

## Standard Development Timeline

*This section is maintained by the drafting team during the development of the standard and will be removed when the standard becomes effective.*

### Development Steps Completed

1. The Standards Committee accepted the Standard Authorization Request (SAR) submitted by the Geomagnetic Disturbance Task Force (GMD TF) and approved Project 2013-03 (Geomagnetic Disturbance Mitigation) on June 5, 2013.
2. The SAR was posted for informal comment from June 26, 2013 through August 12, 2013.
3. The first draft of the proposed Reliability Standard was posted for formal comment and initial ballot from June 13, 2014 through July 30, 2014.

### Description of Current Draft

This is the ~~first~~second draft of the proposed Reliability Standard. It is posted for 45-day comment and ~~initial~~additional ballot.

Anticipated Actions	Anticipated Date
<del>45-day Formal Comment Period with Initial Ballot</del>	<del>June 2014</del>
45-day Formal Comment Period with Additional Ballot	August 2014
Final ballot	October 2014
BOT adoption	November 2014

**Effective Dates**

~~The definition shall become effective on the first day of the first calendar quarter after the date that this standard is approved by an applicable governmental authority or as otherwise provided for in a jurisdiction where approval by an applicable governmental authority is required for a standard to go into effect. Where approval by an applicable governmental authority is not required, the definition shall become effective on the first day of the first calendar quarter after the date this standard is adopted by the NERC Board of Trustees or as otherwise provided for in that jurisdiction.~~

~~The Requirements shall become effective as described in the Implementation Plan beginning on the first day of the first calendar quarter that is 12 months after the date that this standard is approved by an applicable governmental authority or as otherwise provided for in a jurisdiction where approval by an applicable governmental authority is required for a standard to go into effect. Where approval by an applicable governmental authority is not required, the Requirements shall become effective as described in the Implementation Plan beginning on the first day of the first calendar quarter that is 12 months after the date this standard is adopted by the NERC Board of Trustees or as otherwise provided for in that jurisdiction.~~

~~Compliance shall be implemented over a 4-year period as described in the Implementation Plan.~~

See Implementation Plan for TPL-007-1

**Version History**

Version	Date	Action	Change Tracking
1	TBD	Project 2013-03 (Phase 2)	N/A

**Definitions of Terms Used in Standard**

*This section includes all newly defined or revised terms used in the proposed standard. Terms already defined in the Reliability Standards Glossary of Terms are not repeated here. New or revised definitions listed below become approved when the proposed standard is approved. When the standard becomes effective, these defined terms will be removed from the individual standard and added to the Glossary.*

**Geomagnetic Disturbance Vulnerability Assessment or GMD Vulnerability Assessment:** Documented evaluation of potential susceptibility to voltage collapse, Cascading, or localized damage of equipment due to geomagnetic disturbances.

## A. Introduction

1. **Title:** Transmission System Planned Performance for Geomagnetic Disturbance Events
2. **Number:** TPL-007-1
3. **Purpose:** Establish requirements for Transmission system planned performance during geomagnetic disturbance (GMD) events.
4. **Applicability:**
  - 4.1. **Functional Entities:**
    - 4.1.1 Planning Coordinator with a planning area that includes a Facility or Facilities specified in 4.2;
    - 4.1.2 Transmission Planner with a planning area that includes a Facility or Facilities specified in 4.2;
    - 4.1.3 Transmission Owner who owns a Facility or Facilities specified in 4.2;
    - 4.1.4 Generator Owner who owns a Facility or Facilities specified in 4.2.
  - 4.2. **Facilities:**
    - 4.2.1 Facilities that include power transformer(s) with a high side, wye-grounded winding with terminal voltage greater than 200 kV.

Rationale:

Instrumentation transformers and station service transformers do not have significant impact on GIC flows; therefore, they are not included in the applicability for this standard.

5. **Background:**

During a GMD event, geomagnetically-induced currents (GIC) may cause transformer hot-spot heating or damage, loss of Reactive Power sources, increased Reactive Power demand, and Misoperation, the combination of which may result in voltage collapse and blackout.

## B. Requirements and Measures

- R1.** Each Planning Coordinator, in conjunction with each of its Transmission Planners, shall identify the individual and joint responsibilities of the Planning Coordinator and each of the Transmission Planners in the Planning Coordinator's planning area for maintaining models and performing the studies needed to complete GMD Vulnerability Assessment(s). [*Violation Risk Factor: Low*] [*Time Horizon: Long-term Planning*]
- M1.** Each Planning Coordinator, in conjunction with each of its Transmission Planners, shall provide documentation on roles and responsibilities, such as meeting minutes,

agreements, ~~and~~ copies of procedures or protocols in effect between entities or between departments of a vertically integrated system, or email correspondence that identifies ~~that an~~ agreement has been reached on individual and joint responsibilities for maintaining models and performing the studies needed to complete GMD Vulnerability Assessment(s) in accordance with Requirement R1.

**R2.** Responsible entities as determined in Requirement R1 shall maintain System models and ~~geomagnetically induced current (GIC)~~ GIC System models of the responsible entity's planning area for performing the studies needed to complete GMD Vulnerability Assessment(s). [*Violation Risk Factor: Medium*] [*Time Horizon: Long-term Planning*]

**M2.** ~~Responsible entities~~ A responsible entity as determined in Requirement R1 shall have evidence in either electronic or hard copy format that it is maintaining System models and ~~geomagnetically induced current (GIC)~~ GIC System models of the responsible entity's planning area for performing the studies needed to complete GMD Vulnerability Assessment(s).

#### **Rationale for Requirement R2:**

A GMD Vulnerability Assessment requires a GIC System model to calculate GIC flow which is used to determine transformer Reactive Power absorption and transformer thermal response. Guidance for developing the GIC System model are provided in the GIC Application Guide developed by the NERC GMD Task Force and available at:

[http://www.nerc.com/comm/PC/Geomagnetic%20Disturbance%20Task%20Force%20GMDTF%202013/GIC%20Application%20Guide%202013\\_approved.pdf](http://www.nerc.com/comm/PC/Geomagnetic%20Disturbance%20Task%20Force%20GMDTF%202013/GIC%20Application%20Guide%202013_approved.pdf)

The System model specified in Requirement R2 is used in conducting steady state power flow analysis that accounts for the Reactive Power absorption of transformers due to GIC in the System.

The GIC System model includes all power transformer(s) with a high side, wye-grounded winding with terminal voltage greater than 200 kV. The model is used to calculate GIC flow in the network.

The projected System condition for GMD planning may include adjustments to the System that are executable in response to space weather information. These adjustments could include recalling or postponing maintenance outages, for example.

**R3.** Responsible entities as determined in Requirement R1 shall have criteria for acceptable System steady state voltage ~~limits-~~ performance for its System during the benchmark GMD event described in Attachment 1. [*Violation Risk Factor: Medium*] [*Time Horizon: Long-term Planning*]

**M3.** A responsible entity as determined in Requirement R1 shall have evidence such as electronic or hard copies of the criteria for acceptable System steady state voltage ~~limits~~ performance for its System in accordance with Requirement R3.

~~R3.~~R4. Responsible entities as determined in Requirement R1 shall complete a GMD Vulnerability Assessment of the Near-Term Transmission Planning Horizon once every 60 calendar months. This GMD Vulnerability Assessment shall use studies based on models identified in Requirement R2, document assumptions, and document summarized results of the steady state analysis. *[Violation Risk Factor: High] [Time Horizon: Long-term Planning]*

4.1. Studies shall include the following conditions:

- 4.1.1. System ~~peak~~On-Peak Load for at least one year within the Near-Term Transmission Planning Horizon; and
- 4.1.2. System Off-Peak Load for at least one year within the Near-Term Transmission Planning Horizon.

4.2. Studies shall be conducted based on the benchmark GMD event described in Attachment 1 to determine whether the system meets the performance requirements in Table 1.

4.3. The GMD Vulnerability Assessment shall be provided within 90 calendar days of completion to the responsible entity's Reliability Coordinator, adjacent Planning Coordinators, adjacent Transmission Planners, and to any functional entity that submits a written request and has a ~~reliability-related~~reliability-related need.

- ~~34.3.1~~ If a recipient of the GMD Vulnerability Assessment provides documented comments on the results, the responsible entity shall provide a documented response to that recipient within 90 calendar days of receipt of those comments.

~~M3.~~M4. ~~A~~ Responsible entities ~~iesy~~ as determined in Requirement R1 shall have dated evidence such as electronic or hard copies of its GMD Vulnerability Assessment meeting all of the requirements in Requirement ~~R3. Responsible entities~~R4. A responsible entity as determined in Requirement R1 shall also provide evidence, such as email records, web postings with an electronic notice of posting, or postal receipts showing recipient and date, that it has distributed its GMD Vulnerability Assessment within 90 calendar days of its completion to its Reliability Coordinator, adjacent Planning Coordinators, adjacent Transmission Planners, and to any functional entity who has ~~indicated~~submitted a written request and has a ~~reliability-related~~reliability-related need as specified in Requirement ~~R3. Responsible entities~~R4. A responsible entity as determined in Requirement R1 shall also provide evidence, such as email notices or postal receipts showing recipient and date, that it has provided a documented response to comments received on its GMD Vulnerability Assessment within 90 calendar days of receipt of those comments in accordance with Requirement ~~R3~~R4.

**Rationale for Requirement ~~R3~~R4:**

The GMD Vulnerability Assessment includes steady state power flow analysis and supporting studies using the models specified in Requirement R2 that account for the effects of GIC. Performance criteria are specified in Table 1.

System peak Load and Off-peak Load must be examined in the analysis.

Distribution of GMD Vulnerability Assessment results provides a means for sharing relevant information with other entities responsible for planning reliability. Results of GIC studies may affect neighboring systems and should be taken into account by planners.

The GMD Planning Guide developed by the NERC GMD Task Force provides technical information on GMD-specific considerations for planning studies. It is available at:

[http://www.nerc.com/comm/PC/Geomagnetic%20Disturbance%20Task%20Force%20GMDTF%202013/GMD%20Planning%20Guide\\_approved.pdf](http://www.nerc.com/comm/PC/Geomagnetic%20Disturbance%20Task%20Force%20GMDTF%202013/GMD%20Planning%20Guide_approved.pdf)

**R4.—**

**R5.** Responsible entities as determined in Requirement R1 shall provide ~~geomagnetically-induced current (GIC)~~ flow information to be used for the transformer thermal impact assessment specified in Requirement R6 to each Transmission Owner and Generator Owner in the planning area that owns an applicable power transformer. The GIC flow information shall include for each applicable power transformer: *[Violation Risk Factor: Medium] [Time Horizon: Long-term Planning]*

**5.1.** ~~5.1~~ Maximum effective GIC value for the worst case geoelectric field orientation for the benchmark GMD event described in Attachment 1; and

**5.2.** ~~5.2~~ Effective GIC time series, GIC(t), calculated using the benchmark GMD event described in Attachment 1 for each applicable power transformer where the ~~M~~maximum effective GIC value for the worst case geoelectric field orientation exceeds 15 ~~Amperes~~A per phase.

**M5.** ~~Responsible entities~~A ~~responsible entity~~ as determined in Requirement R1 shall provide evidence, such as email records, web postings with an electronic notice of posting, or postal receipts showing recipient and date, that it has provided ~~geomagnetically-induced current (GIC)~~GIC flow information to each Transmission Owner and Generator Owner that owns an applicable power transformer as specified in Requirement R5.

**Rationale for Requirement R5:**

This GIC information is necessary for determining the thermal impact of GIC on transformers in the planning area and must be provided to entities responsible for performing the thermal impact assessment so that they can accurately perform the assessment.

The GIC flows provided in part 5.1 are used to screen the transformer fleet ~~such so~~ that only those transformers that experience an effective GIC flow of 15A or greater are evaluated.

The GIC flows provided by part 5.2-~~and 5.3~~ are used to convert the steady-state GIC flows to time-series GIC data used for transformer thermal impact assessment. Additional guidance is available in the Thermal Impact Assessment white paper:

<http://www.nerc.com/pa/Stand/Pages/Project-2013-03-Geomagnetic-Disturbance-Mitigation.aspx>

**R6.** Each Transmission Owner and Generator Owner shall conduct a thermal impact assessment for each of its solely and jointly owned applicable Bulk Electric System power transformers where the maximum effective ~~geomagnetically-induced-current (GIC)~~ value provided in Requirement R5 part 5.1 is 15 AmperesA or greater per phase. The thermal impact assessment shall: [*Violation Risk Factor: ~~High~~Medium*] [*Time Horizon: Long-term Planning*]

- 6.1. Be based on the effective GIC flow information provided in Requirement R5; ~~and~~
- 6.2. Document assumptions used in the analysis; ~~and~~
- 6.3. Describe suggested actions and supporting analysis to mitigate the impact of GICs, if any; and
- 6.4. Be performed and provided to the responsible entities as determined in Requirement R1 within ~~1224~~ calendar months of receiving GIC flow information specified in Requirement R5.

**M6.** Each Transmission Owner and Generator Owner shall have evidence such as electronic or hard copies of its thermal impact assessment for all of its applicable solely and jointly owned power transformers where maximum effective ~~geomagnetically-induced-current (GIC)~~ value provided in Requirement R5 part 5.1 is 15 AmperesA or greater per phase and have evidence such as email records, web postings with an electronic notice of posting, or postal receipts showing recipient and date, that it has provided its thermal impact assessment to the responsible entities as specified in Requirement R6.

Rationale for Requirement R6:

The thermal impact assessment may be based on manufacturer-provided GIC capability curves, thermal response simulation, or other technically justified means. A process for conducting the assessment is presented in the Transformer Thermal Impact Assessment white paper posted on the project page.

<http://www.nerc.com/pa/Stand/Pages/Project-2013-03-Geomagnetic-Disturbance-Mitigation.aspx>

Thermal impact assessments of non-BES transformers are not required because those transformers do not have a wide-area effect on the reliability of the interconnected Transmission system.

**R7.** Responsible entities as determined in Requirement R1 that conclude through the GMD Vulnerability Assessment conducted in Requirement ~~R3R4~~ that their System does not



meet the performance requirements of Table 1 shall develop a Corrective Action Plan addressing how the performance requirements will be met. The Corrective Action Plan shall: [*Violation Risk Factor: High*] [*Time Horizon: Long-term Planning*]

- 7.1. List System deficiencies and the associated actions needed to achieve required System performance. Examples of such actions include:
    - Installation, modification, retirement, or removal of Transmission and generation Facilities and any associated equipment.
    - Installation, modification, or removal of Protection Systems or Special Protection Systems.
    - Use of Operating Procedures specifying how long they will be needed as part of the Corrective Action Plan.
    - Use of Demand-Side Management, new technologies, or other initiatives.
  - 7.2. Be reviewed in subsequent GMD Vulnerability Assessments until it is determined that the System meets the performance requirements contained in Table 1.
  - 7.3. Be provided within 90 calendar days of completion to the responsible entity's Reliability Coordinator, adjacent Planning Coordinators, adjacent Transmission Planners, functional entities referenced in the Corrective Action Plan, and ~~to~~ any functional entity that submits a written request and has a reliability related~~reliability-related~~ need.
    - 7.3.1. If a recipient of the Corrective Action Plan provides documented comments on the results, the responsible entity shall provide a documented response to that recipient within 90 calendar days of receipt of those comments.
- M7. ~~Responsible entities~~A responsible entity as determined in Requirement R1 that concludes through the GMD Vulnerability Assessment conducted in Requirement ~~R3R4~~ that the responsible entity's System does not meet the performance requirements of Table 1 shall have evidence such as electronic or hard copies of its Corrective Action Plan as specified in Requirement R7. ~~Responsible entities~~A responsible entity as determined in Requirement R1 shall also provide evidence, such as email records, web postings with an electronic notice of posting, or postal receipts showing recipient and date, that it has distributed its Corrective Action Plan or relevant information, if any, within 90 calendar days of its completion to its Reliability Coordinator, adjacent Planning Coordinators, adjacent Transmission Planners, and any other functional entity referenced in the Corrective Action Plan or to any functional entity who has ~~indicated~~submitted a written request and has a reliability related~~reliability-related~~ need as specified in Requirement R7. ~~Responsible entities~~A responsible entity as determined in Requirement R1 shall also provide evidence, such as email notices or postal receipts showing recipient and date, that it has provided a documented response to comments received on its Corrective Action Plan within 90 calendar days of receipt of those comments in accordance with Requirement R7.



Table 1 –Steady State Planning Events				
<p><b>Steady State:</b></p> <ul style="list-style-type: none"> <li>a. Voltage collapse, Cascading and uncontrolled islanding shall not occur.</li> <li>b. <del>Load loss as well as generation</del><u>Generation</u> loss is acceptable as a consequence of the planning event.</li> <li><del>c.</del>—Planned System adjustments such as Transmission configuration changes and re-dispatch of generation are allowed if such adjustments are executable within the time duration applicable to the Facility Ratings.</li> <li><del>d.c.</del> <u>System steady state voltages shall be within acceptable limits as established by the Planning Coordinator and the Transmission Planner in accordance with Requirement R4.</u></li> </ul>				
Category	Initial Condition	Event	Interruption of Firm Transmission Service Allowed	Load Loss Allowed
GMD GMD Event with Outages	1. System as may be postured in response to space weather information <sup>1</sup> , and then 2. GMD event <sup>2</sup>	Reactive Power compensation devices and other Transmission Facilities removed as a result of Protection System operation <u>or Misoperation due to harmonics</u> during the GMD event <sup>3</sup>	Yes <sup>4,3</sup>	Yes <sup>4,3</sup>

Table 1 – Steady State Performance Footnotes
<p>1. The System condition for GMD planning may include adjustments to posture the System that are executable in response to space weather information.</p> <p>2. The GMD conditions for the planning event are described in Attachment 1 (Benchmark GMD Event).</p> <p><del>3. Protection Systems may trip due to the effects of harmonics. GMD planning analysis shall consider removal of equipment that the planner determines may be susceptible.</del></p> <p><del>4.3. Load loss as a result of manual or automatic Load shedding (e.g. UVLS) and/or curtailment of Firm Transmission Service may be neededused to meet BES performance requirements during studied GMD conditions but should not be used as the primary method of achieving required performance. GMD Operating Procedures should be based on predetermined triggers from studied GMD conditions so that the. The</del> likelihood and magnitude of Load loss or curtailment of Firm Transmission Service <u>is/should be</u> minimized <del>during a GMD event.</del></p>

## Attachment 1

### Calculating Geoelectric Fields for the Benchmark GMD Event

The benchmark GMD event<sup>1</sup> defines the geoelectric field values used to compute ~~geomagnetically-induced-current (GIC)~~GIC flows that are needed to conduct a GMD Vulnerability Assessment. It is composed of the following elements: (1) a reference peak geoelectric field amplitude of 8 V/km derived from statistical analysis of historical magnetometer data; (2) scaling factors to account for local geomagnetic latitude; (3) scaling factors to account for local earth conductivity; and (4) a reference geomagnetic field time series or waveshape to facilitate time-domain analysis of GMD impact on equipment.

The regional geoelectric field peak amplitude ~~to be~~ used in GMD Vulnerability Assessment,  $E_{\text{peak}}$ , can be obtained from the reference geoelectric field value of 8 V/km using the following relationship

$$E_{\text{peak}} = 8 \times \alpha \times \beta \text{ (V/km)} \quad (1)$$

where  $\alpha$  is the scaling factor to account for local geomagnetic latitude, and  $\beta$  is a scaling factor to account for the local earth conductivity structure.

#### Scaling the Geomagnetic Field

The benchmark GMD event is defined for geomagnetic latitude of 60° and it must be scaled to account for regional differences based on geomagnetic latitude. Table 2 provides a scaling factor correlating peak geoelectric field to geomagnetic latitude. Alternatively, the scaling factor  $\alpha$  ~~can be~~ is computed with the empirical expression

$$\alpha = 0.001 \cdot e^{(0.115 \cdot L)} \quad (2)$$

where  $L$  is the geomagnetic latitude in degrees and  $0.1 \leq \alpha \leq 1$

For large planning areas that cover more than one scaling factor from Table 2, the GMD Vulnerability Assessment should be based on a peak geoelectric field that is:

- calculated by using the most conservative (largest) value for  $\alpha$  ~~should be used in scaling the geomagnetic field. Alternatively, a planner could use a tool that is capable of performing analysis using; or~~
- calculated assuming a non-uniform or piecewise uniform geomagnetic field.

<sup>1</sup> The benchmark GMD event description is available on the Project 2013-03 Geomagnetic Disturbance Mitigation project page: <http://www.nerc.com/pa/Stand/Pages/Project-2013-03-Geomagnetic-Disturbance-Mitigation.aspx>

Geomagnetic Latitude (Degrees)	Scaling Factor1 ( $\alpha$ )
$\leq 40$	0.10
45	0.2
50	0.3
54	0.5
56	0.6
57	0.7
58	0.8
59	0.9
$\geq 60$	1.0

### Scaling the Goelectric Field

The benchmark GMD event is defined for the reference Quebec earth model described in Table 4. The peak geoelectric field,  $E_{\text{peak}}$ , ~~to be~~ used in a GMD Vulnerability Assessment may be obtained by either

- Calculating the geoelectric field for the ground conductivity in the planning area and the reference geomagnetic field time series scaled according to geomagnetic latitude, using a procedure such as the plane wave method described in the NERC GMD Task Force GIC Application Guide<sup>2</sup>; or
- Using the earth conductivity scaling factor  $\beta$  from Table 3 that correlates to the ground conductivity map in Figure 1 or Figure 2. Along with the scaling factor  ~~$\alpha$~~ ,  $\alpha$  (2),  $\beta$  is applied to the reference geoelectric field using ~~the following equation (1)~~ to obtain the regional geoelectric field peak amplitude  $E_{\text{peak}}$  to be used in GMD Vulnerability Assessment. When a ground conductivity model is not available, the planning entity should use ~~the largest~~  $\beta$  factor of ~~adjacent physiographic regions~~ or a technically - justified value.

$$E_{\text{peak}} = 8 \times \alpha \times \beta \text{ (V/km)}$$

The earth models used to calculate Table 3 for the United States were obtained from publicly available ~~magnetotelluric data that is information~~ published on the U. S. Geological Survey website<sup>3</sup>. The models used to calculate Table 3 for Canada were obtained from Natural Resources Canada (NRCan) and reflect the average structure for large regions. ~~NRCan also has developed some models for sub-regions which should be used when available. Because all models in Table 3 are approximations, a planner can substitute a technically justified earth model for its planning area when available. A planner can also use specific earth model(s) with~~

<sup>2</sup> Available at the NERC GMD Task Force project page:  
[http://www.nerc.com/comm/PC/Pages/Geomagnetic-Disturbance-Task-Force-\(GMDTF\)-2013.aspx](http://www.nerc.com/comm/PC/Pages/Geomagnetic-Disturbance-Task-Force-(GMDTF)-2013.aspx)

<sup>3</sup> Available at <http://geomag.usgs.gov/conductivity/>

documented justification and the reference geomagnetic field time series to calculate the  $\beta$  factor(s) as follows:

$$\beta = E/8 \text{_____} (3)$$

where  $E$  is the absolute value of peak geoelectric in V/km obtained from the technically justified earth model and the reference geomagnetic field time series.

For large planning areas that ~~coverspan~~ more than one  $\beta$  scaling factor ~~from Table 3~~, the most conservative (largest) value for  $\beta$  ~~should~~may be used in ~~scaling~~determining the peak geoelectric field to obtain conservative results. Alternatively, a planner could ~~use a tool that is capable of performing~~perform analysis using a non-uniform or piecewise uniform geoelectric field.

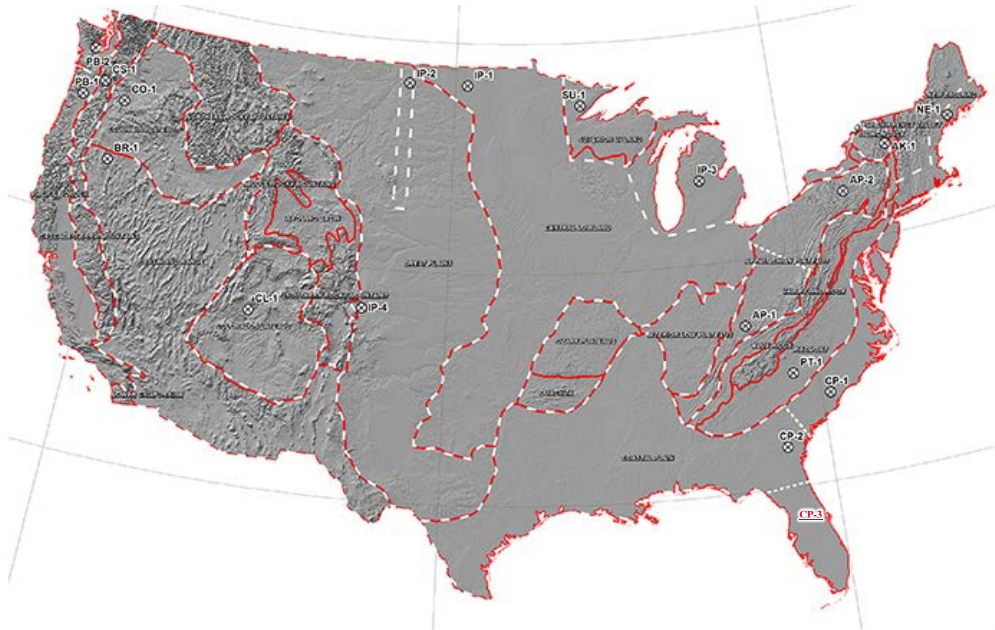


Figure 1: Physiographic Regions of the Continental United States<sup>4</sup>



Figure 2: Physiographic Regions of Canada

<sup>4</sup> Additional map detail is available at the U.S. Geological Survey (<http://geomag.usgs.gov/>)

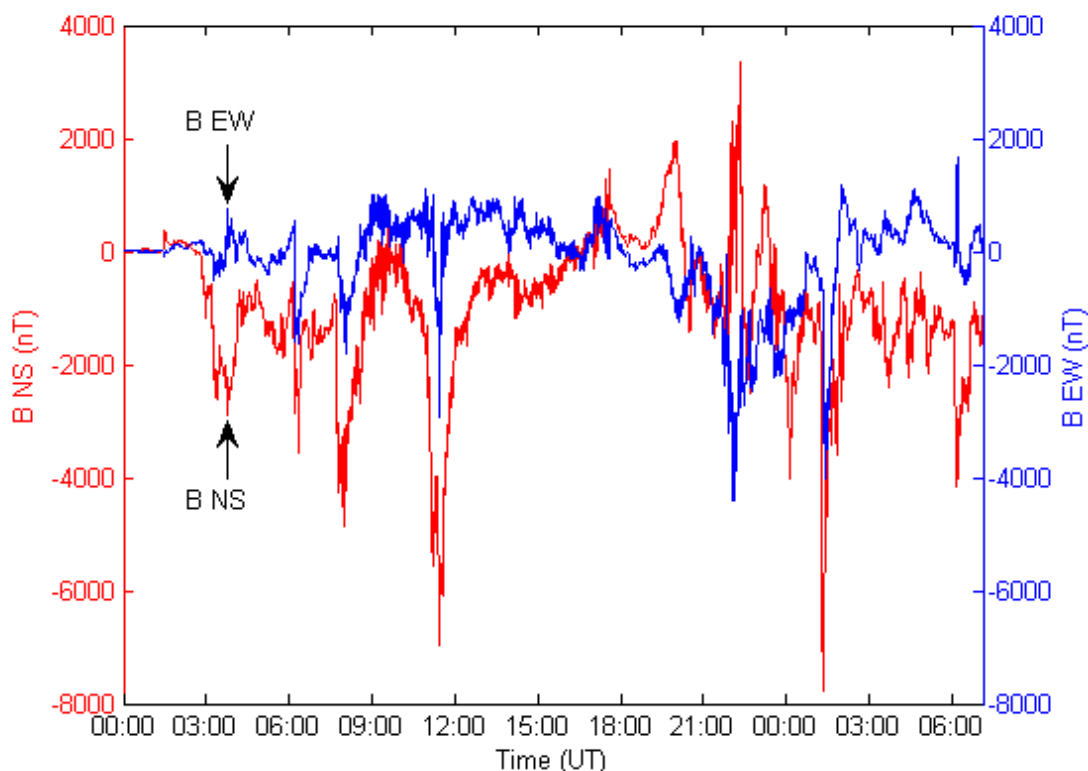
Table 3 Geoelectric Field Scaling Factors	
USGS Earth model	Scaling Factor ( $\beta$ )
AK1A	0.56
AK1B	-0.56
AP1	0.33
AP2	0.82
BR1	0.22
CL1	0.76
CO1	0.27
CP1	0.81
CP2	0.95
<u>CP3</u>	<u>0.94</u>
CS1	0.41
IP1	0.94
IP2	0.28
IP3	0.93
IP4	0.41
NE1	0.81
PB1	0.62
PB2	0.46
PT1	1.17
SL1	0.53
SU1	0.93
BOU	0.28
FBK	0.56
PRU	0.21
BC	0.67
PRAIRIES	0.96
SHIELD	1.0
ATLANTIC	0.79

Table 4: Reference Earth Model (Quebec)	
Layer Thickness (km)	Resistivity ( $\Omega$ -m)
15	20,000
10	200
125	1,000
200	100
$\infty$	3

### Reference Geomagnetic Field Time Series or Waveshape<sup>5</sup>

The geomagnetic field measurement record of the March 13-14 1989 GMD event, measured at NRCan’s Ottawa geomagnetic observatory is the basis for the reference geomagnetic field waveshape to be used to calculate the GIC time series,  $GIC(t)$ , required for transformer thermal impact assessment.

The geomagnetic latitude of the Ottawa geomagnetic observatory is  $55^\circ$ ; therefore, the amplitude of the geomagnetic field measurement data were scaled up to the  $60^\circ$  reference geomagnetic latitude (see Figure 3) such that the resulting peak geoelectric field amplitude computed using the reference earth model was 8 V/km (see Figs. 4 and 5). Sampling rate for the geomagnetic field waveshape is 10 seconds.<sup>6</sup> To use this geoelectric field time series where a different earth model is applicable, it should be scaled with the appropriate conductivity scaling factor  $\beta$ .

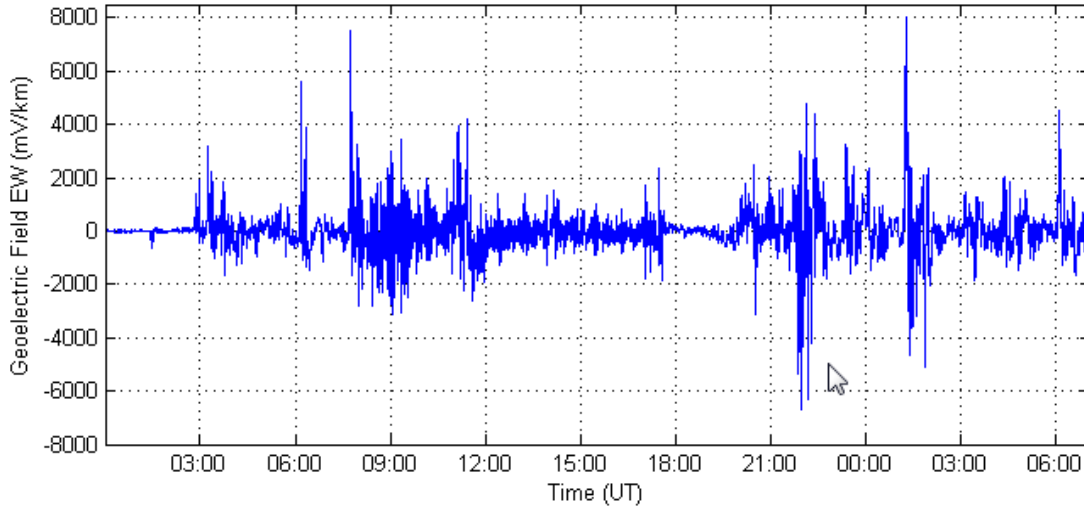


**Figure 3: Benchmark Geomagnetic Field Waveshape. Red  $B_n$  (Northward), Blue  $B_e$  (Eastward)**

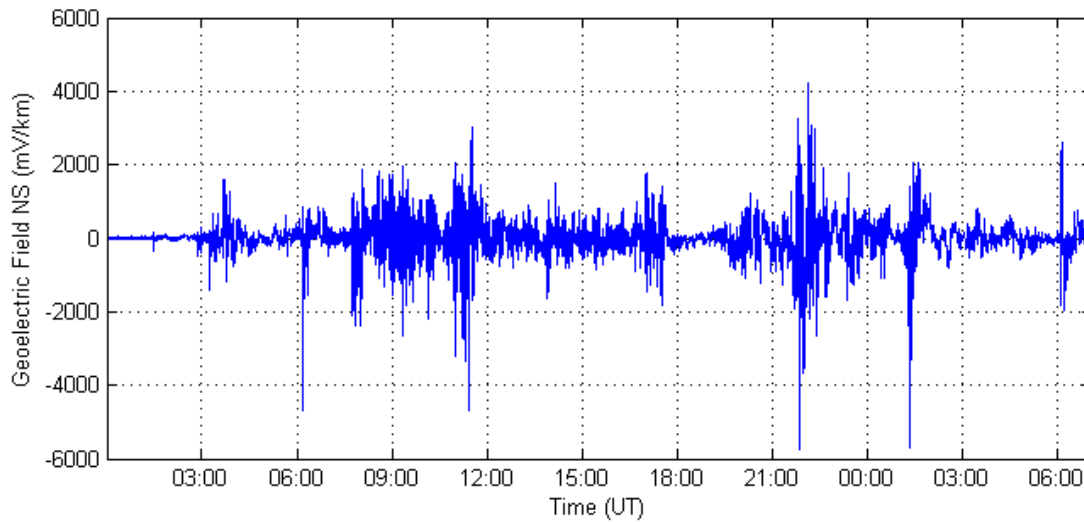
<sup>5</sup> Refer to the Benchmark GMD Event Description for details on the determination of the reference geomagnetic field waveshape: <http://www.nerc.com/pa/Stand/Pages/Project-2013-03-Geomagnetic-Disturbance-Mitigation.aspx>

<sup>6</sup> The data file of the benchmark geomagnetic field waveshape is available on the NERC GMD Task Force project page: [http://www.nerc.com/comm/PC/Pages/Geomagnetic-Disturbance-Task-Force-\(GMDTF\)-2013.aspx](http://www.nerc.com/comm/PC/Pages/Geomagnetic-Disturbance-Task-Force-(GMDTF)-2013.aspx)





**Figure 4: Benchmark Geoelectric Field Waveshape -  $E_E$  (Eastward)**



**Figure 5: Benchmark Geoelectric Field Waveshape –  $E_N$  (Northward)**

**1. Compliance Monitoring Process**

**1.1. Compliance Enforcement Authority**

As defined in the NERC Rules of Procedure, “Compliance Enforcement Authority” means NERC or the Regional Entity in their respective roles of monitoring and enforcing compliance with the NERC Reliability Standards

**1.2. Evidence Retention**

The following evidence retention periods identify the period of time an entity is required to retain specific evidence to demonstrate compliance. For instances where the evidence retention period specified below is shorter than the time since the last audit, the CEA may ask an entity to provide other evidence to show that it was compliant for the full time period since the last audit.

The Planning Coordinator, Transmission Planner, Transmission Owner, and Generator Owner shall keep data or evidence to show compliance as identified below unless directed by its Compliance Enforcement Authority to retain specific evidence for a longer period of time as part of an investigation:

The responsible entities shall retain documentation as evidence for five years.

If a Planning Coordinator, Transmission Planner, Transmission Owner, or Generator Owner is found non-compliant, it shall keep information related to the non-compliance until mitigation is complete and approved or for the time specified above, whichever is longer.

The Compliance Enforcement Authority shall keep the last audit records and all requested and submitted subsequent audit records.

**1.3. Compliance Monitoring and Assessment Processes:**

Compliance Audits

Self-Certifications

Spot Checking

Compliance ~~Violation~~ Investigations

Self-Reporting

Complaints Text

**1.4. Additional Compliance Information**

None

Table of Compliance Elements

R #	Time Horizon	VRF	Violation Severity Levels			
			Lower VSL	Moderate VSL	High VSL	Severe VSL
R1	Long-term Planning	Low	N/A	N/A	N/A	The Planning Coordinator, in conjunction with each of its Transmission Planners, failed to determine and identify individual or joint responsibilities of the Planning Coordinator and each of the Transmission Planners in the Planning Coordinator’s planning area for maintaining models and performing the studies needed to complete GMD Vulnerability Assessment(s).
R2	Long-term Planning	Medium	N/A	N/A	<u>N/A</u> <del>The responsible entity did not maintain either System models or GIC System models of the responsible entity’s planning area for performing the studies needed to complete GMD Vulnerability Assessment(s).</del>	The responsible entity did not maintain <b>both</b> System models and <del>geomagnetically-induced current (GIC)</del> System models of the responsible entity’s planning area for performing the studies needed to complete

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						GMD Vulnerability Assessment(s).
<b>R3R4</b>	Long-term Planning	Medium	N/A	N/A	N/A	The responsible entity did not have criteria for acceptable System steady state voltage <del>limits- performance</del> for its System during the benchmark GMD event described in Attachment 1 as required.
<b>R4R3</b>	Long-term Planning	High	The responsible entity completed a GMD Vulnerability Assessment but it was more than 60 calendar months and less than or equal to 64 calendar months since the last GMD Vulnerability Assessment.	The responsible entity's completed GMD Vulnerability Assessment failed to satisfy one of elements listed in Requirement R4 Parts 4.1 through 4.3;  OR The responsible entity completed a GMD Vulnerability Assessment but it was more than 64 calendar months and less than or equal to 68 calendar months since the last GMD Vulnerability Assessment.	The responsible entity's completed GMD Vulnerability Assessment failed to satisfy two of the elements listed in Requirement R4 Parts 4.1 through 4.3;  OR The responsible entity completed a GMD Vulnerability Assessment but it was more than 68 calendar months and less than or equal to 72 calendar months since the last GMD Vulnerability Assessment.	The responsible entity's completed GMD Vulnerability Assessment failed to satisfy three of the elements listed in Requirement R4 Parts 4.1 through 4.3;  OR The responsible entity completed a GMD Vulnerability Assessment but it was more than 72 calendar months since the last GMD Vulnerability Assessment;  OR The responsible entity does not have a completed GMD

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						Vulnerability Assessment.
R5	Long-term Planning	Medium	N/A	N/A	The responsible entity failed to provide one of the elements listed in Requirement R5 parts 5.1 to 5.2 to each Transmission Owner and Generator Owner in the planning area that owns an applicable power transformer.	The responsible entity failed to provide two of the elements listed in Requirement R5 parts 5.1 to 5.2 to each Transmission Owner and Generator Owner in the planning area that owns an applicable power transformer; OR The responsible entity did not provide <del>geomagnetically-induced current (GIC)</del> GIC flow information to be used for the transformer thermal impact assessment specified in Requirement R6 to each Transmission Owner and Generator Owner in the planning area that owns an applicable power transformer.
R6	Long-term Planning	<del>High</del> Medium	The responsible entity failed to conduct <del>an</del> <u>assessment of a</u> thermal impact <u>assessment</u> for 5% or less <u>or one</u> of its solely owned and jointly owned applicable power	The responsible entity failed to conduct <del>an</del> <u>assessment of a</u> thermal impact <u>assessment</u> for more than 5% up to (and including) 10% <u>or two</u> of its solely owned and jointly owned	The responsible entity failed to conduct <del>an</del> <u>assessment of a</u> thermal impact <u>assessment</u> for more than 10% up to (and including) 15% <u>or three</u> of its solely owned and jointly	The responsible entity failed to conduct <del>an</del> <u>assessment of a</u> thermal impact <u>assessment</u> for more <del>than 15%</del> <u>than 15%</u> <u>or more than three</u> of its solely owned and jointly owned

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		<p>transformers (<u>whichever is greater</u>) where the maximum effective <del>geomagnetically-induced current (GIC)</del> value provided in Requirement R5 part 5.1 is 15 <del>Amperes</del><u>A</u> or greater per phase; OR The responsible entity conducted <del>an assessment of a</del> thermal impact <del>of assessment for</del> its solely owned and jointly owned applicable power transformers where the maximum effective <del>geomagnetically-induced current (GIC)</del> value provided in Requirement R5 part 5.1 is 15 <del>Amperes</del><u>A</u> or greater per phase but did so more than <del>1224</del> <u>1326</u> calendar months and less than or equal to <del>1326</del> <u>1428</u> calendar months of receiving GIC flow information specified in Requirement R5; OR The responsible entity failed to include one of</p>	<p>applicable power transformers (<u>whichever is greater</u>) where the maximum effective <del>geomagnetically-induced current (GIC)</del> value provided in Requirement R5 part 5.1 is 15 <del>Amperes</del><u>A</u> or greater per phase; OR The responsible entity conducted <del>an assessment of a</del> thermal impact <del>of assessment for</del> its solely owned and jointly owned applicable power transformers where the maximum effective <del>geomagnetically-induced current (GIC)</del> value provided in Requirement R5 part 5.1 is 15 <del>Amperes</del><u>A</u> or greater per phase but did so more than <del>1326</del> <u>1428</u> calendar months and less than or equal to <del>1428</del> <u>1530</u> calendar months of receiving GIC flow information specified in Requirement R5; OR</p>	<p>owned applicable power transformers (<u>whichever is greater</u>) where the maximum effective <del>geomagnetically-induced current (GIC)</del> value provided in Requirement R5 part 5.1 is 15 <del>Amperes</del><u>A</u> or greater per phase; OR The responsible entity conducted <del>an assessment of a</del> thermal impact <del>of assessment for</del> its solely owned and jointly owned applicable power transformers where the maximum effective <del>geomagnetically-induced current (GIC)</del> value provided in Requirement R5 part 5.1 is 15 <del>Amperes</del><u>A</u> or greater per phase but did so more than <del>1428</del> <u>1530</u> calendar months and less than or equal to <del>1530</del> <u>1632</u> calendar months of receiving GIC flow information specified in Requirement R5; OR</p>	<p>applicable power transformers (<u>whichever is greater</u>) where the maximum effective <del>geomagnetically-induced current (GIC)</del> value provided in Requirement R5 part 5.1 is 15 <del>Amperes</del><u>A</u> or greater per phase; OR The responsible entity conducted <del>an assessment of a</del> thermal impact <del>of assessment for</del> its solely owned and jointly owned applicable power transformers where the maximum effective <del>geomagnetically-induced current (GIC)</del> value provided in Requirement R5 part 5.1 is 15 <del>Amperes</del><u>A</u> or greater per phase but did so more than <del>1530</del> <u>1632</u> calendar months of receiving GIC flow information specified in Requirement R5; OR The responsible entity failed to include four of the required elements as</p>
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			the required elements as listed in Requirement R6 parts 6.1 through 6.4.	The responsible entity failed to include two of the required elements as listed in Requirement R6 parts 6.1 through 6.4.	The responsible entity failed to include three of the required elements as listed in Requirement R6 parts 6.1 through 6.4.	listed in Requirement R6 parts 6.1 through 6.4.
<b>R7</b>	Long-term Planning	High	N/A	The responsible entity's Corrective Action Plan failed to comply with one of the elements in Requirement R7 parts 7.1 <del>and</del> through 7.3.	The responsible entity's Corrective Action Plan failed to comply with two of the elements in Requirement R7 parts 7.1 <del>and</del> through 7.3.	The responsible entity's Corrective Action Plan failed to comply with <u>all</u> three of the elements in Requirement R7 parts 7.1 <del>and</del> through 7.3; OR The responsible entity did not have a Corrective Action Plan as required by Requirement R7.

**C. Regional Variances**

None.

**D. Interpretations**

None.

**E. Associated Documents**

None.



## Guidelines and Technical Basis

### Benchmark GMD Event (Attachment 1)

The benchmark GMD event defines the geoelectric field values used to compute GIC flows that are needed to conduct a GMD Vulnerability Assessment. A white paper that includes the event description, analysis, and example calculations is available on the Project 2013-03 Geomagnetic Disturbance Mitigation project page:

<http://www.nerc.com/pa/Stand/Pages/Project-2013-03-Geomagnetic-Disturbance-Mitigation.aspx>

### Requirement R2

A GMD Vulnerability Assessment requires a GIC System model, which is a dc representation of the System, to calculate GIC flow. In a GMD Vulnerability Assessment, GIC simulations are used to determine transformer Reactive Power absorption and transformer thermal response. Details for developing the GIC System model are provided in the NERC GMD Task Force guide: *Application Guide for Computing Geomagnetically-Induced Current in the Bulk Power System*. The guide is available at:

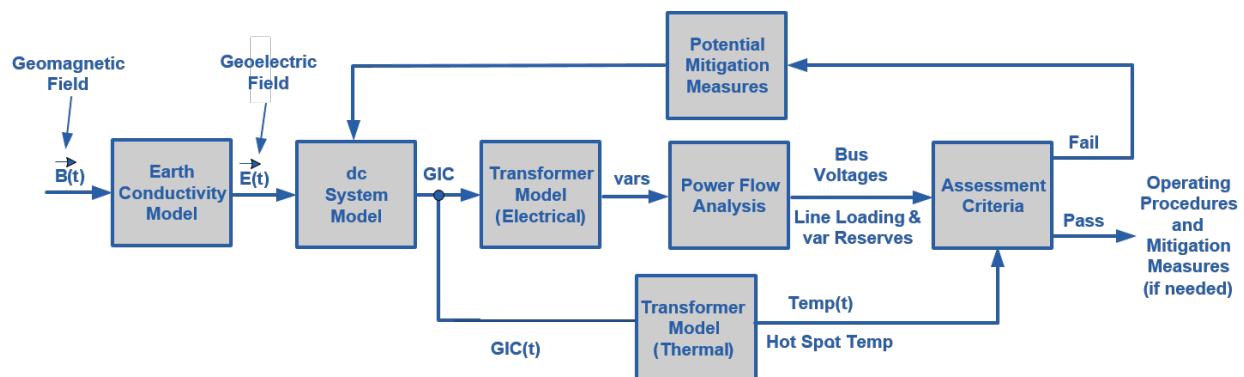
[http://www.nerc.com/comm/PC/Geomagnetic%20Disturbance%20Task%20Force%20GMDTF%202013/GIC%20Application%20Guide%202013\\_approved.pdf](http://www.nerc.com/comm/PC/Geomagnetic%20Disturbance%20Task%20Force%20GMDTF%202013/GIC%20Application%20Guide%202013_approved.pdf)

### Requirement R3/R4

The *GMD Planning Guide* developed by the NERC GMD Task Force provides technical information on GMD-specific considerations for planning studies. It is available at:

[http://www.nerc.com/comm/PC/Geomagnetic%20Disturbance%20Task%20Force%20GMDTF%202013/GMD%20Planning%20Guide\\_approved.pdf](http://www.nerc.com/comm/PC/Geomagnetic%20Disturbance%20Task%20Force%20GMDTF%202013/GMD%20Planning%20Guide_approved.pdf)

The diagram below provides an overall view of the GMD Vulnerability Assessment process:



### Requirement R5

The transformer thermal impact assessment specified in Requirement R6 is based on GIC time series information for the Benchmark GMD Event. This GIC information is determined by the planning entity through simulation of the GIC system model and must be provided to the entity responsible for conducting the thermal impact assessment.

## Application Guidelines

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The maximum effective GIC value provided in part 5.1 is used to screen the transformer fleet such that only those transformers that experience an effective GIC flow of 15A or greater are evaluated.

The effective GIC time series, GIC(t), provided in part 5.2 is used to conduct the transformer thermal impact assessment (see white paper for details).

The peak GIC value of 15 amps per phase has been shown through thermal modeling to be a conservative threshold below which the risk of exceeding known temperature limits established by technical organizations is low. Additional information is ~~available~~ in the ~~transformer thermal impact assessment white paper~~: [following section](#).

### Requirement R6

The thermal impact assessment of a power transformer may be based on manufacturer-provided GIC capability curves, thermal response simulation, or other technically justified means. A process for conducting the assessment is presented in the [Transformer Thermal Impact Assessment](#) white paper posted on the project page.

<http://www.nerc.com/pa/Stand/Pages/Project-2013-03-Geomagnetic-Disturbance-Mitigation.aspx>

[Transformers are exempt from the thermal impact assessment requirement if the maximum effective GIC in the transformer is less than 15 Amperes per phase as determined by a GIC analysis of the System. Justification for this screening criterion is provided in the Screening Criterion for Transformer Thermal Impact Assessment white paper posted on the project page. A documented design specification exceeding the maximum effective GIC value provided in Requirement R5 Part 5.2 is also a justifiable threshold criteria that exempts a transformer from Requirement R6.](#)

The threshold criteria and transformer thermal impact must be evaluated on the basis of effective GIC. Refer to the white paper~~s~~ for additional information.

### Requirement R7

Technical considerations for GMD mitigation planning are available in Chapter 5 of the *GMD Planning Guide*. Additional information is available in the *2012 Special Reliability Assessment Interim Report: Effects of Geomagnetic Disturbances on the Bulk-Power System*:

<http://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/2012GMD.pdf>