



Ferroresonance Guidelines for Modern Transformer Application

White Paper Executive Summary

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Ferroresonance is an overvoltage phenomenon which can occur when single-phase switching of a three-phase transformer, or bank of transformers, is performed. The overvoltages which occur can have high magnitude and persist for as long as one or two phases are open. Long recognized as a distribution system problem, the decrease in prevailing core losses of transformers supplied to the industry has resulted in increased reports of ferroresonance in situations deemed safe by existing ferroresonance avoidance guidelines. This project sought to define new guidelines relevant to the transformers installed today, specifically for grounded wye-wye transformers on five-leg cores.

The research described in this report is based on full-scaled testing of transformers under realistic field conditions. A total of nine transformers were tested, ranging from 150 kVA to 500 kVA, and at 12.47 kV, 24.94 kV, and 34.5 kV. Switching events were performed with a range of cable lengths connected to the open phase, and the over-voltages were measured.

Field test results were analyzed and reduced to formulas which can be applied to any distribution transformers of any voltage and kVA rating. Detailed guidelines for the maximum cable length which can be safely switched with a grounded-wye five-leg transformer were generated for combinations of standard primary voltage, kVA, and cable sizes. Due to the efficiency of today's transformers, the maximum cable lengths recommended are much shorter than those recommended by previous guidelines. These detailed guidelines are bound in a separate Ferroresonance Guidelines Handbook which is Volume II of this report.

Test results analysis yielded significant new information regarding the nature of ferroresonance. Very strong empirical evidence suggests that core loss is the best indicator of ferroresonance susceptibility (in addition to the obvious parameters of primary voltage, kVA, and cable capacitance) contrasted to widespread belief in the industry that rated exciting current is the preferable parameter on which to base guidelines.

Other observations made during the tests are that over-voltages during ferroresonance can be more severe than reported in earlier investigations of grounded-wye transformers. Voltages exceeding 2.5 times rated crest were observed. Also, ferroresonant overvoltages can occur for single-phase switching at the terminals of the transformer, due to the inherent capacitance of the windings. This is particularly true for smaller units and at the higher primary voltage ratings. Very small amounts of secondary load was found to eliminate the ferroresonance, even where moderate cable lengths were connected to the transformer.



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A secondary objective of this project was to develop a simulation model which can allow study of ferroresonance using the ElectroMagnetic Transients Program (EMTP). A model of the five-leg wound-core distribution transformer was created. Ferroresonance results achieved using this model correlated well with field test results. Documentation of this model is included in the report so that member utilities can have the capabilities to perform in-house studies without the burden of full-scale testing.

In conclusion, this project has produced a substantial advancement in the understanding of ferroresonant phenomena in distribution transformers. The results and guidelines provided by this report should prove very useful to member utilities in updating their design and operating practices.

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