Ground Fault Neutralizer (GFN) Questions & Answers

Q1. **What is the advantage of resonant earthed neutral systems over solid earthed or resistance earthed systems?**

A. It is well known that in a predominantly overhead network a high proportion (the Orion network was typically 70%+) of transient faults are only single phase to earth. In solidly earthed or resistance earthed systems these events will generally result in recloser operation and / or feeder tripping, if they are detected successfully. With a resonant earthed neutral system installed the ability to ride-through these events whilst maintaining an uninterrupted normal voltage profile to customers connected to distribution transformers is possible, reducing SAIFI and MAIFI interruptions. Fault current during a single phase fault is also reduced considerably (>100x) extinguishing the fault arc, reducing the mechanical stress to network components and eliminating voltage dips and sags. Resonant earthing the neutral also has the advantage that it provides much higher earth fault sensitivity (typically >>5,000 ohms) over conventional solidly earthed or NER systems so potentially unsafe phase to earth connections in areas with high earth resistivity can be detected, eliminating transferred EPR problems (e.g. telecom, fences, irrigation or other systems).

Q2. **How does the GFN differ from a traditional resonant earthed Peterson Coil systems?**

A. Peterson coil systems only cancel the capacitive component of fault currents, but due to dielectric, corona and leakage losses of the connected network there is an active residual component of current present. The GFN utilises power electronics to fully compensate for this remaining residual current using the Residual Current Compensator (RCC) to inject anti-phase current into the network. By cancelling virtually all current through the point of fault, the faulted phase voltage will be at a low level (~0V) independent of the fault impedance. This also eliminates the problem of cable arc re-striking with Peterson coil only systems. Because around half of permanent faults are single phase to earth, with a GFN system network operators have the ability to operate with continuous earth faults safely without disconnection until fault crews locate and isolate the fault, saving valuable SAIDI customer minutes.

Q3. **What other advantages does the GFN have due to the use of the RCC?**

A. If there are excessive THD levels on the network, standard Peterson coils are tuned only to the fundamental frequency, thus allowing the harmonic frequency currents to continue to flow through the fault increasing the voltage at the point-of-fault. The RCC on the GFN has the ability to cancel the currents of the 3rd, 5th and 7th harmonics by injecting anti-phase current reducing the voltage at the point-of-fault to an insignificant level. If your substation of interest does exhibit THD issues the GFN RCC and arc suppression coil (ASC) must be sized accordingly, at the time of order, to allow for the higher injection current requirements.

A further benefit is that even with an un-faulted system the RCC can be used to manually alter the effective phase-to-earth voltage on each phase to artificially stress the network, whilst the normal phase-to-phase system voltages are maintained. This can be combined with partial discharge monitoring and/or corona scanning as part of an asset management routine.

Q4. **How is the size of the GFN determined for a particular network?**

A. The GFN is sized to accommodate the phase to earth capacitance of the total network supplied from the substation allowing for future growth and any abnormal switching.

Q5. **How will the introduction of a GFN into a substation affect the existing network assets?**

A. The voltage ratings of any downstream plant and assets must be considered to ensure that the insulation can withstand full line-to-line voltage on what is normally phase-to-earth insulation. Distribution transformers, cables and overhead line insulators are generally designed for the increased voltage, but equipment like surge arrestors and substation VT's etc must be inspected and changed if under-rated. What voltage withstand is required depends on how the network owner wishes to operate their GFN system, i.e. if continuous operation for permanent earth faults is not required, then ratings do not have to be as stringent.

It must be noted that on networks that use open-delta / two-tank regulators, they must be changed to closed delta, three tank regulators, before a resonant earthed system can be safely used on these networks.

Q6. **The report on the GFN states that "the existing earth fault protection can be used as backup". Do existing protection settings need to be modified?**

A. Depending on the existing settings and type of earth fault relays used, you may need to increase the earth fault pickup, and/or block the sensitive earth fault elements, to prevent spurious tripping from increased levels of residual capacitive currents flowing in the un-faulted feeders connected to the same bus as the faulted feeder. However if the earth fault relays have polarised earth fault detection then the increased residual capacitive currents can be discriminated from the normal earth fault currents. Leaving the existing protection in service enables the GFN system to be taken out of service if required and revert to direct earthing of the transformer, for maintenance purposes. We also recommend that an independent (SCADA) measurement of the system neutral to earth voltage be provided to the network controller. This will provide an indication of the presence of an earth fault if the GFN is mal-operating, or out of service.

Q7. **What other changes might be necessary to integrate a GFN into a substation?**

A. The essential requirements to integrate the GFN operation into a substation include indications of busbar phase voltage and the residual voltages. The residual voltage can be provided by an open delta secondary winding on the substation VT, if available, or as an option can be provided via equipment on the GFN.

Residual currents of the protected zones must be provided to the GFN to enable fault location ability, i.e. feeders and if required busbars and transformers. The residual currents can be provided from existing protection CT's using the Holmgren connection without the need for additional core balance CT's.

The substation power transformers must be capable of withstanding the full phase to earth voltage across the neutral connection and must be adequately rated to cope with the full network capacitive current. Installing a method to bypass the GFN to conventional earthing is recommended, but not essential, to enable maintenance of the ASC.

To prevent damage to the substation power transformer or ASC, a suitably rated surge arrestor should be installed on the transformer neutral. In the case of a primary voltage earth fault at the substation, there is the possibility of causing over voltages on the secondary network (due to the series resonance of the coil and system capacitance).
Due to the power requirements of the RCC, the local AC supply may need to be upgraded as well.

Q8. **How does the GFN adapt for changes in network size due to switching operations?**

A. The GFN continuously monitors both the magnitude and phase angle of the neutral to earth voltage, and if either one of these monitored values deviates beyond preset limits the GFN will initiate an automated system retune and hence adapt automatically to changes in the network size and configuration.

Q9. **What will happen if there are simultaneous earth faults on two different phases?**

A. If the faults occur on different phases, then effectively this is a phase-to-phase fault, also known as a cross-country fault, so the system voltage cannot be maintained. In this case the GFN would trip the feeder that has the cross-country fault, but if the second fault occurs on a different feeder the first faulted feeder will be tripped.

Q10. **What will happen if a conductor from a GFN protected circuit drops onto an under-built LV circuit and earth?**

A. With the GFN operational and assuming any insulation between HV and LV breaks down, there will be an initial discharge of the HV network capacitance into the LV system followed by approximately 3 cycles of residual current. The RCC will then operate to neutralise the residual current to a very small level. Arcing and hazardous voltage impressed onto the LV system is greatly reduced compared to a conventional earth fault protection system that will either cause major damage to the LV network or perhaps not trip at all due to the possible high fault impedance of the system potentially leaving a public safety hazard. Most broken wire faults result in one end of the broken conductor contacting earth and/or other network components, e.g. poles .cross arms and other circuit conductors; this would be detected by the GFN.

Q11. **What effect will SWER have on the operation of the GFN?**

A. As long as the single-wire-earth-return (SWER) is connected to the network via a two winding isolation transformer then there will be no effect to the operation of the SWER, due to the installation of a GFN, because the phase-to-phase input voltage does not change. Earth faults on the SWER cannot be compensated for.

Q12. **Does the GFN have any impact on live line work?**

A. Live line work can be carried out more safely on a substation protected with a GFN compared to one that is traditionally earthed. This is due to the enhanced sensitivity to detect phase to earth faults. If a fault is detected during live line work, the GFN has an in-built function that prevents the faulted phase returning to the nominal phase voltage once compensated, i.e. held near to zero volts. Generally existing glove and barrier procedures are designed to maintain safe working distances for phase-to-phase clearances and with the GFN these voltages remain the same.

Q13. **Would the conductor be at a lethal voltage in the situation where an 11kV overhead conductor broke, the end touched the ground and the conductor was lifted?**

A. The short answer is no. In the case that the source end of the conductor was the one on the ground, the GFN will compensate for the faulty phase. The GFN system will automatically carry out an automated confirmation after the fault is detected, to determine whether the fault is transient or permanent. If the fault is permanent then the GFN will continue to compensate for the fault.

Q14. **What is the likely mode of failure associated with the GFN system?**

A. That the inverter will not operate when required or there is a fault in the ASC. Both of these have alarms that indicate the failure to the operator, and feeder tripping can be carried out as a backup. These are not failures we have experienced. Failure of the GFN system to indicate an earth fault can be covered by independent monitoring of the system neutral voltage.

Q15. **How long will the fault location process take?**

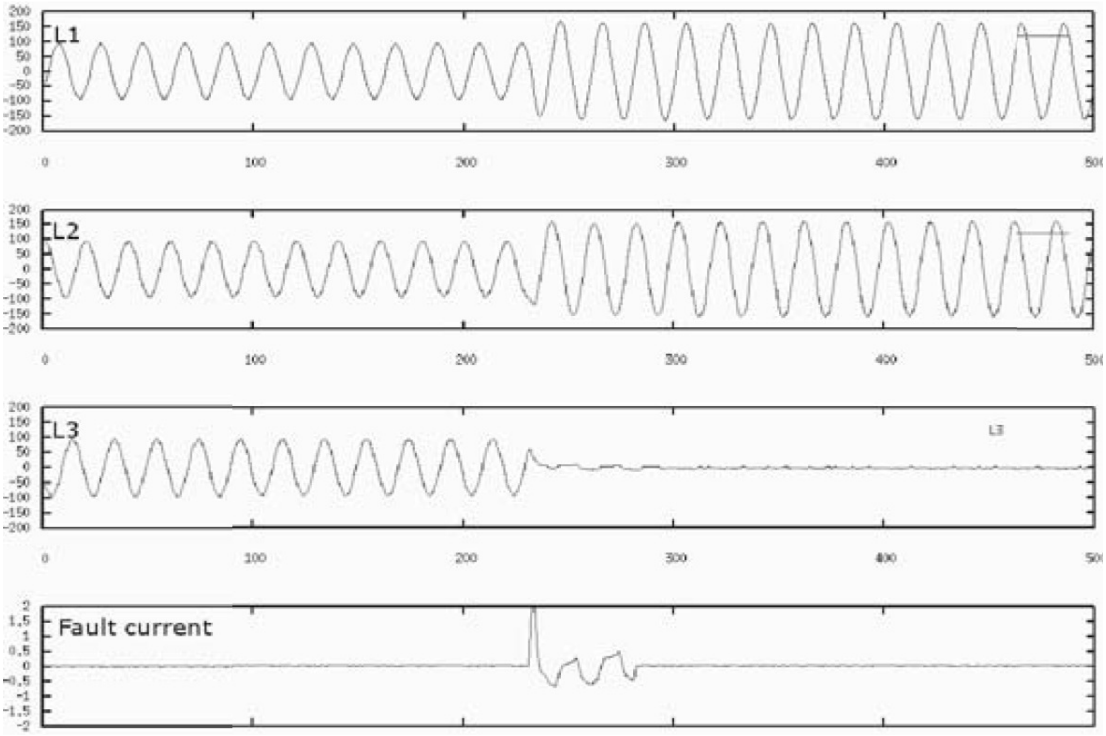
A. The distance to fault method employed by the GFN takes about 1 minute. This method is only applicable where a loop can be made back to the source transformer.
Industry standard methods using the uncompensated 5th harmonic are available for locating faults on a radial line feeder whilst the line is still energised.

Q16. **To what extent is the electrical arcing reduced at the point of fault by the installation of a GFN?**

A. Depending on the fault impedance there may be an initial transient discharge of the network capacitance into the fault at the fault inception, (Australian Bushfire Task Force studies have shown there is not enough energy in this discharge to initiate a fire). Approximately 60ms after the fault inception the GFN's RCC will reduce the fault current to less than 50mA

Q17. **How much time is required for the reduction of electrical arcing to take place?**

A. Within 3 cycles or 60ms all arcing current is reduced to near zero (~50mA). The graph below demonstrates a fault occurring on L3. Note that the voltage to earth after the fault inception reduces to near zero and the capacitive fault current in L3 initially discharging and the residual reducing to zero.



Q18. **With the introduction of a GFN, is there an increase in the system over voltages?**

A. With the initial fault current capacitive discharge there is a transient over voltage in the neutral. Theoretically this could be up to $2.V_{phase}$, but this will be much less in actual installations due to the saturation and losses in the ASC. On MV distribution systems, insulation coordination is influenced to a greater extent by external rather than internal over voltages.