Resonant earthing with residual current compensation brings network performance benefits

Orion's use of resonant earthing technology at its substation near Darfield, in central Canterbury, is the first commercial application of resonant earthing with residual current compensation in Australasia, possibly the Southern Hemisphere.

Conventional direct earthing systems vs resonant earthing

Conventional direct earthing systems used by Orion to supply overhead HV reticulation usually employ sensitive earth fault protection to detect and clear single phase to earth faults.

Earth faults make up about 50% of all permanent faults on Orion's overhead 11kV network, and about 70% of all transient faults. Transient faults and associated momentary interruptions are problematic as they disrupt computer systems, impact on motor loads and cause loss of production.

For both earth and transient faults, circuit breakers at the zone substation or pole mounted reclosers operate and attempt to clear the faults. The customer experiences either a sequence of auto reclose operations (intermittent or momentary interruptions) leading to supply restoration or, in the case of circuit break lock-out, a much longer interruption until the fault can be located, isolated if necessary, and repaired.

During this process, fault location, switching and repair time have significant impacts on 'SAIDI' – the overall reliability index that measures customer minutes of non supply.

The resonant earthed system on the other hand treats single phase earth faults very differently – power supply to customers can continue even when a permanent single phase earth fault is present.

Also, in the case of transient earth faults, a circuit breaker isn't needed to extinguish the fault arc.

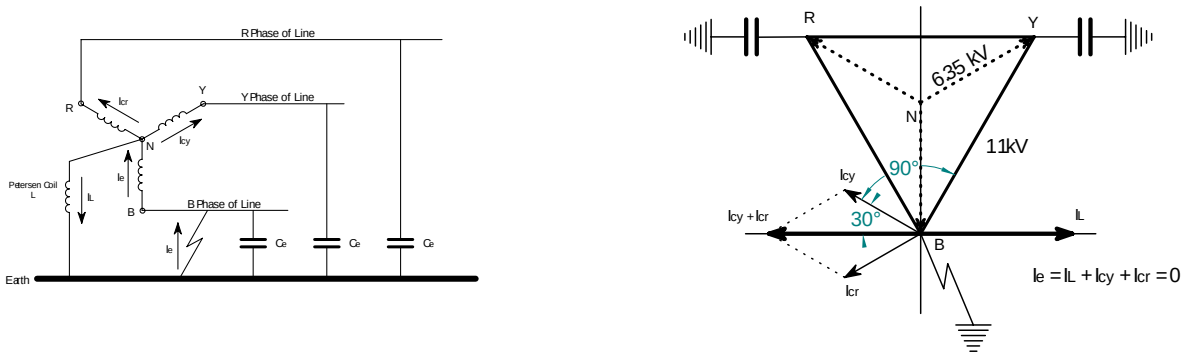
So what is resonant earthing with residual current compensation all about?

The technique involves connecting the neutral starpoint of zone substation secondary windings to ground via a tunable reactance, with the ability to also inject into this reactance a current that is 180° out of phase with a measured residual earth fault current.

The reactance is automatically tuned to the line-to-ground capacitance of two of the three conductors of the three-wire HV distribution network. This capacitance value can change as the feeder network length alters due to operational switching, hence the need to adjust the reactance value to stay 'in tune'. When an earth fault occurs on one phase, and the current in the earthing reactance matches the sum of the live capacitance currents, then in an ideal case no earth fault current flows.

This principle led to the introduction of 'Petersen' or 'arc suppression coils' from the early 20th century, particularly in parts of Europe.

Figure 1: What is resonant earthing?



In practice, networks experience resistance losses and the tunable reactance (sometimes known as an ‘arc suppression coil’) may not by itself eliminate all residual (‘earth fault’) current.

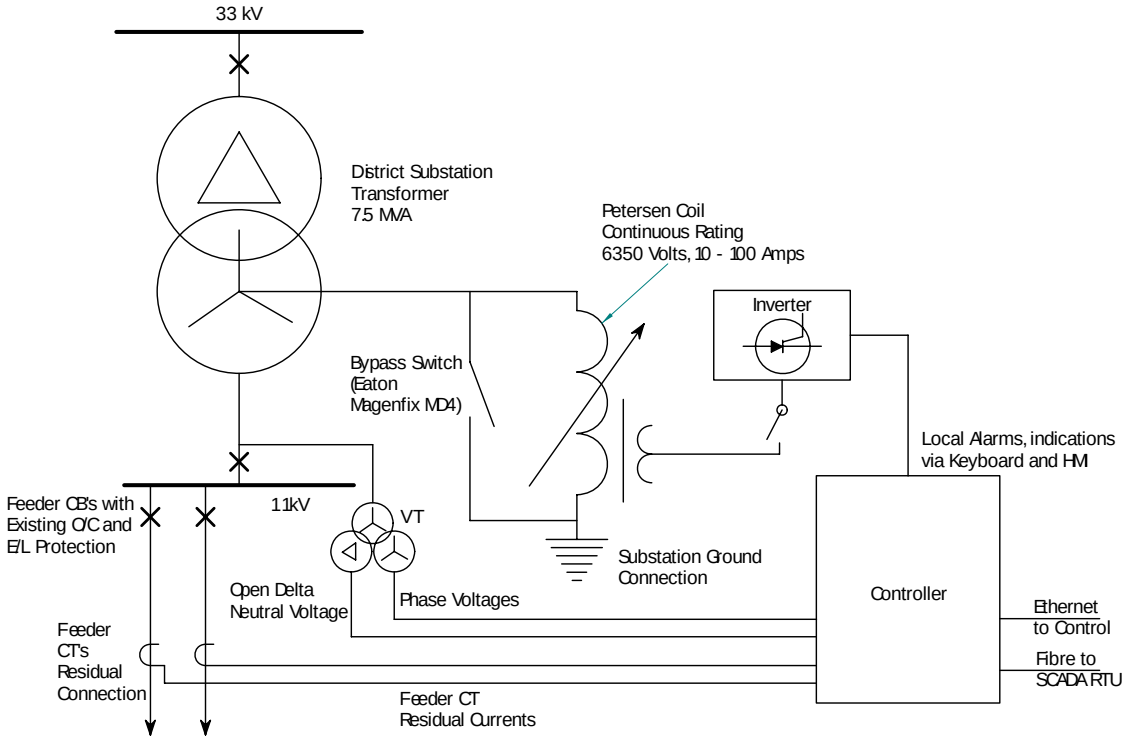
However if this residual current is measured and a ‘neutralising’ current 180° out of phase is injected into the system neutral via the arc suppression coil, then residual current compensation (‘RCC’) can be achieved.

In practice this is a very important feature that enables restriking single phase cable faults to be extinguished and also prevents the cable ‘burn back’ that exists in conventional resonantly earthed systems.

These considerations led a Swedish company to develop an enhanced earth fault protection system which incorporates advanced measurement and control systems and power electronics to achieve residual current compensation on a resonant earthed power network.

The Darfield substation installation schematic is shown below in Figure 2.

Figure 2: Schematic diagram – Darfield installation



In normal operation with a single phase earth fault present, this system alters the usual voltage to ground relationships on the connected 11kV HV network.

The system neutral voltage to ground is elevated to 6.3kV and the fault phase voltage is reduced virtually to earth potential. The unfaulted phase voltage is elevated to 11kV to ground.

This has implications for the over-voltage rating of some network equipment such as lightning arrestors (which need a 12kV rating rather than a 9kV rating).

This particular resonant earthing system also operates to modify system voltage relationships in the absence of any earth faults. Increased voltage stress to ground can be used to find potential or early insulation deterioration problems when used with devices such as ultra violet corona cameras or on line cable partial discharge monitors.

On the Orion network, several high impedance faults have been found and remedial work carried out, for example when a conductor came in contact with a cross arm on a wooden pole and when a tree branch touched a phase conductor. During a wind storm in Canterbury in October 2007 a tree branch broke an 11kV conductor and Orion was able to leave this fault safely for five hours without losing supply to upstream customers while other faults were fixed.

If ‘cross country’ faults occur (that is, simultaneous earth faults on two different phases and possibly two different feeders) the system cannot compensate – usually an alarm is raised and conventional earth leakage or over-current protection clears the faults.

Conclusions

Orion has successfully commissioned the Darfield substation resonant earthing system with excellent results in response to real and live test faults. Reliability, safety and power quality has already improved.

The system's ability to reduce damage to equipment and property at the point of fault and reduce hazardous shock voltages (earth potential rise) creates a significant improvement in public safety.

Network managers looking for cost-effective performance improvements for their HV networks in the range 6.6kV to 132kV should consider adopting this advanced form of resonant earthing.