

## **Single phase earth faults; solutions using reclosers to meet the demands of the modern network**

### **1. Introduction**

The advent of the microprocessor protection relay within a recloser controller has allowed the introduction of a significant number of new protection features and functionality. In parallel to these enhancements the recloser switch has transformed into an extremely reliable switch which operates in a significantly faster time based on the use of the current technology of a vacuum interrupter with an optimised magnetic actuator. The combination of these two components into the single solution of a “recloser” allows new capabilities which can be used to resolve a large number of problems the utilities are facing in their electrical networks today.

As an example, one of the many areas where reclosers can significantly contribute is in the area of faulted phase grounding. Faulted phase grounding is based around reducing the risk associated with a single phase to earth fault whilst maintaining the continuity of supply to the end users for as long as possible or at least to allow sufficient time for the utility to track down the fault. Neutral earthing and earth fault treatment have an impact on safety, supply quality, operational complexity and supply continuity [1].

There are five major grounding systems in MV installations: ungrounded neutral, resistance grounding, reactance grounding, Petersen coil grounding and direct grounding. Each type of grounding system has its advantages and its drawbacks. The use of a specific grounding system is generally dependent on the type of electrical network, the safety requirements and local norms. Couple this in with figures such as 70-80% of faults are transient, Earth faults account for 70-80% of all faults and 83.5% of earth faults on MV networks are transient [2] then significant advantages can be obtained through using the correct methodology in earthing practices in combination with the capabilities of today's technologies. This paper highlights some of the core advantages reclosers can provide based on several of the different types of grounding systems in conjunction with different techniques used to maintain supply after a phase to ground fault has occurred.

### **2. Recloser Contribution to Earthing in the Substation**

The type of neutral to earthing system used in the substation will generally be dependent on the requirements based on personal safety, fire prevention and cost. For example in many European countries an Arc Suppression Coil is used to connect to the transformer neutral to limit the capacitive earth fault current flowing when an earth fault occurs in a high or medium

voltage network. The coil is commonly known as a Peterson coil. The first main advantage of this neutral-point-treatment, using the Peterson coil, is that in most cases the system is self-healing, as the arc distinguishes without any intervention of the protection system. The second main advantage is the possibility of continuing the network operation during a sustained earth fault. As a consequence this reduces the number of interruptions of the customers power supply. Unfortunately the sustaining of the supply under phase to earth fault conditions can result in step voltages being produced which result in safety issues or in the cases of dry environmental conditions such as in Australia, bush fires. Another common problem is associated with the increased use of cables were fault restrikes can result in the creation of a multi-phase or cross-country fault [3].

### 2.1. GFN

The GFN (Ground Fault Neutraliser) is one method for helping to reduce these problems. It is much faster than traditional protection based on feeder tripping. It brings the fault current down to practically zero in typically 60ms, without tripping the feeder. The GFN measures shunt admittance continuously during healthy conditions. A detected change in the network triggers a new determination of zero sequence admittances in all three phases. When an earth fault occurs these admittances change and allows the GFN to compensate for the fault condition (active and reactive current). The earth fault current, faulted phase and faulted feeder are determined from the GFN [1]. Figure 1 provides an example of a GFN installed in a distribution substation.

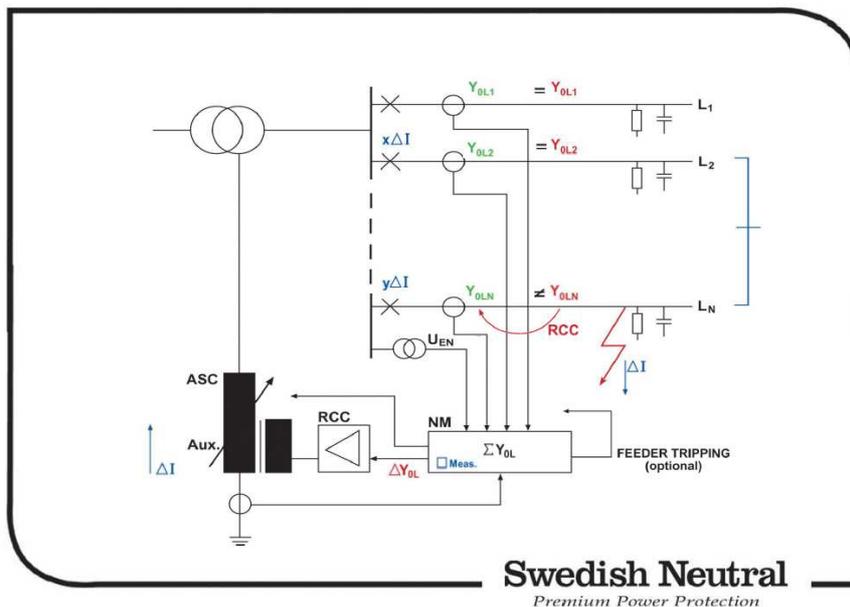


Figure 1: Schematic of a distribution substation with the GFN Ground Fault Neutralizer installed [6]

The resulting earth fault current when the GFN is operating under phase to earth fault conditions can be in the order of 0.2A [1] or less. Based on this level of fault current the actual location of the fault can be difficult to ascertain. To assist in the detection of the location of the fault, the GFN can gradually modify its compensation characteristic for short periods of time to increase the voltage to a level which will produce a fault current which can be detectable by devices on the feeder whilst ensuring the  $V_0$  does not exceed a value which will become a safety issue or cause a fire.

\*Reclosers which provide a suitable algorithm can then be used to detect if the fault occurs through that specific device. The resulting information is then fed back from all reclosers on all feeders originating from the GFN compensated substation to provide a more accurate location for the faulted phase.

## 2.2. Faulted Phase Earthing

Faulted phase earthing monitors all three phase to earth voltages and the neutral voltage displacement. When it detects an earth fault it earths the faulted phase within the feeding substation. This diverts a very high proportion of the earth fault current away from the fault location again minimising the likely-hood of voltage step potential safety issues or the creation of a fire due to arcing.

As an example at 4.2 amps, and an arc duration less than approx. 70ms makes the likely-hood of an ignition causing a fire almost negligible [4]. Figure 3 indicates an example of the network current flow when there is a faulted phase to earth. Figure 4 demonstrates the current flow after the faulted phase is grounded at the substation. The currents are redirected through grounded phase at the substation.

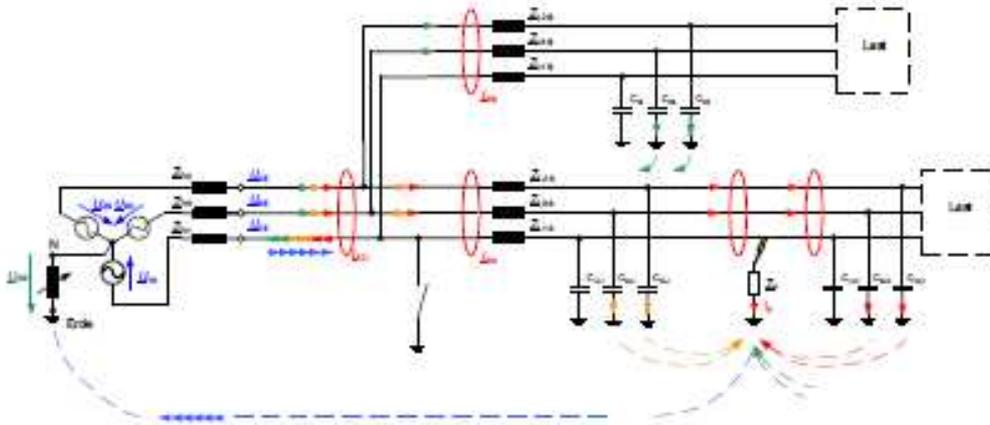


Figure 3: Current flows due to a faulted phase to earth [4]

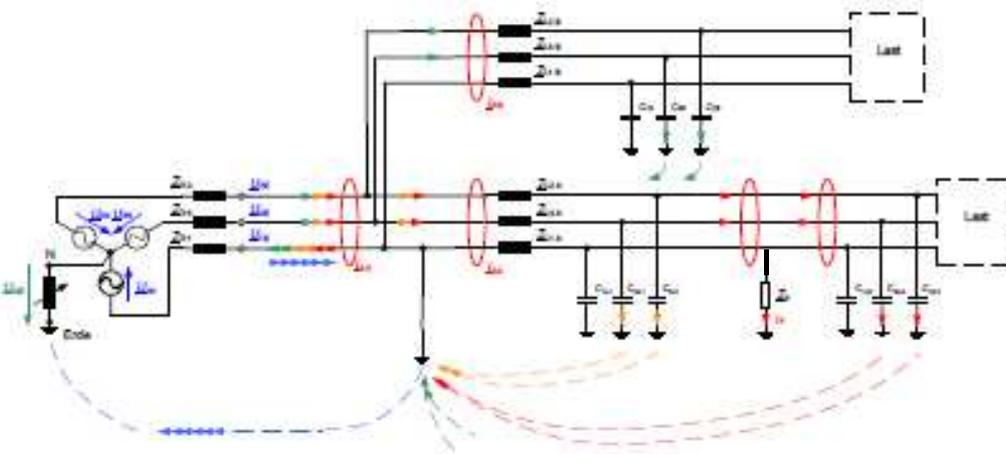


Figure 4: Current flows redirected with the faulted phase grounded [4]

The use of a recloser in performing the grounding of the faulted phase provides several key advantages:

- The recloser can contain the algorithms required to detect a phase to ground fault and then close the faulted phase to ground rather than requiring an individual protection relay.
- The recloser is suitable for short circuit currents in the case of a cross phase to phase fault

- In the case of more elaborate switching to bypass the Peterson coil or NER, dependant on the network requirements for fault detection, a control signal can be directly provided to the recloser to take the required action.

The resulting benefit is a single cost effective flexible solution which can be optimised to provide the required result. Figure 5 provides an example of a NOJA Power Single Triple Recloser used for faulted phase earthing within a substation in Australia.



Figure 5 Single Triple Recloser used for faulted phase earthing within a substation in Australia

### **2.3 Neutral Earth Switching**

SCHOLTZ JP [2011, 52] indicates that in a solid or low resistance earthed network the feeder breaker is likely to be opened for the majority of transient earth faults as arcing may not self-extinguish due to high earth fault currents. He also indicates the combination of a low resistance earthed network with the advantages of an unearthed network by temporarily converting such existing network into an unearthed network upon detection of an earth fault can have a substantial advantage. SCHOLTZ JP has shown in field trials that the disconnection of the source transformer's MV neutral connection to earth, and temporarily converting the network from low resistance earthed to unearthed, will allow transient earth faults to be cleared without the need to

trip the feeder breaker. If the fault is cleared within the time the network is unearthed then no customers supply would have been interrupted.

SCHOLTZ JP goes on to indicate the circuit breaker in the neutral to earth connection is used to detect the earth fault and then instantaneously open in the order of 60ms thereby providing the unearthed network. The circuit breaker will remain open for a user configurable time, in the order of 2 to 10 seconds and then reclose. At this stage any arcing faults will normally have had time to extinguish.

When the circuit breaker reclosers it must then stay closed for a set period to allow the normal protection to operate in the case were the earth fault has not been cleared during the period when the network is unearthed. In this application, the neutral earth switching can easily be achieved with the use of a recloser which will provide the reclosing capability, speed requirement, voltage ratings and protection capability within a single package.

#### **2.4. Faulted Phase Grounding on the Pole**

As discussed in section 2.2 a faulted phase may be grounded at the substation to divert a high proportion of the earth fault current away from the fault location so as to minimise the likely-hood of voltage step potential safety issues or the creation of a fire due to arcing. Unfortunately under circumstances of very long feeder lengths, cross capacitive coupling of phases can induce sufficient voltage on a faulted phase to again create a hazardous environment. A solution to this problem is to provide the faulted phase grounding capability in the form of a recloser at suitable positions along the length of the feeder. The recloser will monitor the state of each of the phases to ground and if the voltage meets specific threshold and timing requirements the recloser will close the faulted phase to ground eliminating the high voltage potential generated by the long feeder length.

#### **4 Summary**

This paper has provided a few of the many examples of where a recloser can be used to provide an integrated solution to a range of techniques being developed to improve the continuity of supply after the occurrence of a phase to earth fault. The voltage ratings, circuit breaker current operation capability, reclose capability, quick operating times and integrated wide range of protection features make it a good all round solution in both indoor and outdoor environments.

## 5 References

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