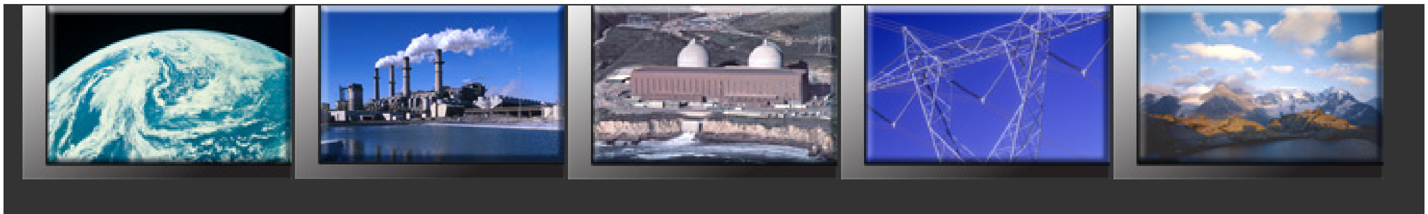
GMD News and Observer

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



An EPRI Newsletter **Issue 3, September 2012**

EPRI EXECUTIVE UPDATE

Welcome to the third issue of our newsletter, *GMD News and Observer.* Published approximately quarterly, this newsletter provides progress reports and insights for the industry on the geo-magnetic disturbance (GMD) area. This issue covers three important research areas that are part of EPRI's overall GMD research initiative. Previous issues can be downloaded from epri.com (Issue 1: ID# 1025857; Issue 2: ID#1025858). In subsequent issues, we will discuss emerging research on GMDs and proposed mitigation plans by various industry leaders. We welcome your feedback.

Best regards,
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EPRI GMD RESEARCH

Research Defines 100-Year GIC Event Scenarios

The first step in any analysis of GMDs is to answer the following question: What is a reasonable definition of an extremely rare but possible GMD? Over the years, storm severity has been measured in various ways, but a consensus method is needed for use as a baseline. Researchers can then use this as input to their analyses of the impact of such an event.

Antti Pulkkinen, a researcher with the Catholic University of America and the NASA Goddard Space Flight Center, and co-researchers are conducting studies to answer the previously posed question regarding storm definition. Their work generates regional extreme geoelectric field "scenarios" (i.e., one in 100-year storm scenarios) that can be used in further engineering analyses. Other scenarios can be considered at the discretion of the analyst. These can include an attempt to recreate the Carrington Event of 1859 (the strongest solar storm ever recorded). For most analyses, the one-in-100 year storm provides a consistent starting point.

In performing calculations to define extreme event scenarios, Pulkkinen et al. considered four physical parameters: ground conductivity, geomagnetic latitude, rate of change of the geomagnetic field (dB/dt), and the spatial structure of the electric fields [1]. The ground conductivity is one of the key parameters in defining the resulting geoelectric field. With regard to geomagnetic latitude, initial evidence indicates that geoelectric field magnitudes tend to decrease dramatically below geomagnetic latitudes of 40-60 degrees. The pulse structure (i.e., the speed of the fluctuations in the signal) of a storm's electric fields and resulting GIC also help define GIC impact on the transmission system. Longer pulses cause more damage to transformers as a result of equipment overheating. In terms of the spatial structure of the electric fields, the researchers considered variation of the geoelectric field by location.

Currently, Pulkkinen and his team are refining these geophysical scenarios using additional data available through NASA to create large-scale numerical simulations of these events. These simulations will provide a better understanding of the extreme amplitudes of geoelectric fields that result from these storms.

Earth Conductivity Modeling Aids Scenario Definition and GIC Modeling

An important part of defining the one-in-100-year scenario and in modeling GIC flows is the conductivity of the Earth, which can vary by orders of magnitude from one location to another. Determining the Earth conductivity for GIC analyses requires knowledge of the surface geology down to the deep crust and mantle of the Earth. For example, the Precambrian crystalline bedrock that is present in Minnesota has a lower conductivity than the younger sedimentary rock that makes up the top layer of the Earth in Oklahoma. The conductivity increases at greater depths within the earth's layers, where the pressure and the temperature also increase. Mineralogical changes also impact the level of conductivity, as some minerals are more conductive than others.

The deep Earth soil conductivity is important because the skin depth of the return current can be tens of kilometers deep. This deep Earth conductivity drives the electric field. For a given storm magnetic field, lower conducting soil creates higher electric fields at the Earth's surface, which induces larger voltages in the transmission lines resulting in larger GICs.

Although Earth's internal structure can have a complex three-dimensional distribution of electrical conductivity, the use of a one-dimensional (1D) model provides a useful first-order approximation for modeling gross conductivity structure and its effect on surface electric field in a particular region. A 1D model provides a general representation that shows the varying thickness of the Earth's crust and mantle to depths ranging from 600-1000 kilometers, as well as the conductivity of each layer.

Peter Fernberg, an independent researcher from Ottawa, recently 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. (This is part of a joint project between NERC, EPRI, the United States Geological Survey [USGS] Geomagnetism Program, National Resources Canada, and the USGS Crustal.) Natural Resources Canada and Professor Ian Ferguson at the University of Manitoba have already produced similar 1D models of Canada [2]. The 1D models were created using information gleaned from government reports and scientific journals, which include determinations of crustal and mantle thickness from seismic surveys and measurements of electrical conductivity using various geophysical survey methods such as magnetotellurics, which can map conductivity differences to depths of hundreds of kilometers. Additional models are being developed to provide a more complete picture of the US.

The available 1D Earth conductivity models will be used with regional geomagnetic data to calculate the surface electric field for a particular region. The surface electric field values are then used as an input to EPRI's Open Source Distribution System Simulator (OpenDSS) to calculate the GIC that will be produced in the power grid (see Figure 1).

Power Flow Simulator Software Models Impact of GMDs on Power Grid

The next step in the GMD analysis is to conduct system planning studies to determine the impacts of the GMD (see Figure 2). Power system planners currently have few tools to help them assess the impact of GMDs on their systems. The goal of research in the GMD system planning area is to initiate development of tools that help power system planning and operations engineers perform assessments and create operating procedures. This means working to help integrate GMD assessment into commercially available power flow and transient stability analysis software. This will help address issues of how to prepare for GMDs in both the longer term planning time period and the shorter term operations environment.

University of Illinois Professor Thomas Overbye has incorporated new functionality into existing power flow analysis software (i.e., PowerWorld software) to accommodate GMD analyses. To calculate time-varying GMD-induced dc voltages, the latitude and longitude of the transmission lines must be known. PowerWorld already incorporates this data for all of North America. The EPRI project, now underway, is performing a GIC study using the power flow models in PowerWorld of the Eastern and Western Interconnections to assess system impacts. The project is also considering the transient stability level impacts of the GMD scenarios on a smaller model, such as a 19,000-bus Commonwealth Edison case. The project is considering various GMD storm scenarios. Similar functionality is being incorporated into PSSE and is expected to be available in the fall of 2012.

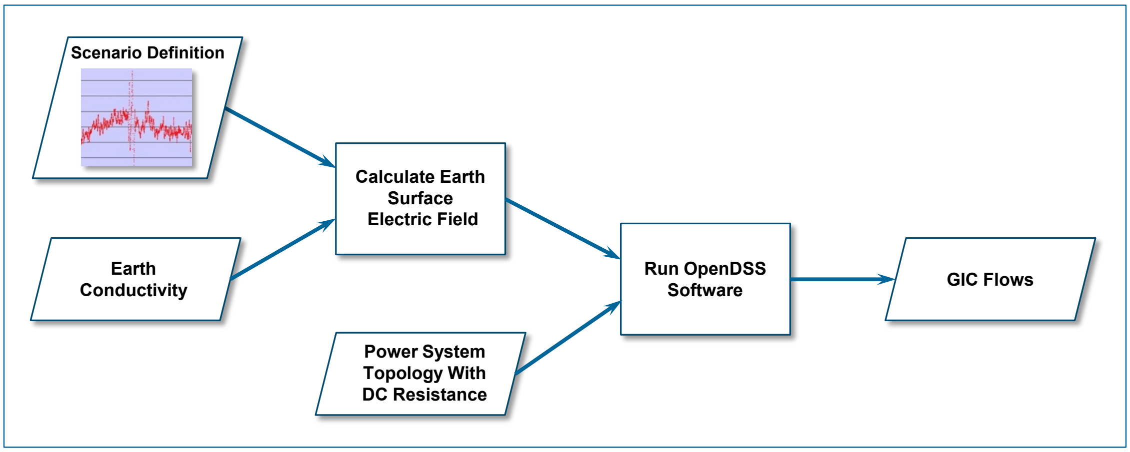

Figure 1. The Process of Using Earth Conductivity Modeling to Model GIC Flows

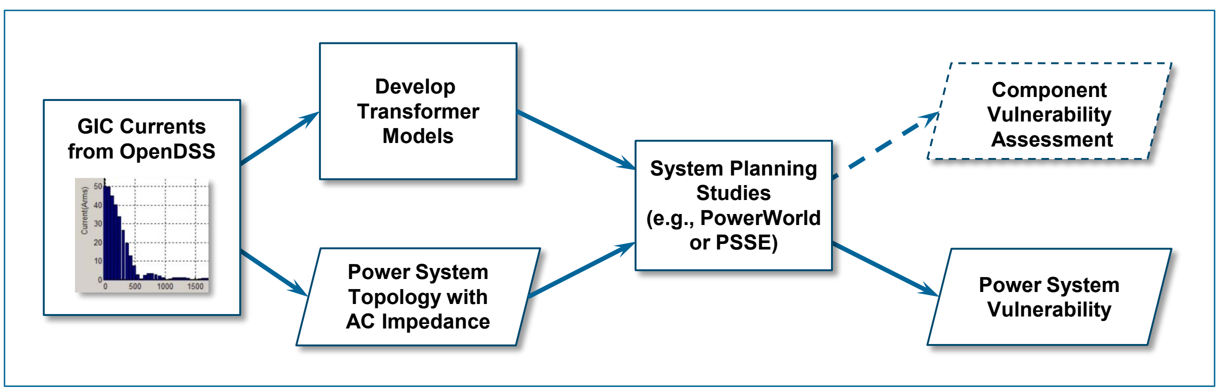

Figure 2. The System Planning Process with GICs

References

1. A. Pulkkinen, E. Bernabeu, J. Eichner, C. Beggan, and A. Thomson, "Generation of 100-year geomagnetically induced current scenarios," *Space Weather: The International Journal of Research and Applications*, vol. 10, S04003, 2012, http://www.agu.org/pubs/crossref/2012/2011SW000750.shtml.
2. Ferguson, I. and Odwar, H., 1998. Appendix 3: Review of conductivity soundings in Canada, in "Geomagnetically Induced Currents: Geomagnetic Hazard Assessment Phase II", Final Report, Volume 3, (principal author) Boteler, D.H., Geological Survey of Canada and Canadian Electricity Association, 357 T 848A, 121 p.

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 October 10, 2012. This meeting's topics include operating guidelines and GIC modeling.
- EPRI will conduct its next SUNBURST monthly update webcast on GMD storm activity on October 12, 2012.

For more information on these events, contact EPRI Senior Technical Executive Rich Lordan, rilordan@epri.com, (650) 855-2435.

News

NERC recently held a meeting to kickoff off Phase II of its GMD Task Force (GMDTF) work. After industry representatives, scientists, and vendors provided updates, NERC described the four GMDTF teams, which include 1) planning study and assessment design; 2) equipment model development and validation; 3) GIC model development and validation; and 4) system operating practices, tools, and training. Short-term tasks include the following:

- Develop survey for planning and vulnerability assessment (3 months)
- Finalize USGS ground conductivity models (3 months)
- Gather input from operators and the North American Transmission Forum (NATF) to update the NERC Advisory (3 months)
- Update system operator training (6 months)

NERC plans to work with vendors and manufacturers to complete most planned modeling work within the next 12 months. NERC is working with EPRI to identify transformer test candidates. After these activities, standards evaluation and reporting will follow. NERC is tentatively scheduling a webinar update for December 2012 and a face-to-face meeting in January 2013.

Resources

The following resources provide additional information about GMDs and their potential impact on transmission system equipment.

NERC, "2012 Special Reliability Assessment, Interim Report: Effects of Geomagnetic Disturbances on the Bulk Power System," February 2012, http://www.nerc.com/files/2012GMD.pdf.

EPRI, "Geomagnetic Disturbances (GMD): Monitoring, Mitigation, and Next Steps; A Literature Review and Summary of the 2011 NERC GMD Workshop," EPRI Final Report, 1024629, November 2011.

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