ground fault on any branch circuit, feeder or sub-feeder, anywhere in the system, will cause the current to flow back to the neutral through the system bonding jumper which, in turn, generates an output signal to the relay and the circuit is opened.
- Ground strap sensing is applicable where the system neutral is grounded in the switchgear and isolated from ground at the transformer.
- The transformer neutral may be grounded at the transformer only if the ground strap sensor is located at the transformer as well. In this case, the neutral must remain ungrounded at the switchboard.

- Most LDCs require grounding of the secondary neutral at the transformer. If the current sensor is installed in the main switchboard, an alternative to ground strap sensing shall be chosen.

Diagram B4 – Ground strap sensing



Note to Diagram B4:
Exception permitted by Paragraph 14-102 5) b) and Subrule 14-102 7).

3) Ground fault protection for circuits

Other important points to consider are:

The ampere rating of the circuits referred to in Rule 14-102 1) shall be considered to be:

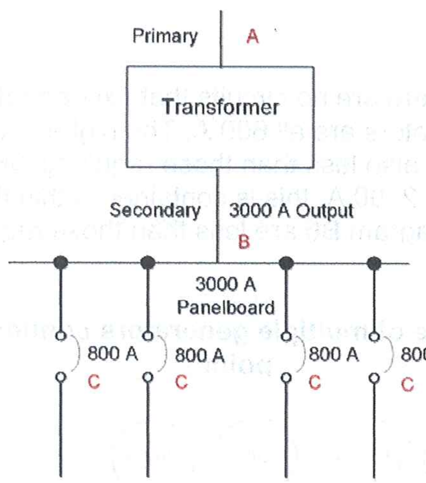
a) The rating of the largest fuse that can be installed in a fusible disconnecting device, therefore, a 1000 A switch fused at 800 A would require ground fault protection.

b) Where an adjustable trip circuit breaker is used and set below the values in Rule 14-102 1) a) or b), the requirement for GFP may be omitted where:

1) Permanent labels are attached to the switchgear or panel board to clearly indicate for each adjustable trip breaker the maximum permissible trip setting for the installation (both in amperes and in terms of the scale/read-out) (Rule 2-100); and
2) If the ampere rating of the breaker can be changed without removing the trip unit, the means of adjustment shall be factory sealed or behind sealed covers.

c) The ampacity of the main conductor feeding the devices located at points marked with an asterisk in Item 2 of Diagram 3 of the OESC, in the case where no main disconnecting device is provided.

Diagram B5 – An example where a transformer supplies a panelboard with no main secondary breaker



On the above arrangement, Diagram B5, GFP requirements can be satisfied by providing:

1) A shunt trip circuit breaker in the primary circuit (A) activated by ground fault sensing in the secondary circuit;
2) A GFP breaker in the secondary circuit ahead of the panelboard (B) *; or
3) A GFP breaker on each 800 A feeder (C). All feeders' breakers must be de-energized, regardless of trip setting.

Note * - The OESC does not require an additional overcurrent device in the secondary circuit of a dry-type transformer rated 750 V or less where it is adequately protected on the primary side per Rule 26-254, and the conductors and panelboard(s) are protected per Rules 26-256 and 14-606 .

Question 1

When a ground fault occurs on the secondary of a transformer, if the rating of the supplied system exceeds the limits of Rule 14-102, is it required to trip the primary overcurrent device?

Answer 1
No

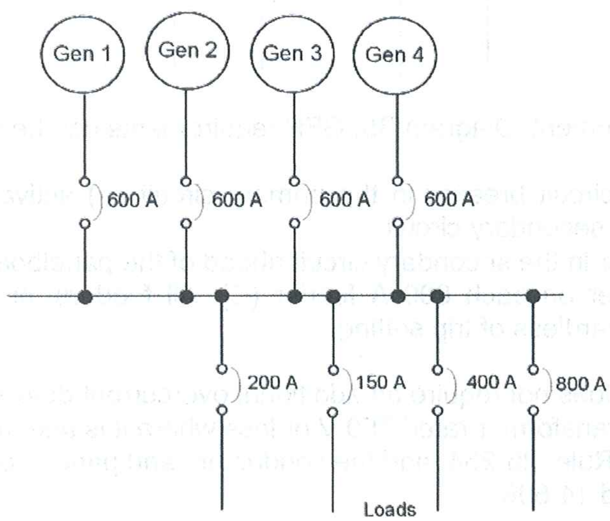
Rationale 1
Although recommended by the Appendix B note to Rule 14-102, it is not a requirement.

Question 2
Where there are multiple systems with circuit ratings less than those requiring GFP as per Rule 14-102 1), which are connected to a common tie-point (see Diagram B6), should the combined circuit rating of all sources be used to determine if GFP is required?

Answer 2
No

Rationale 2
In the case of Diagram B6, there are no circuits that exceed ratings requiring GFP. The circuits supplied by the generators are all 600 A. The highest rated circuit leaving the panelboard is 800 A, which is also less than those requiring GFP. Although the 4 generators combine to create 2400 A, this is contained within the equipment. As all input and output circuits in Diagram B6 are less than those requiring GFP, it does not need to be provided.

Diagram B6 – An example of multiple generators connected to a common tie-point



a) Power supply connection for ground fault protective systems

While some ground fault protective systems derive power for tripping from the fault source, others require separate power supply or use stored capacitance discharge.

It has been noted that installers have sometimes failed to provide separate supplies where required or have failed to make the necessary connections.

The person responsible for the ground fault protective system design shall check manufacturer's requirements and ensure that, where necessary, separate (or external) supplies are provided and connected to protective equipment.