POWER AUTOMATION TECHNOLOGIES

Petersen Coils – Basic Principle and Application

Petersen coils are used in ungrounded 3-phase systems to limit arcing currents during earth faults. The coil was first developed by W. Petersen in 1916. However the use of modern power electronics has revolutionised the performance of these classical solutions.

When a phase-to-earth fault occurs in ungrounded 3 phase systems, the phase voltage of the faulty phase is reduced to the earth potential as the capacitance of the faulty line is discharged at the fault location, the phase-to-earth voltage of the other two phases rises by √3 times. A charging current "I_C" occurs between these phase-to-earth capacitances, which will continue to flow via the fault path while it remains. I_C is three times the charging current of each phase-to-earth.

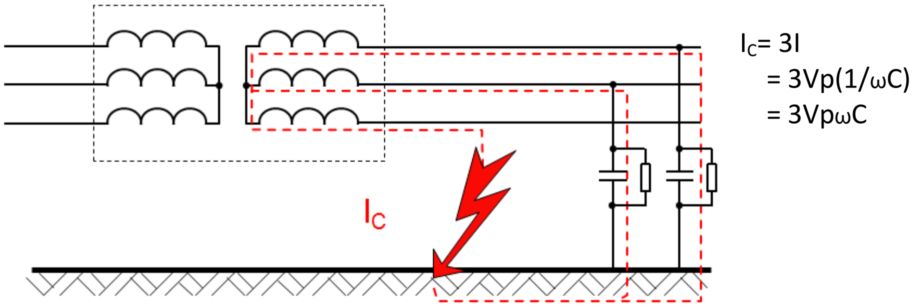

Figure 1. Isolated distribution system where I_C, is the discharge current due to capacitance of healthy phases.

A modern steplessly adjustable Petersen coil consists of an iron-cored reactor connected between the star point of the substation transformer and earth in a three-phase system. In the event of a fault, the capacitive earth fault current (I_C) is now neutralised by the current in the reactor as this is equal in magnitude, but 180 degrees out-of-phase.

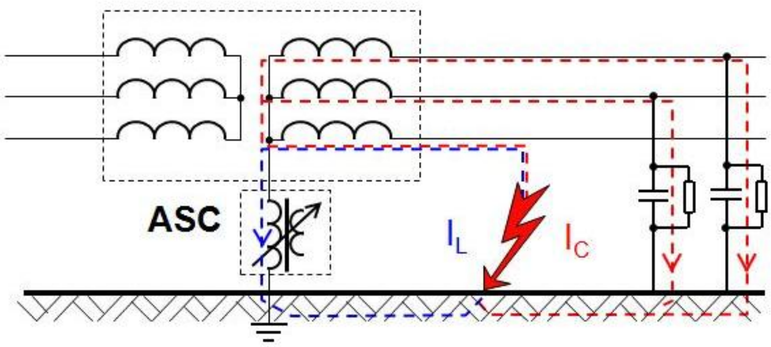

Figure 2. Compensated system where $-I_L = I_C$.

The Petersen coil may also be referred to as an Arc Suppression Coil (ASC).

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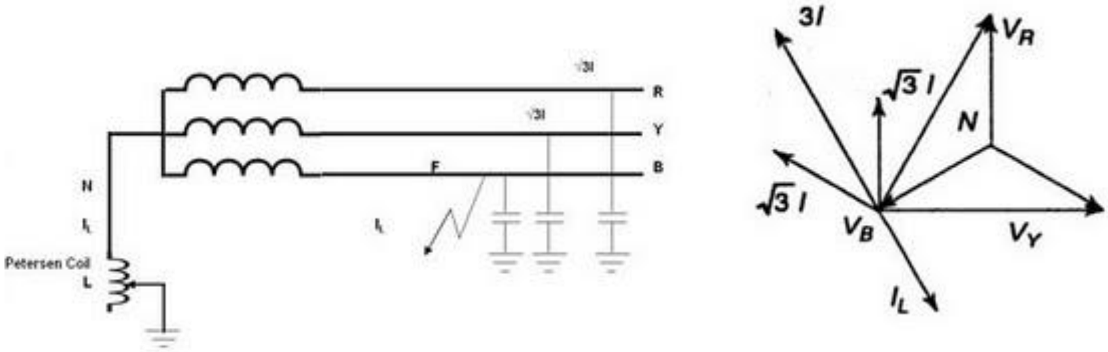

Figure 3. Petersen coil and resultant phasor during single phase earth fault.

Consider a Petersen coil connected between the star point of the transformer and earth with inductive reactance ωL. Then the current flowing through it is given by:

$$I_t = Vp/\omega L$$

To obtain an effective cancellation of the capacitive charging currents, I_t has to be equal to $I_{c,}$ therefore;

$$Vp/\omega L = 3Vp\omega C$$

From which we get;

$$L = 1/(3\omega 2C)$$

The value of the inductance in the Petersen coil needs to match the value of the network capacitance which may vary, as and when switching in the network is carried out. Modern coil controllers continually monitor the zero-sequence voltage and detect any change which occurs when there is a change in the network capacitance, the controller then auto-tunes the Petersen coil to this new level to ensure that the Petersen coil is tuned to the correct point to immediately neutralise any earth fault which may occur. This Rapid Earth Fault Current Limiting occurs automatically without any further intervention from the system.

Figure 4. Modern coil controller and outdoor Petersen coil.

In networks consisting of mainly overhead lines the majority of earth faults are intermittant in nature and most of these become self-extinguishing without causing any outage for customers, and cause no damage to the network. This results in a significant improvement in customer service and a corresponding improvement in network performance levels.

Figure 5 gives the level of current in Amps, below which, most intermittent earth faults are self-extinguishing.

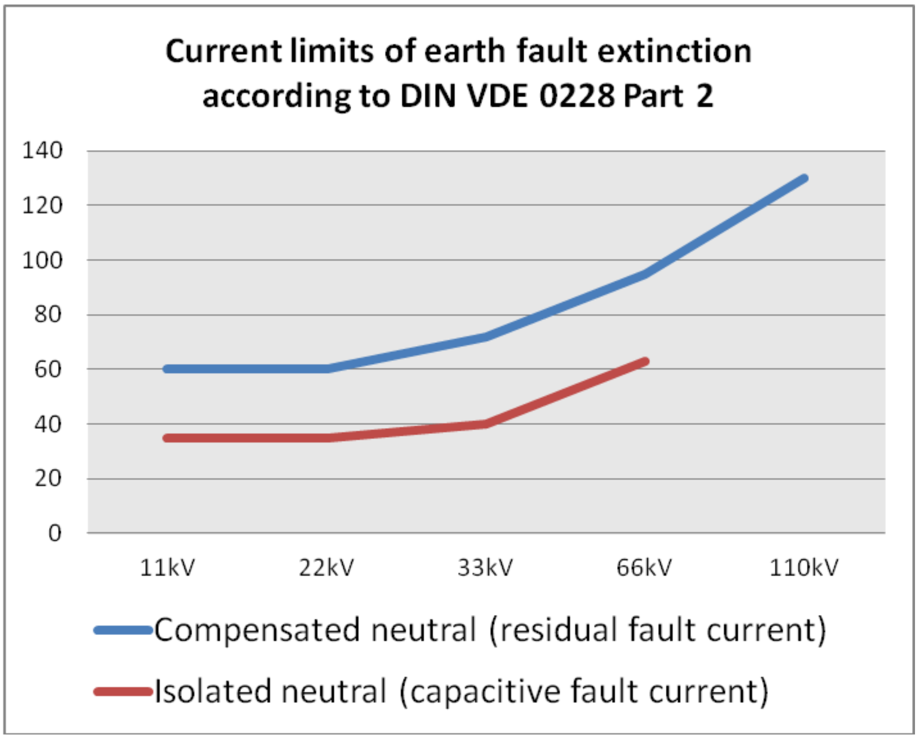

Figure 5. Current limits (in Amps) for self extinguishing faults.

In the case of a permanent earth fault the resulting capacitive current is neutralised by the Rapid Earth Fault Current Limiting inductive current provided by the Petersen coil. However, there will remain a very small resistive or watt-metric current which will flow as a result of losses in the network. Generally this residual current will be in the order of 5 % of the capacitive current. Note the unlike traditional fault currents in grounded systems which are highly inductive (as well as large), in a compensated system the power factor of the remaining watt-metric residual current is close to unity, which further facilitates the easy extinguishing of any arcing as both the voltage and current have a similar zero-crossing.

Typically in Australian rural overhead networks this residual current would be in the order of 5 Amps or less. This current will also be reduced depending on the resistance of the earth fault. In hot dry bushfire conditions the earth resistance is typically high (dry ground and vegetation) which will significantly reduce the residual current level, thereby further reducing the risk of ignition of bushfires.

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