



# Sensitive Ground Protection in the F60

**GE Publication No. GET-8390**

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## Scheme Description

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Protection against phase to ground faults can be a difficult problem since ground fault currents vary within a large range, becoming almost negligible in some situations. The ground fault current magnitude depends on the power system grounding which can vary from solidly grounded to ungrounded. This application note applies to low resistance grounded, high resistance grounded, and solidly grounded systems.

The ground fault current magnitude is calculated as:

$$I_{GF} = \frac{3V_{LN}}{Z_0 + Z_1 + Z_2 + 3Z_G} \quad (\text{EQ 1})$$

where  $Z_1$ ,  $Z_2$ , and  $Z_0$  are the positive, negative, and zero sequence impedances respectively.  $Z_G$  represents the impedance of the ground return circuit including the fault arc, the grounding circuit, and the intentional neutral impedance, when present.

If one assumes  $Z_G = 0$  and  $Z_1 = Z_2 = Z_0$ , the ground fault current magnitude will be:

$$I_{GF} = \frac{V_{LN}}{Z_1} \quad (\text{EQ 2})$$

In resistance grounded systems, the ground resistor limits the ground fault current to a specific value regardless the fault type or location.

## Typical Connections for Ground Fault Protection

### RESIDUAL CONNECTION

The ground fault elements are connected in the common neutral connection of the line current transformers. This is the most common connection for ground fault current relays.

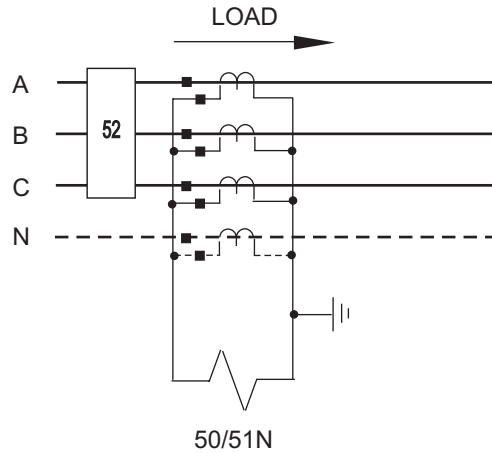


FIGURE 1. Residual Connection

The protection responds to the residual current (also called neutral or zero-sequence current) shown below:

$$I_n = 3I_0 = I_a + I_b + I_c \quad (\text{EQ 3})$$

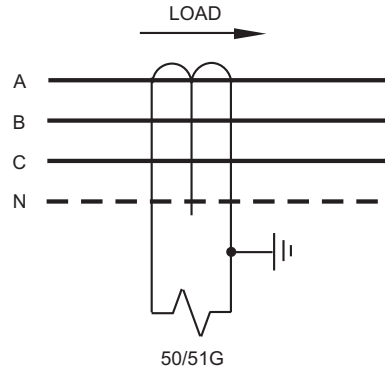
The protection setting should take into consideration that the 3 CTs do not have identical characteristics and will perform differently for heavy phase-to-phase faults or for initial asymmetrical motor starting currents. This can produce false residual currents. The setting should also be above the line maximum unbalance current.

The above conditions must be satisfied to avoid nuisance tripping. In addition, the ground fault protection must be sensitive to minimum ground fault current at the end of the line. It is often difficult to determine a setting that satisfies both sensitivity and selectivity requirements.

On four-wire circuits a fourth current transformer should be connected in the neutral circuit as shown in Figure 1 (in dotted line).

**CORE BALANCE (ZERO SEQUENCE) CT**

This method is based on primary current vector addition or flux summation. The conductor cables pass through the center hole of the core balance CT. Secondary current is the system zero-sequence current  $3I_0$



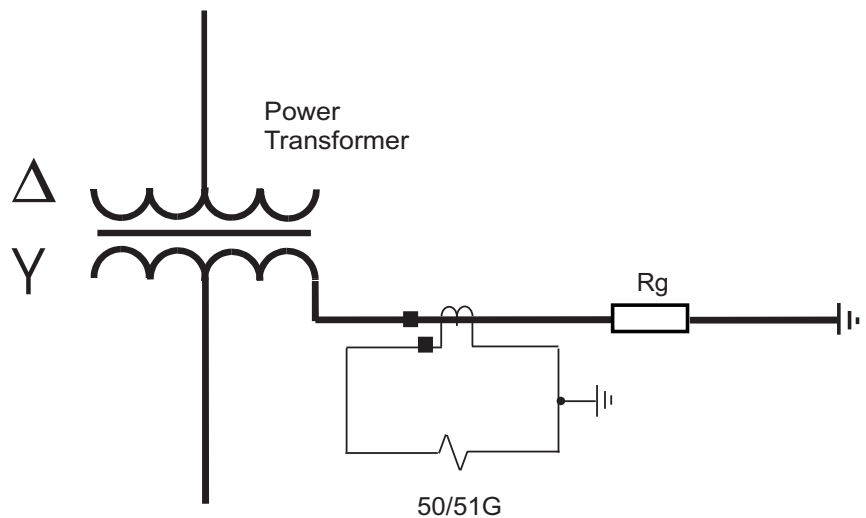
**FIGURE 2. Core Balance CT Connection**

This scheme provides increased sensitivity with no false residual currents. However, care must be taken to prevent false tripping from unbalanced inrush currents that may saturate the current transformer core.

**GROUND RETURN**

The ground fault current returns through the current transformer in the grounded neutral of the power transformer. This connection is merely used for transformer protection; it is not recommended for feeder circuits because it would require a special insulated joint in the cable busway which is difficult to maintain.

This connection can be used to provide backup ground protection for feeder circuits.



**FIGURE 3. Ground Return CT Connection**

## GROUND DIFFERENTIAL

Ground differential protection is effective for main bus protection. Core balance current transformers are installed on each feeder and another current transformer is placed in the transformer neutral connection to ground. This arrangement can be made sensitive to low ground fault currents without incurring tripping for ground faults beyond the feeder current transformers. All current transformers must be carefully matched to prevent improper tripping for high magnitude faults occurring outside the differential zone.

Bus differential protection protects only the zone between current transformers and does not provide backup protection against feeder faults

A similar protection generically called restricted ground differential is used for transformers protection against faults on the grounded wye winding, close to the neutral point of the transformer.