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# Application Note

# Application of Split-Phase and Self-Balancing Schemes in the BE1-11*g*

**The BE1-11*g* Generator Protection System can be easily set to provide protection for split-phase generator windings and for self-balancing generator protection schemes.** Split-phase generator protection can detect turn-to-turn shorts at low levels. These faults cannot be detected by traditional phase-differential or ground-fault protection until the fault transitions into a phase-to-phase or phase-to-ground fault. Self-balancing protection schemes provide effective protection against phase-to-phase and phase-to-ground faults. This application note explains the operation of split-phase and self-balancing schemes and how to set the BE1-11*g* relay to perform in these applications. [1] [2].

## Split-Phase Protection

Usually, split-phase generator windings are found on low-speed, hydraulic-type generators. As the name implies, in a split-phase configuration each phase of generator windings is split into parallel sets of windings. Protection engineers can use this design characteristic to detect turn-to-turn shorts. When a turn-to-turn short occurs, current circulates in the generator winding because of the voltage imbalance that occurs as a result of the shorted turn. This fault can be detected by several different CT configurations. Regardless of the chosen CT configuration, an inverse time element (51) combined with an instantaneous element (50) for each set of windings provides adequate protection for turn-to-turn shorts. [2] For this application note example, the CT configuration and wiring to the BE1-11*g* relay is depicted in Figure 1.

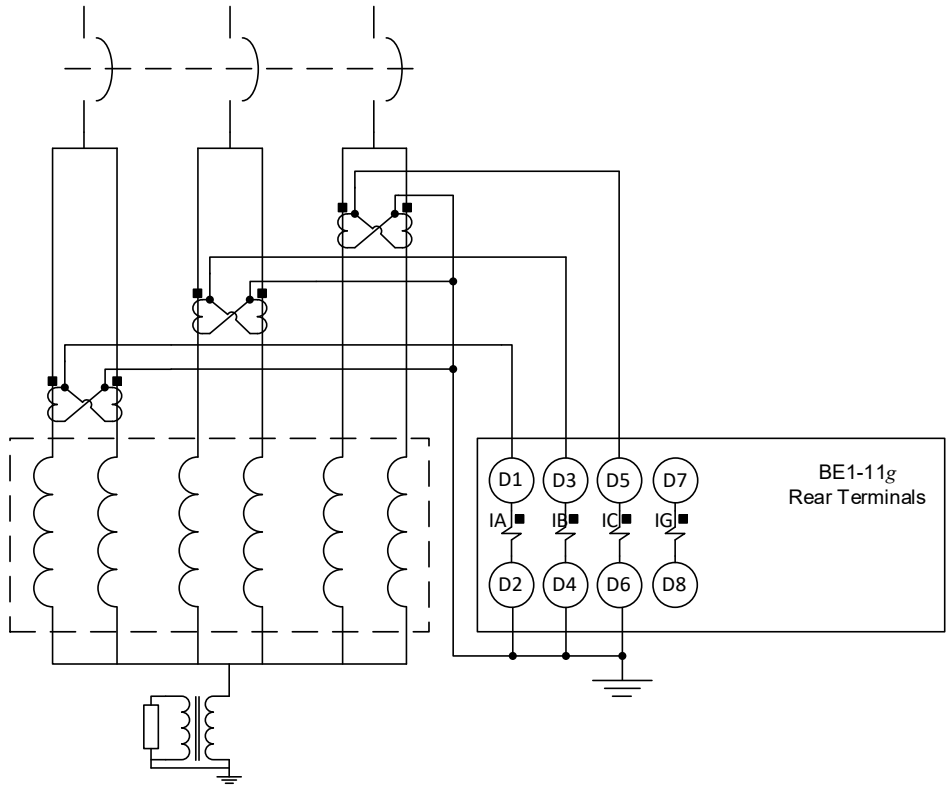


**Figure 1 - BE1-11*g* Relay CT Configuration and Wiring Connections**

Therefore, it is recommended to recheck these measurements periodically and adjust the settings as needed. The IEEE generator protection tutorial [2] suggests that a very inverse time overcurrent element should pick up at 1.5 times the normal circulating current and have a time dial setting such that the relay trips in 0.5 seconds at two times pickup. The instantaneous element should be set to seven times the normally circulating current.

The BE1-11*g* relay offers seven inverse time overcurrent elements (51) and six instantaneous overcurrent elements (50) that can be set to specific phase currents (IA, IB, and IC). To configure the BE1-11*g* for split-phase protection, the 51-1, 51-2, 51-3 elements and the 50-1, 50-2, 50-3 elements are set to the corresponding generator phase by selecting IA, IB, and IC, respectively, as the Mode in the BESTCOMS*Plus*® configuration software Inverse Overcurrent window (see Figure 2).

The following example uses the IAC Very Inverse curve. Select V2 as the Curve. Set the pickup at 0.5 in the Pickup (Secondary Amps) field. Calculate the time dial, D, using equation 1. Solve for D and insert the time constants from Table 1. Use a time-to-trip value, $T_T$, of 0.5 seconds. Equation 1 yields a time dial setting of 0.2875, which is rounded to 0.30. Enter 0.30 as the Time Dial setting.

Follow this same procedure for current IB with Inverse Overcurrent 51-2, and current IC with Inverse Overcurrent 51-3. Thus, each phase is set for a different pickup value (if needed), depending on the level of naturally occurring split-phase current per phase. The time dial setting remains the same for each phase because it is a function of the multiple of pickup.

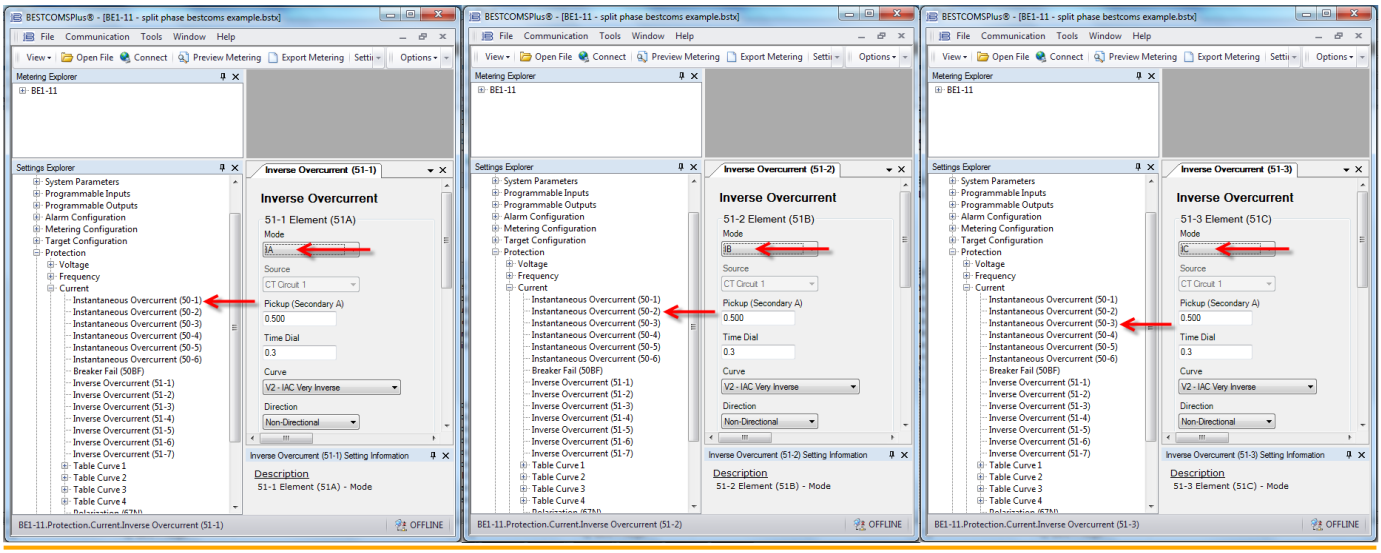


**Figure 2 - Setting Inverse Time Overcurrent Elements in BESTCOMS*Plus***

$$T_T=(AD/M^N-C)+BD+K$$

**Equation 1 - BE1-11*g* Inverse Overcurrent Time Dial Equation**

| Curve Selection | Curve Name | Trip Characteristic Constants | | | | | Reset |
|---|---|---|---|---|---|---|---|
| | | A | B | C | N | K | R |
| V2 | IAC Very Inverse | 4.4309 | 0.0991 | 1 | 1.9531 | 0.028 | 5.8231 |

**Table 1 - Excerpt from BE1-11*g* Instruction Manual Time Characteristic Curve Constants Table**

Configure the instantaneous overcurrent elements (50) in the same manner as the inverse time overcurrent elements (51) (see Figure 3). For this example, the Instantaneous Overcurrent 50-1 Mode is set to IA to correspond with the A-phase generator winding. Pickup is set to 2.33 secondary A (seven times the normal circulating current value) and Time Delay remains at the default 0 milliseconds. The same procedure is followed for IB with Instantaneous Overcurrent (50-2) and IC with Instantaneous Overcurrent (50-3).

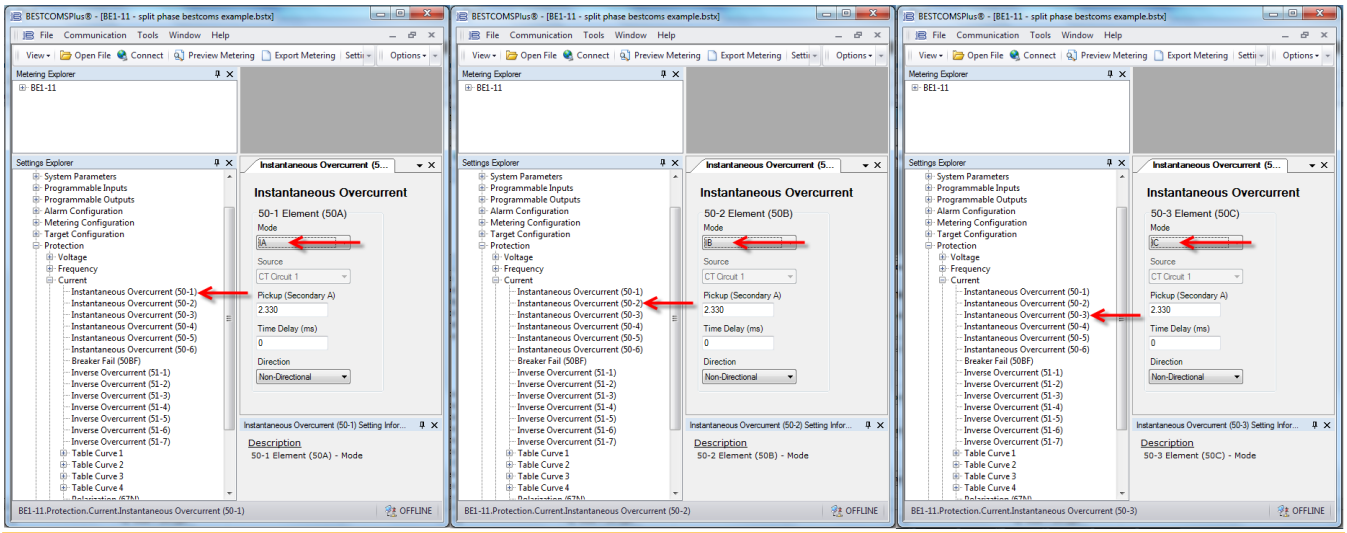


**Figure 3 - Setting Instantaneous Overcurrent Elements in BESTCOMS*Plus***

## Self-Balancing Protection

Small generators tend to use self-balancing CT configurations because the physical size of the winding leads works well in an application with window CTs. Less expensive, low accuracy-class, low-ratio CTs can be used for adequate phase-fault and ground-fault protection of the generator stator. In a self-balancing arrangement, the phase and neutral side of each phase of the winding route through a CT so the net flux is zero under normal conditions, see Figure 4. Typically, a three-phase instantaneous overcurrent element (50) provides self-balancing protection. [2]

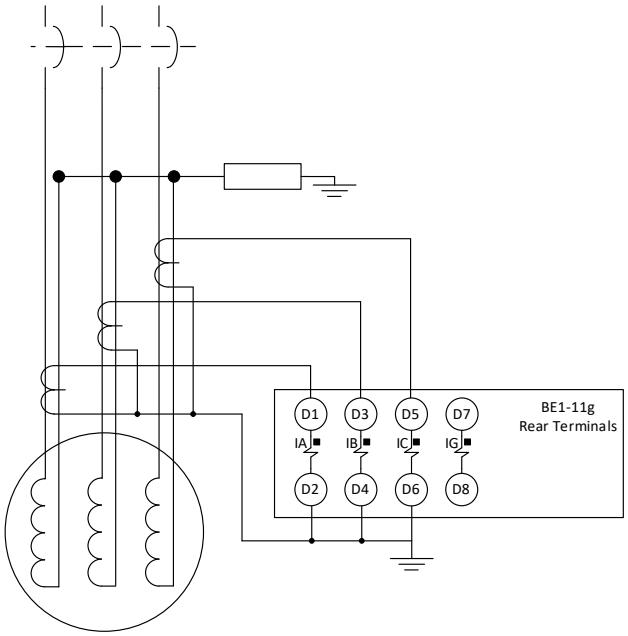


**Figure 4 - Self-Balancing Protecction Connections**

In BESTCOMS*Plus* software, the method to configure the BE1-11*g* relay for self-balancing protection is identical to the configuration for any three-phase overcurrent element (50). In this example, use Instantaneous Overcurrent 50-1 (see Figure 5). In the software window, Instantaneous Overcurrent 50-1 has Mode set to 3 Phase. The Pickup setting is the user-defined pickup value in secondary amps. If needed, set Time Delay from 0 to 60,000 milliseconds.

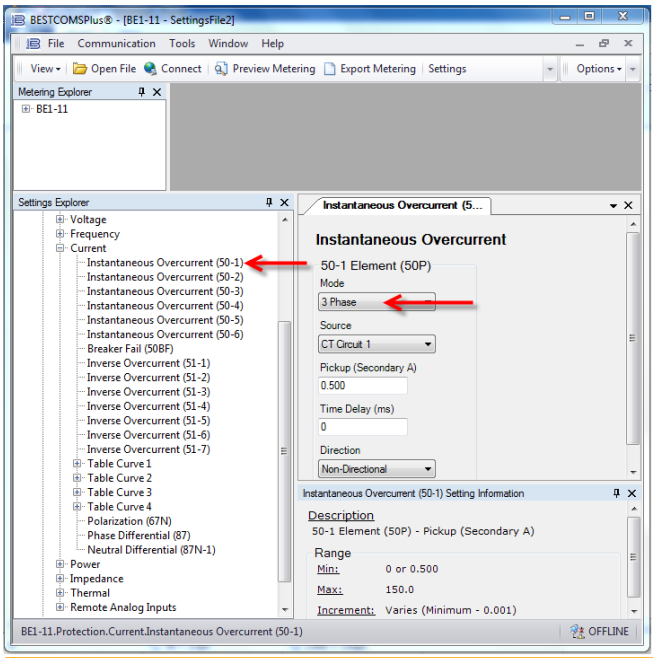


**Figure 5 - Setting Instantaneous Overcurrent Elements for Self-Balancing Differential Protection**

If a BE1-11*g* relay is equipped with the differential option (relay style number G6XXXXJXPXXXXX or G6XXXXJXTXXXXX), an alternate method can be used to configure self-balancing protection (see Figure 6). In the Phase Differential (87) window of BESTCOMS*Plus*, set the Mode to Flux Balance. In this mode, the BE1-11*g* compares the setting in the Flux Balance Pickup setting (secondary A) on a per-phase basis to the current in CT circuit 1 (CT1). The link between CT1 and the Flux Balance mode is fixed in firmware; the flux balance circuit must be wired to CT circuit 1 (terminals D1 through D8 in Figure 4). The "Flux Balance" mode is equivalent to a three-phase 50 element. Ignore the Transient Monitor settings when configuring the differential element for Flux Balance mode.

## For More Information

For more information about Basler BE1-11 Protection Systems, visit www.basler.com or contact Basler Electric Technical Support at +1 618.654.2341.

## References

[1] Generator Protection Guide, Revision E.0 Feb 2013, Basler Electric Company, Highland, IL 62249

[2] IEEE Tutorial on The Protection Of Synchronous Generators, Second Edition 2011, IEEE Power and Energy Society

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