

The ENSTO logo is rendered in a bold, blue, sans-serif font. It is positioned in the upper right area of the slide, above a large blue geometric shape that resembles a triangle pointing downwards.In the top left corner, there are several overlapping blue geometric shapes, including a large triangle pointing down and two smaller diamonds, one of which is lighter in shade.

Modern Adaptive Earth Fault Compensation: Enhancing Grid Safety

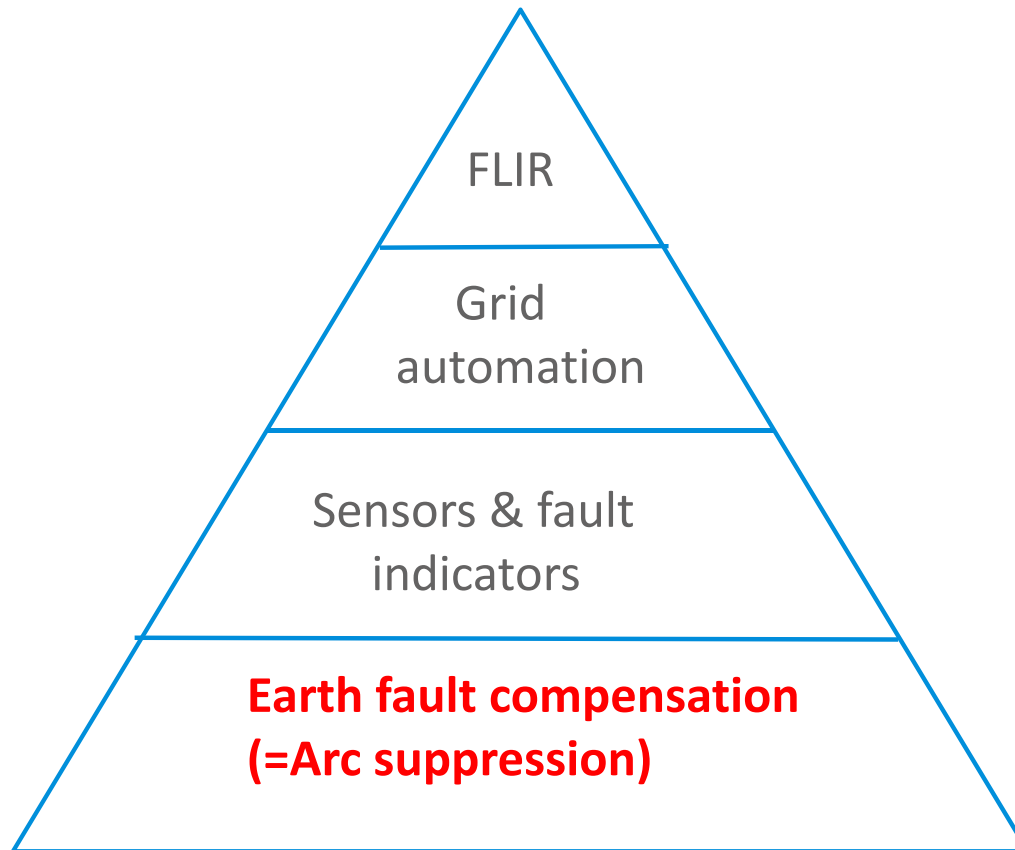
i-PCGRID 2019, Jyrki Penttonen

29.3.2019

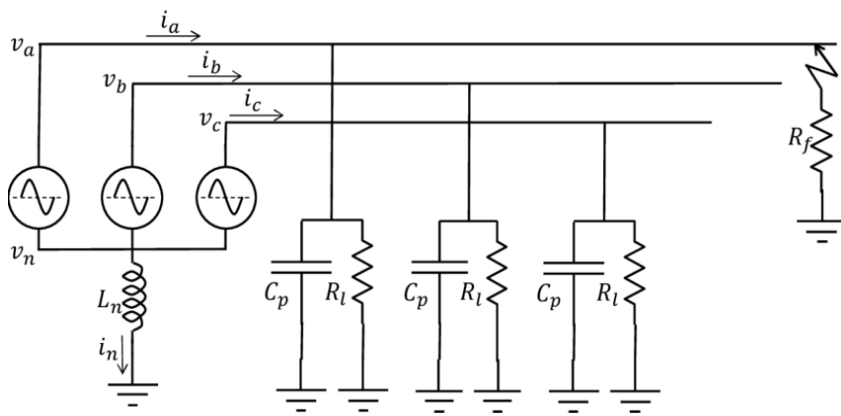
Better life.
With electricity.



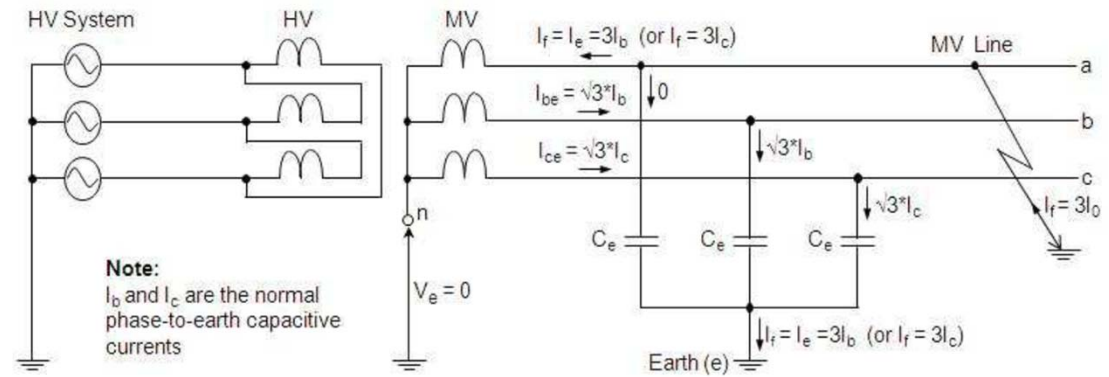
Making Grids Safer: Look at low hanging fruit first



Method of Grounding has Large Impact on Safety

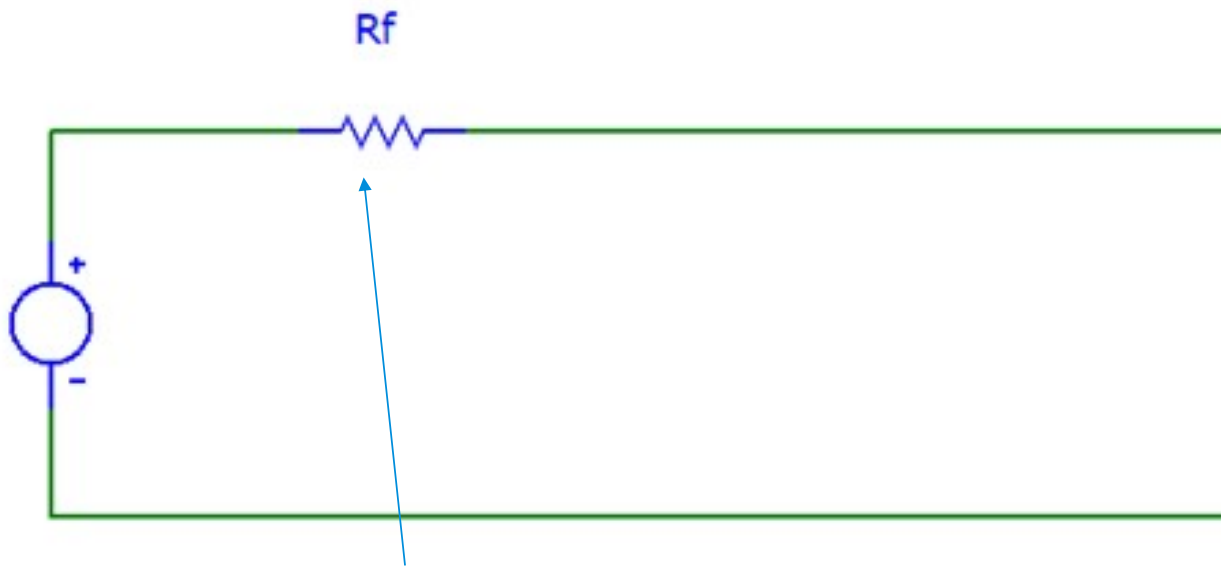


Compensated network
 = High impedance grounded
 = Petersen coil grounded
 = Arc suppression coil



Solidly earthed network

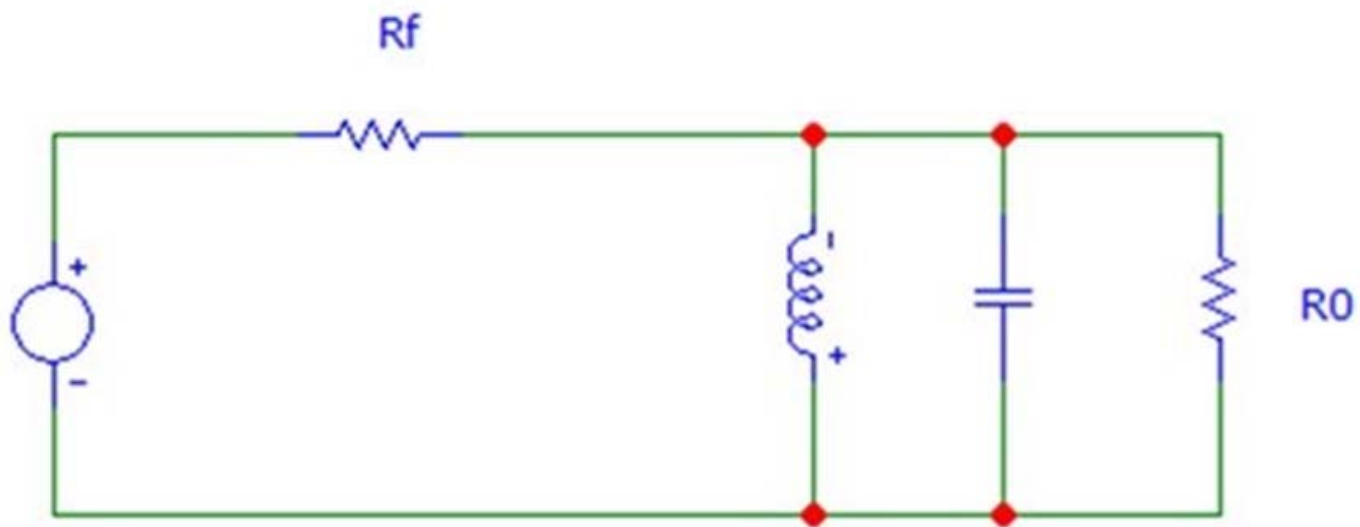
In Solidly Earthed Network Power Injected to Fault Location is Large



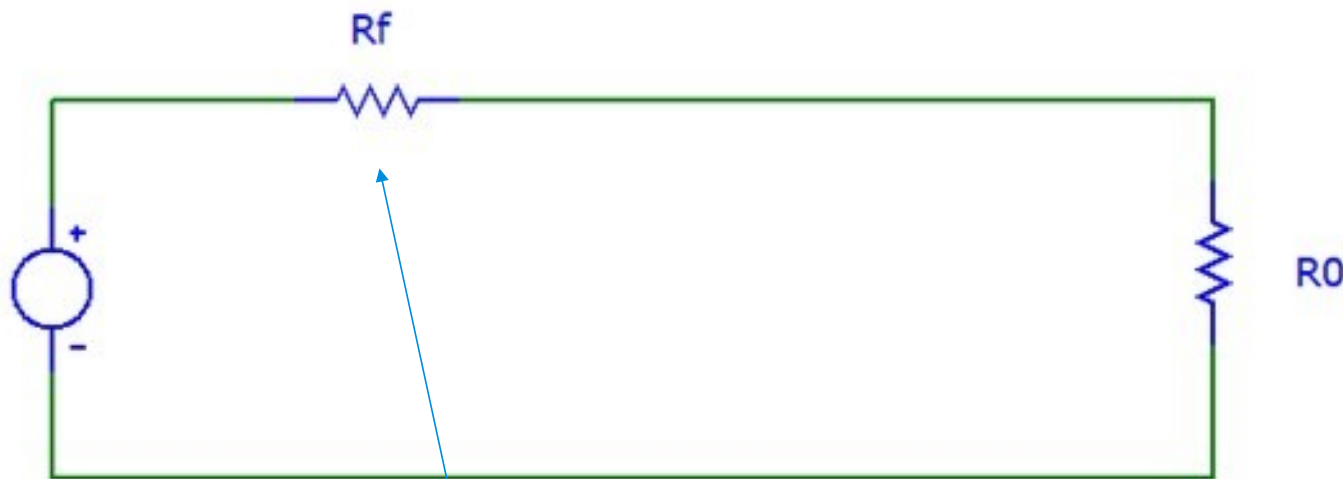
$$P_s = \frac{V_p^2}{R_f}$$

Power going into the fault location in 20 kV system with 1000 Ohm fault resistance is 140 kW.

In Compensated Network both Voltage and Current in Fault Location Reduce



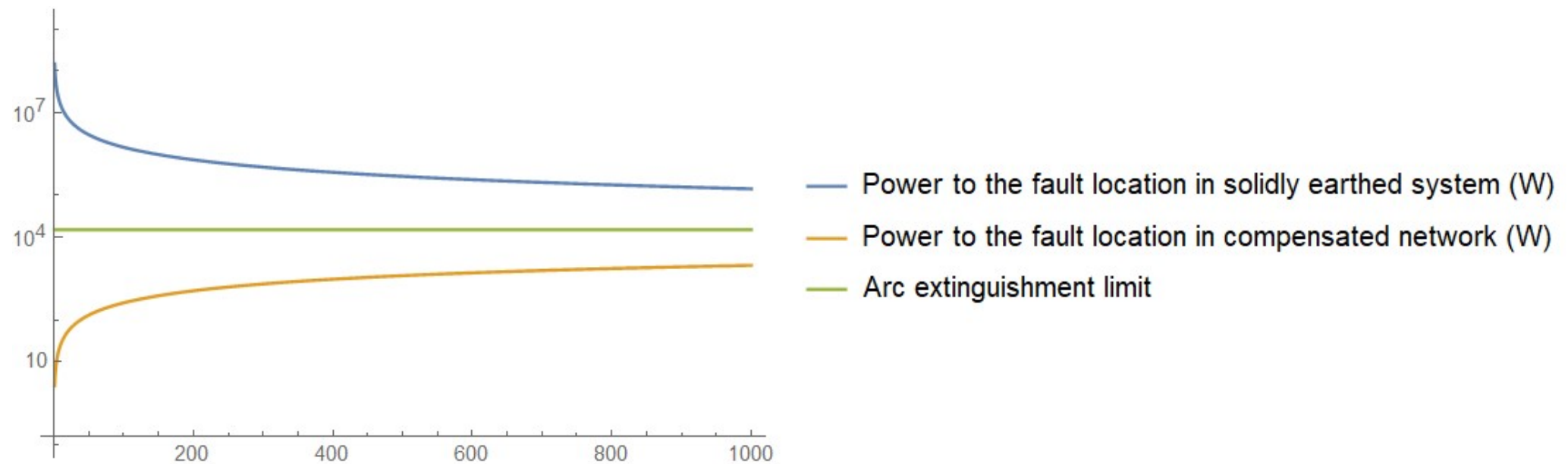
Fully Compensated Network Limits the Power Going to Fault Location by Two Orders of Magnitude



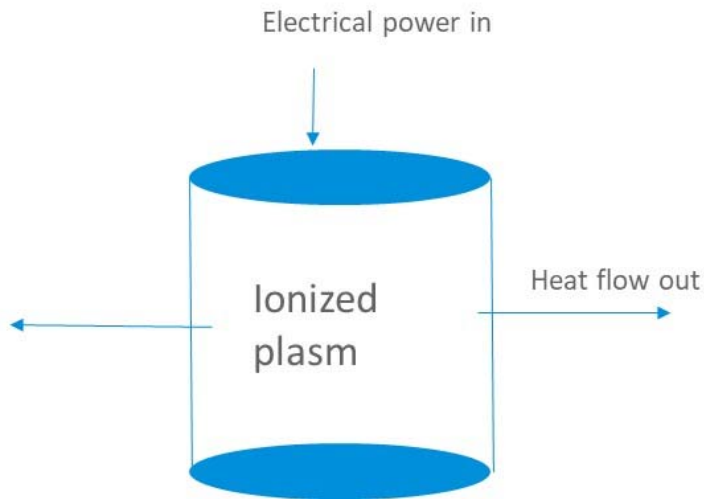
$$P_c = \frac{R_f V_p^2}{(R_f + R_0)^2}$$

Power going into the fault location in 20 kV system with 1000 Ohm fault resistance is 2.1 kW (500 miles overhead line).

Solidly Earthed and Compensated Systems, Power comparison



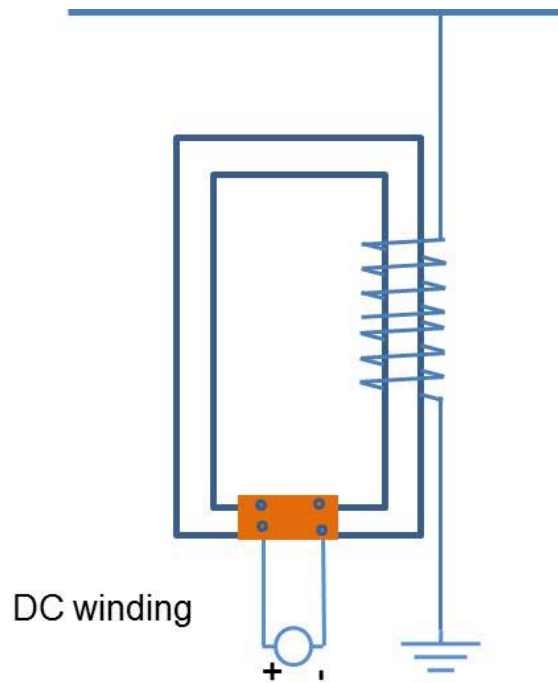
Notes on Earth Fault Arc Models



Notes on earth fault arcs:

- Energy balance: heat transfer out from the arc channel, typically some 10-20 kW in earth fault arcs.
- To maintain the arc, the external electrical network should provide at least the minimum cooling power.
- The plasm physics of such arcs is well established and plenty of empirical data is available.

Ensto ASC100 with Virtual Air Gap Concept



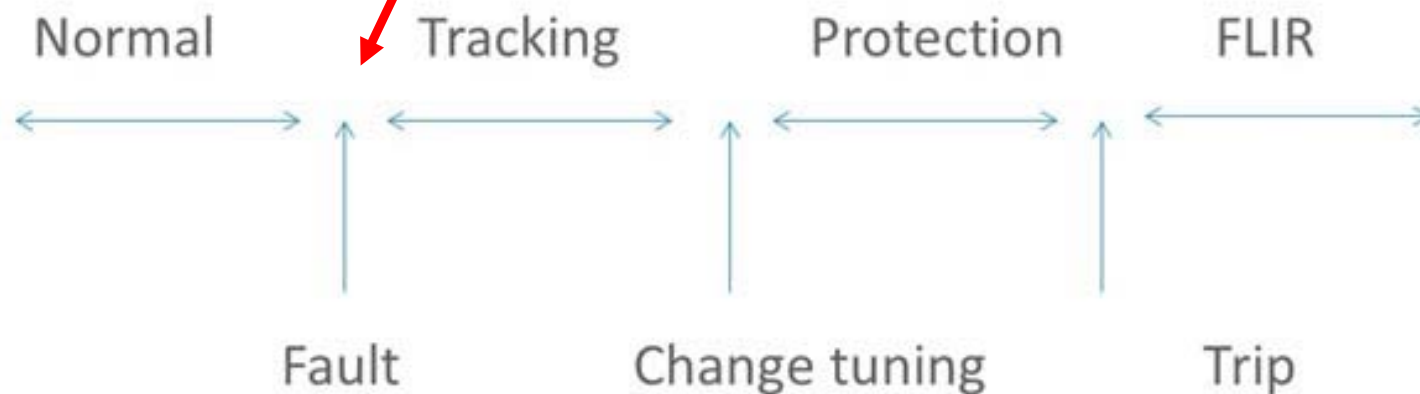
Virtual air gap:

- DC windings saturate locally the magnetic core, which creates an effect similar to air gap, thus increasing the reluctance of the corresponding limb.
- The DC windings are arranged in such a way, that there is no induction to the DC circuit from the AC side.
- Result is a linear operation and very fast tuning (inductance can be varied from low to high value in milliseconds).

Operation of the ASC100

- Fault detection via real time sensor data analysis
- Rapid tuning to resonance at zero point

==> Operation completed within single cycle



Summary

Solid earthing and hard to detect higher impedance faults are a dangerous combination.

Arc suppression coil reduces both current and voltage at fault location.

Ensto ASC100 arc suppression coil activates within milliseconds from fault inception and tunes optimally during first 60 Hz cycle. This creates extinguishes the fault arc at high probability and prevents arc restrike.



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