Generator Third-Harmonic Stator Ground Fault Detection Element Operation

Overview

Generator ground fault detection for high impedance grounded generators using third harmonic measurements has been a proven and effective method for many years. The integration of these elements into multi-function, microprocessor based protective relays has improved the availability and accuracy of these elements.

Third harmonic-based generator ground fault detection elements (let's abbreviate this mouthful to 64G for this article) use the characteristic of many generators, by virtue of their stator winding configuration, to produce third-harmonic voltages. When the generator is grounded through high impedance and isolated from the rest of the electrical system (including all other generators) by a delta-connected transformer winding, third harmonic voltage measurements can be used to determine the presence of a ground fault within the generator. Certain implementations can also detect ground faults on the generator bus. When 64G elements are used in combination with neutral, fundamental-frequency overvoltage elements (abbreviated 59N), ground faults in any part of the generator stator, including a ground fault at the generator neutral point, can be detected.

Conference technical papers and manufacturer documents do a good job of describing the implementation and function of the various 64G element types. It may not be clear from these publications all the steps necessary to ensure that these elements remain both secure and dependable through the life of the relay installation.

Generator Third Harmonic Characterization

The third harmonic signals produced by a generator are dependent on:

- the generator construction
- generator excitation
- generator loading

The third harmonic signals measured by the protective relay are dependent on:

- the third harmonic signal produced by the machine
- the zero-sequence impedances of the generator, grounding system, and transformer(s) connected to the generator bus
- the connection and characteristics of the instrument PTs serving the relay
- the filtering and scaling methods implemented in the relay itself

When a new 64G element is commissioned, it is very important that the generator third harmonic response under normal, un-faulted conditions be well understood. Regardless of the 64G implementation used, it is critical that third harmonic neutral voltage measurements be taken while the generator is producing its minimum third harmonic voltage. This typically occurs at minimum load, minimum excitation, with the generator breaker closed. Because this performance is typical, but not universal, third harmonic voltage measurements should be taken at several unit operating points, and with the generator breaker open, generator at rated speed.

When the 64G element implementation uses third harmonic voltage measured by the relay at the generator terminals (such as the third harmonic voltage differential element available in the SEL-300G

Relay and employed in our ELGEN protection module) it is also critical that the minimum and maximum values of third harmonic generator terminal voltage be measured. Maximum values typically, but not universally, occur at generator maximum load, maximum excitation.

Because the 64G element is implemented in the protective relay, it is the relay's own measurement of the signals serving the element that is critical to proper element setting. When you perform the unit third harmonic voltage characterization, use the relay metering functions and consult the relay manufacturer documentation for complete details.

Challenges to Generator Third Harmonic Element Operation

Since 64G elements operate when the measured third harmonic voltage deviates in a manner that suggests the presence of a fault, any non-fault condition that changes these voltages could cause the element to operate incorrectly. Some of the risk factors include:

- an open generator breaker
- loss of connection to relaying voltages
- change in the ground zone apparatus
- change in the generator itself

Generator breaker position can have an impact on the 64G element. When the generator breaker is open, load is zero and the zero-sequence impedance network seen by the generator third harmonic voltage is limited to the generator and grounding system. These conditions impact both the magnitude of the third harmonic voltage produced by the generator and the distribution of that voltage across the ground zone impedances. To maintain element security, it may be necessary to disable the 64G element while the generator breaker is open, relying only on the 59N element for ground fault detection during this time.

Loss of connection to the relaying voltages will have an impact on the 64G element to the extent that the voltages lost are used by the element. Loss of the voltage connection to the generator neutral voltage impacts any 64G implementation, but should only occur if that voltage test switch is opened, or if a generator ground system disconnect switch is left open. Either condition would completely remove third harmonic signals from the relay and cause the element to trip. Removal of generator terminal voltages from the relay could occur due to blown PT fuse(s). Usually, relay logic can prevent a misoperation in this case if these voltages are used by the 64G element.

Less frequently, the generator bus topology could be changed by addition or replacement of a station service transformer or replacement of the main step-up transformer. Because this new equipment changes the zero-sequence impedance network in the generator ground zone, the third harmonic voltages presented to the relay during generator operation are changed. A major generator overhaul or rewind can change the third harmonic voltages produced by the unit. Any change in the apparatus connected to the generator bus should trigger a new characterization of the generator third harmonic voltage signals through the methods outlined above.

Conclusion

When properly set, third harmonic voltage-based 64G elements provide both secure and dependable protection for generator ground faults and are an important part of any complete generator protection package. Achieve secure dependable 64G element operation by a thorough understanding of how the elements work and a careful characterization of the generator itself. Re-characterize the system any time you revise the apparatus in the generator ground zone.