IEEE/PES Transformers Committee
Spring 2012 Meeting
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"Geo-magnetically Induced Current: Effects on Power Transformers and the Power System; Monitoring, and Potential Mitigation"

-- Technical Presentation --
Thursday, March 15, 2012
8:00 to 10:45 am

by Emanuel Bernabeu, David Fugate, Ramsis Girgis, Frank Koza

1. Abstract

Geo-magnetically induced currents (GIC) flow into power transformers through the neutral. These currents can cause core saturation depending on the magnitude of the GIC and the design of the transformer. However, there is some misconception in the electric power industry today that GIC currents have caused and will cause significant damage to large and medium power transformers installed on power grids. The purpose of this tutorial is to present the true effect of GIC on power transformers and power systems, and the available methods to monitor GIC, as well as mitigating its effects.

This tutorial has four parts. First, factors that influence the susceptibility of power transformers to overheating due to GIC will be explained. This will be followed by a presentation on simulating GIC flow in power systems and the impact of the resulting MVAR demands and magnetizing current harmonics on voltage stability, system protection, and other power system components. The third part of the tutorial will include an overview of GIC monitoring, typical time-scale & magnitude characteristics of GICs, the type of sensors that are required (and sensor locations relative to the monitored transformer), and the data acquisition hardware used to capture and transmit GIC information. The last part of this tutorial will deal with the work of a task force (TF) formed by NERC to study all aspects of Geomagnetic Disturbances (GMD). Finally, representatives of power utilities in North America who will be attending the tutorial will be given the opportunity to share with the attendees the processes & procedures presently used by those utilities to manage and mitigate the effects of GIC.

2. Learning Objectives

This tutorial will:

- Explain the possible harmful effects of geomagnetically induced currents on power transformers, accounting for the special nature of the GIC signature.
- Describe the simulation of GIC flow in power systems to evaluate its impact on power system stability and power system components.
- Present methods available today to monitor, mitigate, and protect against the effects of GIC.
- Give an overview of the activities of, and the final report produced by, a NERC GMD TF covering all aspects of GMD.

3. Learning Outcomes

As a result of attending this tutorial session, you will gain an understanding of the following:

- Factors affecting the magnitude of the effect of GIC in power transformers.
- Presently used methods to monitor, mitigate, and protect against the effects of GIC.
- The impact of GIC on power system stability and power system components.
- GIC monitoring, the typical signature of GIC, the type of sensors required and sensor locations relative to the monitored transformer, and the data acquisition hardware used to capture and transmit GIC information.
- The process used in forming the NERC GMD TF, the development of the material of the final report, an overview of the content of the report, and needed GIC industry standards.

4. Presenters' Biographies

Dr. Emanuel Bernabeu holds an engineering position in T&D Operations Engineering at Dominion Virginia Power. He received his bachelor's degree in Electrical and Electronics Engineering from *Universidad Catolica de Cordoba* in 2005. He joined *Virginia Tech's* graduate program in 2005. He received his M.S and Ph.D. in Power Systems in 2009. He also received his M.S. in Applied Economics at the same institution in 2009. Dr. Bernabeu is the lead engineer for GMD studies at Dominion, assessing transformer vulnerability and system wide impacts of geomagnetic storms. He is responsible for special power system studies at Dominion: TOV, GMD, EMI, "Aurora" cyber/physical attack, N-1-1 contingency analysis, black-start stability analysis, adaptive protection schemes based on wide area measurements and data mining, phasor measurements units (PMUs), deployment, etc. He is a member of NERC's Severe Impact Resilience Task Force (SIRTF) and NERC's Geomagnetic Disturbance TF (GMDTF).

Dr. David Fugate is President and Consulting Engineer of Electric Research & Management, Inc. (ERM), a small research company that has been involved in monitoring of GICs and their impact on the grid for nearly 20 years. ERM operates a near real-time GIC monitoring network as part of the Electric Power Research Institute (EPRI) SUNBURST Project. Dr. Fugate's expertise is in the area of electromagnetic effects associated with power systems. Prior to joining ERM, he was a Senior Engineer at the Westinghouse Science & Technology Center. He has a Ph.D. in Electrical Engineering from Carnegie Mellon University and is a registered Professional Engineer in Pennsylvania and New York.

Dr. Ramsis Girgis is the leader of ABB's global R&D activities in the areas of "transformer core performance" and "ultra-low noise power transformers". He leads Westinghouse's, and now ABB's investigations of effect of GIC on power transformers since the 1989 GMD in North America, and over the past year he contributed to the activities of the NERC TF on GMD. Ramsis received his Ph.D. degree from the University of Saskatchewan, Canada, in Electrical Power Engineering in 1978. He published and presented over 70 technical papers in IEEE, IEE, CIGRE, and other international journals in transformers and rotating electrical machines. He co-authored chapters in two electrical engineering handbooks on transformer design and transformer noise. Dr. Girgis was awarded the IEEE Fellow Grade in 1987. In the mid-eighties, Dr. Girgis was the Technical Advisor; representing the US National Committee in IEC's "Power Transformer Technical Committee (14)". He is presently heading an IEEE TF revising the IEEE Transformer Noise Testing Standards.

Mr. Frank J. Koza is Executive Director of Operations Support at PJM Interconnection, where he is responsible for the technical staff supporting real time operations. He is Vice Chair of the NERC Geomagnetic Disturbance Task Force and was formerly Chair of the NERC Operating Reliability Subcommittee. He received a BSME degree from the University of Pennsylvania and a MEng degree from Widener University. Prior to being employed at PJM, he was employed by Exelon for 29 years in a variety of positions in transmission maintenance, construction, system operations, and system planning.