NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Geomagnetic Disturbances

Reducing Risk to the North American Electric Grid

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Space Weather Operations and Research Infrastructure Workshop

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RELIABILITY | RESILIENCE | SECURITY

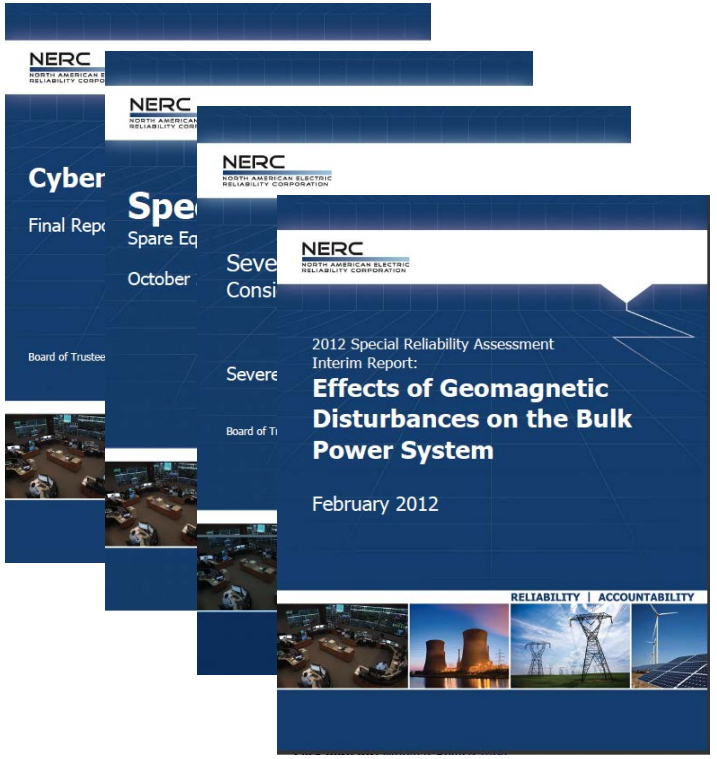



About NERC: Mission

- To assure the effective and efficient reduction of risks to the reliability and security of the North American bulk power system
  - Develops and enforces reliability standards
  - Annually assesses seasonal and long-term reliability
  - Monitors the transmission system
  - Educates, trains, and certifies industry personnel
- NERC is subject to oversight from the Federal Energy Regulatory Commission (FERC) and authorities in Canada

Taking Action on Extreme Risks

- The U.S. Department of Energy-NERC report on *High-Impact, Low- Frequency (HILF) Event Risk* (2010) characterized rare risk scenarios with the potential to disrupt reliable operations
  - Cyber Attack
  - Coordinated Physical Attack
  - Geomagnetic Disturbances (GMD)
- Severe GMD Event may cause
  - Voltage Collapse (Blackout)
  - Damage to transmission system power transformers
- NERC 2012 GMD Report: Widespread transformer damage is unlikely

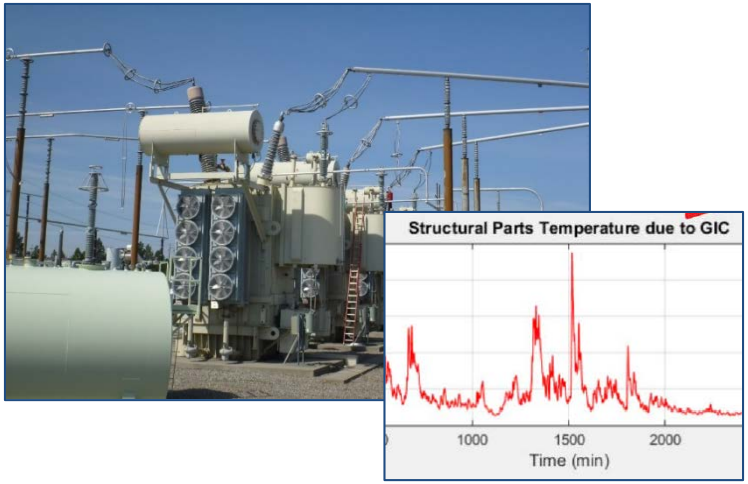


GMD Partnerships

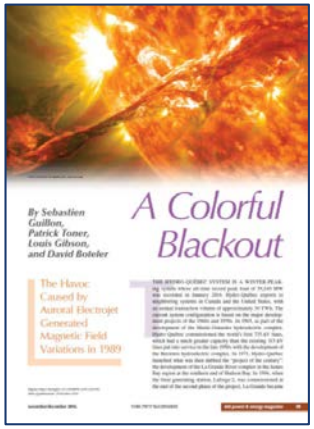
- NERC works with diverse stakeholders throughout North America to carry out its vision
  - Department of Energy and U.S. National Labs
  - Electric Power Research Institute (EPRI)
  - North American Transmission Forum (NATF)
  - NASA, Canadian Space Agency
  - U.S. Geological Survey (USGS) and Natural Resources Canada
  - U.S. Space Weather Prediction Center (SWPC)
  - Utilities from all regions in North America
- Focused on improving tools for electric power industry planners, owners, and operators to manage GMD impacts

Severe GMD Events Can Impact the Grid

- Changing magnetic field induces a quasi-dc current in long transmission lines and flows through equipment (transformers) to ground



- GIC can cause transformers to consume reactive power, produce harmonic currents, and experience hot-spot heating

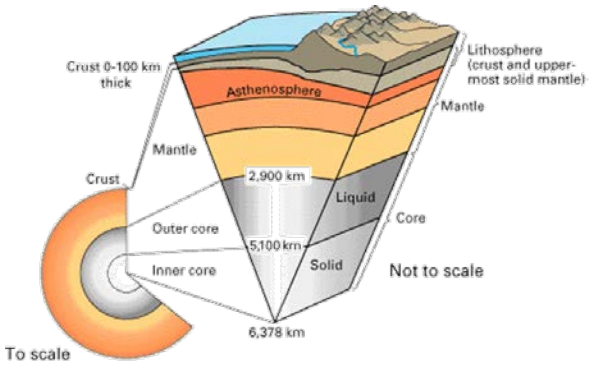


- Reduced reactive power and harmonic related tripping of voltage support devices can lead to system blackout

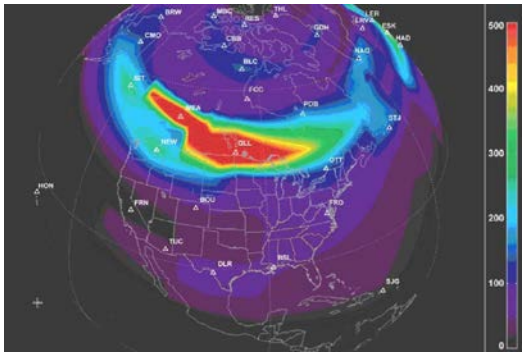
NERC Conclusions from 2012 Task Force Report

Major Conclusion	• Most likely result from a severe GMD event in North America is elevated risk of voltage instability or collapse
Major Conclusion	• System operators and planners need analytic tools and information sharing to understand impacts and develop mitigation strategies
Major Conclusion	• Some transformers may be damaged or experience reduced life, depending on design and current health

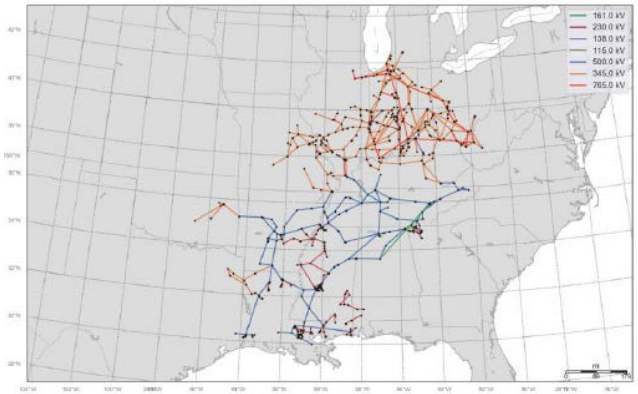
Factors Influencing GMD Impacts



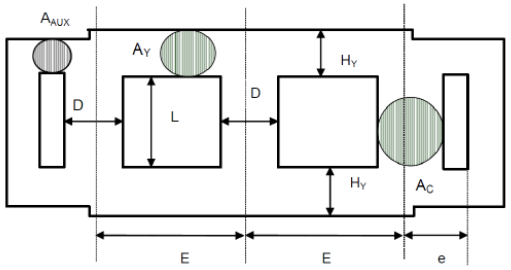
Deep Earth Structure



Location (Magnetic Latitude)



System Topology and Orientation to Magnetic Fields



Transformer and Equipment Design and Condition

Risk Varies Across the North American Bulk Power System

Vision for Mitigating GMD Impacts

- NERC has multiple complementing lines of effort to reduce risks:

GMD Reliability Standards

- NERC Reliability Standards are mandatory and enforceable in the U.S. and Canadian Provinces
- In 2013, FERC Order No. 779 directed NERC to develop GMD Reliability Standards in two stages
  - GMD Operating Procedure requirements (EOP-010-1) became effective in April 2015
  - GMD Vulnerability Assessment requirements (TPL-007) are being implemented in a phased approach through 2024

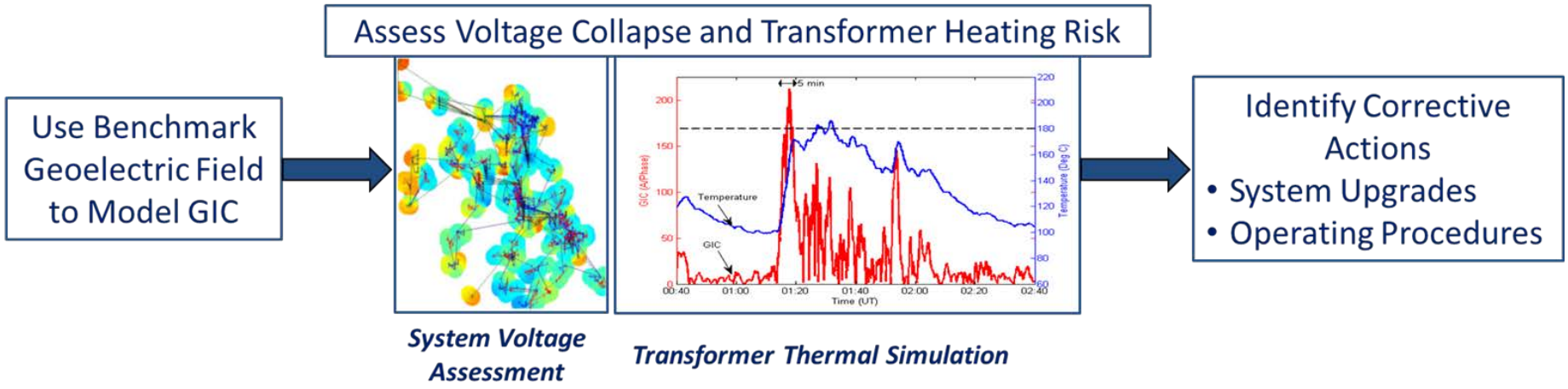
EOP-010-1: Operating Procedures

- Space weather alerts prompt operators to posture the power system, increase awareness of voltage and equipment conditions, and make real-time adjustments
  - GIC monitoring enhances the effectiveness
- Grid operators receive alerts from NOAA Space Weather Prediction Center (SWPC) and Space Weather Canada

System Operator at Electric Reliability Council Texas

TPL-007: GMD Assessments

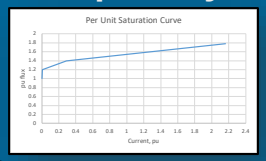
- Grid planners and asset owners periodically assess and mitigate risks of voltage collapse and equipment damage from a 100-year Benchmark GMD Event



NERC GMD Research Plan Objectives

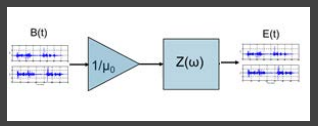
Improved Earth Conductivity Models

Improved Harmonic Analysis Capability

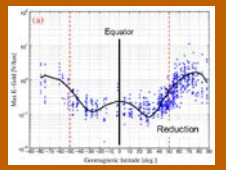


- Two-year research project with EPRI is concluding in 2020
- Further advance GIC modeling and system impact assessment
- Includes earth-space modeling contributions from national labs and NASA

Geoelectric Field Evaluation

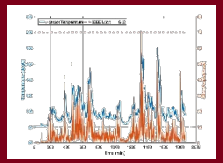


Latitude Scaling



Harmonic Impacts

Transformer Thermal Impacts



Field Spatial Structure

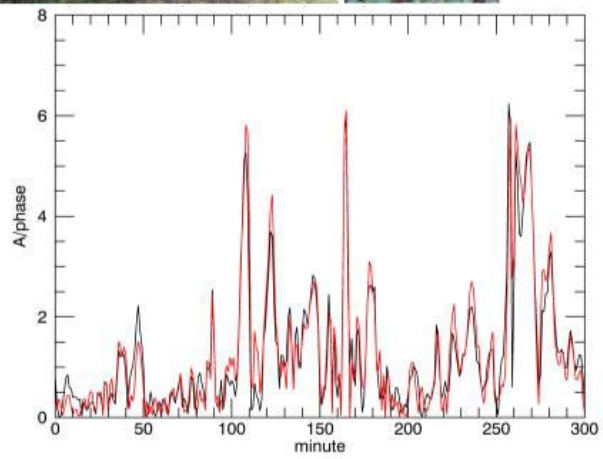
$$E_{peak} = 8 \times \alpha \times \beta \text{ (V/km)}$$

α= Geomagnetic Latitude Scaling Factors

β= Conductivity Scaling Factor

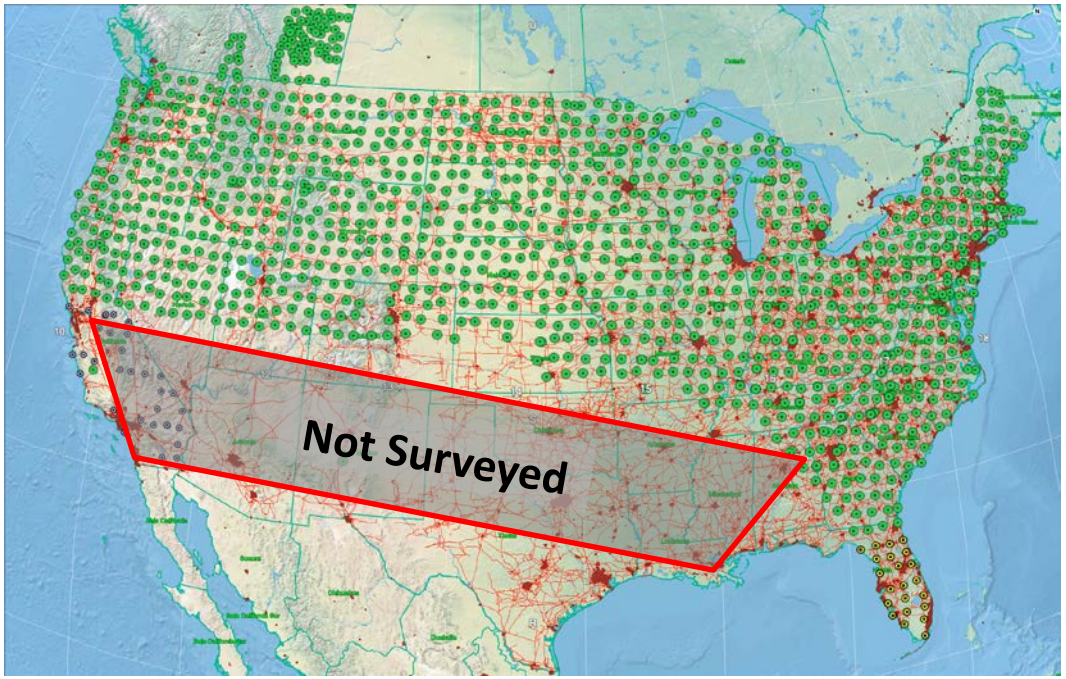
Data Collection

- NERC will begin collecting GIC and magnetic field data from monitors at U.S. utilities in 2020
- Collecting for all strong GMD events (G3 / K_P = 7 and above)
- Data is used to improve the accuracy of GMD assessments
  - Update earth conductivity models
  - Validate power system GIC models



Electricity Industry Needs

- Magnetotelluric (MT) surveying of the continental U.S. can inform earth models to improve the accuracy of GMD assessments

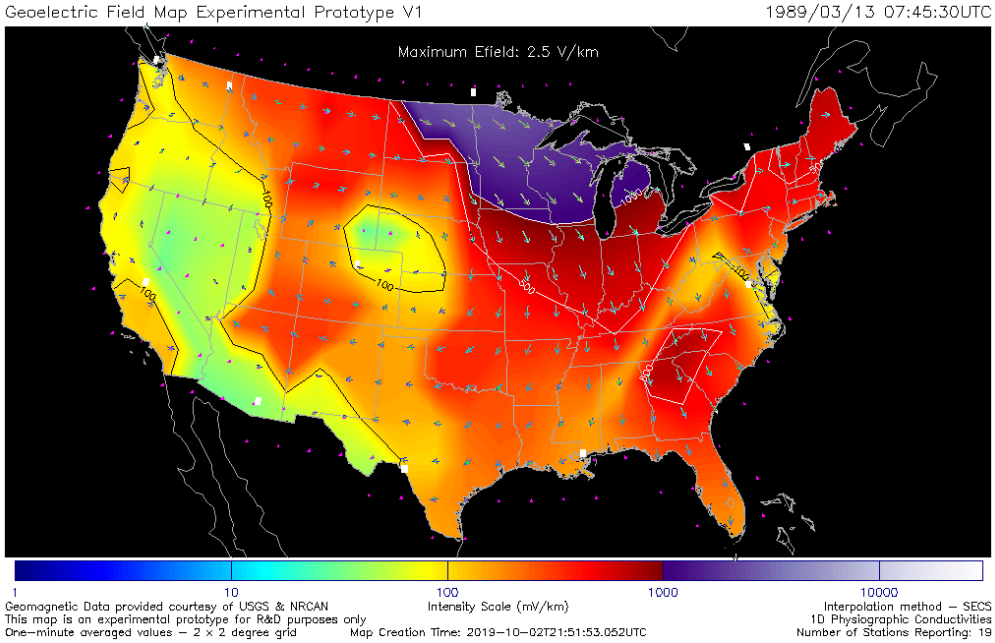


U.S. MT Surveying Conducted under National Science Foundation Grant, Continuing with NASA and USGS support

- EPRI used available MT data to refine earth conductivity models used by industry as part of NERC's GMD Research Program

Electricity Industry Needs

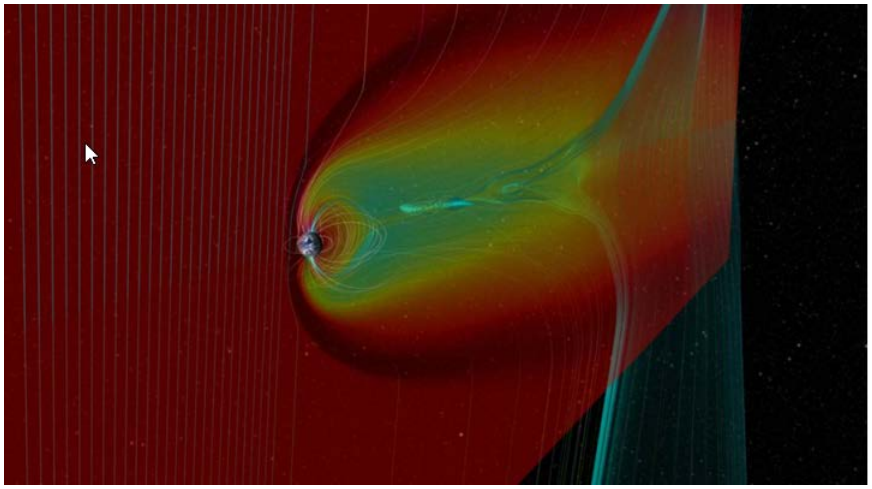
- Enhanced warning and forecasting products can improve the effectiveness of grid operator response to severe GMD events



- This geoelectric field map developed by SWPC, USGS, and NASA informs to grid operators of expected area GMD conditions

Electricity Industry Needs

- Advances in space weather modeling and expanded data sets can help understand the geoelectric fields that drive GIC in the power grid
  - Helps overcome the limited observation data for rare extreme GMD events
- Approach has been used by EPRI and research collaborators at NASA and DoE national labs to better understand extreme GMD event characteristics



Example of MHD-based global space weather modeling output, NASA

Going Forward

- Electricity is vital to society – high Impact / Low Frequency events like severe GMD require special attention
- NERC and the industry are responding with engineering-based system analysis and effective operating mitigations and hardening
- Collaborative partnerships among electricity sector and space weather research communities continue to advance the state-of-the-art in GMD risk mitigation

Questions and Answers