APPLICATION NOTE

New solution for feeder earth-fault protection

AQ-200 IED series

The Problem

The increase of medium voltage cabling, connection of distributed generation and compensated networks (Petersen coil) along with distributed compensation has led to new challenges in earth-fault protection of distribution feeders. Challenging combinations of short cable feeders, long overhead feeders and mixed cable and overhead network is increasing significantly among distribution system operators and relaying on conventional protection methods may lead to either nuisance trips of healthy feeders or undetected faults in faulty feeders.

New earth-fault protection methods have been researched with aim to improve the dependability of the protection. These new methods have often required additional hardware thus increasing the cost and reducing the mean time between failure. Another drawback has been difficulty in selecting the relay settings as additional network data has often been required.

This application note describes Arcteq's novel method to increase the sensitivity of the earth-fault protection without any additional hardware. The implementation does not require any additional settings of the protected network either.

Traditional operating modes of directional earth-fault protection

Arcteq's AQ 200 series IEDs have different operating modes for feeder directional earth-fault protection. The traditionally available modes are "Unearthed", "Petersen Coil Grounded" and "Grounded".

When unearthed (capacitive) network mode is chosen the IED expects the fault current to be lagging zero sequence voltage by 90 degrees. Healthy phases of healthy feeders produce capacitive current during ground fault just like faulty feeder but current is flowing towards busbar and trough incoming transformer or grounding transformer to faulty feeder. Healthy feeders do not trip since capacitive current is flowing to opposite direction and selective tripping can be ensured.

When Petersen coil grounded (compensated) network mode is chosen the IED expects the fault current to be opposite direction to zero sequence voltage. Healthy phases of healthy feeders and faulty feeder produce capacitive current similar to unearthed network. Inductance of Petersen coil is compensating the capacitive current and therefore residual current in fault location is close to zero. Size of the inductance is chosen according the

prospective earth fault current of the network. Desired compensation grade is achieved when k-factor is close to 1.0 and network is fully compensated. Network is over compensated when k-factor is greater than one and under compensated if the factor is smaller than one.

Inductance connected to the star point of incoming transformer or like in most cases to grounding transformer compensates the capacitance of the network but due this the capacitive fault current cannot be measured anymore. Fault detection is handled by connecting a resistance on parallel with the inductance. This resistance defines the amplitude of fault current. In under –or over compensated situations the resistive component during the fault does not change, therefore selective tripping is ensured even if the network is bit under –or over compensated.

Below figure 1 shows the operating areas of traditional “Unearthed” and “Petersen coil grounded” modes. For more details refer to AQ 200 series instruction manuals.

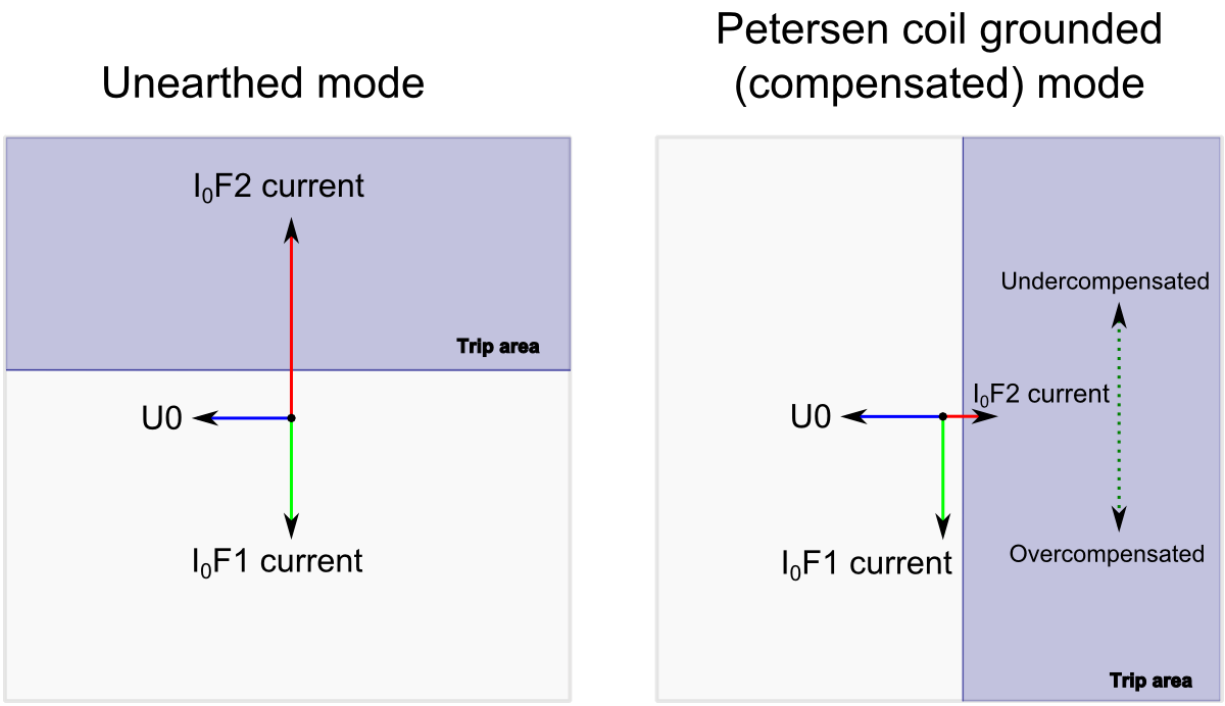

Figure 1 Traditional directional earth-fault protection modes

New broad range mode with multi-criteria detection

When protecting compensated long-distance cables and overhead lines it is in some cases difficult to distinguish between healthy- and faulty feeder. Merely measuring the angle and magnitude of residual voltage and currents is not always enough, but changes in symmetrical components of phase currents and voltages are also needed. Also, when protecting feeders from earth faults two modes are used depending on the network status (ungrounded or compensated). When changing between these two statuses setting group must be changed and especially in case of distributed compensation the change may be difficult or impossible to arrange. Lastly, in a compensated network protection, the relay with traditional algorithms may sporadically detect an earth-fault in a long healthy feeder due to CT errors. For all of these reasons, Arcteq has developed an improved alternative to these traditional directional earth fault protections.

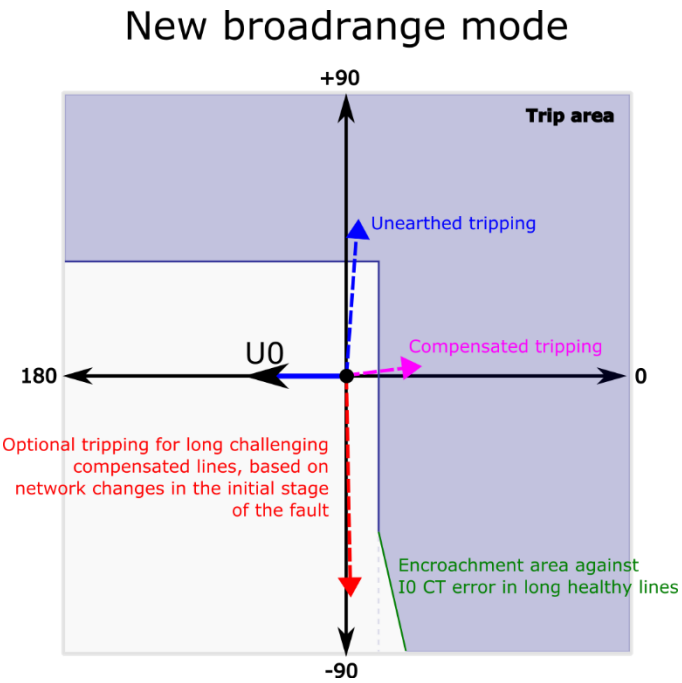

Figure 2 Operation of new broad range mode covers both ungrounded and compensated networks and is equipped with optional additional multi-criteria detection for compensated networks to increase the protection sensitivity

New broad range mode is capable of protecting against earth-fault in both ungrounded and compensated networks not only by just combining the two stages together but using a new multi-criteria detection. This optional additional tripping condition for compensated networks uses Arcteq's patented, high-resolution intermittent earth-fault algorithm with added

symmetrical component calculation of phase currents and voltages. If this mode is activated the tripping criteria comprises of a measured residual current in the fourth quadrant and the symmetrical components of voltages and currents detecting a fault. No extra parameterization is required compared to traditional method. Multi-criteria algorithm can be tested with Comtrade files supplied by Arcteq. Function requires connection of 3-phase currents, residual current and residual voltage to operate correctly.

To avoid unnecessary trips encroachment area against I0 CT errors in compensated long healthy lines can be added.

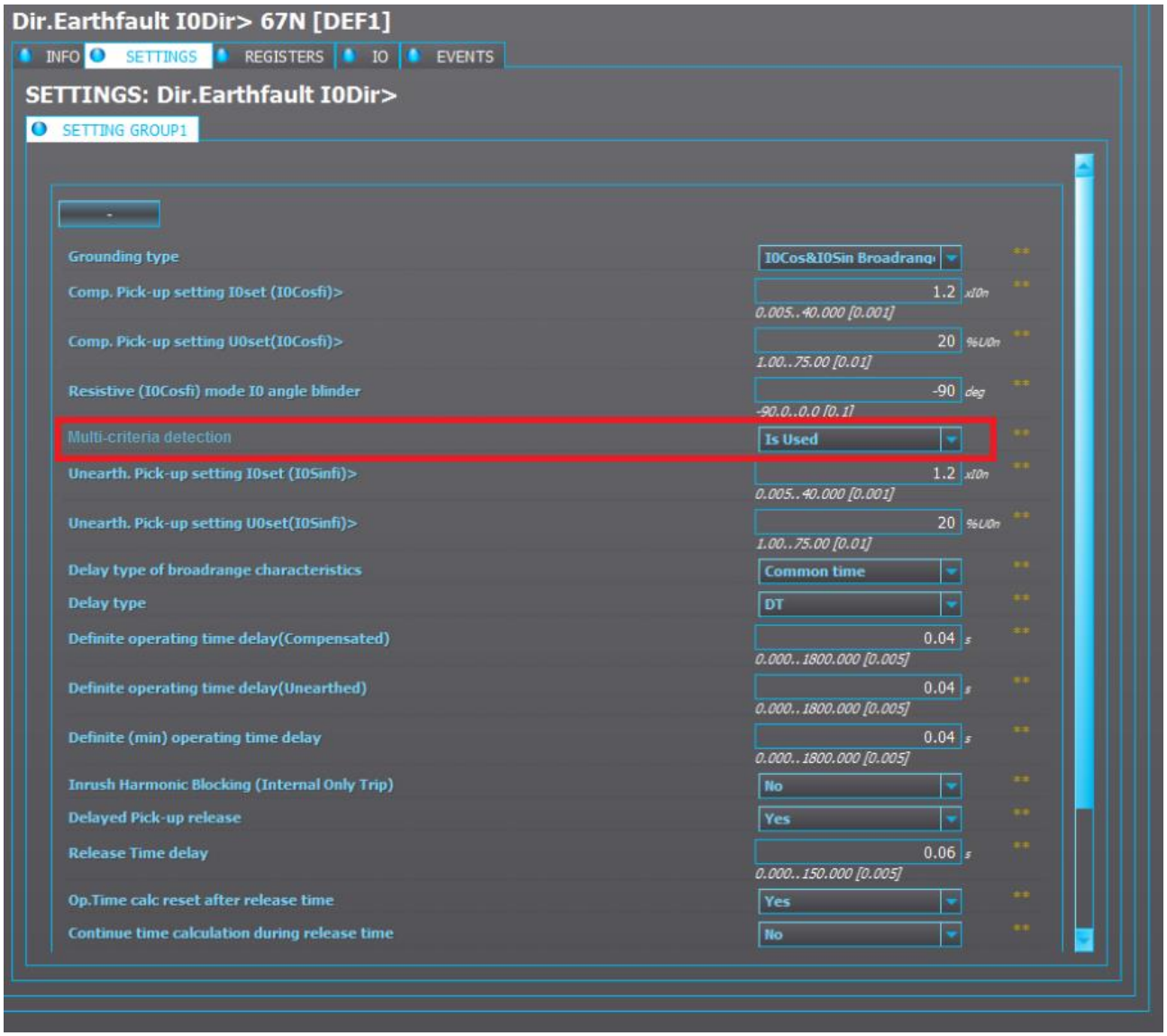

Figure 3 Screen capture of new broad range earth fault protection stage settings with added multi-criteria detection. Setting of this protection mode requires no additional network parameters and can be tested with comtrade files supplied by Arcteq.

Research results

The new multi-criteria earth-fault detection method has been researched using simulated PSCAD software models. Different type of networks including distributed compensation and mix network have been modeled and the new multi-criteria detection algorithm has been operating satisfactorily in these simulations. Below simulation captures show an example of mixed network where traditional earth-fault algorithms are not able to trip but Arcteq's multi-criteria detection is able to clear the fault correctly.

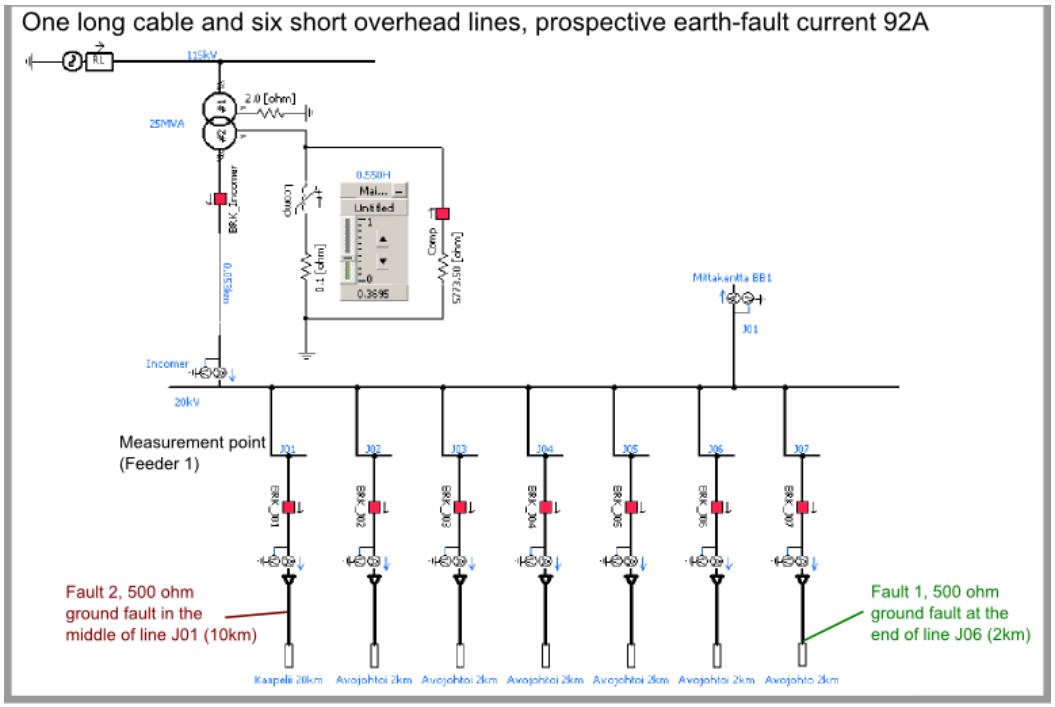

Figure 4 Example of simulated mixed network substation with end of line fault.

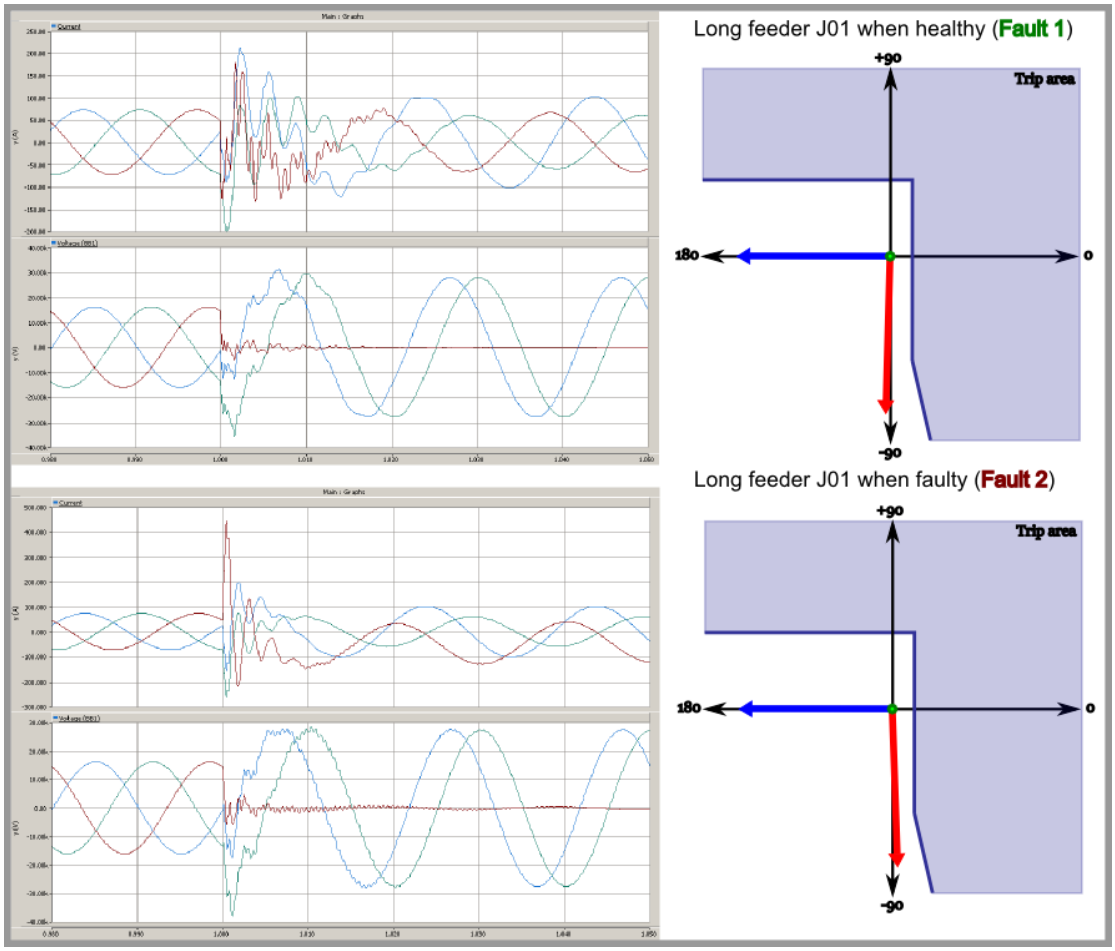

Figure 5 Simulation result with end of line fault in mixed network. Traditional earth-fault protection would not trip but Arcteq's new multi-criteria detection is able to trip on fault and is not operating on healthy feeders

Intermittent / transient earth-fault protection

For a complete coverage of feeder earth-faults in compensated networks, the intermittent / transient type of earth-faults are to be protected by Arcteq's patented intermittent earth-fault protection stage available in the AQ 200 series feeder protection IEDs. For more information refer to AQ 200 series instruction manuals and intermittent earth-fault guide at www.arcteq.fi/downloads and www.arcteq.fi/arcteq-innovations/.

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