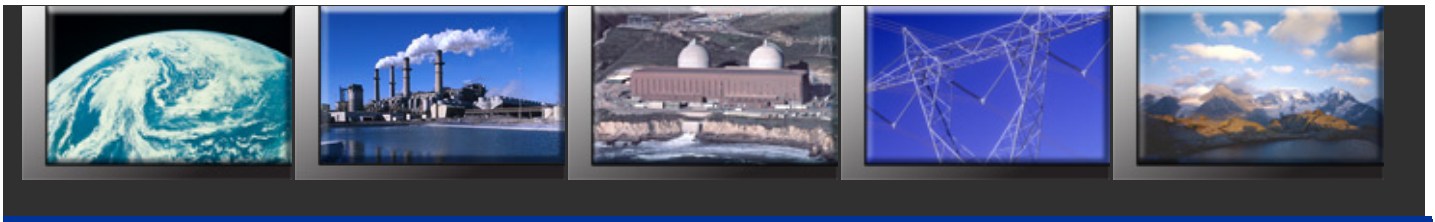
EPRI ELECTRIC POWER RESEARCH INSTITUTE

GMD News and Observer

Your View into EPRI Research on Geomagnetic Disturbance Vulnerabilities, Impacts, and Mitigation



An EPRI Newsletter Issue 4, April 2013

EPRI EXECUTIVE UPDATE

Welcome to the fourth issue of our newsletter, *GMD News and Observer.* Published approximately quarterly, this newsletter provides progress reports and insights for the industry on the geomagnetic disturbance (GMD) area. This issue covers efforts accomplished to date in 2012 and summarizes plans for 2013.

Previous issues can be downloaded from epri.com (Issue 1: ID# 1025857; Issue 2: ID#1025858; Issue 3: ID#1025859). In subsequent issues, we will discuss emerging research on GMDs and proposed mitigation plans by various industry leaders. We welcome your feedback.

Best regards,
Rich Lordan
Senior Technical Executive
rilordan@epri.com, (650) 855-2435

EPRI GMD RESEARCH

Efforts Accomplished to Date

This section summarizes work completed to date (primarily in 2012) and provides links to associated reports. As part of GMD scenario definition, an understanding of the complex, multi-faceted phenomenon of space weather is essential. EPRI published a white paper that explains some of the basic physical concepts associated with space weather as they pertain to impacts on high-voltage power transmission systems. (See EPRI white paper, “Space Weather 101,” 1025860, http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001025860)

An important part of defining GMD scenarios and in modeling geomagnetic-induced current (GIC) flows is the conductivity of the Earth, which can vary by orders of magnitude from one location to another. In research sponsored by EPRI along with NERC and U.S. and Canadian government support, Peter Fernberg, an independent researcher from Ottawa, completed the development of many 1D models that show the Earth’s conductivity for different physiographic regions (reflecting the bedrock geology) of the continental United States and Alaska. (See EPRI Technical Update, “1D Earth Resistivity Models for Selected Areas of Continental United States and Alaska,” 1026430, http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001026430)

Once the GMD scenario is defined (geoelectric field magnitude and orientation), the next step is to compute the GICs that are likely to flow in the transmission system and power system components. EPRI and NERC developed and released an open source software tool that performs this analysis. In April 2012, the GIC simulation models were added to EPRI's Open Source Distribution System Simulator (OpenDSS.). To download EPRI's OpenDSS, visit http://sourceforge.net/projects/electricdss/. A Wiki containing supplementary documentation, the latest information, and hints and tips is available at http://electricdss.wiki.sourceforge.net/. EPRI worked closely with commercial transmission analysis software vendors to support incorporation of this functionality into their power system software so that transmission utilities can begin to conduct GMD related analyses using the typical software platforms. Additional model development and tool augmentation may be needed to fully represent and assess GMD system impacts.

> "In 2012, EPRI delivered research results and insights on topics ranging from GMD scenario definition and GIC flow modeling and analysis to transformer models, mitigation devices, and more. The research team of distinguished contractors forms a Center of Excellence for the industry."

To better understand transformer vulnerability to GMDs, transformer models need to be developed that can accurately model the impact of very low frequency GICs on the transformers. In 2012, EPRI published a literature survey of transformer models capable of simulating the electrical response of transformers subjected to GIC. (See EPRI Technical Update, "Literature Survey on Transformer Models for the Simulation of Electromagnetic Transients with Emphasis on GIC Applications," 1025844, http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001025844)

EPRI also produced a white paper entitled "How the EPRI Geomagnetic Disturbance (GMD) Research Fits Together," (See EPRI 1026425, http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001026425)

2013 Plan

For 2013, EPRI has developed the GMD Research Action Plan shown in Figure 1. The plan is revised and enhanced to more closely support EPRI's transmission utility members, NERC, and the general public in preparing for GMD events. Thirteen task activities are identified for 2013. Each task in Figure 1 describes the activity, the deliverable, the start and end period, and the relevant NERC Task Force sub-team. The activities are aggregated into four research areas:

- GIC Calculation
- GIC Integrated Power Flow Analysis and Models
- Vulnerability Assessment
- Mitigation

GIC Calculation Areas. In 2012, statistics of the magnitude of a 1 in 100-year storm scenario were developed. Further, these statistics were normalized for four region types defined by combinations of high and low latitudes and high and low soil resistivity. In task 1, these statistics will be mapped directly to the multiple 1D Earth resistivity models for selected areas of the continental United States and Alaska by June 2013. This will support utilities and researchers seeking to perform scenario analysis for their specific region. Additionally, new statistics will be used along with state-of-the-art large-scale magnetospheric simulations at NASA Goddard Space Flight Center (GSFC) to explore the upper physical/theoretical limit for the geoelectric field magnitudes. Also in this task, synthetic storms will be provided for the 25 regions by August 2013 for the 1-100 year storm and the theoretical maximum event. In addition to the 1-100 year storm, researchers will provide a reconstruction of the Carrington event of 1859, which is the largest geomagnetic storm on record. Unfortunately, the monitoring detail was quite crude at that time and it is difficult to exactly characterize the storm. An attempt will be made to reconstruct the geoelectric field and GIC waveforms of the Carrington event using available historical records. All assumptions used in the generation of the approximate waveform will be clearly articulated.

> "GIC calculation work in 2013 will enable utilizes to perform scenario analysis for their specific region."

Currently commercially available study tools generally assume both a uniform magnetic and electric field for modeling GIC. However, large service territories and operating regions can be comprised of multiple geological regions resulting in a non-uniform geoelectric field (differing magnitude and direction for each region). Task 2 will quantify two sources of error in this area: the potential error of assuming a uniform electric field across adjacent geological regions, and the error in assuming uniform electric fields in regions that abut large bodies of water. For both of these efforts, the potential scale of the GIC calculation errors will be identified along with the subsequent ramifications to planning study results. Deliverables for task 2 will be completed in June 2013.

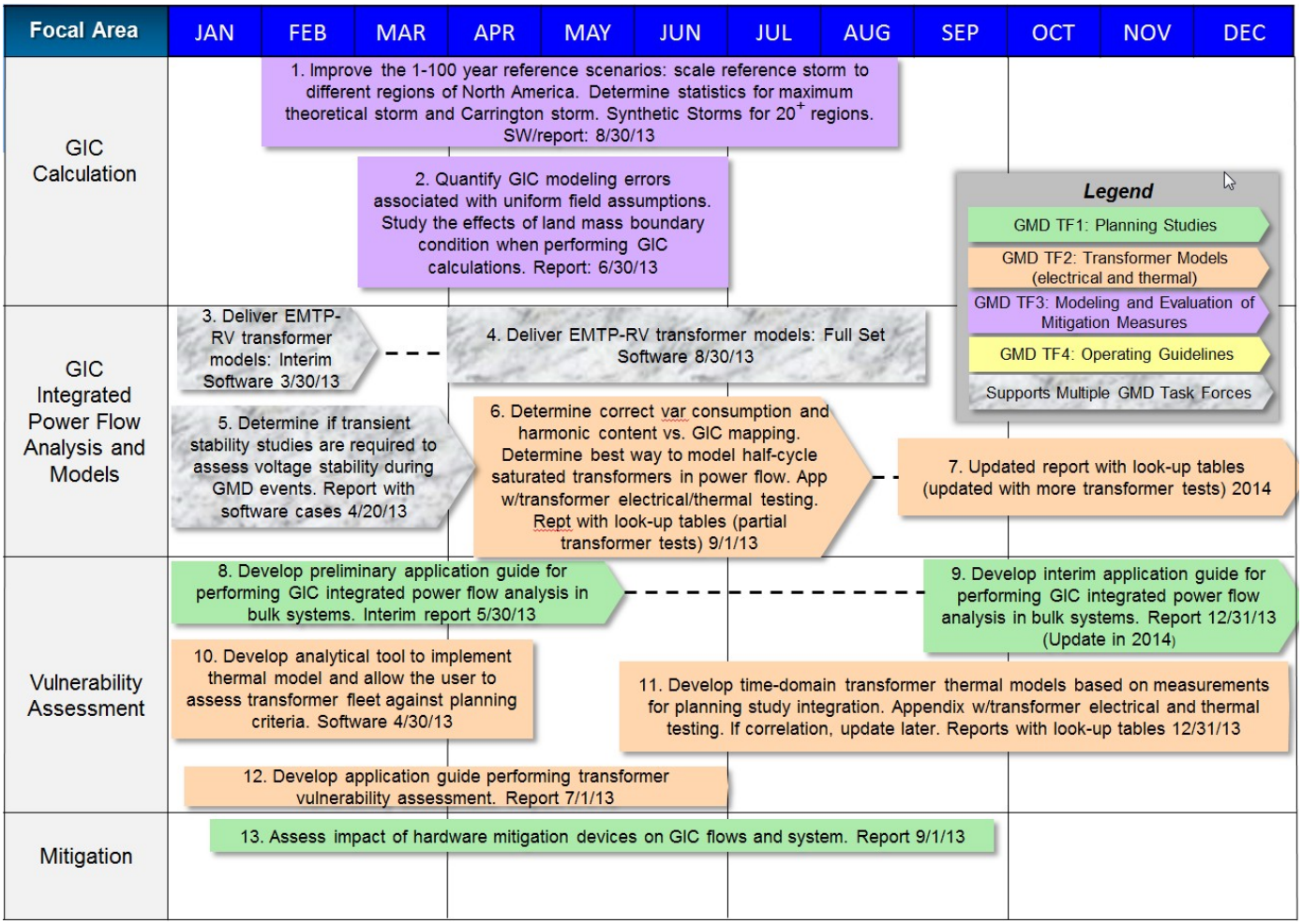


Figure 1. Overview of 2013 Research Activities Plan

GIC Integrated Power Flow Analysis and Models. Task 3 and 4 will provide EMTP-RV transformer models for the industry to use in calculating transformer response to GIC. Electrical models for single-phase transformers, and three-phase, three-leg transformers will be made available in March 2013. Additional models (five-leg, seven-leg transformers, etc.) will be developed and delivered as available with expectation by the end of August 2013. Additional models will be added and delivered throughout the remainder of the project, which is scheduled to end in 2014. Transformer test data is an important element to validate these models, and EPRI is actively seeking test results from electric power providers.

Transparent, validated models and assessment methods are critical elements in understanding GMD impacts and developing effective mitigation strategies. Task 5 will determine if transient stability studies are required to assess voltage stability during GMD events. Voltage stability impacts associated with the temporal and spatial

GIC variations are currently being evaluated to determine when and if transient stability studies are needed. A draft report will be delivered to the NERC GMD TF1 for review in the shortly. The report is scheduled to be finalized and delivered at the end of April 2013.

> "Throughout 2013, EPRI will deliver EMTP-RV models of various transformer types for the industry to use in calculating transformer response to GIC."

Tasks 6 and 7 will determine the most appropriate way to model half-cycle-saturated transformers in power flow studies. The available EMTP transformer models will be used to assess the half-cycle saturation response under various steady-state conditions. Differences will be vetted and communicated with the model developers and other experts with the goal of understanding the true behavior of transformers subjected to GIC. A report providing the state of the science will be provided in August 2013. The report will be updated throughout the project as new models and validation results are obtained.

In related work, tasks 6 and 7 will also determine the correct reactive power consumption and harmonic content versus GIC using limited measurement data and EMTP simulation results. An interim report with look-up tables for available transformer models will be delivered in September 2013. Additional transformer models will be provided as they are developed and validated through the remainder of the project.

Vulnerability Assessment. Vulnerability assessments are an important element of the GMD risk management strategy. It must be emphasized that EPRI, as the principal research provider for the NERC initiative, is focusing on model, method, and tool development and associated validation. While development of these tools requires that EPRI perform analyses to validate and refine the available tool set, the analysis of specific GMD related system impacts and identification of associated mitigation requirements is expected to be executed by electricity providers.

EPRI is developing an application guide for performing GIC integrated power flow analysis in bulk systems (tasks 8 and 9). This guide will help utilities implement the current tools for evaluating potential voltage stability issues under user-defined storm scenarios. While practices for incorporating the potential loss of reactive power support and assets will be discussed, methods for specific thermal and harmonic impacts to system assets will be covered further in related reports. A preliminary report will be delivered in May 2013, and an interim version incorporating additional findings from other related tasks will be delivered at the end of 2013. A final version will be delivered in 2014.

> "In 2013, EPRI will provide the industry a step-by-step application guide to help utilities assess the vulnerability of their transformer fleet."

Task 10 will develop an analytical tool that will implement thermal models allowing the user to screen transformer fleet impacts against specified planning criteria. This tool will calculate transformer hot-spot temperatures over time using developed transformer thermal models along with user-provided, time-series GIC values representing specific storm scenarios. These calculated hot-spot values can in turn be used to identify assets requiring further detailed analyses based on defined planning criteria. The software tool will be delivered in April 2013. The open-source software tool with graphical user interface will initially be populated with the models developed by Hydro One and will be able to readily incorporate thermal models for other transformer types as they are developed.

In a related activity, task 11 will develop transformer thermal models for planning study integration. These models will be based on measurements and/or simulation data. A limited number of select models are currently being developed based on empirical results of hot-spot temperature rise measured as a function of time for different levels of injected GIC. Additional models will be developed based on data collected from manufacturers and through test results. A report will be delivered in December 2013 incorporating developed models along with additional test results. Updates will follow through the remainder of the initiative.

Task 12 will develop an application guide to help utilities assess the vulnerability of their transformer fleet. The guide will provide step-by-step instructions to calculate the transformer temperature rise as a function of time for a given GIC input function. The guide will then describe how to analyze the results and help identify needed next steps.

Mitigation. Task 13 will use simulation results (i.e., GIC integrated power flow and EMTP) to assess the impact of GIC hardware mitigation devices on GIC flows. This will illustrate the changes in GIC flows at adjacent transformers when GIC is mitigated at one or more transformers in a region. Task 13 will also assess the effectiveness of GIC hardware mitigation devices to reduce transformer vulnerability and system vulnerability to GMD. Lastly, the task will assess potential unintended consequences of mitigation device application. This includes insulation coordination, resonance, and system protection. The report will be delivered in September 2013. The results of the local transformer impacts of the GIC blocking devices will also be used to assess the viability of resulting system operating conditions. Operating procedures for mitigation will be evaluated in 2014.

EVENTS, NEWS, AND RESOURCES

Opportunities for Participation

To find out about opportunities to participate in EPRI's research on GMDs, please contact EPRI Senior Technical Executive Rich Lordan, rilordan@epri.com, (650) 855-2435.

Upcoming Events

- EPRI will conduct its next monthly GMD webcast, which covers various EPRI GMD research activities, on April 26, 2013. This meeting will cover the latest on the GMD planning guide.
- NERC's GMD Task Force webinar meeting will be held May 16, 2013 from 1-3 pm ET
- The Electric Infrastructure Security Summit (EIS Summit IV) will be held in Washington DC on May 20-21, 2013. (See www.eissummit.com for more information.)
- The 2013 IEEE Power & Energy Society General Meeting will be held July 21-25, 2013 in Vancouver, British Columbia, Canada. Super session #3 will cover the impacts of GMD events on electric power systems. See http://pes-gm.org/2013.
- The next face-to-face meeting of the NERC GMD Task Force is July 25-26, 2013 in Vancouver, British Columbia, Canada (tentative).

News

FERC NOPR on GMD Standards

The recent Federal Energy Regulatory Commission (FERC) Notice of Proposed Rulemaking (NOPR) on Reliability Standards for Geomagnetic Disturbances (issued October 18, 2012) includes two stages. In the first stage, the Commission proposes to direct NERC to file, within 90 days of the effective date of a final rule in this proceeding, one or more reliability standards that require owners and operators of the bulk power system to develop and implement operational procedures to mitigate the effects of GMDs consistent with the reliable operation of the bulk power system. In the second stage, the Commission proposes to direct NERC to file, within six months of the effective date of a final rule, one or more reliability standards that require owners and operators of the bulk power system to conduct initial and ongoing assessments of the potential impact of GMDs on bulk power system equipment and the bulk power system as a whole. Industry stakeholders have submitted significant comments on the NOPR, and as of this printing, no final ruling has yet been issued. EPRI is supporting NERC in its effort to respond to the anticipated ruling.

3002000847