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Mitigation Methods for Device Failures Associated with Transformers, Reactors, and Switching Devices System Interactions

— Technical Presentation —
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1. Abstract

The objective of this tutorial is to present the findings of the IEEE Transformers Committee Dielectric Test Subcommittee task force charged with compiling methods of mitigating power transformer and reactor failures when the cause of the failure is system interactions.

In most cases, the common design criteria for power transformers provide the end user with extremely long service life. The IEEE standard requirements for transformers have been developed over many years of service experience and are often designed well above the in-service conditions. However, there are times when system interactions can create operating conditions that may overstress these typical design requirements. In these instances, the transformer may experience premature failure due to the system interactions that may occur during normal system operations.

Many mitigation methods have been presented and discussed during the task force meetings. This tutorial will summarize the primary methods identified which could be used to decrease or prevent these failures. The topics which will be covered are included in the list below:

- Use of RC snubbers to reduce system resonance with transformers
- Use of internal series capacitance to grade voltage stress within a winding
- Use of GSU transformers in back feed mode with modeling and increased insulation
- Use of controlled switching and resistance damping to reduce system interactions
- Use of internal surge arresters to reduce/clamp overvoltages within a transformer
- Use of transient voltage monitoring to assess interactions and determine overvoltage stress requirements
- Use of STLI or FFSI impulse tests to evaluate transformer response with system impedances

2. Learning Objectives and Outcomes

This tutorial provides the following learning opportunities:

- Identify system conditions that may present damaging levels of stress to power transformer assets
- Present potential mitigation methods for reducing the severity of system interactions
- Present methods to help determine the presence of these interactions

3. Presenters' Biographies

Phil Hopkinson is an IEEE Life Fellow and long service transformer engineer. From 1966 to 2002, Phil held numerous design and engineering management assignments in the transformer businesses of GE, Cooper Power Systems and Square D for liquid-filled, dry, and cast resin transformers of all power ratings and voltage classes. In 2001, Phil formed a power transformer consulting company, called HVOLT Inc., and, since 2002, has managed HVOLT full-time. He currently holds 15 U.S. patents, is a registered Professional Engineer in North Carolina, and is Technical Advisor (TA) to the U.S. National Committee for IEC TC14 for Power Transformers and past TA for IEC TC 96. He has authored IEEE Transactions papers on the effects of DBPC in transformer oil, on low voltage surge phenomena in distribution transformer windings, panel sessions on natural ester fluids at the 2006 IEEE Transmission and Distribution conference and the 2009 IEEE PES general meeting, led a panel session on high voltage bushing failures at the IEEE 2010 general meeting, co-authored a paper at the 2011 International Conference of Doble Clients, has Chaired NEMA's activities and was primary author of NEMA TP-1 Guide for Energy Efficiency for Distribution Transformers. He has conducted seminars on circuit breaker switching and transformer interaction at the IEEE Transformers Committee meetings in 2003 and 2007, the International Conference of Doble Clients in 2006, and has investigated numerous transformer failure incidents related to switching. He continued into 2018 giving seminars on switching transients for manufacturers and users world-wide. He led an IEEE panel session in 2011 to examine high voltage bushing failures and co-authored a Doble paper on the same aspects relating to bushings and switching transients. In 2013, he published a Doble paper on wind power transformers. He has chaired many IEEE and NEMA working groups and is heavily involved with U.S. energy policy through the IEEE USA Committee and the IEEE PES Policy Development Coordinating Committee. An important accomplishment was the issuance of the IEEE Power and Energy Society Policy on Energy and Environment (adopted by the Board of Governors in 2007) and the IEEE USA policy on Energy and the Environment issued in 2009. In December 2012, Phil was awarded the IEEE Standards Medal. In 2013, he was awarded the IEC 1906 award for his work to improve harmonization of North American and international standards globally. In 2017, he received the IEEE Standards Association's Lifetime Achievement Award. He received his BS in EE from Worcester Polytechnic Institute and graduated from GE's Advanced Engineering Course while simultaneously receiving his MS in System Science (EE) from Brooklyn Polytechnic Institute.

Bertrand Poulin started his career in a small repair facility for motors, generators, and transformers in Montréal in 1978 as a technical advisor. In 1980, he joined the transformer division of ASEA in Varennes, Canada as a test engineer and later as a design and R&D engineer. In 1992, he joined North American Transformer where he was involved in testing and R&D and finally manager of R&D and testing. In 1999, he went back to ABB in Varennes (now part of Hitachi Energy), where he currently holds the position of Senior Principal Engineer for the Power Transformer Division of Hitachi Energy worldwide. He is a member of IEEE Power and Energy Society, an active member of the Transformers Committee, and a registered Professional Engineer in Québec, Canada. Bertrand received his Bachelor of Engineering Degree in Electrical Engineering from École Polytechnique Université de Montréal and his MS degree in High Voltage Engineering from the same University.

Juliano Montanha joined the Siemens Energy power transformer factory in 1999 in Jundiai, Brazil, in the R&D department. Since then, he has specialized in high voltage insulation design and transient studies for power transformers up to 800kV. He also has extensive experience in failure investigations. In 2013, Juliano became a member of the IEEE and CIGRE committees. Since 2011, he has been part of the transient and dielectric team, focusing on technology harmonization across Siemens' power transformer factories. He has actively contributed to several R&D projects worldwide for Siemens Energy and has provided technical support to the company's worldwide factory network. Currently, he is delegated as the technical expert for the company's power transformer factories in the Americas and is a member of the new CIGRE JWG A2/C4/D1.77, which focuses on the design of transformers for very fast transient overvoltages. Juliano graduated with a degree in electrical engineering from the University of São Paulo, Brazil.

Jim McBride has worked in power system research and development for 40 years, extensively with calibration, high voltage testing, and frequency response testing. His areas of expertise include data acquisition, software development, and high voltage testing. Jim developed several pieces of equipment used for evaluation and testing of power equipment. He is currently president of JMX Services, Inc., a provider of impulse test equipment, online frequency response and transient monitoring equipment, arrester test systems, and other high voltage test equipment for the power industry. Jim is a senior member of IEEE PES and is currently the chairman of the working group on revision of C57.142, chairman of PSIM HVTT Subcommittee, and vice chairman of PES Technical Council. He received his Bachelor of Electrical Engineering Degree from Georgia Institute of Technology.