ELECTRIC POWER RESEARCH INSTITUTE

GMD News and Observer

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

Issue 9, October 2014

EPRI EXECUTIVE UPDATE

Welcome to the ninth 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 summarizes work completed to date and planned work. It also describes recent coronal mass ejection (CME) activity and provides an update on technology used in the SUNBURST Network.

Previous issues of this newsletter can be downloaded from epri.com (Issue 1: ID# 1025857; Issue 2: ID#1025858; Issue 3: ID#1025859; Issue 4: ID#3002000847; Issue 5: ID#3002000848; Issue 6: ID#3002000849; Issue7: ID#3002000850; and Issue 8: ID#3002003934). In subsequent issues, we will discuss emerging research on GMDs and proposed mitigation plans by various industry leaders.

In close collaboration with the North American Electric Reliability Corporation (NERC), EPRI has continued its research on GMDs in 2014. We are now welcoming new participants to our existing team, so please contact me if you are interested in collaborating with us in this fascinating and important area.

We welcome your feedback.

Best regards,
Rich Lordan
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Ongoing GMD Efforts with NERC

EPRI has worked closely with NERC in its GMD research. This collaboration has led to significant progress on important GMD deliverables to date. EPRI ongoing and new GMD work with NERC is in the following four areas:

- GIC mitigation planning guide (initiate in 2014)
- Potential harmonics consequences of GIC (initiate in 2014)
- Earth conductivity validation using direct measurement (initiate in 2014; deliver in 2015)
- Develop generic transformer thermal and electrical models (continue in 2014; deliver periodically as data is received and models are enhanced; 2015 or later)

These efforts are summarized below.

GIC Mitigation Planning Guide

EPRI will support NERC in developing a guide for the application of GIC mitigation devices. This guide is intended for use by electricity delivery companies and their consultants who are considering the installation of devices to block, or substantially impede, the flow of quasi-dc GIC through power transformer neutrals and through transmission lines. This guide will describe the potential consequential impacts of such devices on other equipment and system performance. It will define the studies needed to specify the ratings of the devices, evaluate their effectiveness, and assess the risks of consequential impacts.

Potential Harmonics Consequences of GIC

EPRI will develop a reference guide for the evaluation of high-level harmonic voltages and currents resulting from a severe GMD. The new 2014 guide will describe the impacts of high-level distortion on capacitors, generators, protection system, power electronics controllers (e.g., flexible ac transmission systems [FACTS]), high-voltage direct current (HVDC) systems, and surge arresters, as well as other affected bulk power system components.

Earth Conductivity Validation; Potentially using Direct Measurement

The purpose of this work is to enhance the accuracy of Earth ground conductivity/resistivity. EPRI expects to refine the models using a method of actually directly measuring the earth conductivity/resistivity. EPRI will use this direct measurement approach to refine the Earth conductivity models and their effect on surface electric field. EPRI will validate these models as possible with GIC measurements from the EPRI Sunburst system, Magnetic field variance measurements from USGS, Natural Resources Canada, and EPRI, and system topology models of transmission systems in North America.

Generic Transformer Thermal and Electrical Models

Work currently proposed for funding by DOE includes preparing test plan specifications for thermal and electrical testing of transformers in the presence of GICs, and conducting actual transformer thermal (hot spot) and electrical (aka magnetic, including harmonics and var generation) testing. This work will feed into modeling analytics to develop refined generic transformer thermal and electrical models. The overall purpose of these activities is to determine transformer vulnerability to GICs and determine transformer electrical response to GICs to assess power system vulnerability and develop mitigation strategies.

EPRI GMD RESEARCH

EPRI Project: Providing Industry Support for Compliance with the Stage 2 GMD Standard

In its 2015 Annual Research Portfolio, EPRI has initiated an effort to provide a single, easy-to-follow reference, guidance on the forthcoming NERC Stage 2 GMD Standard, and example case studies illustrating the analysis techniques and mitigation strategy evaluation. (For more information, see project P40.023; "Planning Study Tools and Methods (GMD Planning Analysis/Tool Application Guidelines;" http://www.epri.com/our-Portfolio/Pages/Portfolio.aspx?program=027570#tab=1). As the Stage 2 Standard is expected to require reporting of initial analysis results to NERC in 2019 or 2020, the creation of easily assessable technical material that provides instruction and guidance when performing the newly developed GMD studies is expected to be timely.

This effort will leverage recent EPRI supported research related to the development and advancement of GMD assessment and planning tools. Industry experience, system studies, and expert guidance will be compiled for planners, operators, and analysts in evaluating potential system vulnerability to GMD as well as potential mitigation options, along with the development of illustrative examples. The research conducted and the associated guidelines to be developed from this effort will work in concert with the existing NERC GMD guidelines and forthcoming standards.

EPRI GMD RESEARCH

Wireless Radio Frequency Sensor Successfully Tested, Intended for Phase Conductor SUNBURST Monitoring

EPRI recently successfully tested a wireless radio frequency (RF) sensor that can be installed directly on conductors to measure geomagnetically induced currents (GICs).

In the present SUNBURST Network, GICs are measured in the neutral of the power transformers and integrated into a data management system. The reason for measuring the currents in the neutral is that access is possible, it is at low voltage, and the data is easy to integrate into a measurement system. However, the limit to this measurement approach is that it does not measure dc current in the individual phases. By capturing current on the phase conductors, engineers will be better able to understand the total excitation impacting the power transformer. This includes not only the GIC that passes to and from the transformers to ground, but also GIC that passes through the transformer from one high side voltage conductor to the second voltage conductor.

EPRI is leveraging research it has performed in developing wireless radio frequency (RF) sensors for conductors and insulators to develop a sensor that can be installed on energized conductors to measure GICs. The sensor under development will have the following core features:

- The sensor clips on and around the high-voltage leads supplying the transformer or an overhead transmission conductor (see Figure 1 and 2). The sensor is designed to be adjustable for different conductor diameters.
- The sensor measures and discriminates between dc and ac currents. It will be able to measure current accurately on the order of tens of ac amps and thousands of ac amps.
- System development focuses on GIC (dc) capture. In the future, the sensor will have the ability to capture ac as well.
- The RF sensor communicates with a local base station.
- The sensor is powered by harvesting from the magnetic field generated by the current flowing in the conductor.
- The sensor has a battery backup that will enable over one month of operation with no power harvesting.

In early 2014, a technology demonstrator made of discreet components was built and successfully tested at 138 kV. Both ac and dc currents were measured at high voltages and transmitted to a local receiver, which integrated the data into a monitoring system. A fully integrated laboratory prototype has been designed and is presently being constructed. Testing is planned for November 2014. If testing is successful, the design will be revised as needed, and field prototype units will be built and deployed in field trials in 2015.

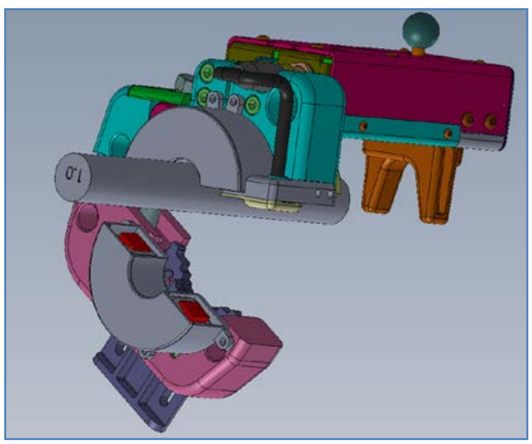

Figure 1: Laboratory prototype design of EPRI-developed RF conductor sensor

Figure 2: RF conductor sensor that is now commercially available

Solar Storm Activity in September 2014

Two coronal mass ejections (CMEs) launched from the Sun September 9th and 10th (see Figure 3), 2014 arrived at the Earth's surface on September 11th and 12th. EPRI's SUNBURST Network is presently recording geomagnetically induced currents (GICs) flowing onto and out of the electric transmission system at 32 participating utility sites across North America. As per the monitoring design, the SUNBURST Network automatically distributed an "Event Notice" to SUNBURST member utilities when five sites reported greater than 10 amperes of GIC. The readings were captured and the notice was sent Friday, September 12, 2014 just before noon EDT, 13:54 UT. The sites that triggered the event notification are in the southeastern US (at locations from western Kentucky south to northern Alabama), in Wisconsin, and at a site in the northeastern U.S.

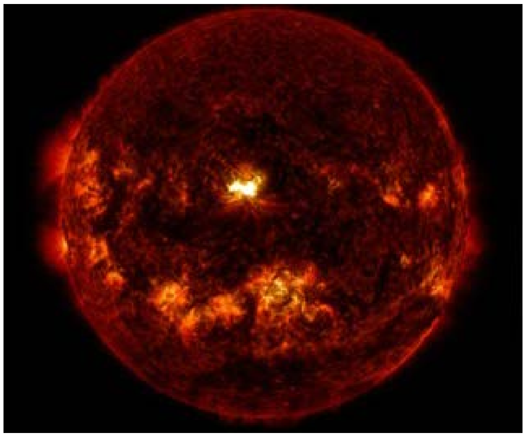

Figure 3: In this image captured by NASA's Solar Dynamics Laboratory, the solar flare that flashed in the middle of the sun on September 10, 2014 resulted in significant GICs, as measured by the EPRI SUNBURST Network.
Photo Credit: NASA/Goddard Space Flight Center/Solar Dynamics Observatory (http://svs.gsfc.nasa.gov/goto?11651)

The arrival times of the CMEs were visible not just in the SUNBURST GIC data, but also in preliminary magnetic field data recorded on a prototype magnetometer system in western Pennsylvania. The second CME was clearly visible on the system before noon EDT. This prototype magnetometer system is part of an EPRI effort to add direct geomagnetic variation data to the SUNBURST Network at multiple sites and provide more spatial resolution when combined with U.S. Geological Survey (USGS) observatory data. This solar storm activity will be used to evaluate the accuracy and resolution requirements of the magnetometers planned for the SUNBURST Network.

The sudden impulse of the September 9 CME arrived at the Earth's surface in the evening of September 11th, around 7:45pm EDT. The second CME from September 10 was stronger than the first. The National Oceanic and Atmospheric Administration (NOAA) reported a sudden impulse of 43 nT associated with the arrival of this CME. The second CME created a K-7 storm (where K-9 is the highest) as well as colorful nighttime auroras. The largest neutral DC current recorded for this storm was 24.5 amperes (see Figure 4).This is this first GIC activity of note since October 2013, although low levels of GIC activity have been recorded several times in the interval. Significant GIC events were recorded by the SUNBURST Network in 2000, 2001, and 2003.

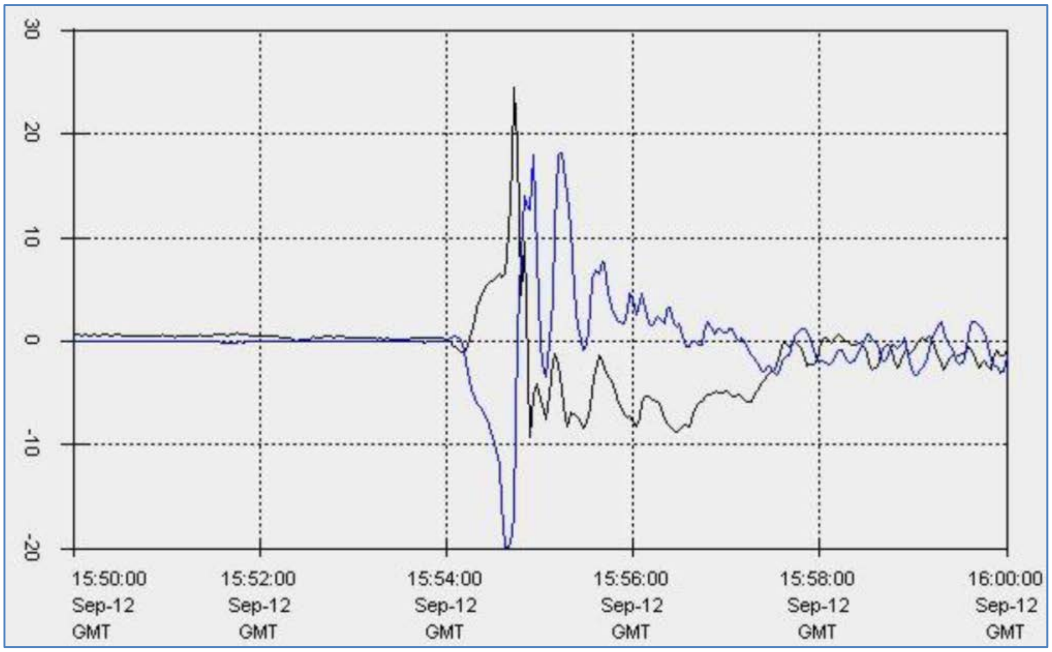

Figure 4: This plot of amperes of geomagnetically-induced current was measured at two SUNBURST Network stations on September 12, 2014, showing a peak of 245 amperes.

Opportunities for Participation

To find out about opportunities to participate in EPRI GMD research, please contact EPRI Senior Technical Executive Rich Lordan, rilordan@epri.com, 650.855.2435.

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