

Effective Grounding for Customer Generation Facilities

This document covers common questions concerning the design of an effectively grounded system.

Why is Effective Grounding needed?

To prevent against transient overvoltage conditions when a line-to-ground fault occurs on the power grid.

What does Effective Grounding do?

Effective grounding maintains voltages within specified limits during a line-to-ground fault (short-circuit condition), typically through the use of a grounding bank. While maintaining voltage, the grounding bank generates a neutral current during the fault which is monitored to trip protective devices, turning the generation facility off. This prevents damage to customer and utility equipment from overvoltage or the grounding bank's neutral current.

How does it provide this neutral current?

Effective grounding typically utilizes a grounding bank, either a wye-delta or a zig-zag transformer, connecting the phase wiring to the neutral wire of the system. The grounding bank needs to have certain impedance characteristics to balance the symmetrical components of the system during a fault in order to achieve effective grounding. Please see Appendix A for details on the impedance requirements.

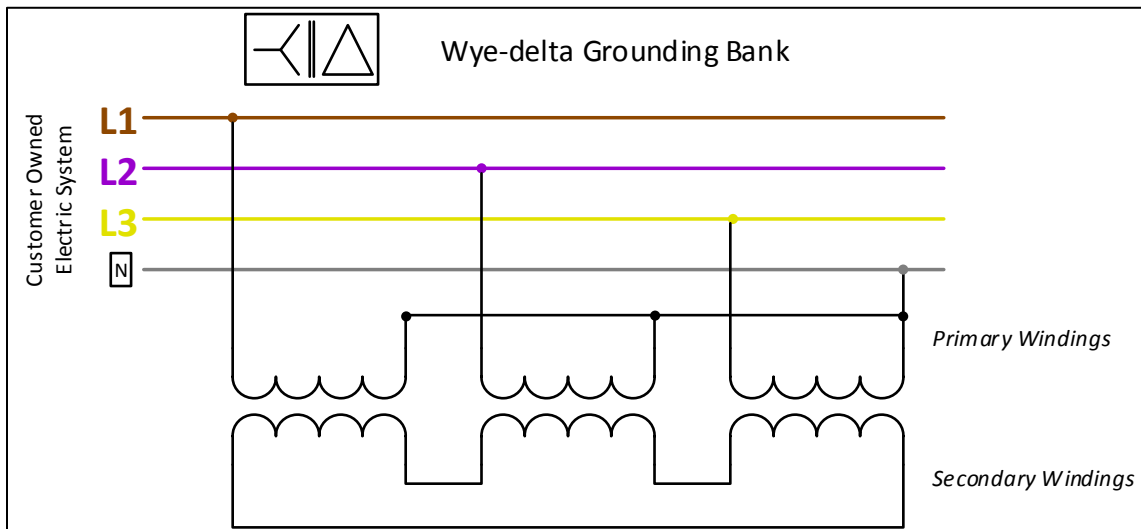


Figure 1 – Shunt-Connected Wye-Delta Grounding Bank Schematic

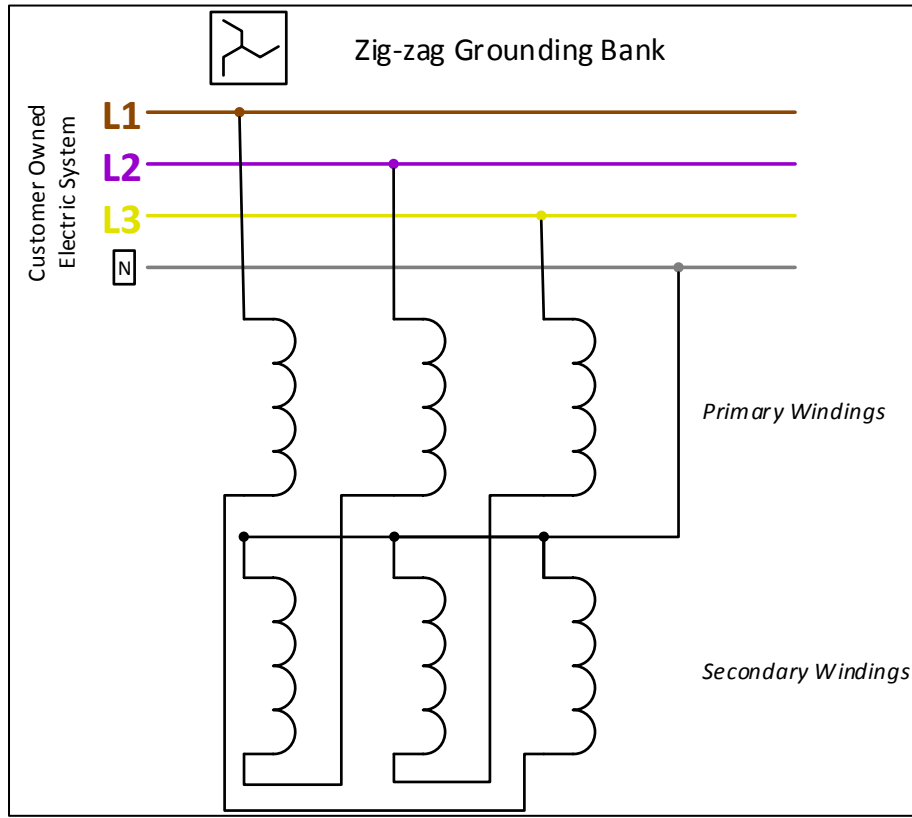


Figure 2 – Shunt-Connected Zig-zag Grounding Bank Schematic

What is needed for Effective Grounding?

The electric service to the site must be supplied through a service transformer with a grounded wye/wye configuration. This is necessary so neutral current from the customer-owned effective grounding equipment can be passed to the electric utility's primary wires. If the existing service transformer has a different configuration, it will need to be changed.

The following system components are needed:

- **Grounding bank.** Typically a grounding transformer connected as a shunt to the system, with a connection to the system neutral (not ground). Specifications will be provided to size the transformer. Note: the grounding bank can be a three-phase unit or three individual transformers connected in the desired configuration.
 - The grounding bank will maintain the voltage within specified limits until the generation system and grounding bank are disconnected.
- **Breakers.** The inverters and the grounding bank need to have overcurrent protection between them and the service transformer. You can use a main breaker for the whole system, or you can use multiple breakers – one for the grounding bank and one or more for the inverters.

- The overcurrent protective device(s) (breaker) shall open simultaneously all ungrounded conductors connected to the generation system and grounding bank when it operates.
- **Neutral Overcurrent Protection.** Typically a relay and a current transformer (CT) are used to monitor the neutral current of the grounding bank or system and trip the breakers when the neutral current limit is reached. The neutral current trip point will be supplied with the grounding bank specifications.
 - When a fault is detected, the relay system shall operate the overcurrent protective device(s) to disconnect the generation system and the grounding bank.
- **A Continuous Power Supply.** The relay and breakers must be operational any time the customer generation facility is energized. If the normal power supply to the relay is lost, there needs to be a means to power for the relay until it can open the breakers.
 - The continuous power supply needs to last long enough to power the relay until the breakers are opened.
 - The relay can't be allowed to lose power while the inverter(s) and grounding bank remain connected to the system. If this were to happen during a line-to-ground fault on the system, the breakers wouldn't trip until after serious damage to your equipment (and possibly other people's equipment, too).
 - An alternative is to use a breaker scheme that requires an active signal from the relay to remain closed. If the relay loses power, the breakers would open. This would eliminate the need for a continuous power supply, but it could result in more breaker trips.

Additional technical specifications can be found in Appendix A.

While system schematics later in this document use a wye-delta grounding bank, a zig-zag grounding bank is also acceptable and may be required in certain applications. Figure 3, below, shows a four-wire call-out for both types of grounding banks.

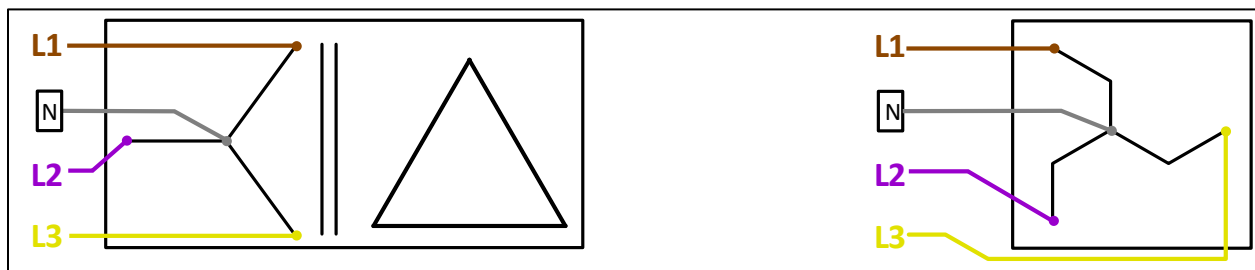


Figure 3 – Four-Wire Call-Outs for Wye-Delta and Zig-zag Grounding Transformers

Operation Requirements – Main Breaker System

If a main breaker is used upstream of the generation and grounding bank, the relay has to be operational before the breaker can be closed. An example system configuration is shown in Figure

4, below (note: all systems must be designed according to local codes, and will be subject to inspection by the Authority Having Jurisdiction).

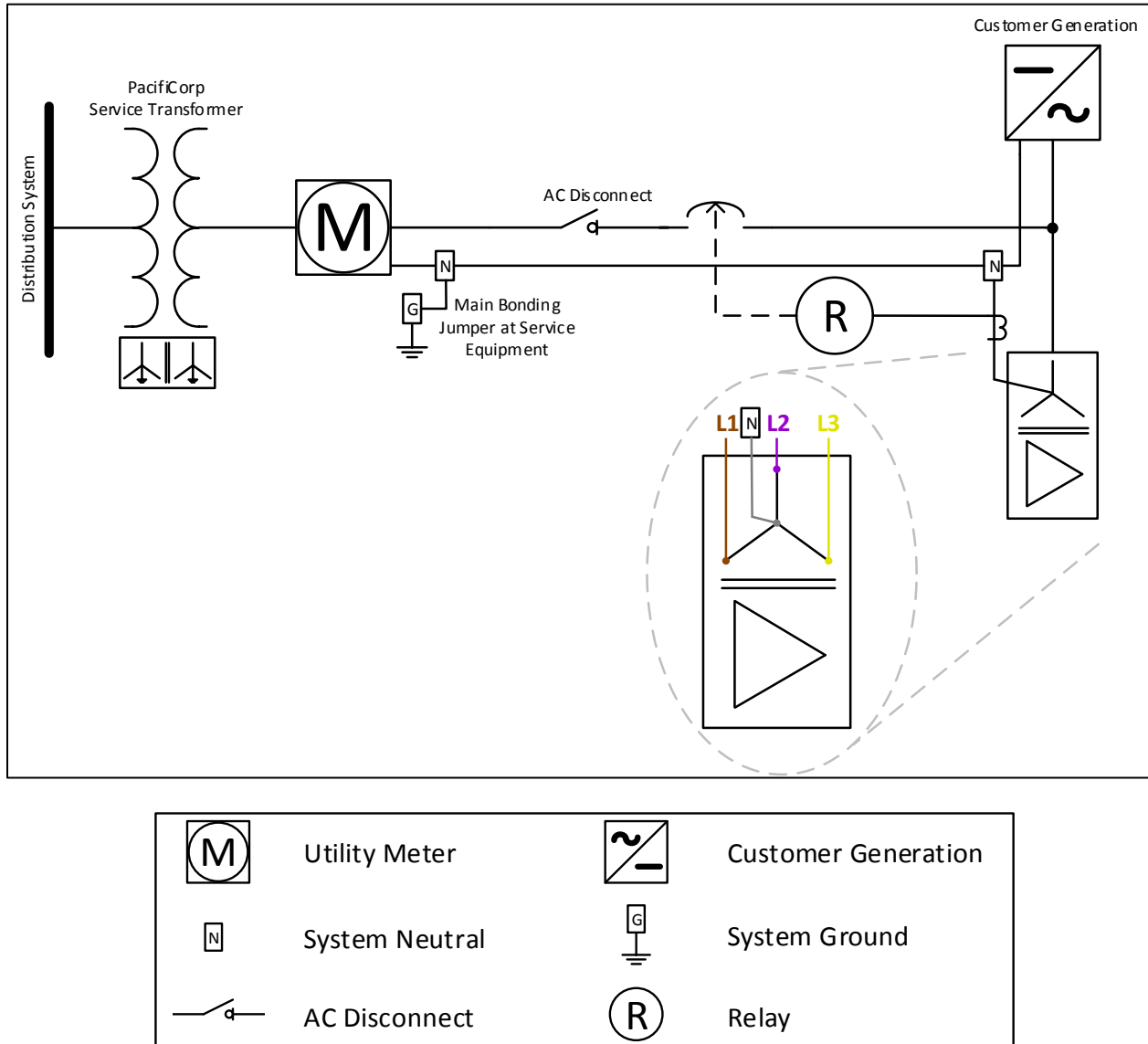


Figure 4 - Main Breaker System

Operational Requirements – Multiple Breaker System

If you decide to go with a multiple-breaker system, the relay needs to control all breakers so that:

- When the neutral current trip-point is reached, the breakers are opened.
- If the grounding bank breaker opens, the inverter breakers must also open.

- After a trip, the relay has to be operational before the breakers can be closed.
- The grounding bank breaker must be closed first.

Additionally, there must be a mechanism which will open the generation system breaker if the grounding bank breaker is manually opened (implementing an auxiliary switch on the grounding bank breaker is one way to accomplish this). An example system configuration is shown in Figure 5 below.

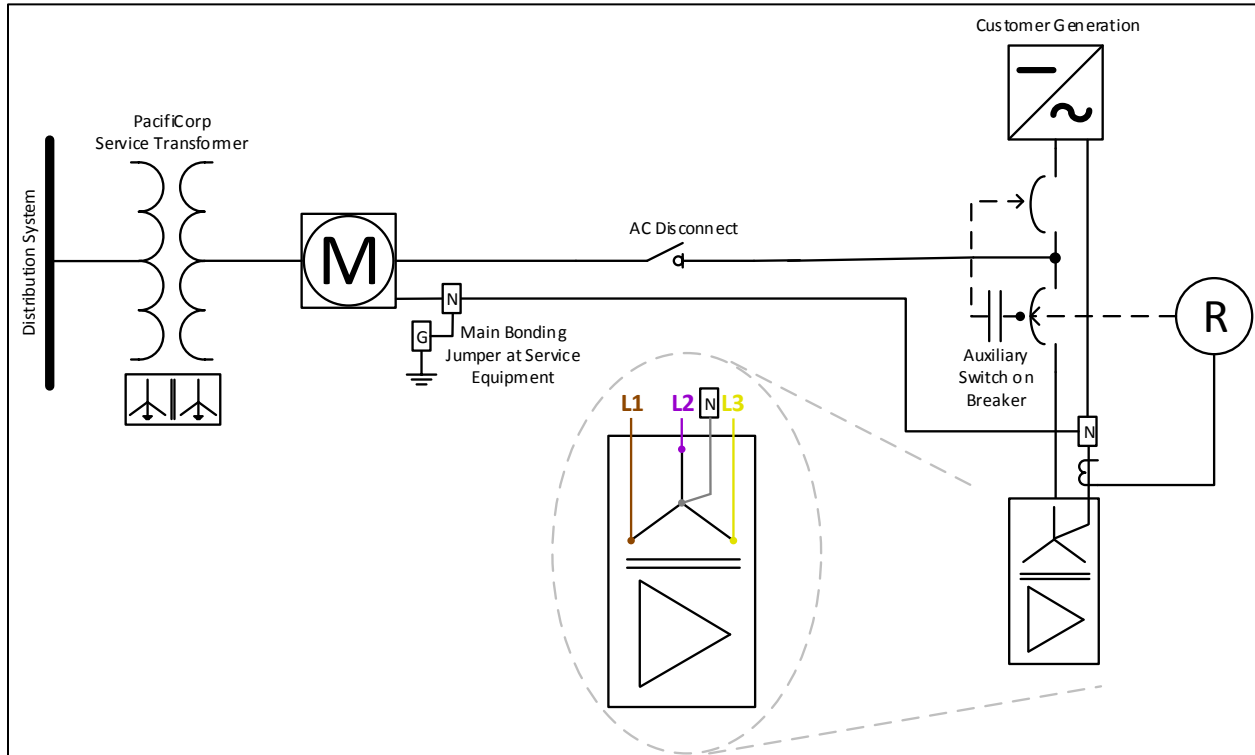


Figure 5 - Multiple Breaker System

Main Breaker & In-line Wye-Delta Transformer System

If your design requires a step-up or step-down transformer, this may be a great option for you. The in-line wye-delta transformer provides the effective grounding, without the need for an additional shunt-connected grounding bank. The delta winding, however, must be on the generation side of the system as shown in Figure 6 below.

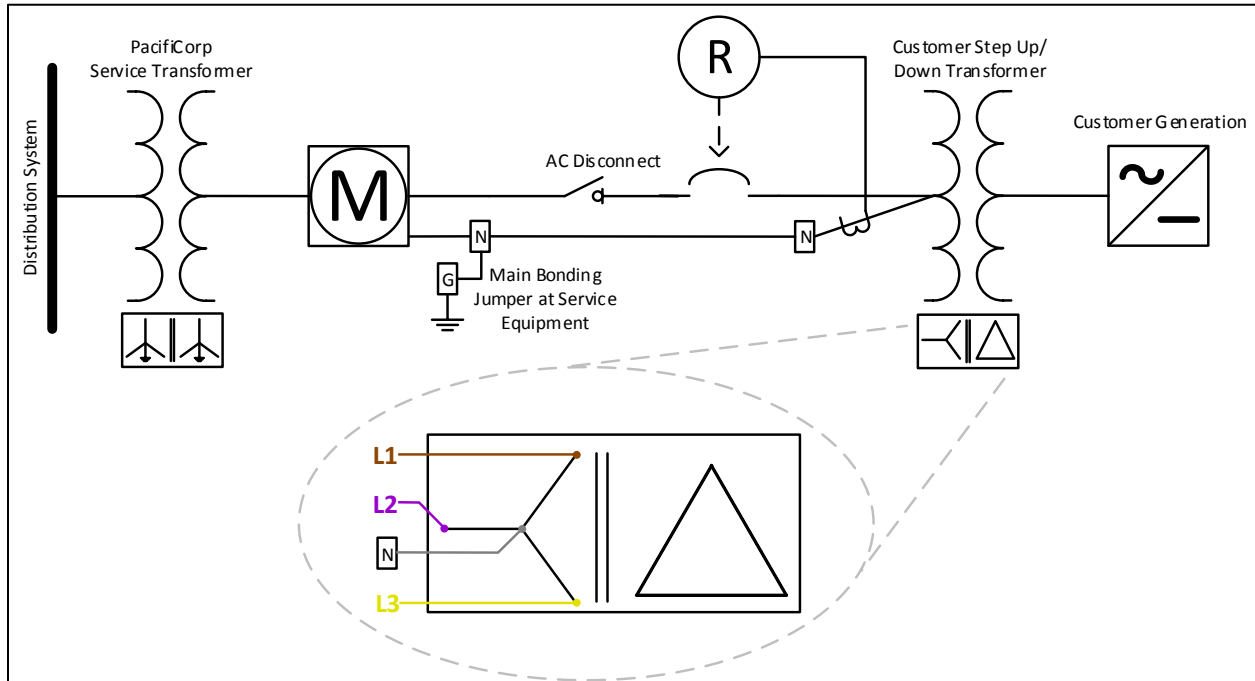


Figure 6 - Main Breaker & In-line Wye-Delta Transformer System

What we need from you

We'll need an updated generation system one-line drawing which includes the effective grounding system. Use the information in this document, along with the sizing specs we'll provide for the grounding bank to modify the one-line drawing. We have included a specific checklist of review items Appendix B, but in general the items we'll be looking for are:

- The main bonding jumper at the service equipment.
- The grounding bank's connection to the system (including a four-wire call-out)
- The grounding bank specifications.
- Both the generation system and the grounding bank protected by the breaker(s) controlled by the relay system.
- The relay connections to the breaker(s), the CT on the neutral wire, and the continuous power supply connections.
- The relay control settings (including the neutral trip-point). If available, an export of the settings is preferred.



Once received, we will review for completeness and provide any needed feedback. We want this to be a smooth and simple process but sometimes system complexities require adjustments. Working closely with you, we will do all we can to efficiently reach a design that protects both our system and your equipment. Once the installation is complete, a site visit may be required before your system is connected.

We thank you for your interest in our customer generation program. We want this to be a smooth and efficient process for you and PacifiCorp. If you have any questions, you can always reach us at **CustomerGeneration@PacifiCorp.com**.

Appendix A – Technical Specifications

The following are technical specifications and guidelines for the effective grounding system. Please note that these specifications do not supersede applicable electrical code or ESR requirements. An effectively grounded system will meet all applicable electrical code and ESR requirements while achieving these technical specifications.

Grounding Bank Specifications

The definition of effective grounding is taken from the NESC as defined by IEEE standards. The NEC definition, taking the term effectively grounded as meaning “well grounded” does not apply. Grounding bank impedances must meet the IEEE definition of effectively grounded:

$$\frac{X_0}{X_1} \leq 3 \qquad \frac{R_0}{X_1} \leq 1$$

Additionally, PacifiCorp requires the following impedance ratio for the grounding bank to be satisfied:

$$\frac{X_g}{R_g} \geq 4$$

Copper windings in the grounding bank will typically accomplish this ratio. If necessary, a line reactor inserted into each phase, or between the neutral of the grounding bank and the neutral of the system, is an acceptable means of achieving the needed ratio.

System Design Guidelines

In addition to the requirements given in the main body of this document, the following guidelines should be observed in designing the effective grounding bank’s connection to the system.

- In most cases the grounding bank should have a shunt (or parallel) connection to the system.
 - An exception to this is where an in-line wye-delta transformer is utilized.
- A low impedance neutral current path meeting the IEEE definition for effective grounding must exist, through all customer-owned equipment including transformers, from the effective grounding equipment to the service transformer.
 - The center point of the grounding bank shall not be bonded to ground, creating a separately derived system, but only have a path to the neutral bus of the service.
- Connecting inverters in a wye configuration (phase-to-neutral) will provide effective grounding without the need of a grounding bank. Balanced loads are required.

Appendix B – Design Review Checklist

The following check-list will help ensure that the effective grounding system contains the needed information for approval. As each customer generation installation is unique with specific requirements, there may be additional items not part of this checklist which are needed. Please use this list as a guide and starting point as you work out your system design.

Grounding Transformer

- The grounding bank specifications are included on the one-line drawing.
- The drawing shows at least a four-wire connection to the grounding bank (three phases and the neutral).
- The neutral of the grounding bank is connected to the neutral of the electrical system and not to the grounding system.

System Protection

- The main bonding jumper between the neutral and the grounding system is represented.
- The grounding bank has appropriate over-current protection.
- The generation system has appropriate over-current protection.
- The AC disconnect switch will disconnect the grounding bank and the generation system at the same time.
- There isn't a way to open the grounding bank's breaker while leaving the generation system connected.

Relay System

- The design includes a relay (or equivalent).
- The relay trip-point (neutral pickup) is shown on the drawing.
- There is a current transformer (CT) shown on the neutral wire of the grounding bank.
- There is a connection shown between the CT on the neutral wire and the relay.
- There is a control connection shown between the relay and the breaker(s) protecting the grounding bank and the generation system.
- When the relay operates, it will disconnect both the grounding bank and the generation system at the same time.
- There is a continuous power supply to the relay.
 - If there is not a continuous power supply to the relay, the system is designed so that when power is lost to the relay the breaker(s) protecting the grounding bank and generation system will automatically open.