IEEE/PES Transformers Committee
Fall 2007 Meeting
Minneapolis, Minnesota USA

"Transformer Switching - A Current Update"

-- Technical Presentations --
Monday, October 15, 4:45 pm
Tuesday, October 16, 4:45 pm

By Bob Degeneff, Phil Hopkinson, Larry Coffeen, and Nigel McQuin

1. Abstract

Transformer failures from predominantly vacuum and SF6 breaker switching are seen in ever increasing numbers around the world at voltage classes from 5 kV to 345 kV. Working groups were established in both the Transformers Committee as well as the Switchgear Committees to develop understanding and guides to deal with system vulnerabilities in the mid 1990's. Draft Guide C57.142 is a living document developed by the Transformers Committee and has evolved through our understanding of the mechanism of failure. Winding resonance is taught as the source of damaging overvoltage with transient recovery voltage (TRV) from switching as the stimulant. Although this is a very important topic, continuing work by the authors has added another dimension to the failure mechanism. A superposition of TRV with much faster waves associated with breaker reignitions and current chops are introduced which may produce standing waves across the transformer windings and breakdowns from extreme voltage differentials (gradients) between small spaces. These overvoltages may exceed normal impulse stresses by more than ten times.

In all cases, the industry has been able to cure overvoltages by applying resistor-capacitor snubbers between transformer line terminals and ground, which have provided a path for high frequency energy to enter ground and dissipate. The use of snubbers is covered well in the C57.142 Draft Guide.

Monday's presentations are planned to give a breadth of understanding of the status of the guide, the mechanisms of failure, supporting test data, and more insights of breakers.

Tuesday's presentation will concentrate on mitigation and introduce the possibility of a test that can demonstrate system immunity to switching. Concepts from these presentations may set-up future objectives for the Transformers Committee to pursue.

2. Learning Objectives

The tutorial will provide:

- Status of document C57.142.
- Data and conceptual understanding of standing wave failure mechanism.
- Importance of breaker reignitions and current chops in the standing wave concept.
- Conceptual understanding of reignition prevention to prevent failures.
- Breadth of involvement of the problem at medium, high and very high voltage classes.
- Mitigation concepts.
- Potential future test in the factory.

3. Learning Outcomes

As a result of attending of this tutorial session members will gain:

- An understanding that transformer failures are not limited to only a few suppliers or transformer types.
- An understanding of the importance of standing waves initiation failures.
- A view of the frequencies that are involved at all voltage classes.
- Mitigation techniques.
- Potential future in-plant test for immunity.

4. Presenter's Biographies

Dr. Robert C. Degeneff: Dr. Degeneff is a transformer engineer and also a professor at the Rensselaer Polytechnic Institute, with 34 years of experience in large power transformer technology from all perspectives. Bob is also president of Utility Systems Technologies, Inc (UST), located in Latham, NY. Since 1997, Bob has led a working group within the Transformers Committee to develop a guide for the interaction between transformers and breakers and has achieved the Draft Guide C57.142.

Bob received his Bachelors Degree in Mechanical Engineering from the General Motors Institute in 1966. He received his Masters Degree in Electric Power Engineering from Rensselaer Polytechnic Institute in 1967, and Doctor of Engineering in Electric Power Engineering in 1973, also from Rensselaer Polytechnic Institute. His thesis was titled: "Transient Interaction of Transformers and Transmission Lines".

He is an IEEE Fellow, a member of the IEEE/PES Transformers Committee, and also a member of CIGRE. He lives in Schenectady, NY.

Larry T. Coffeen: Larry has 40 years of test engineering experience in the utility industry. He was employed for 29 years by Georgia Power Company in various engineering positions in transmission substation and high voltage testing. He continues work to the present date in the NEETRAC High Voltage Laboratory after the formation of NEETRAC in 1996. Larry's present work includes the development of technology and equipment to perform off-line and on-line transformer frequency response analysis (FRA).

Larry received a Bachelor Science of Electrical Engineering from Georgia Tech in 1970 and holds five US patents, three of which are on applied technology for transformer frequency response analysis testing.

Larry has recorded a significant number of bus transients near the 230 kV bushing of a 500/230 kV auto-transformer. These measurements were made with a calibrated, laboratory grade, wide bandwidth, voltage divider, and are compared to measurements made at the 230 kV and 500 kV bushing taps. He has obtained some very interesting relationships between the transients, their amplitudes and the frequencies for area lightning strikes and station switching operations. The data will also demonstrate that a large transformer can pass some rather high frequencies that were previously thought impossible.

Nigel P. McQuin: Nigel is skilled in laboratory management and instrumentation as well as a general expert in transformers, switchgear, and power systems studies. Since the early 1990's, Nigel has been performing high voltage testing of all types of circuit breakers, and he has excellent knowledge of their characteristics. He also has performed systems studies and has an excellent background in transformers and motors. One testimony to his motor skills is the high speed electric motor-driven land car that achieved nearly 322 mph on the Bonneville Salt Flats.

Nigel's early experience is from the UK, where he graduated from the Imperial College of Science and Technology with a degree in electrical engineering where he focused on power engineering, systems analysis and machines.

Philip J. Hopkinson: Phil Hopkinson is a transformer engineer with a career path which includes engineering and managerial assignments at GE, Cooper Power Systems and Square D/Schneider Electric in distribution, medium power and large power transformers of liquid, dry and cast resin constructions and of all 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 US patents and is a registered professional engineer in North Carolina, and is Technical Advisor (TA) to the US National Committee for IEC TC14 for Power Transformers. He has authored IEEE Transactions papers on the effects of DBPC in transformer oil, on low voltage surge phenomena in distribution transformer windings. Phil also led a panel session on natural ester fluids at the 2006 IEEE Transmission and Distribution Expo, and has chaired activities and was primary author of NEMA TP-1 Guide for Energy Efficiency for Distribution Transformers. Phil conducted a presentation on circuit breaker switching and transformer interaction at the IEEE Transformers Committee meeting in 2003, and also at the Doble International Conference in 2006. He has chaired numerous IEEE and NEMA working groups, and from 2001-2006 served as chairman of IEEE's Policy Development Coordinating Committee, and continues on the executive board where the PES Energy Policy was approved by the Board of Governors in 2007.

Phil received his Bachelor Science Degree from Worcester Polytechnic Institute in 1966. He is a C-Course graduate of GE's Advanced Engineering Program. He received his Master Science Degree in System Science from Brooklyn Polytechnic institute in 1970, where his masters thesis was on impulse voltage distribution in transformer windings.