

# TechTopics No. 75

## Ferroresonance in ungrounded systems with voltage transformers connected line-to-ground

Ferroresonance can occur when voltage transformer (VT) primaries are connected line-to-ground in a circuit that is normally ungrounded or that can become ungrounded during certain switching operations. When the VTs are connected line-to-ground on an ungrounded system, the VT primary becomes a principal path for system ground current.

Ferroresonance can occur when a system transient occurs that causes a ringing current (resonance) between the magnetizing reactance of the VT and coupling capacitance to ground, under conditions in which the VT secondary circuit is lightly loaded.

The "IEEE Standards Dictionary: Glossary of Terms & Definitions" (formerly known as IEEE Std 100), contains this definition (among others):

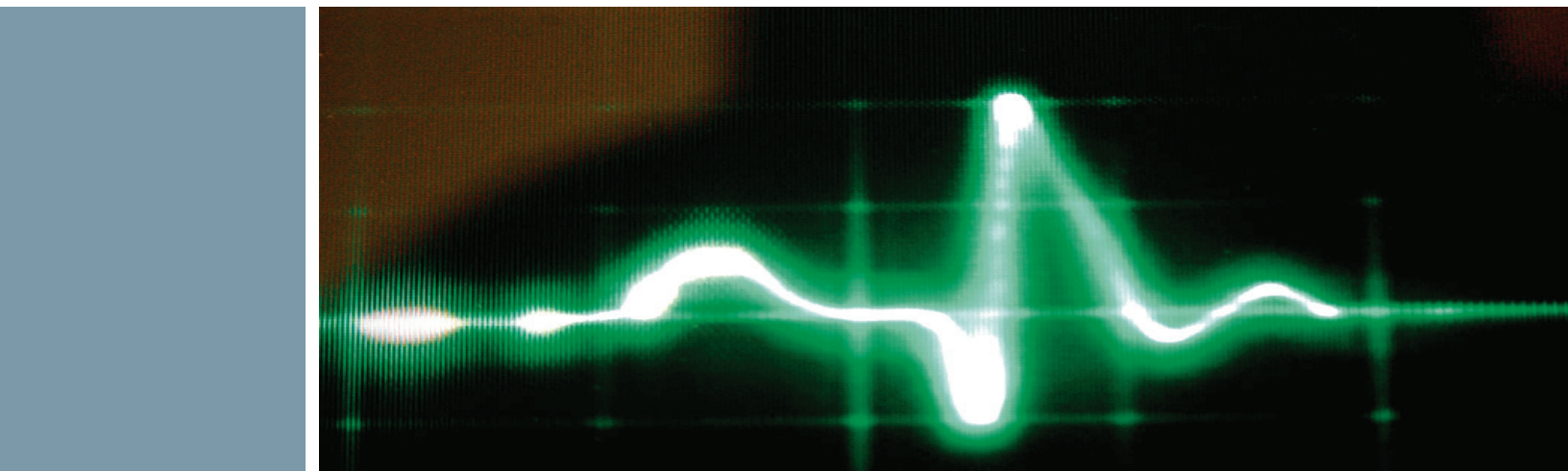
"Ferroresonance...A phenomenon usually characterized by overvoltages and very irregular wave shapes and associated with the excitation of one or more saturable inductors through capacitance in series with the inductor."

This definition elegantly describes the phenomenon, but more importantly gives an indication of the problem ferroresonance poses for the system. The overvoltages that result from ferroresonance will overstress the dielectric capabilities of the system and also will likely damage the voltage transformers.

Now, some more discussion of what actually happens during a ferroresonance condition.

The value of the magnetizing reactance of the VT is a function of the flux in the iron core. The coupling capacitance of each phase of the system is the value of capacitance between the primary phase conductor and ground. The magnetizing reactance and coupling capacitance form a parallel circuit of capacitance (C) and inductance (L) from line to ground, in other words, an LC circuit. If the VT operates in its linear magnetic range, no particular problem exists. However, the LC circuit requires only a relatively small voltage transient to make the circuit ring at the resonant frequency of the LC circuit. Once the circuit begins to ring (resonate), constructive interference during the oscillations causes the voltage to increase to high levels. When the voltage reaches a sufficiently high level, the VT magnetic circuit is driven into saturation, causing the reactance to collapse. However, the charge trapped in the capacitance at this high-voltage level is still significant, and the capacitive charge is discharged through the (low) saturated VT reactance.

If the VT secondary circuit is lightly loaded, there is very little resistance (and therefore, losses) and the current through the VT winding can easily reach levels that will damage the VT winding before the VT fuse interrupts. (In this respect, it should be noted that primary fuses for VTs do not protect the VTs from damage by overcurrent, but are intended to separate the VTs from the power system so that a complete power system shutdown is avoided.)



The "classic" method to deal with this situation is to add resistance (R) to the circuit, converting it from a simple LC circuit to a RLC (damped) circuit. Two methods are commonly used to avoid problems with ferroresonance:

1. Connect the VTs with primary windings connected in grounded wye, with secondary windings connected in open delta, with a loading resistor across the open delta (probably most common). The resistance value should be chosen so that dissipation during ground fault conditions is approximately 50 percent of the continuous VA rating of a single VT.
2. Connect the VTs with both primary and secondary in wye, with a loading resistor across the secondary of each VT. Various references indicate that the resistor dissipation during ground fault conditions should be in the range of the excitation watts of the VT, up to 50 percent of the continuous VA of a single VT. Problems have been reported with the lower value, and a higher value is recommended.

In either case, VTs must be rated for full line-to-line voltage.

Ferroresonance is an infrequent occurrence, very much influenced by system topology and conditions. It is also influenced by the inductance of the VT and the nature of system transients. Thus, ferroresonance does not happen in every system. For those applications in which ferroresonance is a problem, loading resistance in the VT secondary circuit is normally sufficient to alleviate the affects of ferroresonance.

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