

# NERC

NORTH AMERICAN ELECTRIC  
RELIABILITY CORPORATION



U.S. DEPARTMENT OF  
**ENERGY**

Infrastructure Security &  
Energy Restoration

# Protecting the Grid Against Space Weather

Mark Olson, NERC, Senior Developer, Reliability Standards  
John Ostrich, DOE, Program Manager, Risk and Hazards  
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RELIABILITY | ACCOUNTABILITY

*Prepare Respond Adapt.*



- Sunspots, Flares, **Coronal Mass Ejections (CMEs)**
- 11-Year Solar Cycle
- Geomagnetic Storms (GMDs) and Geomagnetically-Induced Currents (GICs)
- Frequency, Magnitude, Duration
- Factors that Affect Impacts to Power Systems



- NOAA, NASA, USAF:  
Sunspots, flares, CMEs  
- SWPC reports



- USGS & Others:  
Changes in magnetic fields  
-Magnetic field changes



- DOE, EPRI, Industry:  
GICs  
-Sunburst reports

- System Operators

Monitoring system, all of the above, and taking mitigation measures  
- Actions taken prior to and during GMDs

GICs can affect the reliable operation of the electric grid

Voltage Collapse resulting from reactive power losses in high voltage transformers and equipment tripping

Equipment Damage from transformer heating

Power system design, location, and GMD event characteristics affect vulnerability

March 1989 blackout in  
Quebec due to tripping of  
voltage support equipment

Damage to generator step-  
up (GSU) transformers  
Salem, NJ (1989)

## March 13, 1989 Geomagnetic Disturbance

### Hydro-Québec Blackout

#### Summary

Just before 0245 EST on March 13, 1989, an exceptionally intense magnetic storm caused the shutdown of seven static compensators on the La Grande network. This equipment is essential for control of the Hydro-Québec grid and its loss caused voltage to drop, frequency to increase, and the resultant instability caused the tripping of the La Grande transmission lines.

The rest of the Hydro-Québec system, supplied by the Manicouagan and Churchill Falls complexes, collapsed within seconds of the loss of the 0.500 MW of generation from the La Grande

automatic rejection of the generation of two La Grande 4 generating units.

Three other 735 kV lines of the La Grande transmission network tripped next, and faults occurred in two single-phase units of two La Grande 4 transformers and in the surge arrester of a shunt reactor at Nemiscau substation. The remaining line of the La Grande transmission network tripped next. Thus, the La Grande network was separated completely from the Hydro-Québec transmission network.

With separation of the La Grande network, the frequency fell rapidly. In response, automatic load-



GSU Transformer from Salem

## Mitigation strategies vary depending on system needs

**Operating Procedures** can prevent voltage collapse by posturing the system for resilience

**Monitoring** informs operator actions



**Equipment upgrades** can improve grid resilience

Installing **GIC reduction devices** in transformers can protect critical system components

FERC Order No. 779 (2013) directed NERC to develop  
GMD Reliability Standards

Operating Procedures: EOP-010 mandatory since April 2015

Vulnerability Assessments: TPL-007 approved September  
2017

Both apply to 200 kV and above Bulk Electric System

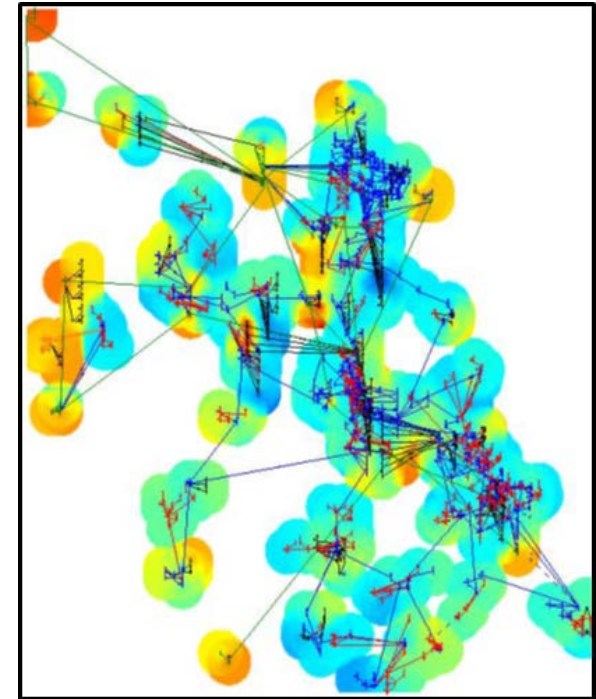


TPL-007-1 requires assessments and corrective actions to address risks from 1-in-100 year GMD event

Applies to registered NERC entities:

- Planning Coordinators and Transmission Planners
- Transmission Owners
- Generator Owners

Implementation over five years beginning in July 2017



Voltage Contour in a GIC Study



- Current Protection
  - GIC blockers on transformer neutrals
  - Series compensation on transmission lines
  - Transformers with high GIC withstands
  - Protective device settings to prevent premature trips
- Potential Protection Measures
  - Transformers with higher GIC withstands
  - Configuring and building systems with:
    - less reliance on high voltage equipment  
and/or long distance power lines
- Cost for Protection

- Data Collection
  - Sunburst – GIC monitors
  - Variometers – Magnetic field changes
  - GMD Monitoring Plan
- Assessment, Modeling, Testing
  - Susceptibility of Eastern Grid
  - Assessment of GMD benchmark event
  - Assessment and testing of transformers
- Mitigation and Protection
  - Plan for pilot program to deploy mitigation or protection devices on grid

Support implementation of GMD Reliability Standards

Develop TPL-007 revisions to address FERC directives

- Apply enhancements to the benchmark GMD event
- Establish deadlines for completing mitigation
- Require entities to obtain GIC data for validation and awareness

Submit a work plan to FERC for additional research





# Questions and Answers