TIP 359: Improved System Modeling for GMD and EMP Assessments

Context

The potential for geomagnetic disturbances (GMDs) and electromagnetic pulse (EMP) to cause significant impacts on the power grid is now a well-recognized issue. Recently, NERC has been directed by FERC to develop reliability standards to address GMD assessments*, with the GMD operational/reliability standards already in effect (NERC standard EOP-010-1). GMDs induce very low frequency (much less than 1 Hz) electric fields at the earth's surface and consequently drive quasi-dc geomagnetically induced current (GIC) in the grid. GICs can cause half-cycle saturation of transformers, giving rise to harmonics and increased reactive power absorption in transformers. This transformer reactive power loss could severely impact the system voltage stability, while harmonics currents can cause misoperation of protection devices. Unintended isolation of needed components such as capacitor banks and transformers during GMDs further increase the vulnerability of the network to voltage collapse, as seen in the March 1989 collapse of Hydro-Quebec.

Description

This work built upon the successful GMD modeling and validation work by the University of Illinois and other industrial partners. These efforts include an EPRI project on GIC flow modeling and the collaboration with AEP to assess their system.

The project provides BPA engineers with a methodology for a validated GMD flow model and benchmark GMD scenarios, as required to be available per the upcoming FERC standards.

The project is to established an integrated system-data model to validate the GIC flow model. This can be used by BPA to construct a benchmark GMD storm scenario as required by standards, and to improve the accuracy of the GIC flow modeling. The second goal is to develop and validate the modeling of transformer response to the GIC flow using BPA system power flow data, as an extension to the GIC flow validation to improve the quantitative understanding of the negative GMD impacts in planning studies. The third goal of this project is to build on the GMD modeling to develop models and tools for EMP assessment of power systems, in the necessary power system dynamics time frame.

Benefits

Validating the source of uncertainty using real data results in a better GMD/EMP model. And a better model provides a higher probability of mitigating the potential impacts at both system level (higher reactive power losses) or asset level (transformer/capacitor misoperation). Also, better GMD/EMP assessment models will provide operators with the tools needed to mitigate system voltage collapse and transformer heating, which would help prevent wide-area power outages.

The research activities on GMD assessment and benchmark electric field construction directly fulfills the requirements per the recently released NERC reliability/ operational standard EOP-010-1.

Accomplishments

The project's overall objective was to validate BPA's system models and to improve the models related to geomagnetic disturbances (GMD) in power system simulations, for better GMD and electromagnetic pulse (EMP) risk assessments. The EMP E3 part bears several similarities with GMDs, which makes the modeling applicable to both, except for the time frame of the simulation.

This ultimate benefit includes enhanced decision-making regarding planning, operations and mitigation strategies in the presence of GMDs. This was done by validating several GMD-related system parameters and modeling approaches for the BPA system, thanks to available data measurement during GMD storms.

Related Projects:

TIP 264: Modeling Geomagnetic Induced Current for Evaluation and Mitigation

TIP 290: Modeling High-impact, Low-frequency Geomagnetic Disturbances using Magnetic Field Data from Solar-orbiting Spacecraft

Reports, References, Links

* "Reliability Standards for Geomagnetic Disturbances," FERC Final Rule, Docket No. RM12-22-000; Order No. 779, May 16 2013

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Project Start Date: October 2015

Project End Date: May 2018

Deliverables

All the validation results and methods developed in each of the tasks.

Discussion on the accuracy of the GIC flow model offered to guide future placement of GIC monitoring devices. Documentation on the usage of those methods

The validation studies performed using these methods and the results of those are delivered through reports, including the discrepancies found and the following analysis.

Deliverables include the benchmark Electric field model for the BPA footprint, as required by the NERC standards.

The final report describes the execution and achievements of the entire project in detail, as well as charting out the future directions.

Funding

Total Project Cost: $503,000

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Conclusions

To improve assessments of high altitude electromagnetic pulse (HEMP) impacts on power grids, a method was introduced which converted a publicly available electric field calculated under a simple uniform conductivity model to a more realistic 1D conductivity model. The magnitude of the electric fields resulting from the 1D conductivity model varied greatly from region to region. The uniform conductivity model does not consider these regional differences. When applying these two electric fields to a 10,000 bus synthetic case, using the 1D conductivity model yielded impacts that were much less severe. The differences between the electric fields resulting from each model are significant. From the perspective of a power system operator, it can mean the difference between taking out transmission lines to protect system equipment and taking no action because the system appears to be safe from instability or damage.

Since the 1D model is a more realistic representation of the conductivity of the earth than the uniform model, the use of the 1D model may be preferred when performing HEMP vulnerability studies on a real system. The 1D conductivity model has been tested in multiple papers which conclude that transformer neutral currents measured in the field have high correlation with values simulated with the 1D model.

Based on the significantly varying simulation results between the six EMP Commission waveforms, it can be concluded that completing a thorough HEMP vulnerability assessment cannot be done with a single waveform. To protect a grid, whose footprint resides on multiple conductivity regions, against voltage instability and transformer damage, it is important to study multiple HEMP waveforms to ensure a comprehensive understanding of a grid's vulnerabilities.