White Paper **WP027003EN** Effective December 2013

Ground fault isolation with loads fed from separately derived grounded sources

Introduction

Ground fault sensing detects current that flows between a source and a (faulted) load traveling on other than normal current-carrying conductors using one of several methods.

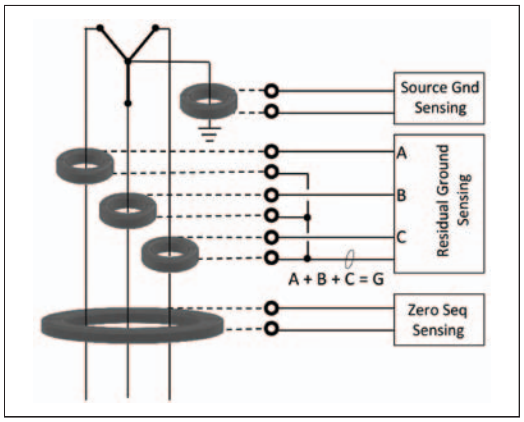

Figure 1. Common Ground Sensing Schemes

Source ground sensing

If the neutral to ground bond at the source is accessible, a current sensor can be installed to measure current flowing through that bond. Depending on the model of protective device, it may be reconfigurable to reuse an existing input (perhaps the neutral current sensor input) as a "source ground" input. Neutral current can still be calculated by inference (because A + B + C – G = N). This method is a cost savings because the need for a fifth input point on a 4W system is eliminated. The Eaton Digitrip™ trip units use this method.

Residual sensing

If all current is assumed to only travel over "normal" current-carrying conductors, then at any instant in time, the current flowing from the source to the load must be balanced with current returning to the source from the load, thus completing the circuit.

Therefore, by summing instantaneous current measurements on each of the normal current-carrying conductors, the sum of those currents is zero. If the sum is not zero, then current is flowing between the source and the load from somewhere other than these conductors, that is, a ground path.

This is a common method of detecting a ground fault using a circuit breaker because each conductor is already provided with current sensors.

Zero sequence sensing

While residual sensing places current sensors on each conductor individually, in the zero sequence method, one sensor is placed around all current-carrying conductors of a particular bus. Of course, this method requires the extra current sensor and an extra input point on the protective device to measure this extra sensor but can provide superior sensitivity to low-level ground faults.

Multipoint ground sensing

When a ground fault occurs, the current flows from the point of the fault back to the source via the ground path. On three-phase, four-wire systems using an unswitched neutral, there is more than one source-to-ground path. These multiple paths permit the current flowing from the fault to divide between the sources. Any individual protective device, therefore, only sees a fraction of the actual ground fault current. This can result in reduced clearing times, excessive arc flash, and improper selective coordination.

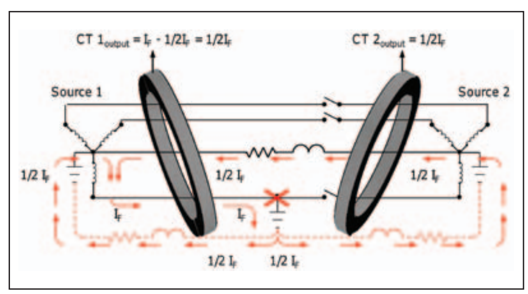

Figure 2. Two Grounded Sources with Unswitched Neutral Allow Ground Fault Current to Circulate

Solutions to this problem include using four-pole breakers (to switch neutral), or grounding only one source.

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Differential ground fault sensing (DGFS)

For a three-phase, four-wire system with multiple grounded sources switched with three-pole breakers, another method exists to correctly measure ground fault current flowing in each breaker. This is important because only the closest breaker to the ground fault must clear the ground fault.

Differential ground fault sensing can provide the needed selectivity by connecting the ground sensors in a bridge. The circuit breakers are connected across the bridge, in effect, measuring the difference in current flowing into and out of "zones" bounded by the breakers.

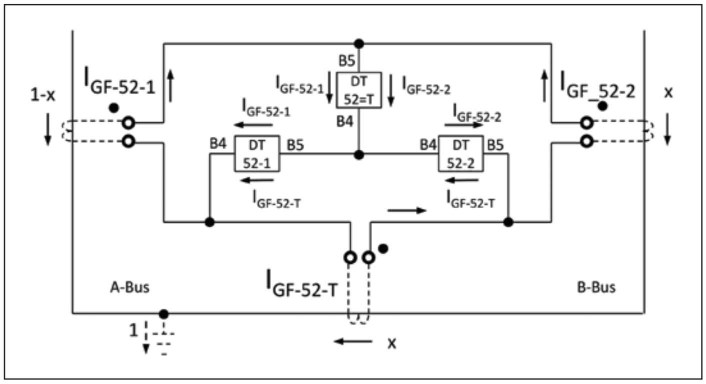

Figure 3. General Design of DGFS

Figure 3 shows a ground fault (in this example with a magnitude "1") flowing out of the A-Bus. Because the two sources are grounded, some unknown portion of this ground current flows from each source. The sum of the two unknown ground fault currents equals the total current. In this example (1-x) amperes flow from Source 1, while x amperes flow from Source 2. The sum of the two ground currents must equal 1 and by inspection it is easily confirmed that it does: (1-x) + x = 1.

Connecting the sensor polarities as shown, the equations for the ground current flowing through each trip unit are defined as:

- DT 52-1 = $I_{GF\text{-}52\text{-}1} + I_{GF\text{-}52\text{-}T} = (1\text{-}x) + x = 1$
- DT 52-T = $I_{GF\text{-}52\text{-}1} + I_{GF\text{-}52\text{-}2} = (1\text{-}x) + x = 1$
- DT 52-2 = $I_{GF\text{-}52\text{-}2} - I_{GF\text{-}52\text{-}T} = x - x = 0$

Correctly, the only circuit breakers "seeing" ground current are the 52-1 and 52-T breakers. The 52-2 breaker being out of the "zone" does not see ground current.

The reader can easily confirm that a ground fault placed on the B-Bus results in only the Source 2 and tie breakers detecting the ground current.

- DT 52-1 = $I_{GF\text{-}52\text{-}1} + I_{GF\text{-}52\text{-}T} = (1\text{-}x) - (1\text{-}x) = 0$
- DT 52-T = $I_{GF\text{-}52\text{-}1} + I_{GF\text{-}52\text{-}2} = (1\text{-}x) + x = 1$
- DT 52-2 = $I_{GF\text{-}52\text{-}2} - I_{GF\text{-}52\text{-}T} = x + (1\text{-}x) = 1$

DGFS designs with variety of ground sensor types

Consider the design where two grounded sources are connected to a main-tie-main (M-T-M) lineup where the tie breaker uses zero sequence ground sensing.

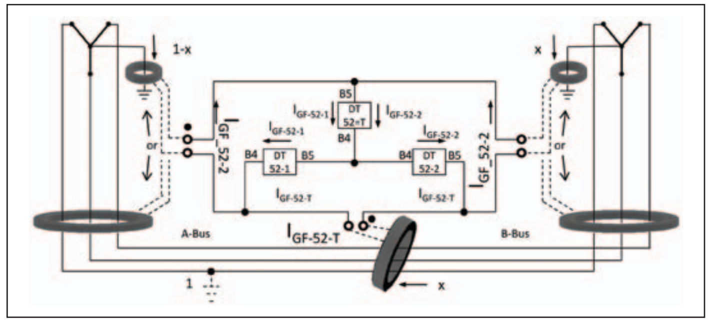

Figure 4. Two Grounded Sources Connected to Three-Phase, Three-Wire M-T-M Lineup

As with **Figure 3**, the equivalent equations for the current flowing through the trip units shown in **Figure 4** are for a ground fault on the A-Bus:

- DT 52-1 = $I_{GF\text{-}52\text{-}1} + I_{GF\text{-}52\text{-}T} = (1\text{-}x) + x = 1$
- DT 52-T = $I_{GF\text{-}52\text{-}1} + I_{GF\text{-}52\text{-}2} = (1\text{-}x) + x = 1$
- DT 52-2 = $I_{GF\text{-}52\text{-}2} - I_{GF\text{-}52\text{-}T} = x - x = 0$

Simulations

To verify that the DGFS design operates in a variety of scenarios, it is convenient to model these circuits. The example that follows uses LTSPICE ①.

Modeling the differentially connected trip units confirms that the actual (modeled) currents are what were expected.

- DT 52-1 = $I_{GF\text{-}52\text{-}1} + I_{GF\text{-}52\text{-}T}$
- DT 52-T = $I_{GF\text{-}52\text{-}1} + I_{GF\text{-}52\text{-}2}$
- DT 52-2 = $I_{GF\text{-}52\text{-}2} - I_{GF\text{-}52\text{-}T}$

① Available free from Linear Technology http://www.linear.com/designtools/software/. Models used here can be downloaded from http://pps2.com/go/dgfs/

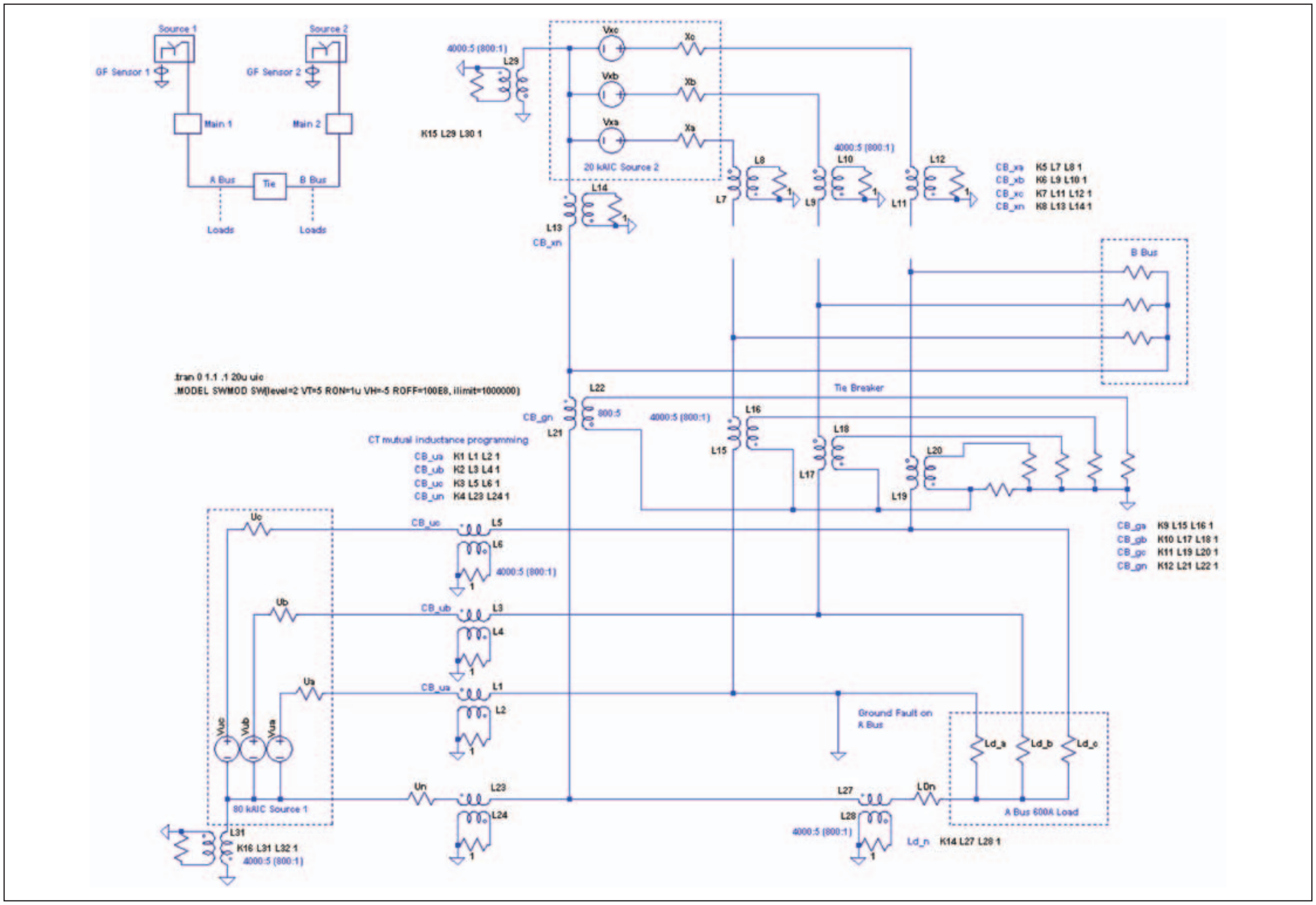

Figure 5. LTSPICE Simulation of Two Grounded Sources Connected to M-T-M Lineup

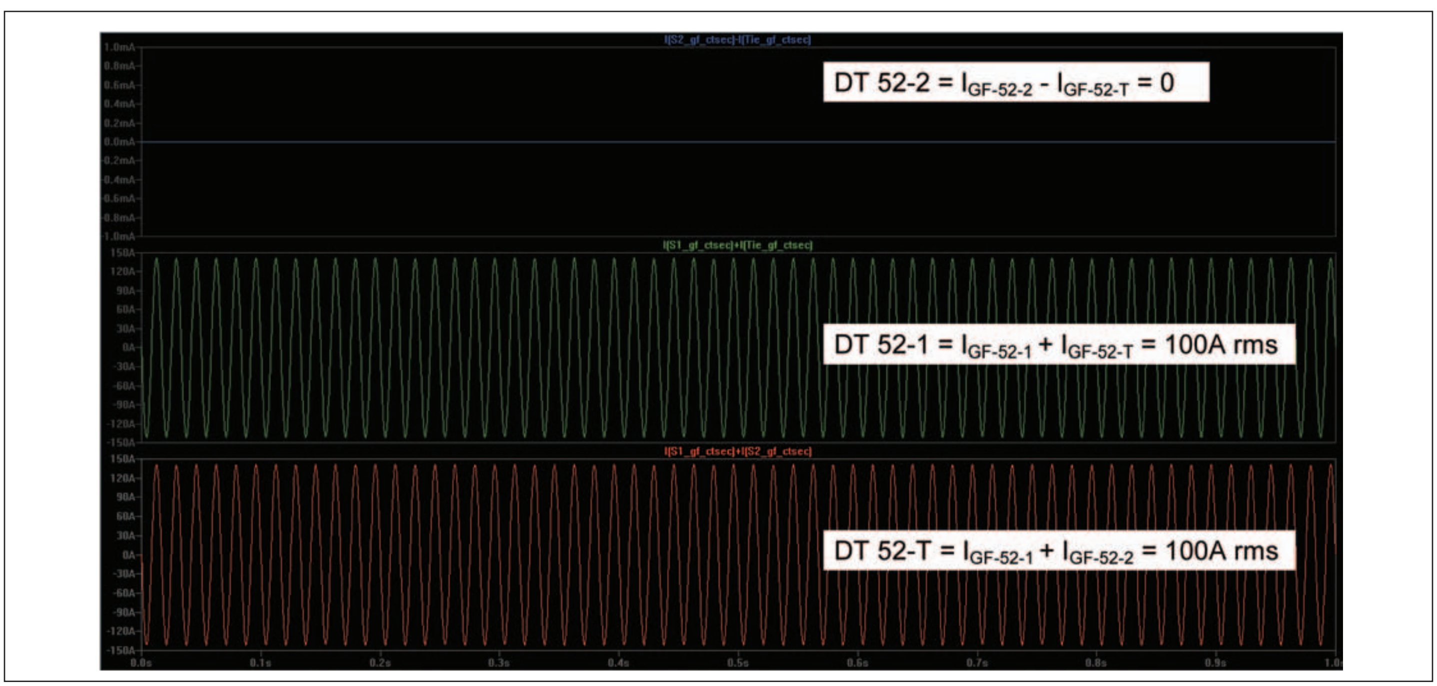

Figure 6. Simulation Output of Circuit Shown in Figure 5

DGSF examples

The system shown in **Figure 7** is very similar to that shown in **Figure 8** and **Figure 9** with the following differences:

- **Figure 8** requires a source grounded system where the ground sensor is mounted between the neutral bushing and the ground, whereas **Figure 7** does not include that restriction
- **Figure 9** requires that only two of the three breakers be closed at any time, whereas **Figure 7** places no such restriction on the breaker operation
- Because the generator source is ungrounded, only two ground fault sensors are required while still providing selective ground fault tripping for 52-U, 52-G, and 52-X breaker

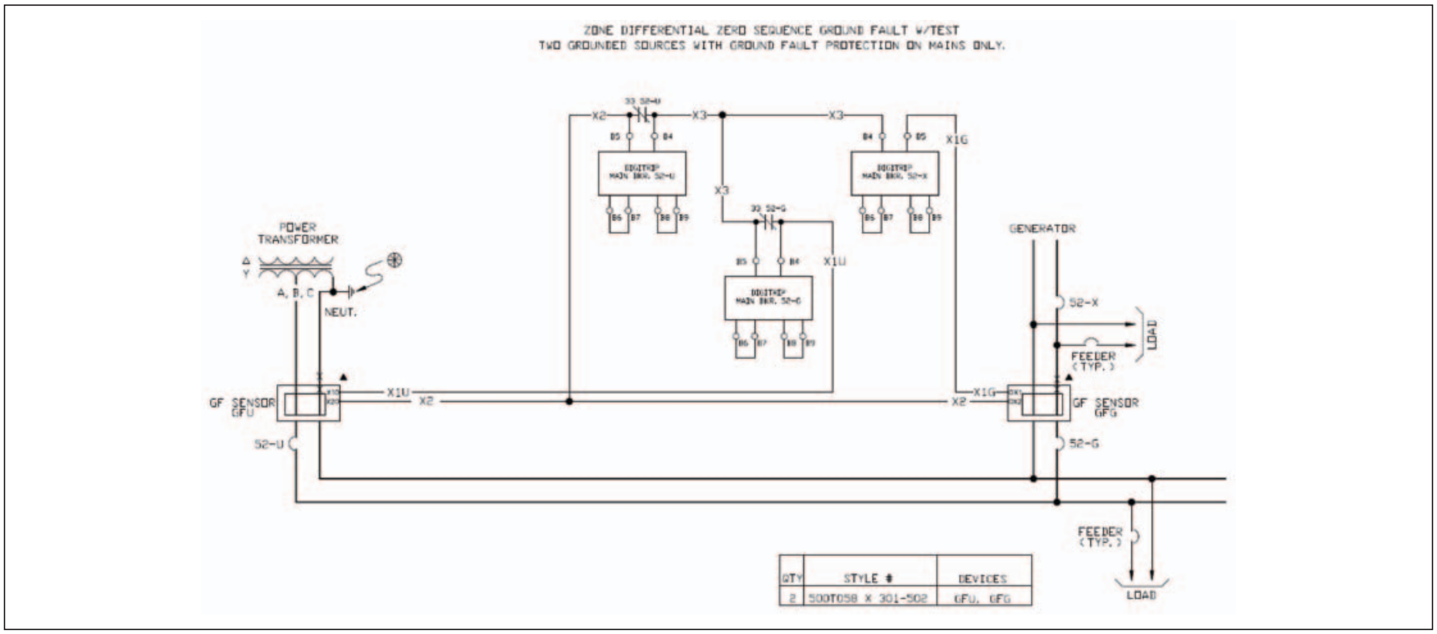

Figure 7. M-T-M, Single Ground

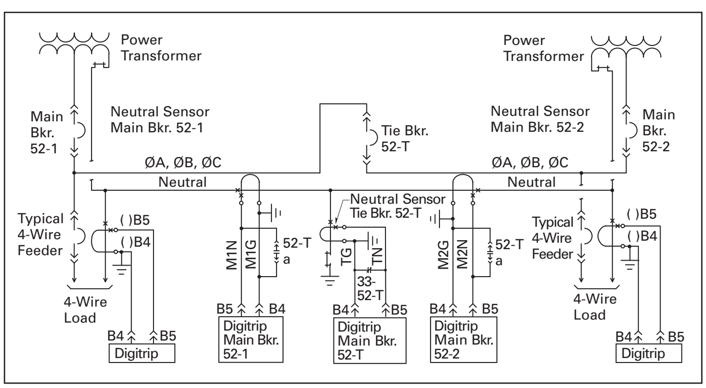

Figure 8. Dual Source System—Single Point Grounding

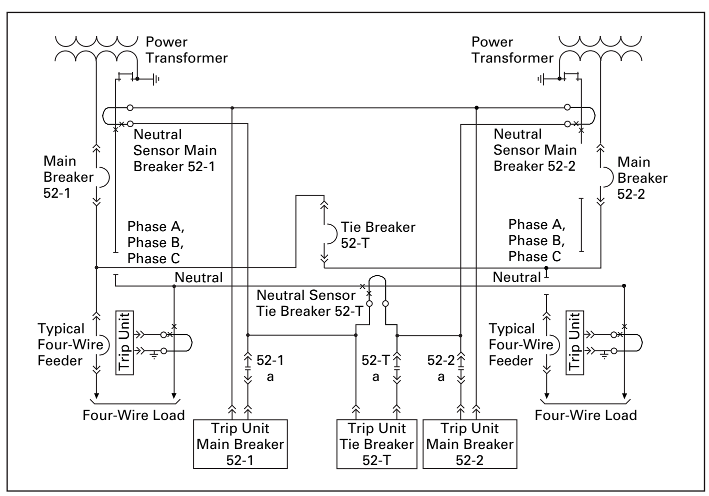

Figure 9. Dual Source System—Multiple Point Grounding

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Printed in USA
Publication No. WP027003EN / Z14557
December 2013

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