



**IEEE/PES Transformers Committee
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Switching Transients Induced by Transformer/Breaker Interaction

-- Presentation, Tuesday, March 18, 4:45 p.m. --

by Robert Degeneff, Philip Hopkinson, and Thomas Tobin

1. Abstract

Occasionally, when a transformer is switched into or out of a system, the transient voltage produced at the terminals of the transformer may contain a high frequency oscillatory component. This oscillatory voltage is the result of the system configuration and breaker characteristics. When this voltage has a frequency component near one of the natural frequencies of the transformer, and is of sufficient magnitude and duration, damage to the internal insulation structure of the transformer may result. This is a subject of interest of both the IEEE Transformers Committee and CIGRE.

This presentation explores the internal transient voltages that maybe produced as a result of the application of oscillatory voltages to the input terminal of a transformer. These transients are typically produced by the interaction of the transformer, breaker, load, and system. This presentation defines conditions that may produce voltages adverse to the transformer insulation system. It discusses the electrical characteristics of the system source, breaker, transformer, and load and the nature of their transient interaction. It suggests mitigation techniques. Several examples are provided.

2. Learning Objectives

This presentation will discuss the characteristics of the breaker, transformer and load, and their interaction. Specific topics discussed are:

- Characteristics of switching devices including closing phenomena addressing both ideal energization and repetitive reignitions. Opening phenomena will be discussed addressing both ideal interruption, current chopping, reignitions and repetitive reignitions. Device characteristics will be presented outlining the difference between switches and breakers and the differences between various interrupter mediums.
- Impedance characteristics of transformers will be explored and compared to normal impulse voltage characteristics. An example of a two winding transformer will be used to illustrate the definitions of resonance and internal amplification.
- The dynamic interaction of a system, breaker, and transformer will be explored. The effect of system topology will be examined. Mitigation methods will be suggested. Finally, several examples will be presented.

3. Learning Outcomes

The purpose of this presentation is to provide the participant a review of the characteristics of breakers and transformers and their unique interaction to aid in their recognition of conditions and applications where transformers are subjected to oscillatory switching transients that maybe damaging to their internal insulation structure. Additionally, this presentation will discuss means to quantify their effect, and, if necessary, present methods of mitigation. Additionally, it will discuss the work presently underway by the IEEE and CIGRE.

4. Presenter's Biographies

Robert C. Degeneff: Dr. Robert C. Degeneff is Professor of Electric Power Engineering at Rensselaer Polytechnic Institute in Troy, New York. Additionally, Dr. Degeneff is president of Utility Systems Technologies, Inc., which builds electronic power quality mitigation equipment. Before joining RPI, Bob was with General Electric for 15 years, initially as a senior engineer and later, a manager in GE's Large Power Transformer Department working in the area of development engineering. Subsequently, he then worked as a manager in GE's HVDC business and then utility planning. He has been active on the IEEE/PES Transformers Committee for a number of years and is currently the chairman of the working group charged with writing IEEE C57.142, "A Guide To Describe The Occurrence And Mitigation Of Switching Transients Induced By Transformer And Breaker Interaction." Bob received his B.Eng degree from Kettering Institute and his masters and D.Eng from RPI. He is a member of Tau Beta Pi, Eta Kappa Nu and Sigma Xi. He is a registered Professional Engineer in New York and has published over five-dozen papers and holds eight patents. He is an IEEE Fellow.

Thomas J. Tobin: Thomas J. Tobin received his BEEE degree in 1968 and a ME degree in Electric Power Engineering in 1969, both from Rensselaer Polytechnic Institute. For over 30 years, he has developed fuses, switches, circuit switchers, and fault interrupters rated 15 kV through 500 kV, and received numerous patents for these devices. His particular areas of expertise are high-voltage and high-power testing, switchgear applications, and switching transient calculations. He is presently Vice President of R&D at S&C Electric Company, responsible for new product development. Tom is active in the IEEE Switchgear Committee and various IEC and CIGRE working groups related to switching equipment. He is a member of IEEE and a registered Professional Engineer in Illinois.

Phil Hopkinson: Philip J Hopkinson, President & CEO of HVOLT Inc., is a long-time member of the IEEE Transformers Committee, a Registered Professional Engineer in the State of North Carolina, a graduate of the General Electric's Advanced Engineering Program, a holder of 14 US Patents, and an IEEE Fellow.

Phil's 37 year career in the transformer industry has been devoted to the design, development and management of power and distribution transformer engineering, at all voltage classes, in liquid, dry and cast-resin constructions. During this period, Phil has worked for three large companies and has mentored under, worked along side, and led many of the experts in the transformer industry.

Phil has been very active with the US Department Of Energy, and led NEMA's Task Force to develop the NEMA TP-1 Energy Efficiency Standard. He is also Technical Adviser to the US National Committee for IEC TC 14 (Power Transformers), a position that he has held since 1996, and has led the US delegation at each TC14 Main Committee meeting since his appointment. Phil's experience with transformer switch-induced resonance dates to 1995, when three 3,000 kVA open-ventilated disk-wound dry-type transformers failed at a data center. This early experience was followed by additional related events that involved other transformer constructions, including liquid and cast-resin, representing a multiplicity of load types, switchgear constructions, and transformer manufacturers.