Geomagnetic Disturbances

Update on Project 2013-03 and GMD Task Force

Frank Koza, PJM Interconnection
PJM Reliability Standards and Compliance Subcommittee
March 21, 2014
• Update on GMD Standards Development
  ▪ EOP-010  GMD Operations
  ▪ TPL-007  Transmission System Planned Performance during GMD

• NERC GMD Task Force Activities
GMD Concern for the Power System

GICs can cause:
Increased reactive power consumption, transformer heating, and P&C misoperation
On May 16, 2013, FERC issued Order 779 which directs NERC to submit Reliability Standards that address the impact of geomagnetic disturbances (GMD) on the reliable operation of the Bulk-Power System:

- **Stage 1 – Operating Procedures**
- **Stage 2 – Detailed Assessments (Planning Studies)**
<table>
<thead>
<tr>
<th>Name</th>
<th>Registered Entity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frank Koza (Chair)</td>
<td>PJM Interconnection</td>
</tr>
<tr>
<td>Dr. Randy Horton (Vice-chair)</td>
<td>Southern Company</td>
</tr>
<tr>
<td>Donald Atkinson</td>
<td>Georgia Transmission Corporation</td>
</tr>
<tr>
<td>Dr. Emanuel Bernabeu</td>
<td>Dominion Resource Services, Inc</td>
</tr>
<tr>
<td>Kenneth Fleischer</td>
<td>NextEra Energy</td>
</tr>
<tr>
<td>Dr. Luis Marti</td>
<td>Hydro One Networks</td>
</tr>
<tr>
<td>Dr. Antti Pulkkinen</td>
<td>NASA Goddard Space Flight Center</td>
</tr>
<tr>
<td>Dr. Qun Qiu</td>
<td>American Electric Power</td>
</tr>
</tbody>
</table>
• Passed final ballot of the industry ballot pool:
  
  | Quorum:       | 86.65 %         |
  | Weighted Segment Vote: | 91.95 %         |

(2/3 approval required)

• Approved by the NERC Board of Trustees on November 7, 2013
• Submitted to FERC in November 2013, as required by FERC Order 779, and ahead of schedule (Jan 2014)
• At its January 16 meeting, FERC indicated its intention to approve the standard, subject to NOPR comments
EOP-010 Requirements

- R1 -- Each Reliability Coordinator (RC) required to develop, coordinate, maintain, and implement, as necessary, a GMD Operating Plan
- R2 – Each RC is responsible for disseminating forecast and current space weather information
- R3 – Each Transmission Operator (TOP) required to develop, maintain, and implement an Operating Procedure or Operating Process to mitigate the effects of GMD events
- Requirements are not prescriptive to allow the entity to tailor Operating Procedures based on entity-specific factors
  - Geography, geology, and system topology
EOP-010  Applicability

• Reliability Coordinators (RCs)
• Transmission Operators (TOPs) with a Transmission Operator Area that includes a power transformer with a high side wye-grounded winding with terminal voltage greater than 200KV

Does not apply to:
• Balancing Authorities (BAs)
• Generator Operators (GOPs)

Actions are either covered under other requirements or would require detailed studies as described in the whitepaper:

For lines less than 200kV, impedance is higher, lines are generally shorter, and lower voltage lines provide minimal contribution to GIC; hence, such lines are ignored in analysis. [Example calculation included in the whitepaper]

If 230 kV lines were ignored, significant GIC would be mistakenly excluded from analysis and could result in inaccurate var consumption calculations. [Example calculation included in the whitepaper]

Whitepaper includes rationale explanation, example calculations, and reference list:

http://www.nerc.com/pa/Stand/Project201303GeomagneticDisturbanceMitigation/ApplicableNetwork_clean.pdf
• Operating Procedure Template - Transmission Operator
  http://www.nerc.com/comm/PC/Geomagnetic%20Disturbance%20Task%20Force%20GMDTF%202013/Template_TOP.pdf

• Operating Procedure Template – Generation Operator

• GIC Application Guide
• Require a planning assessment of the system for its ability to withstand a Benchmark GMD Event without causing a wide area blackout, voltage collapse, or damage to transformers. 

**Applicability:** PCs, TPs, TOs, GOs

- Need system models— DC (GIC calculation) and AC (power flow)
- Transformer information— internal winding resistance
- Substation grounding information

• Studies that may be necessary to perform a GMD assessment:
  - Transformer GIC Impact (Reactive Power and Thermal)
  - Power Flow System Studies
  - Impact of Harmonics on Reactive Power compensation devices
• The standard drafting team and GMD Task Force are addressing challenges to specifying a benchmark GMD event
  ▪ Lack of validated earth conductivity models
  ▪ Limited historical geomagnetic data for many regions
  ▪ Practical application of research
• Benchmark GMD event must be technically justified and provide:
  ▪ Adequate design basis for GMD resilience
  ▪ Balance between reliability and cost
• Whitepaper describing statistical analysis, technical considerations, and application is in development
GMD Benchmark Geo-electric Field

\[ E_{\text{peak}} = E_{\text{benchmark}} \times \alpha \times \beta \text{ (in V/km)} \]

where,

- \( E_{\text{peak}} = \) Benchmark Geo-electric field magnitude at System location
- \( E_{\text{benchmark}} = \) Benchmark Geo-electric field magnitude at reference location (60° N geomagnetic latitude, resistive ground model)
- \( \alpha = \) Factor adjustment for geo-magnetic latitude
- \( \beta = \) Factor adjustment for regional Earth conductivity model
Geo-electric field magnitude ($E_{\text{benchmark}}$)

Take many years of magnetometer data and extrapolate the data to arrive at a statistical probability of a $\sim 1:100$ year event at reference location.

3-8 V/km Range at 60° N

8 V/km to be conservative
• Sample $\alpha$ scaling factors for geomagnetic latitudes
  1.0 at 60° N  Juneau; Winnipeg; Churchill Falls, NL
  0.3 at 50° N  New York; St Louis; Salt Lake City
  0.1 at 40° N  Jacksonville; New Orleans; Tucson

LaGrande Complex at James Bay is at ~65° N geomagnetic

• Factors are illustrative and subject to change

Geomagnetic Latitude Chart. Application for converting geographic latitude to geomagnetic latitude is available from NOAA website
Earth conductivity model factor ($\beta$)

Scaling Factor: 0.81 Atlantic Coastal (CP-1)
(analysis ongoing) 0.30 Columbia Plateau (CO-1)

Based on data from USGS and Natural Resources Canada
Historical Perspective on Benchmark

1989 Hydro Quebec Storm
( Estimated 1-in-50 to 1-in-100 year event)

Example Calculation
Benchmark Geoelectric Field for Fredricksburg vicinity:

\[ E_{\text{peak}} = 8 \times \alpha \times \beta \]

\[ \alpha = 0.18 \ @ 45^\circ \text{N} \]
\[ \beta = 0.81 \ (\text{Model CP-1}) \]

\[ E_{\text{peak}} = 1.17 \ \text{V/km} \]
(Estimated 1-in-75 to 1-in-100 year event)

Let’s be clear: There are significant error bars involved in estimating rare events
Assessment Process Overview

“New” Planning Steps
GIC Calculation is now available on most power system analysis software

Assemble model and equipment data → Create DC model of the system → Calculate GICs for each transformer → Use GICs to calculate reactive losses

“Standard” TPL Planning
Run AC power flow w/ reactive losses included → Identify limit violations and system issues → Conduct thermal assessment of transformers

Corrective Action Plan
Investigate mitigation options
Thermal Assessment of Transformers

- Thermal limits: IEEE C57.91 (Guide for Loading Mineral-Oil-Immersed Transformers) provides temperature limits
- Transformer manufacturer capability curves
- Thermal response simulation
• GICs will vary based on a number of factors—geology, geography, topology, proximity to large bodies of water, etc.

Mitigation strategies
• Op procedures
• Blocking devices
• Selective outages
• Protection upgrades
• Equip replacement
• New equip specs
NERC GMD Task Force

• Issued in 2013
  ▪ GIC Application Guide
    ○ GIC Calculation
  ▪ GMD Planning Guide
    ○ System Impact Studies
    ○ Equipment Assessment
    ○ Mitigation and Monitoring

• In progress in 2014
  ▪ Transformer modeling and testing
Challenges

• Lack of commercially available software tools and validated models for transformers and harmonics analysis
  ▪ Transformer heating has been a “hot” topic (pun intended) and we won’t have a definitive “answer” to this issue for some time (read: years)
  ▪ We will attempt to address these issues at a high level in the standards

• Assessment criteria (how do you know if you have an issue?)
  ▪ Less stringent acceptance criteria than “standard” planning-- this is about preventing a cascade and blackout.
  ▪ What are the necessary criteria in analysis that will prevent a cascade and blackout? [Hint: It is not Table 1 of TPL-001]
Questions and Answers