Agenda
Geomagnetic Disturbance Task Force (GMDTF)

June 13, 2018 | 8:30 a.m. – 4:00 p.m. eastern

EPRI Office
Building 3, Room 741 C&F
1300 West W.T Harris Boulevard
Charlotte, NC 28262

Join Webex Meeting
Access Code: 738 370 131
Dial-in: 1-415-655-0002 (US Toll); 1-416-915-8942 (Canada Toll)

Introduction and Chair's Remarks

NERC Antitrust Compliance Guidelines and Public Announcement

Agenda Items

1. **NERC Update on GMD Activities*** – NERC Staff
2. **Space Weather Policy Update**
    a. U.S. Department of Energy Initiatives – John Ostrich, U.S. DoE
3. **Space Weather Prediction Center (SWPC) Update*** – Chris Balch, NOAA SWPC
4. **Panel Discussion: TPL-007-1 Implementation and Preliminary Results***
    a. Ian Grant – Tennessee Valley Authority (TVA)
    b. Justin Michlig – Midcontinent Independent System Operator (MISO)
    c. Rui Sun – Dominion
    d. Michael Juricek (ERCOT Planning GMD Task Force) – Oncor Electric Delivery
5. **Panel Discussion: Considering GMD-related Harmonics in GMD Vulnerability Assessments**
    a. EPRI Recommended Guidelines for Assessing GMD-related Harmonics – Bob Arritt, EPRI
    b. Harmonic Impacts to Protective Relaying - Karl Zimmerman, Principal Engineer, SEL
6. **American Transmission Company, LLC, Experience with Geomagnetically-Induced Current Blocking Device** – David Wojtczak, ATC LLC
7. **EPRI GMD Supplemental Project Status Update** – Bob Arritt, EPRI Project Lead, EPRI and NERC Staff

8. **Research Community Updates**
    a. Earthscope and NSF SMART Grid Project Update – Adam Schultz, Oregon State University
    b. U.S. Geological Survey Update – Jeffrey Love, USGS, and Greg Lucas, USGS
9. **NERC Rules of Procedure Section 1600 Data Request Update and Next Steps*** – NERC Staff
10. **Participant Roundtable**
11. **Wrap up**

NERC
NORTH AMERICAN ELECTRIC
RELIABILITY CORPORATION

NERC GMD Update

Mark Olson, Senior Engineer
GMD Task Force Meeting
June 13, 2018

RELIABILITY | ACCOUNTABILITY

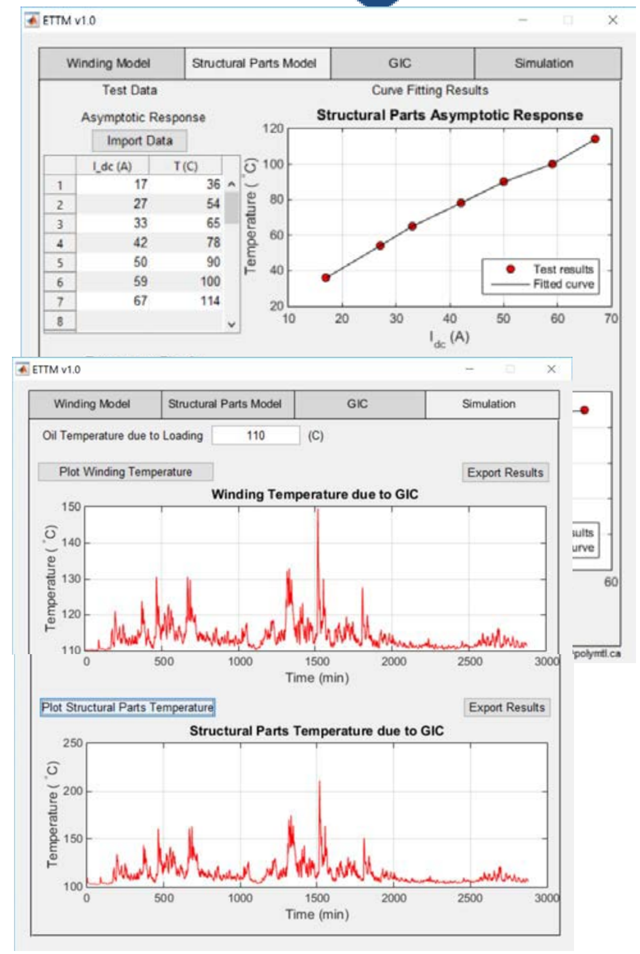



Significant Updates

- FERC issued Notice of NERC GMD Research Plan filing (RM 15-11-2)
  - Public comment April 20 – May 21, 2018
  - Commenters emphasized need to validate results
- FERC issued Notice of Proposed Rulemaking (NOPR) on proposed TPL-007-2
- NERC Standards Committee review of Standards Authorization Request (SAR) for Canada-specific variance for TPL-007-2
- NERC Rules of Procedure Section 1600 Data Request for GMD Data Progressing for Approval

Transformer Thermal Assessment Tool

- EPRI developed an open-source tool for transformer thermal assessments
  - Transmission Owners and Generator Owners can use to meet TPL-007 requirements
  - Use default transformer heating models or user-supplied models
- Reviewed during January GMDTF meeting and beta tested by GMDTF participants
- In process for release through EPRI.com (free of charge)



TPL-007-2 NOPR

- FERC NOPR issued on May 17 proposes to approve TPL-007-2 and direct NERC to develop modifications requiring Corrective Action Plans (CAP) to address supplemental GMD event
  - Proposed TPL-007-2 requires entities to consider mitigation for the supplemental GMD event but does not require CAP (Requirement R8 Part 8.3)
- NOPR also seeks comment on a proposed directive that would require entities to obtain NERC approval when CAP deadlines for GMD Vulnerability Assessment cannot be met
  - Proposed TPL-007-2 requires entities to implement CAPs for the benchmark GMD Event and complete actions by prescribed deadlines, but deadlines can be extended by entities (Requirement R7)
- FERC established 60 day comment period **(ends July 23, 2018)**

Canadian Revisions SAR

- Canadian Electricity Association (CEA) members submitted a SAR for developing Canadian-entity specific revisions to TPL-007-2
- Changes to be developed in an approved standards project:
  - Alternate benchmark and supplemental GMD events for Canadian entities
  - Corrective Action Plan (CAP) requirements that recognize Canada regulatory process
- SAR was posted for stakeholder comment March 30 – April 30, 2018 (Project 2018-01)

TPL-007-1 Implementation

January 1, 2017*

July 2017

- R1
- Identify Responsibilities

July 2018

- R2
- System Models

January 2019

- R5
- GIC Flow Information

January 2021

- R6
- Thermal Assessment

January 2022

- R3, R4, and R7
- GMD Assessment
- Corrective Action Plan

**January 1, 2017 is the first day of the calendar quarter after Order No. 830 became effective. For more info see the* *Implementation Plan* *posted on the project page.*

GMD Data Request Status

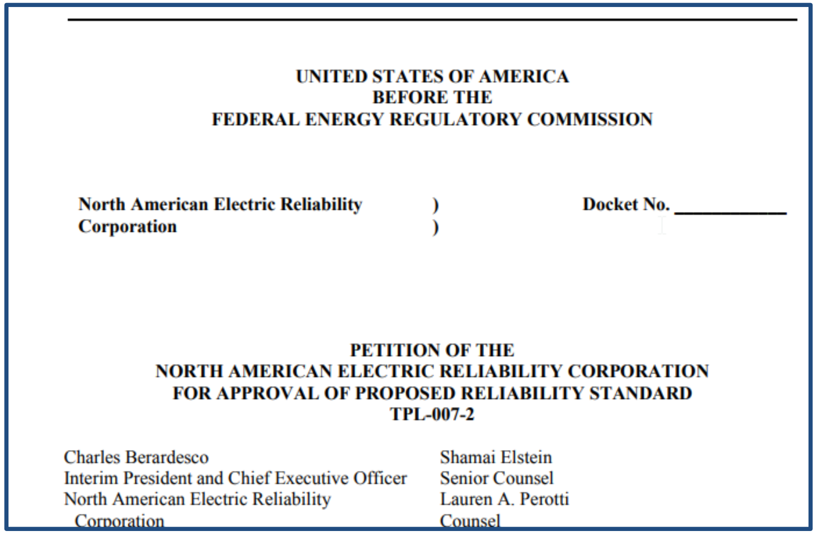
- PC endorsed GMD Data Request on June 6, 2018
- Next steps pending PC endorsement of the GMD Data Request
  - August 2018 | Request NERC Board Approval
  - Q3 2018 | GMDTF and NERC Staff begin developing a Data Reporting Instructions (DRI)
- NERC staff will continue development of information technology application for collecting GMD Data

Questions and Answers

Back-up Slides

Revisions to TPL-007

- TPL-007-2 filed January 22, 2018
  - Includes Supplemental GMD Event Description for locally-enhanced GMD event assessment
  - Establishes deadlines for Corrective Action Plans (CAPs) and mitigating actions
  - Requires processes of obtaining GIC and magnetometer data
- Implementation of TPL-007-1 continues while revised standard is pending approval


UNITED STATES OF AMERICA
BEFORE THE
FEDERAL ENERGY REGULATORY COMMISSION

North American Electric Reliability Corporation))   Docket No. __________

PETITION OF THE
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION
FOR APPROVAL OF PROPOSED RELIABILITY STANDARD
TPL-007-2

Charles Berardesco
Interim President and Chief Executive Officer
North American Electric Reliability Corporation

Shamai Elstein
Senior Counsel
Lauren A. Perotti
Counsel

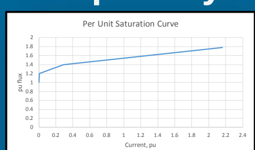
FERC Docket RM 18-8

NERC GMD Research Plan Objectives

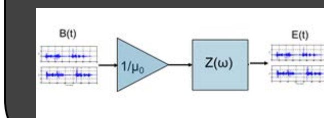
- Work is underway on all Order No. 830 research objectives
- Support TPL-007 standard
- EPRI will publish technical reports for each objective

Improved Earth Conductivity Models

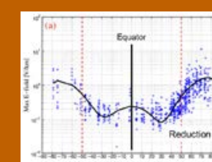
Improved Harmonic Analysis Capability



Geoelectric Field Evaluation

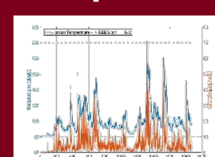


Latitude Scaling Factor



Harmonic Impacts

Transformer Thermal Impacts



Spatial Averaging

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

α= Geomagnetic Latitude Scaling Factors

β= Conductivity Scaling Factor

U.S. DEPARTMENT OF
ENERGY

Infrastructure Security
& Energy Restoration

Prepare. Respond. Adapt.

GMD Monitoring and Mitigation

John Ostrich

Office of Cybersecurity, Energy Security, and Emergency Response

U.S. Department of Energy

June 13, 2018

GMD MONITORING APPROACH: Requirement

NATIONAL SPACE WEATHER ACTION PLAN

4.2 Develop a Real-Time Infrastructure Assessment and Reporting Capability The following actions will enable and increase capacity for real-time monitoring of the electric power system during space-weather events:

4.2.1 DOE, in coordination with DHS, DOC, and stakeholders in the energy sector, will develop plans to provide monitoring and data collection systems. The plans will inform a systemwide, real-time view of geomagnetically induced currents (GICs) at the regional level and, to the extent possible, display the status of power generation, transmission, and distribution systems during geomagnetic storms. Deliverable: Complete plan for national GIC and grid monitoring system and delineate responsibilities for deployment Timeline: Within 1 year of the publication of this Action Plan

4.2.2 DOE, in coordination with regulatory agencies and the electric power industry, will define data requirements that facilitate a centralized reporting system to collect real-time information on the status of the electric power transmission and distribution system during geomagnetic storms. Deliverable: Define data requirements Timeline: Within 1 year of the publication of this Action Plan

GMD MONITORING APPROACH: Benefits

Increases understanding of the specific technical impacts of a GMD event on the grid to better assist the electricity sector in determining ways to mitigate or prevent widespread power outages;

Improves accuracy and reliability of models and modeling parameters, allowing for greater reliability, optimization of operations, and increased resilience against high-impact, low-frequency events;

Provides insights on options for operational plans and mitigation and protection investments

Identifies knowledge gaps related to GMD events

GMD MONITORING APPROACH: Overview

FOUR PARTS to the RECOMMENDED APPROACH

Transformers: Collect individual transformer data on temperature, voltage, and current measurements above what is presently done in control systems for the operation and protection of transformers.

Substations: Outfit substations for additional monitoring of harmonics for predictive capabilities and additional warning indicators specific to GMD.

Regional data collection: Establish regional indicator systems through intensive monitoring of critical transformers and more fully equip them with data-gathering systems focused on GMD monitoring.

Data dissemination: Encourage real-time external distribution of geomagnetic measurements, which can then be incorporated into more accurate and comprehensive nationwide databases.

GMD MONITORING APPROACH: Report

DOE GMD Mitigation Pilot Program

EXECUTIVE ORDER

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COORDINATING EFFORTS TO PREPARE
THE NATION FOR SPACE WEATHER EVENTS

By the authority vested in me as President by the Constitution and the laws of the United States of America, and to prepare the Nation for space weather events, it is hereby ordered as follows: …

Sec. 5. Implementation. (a) Within 120 days of the date of this order, the Secretary of Energy, in consultation with the Secretary of Homeland Security, shall develop a plan to test and evaluate available devices that mitigate the effects of geomagnetic disturbances on the electrical power grid through the development of a pilot program that deploys such devices, in situ, in the electrical power grid. After the development of the plan, the Secretary shall implement the plan in collaboration with industry. In taking action pursuant to this subsection, the Secretaries of Energy and Homeland Security shall consult with the Chairman of the Federal Energy Regulatory Commission.

DOE GIC Blocker Pilot Program

Federal Register / Vol. 81, No. 201 / Tuesday, October 18, 2016 / Presidential Documents 71573

Presidential Documents

Executive Order 13744 of October 13, 2016

Coordinating Efforts To Prepare the Nation for Space Weather Events

By the authority vested in me as President by the Constitution and the laws of the United States of America, and to prepare the Nation for space weather events, it is hereby ordered as follows:

Section 1. *Policy*. Space weather events, in the form of solar flares, solar energetic particles, and geomagnetic disturbances, occur regularly, some with measurable effects on critical infrastructure systems and technologies, such as the Global Positioning System (GPS), satellite operations and communication, aviation, and the electrical power grid. Extreme space weather events—those that could significantly degrade critical infrastructure—could disable large portions of the electrical power grid, resulting in cascading failures that would affect key services such as water supply, healthcare, and transportation. Space weather has the potential to simultaneously affect and disrupt health and safety across entire continents. Successfully preparing for space weather events is an all-of-nation endeavor that requires partnerships across governments, emergency managers, academia, the media, the insurance industry, non-profits, and the private sector.

It is the policy of the United States to prepare for space weather events to minimize the extent of economic loss and human hardship. The Federal Government must have (1) the capability to predict and detect a space weather event, (2) the plans and programs necessary to alert the public and private sectors to enable mitigating actions for an impending space weather event, (3) the protection and mitigation plans, protocols, and standards required to reduce risks to critical infrastructure prior to and during a credible threat, and (4) the ability to respond to and recover from the effects of space weather. Executive departments and agencies (agencies) must coordinate their efforts to prepare for the effects of space weather events.

Sec. 2. *Objectives*. This order defines agency roles and responsibilities and directs agencies to take specific actions to prepare the Nation for the hazardous effects of space weather. These activities are to be implemented in conjunction with those identified in the 2015 *National Space Weather Action Plan* (Action Plan) and any subsequent updates. Implementing this order and the Action Plan will require the Federal Government to work across agencies and to develop, as appropriate, enhanced and innovative partnerships with State, tribal, and local governments; academia; non-profits; the private sector; and international partners. These efforts will enhance national preparedness and speed the creation of a space-weather-ready Nation.

Sec. 3. *Coordination*. (a) The Director of the Office of Science and Technology Policy (OSTP), in consultation with the Assistant to the President for Homeland Security and Counterterrorism and the Director of the Office of Management and Budget (OMB), shall coordinate the development and implementation of Federal Government activities to prepare the Nation for space weather events, including the activities established in section 5 of this order and the recommendations of the National Science and Technology Council (NSTC), established by Executive Order 12881 of November 23, 1993 (Establishment of the National Science and Technology Council).

On October 18, 2016, President signed Executive Order 13744.

- Executive Order 13744: Coordinating Efforts To Prepare the Nation for Space Weather Events
- “Extreme space weather events…degrade critical infrastructure--could disable large portions of the electrical power grid, …”

This Executive Order has several directives including:

- **Oversite of DOE** to develop a plan to implement a pilot program to deploy, test, and evaluate technology and/or devices (in the field) to prevent or block geomagnetically-induced currents (GICs) from space weather events from entering transformers.

Evaluate GMD mitigation devices

DOE Pilot Program to Mitigate GIC Effects

Physical representation of a neutral

EPRI worked with DOE to help develop the pilot program plan to protect transformers in the field as directed in Executive Order 13744.

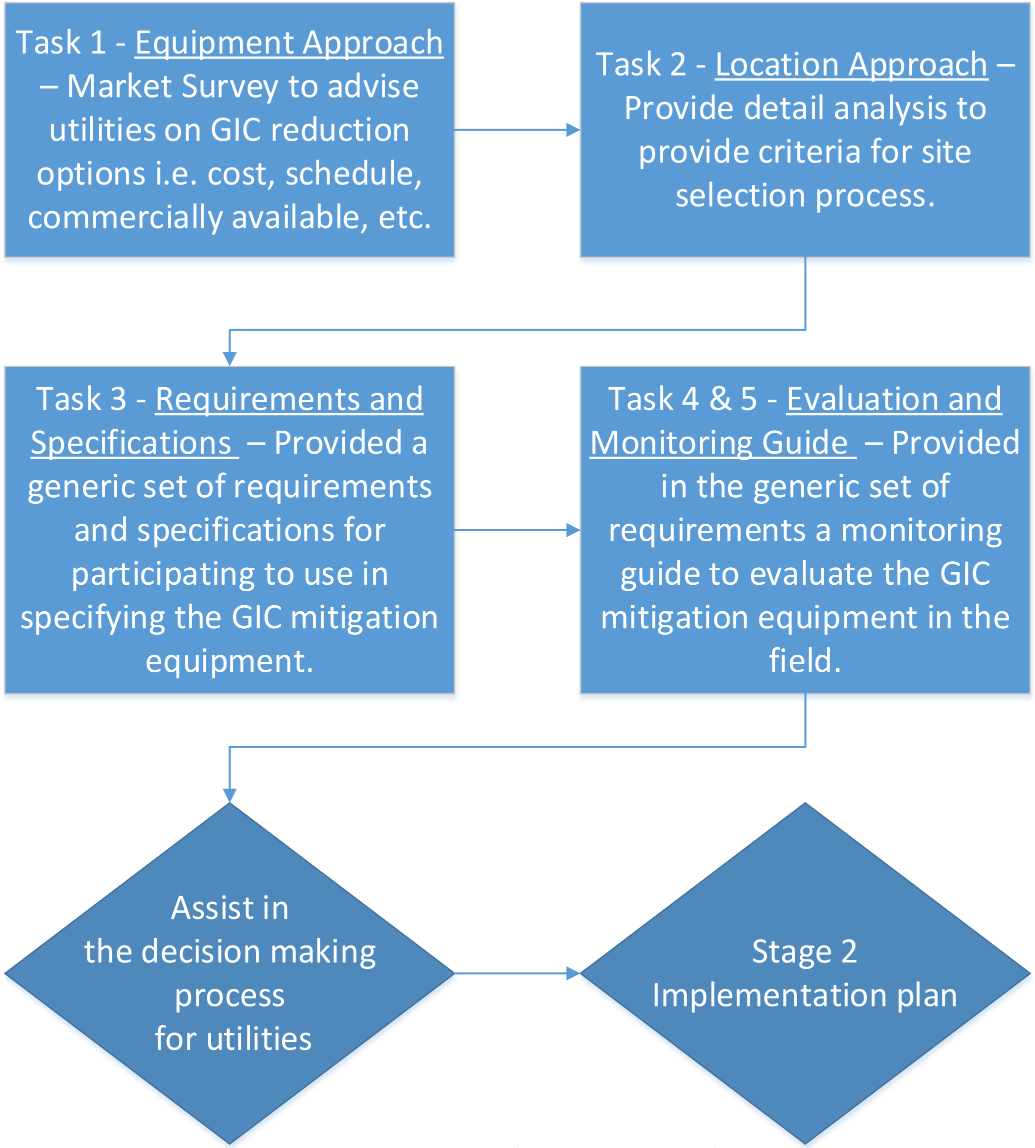
EPRI providing the following:

- Market survey to identify solution options
- System approach to selecting sites
- Hardware specifications
- Identified potential utility partners
- Work with partner(s) to develop monitoring plan
- Evaluate GIC blocking devices in the field

Phase 1 Project Overview

The information in this report can be used in

- developing an approach/criteria to evaluate viable GIC mitigation equipment and technologies
- determining the number and type of equipment to be purchased and installed to implement the pilot program and
- estimate equipment lead times to be included in a master implementation schedule.



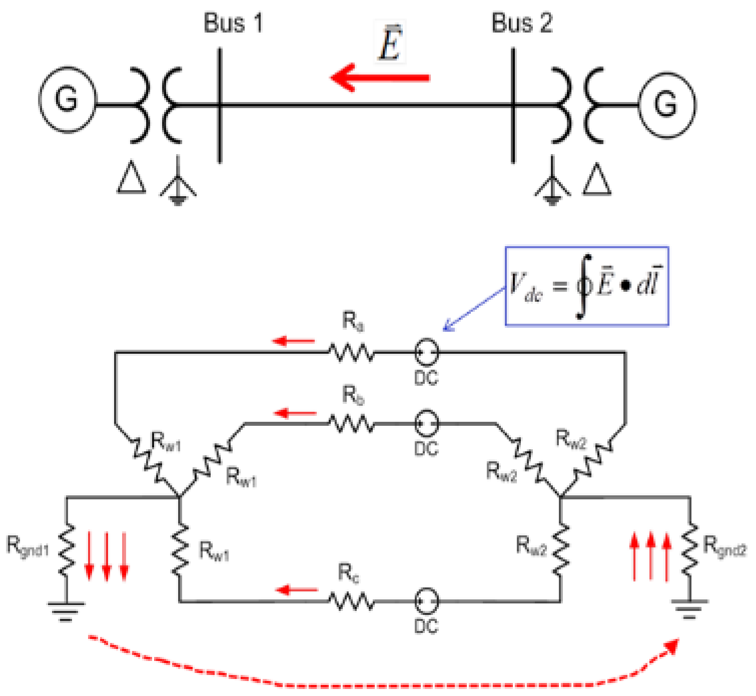
Equipment Approach

	Series compensation Capacitors	Neutral Blocking Devices	Neutral Resistive Devices	Use of a sacrificial MOV (surge arrester) as a GRD	Low capacitance NBD
Commercially Available	✓	✓	✓		✓
Equipment Cost	$12M estimate	$500K	$100k estimate	<$50k estimate	<$10k [estimate]
Installation Costs	$19.5M estimate	$470K	$200k estimate	$100k estimate	$100k estimate
Equipment has been Operational Experience	✓	✓	✓		✓
Lead times	6-8 months	6 months	3 months	minimal	minimal
Additional Considerations	Needs a large amount of space to install.	Greater number of components compared to some GRD methods potentially reducing reliability.	Does not prevent harmonics associated with transformer GIC.	Once the MOV is sacrificed the device no longer blocks GIC.	Transformer will need full insulation level through to neutral.
Relative Study complexity (1-10)	8	10	4	3	2

Location Approach

Developed the recommended approach for determining critical factors, to include appropriate sites for mitigation or protection devices

Provided GIC monitoring recommendations for non-protected transformers in proximity to mitigated or protected transformers.

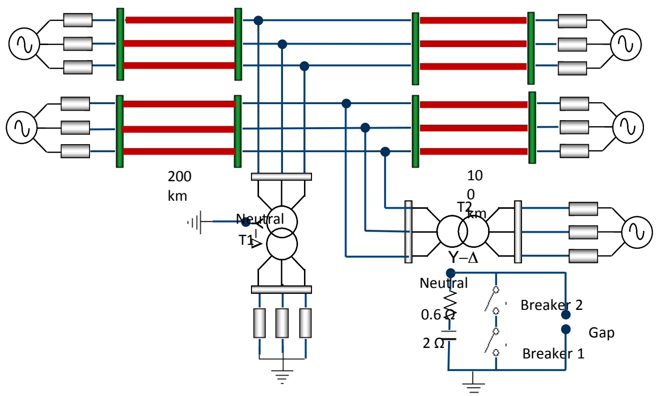


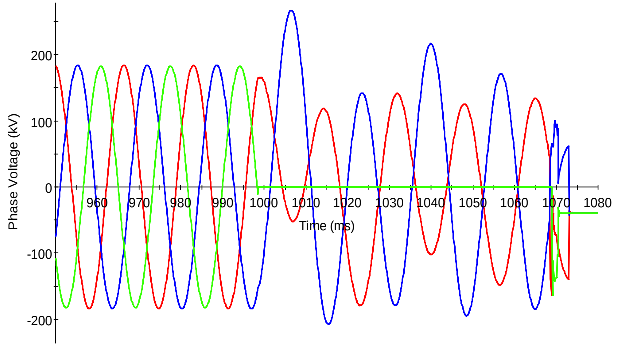
GRD Specifications

Provide an approach to evaluate and specify GIC mitigation equipment and technologies.

Provided generic set of requirements and specifications for GMD mitigation equipment to the utility that will be part of this pilot program.

Those who choose to participate in the pilot program will be able to use this information to develop their own specific specifications.



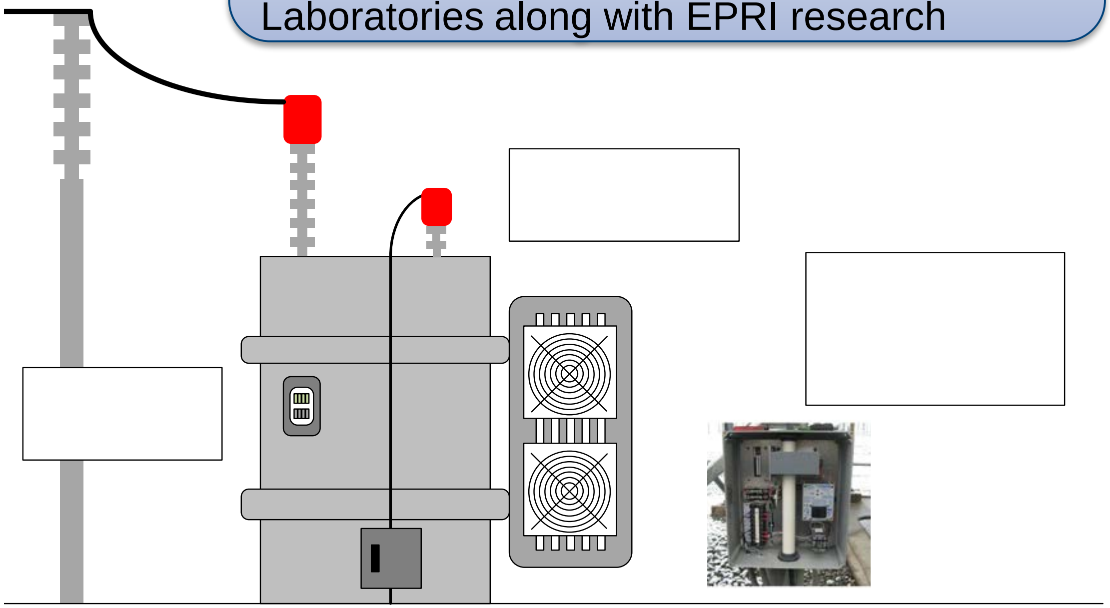


Field Evaluation Monitoring

Monitoring recommendations based on the "Geomagnetic Disturbance Monitoring Approaches & Implementation Strategies" report developed by Idaho National Laboratories along with EPRI research

Evaluating the GRD equipment

Monitor the impact on the protected transformer along with the impact on the non-protected transformers which may see an increase in GIC due to the use of the GRD.



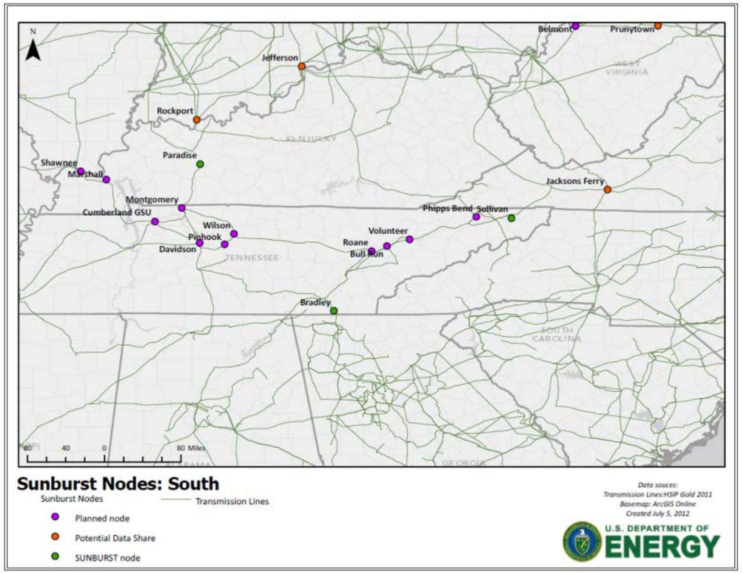
Leverage on SUNBURST Nodes

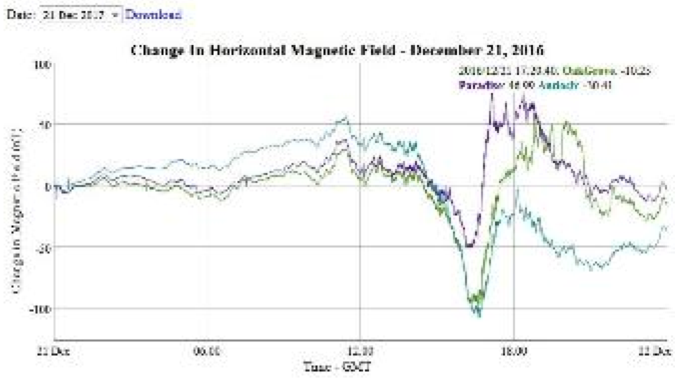
GIC Monitoring: 49 Sites

- Plans for additional sites in 2018

Adding capability to monitor magnetic fields

- Objective: To record B-field variations that drive GICs
- 6 variometers installed and 11 additional sites planned





Participation of Utilities

Stakeholder guidance and utilities' willingness to participate in a pilot program will decide the specific utility and the placement of GRD.

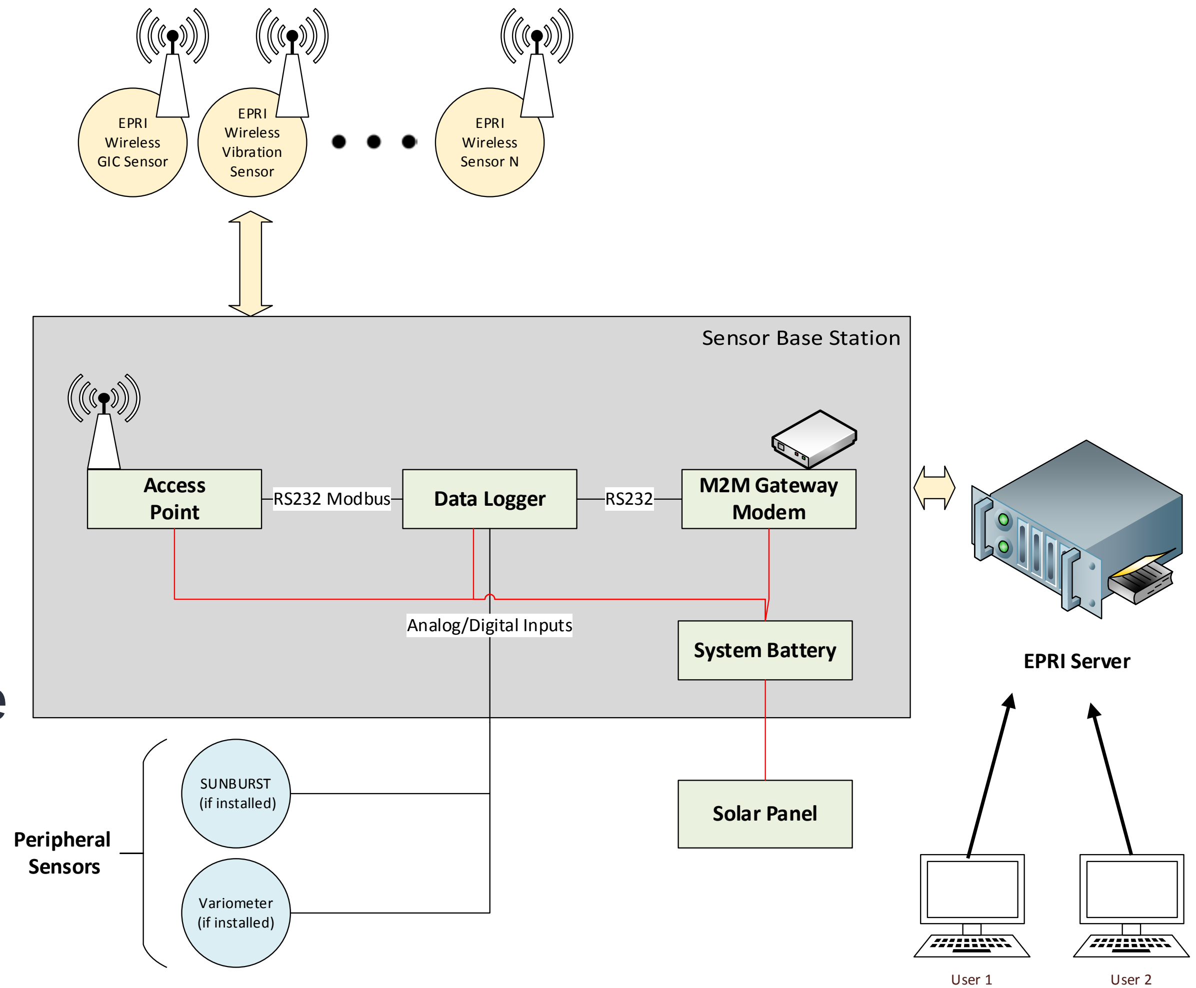
Presently EPRI and the DOE are in communication with four utilities interested in the pilot program.

Ultimately the decision on which GRD to implement on the system is the decision of the participating utility, this information will aid in deciding the number and type of equipment to be purchased and installed.

Next Steps – Proposed Monitoring Architecture

Phase 2 – implementation stage

- Work with utilities participating in pilot program to select site.
  - Criteria and results based on Task 2 of Phase 1 report
- Provide cost estimates and monitoring guidance needed for evaluation.
- Provide data collection and evaluation.



John Ostrich
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https://energy.gov/oe/mission/infrastructure-security-and-energy-restoration-iser

Space Weather Prediction Center Update: Progress on NOAA's operational near real-time Geoelectric Field Estimation Capability

Christopher Balch
Space Weather Prediction Center
NERC GMDTF meeting
Charlotte, NC
13 June 2018

Outline

- Collaborators & Acknowledgements
- Current & Planned Capability
- Sample Outputs from September 2017 storm
- Some initial validation work
- Challenges & Summary

Collaborators - Acknowledgements

- The near real-time E-field mapping project is a joint effort between
  - NOAA/SWPC (Balch, Millward + SWPC development & transition team)
  - USGS Geomagnetism group (Anna Kelbert, Josh Rigler, Greg Lucas, Jeff Love)
  - NASA/CCMC (Antti Pulkkinen)
- Key data provider agencies are gratefully acknowledged:
  - U.S. observatories operated and maintained by USGS
  - Near U.S. observatories operated and maintained by NRCAN
- Results from NSF's Earthscope USArray project are being used for upgrading Earth-conductivity specification
- Ongoing validation collaborations are gratefully acknowledged:
  - Dominion (Rui Sun)
  - PJM (Emanuel Bernabeu & Raymund Lee)
  - TVA (Ian Grant & Gary Kobet)

E-field maps – current capability

USGS observatories (8)
B-field time series

NRCAN observatories (5)
B-field time series

Detrending Algorithm

Interpolation Algorithm †
B-field on <u>0.5°x0.5° grid</u>

E-field calculation:
2°x2° grid, 1D conductivities

E-field experimental products:
- ***results in database***
- ***graphical maps (public release Oct '17)***
- ***gridded data files (available on request)***
- ***<u>GeoJSON format for dissemination</u> (June 15, 2018)***

URLs
https://www.swpc.noaa.gov/products/experimental-geoelectric-field-1-minute
http://services.swpc.noaa.gov/experimental/products/lists/rgeojson ***(for list of geojson files)***
http://services.swpc.noaa.gov/experimental/text/lists/rgeojson/geoelectric/interpolated_input/datadir_1m/geojsons/ **(geojson directory)**

Station Latencies (typical):

BOU, BSL, FRD, FRN, NEW, SIT	~1.6 min
SJG, TUC	~2.8 min
MEA, OTT	~2-4 min
VIC, BRD*, STJ	~4-8 min

These calculations can also be run retrospectively using historical magnetometer data

† SECS - Amm & Viljanen, 1999; Pulkkien et al., 2003

Data Dissemination via GeoJSON

- **About GeoJSON**
  - **Adheres to a standard (RFC 7946): https://tools.ietf.org/html/rfc7946**
  - **Can be read by web and desktop GIS clients**
  - **Can be parsed as json, or by geojson libraries in a variety of languages**
  - **Could be returned by a geospatial data service (e.g. ESRI ArcGIS Online)**
  - **ASCII for human readability, compresses well when served with gzip enabled**
- **Sample data available from the September 2017 storm**

- **Each "feature" has properties (data) and geometry (coordinates)**
- **Can contain points, lines, multi-point lines, and polygons**
- **Human and machine readable ASCII - compresses well with gzip**
- **< 5 Kilobytes compressed for each minute**


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          24.0
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      },
    ...
```

E-field maps – in development

USGS observatories (8)
B-field time series

NRCAN observatories (5)
B-field time series

Detrending Algorithm

Interpolation Algorithm
B-field on <u>0.5°x0.5°</u> grid

E-field calculation:
<u>0.5°x0.5°</u> grid, <u>3D conductivities</u>

<u>Two grids: Northwest &</u>
<u>NorthMidWest-NorthEast</u>

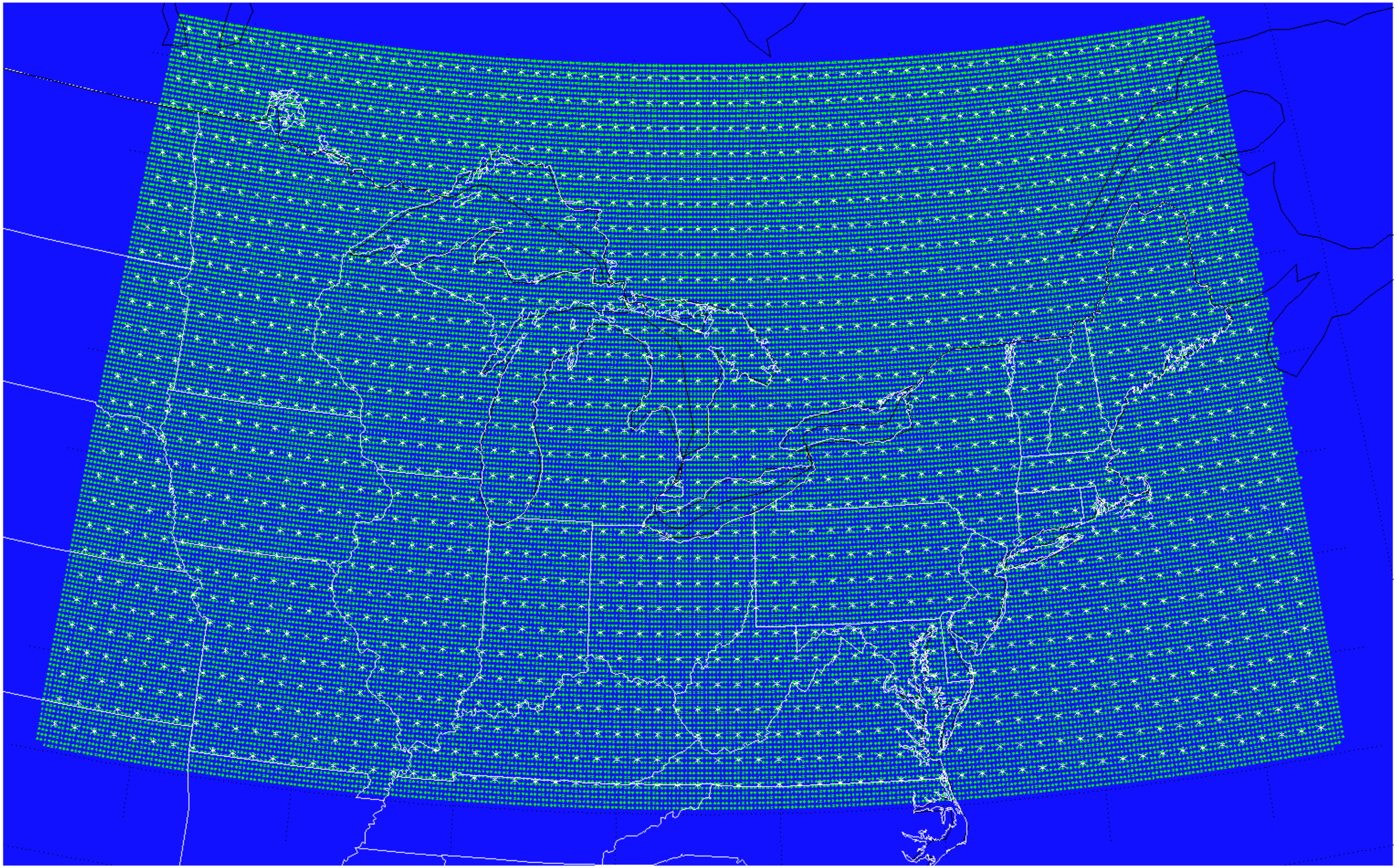
E-field experimental products:
-results in database
-two new graphical maps
-two new types of gridded data files
-geojsons for dissemination

Transfer functions in the system database:
Grid 11 – NW – 1915 transfer functions
Grid 12 - NMW-NE – 1857 transfer functions
(cf 20 transfer functions for 1D processing)

Whole grid processing 'refactoring' has been completed - enables processing large number of grid points in a single step

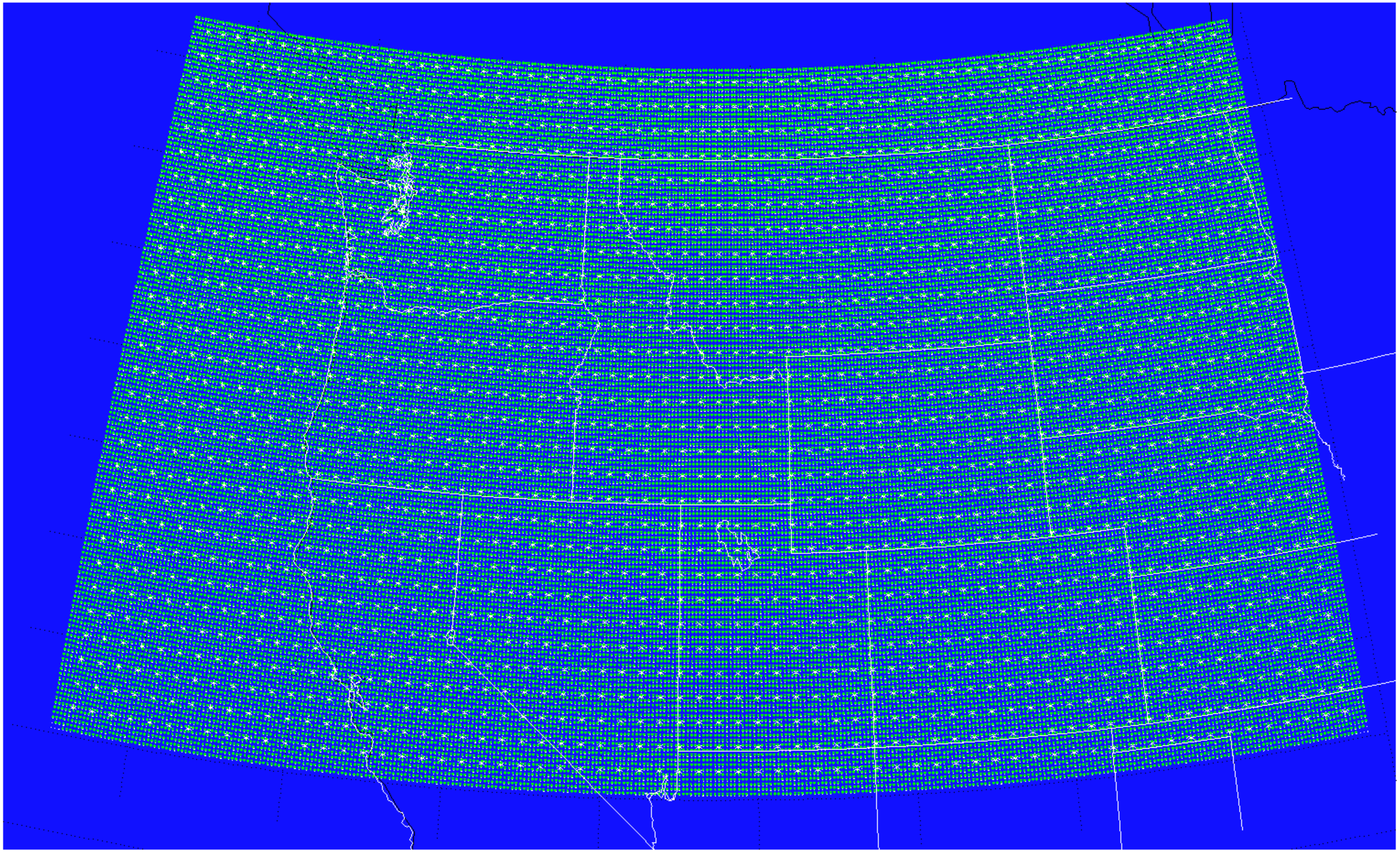
Future:
increase cadence from one minute to one second
Add more regional grids as models become available

High resolution grid (grid 12)



0.1 degree resolution model from MT inversion (USGS) together with ½ degree grid

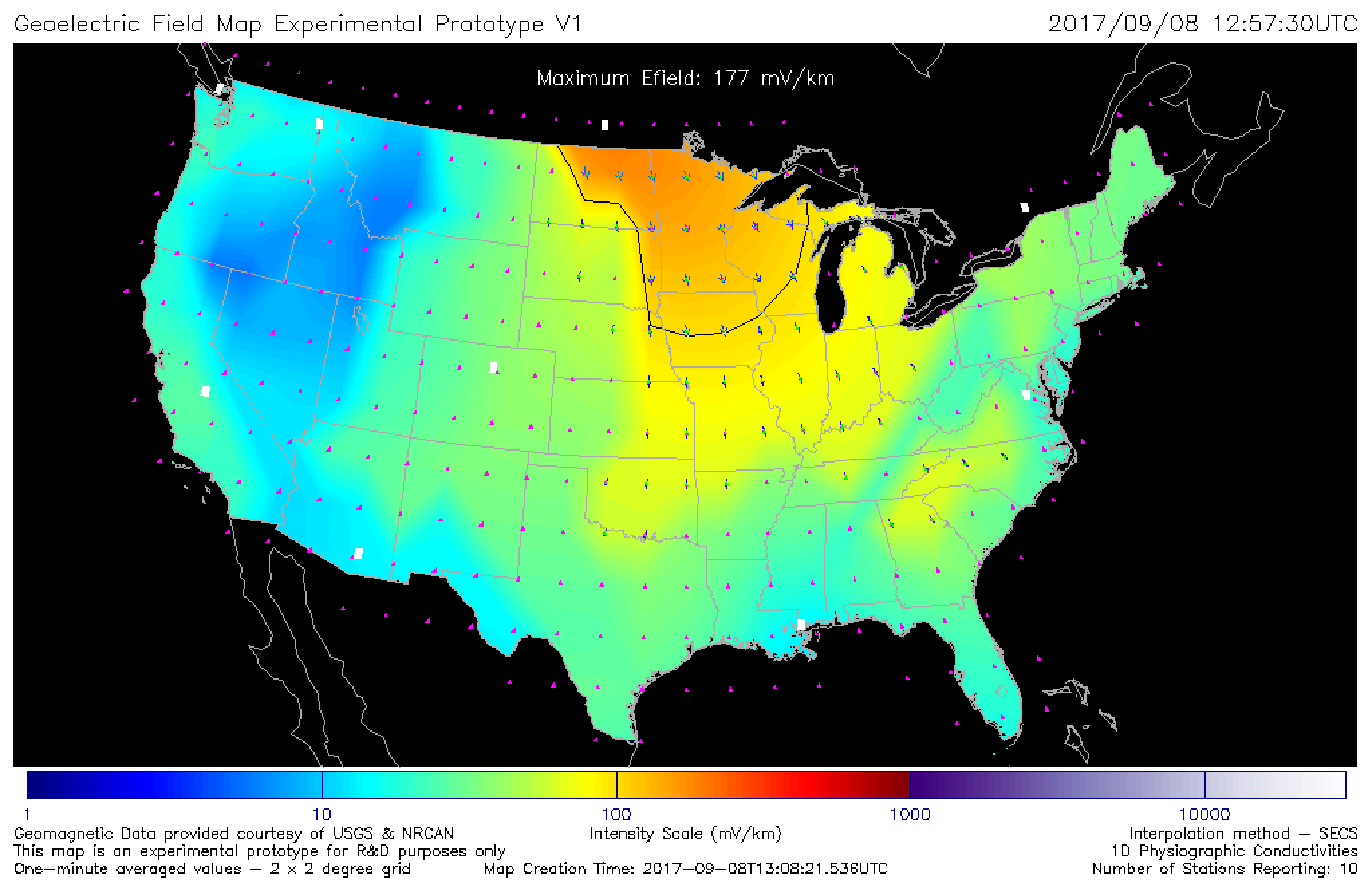
High resolution grid (grid 11)

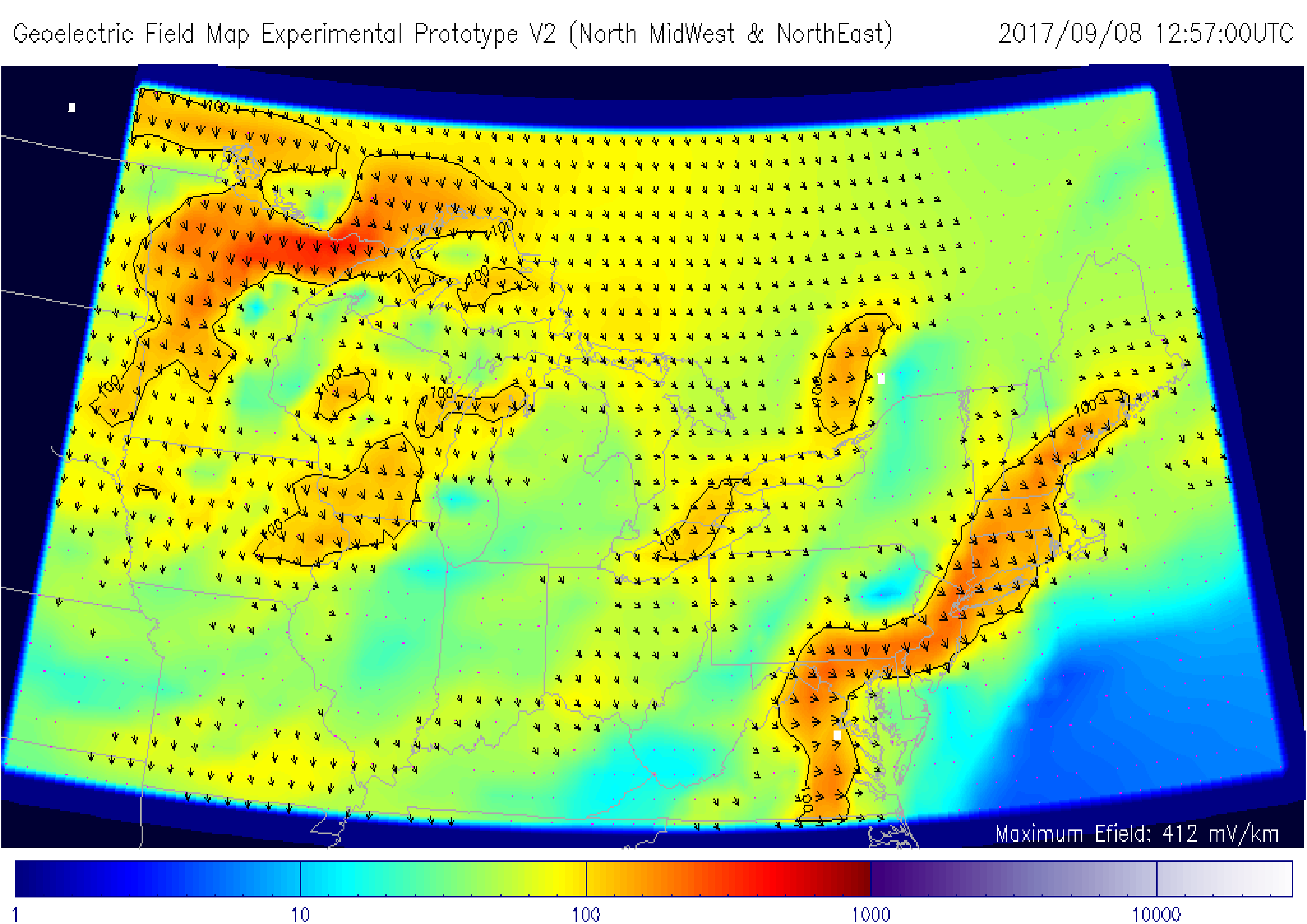


New Grids – using 3D conductivity models

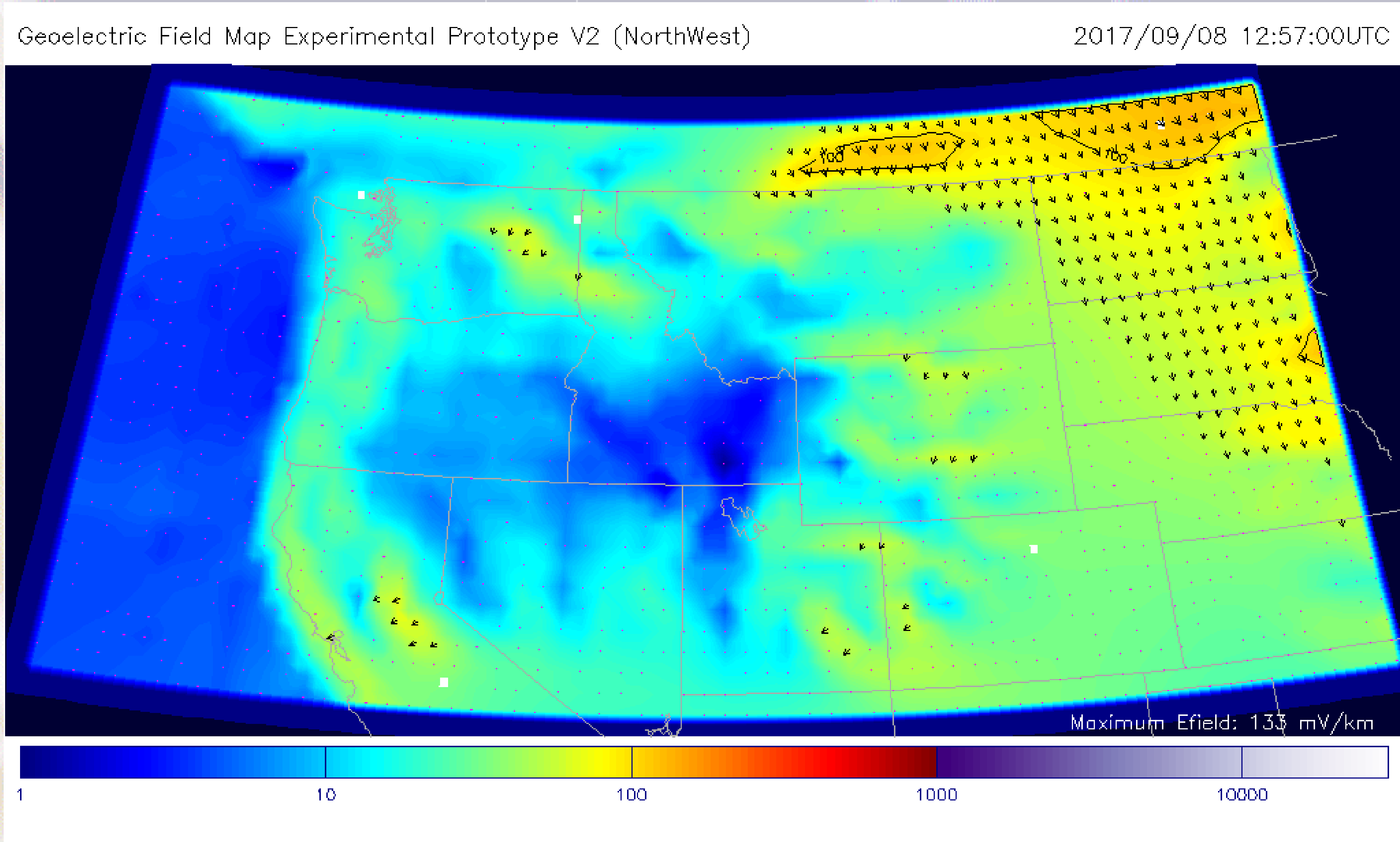
- Provided by USGS
- Earthscope MT data used with ModEM MT inversion code (Kelbert et al 2014) to generate high resolution 3D electrical conductivity model. (Enables interpolation between survey sites and filters out near surface ‘noise’)
- 3D model(s) constrained by MT survey data
- Provides transfer functions at 0.1 degree resolution
- We smooth to 0.5 degree grid with 50 km averaging radius as an initial hypothesis on the appropriate regional scaling for GIC applications
- Full description of the technique is in Kelbert et al. 2018 (in press – new AGU monograph on GIC)

Sample E-field (1D) Map





½ degree grid with 50 km averaging radius – sample E-field calculation

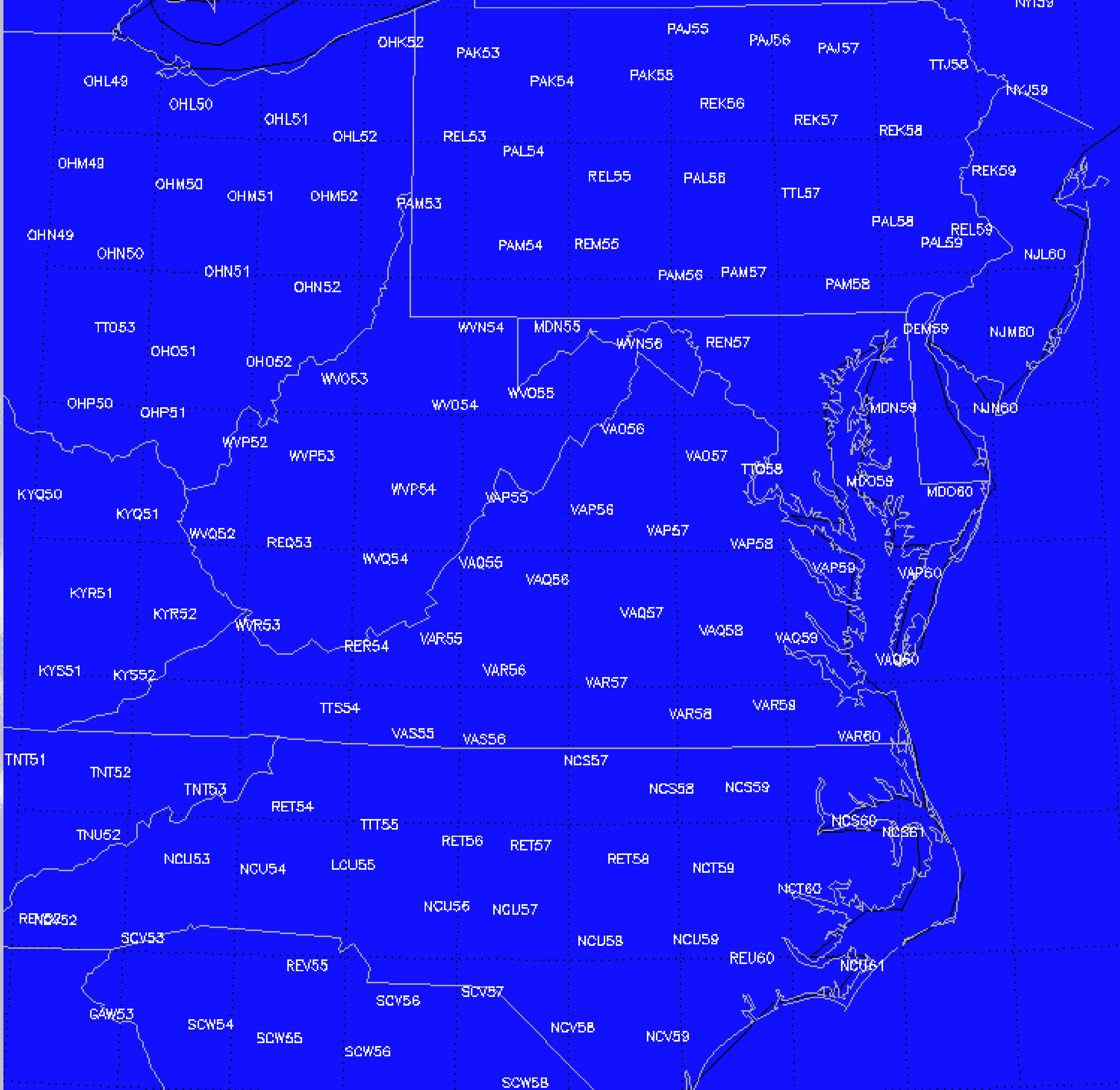


½ degree grid with 50 km averaging radius – sample E-field calculation

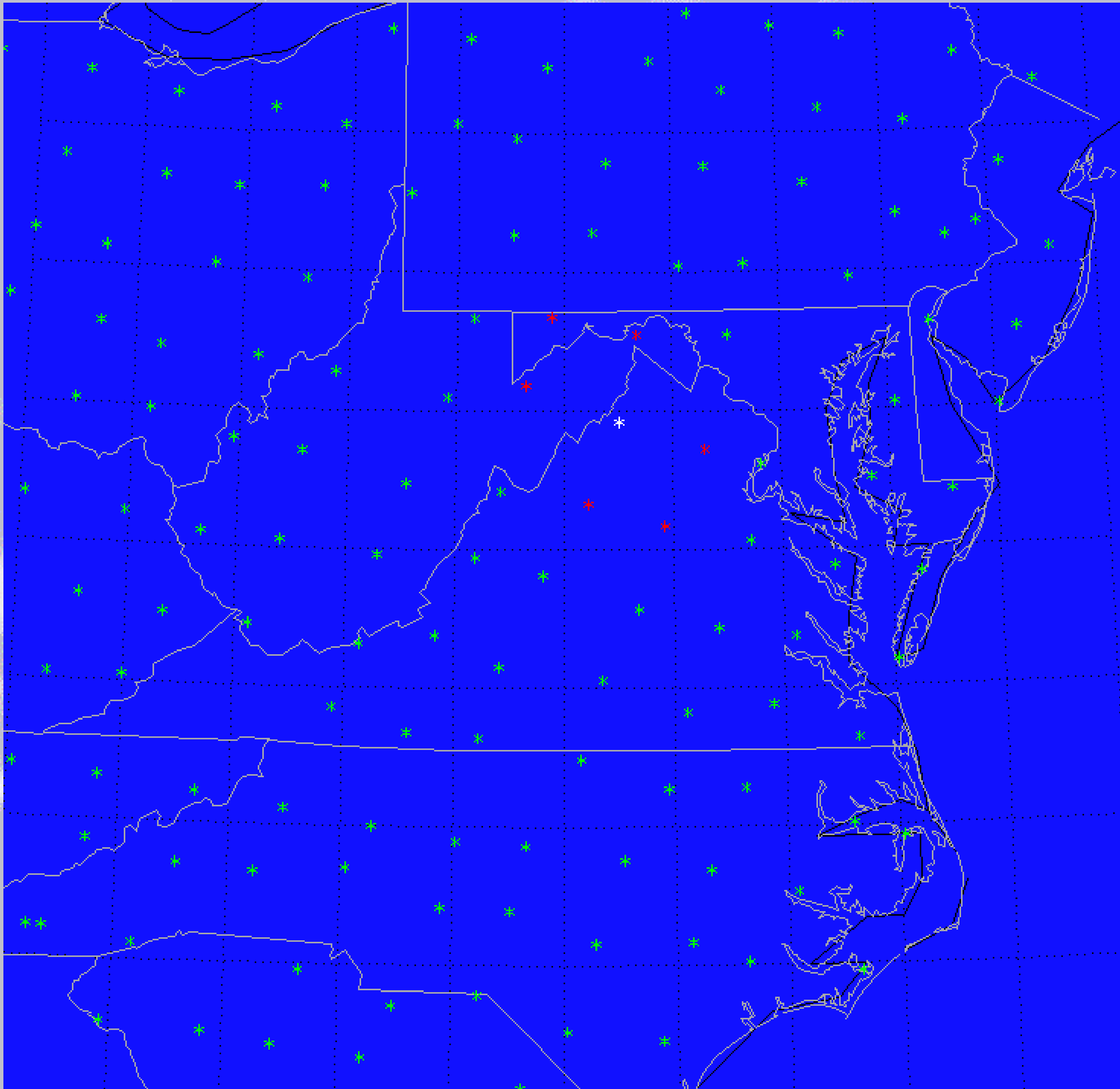
Some Initial Validation Work

- Study for September 2017 storm in mid-Atlantic
- Downloaded and used USArray MT transfer functions from the IRIS webpage (quality ≥ 3)
- Ran calculations using FRD as input B-field
- Nominal 70 km resolution – but grid is irregular
- Original & 100 km smoothed transfer functions
- Used both irregular and regular grids for a total of four different E-field calculations
- Provided to Dominion (Rui Sun) with two goals:
  - Run a GIC calculation
  - Compare calculated and observed GIC
- Need to rerun using GRID 12 outputs

Survey Sites used for mid-Atlantic validation study

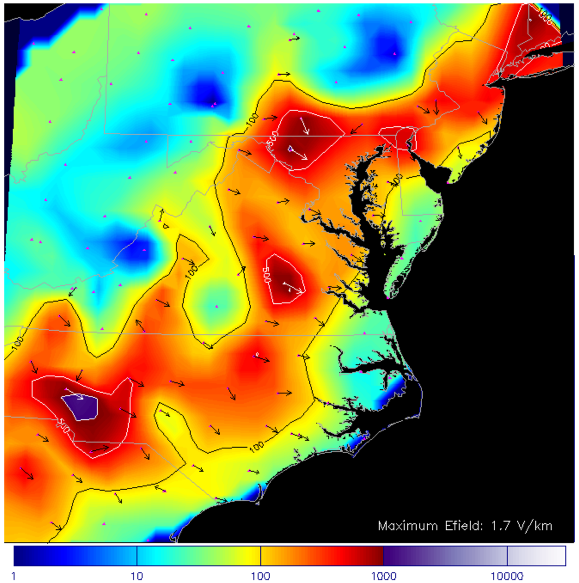


Sample – 100 km averaging radius



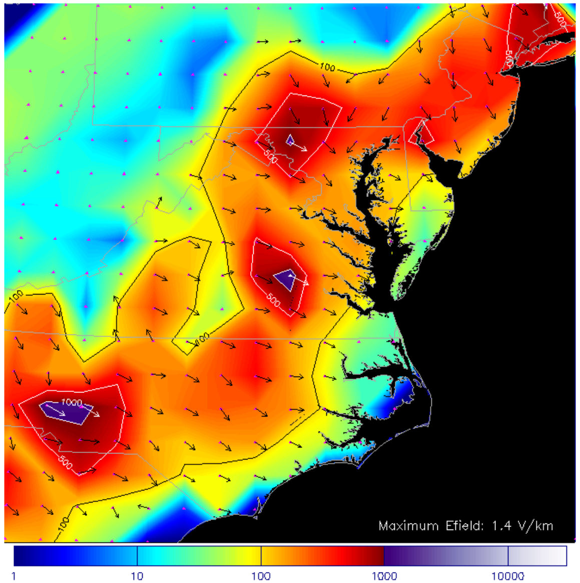
Side by side comparison

Geoelectric Field Map Experimental Prototype V2 (East Atlantic Region) 2017/09/08 12:57:00UTC



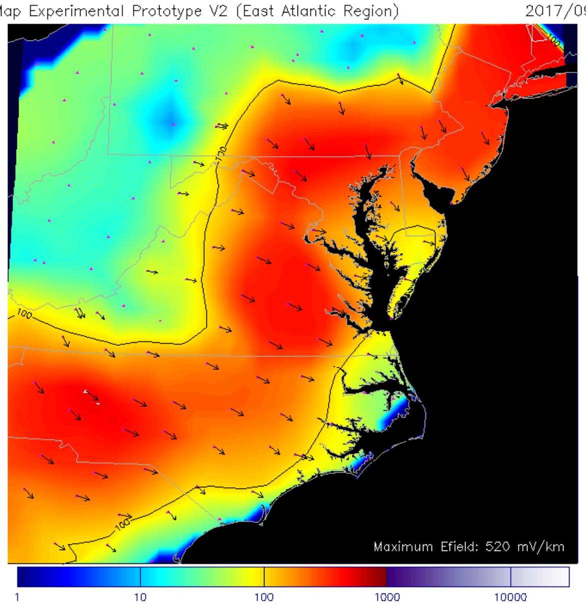
Geomagnetic Data provided courtesy of USGS Intensity Scale (mV/km) Interpolation method – nearest observatory
This map is an experimental prototype for R&D purposes only Earthscope Transfer functions (GE3) no smoothing
One–minute averaged values – nominal 70 km grid Map Creation Time: 2017–12–07T00:44:05.356UTC Input Magnetometer Data is FRD

Geoelectric Field Map Experimental Prototype V2 (East Atlantic Region) 2017/09/08 12:57:00UTC



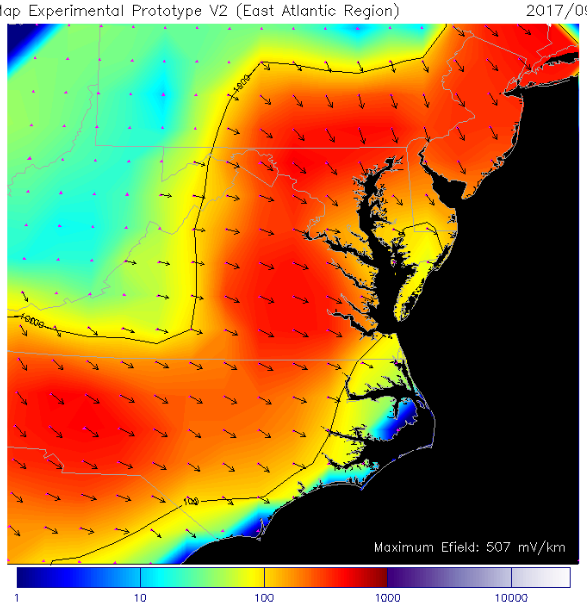
Geomagnetic Data provided courtesy of USGS Intensity Scale (mV/km) B–field Interpolation method – nearest observatory
This map is an experimental prototype for R&D purposes only Earthscope Transfer functions no smoothing & interpolated
One–minute averaged values – 0.5 x 0.5 degree grid Map Creation Time: 2017–12–11T23:48:23.320UTC Input Magnetometer Data is FRD

Geoelectric Field Map Experimental Prototype V2 (East Atlantic Region) 2017/09/08 12:57:00UTC



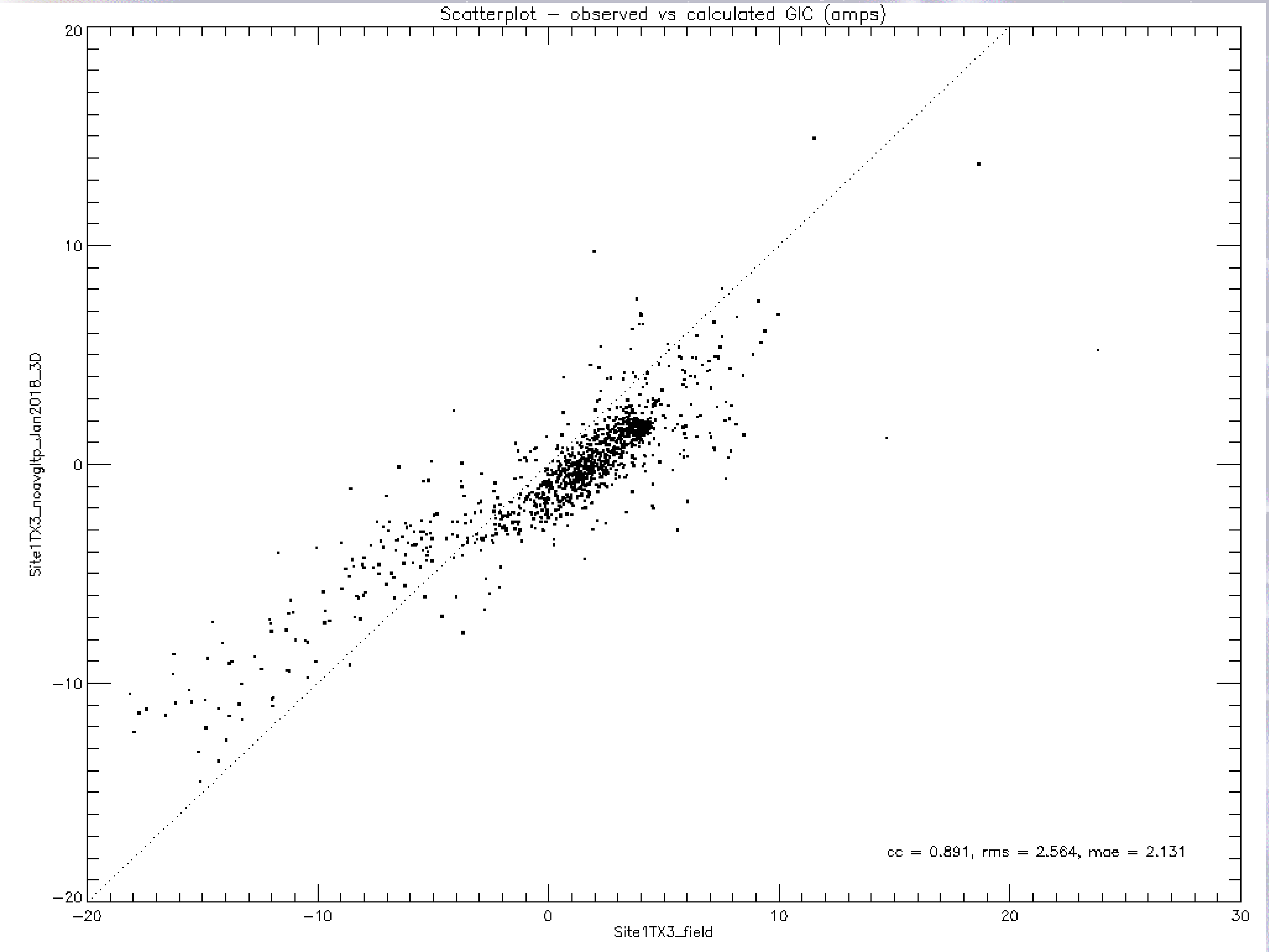
Geomagnetic Data provided courtesy of USGS Intensity Scale (mV/km) Interpolation method – nearest observatory
This map is an experimental prototype for R&D purposes only Earthscope Transfer functions (GE3) 100km smoothing
One–minute averaged values – nominal 70 km grid Map Creation Time: 2017–12–07T00:35:16.079UTC Input Magnetometer Data is FRD

Geoelectric Field Map Experimental Prototype V2 (East Atlantic Region) 2017/09/08 12:57:00UTC



Geomagnetic Data provided courtesy of USGS Intensity Scale (mV/km) Interpolation method – nearest observatory
This map is an experimental prototype for R&D purposes only Earthscope Transfer functions 100km smoothing & interpolated
One–minute averaged values – 0.5 x 0.5 degree grid Map Creation Time: 2017–12–11T20:00:08.230UTC Input Magnetometer Data is FRD

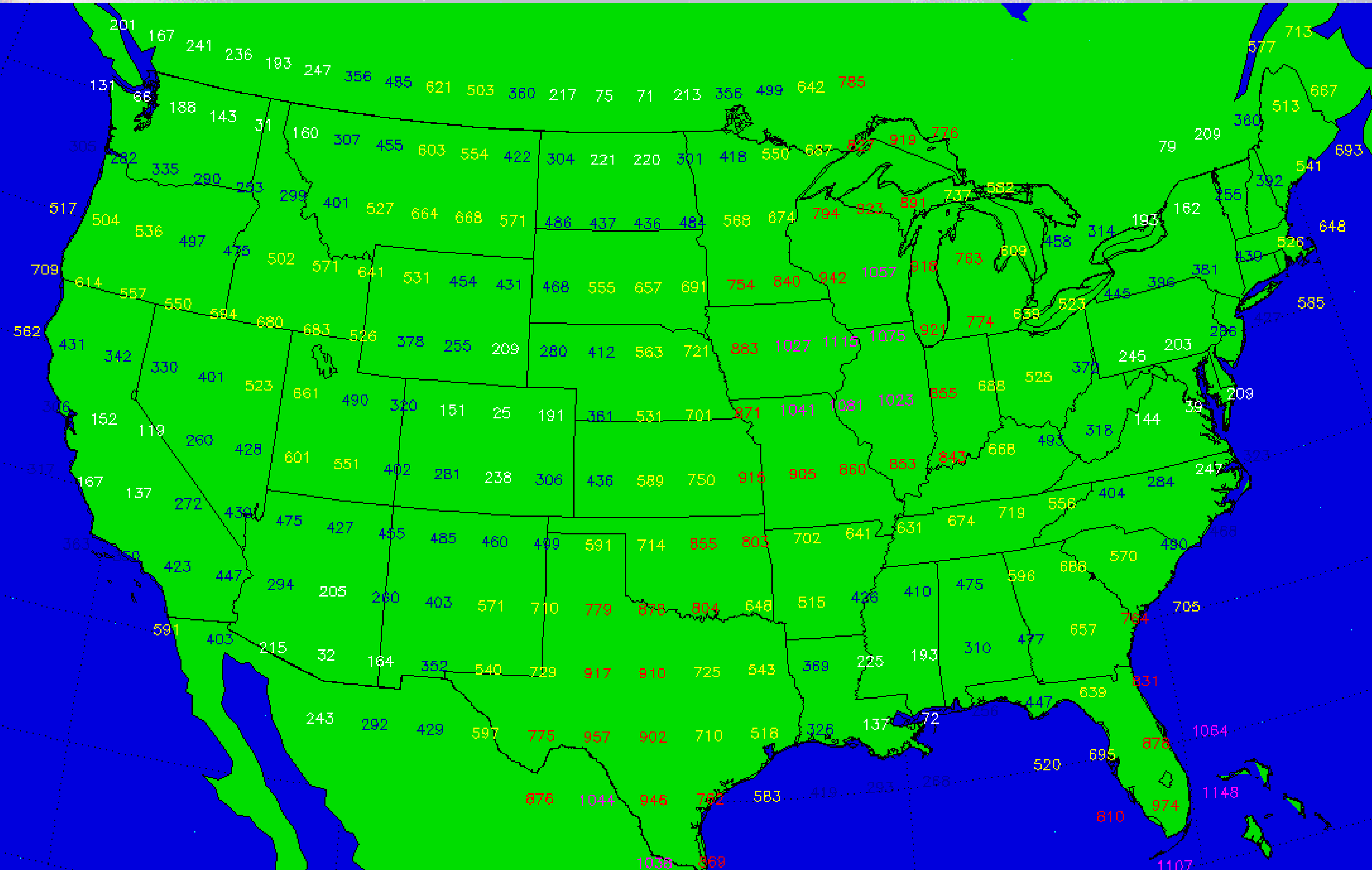
Sample validation plot (preliminary)



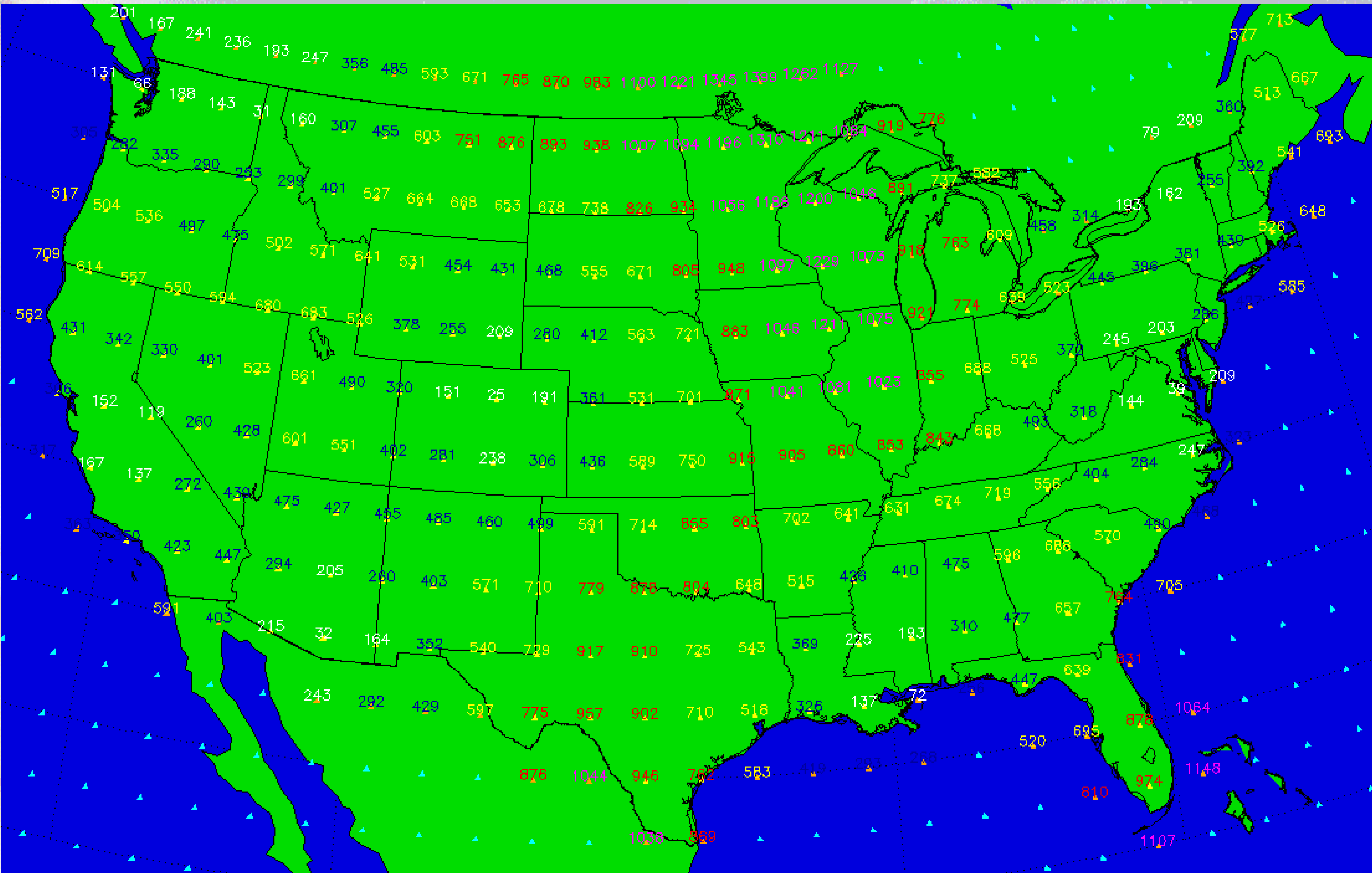
Challenges

- Observatory delays, drop-outs, varying latency
  - We could generate maps using a smaller number of observatories, trading accuracy for timeliness
  - Should we generate ‘preliminary’ maps with incomplete (but more timely data), which are later updated as slower data arrives?
- Sparseness of the observatory network
  - Very important to add more observatories to the network
  - If you can contribute observations for your region the results for your area will be more accurate
- Incompleteness of MT surveys for CONUS
  - There are still areas that have not been surveyed so this will likely limit the accuracy of what can be provided for those regions
- End-user validation is under way
  - More participants are welcome and are needed
  - September 2017 storm is great opportunity for validation
  - Validation studies can enable participants to determine how they would use E-field data in real-time for operations

Station Distances (km)



Station Distances (km) w/o BRD



Summary

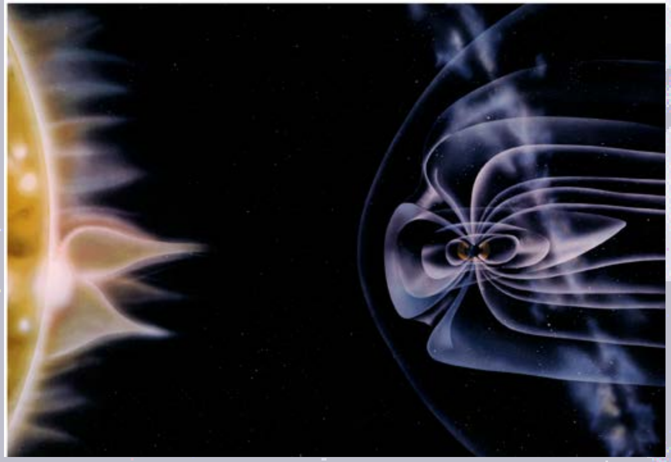
Currently

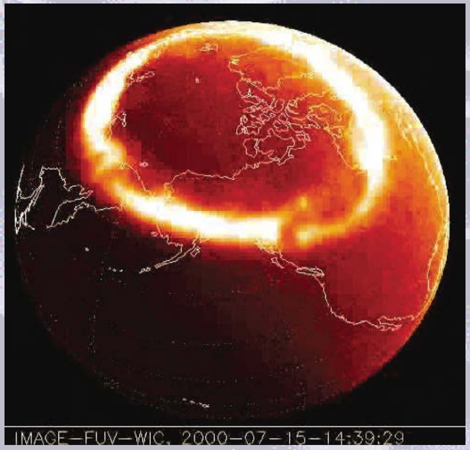
- Near real-time updating maps are publicly available as an experimental product (2° x 2°, 1D conductivities, GeoJSONs by 6/15/2018)
- Results for this event, past events, or more recent periods of interest are available by request
- Results are stored on an ongoing basis so future periods of interest will also be readily available
- The September 2017 storm has been run through 3D models for the two regional grids and can be provided for validation

In progress

- Industry collaborators are assisting with validation
- Will be doing more 'past storm' calculations using the 3D models & the 1D model and welcome their usage for historical validation work
- An upgrade to the near-real time processing using Earthscope-based 3D conductivity models is in active development

Questions?

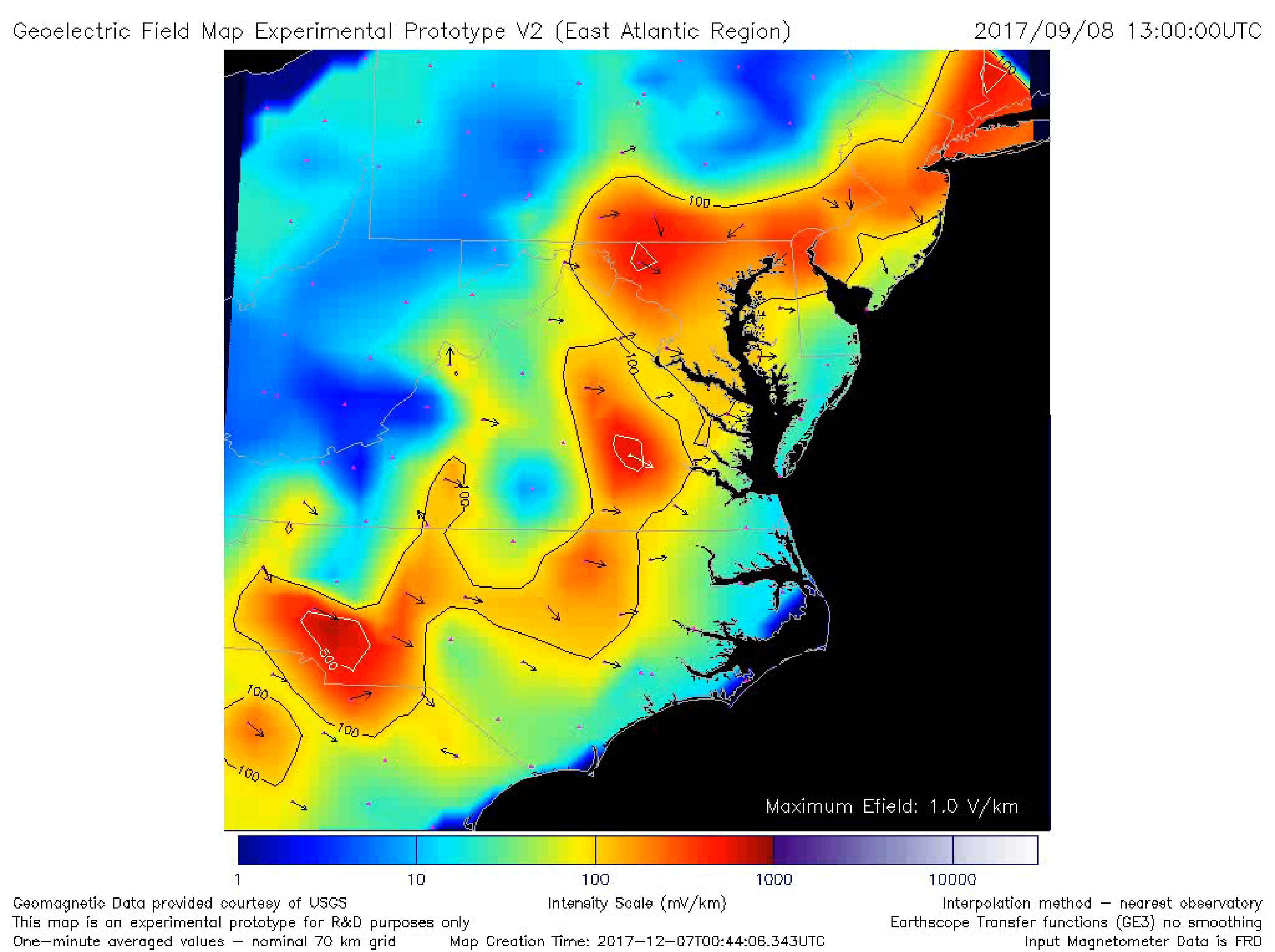




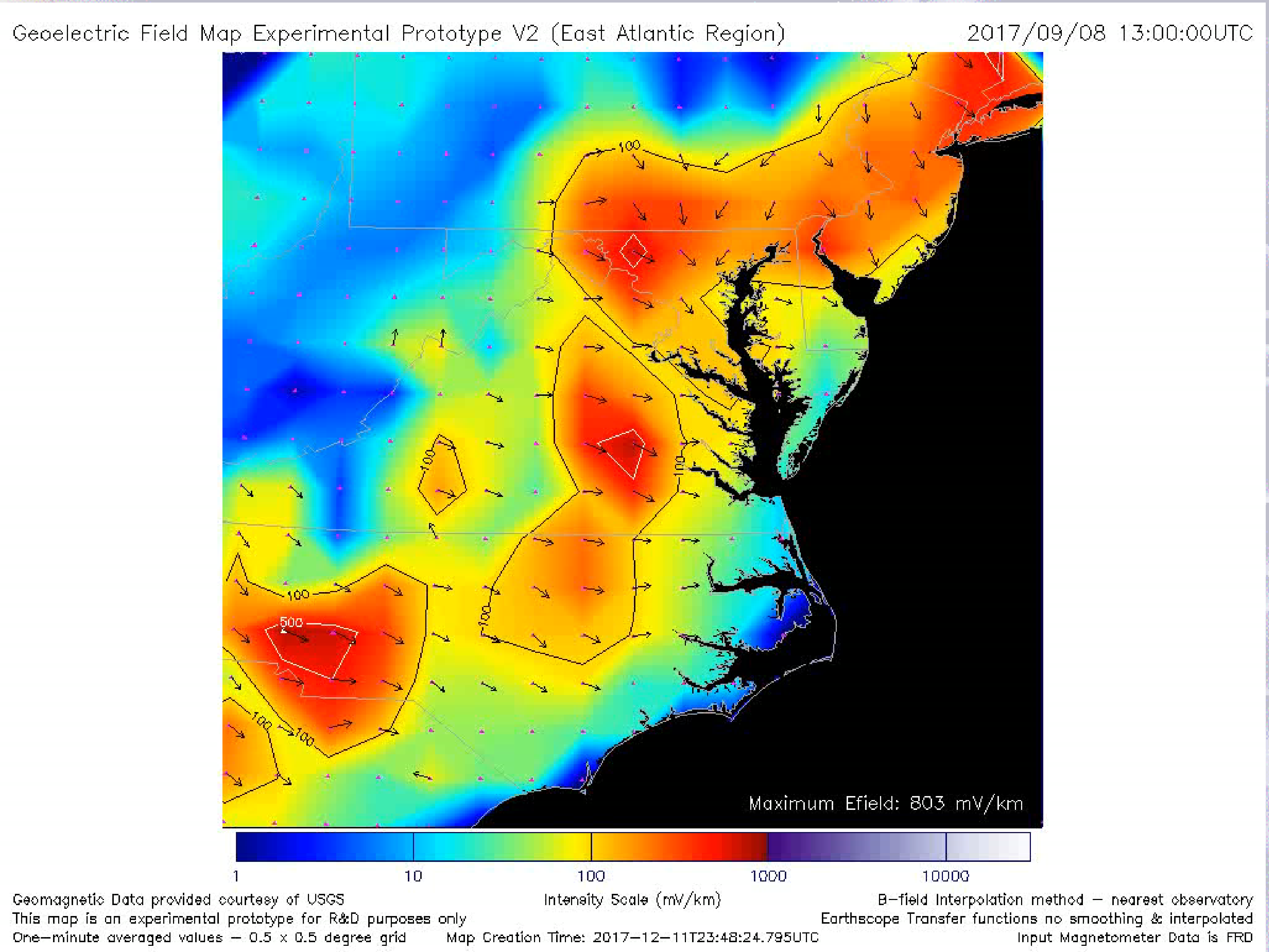
Forecasting - Geospace Model

- SWMF (Space Weather Modeling Framework)
  - Declared operational on NCEP supercomputer 09-2016
  - Uses upstream solar wind to predict future state of the magnetosphere/ionosphere system
- Initial Products
  - Predicted **B** on 5 degree x 5 degree geographical grid
    http://www.swpc.noaa.gov/products/geospace-ground-magnetic-perturbation-maps
  - Various global geomagnetic indices
    http://www.swpc.noaa.gov/products/geospace-global-geomagnetic-activity-plot
  - Equatorial and Meridional cross section views
    http://www.swpc.noaa.gov/products/geospace-equatorial-and-meridional-magnetospheric-views
- New Experimental Product
  - Predicted **B** on the 2 degree x 2 degree grid used by the E-field model

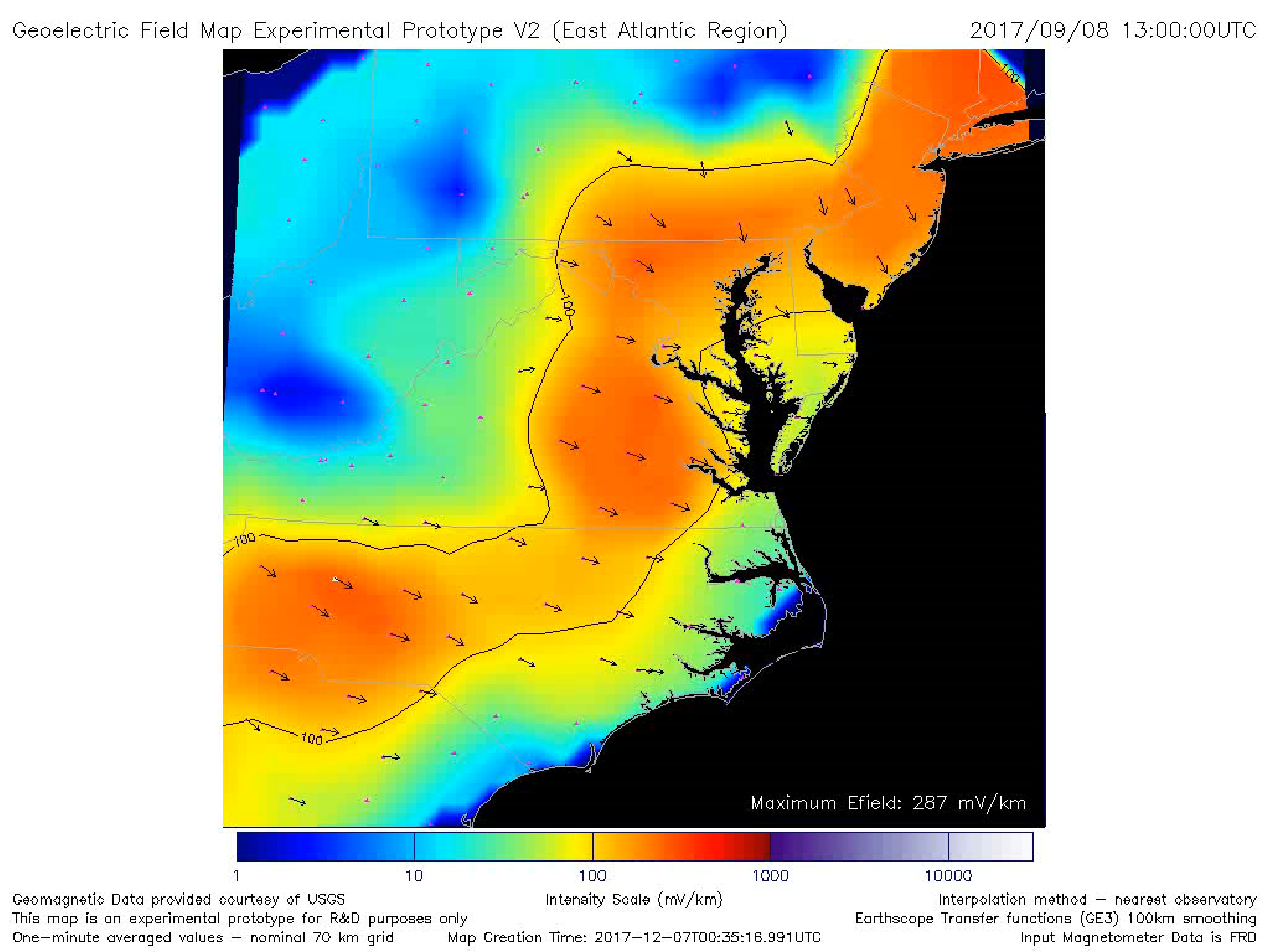
Using MT sites directly (irregular grid)



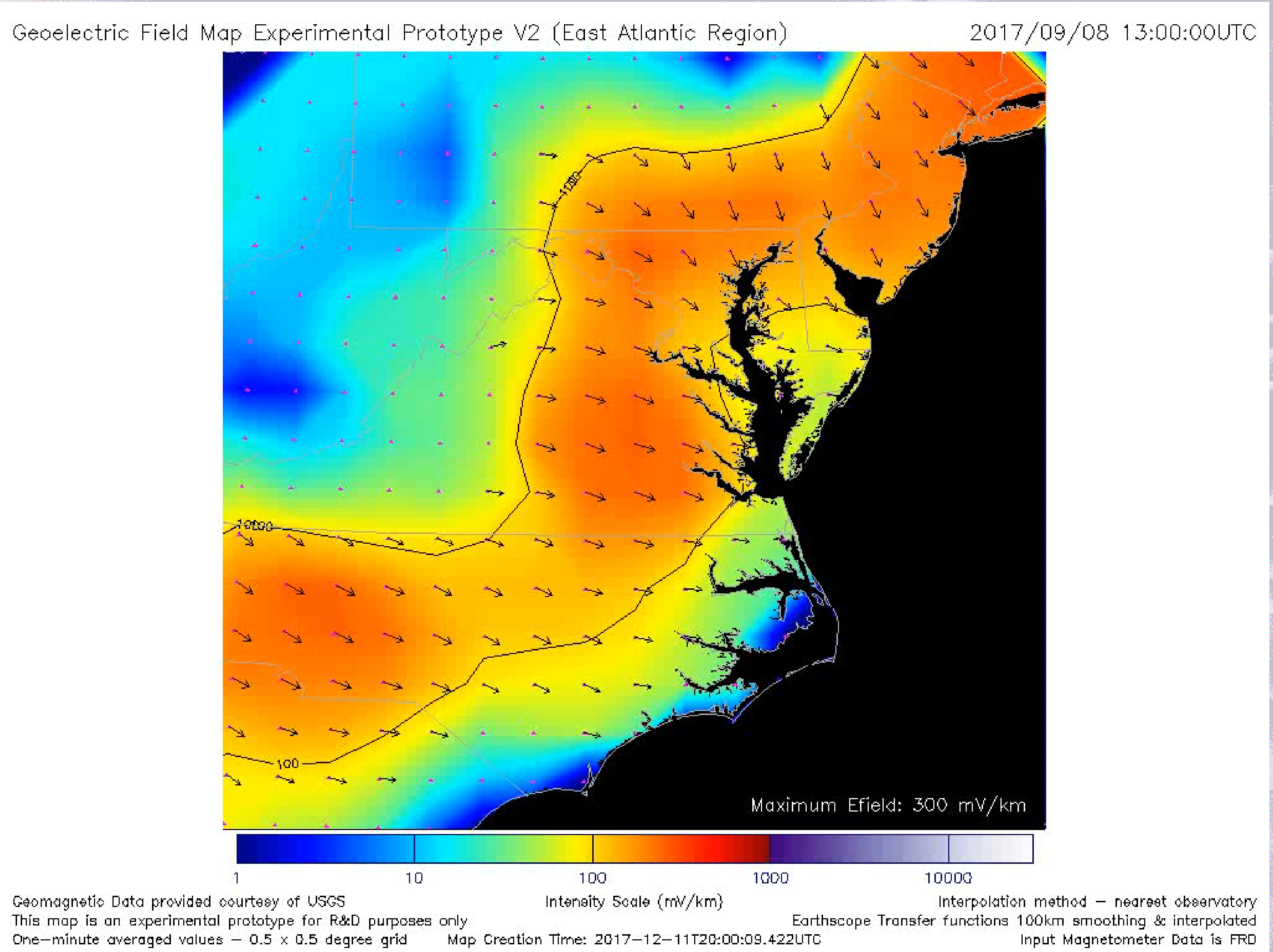
Interpolate from MT sites to 0.5° grid



Irregular grid with 100 km smoothing



100 km smoothing on regular 0.5° grid



TVA GMD Study Results

TPL-007-01 & TPL-007-02

Ian Grant & Gary Kobet, TVA

Scott Dahman, PowerWorld Corporation

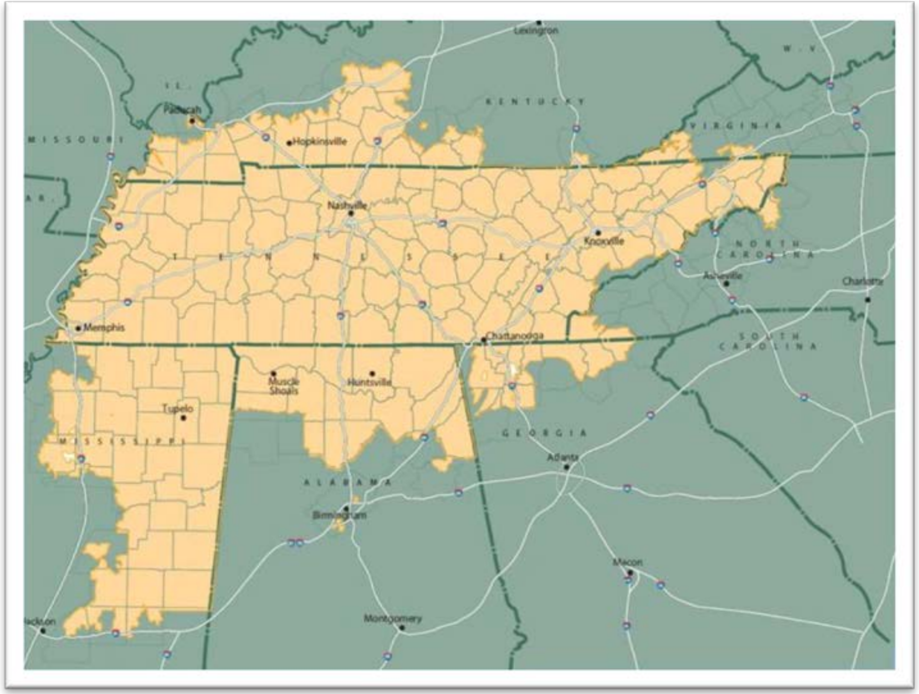
June 12 2018

Work at TVA

- Develop GIC model and studies
- Work with ABB on transformer models for 500 kV fleet
- Analysis of neutral blocking design at UTC
- Establish GIC monitor network, plan variometer matrix
- High magnitude studies (EMP) – FAST Act

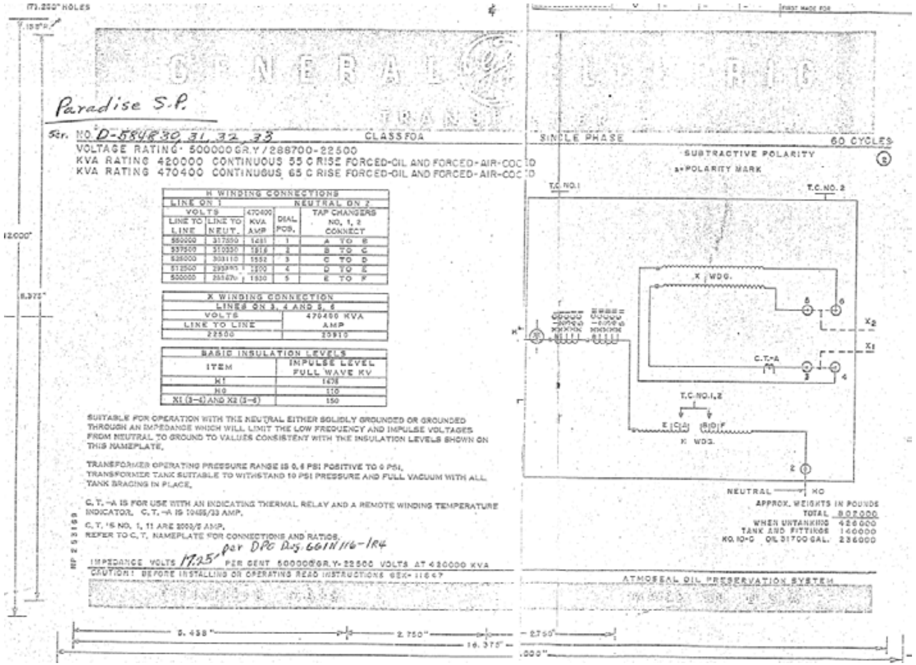
Tennessee Valley Authority

- A federally-owned, self-financed corporation
- Mission: Provide navigation, flood control, & electric power in the Tennessee Valley region
- Largest public power system
- Service Area:
    - Parts of 7 states
    - 80,000 square miles
    - 9 million people
- Primarily a wholesaler of power serving distributors
- TVA also sells power to direct served customers



Modeling

- TVA has ~2500 miles of 500kV transmission line, 85 EHV transformer banks (most with three single-phase units), 51 substations
- Modeled 500kV and underlying 161kV network using PowerWorld
- Transformer DC winding resistance (bridge)
- Substation ground resistance by test



GROUND IMPEDANCE VALUES

Technical Support Branch ← Jerry Cooke
Compiled October 1, 1985

Substations, Generating Plants, Switching Stations, and Line Metering Points

Location	Station Ground Ohms 1	2	3	Fence Ground Ohms	Fence Tied to Station	Ground Condition	Test Date	Date Verified or Remarks

Resistances

Voltage	1-2 @ 24.7°C	1-2 @ 75°C
317550	.1631	.1950
310330	.1593	.1908
303110	.1554	.1856
295890	.1520	.1814
288670	.1483	.1722

LV	3-5 @ 24.7°C	3-5 @ 75°C	4-6 @ 24.7°C	4-6 @ 75°C
22500	.001568	.0009055	.001534	.0009055

TVA

PowerWorld

Simulator GIC option

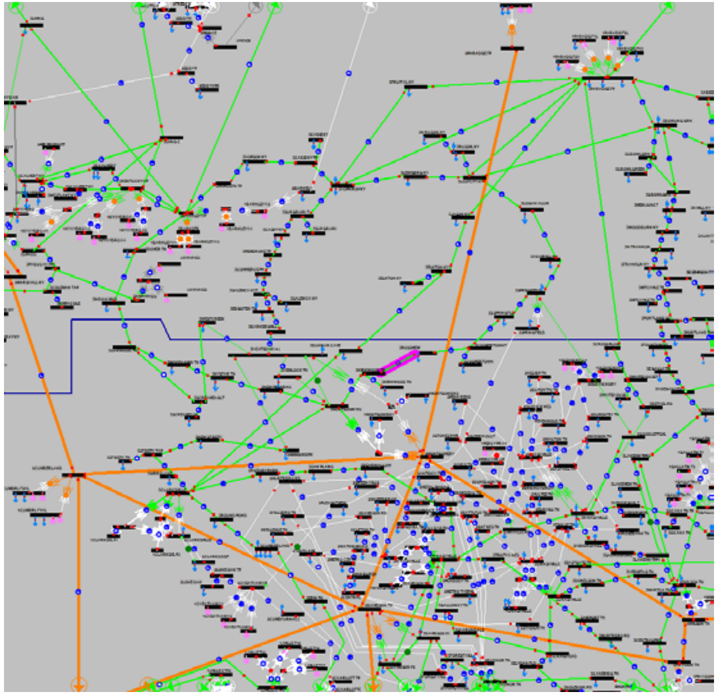
DC circuit model of the power grid for quasi-DC GIC calculation

GMD surface electric fields modeled as DC sources in series with transmission lines

Incorporates earth resistivity models, geomagnetic latitude scalars

Identify worst-case field orientation

Export transformer GIC time-series for thermal evaluation



Additional capability

GIC → Xfmr MVAR losses → AC loadflow

Vary E-field strength, calculate QV curves to point of collapse

Identify locations for mitigation

Building the Model

3.0 Resistance

HV Winding Voltage (kV)	HV Winding Position	Resistance at 75 °C (Ω)
550.00	17	0.201953
543.75	16	0.200626
537.50	15	0.199180
531.25	14	0.197612
525.00	13	0.196286
518.75	12	0.194839
512.50	11	0.193513
506.25	10	0.191945
500.00	9	0.190137
493.75	8	0.191945
487.50	7	0.193513
481.25	6	0.194598
475.00	5	0.196165
468.75	4	0.197492
462.50	3	0.199300
456.25	2	0.200626
450.00	1	0.202073

LV Winding Voltage (kV)	LV Winding Position	Resistance at 75°C (Ω)
165.025/√3	-	0.020002

TV Winding Voltage (kV)	TV Winding Position	Resistance at 75°C (Ω)
13.2	-	0.002157

Data gathering

- Transformers:
  - DC bridge test data from test reports
  - Core construction for three-phase banks
- Substation grounding resistances (dated 1960s-1980s)
- Transmission line DC resistance assumed equal to AC

Exchanging models with neighbors on request

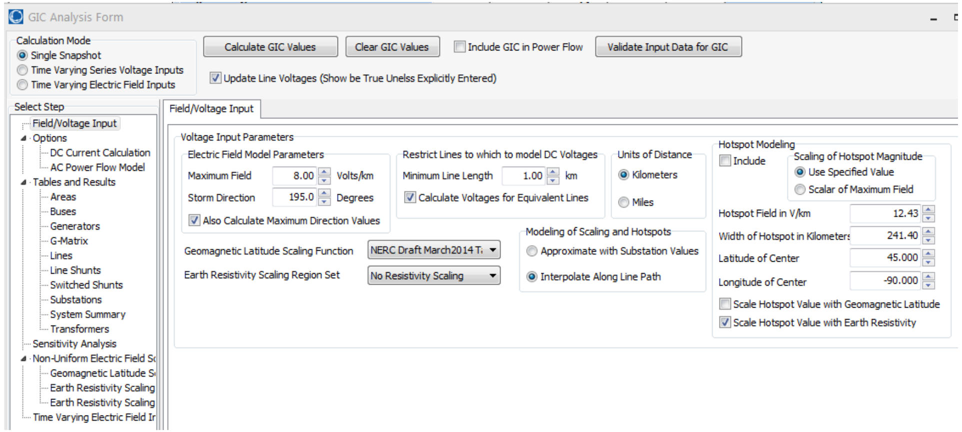
Took about 12 months

Sources included Transmission Planners, Field Offices, Equipment Vendors

Studies

- Winter 2016 base case
- Solve AC power flow
- Input substation/transformer/earth resistivity scaling region data
- Calculate GIC Values:
  - Constant electric field strength (8V/km), varying storm direction 0-360 degrees in 5 degree steps
  - Constant storm direction (15 degrees), increasing field strength up to 20V/km in 1V steps
    - 15 degrees was determined from step 1 to be worst case with all-ties-closed

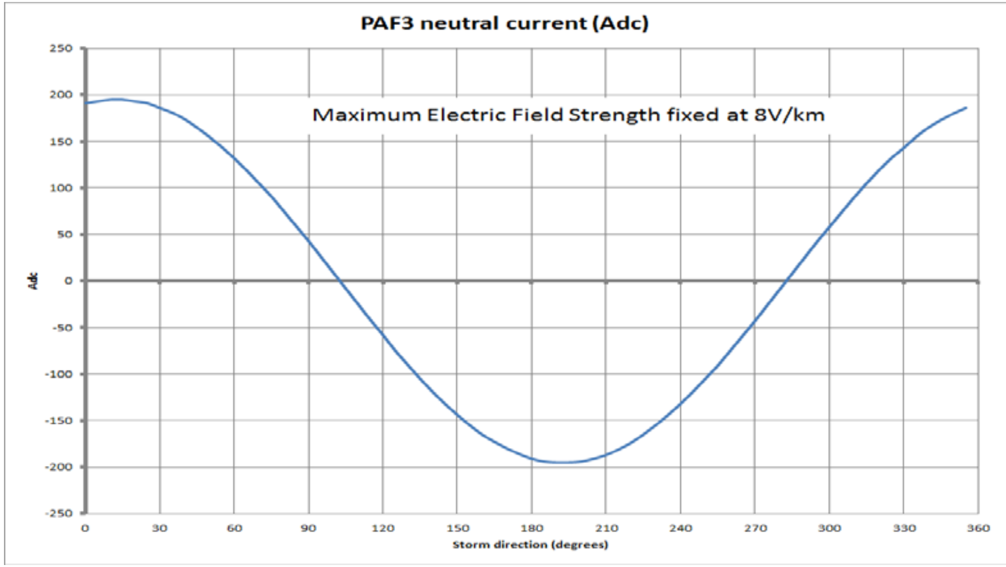
Substation Records						
Sub Name	Sub Num	Nominal kV(max)	Grounding Resistance (Ohms)	Latitude	Longitude	Bus Num
8BENTON MS	26512	500	0.47	34.829361	-89.20015	360612
8BR FERRY NP	26094	500	0.15	34.704365	-87.11862	360052
8BRADLEY TN	26547	500	1.31	35.04253	-84.95871	360662
8BULL RUN FP	26117	500	0.09	36.018799	-84.15793	360093
8ACKERMAN CC	26522	500	0.219	33.385777	-89.21067	360627



GIC Transformers													
Sub Name High	Nom kV High	Nom kV Med	Nom kV Ter	Manually Enter Coil Resistance	Coil Resistance (Ohms) for High winding	Coil Resistance (Ohms) for Medium winding	XF Config High	XF Config Med	XF Config Ter	Is Autotransformer	Core Type	GIC Model Type	GIC Model Param
Paradise Fossil Plant	500	24		Yes, User Set	0.1769	0.0018	Gwye	Delta		NO	Single Phase	Default	0
Montgomery TN 500kV Substation	500	161	13	Yes, User Set	0.2092	0.0216	Gwye	Gwye	Delta	NO	Single Phase	Default	0
Montgomery TN 500kV Substation	500	161	13	Yes, User Set	0.179936	0.015631	Gwye	Gwye	Delta	NO	Single Phase	Default	0
Browns Ferry Nuclear Plant	500	20		Yes, User Set	0.164575	0.00068258	Gwye	Delta		NO	Single Phase	Default	0
Browns Ferry Nuclear Plant	500	20		Yes, User Set	0.160235	0.0006717	Gwye	Delta		NO	Single Phase	Default	0

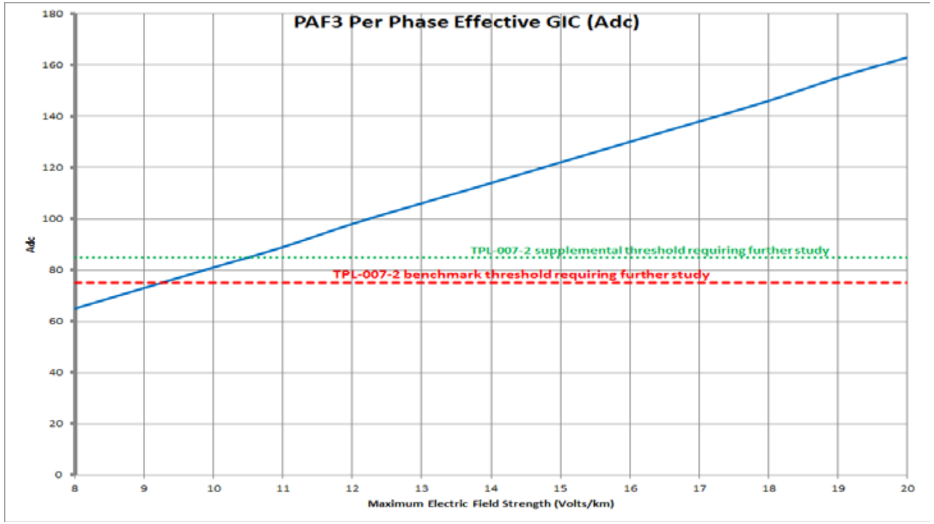
Results

- Most sensitive site is Paradise GSU #3
- Worst case is storm direction 15 (195) degrees: 195 Adc neutral current at 8V/km electric field strength

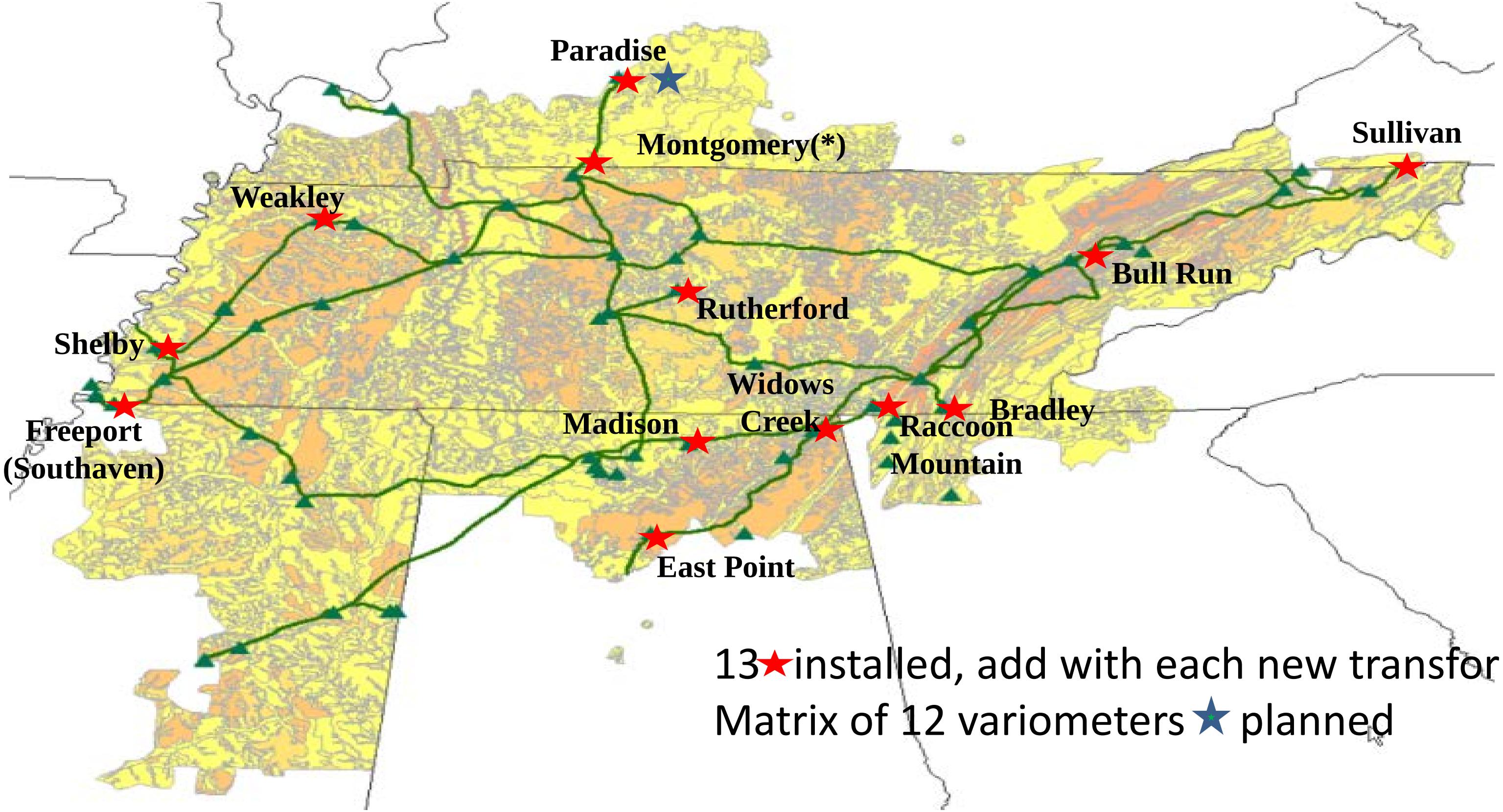


Results

- TPL-007-01 requires further study if GIC exceeds 75A/phase
- Study indicates PAF3 exceeds that threshold for electric field strength at 10V/km
  - At 19V/km two additional banks exceed 75A/phase: Bull Run, Weakley
  - At 20V/km one additional bank exceeds 75A/phase: Union Bk1
- A neutral blocking device (NBD) at PAF3 introduces no additional problems
- No thermal studies or remedial action required



GIC Monitor Network – EPRI Sunburst



13★installed, add with each new transformer

Matrix of 12 variometers ★ planned

TPL-007-01 Compliance

Requirement	Due Date	TVA Completion
R1 - identify PC & TP responsibilities	7-1-17	2-17-16
R2 - maintain system and GIC system models	7-1-18	2-17-16
R3 - have criteria for steady state voltage	1-1-22	2-17-16
R4 - GMD assessment complete & provided to RC and any requesters	1-1-22	2-17-16
R5 - provide GIC information to TO and GO for transformer assessment	1-1-21	2-17-16 (NA)
R6 - TO & GO conduct transformer thermal assessment for all >75A/ph	1-1-21	2-17-16 (NA)
R7 - develop corrective action plan as necessary	1-1-22	2-17-16 (NA)

Transformer Studies

A fleet of 231 Power Transformers (GSUs, Autos, and multiple windings)

- **Phase – I: Data Collection**
- **Phase – II: GIC Susceptibility analysis**
  - Using a design Index and a GIC level index**

    *** Based on GIC level a transformer is expected to be exposed to under 1 – 100 years Benchmark storm*

    => 94 Transformers requiring Thermal Assessment
- **Phase – III: Magnetic Fleet Assessment**
  - Provided K factor, VAR Demand, and Current Harmonics for all transformers on the fleet
    - For a range of GIC from 0 to maximum GIC provided by TVA
- **Phase – IV: Thermal Fleet Assessment**
  - Provided Windings and Structural parts hot spot temperatures for all 94 transformers on the fleet
    - When subjected to GIC Signatures provided by TVA

Transformer Studies

Task – I: Data Collection

General Information on Transformer				Transformer Information From Name Plate							
Transformer Serial #	Location	Ambient Temperature, C	Status	Type of Transformer	Manufacturer	Year of manufacture	Phase Count	MVA	HV Rated_Voltage, kV	LV Rated_Voltage, kV	HV Y-Connected Yes/No
12252	Canada	30	In Service	GSU	ABB	2009	1	290	735	13.8	Yes
12225	USA	30	In Service	Auto	ABB	2005	1	333	500	230	Yes
9855	Asia	30	Spare	GSU	ABB	2006	1	86	500	13.2	Yes
12140	Europe	30	In Service	Auto	ABB	2004	3	750	450	240	Yes
11111	India	30	Spare	Auto	ABB	2017	3	500	500	230	Yes

Information from Test Report				Design Information		GIC parameters	
Load Losses, kW	Top Oil Rise above Ambient, K	Windings Hot Spot Gradient, K	HV Windings Gradient at Full Load, K	Core Type	Mass of Windings, kg	Peak of GIC Pulse, Amps/ phase	Duration of GIC Pulse, minutes
588	48.2	17.4	12	1-Phase-Core-Form-4-limb-Core	20661	200	2
622	40.6	29.3	25.1	1-Phase-Core-Form-3-limb-Core	13993	200	1
260	48.9	19.2	15.8	1-Phase-Core-Form-2-limb-Core	9000	100	3
1093	36.5	35.5	23.5	3-Phase-Core-Form-5-limb-Core	56070	100	2.5
1000	40	30	25	1-Phase-Core-Form-3-limb-Core	25000	100	2

Transformer Studies

- **Based on Design and Maximum level of GIC**

  => 94 Transformers requiring Thermal Assessment

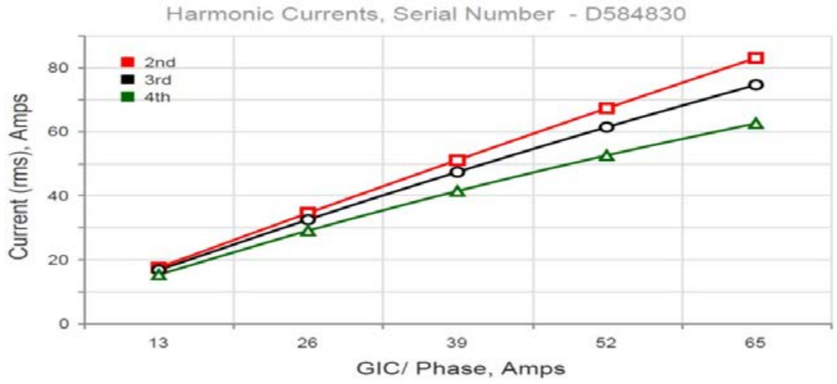
Number of transformers	Total Susceptibility Categories				
	IV	III	II	I	Total
Actual Count	22	72	137	0	231
% of Total	9.5 %	31.2 %	59.3 %	0 %	100 %

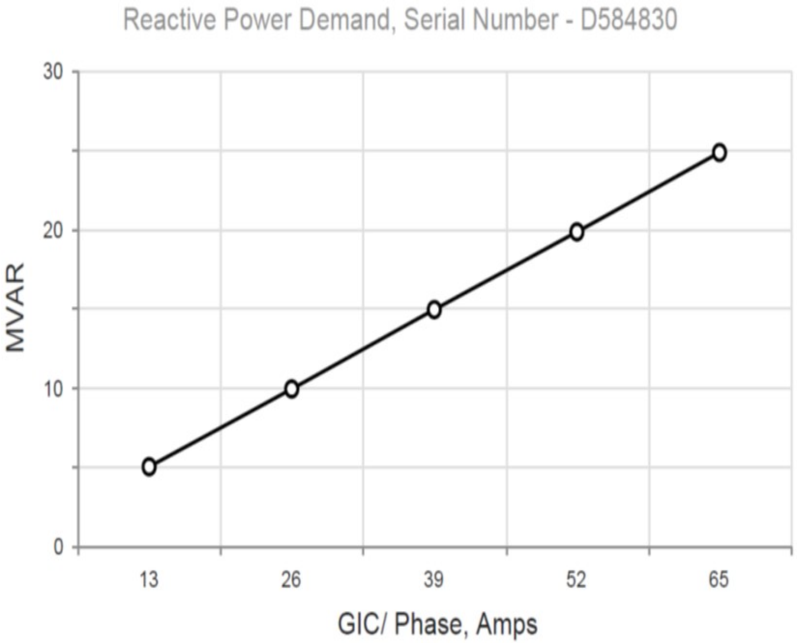
Transformer Studies

Phase – III: Magnetic Fleet Assessment

- Provided VAR Demand and Current Harmonics for all transformers on the fleet

Serial Number:	D584830
Location:	Paradise
Type:	GSU
Phase Count:	1
Top Rated Power:	470.4 MVA
Rated Voltage (HV):	500 kV
Rated Voltage (LV):	22.5 kV
Manufacturer:	GE
Manufacture-Date:	1966
Status:	In Service

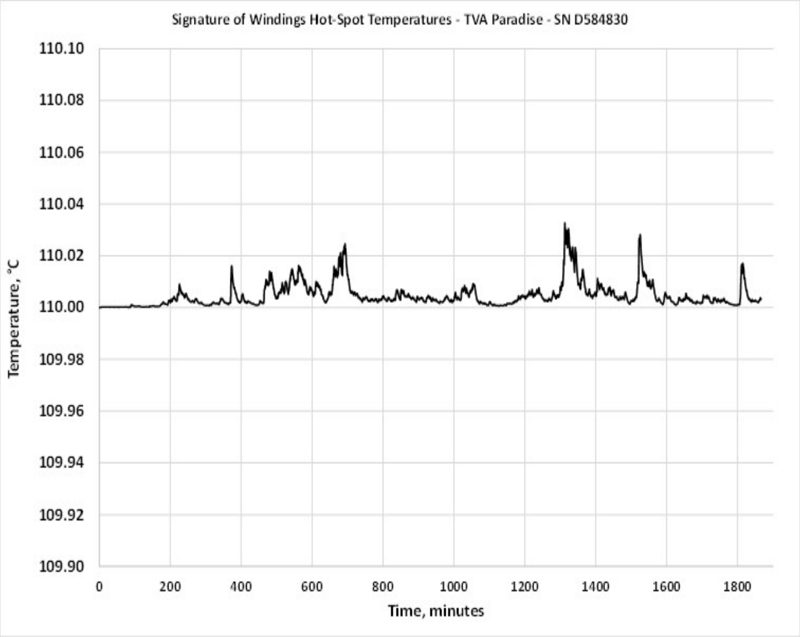


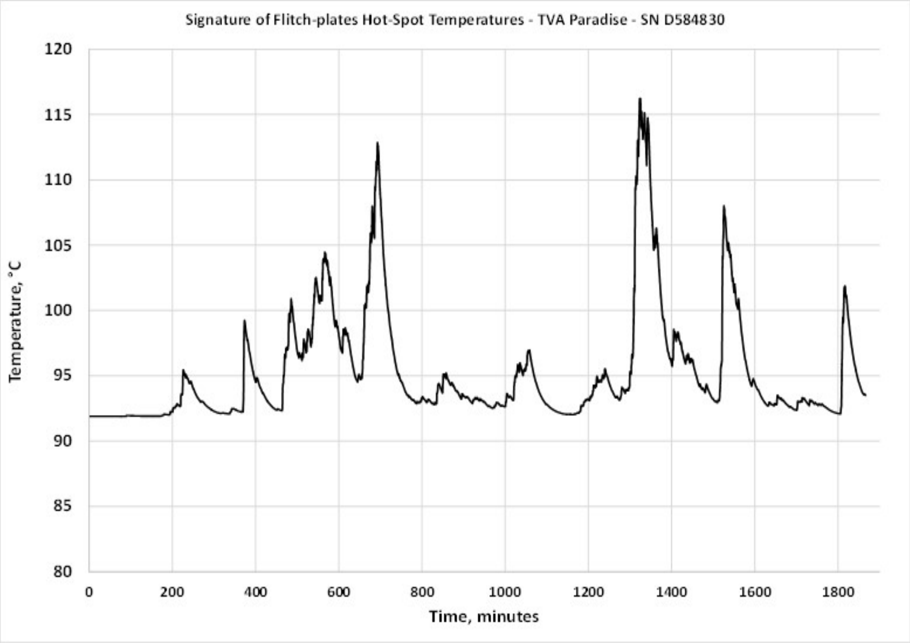


Transformer Studies

Phase – IV: Thermal Fleet Assessment

- Provided Windings and Structural parts hot spot temperatures for 94 transformers on the fleet
    - When subjected to GIC Signatures provided by TVA





Continuing Work

Calibration of model from measured data (we need a storm!)

Real time display for GIC and magnetic field

Operations steps for >> 1/100 year storm

Harmonic analysis and hardware sensitivity check

Questions?

isgrant@tva.gov

MISO TPL-007 Study Effort

NERC 6/13/2018 GMDTF Meeting

Justin Michlig – MISO Expansion Planning

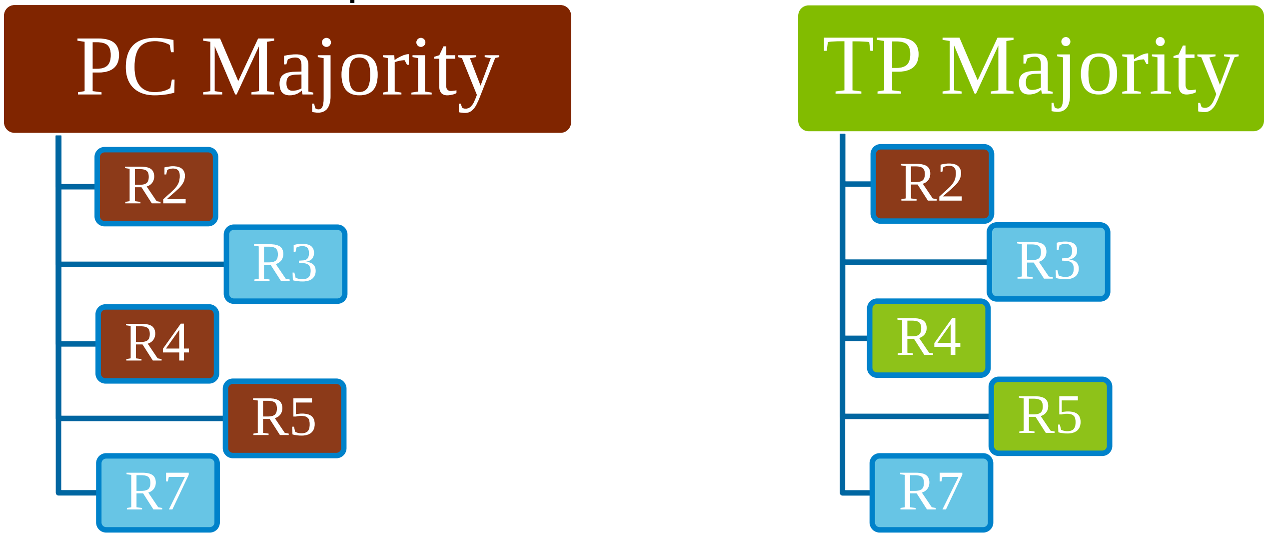
Objective

- Review study agreements between MISO and its Transmission Planners
- Discuss model creation
- Provide overview of study scope
- Present preliminary GIC flow magnitudes

TPL-007 Assignment of Responsibility

R1 Summary: Each PC and TP agree and identify who is responsible for each requirement.

Approach: Two agreements were developed collaboratively by MISO and applicable Transmission Planners within its footprint to assign PC, TP and Shared responsibilities



Model Creation for MISO Footprint

MISO Footprint

- Held multiple workshops
- Submission Deadline of December 2017
- Data was iteratively improved with member feedback

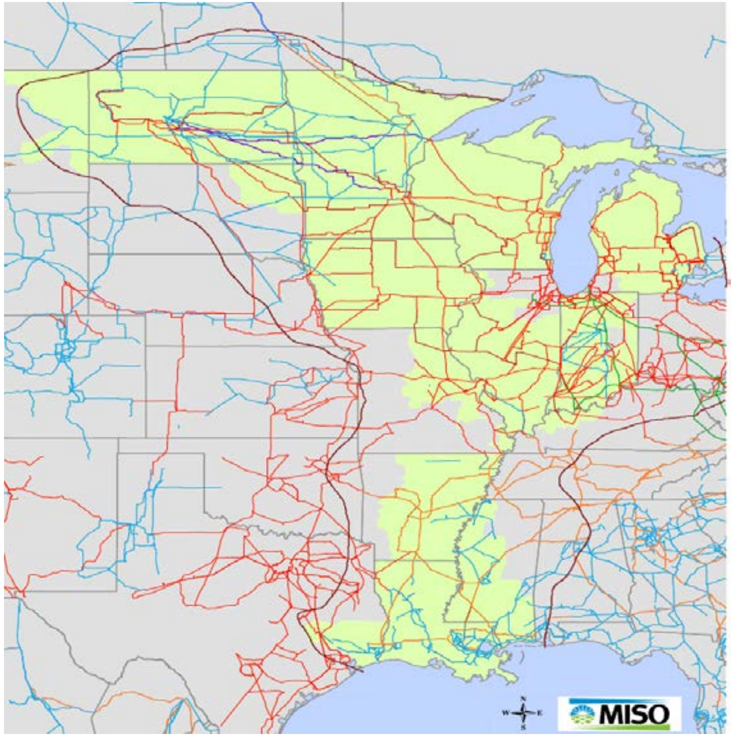
Neighbor Coordination

- MISO met with interconnected PCs
- Shared data mid April
- Currently incorporating non-MISO data for 7/1 deadline

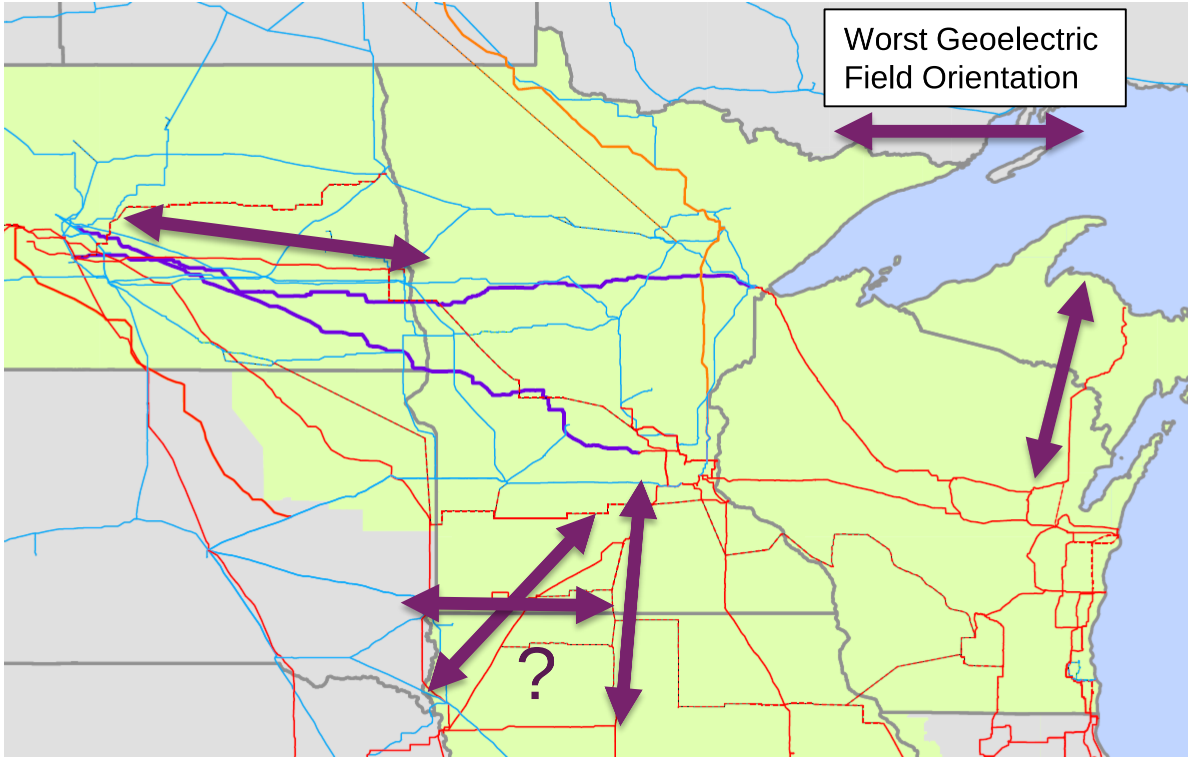
Common Theme: The complexity and newness of GIC data collection and compilation posed an increased challenge to both MISO, its TPs and neighbors. Assembled data quality varied and multiple iterations of feedback were required to improve overall model accuracy.

TPL-007 Study Area

- Study area
  - Generally two substations into External with additional pockets below
  - Coal fields in ND to Iowa, north to MH parallel 230 KV east west system around the angle into MISO
  - All Chicago area
  - Most AECI
  - Northern Indiana/Southern Michigan
- Additional details
  - Generally 200+ kV
  - Lower kV inclusions submitted by MISO members
  - Future facilities are included in study to represent 2023 topology



Geoelectric Field Orientation Selection

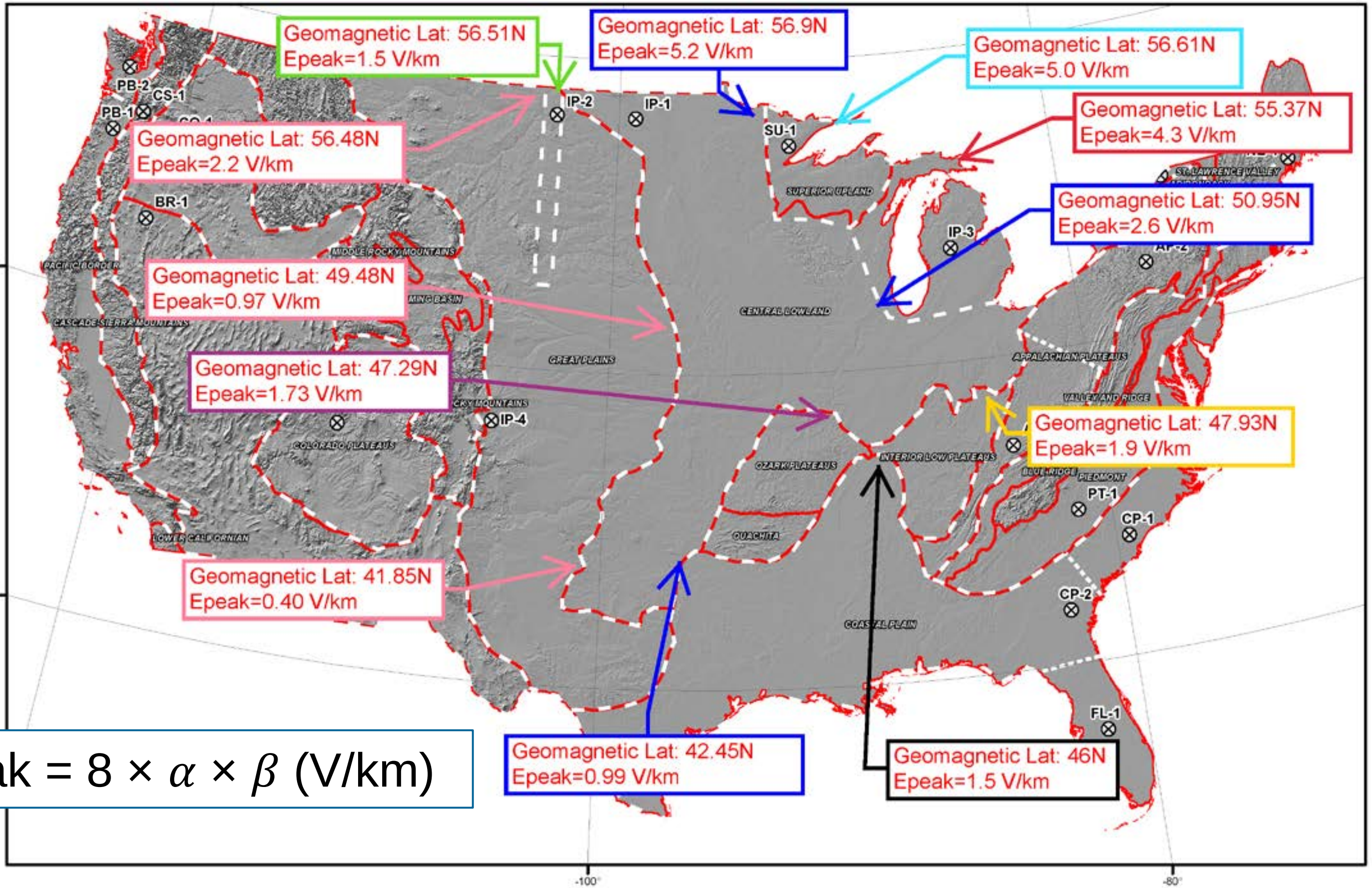


MISO plans to increment in single degree steps for Geoelectric field orientation and solve the AC power flow on each step.

GIC and AC Power Flow Simulations

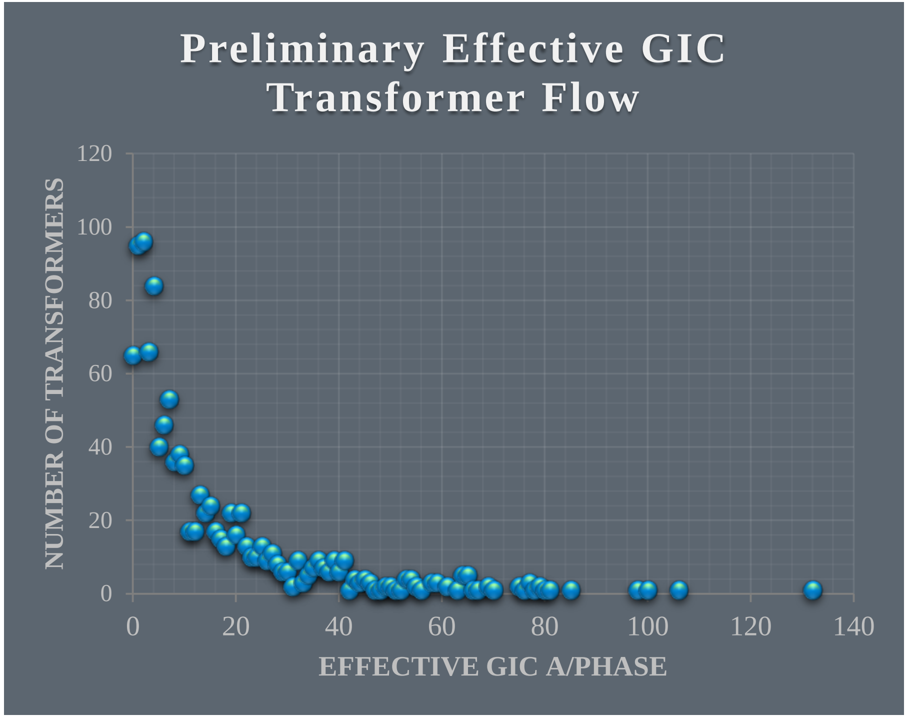
- Assumptions within simulation
  - Energization of normally open assets
    - Assets remain interconnected, but out-of-service in the model which will impact GIC paths and performance
  - Implicit device inclusion
    - Ex. HVDC and load represented transformers
    - MISO will apply var consumption from devices which tools do not include
- Sensitivity runs
  - Varying ground grid resistance assumptions when data not provided
  - Bypassing series capacitors

Geoelectric Field Throughout MISO



Epeak = 8 × α × β (V/km)

Preliminary GIC Flow Results



- Approximately 1,100 transformers in MISO
- 16 are at or above 75 A/phase
- Based on model prior to integrating Neighboring system
- Refinements for MISO member data pending

Questions and Contact

Expansion Planning

- Justin Michlig
  - Jmichlig@misoenergy.org
- Hilary Brown
  - Hbrown@misoenergy.org
- Lynn Hecker (Sr. Manager)
  - Lhecker@misoenergy.org

System Modeling

- Matthew Ladd
  - Mladd@misoenergy.org
- Amanda Schiro (Manager)
  - Aschiro@misoenergy.org

GIC Analysis with Real Operation Topologies

Rui Sun
Transmission Planning, Dominion

Dominion

GMTDF, 6/13/2018

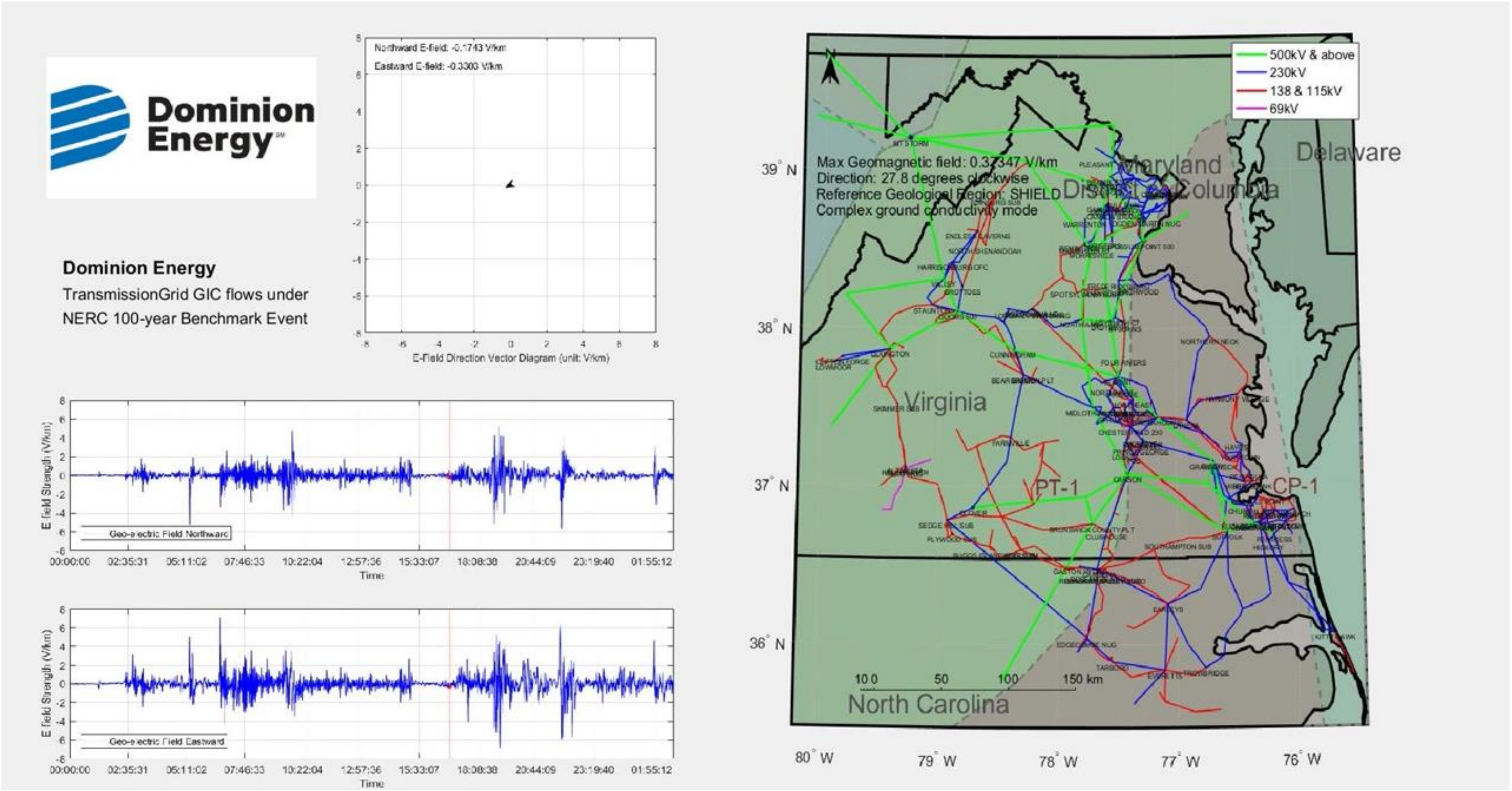
Dominion GIC Model

Modeling Dominion Transmission System

<table>
<tr><th></th><th>2015</th><th>2017-2018</th></tr>
<tr><td>Map Size</td><td>1000 nodes</td><td rowspan="3">ET Planning model (MMWG/RTEP model PSS\e format)</td></tr>
<tr><td>Voltage Included</td><td>500, 230, partially 115</td></tr>
<tr><td>Transformers</td><td>69kV and above, ET and GSUs</td></tr>
<tr><td>Real Time Topology</td><td>Included</td><td>Included</td></tr>
<tr><td rowspan="2">Ground conductivity</td><td rowspan="2">EPRI 1D Ground conductivity model</td><td>EPRI 1D Ground conductivity model</td></tr>
<tr><td>Earthscope 3-D Magnetotelluric transfer functions</td></tr>
<tr><td>Latitude coefficients</td><td>Considered</td><td>Considered</td></tr>
<tr><td>Time series capability</td><td>Yes</td><td>Yes</td></tr>
<tr><td>Local Enhancement</td><td>Partially</td><td>Yes</td></tr>
<tr><td>VAR Consumption</td><td>Yes, export to PSS\e</td><td>Yes,export to PSS\e</td></tr>
<tr><td>Thermal Analysis</td><td>Static</td><td>Static and Dynamic</td></tr>
</table>

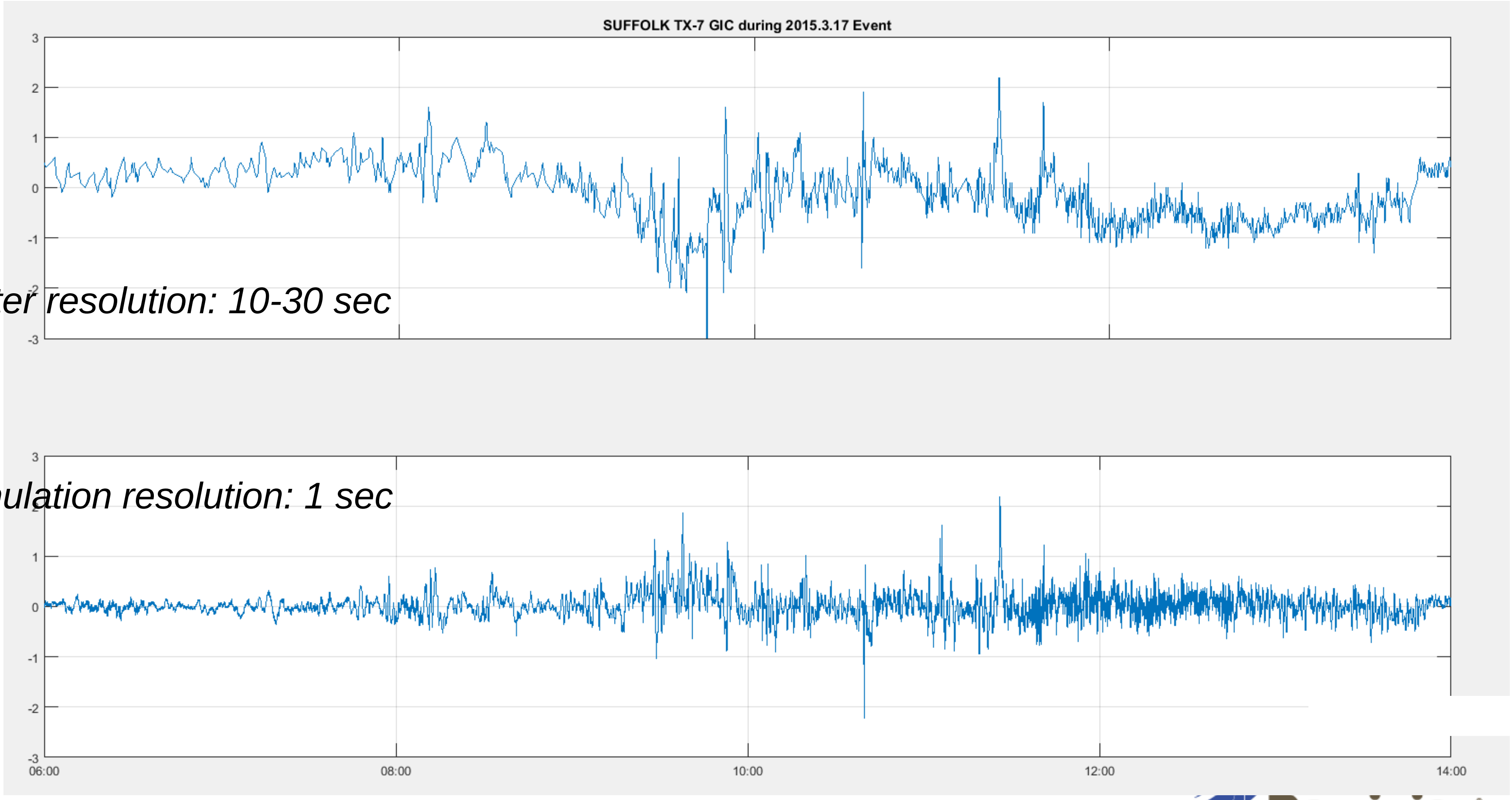
Dominion GIC Model

Modeling Dominion Transmission System



GIC Model Validation

GIC Model validation – Playback of 2015.3.17 K8(G4) storm:



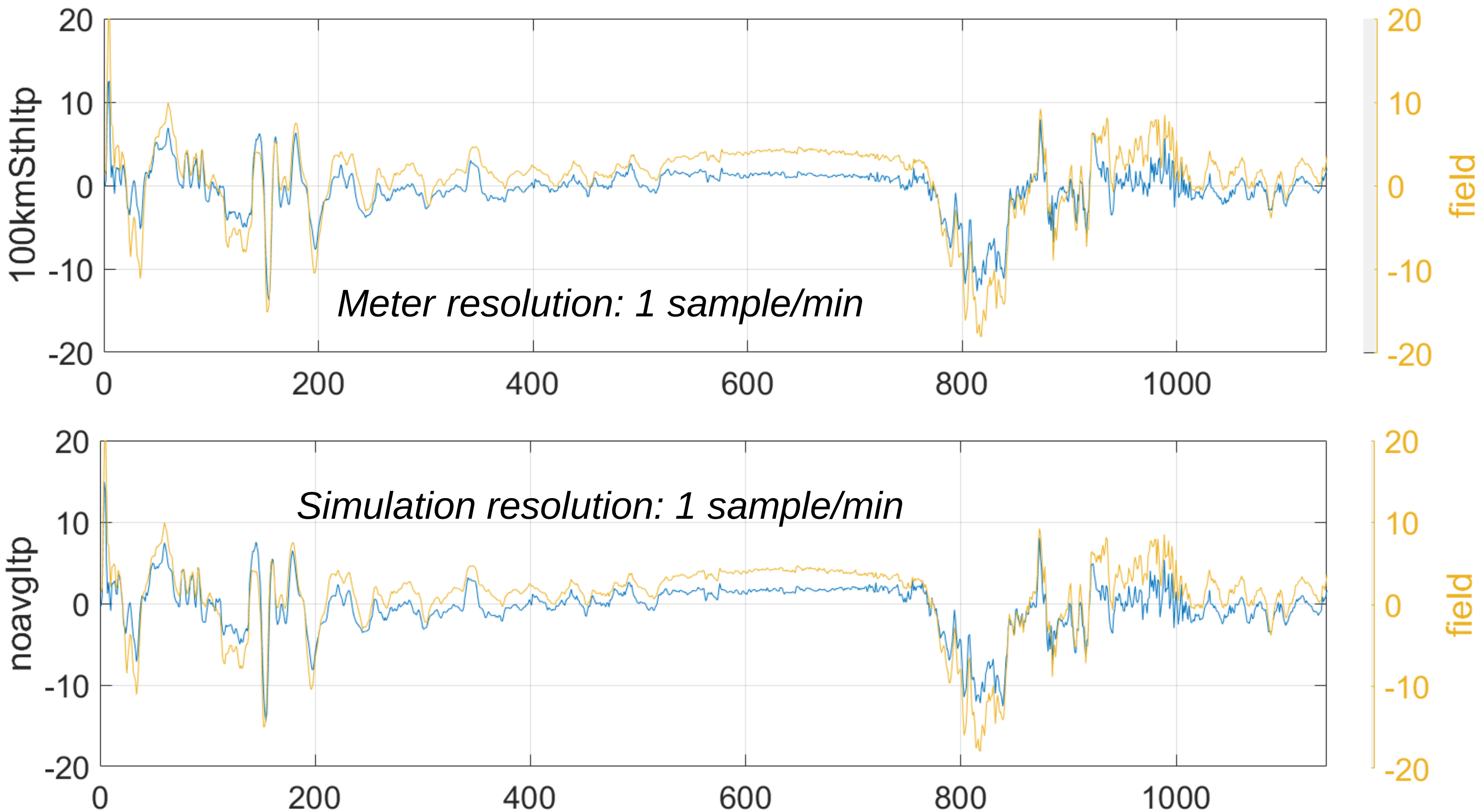
Meter resolution: 10-30 sec

Simulation resolution: 1 sec

Dominion

GIC Model Validation

GIC Model validation – Playback of 2017.9.7 K8(G4) storm with E-fields from Earthscope 3-D *Magnetotelluric transfer functions*:



Transformer GIC Analysis

TPL-007: Each TO/GO shall conduct a thermal impact assessment for its solely and jointly owned applicable BES power transformers where the maximum effective GIC value provided is **75A per phase** or greater.

GIC assessment on ET Planning model:

- MMWG/RTEP model with Summer Peak Loading condition;
- All lines are in service;
- EPRI 1-D model is used;
- 8V/km storm peak is used.

Transformer GIC Analysis

GIC assessment on ET Planning model:

MMWG/RTEP model with Summer Peak Loading condition and all lines in-service results

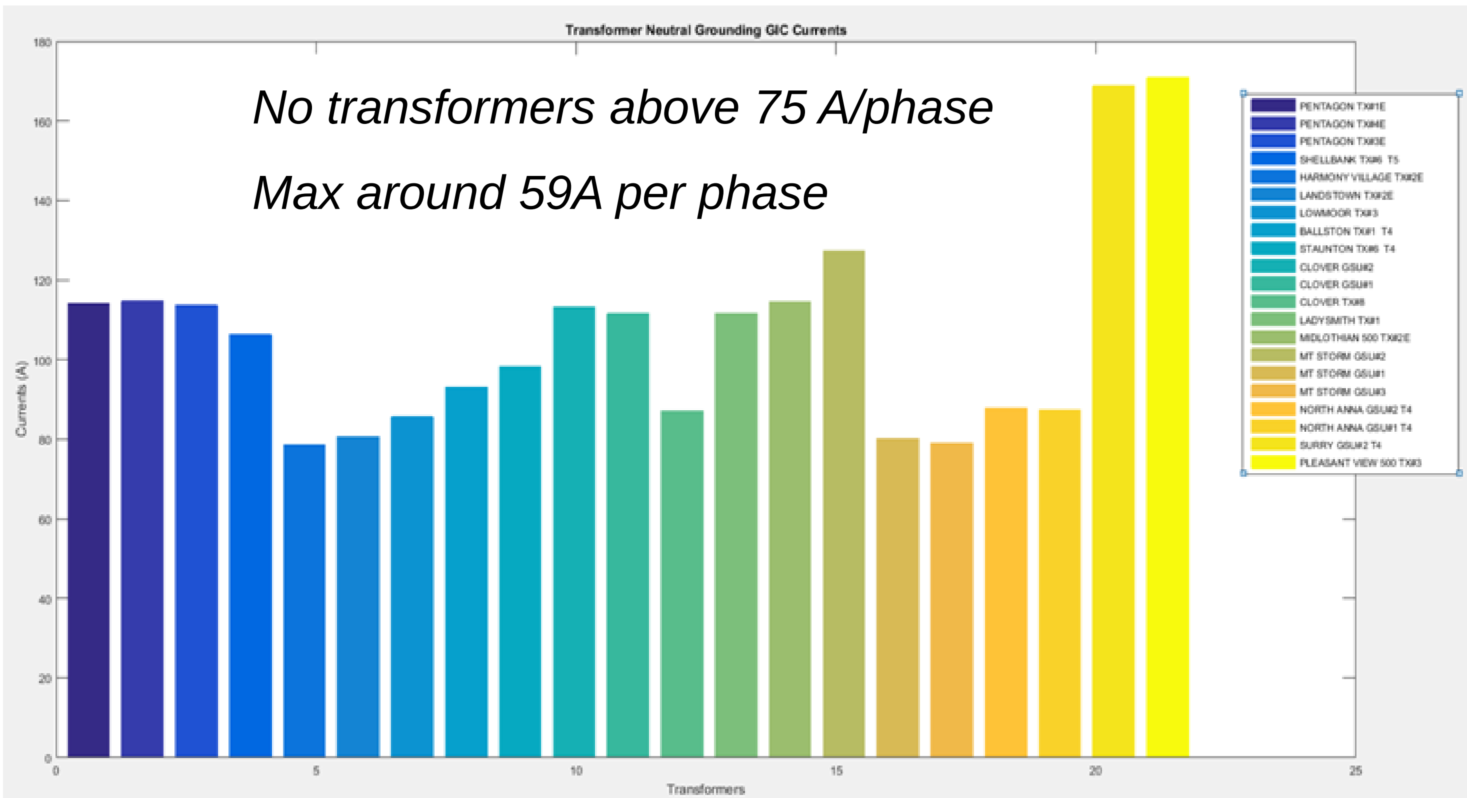


Figure 1: Transformer Neutral Grounding GICs under 100-year Benchmark Case (above 75A)

Transformer GIC Analysis

GIC assessment on ET Planning model using actual system topologies:

- Outage records of a whole physical year (365 snapshots of system operation topologies from Dominion System Operations Center);
- Daily peak load data is obtained as well;
- Summer Peak Load Model with updated topologies.

Transformer GIC Analysis

GIC assessment on ET Planning model using actual system topologies:

- 17 out of 400 TXs above 75A/phase at neutral/primary winding (16 of 17 are 500kV Auto TX or GSU)
- Test shows coherence with "full in-service" topology model

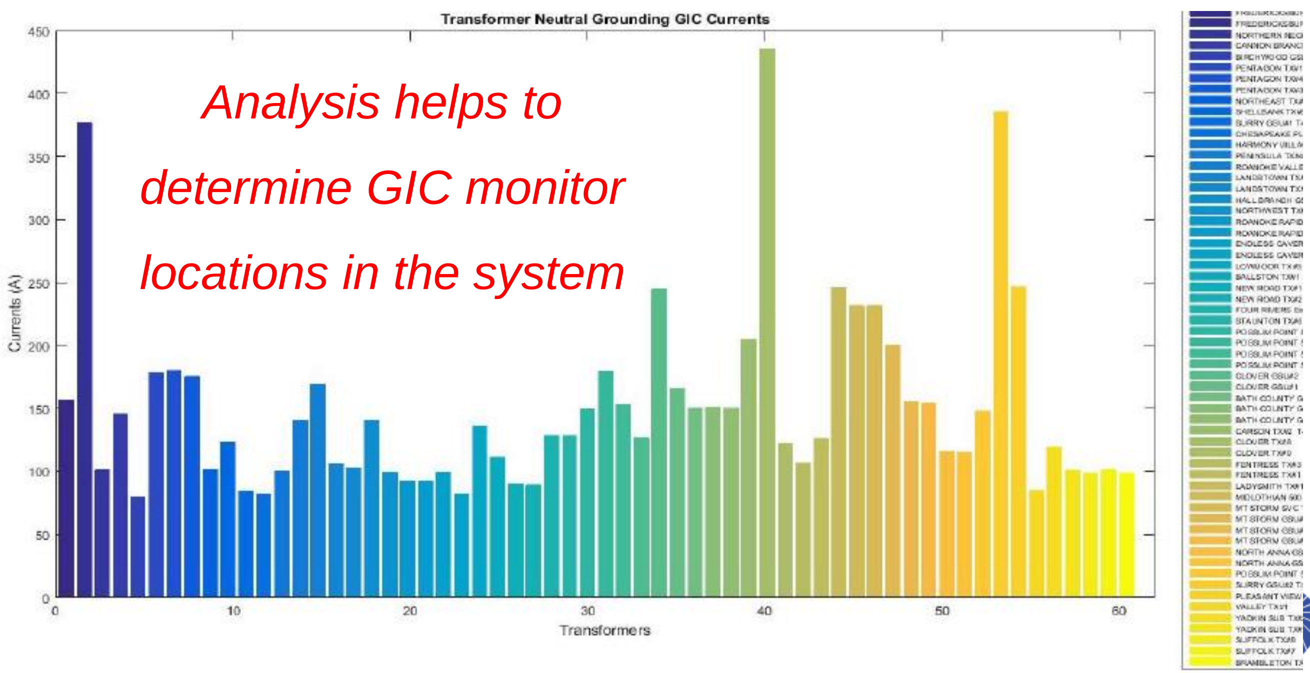


Figure 4: Transformer Neutral Grounding GICs under 100-year Benchmark Case (above 75A)

Transformer GIC Analysis

Transformer thermal assessment

- Static “Envelop Method” thermal assessment
- Dynamic thermal assessment use Dominion transformer thermal model

No Violation – no hot spot temperature rise above 200 C

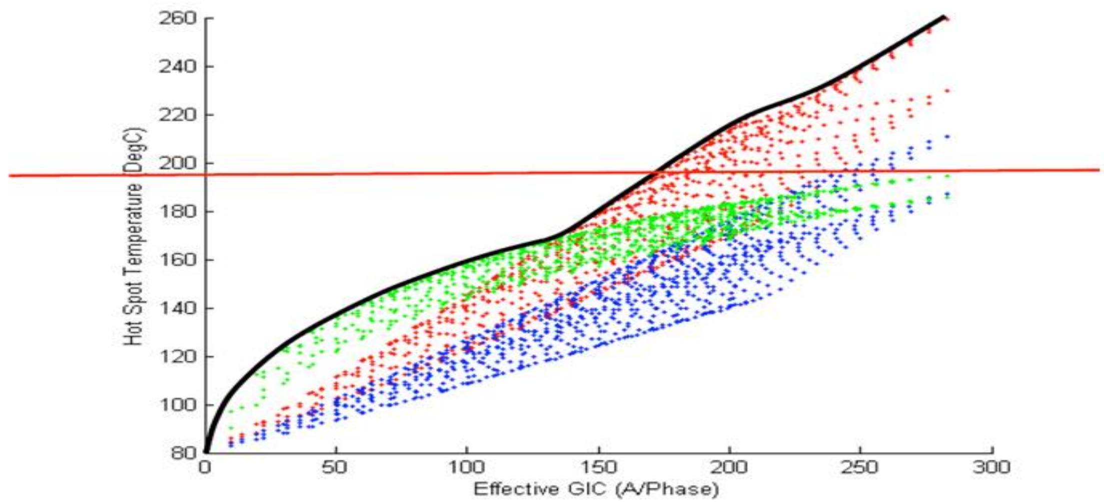
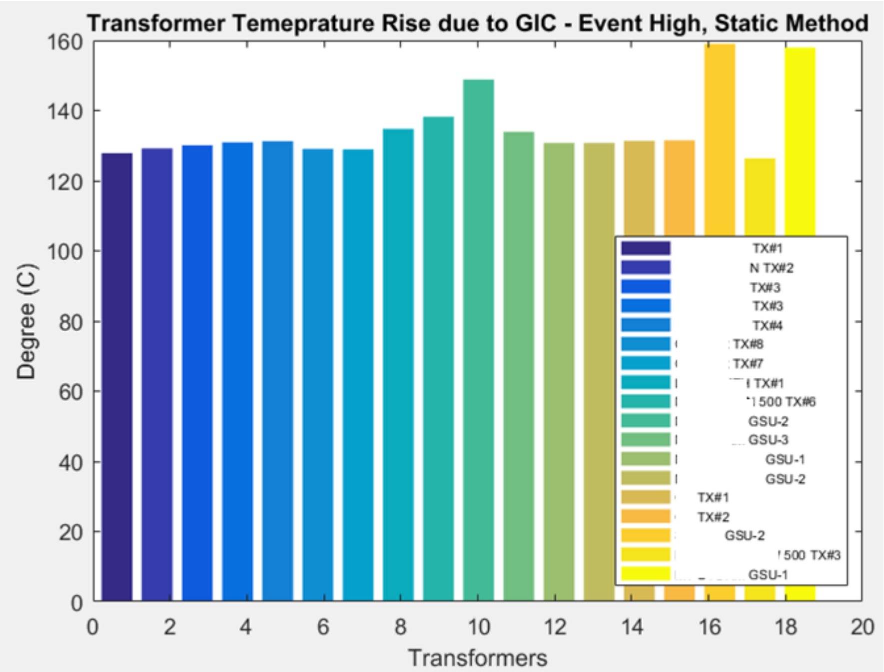


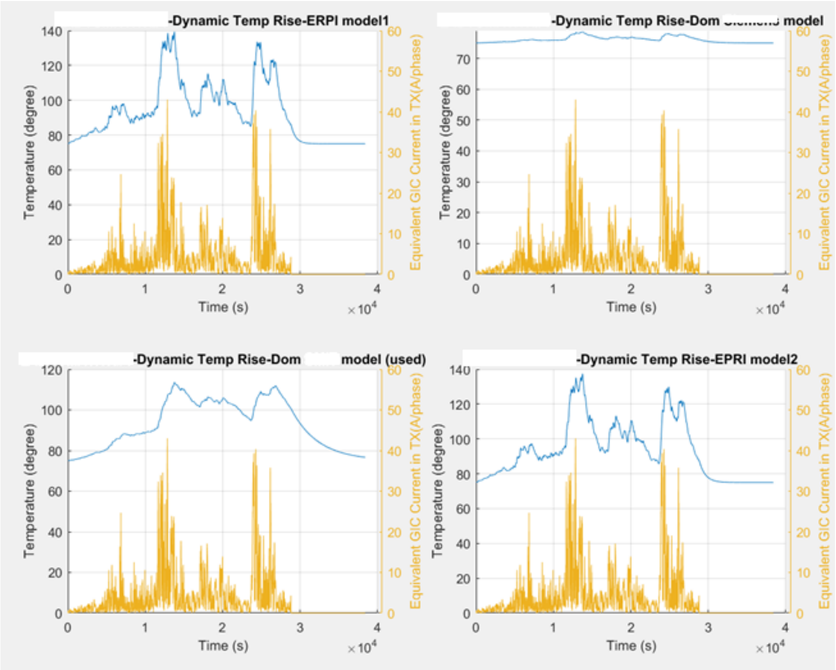
Figure 7: The Thermal Envelope of Peak Hot Spot Temperatures of different Transformer Thermal models (Green: Autotransformers; Red: SVC Coupling Transformers; Blue: Fingrid Transformers)[12]

Transformer GIC Analysis

GIC Modeling – Transformer Thermal Analysis



Static Envelop method for TX temperature rise



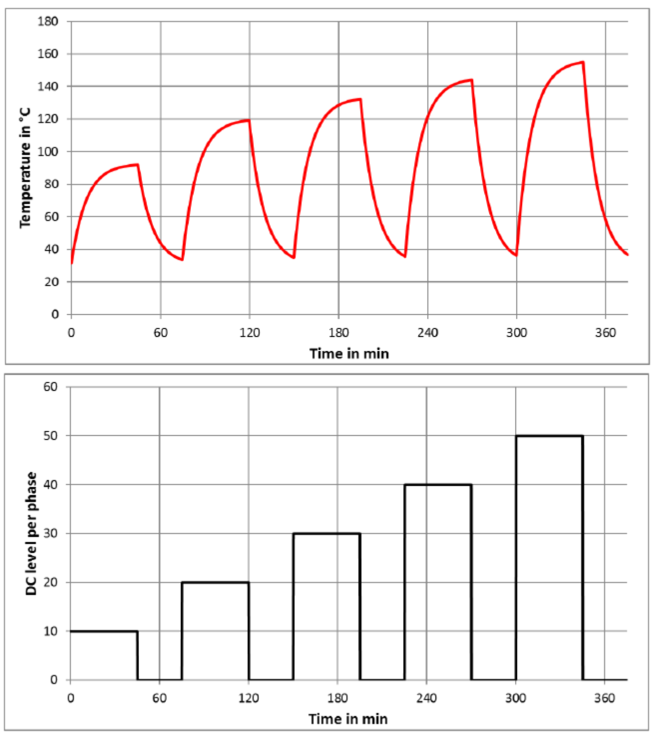
Dynamic TX temperature analysis

Standard requires static method to be applied by TO/GOs.
Dynamic method has higher requirement but more accurate.

Transformer GIC Analysis

Transformer Thermal Analysis

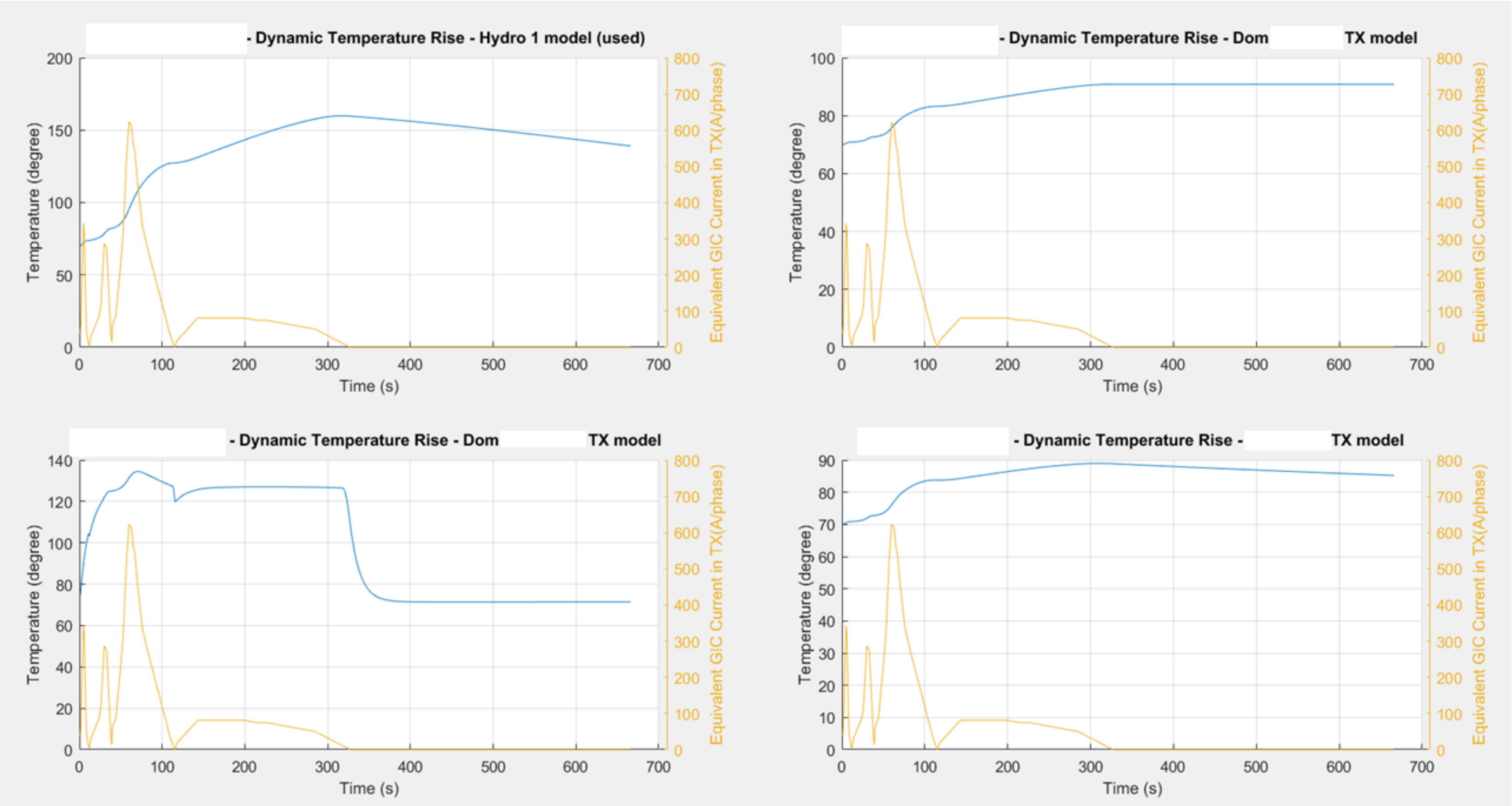
- GMDTF/EPRI Hydro 1 transformer thermal model;
- Three thermal models for major Dominion 500kV auto transformers (from vendor factory test and simulation reports).



- *Single phase 133.3MVA 230-115-13.2kV auto*
- *Single phase 133MVA, 500-16.5kV GSU*
- *3 phase 400MVA, 410-120-21kV GSU*
- *Dominion model1, 500-230kV auto (Core form)*
- *Dominion model2, 500-230kV auto (Shell form)*
- *Dominion model3, 500-20kV GSU*

Transformer GIC Analysis

TX thermal assessment – same technique used for HEMP E3 calculation

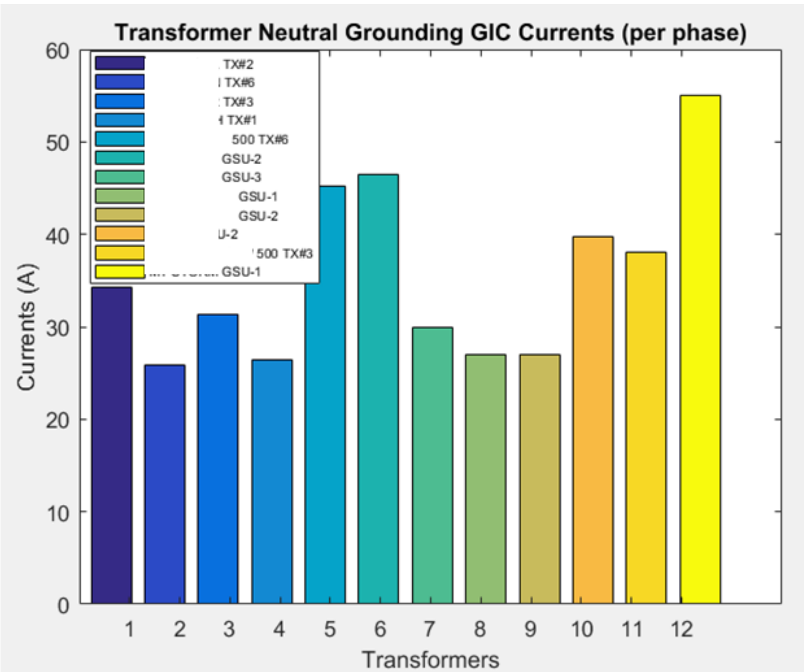


Dynamic temperature rise with ORNL-Sub-83/43374/1 report HEMP signature

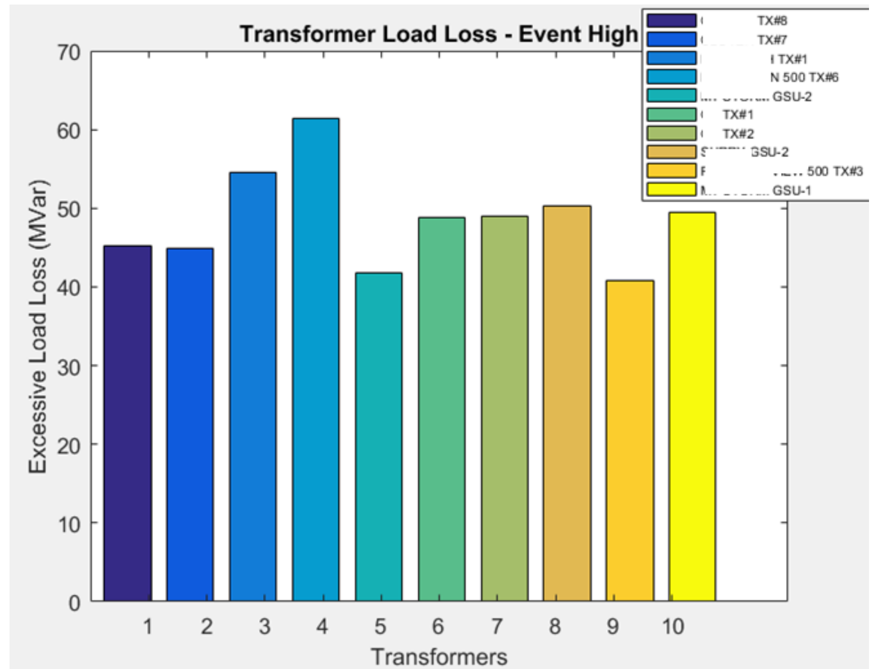
Dominion

Transformer GIC Analysis

GIC Modeling – Analysis of Transformer VAR consumption



Max neutral grounding GIC during 100 year event



Max VAR consumption during 100 year event

PSS\e TX VAR consumption model automatically generated to study system reliability

Dominion

Transformer GIC Analysis

Next Step:

- Dynamic simulation for excessive VAR consumptions;
- GIC Local enhancement analysis;
- GIC analysis using E-fields from Earthscope 3-D Magnetotelluric transfer functions.

Transformer GIC Analysis

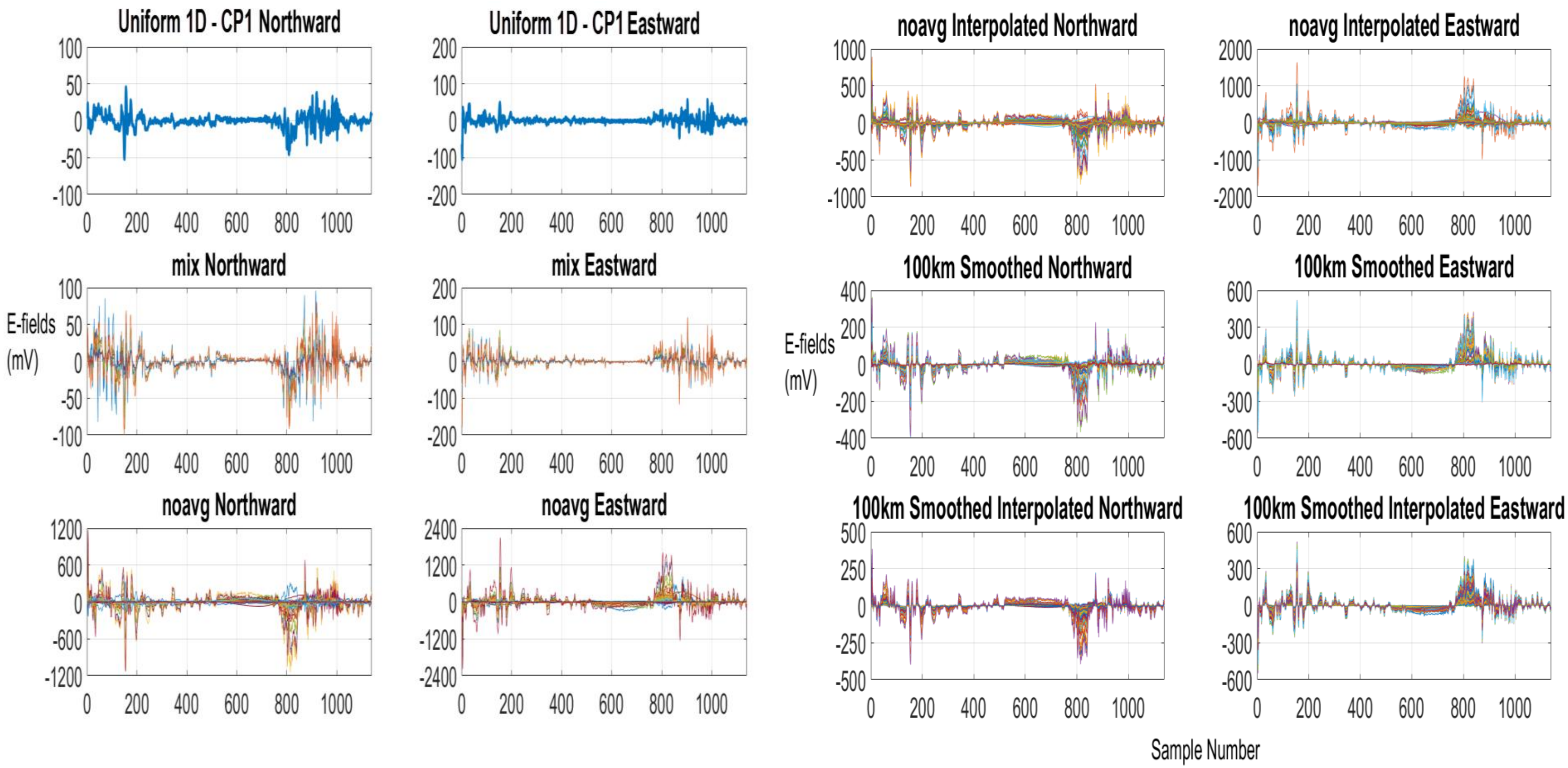
Earthscope 3-D Magnetotelluric transfer functions:

- Currently collaborating with Christopher Balch (NOAA);
- Utilize E-fields generated through Earthscope 3-D Magnetotelluric transfer functions for GIC calculation;
- Preliminary findings show the GICs are significantly larger due to larger local E-fields;
- At some locations a better matching between measurements and the simulation is observed using 3-D data;

<u>Everything is preliminary now and subject to change/updates.</u>

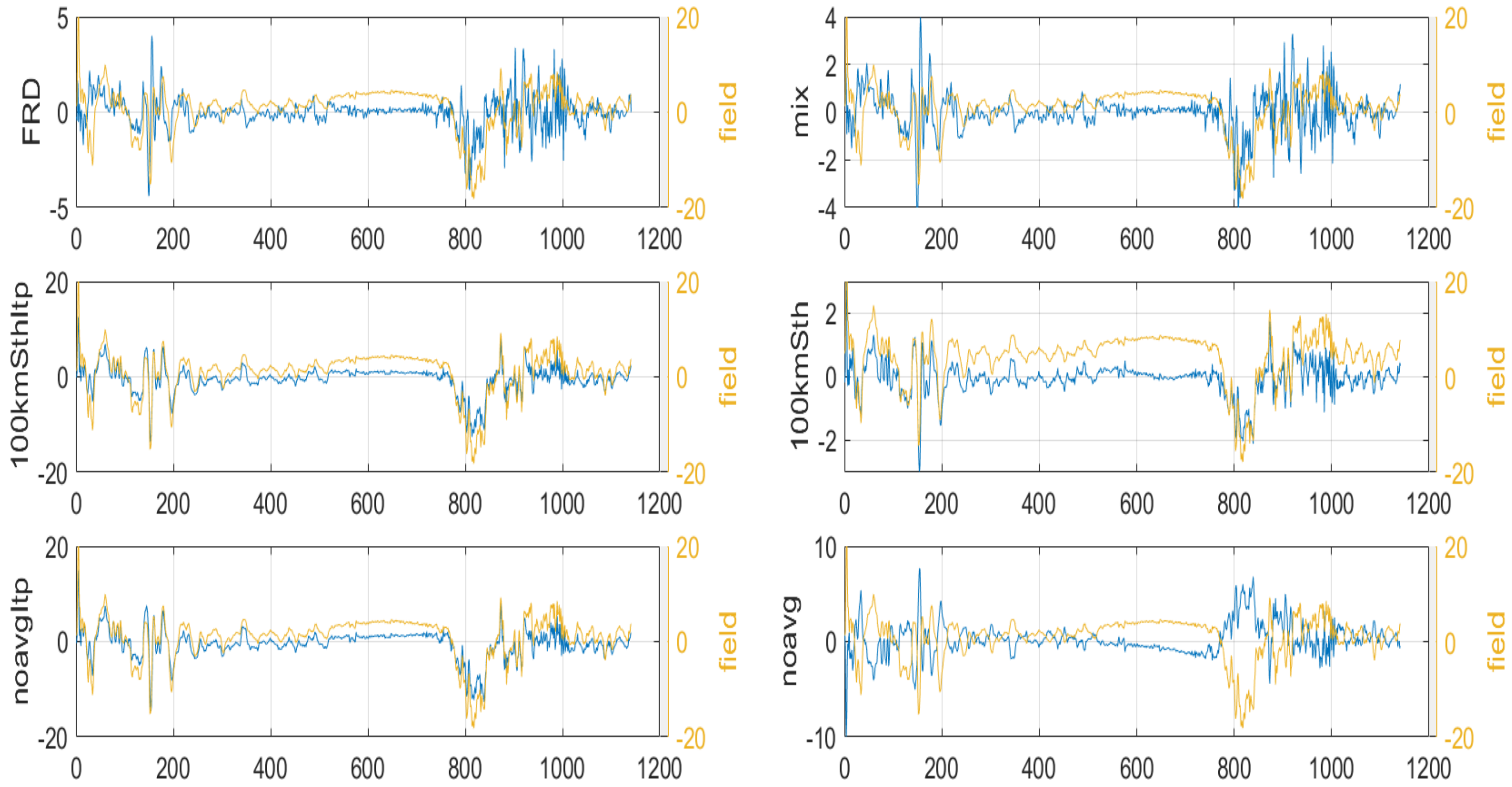
Transformer GIC Analysis

Earthscope 3-D Magnetotelluric transfer functions:



Transformer GIC Analysis

Earthscope 3-D Magnetotelluric transfer functions:



Dominion

Transformer GIC Analysis

Earthscope 3-D Magnetotelluric transfer functions:

Averaged Line GIC Magnitudes

$$\text{ALGM}_{Voltage\ level=n} = \frac{\sum_{Voltage\ level=n} GIC\ on\ the\ line \times line\ length}{\sum_{Voltage\ level=n} line\ lengths}$$

(unit: A)

AVERAGED LINE GIC MAGNITUDES INDEX WITH DIFFERENT E-FIELD CONDITIONS FOR DVE SYSTEM AND TIE-LINES

	FRD data (ref)	Mix	Noavg	Noavg inter-polated	100km smooth	100km smooth Interpolated
ALGM_{500kV}	11.2	9.7	41.8	46.2	36.4	38.2
ALGM_{230kV}	2.3	2.4	11.8	11.0	8.3	8.7
$\text{ALGM}_{<200kV}$	1.8	2.3	7.1	6.8	6.3	6.1
$\text{ALGM}_{all\ kVs}$	**4.4**	**4.2**	**17.5**	**18.5**	**14.7**	**15.2**

Thank you!
Questions/Comments?

ERCOT PGDTF TPL-007-1 Implementation and Preliminary Results

Presentation to

NERC Geomagnetic Disturbance Task Force (GMDTF) Meeting

June 13, 2018, Charlotte, NC

Michael Juricek

Oncor Electric Delivery

ERCOT PGDTF TPL-007-1 Administrative Activities

- Late 2014 ERCOT Reliability Operations Subcommittee (ROS) Created Planning Geomagnetic Disturbance Task Force (PGDTF).
- July 2016 − Completed a GIC System Model Procedure Manual.
- July 2016 − Acquired Software to build the Models and Perform Assessments (ERCOT and some TPs).
- October 2016 − Revision to Planning Guide for GIC Model Data.
- October 2016 − Resource (GO) Registration Glossary Update for GIC Model Data.
- June 2017 − Completed Revision to Planning Guide to Document Responsibilities (TPL-007-1 Requirement 1).
- January 2018 – Updated GIC System Model Procedure Manual.

ERCOT PGDTF TPL-007-1 Modeling Activities

- September 2016 − Created a Template for the TPs’ GIC Data Submissions.
- Fall of 2016 − Began Utilizing PSSE GIC Module to build the ERCOT GIC System Model.
- December 2016 − Completed First TP Data Submittal for 345 kV System Based on 2021 Summer Peak Case.
- March 2017 − Completed Second TP Data Submittal for 138 kV and 69 kV System.
- May 2017 − ERCOT Completed First Request for GO Data.
- May 2017 − TPs Sponsored a Workshop for GOs to Share Experiences and Best Practices Related to GIC System Model Data.

ERCOT PGDTF TPL-007-1 Modeling Activities Continued

- September 2017 − Completed Several Additional ERCOT GIC System Model Revisions with the First In-Person TP Only GIC Model Review.
- October 2017 − Began TP Data Submittal for GIC System Model Based on 2021 Minimum Case.
- April 2018 – Completed Final Draft Version of GIC System Models for 2021 Peak Case and 2021 Minimum Case (TPL-007-1 Requirement 2).
- May 2018 − Began Discussing Adjustments to GIC System Models before Starting GMD Vulnerability Assessment.

ERCOT PGDTF TPL-007-1 Vulnerability Assessment Activities

- August 2017 − Completed First Draft of Vulnerability Assessment Scope and Process. Revision is Being Discussed.
- October 2017 − Begin Drafting Criteria for Acceptable System Steady-State Voltage Performance (TPL-007-1 Requirement 3).
- ERCOT Vulnerability Assessment activities to begin July 2018
  - ✓ Targeting ERCOT Release of Initial GIC Values − July 2018.
  - ✓ Targeting Event Descriptions from TPs − December 2018.
  - ✓ Targeting Transformer Assessments for inclusion in Vulnerability Assessment − July 2019.
  - ✓ Targeting ERCOT Release of Preliminary Vulnerability Assessment Results − July 2019.
  - ✓ Targeting ERCOT Release of Draft Final Corrective Action Plan, if Needed − October 2019.
  - ✓ Targeting ERCOT Release of Final Draft Vulnerability Assessment and Corrective Action Plan − December 2019.

ERCOT PGDTF TPL-007-1 Preliminary Results

- Preliminary GIC Flows Through Transformers are Below 75 Amperes.
- Reactive Power Losses for Transformers Have Increased, but are Not Excessive.
- Impact on Steady-State Voltages has Not been Determined.

ERCOT PGDTF TPL-007-1 Identification of Issues and Concerns

- Some Transformer and Shunt Reactor Test Reports are Not Readily Available.
- K Factor Values are Not Readily Available and Assumptions are Noticeably Different in Different GMD Software.
- Substation Grounding Resistance Calculations/Measurements are Not Readily Available.
- Inclusion of Shield Wires in Substation Grounding Resistance Calculations Practice is Different for TPs and GOs.
- Reconciling Ownership Interface Data Submissions (TP/GO or TP/TP).
- Determination of Event Descriptions for Vulnerability Assessment including a concern of timing of EPRI/NERC Harmonic Tool Availability.

ERCOT PGDTF TPL-007-1 Identification of Issues and Concerns Continued

- Difficulty getting Stakeholders to Respond to Data Request.
- GMD Software is Still Evolving, and There are Challenges Combining GIC Data from Multiple TPs and GOs.
- Checking GIC Data and Models is Challenging.
- GIC Models Quickly Become Stale during 60-Month GMD Vulnerability Assessment Period.
- Should the Same System Models be Used to Build the GIC Models that Will be Used for the GIC Calculation for Transformer Thermal Impact Assessment and GMD Vulnerability Assessment?
- Should Non-GMD Related Equipment Outages be Included in GMD Vulnerability Assessment?
- How Should TPL-007-2 be Combined with TPL-007-1 Implementation?

Discussion

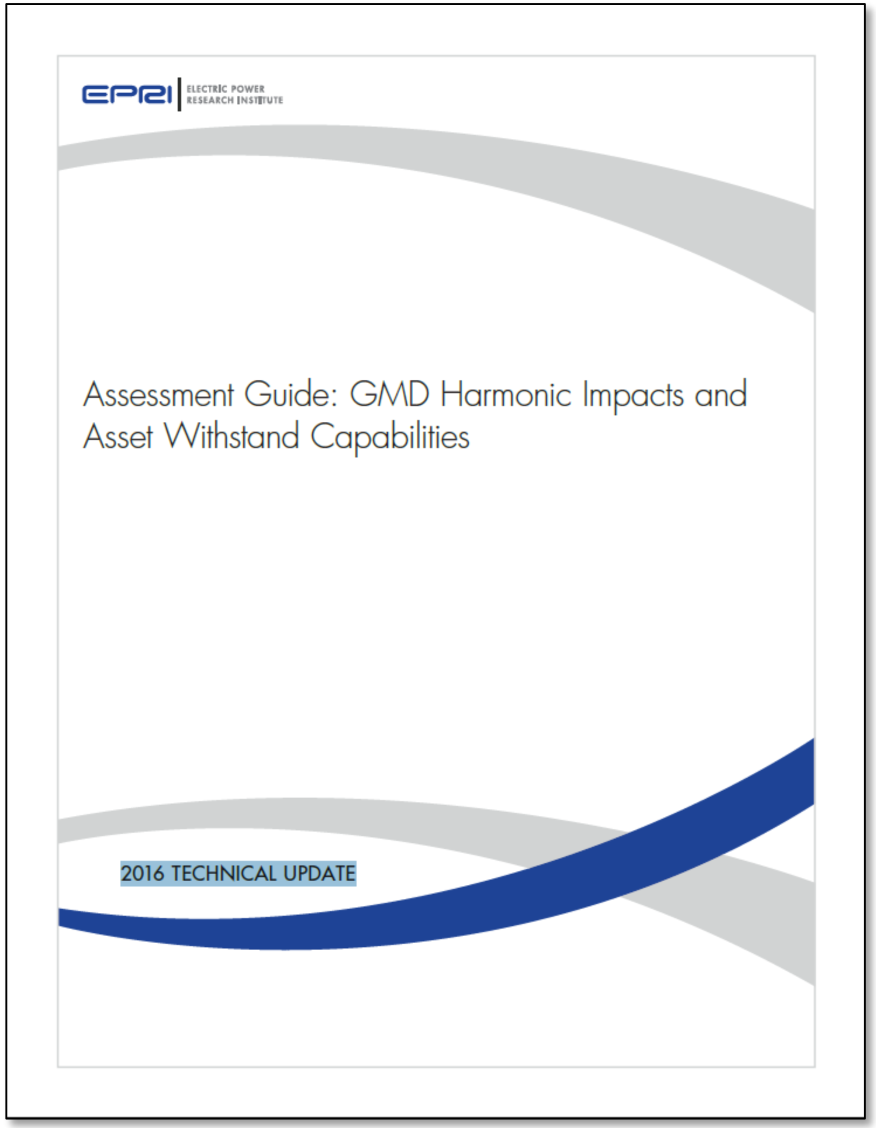
NERC GMD Task Force:
EPRI Recommended Guidelines for Assessing GMD-related Harmonics

Bob Arritt

Charlotte, NC
13 June 2018

Assessment Guide: GMD Harmonic Impacts and Asset Withstand Capabilities

- 2016 Publically Available Report
- Report # 3002006444
  - www.epri.com
- This guide discusses the harmonic withstand and performance issues of major power system components:
  - transformers, shunt capacitor banks, generators, cables, overhead lines, high voltage direct current (HVDC) systems, flexible ac transmission system (FACTS) devices, surge arresters, distribution systems, consumer loads, relays, and protection systems.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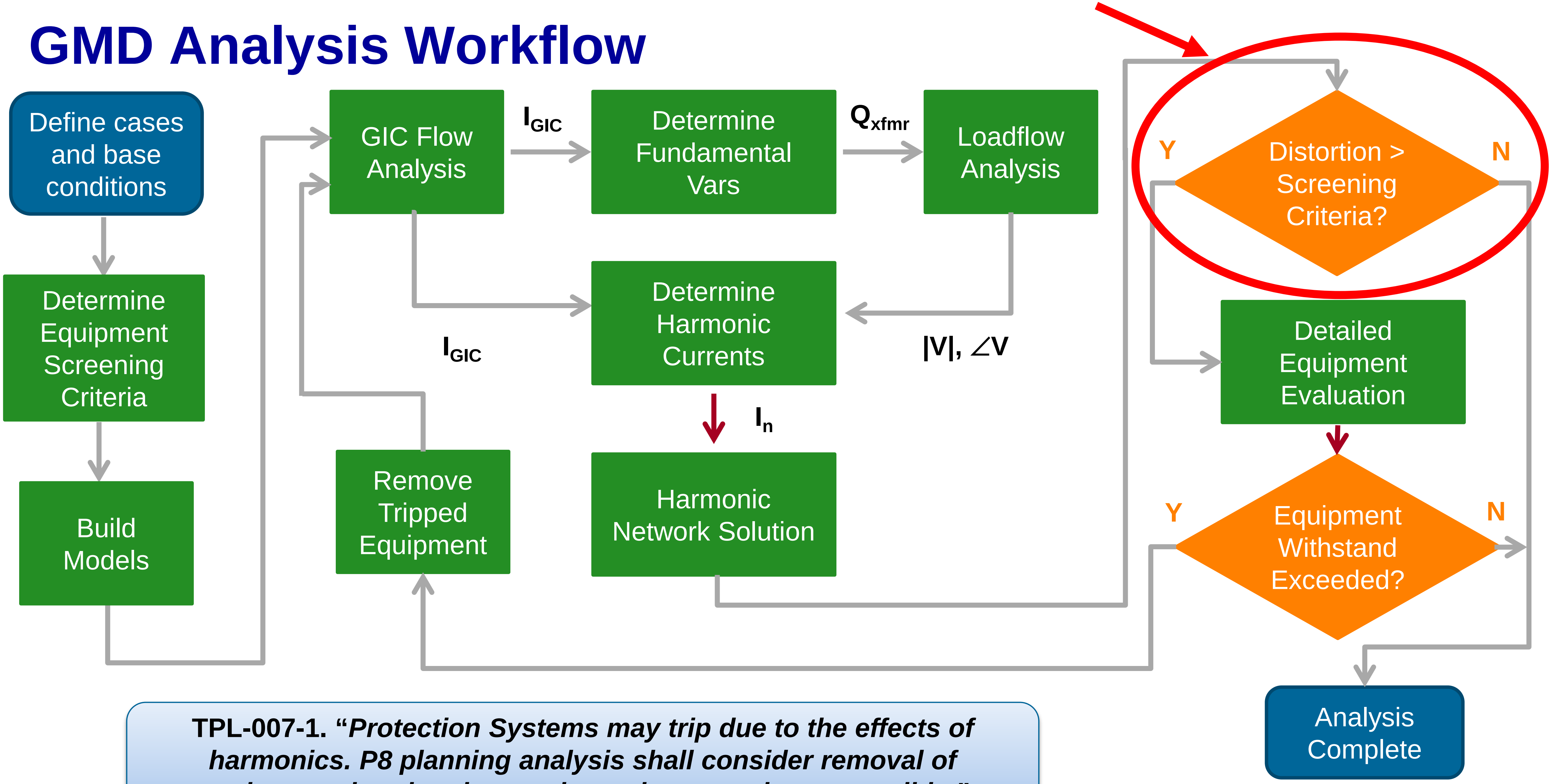
Assessment Guide: GMD Harmonic Impacts and Asset Withstand Capabilities

2016 TECHNICAL UPDATE

Scope and Organization of Guide

- Detailed evaluation of the harmonic impact on various types of equipment requires equipment data that are often not easily obtained.
- Therefore, for each type of equipment and where feasible, this guide suggests simplified screening criteria.
- These criteria are intentionally conservative.
- Harmonic values exceeding these criteria do not imply that the component will endure excessive duty, but rather indicate that more detailed evaluation of that component is prudent.

GMD Analysis Workflow

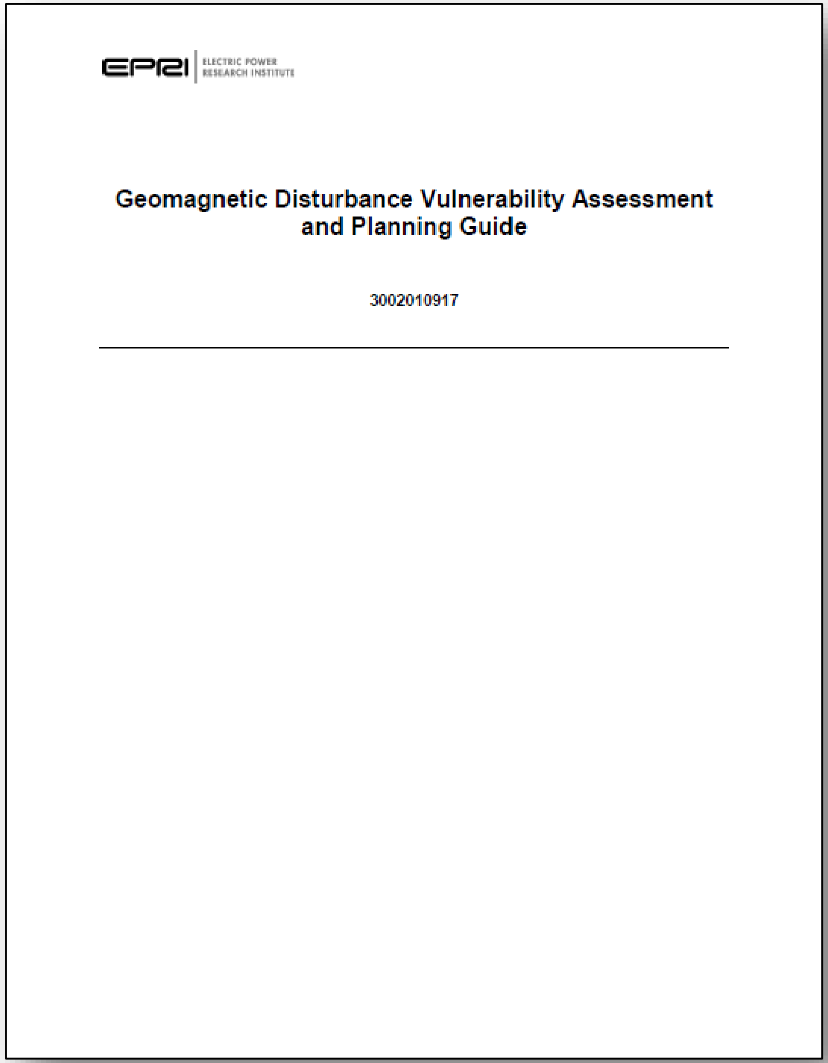


TPL-007-1. "*Protection Systems may trip due to the effects of harmonics. P8 planning analysis shall consider removal of equipment that the planner determines may be susceptible.*"

EPRI | ELECTRIC POWER RESEARCH INSTITUTE

Recent EPRI work on GMD Planning Guide – Harmonic Assessment Chapter

- Overview of GIC-saturated transformer harmonic current injection
- Summary of harmonic impacts on transmission equipment and protection systems
  - Generic screening thresholds provided
  - Special equipment evaluation requirements
- Alternative harmonic analysis approaches
- Detailed step-by-step guidelines for study performance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Geomagnetic Disturbance Vulnerability Assessment and Planning Guide

3002010917

"Geomagnetic Disturbance Vulnerability Assessment and Planning Guide" EPRI Product ID: 3002010917
http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002010917

Software Requirements – GMD Research in Work Plan

- ☑ The tool must be capable of extensive system modeling, accepting models with a large number of buses.
- ☑ Provide full three-phase representation of the system including mutual couplings.
- ☑ Accept data from other sources such as loadflow, stability, and short-circuit databases.
  - Converts fundamental-frequency data from these data sources to appropriate parameters for harmonic analysis.
- ❑ The tool should provide accurate representation of harmonic sources (saturated transformers) based on the results of GIC flow analysis. These sources are also dependent on fundamental-frequency voltage and angle, so it is desirable for the tool to accept loadflow results with minimum user intervention.
- ❑ Representation of GIC-saturated three-phase transformers requires either the capability within the tool to perform nonlinear magnetic circuit analysis of transformers, or accept multi-dimensional lookup tables of relationships between harmonic currents and GIC developed offline.
- ❑ Tool to represent closed-loop interaction to take in to account voltage distortion.
- ☑ The tool should facilitate parametric analysis of a variety of system conditions and configurations.
- ☑ The tool must be able to accommodate a large number of simultaneous harmonic current injections.

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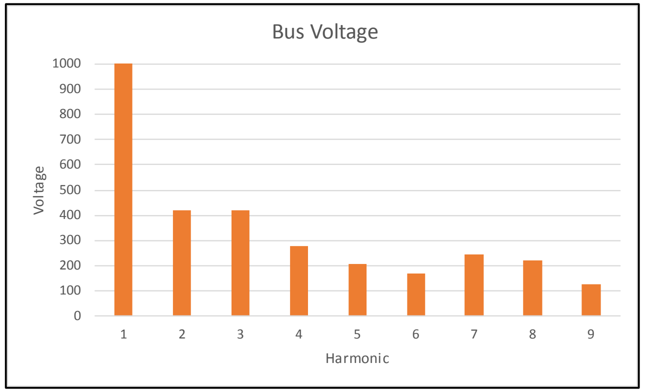
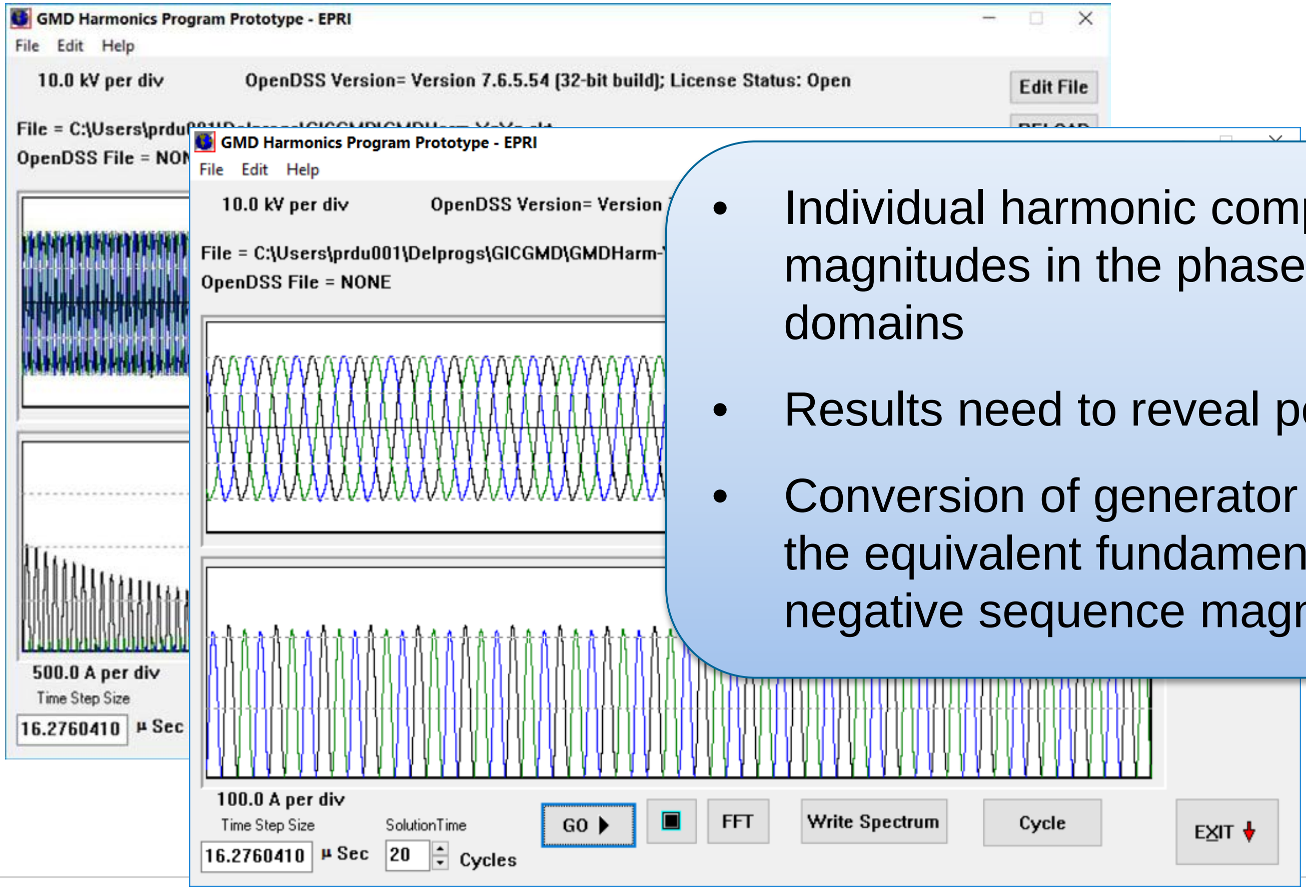
GMD Harmonic Tool

- The EPRI OpenDSS solution algorithm will be used
  - Harmonic solution has been an integral part of the program since its inception

Examine impacts on protection





- Individual harmonic component magnitudes in the phase and sequence domains
- Results need to reveal peak voltages.
- Conversion of generator stator currents to the equivalent fundamental-frequency negative sequence magnitude

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Together…Shaping the Future of Electricity

Geomagnetically Induced Current (GIC) Impacts on Protective Relay Performance

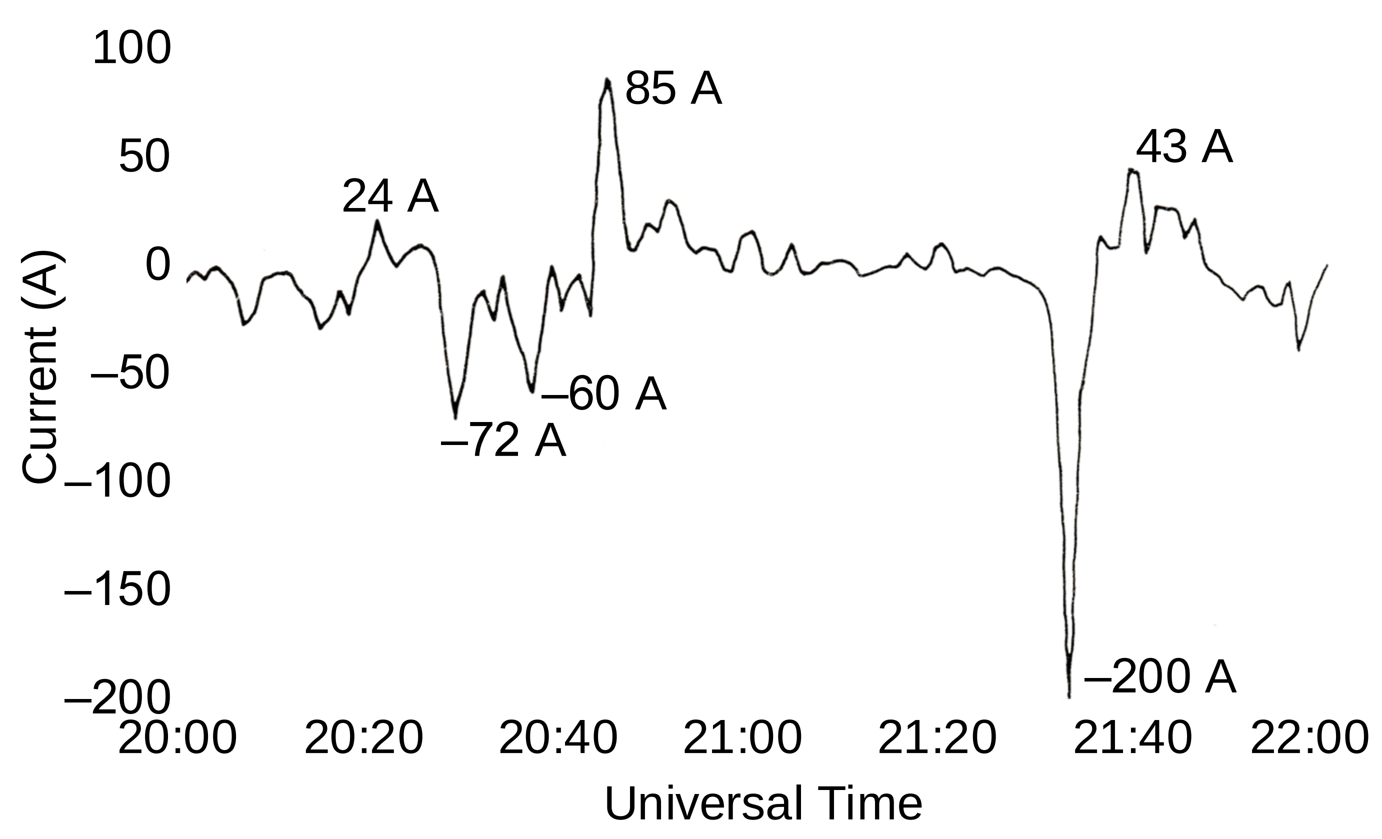
Karl Zimmerman and Derrick Haas
Schweitzer Engineering Laboratories, Inc.

Overview

- Overview of relay filtering
- Impact of GIC on CTs
- Impact of GIC on relay applications

GIC Characteristics

- Changes very slowly – quasi-dc
- Produces up to 300 A primary, measured in neutral CT
- Splits equally between phases (100 A per phase)



GIC measured in transformer neutral in Finland during geomagnetic storm on March 24, 1991

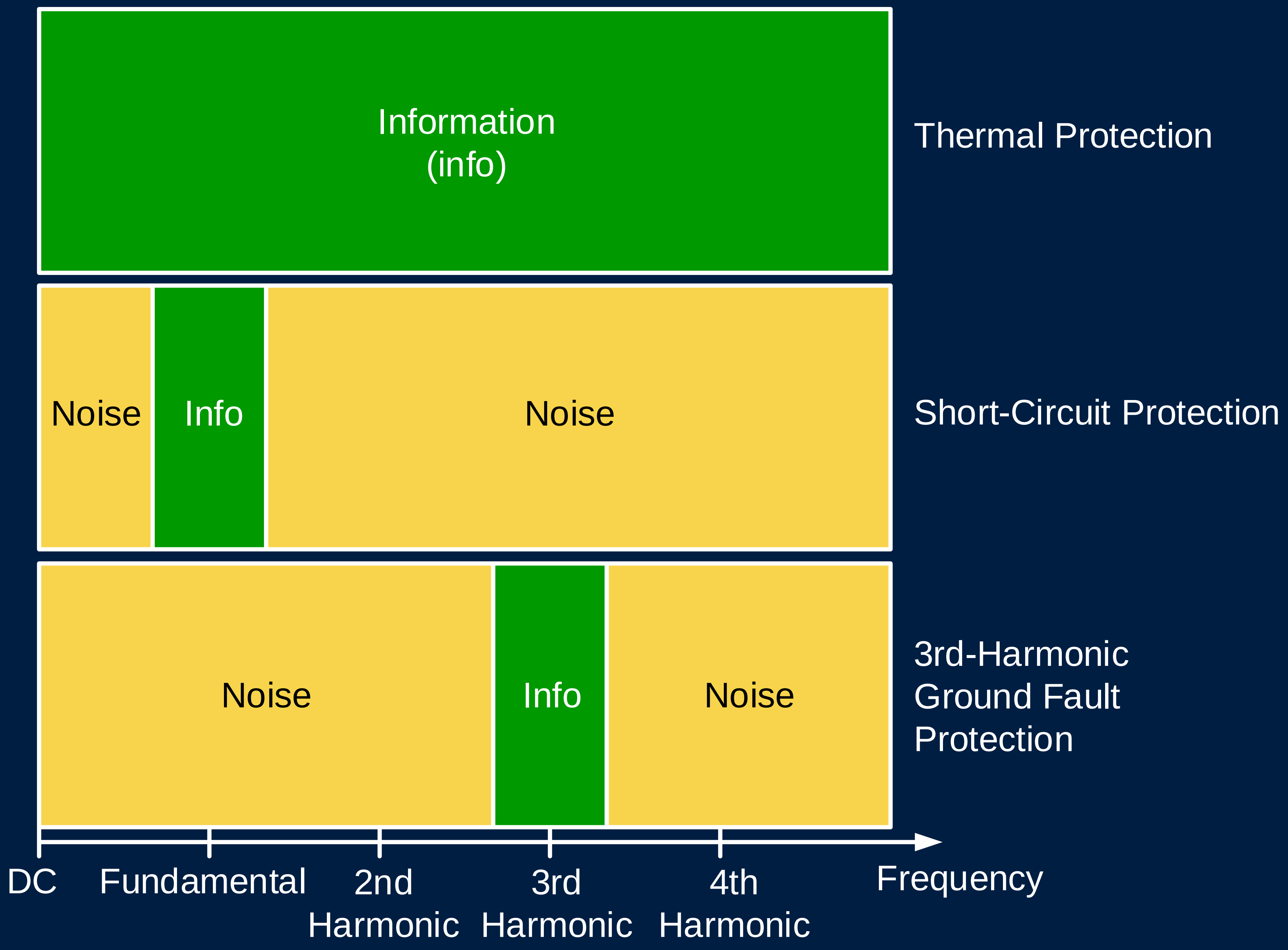
Factors Affecting Protection

- Relay filtering in digital relays
- Performance of CTs
- Protection algorithms

Line Relay Principles
Filtering Requirements

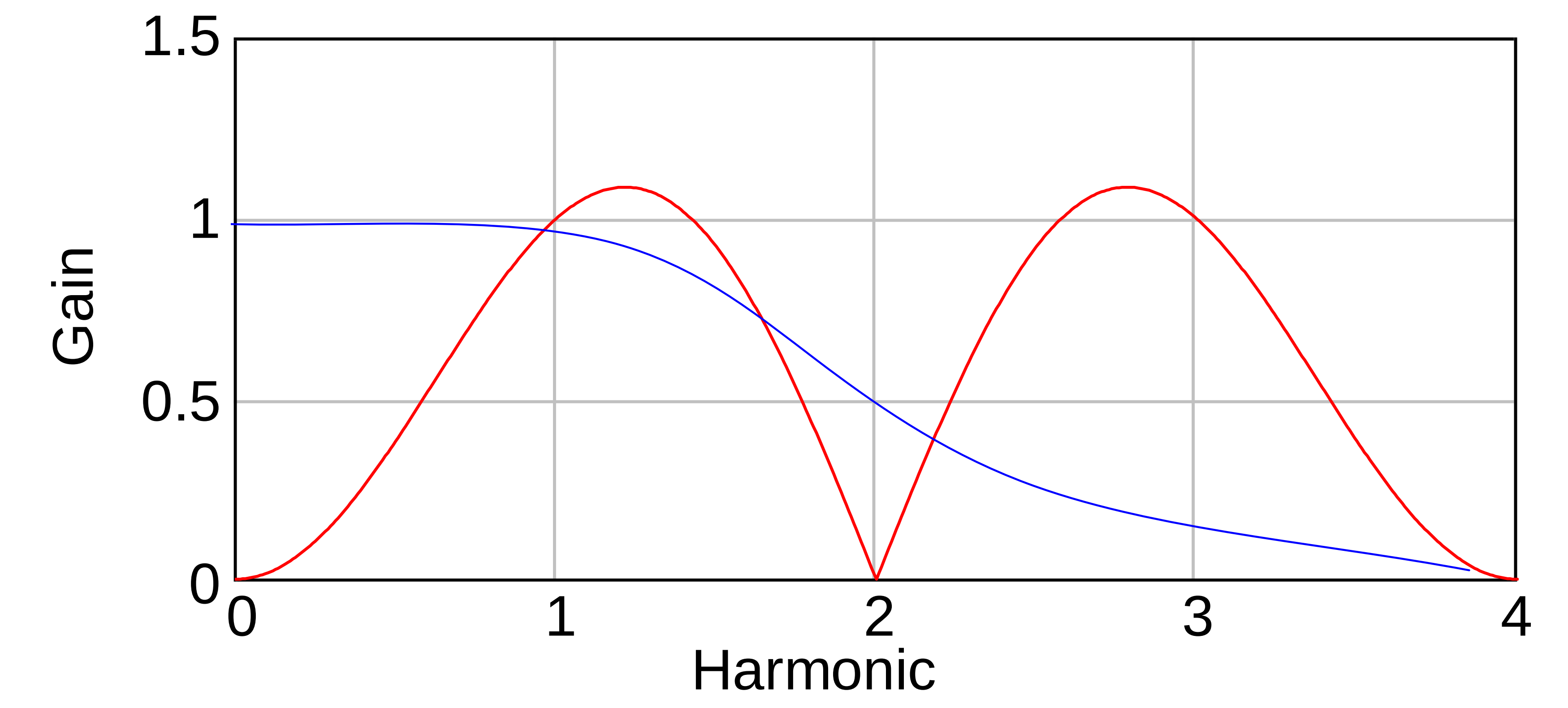
Algorithm	Phasor-Based	Differential Equations	Traveling Waves
Spectrum	50 / 60 Hz	1 kHz	100 kHz
Filtering			
Sampling	16–32 samples / cycle	8 kHz	1 MHz
Line theory	$V_F = V - ZI$	$\nu_F = \nu - \left(Ri + L\frac{di}{dt} \right)$	$i_{S(t)} \approx -i_{R(t-\tau)}$
Operating time	~1 cycle	A few milliseconds	1 ms

Generator Protection Filtering



Examples of Phasor-Based Relay Filtering

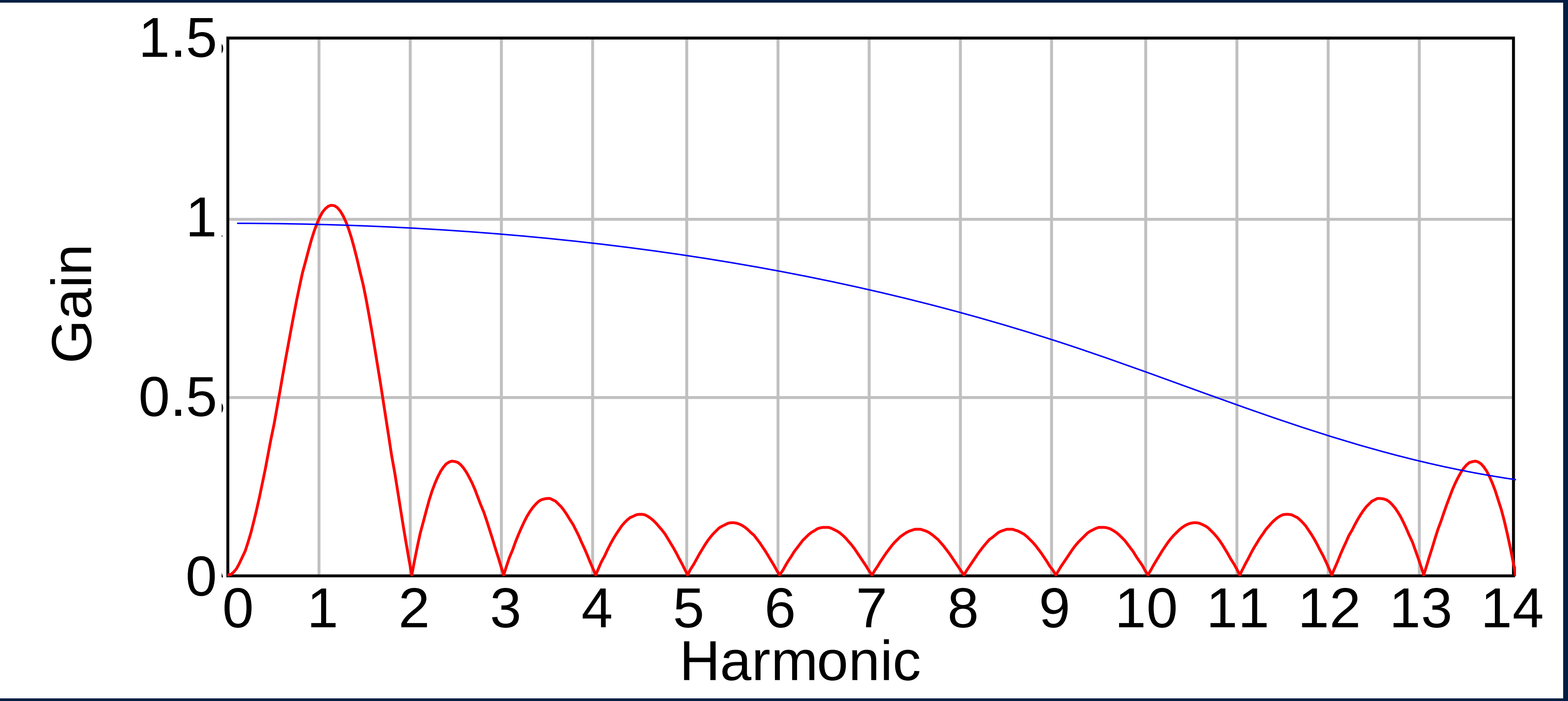
1984 Line Relay Design



4 samples per cycle, CAL filter

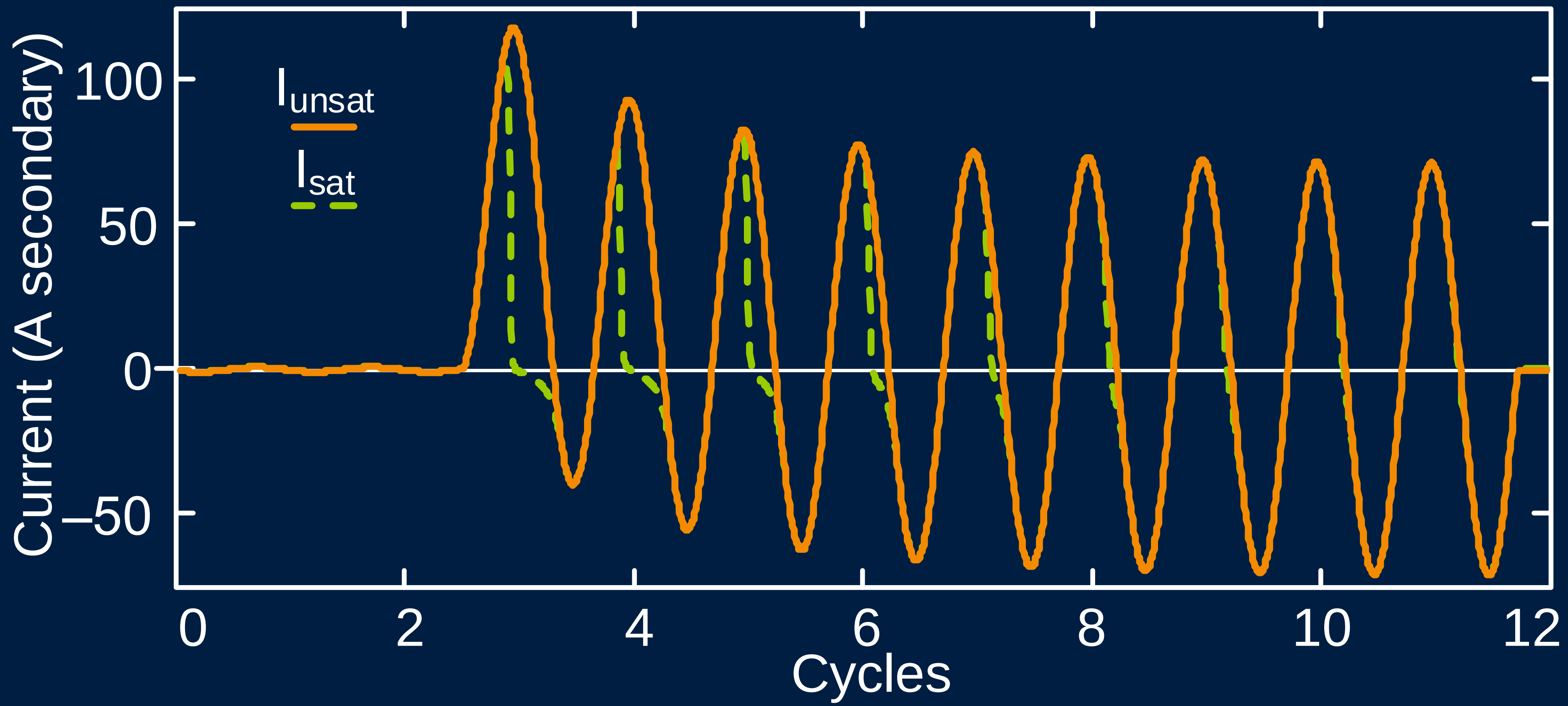
Examples of Phasor-Based Relay Filtering

1996 Line Relay Design



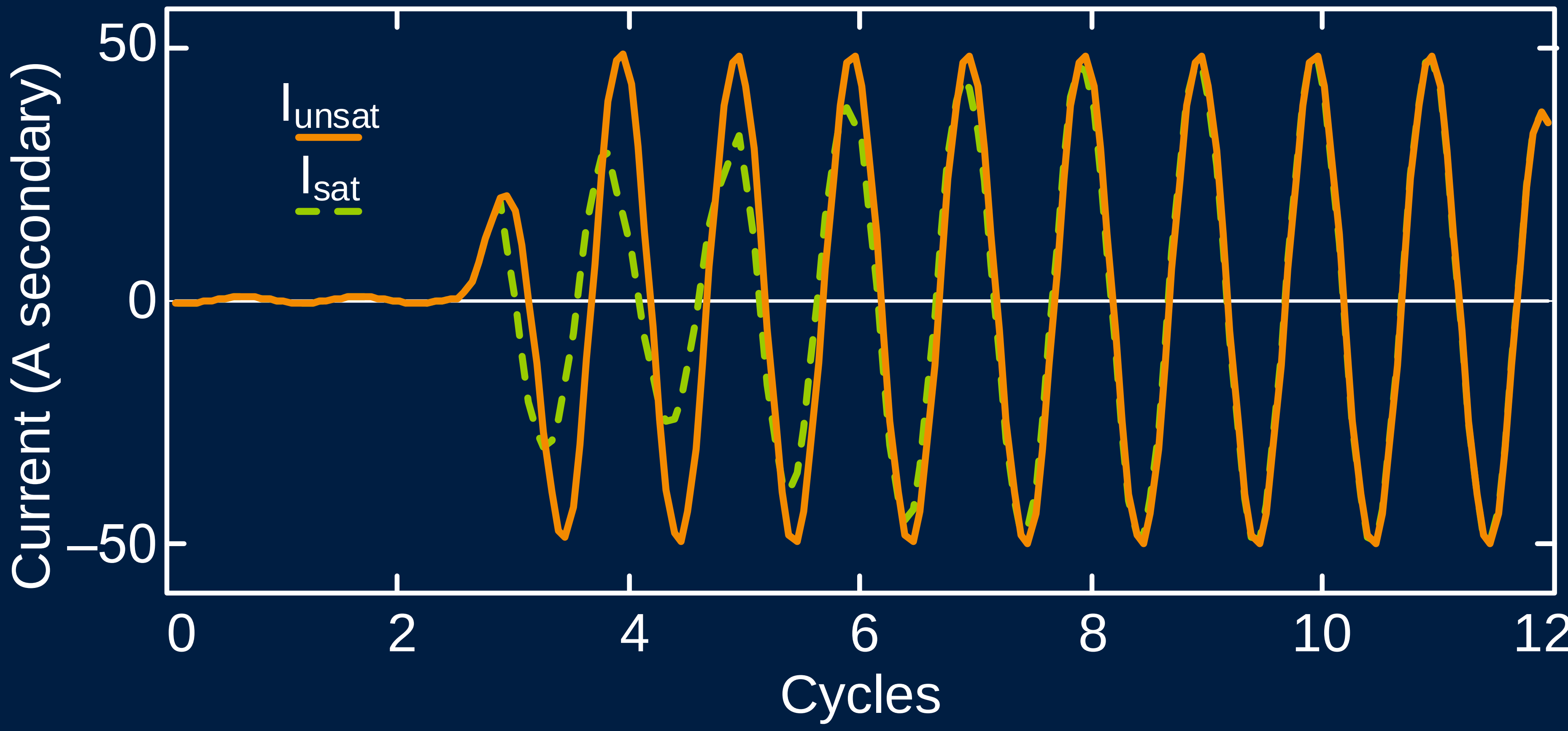
16 samples per cycle, cosine filter

CT Saturated and Unsaturated Unfiltered Secondary Current

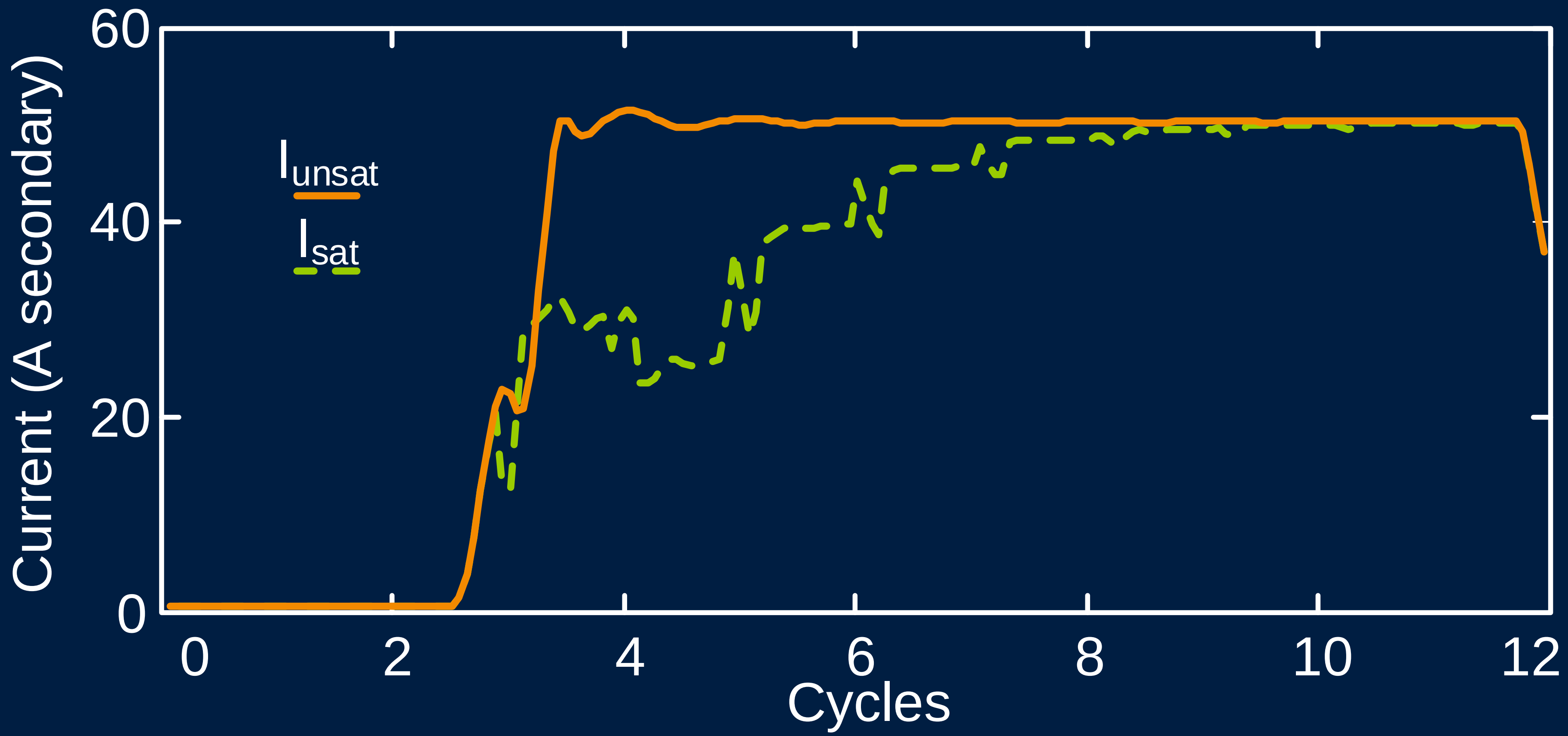


Actual system fault, taken from IEEE PSRC report, “Distance Element Response to Distorted Waveforms”

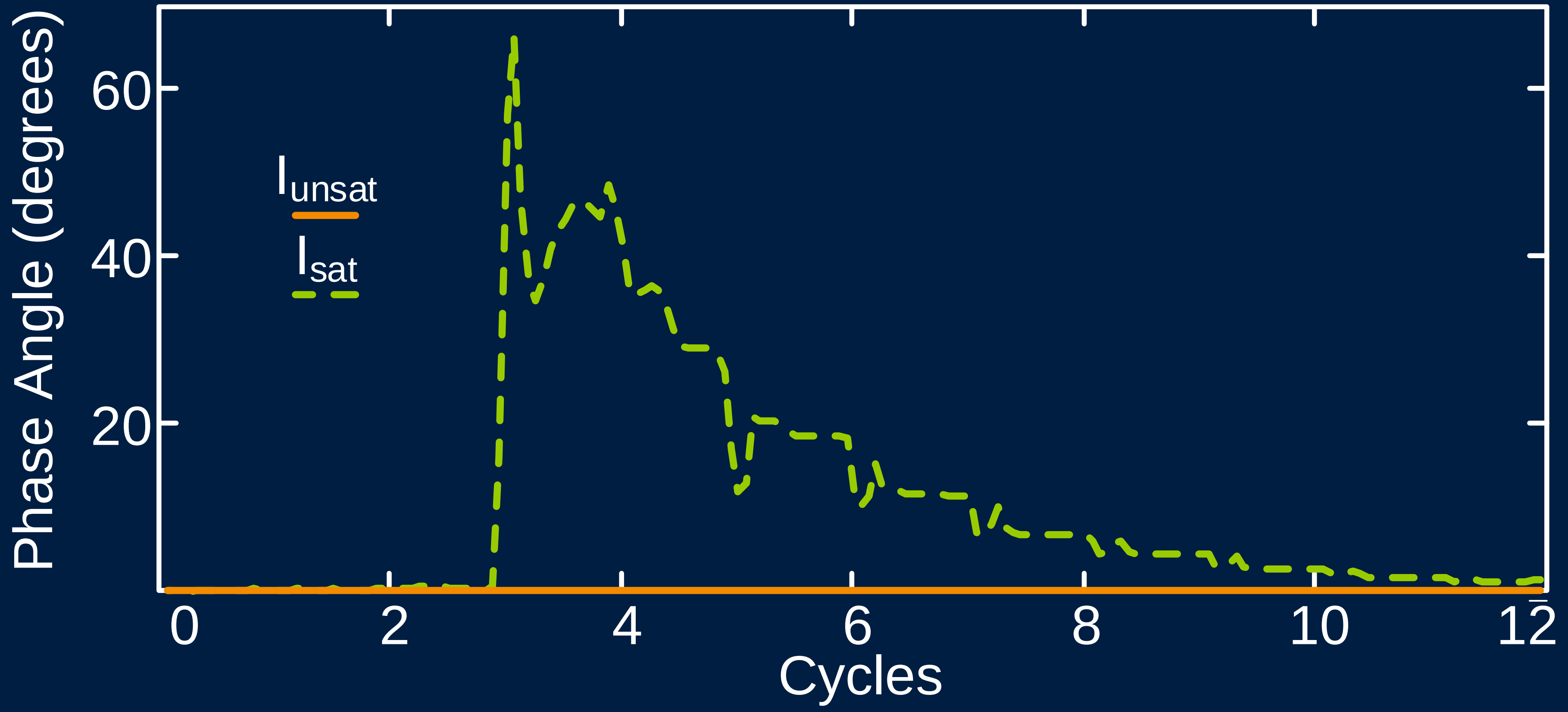
CT Saturated and Unsaturated Output of Cosine Filter



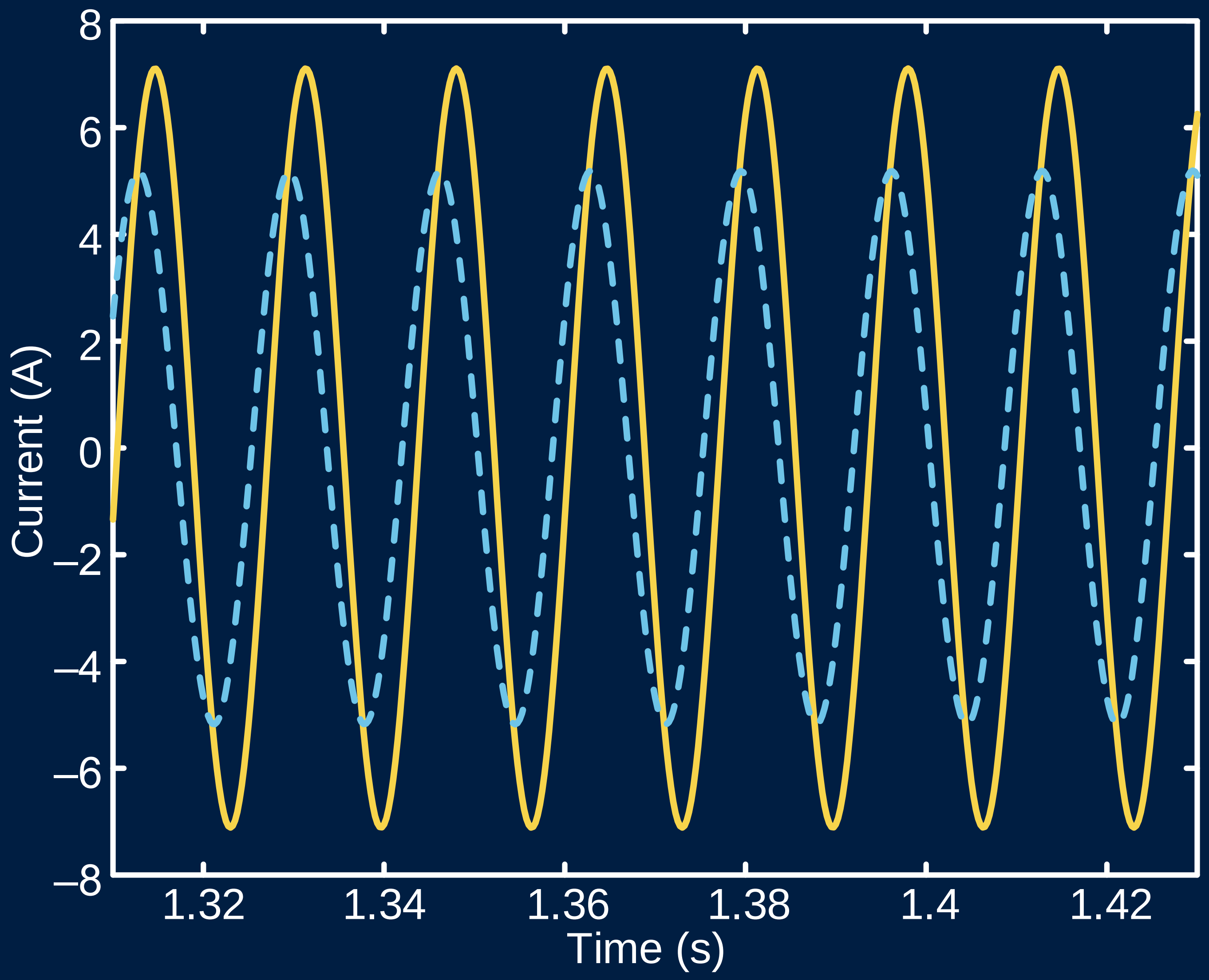
Current Magnitude and Angle of Saturated vs. Unsaturated CT Magnitude



Current Magnitude and Angle of Saturated vs. Unsaturated CT Phase Angle



Low-Frequency GIC Produces Minimal Error

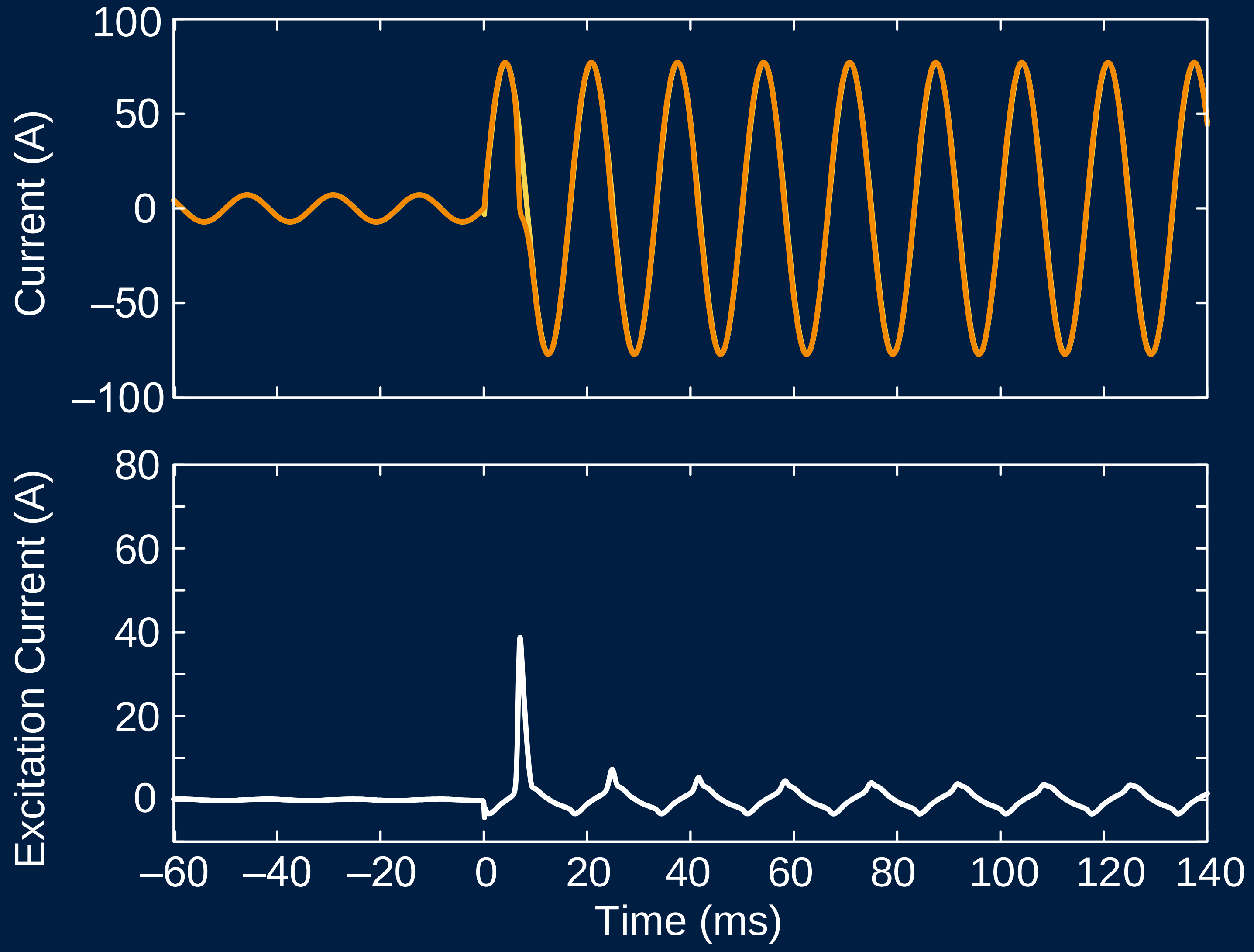


Yellow solid line – primary ratio current

Blue dashed line – filtered secondary current

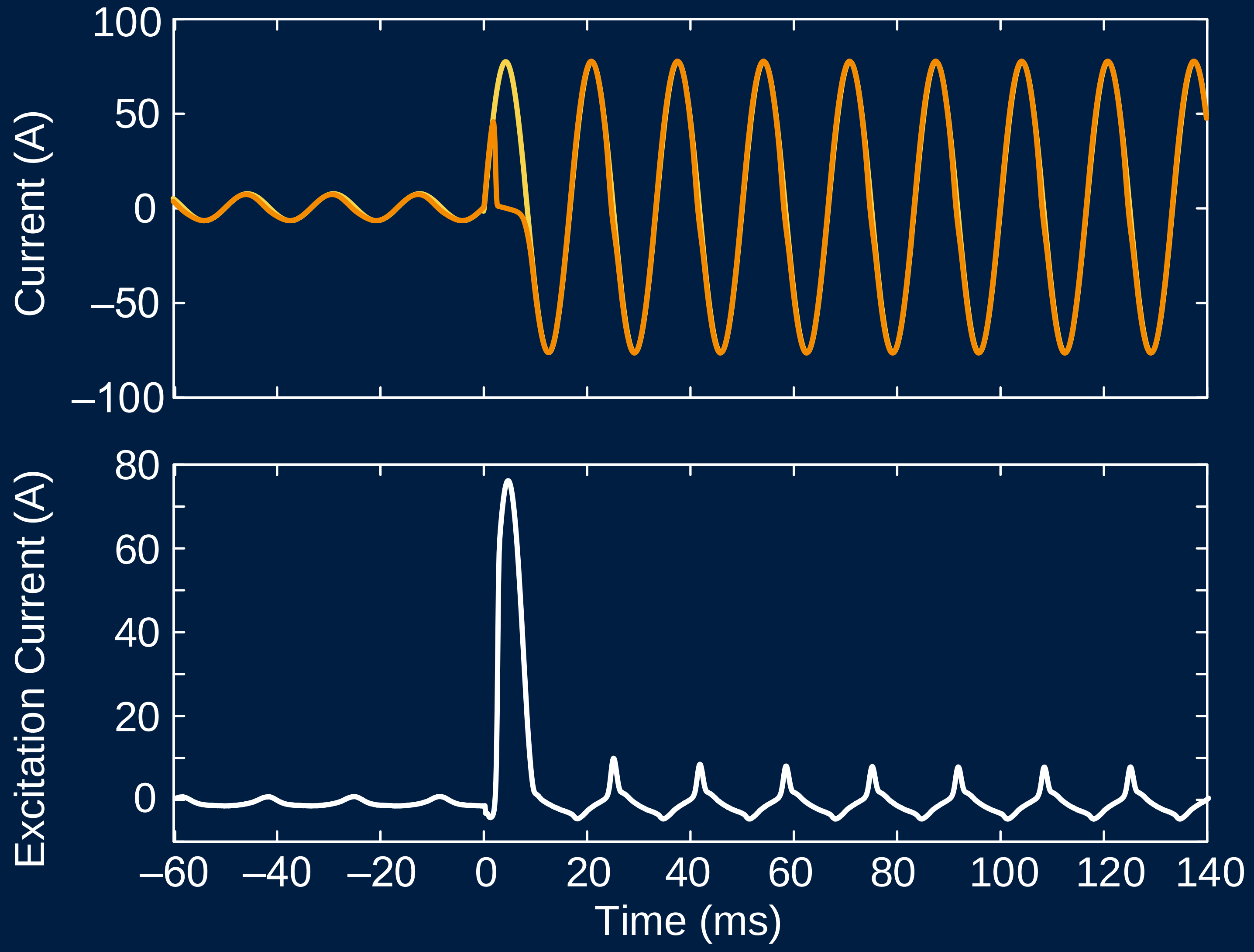
Lab simulation – (0.2 Hz, **150 A**) + (60 Hz, 150 A)

Transient CT Performance Without GIC



C10, 150:5 CT – fault current of 1.6 kA rms with pre-fault load of 150 A rms and no GIC current

Transient CT Performance With GIC

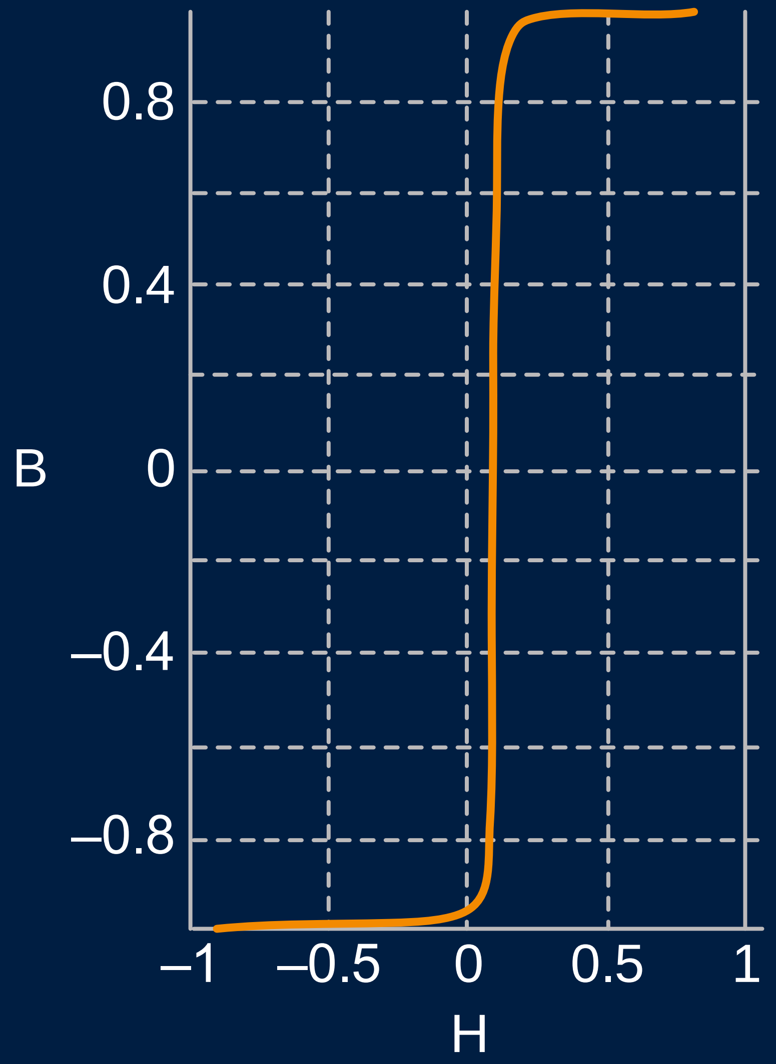


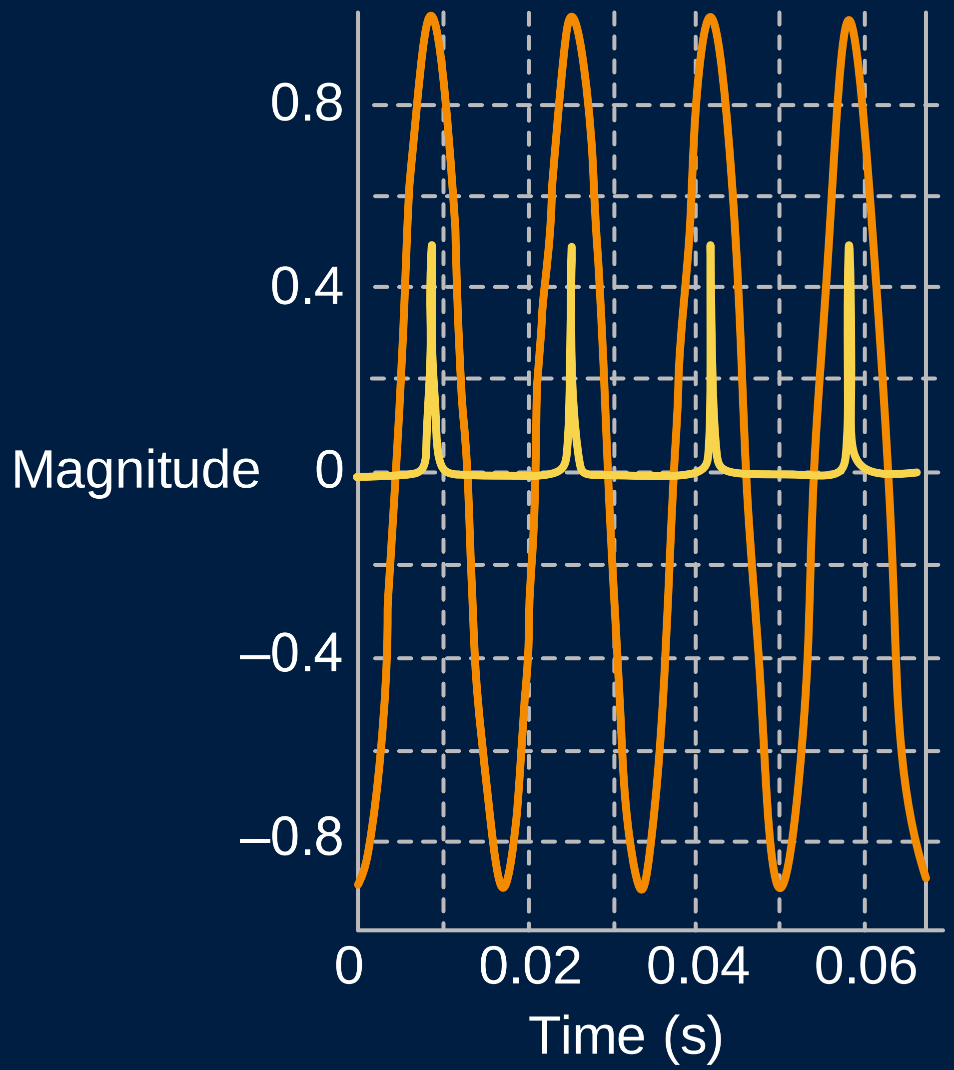
C10, 150:5 CT – fault current of 1.6 kA rms with pre-fault load of 150 A rms and 15 A dc GIC current

CT Performance Questions

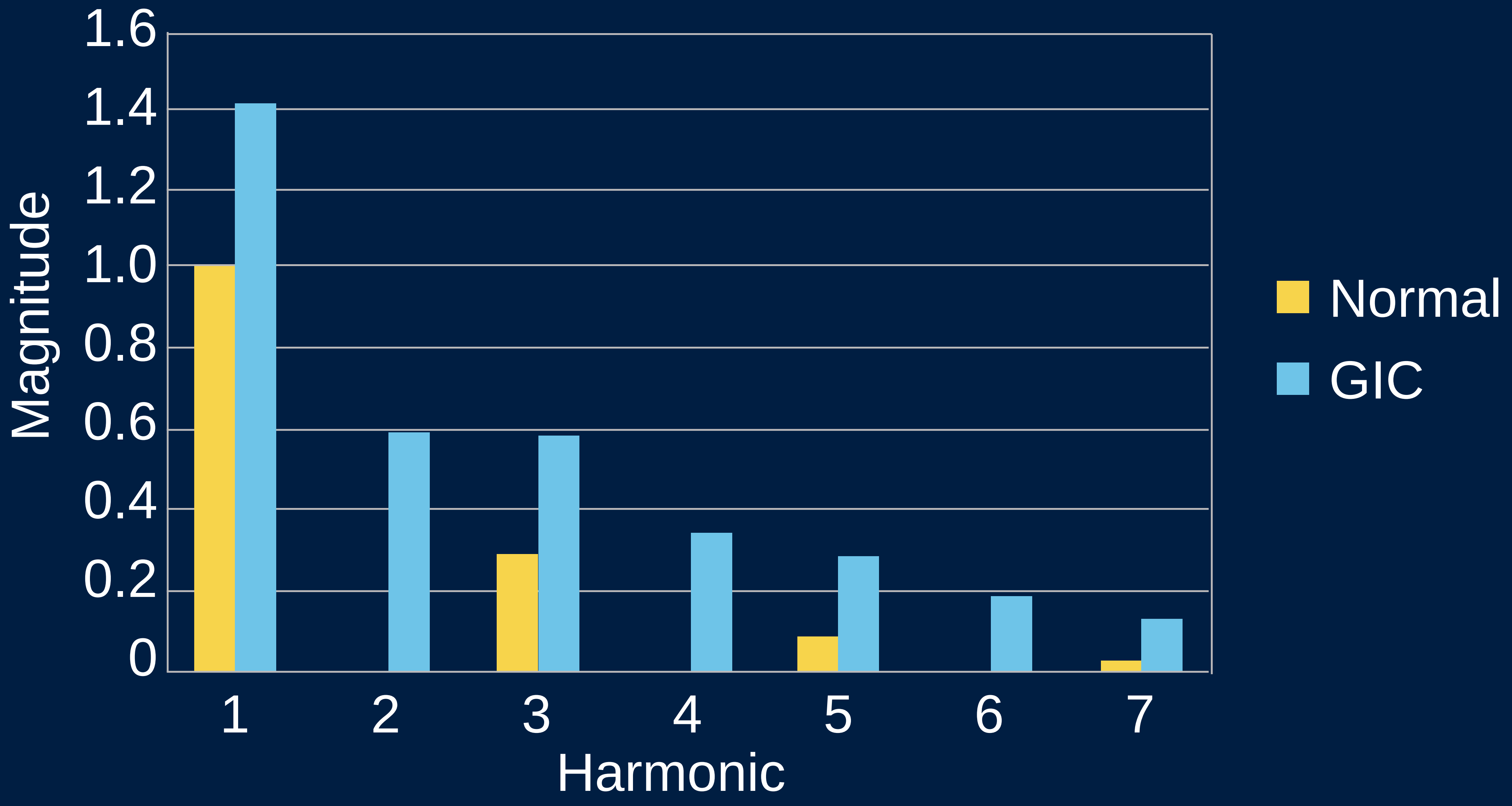
- Do CTs “like” dc?
  No, CTs cannot measure dc
- Do CTs “mind” dc?
  A little; standing dc impacts accuracy of ac measurement
- What is the GIC impact on protection CTs?
  Very short-lived; similar to residual flux
- Is protection affected?
  In general, impact is minimal

GIC Induces Half-Cycle Saturation in Transformer Core





Harmonic Content During Half-Cycle Saturation



Impact on Protective Relaying

- Overcurrent and distance elements
  - Remain secure during GIC event
  - Remain dependable, may slightly underreach or be slightly delayed for fault during GIC
- Line current differential protection
  - Has algorithms to handle steady state and transient CT errors
  - Remains secure and dependable

Transformer Differential Protection (87)

- Includes percentage restraint to cope with steady-state CT saturation
- Includes algorithms that safeguard against misoperations and failures to operate
  - External fault detection, harmonic restraint, blocking, waveshape recognition, unrestrained elements
- Remains secure and dependable

Conclusions

- Impact of GIC on protection presents challenges but is minimal overall
- Digital filtering removes dc and harmonics
- GIC impacts CT performance, but it is short-lived
- Most relay algorithms are resilient to impact of GICs, just as they are resilient to other factors (e.g., magnetizing inrush, CT errors due to saturation, remanence)

References

1. “Effects of Geomagnetic Disturbances on the North American Bulk Power System” (NERC report)
2. “Do CTs Like DC? Performance of Current Transformers With Geomagnetically Induced Currents” (www.selinc.com)
3. “Distance Element Response to Distorted Waveforms” (www.pes-psrc.org)
4. “Geomagnetically Induced Currents: Detection, Protection, and Mitigation” (AG 2011-16, www.selinc.com)

Questions?

EPRI GMD Supplemental Project Status Update:

Furthering the Research of GMD Impacts on the Bulk Power System

Bob Arritt, P.E.
Luke van der Zel, Ph. D.

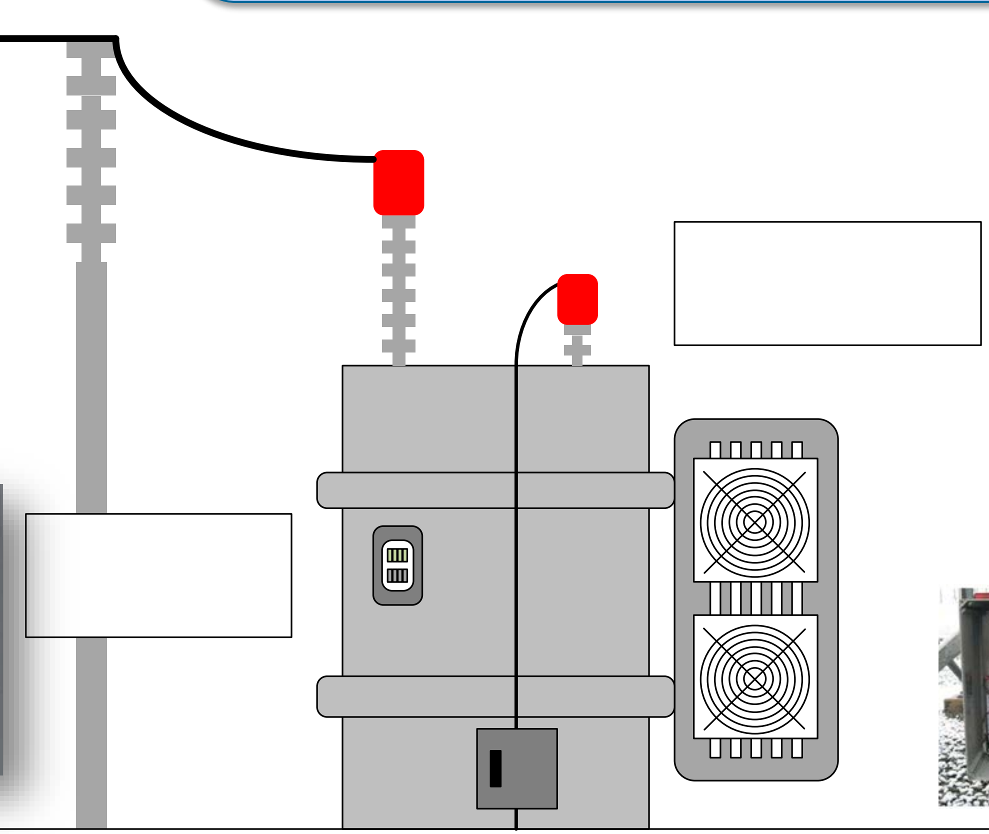
Charlotte, NC
13 June 2018

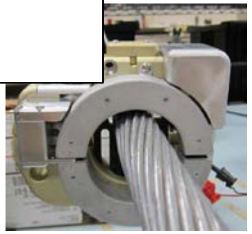
Summary Report on Initiatives in GMD research

- Whitepaper #3002013726
- Outline
  - Title: Furthering the Research of GMD Impacts on the Bulk Power system
    - Executive Summary
    - GMD Primer: How GMDs Occur
      - New Research Will Further Enhance the Science of the 100-Year GMD Event Scenario
      - Earth Conductivity Modeling
      - Validating/Refining Transformer Models and Screening Criteria
      - Harmonic Impact Analysis
    - Industry Awareness
    - Conclusions

Transformer GIC Field Monitoring

- Field sensors added field transformers to.
  - Use in the validation process of transformer tools.
  - Better understanding of GIC impacts on transformers.





"…delta winding heating due to harmonics has not been adequately considered …, thermally, this is a bigger concern than metallic hot spot heating" – Comment in FERC 830

Candidate Transformers

Status	Voltages, kV			MVA	Type	# Phases	Core / Shell form	Core type	Locations of thermal sensors
	HV	LV	YV						
Nuclear	230	13.2	13.2	230	GSU	3	Core Form	3-limb	All Windings
Out of Service	352	143	13.8	200	Auto	1		3-limb	All Windings + F.P., Core, Core Surface
Pursuing	735	124.7	12.5	150	Step down	1		3-limb	All Windings, F.P., and Core clamps
Pursuing	325	161	12.5	160	Auto	3		3-limb	All Windings
Gathering Data	500	165	13.2	448	Auto	1		4-limb	All Windings
Pursuing	345	143	23	800	Auto	3	Shell Form	7-limb	All Windings and T-beam
Pursuing	500	22.8	--	511	GSU	1		3-limb	All Windings and T-beam
Nuclear	531	22	--	525	GSU	1		3-limb	All windings
Nuclear	362.3	25	--	820	GSU	3		7-limb	All windings

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Monitoring Site 1

Location

- Tennessee
- 500/165kV 448MVA Auto

Monitoring Status

- Fiber in all three windings
- GIC Monitor on the neutral
- Adding a vibration sensor in Summer 2018

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Monitoring Site 2

Location

- Alabama
- 500/230kV 450MVA Autos

Monitoring Status

- GIC Monitors on the HV and LV phase conductors of each single phase transformer
- Vibration sensors on each transformer tank

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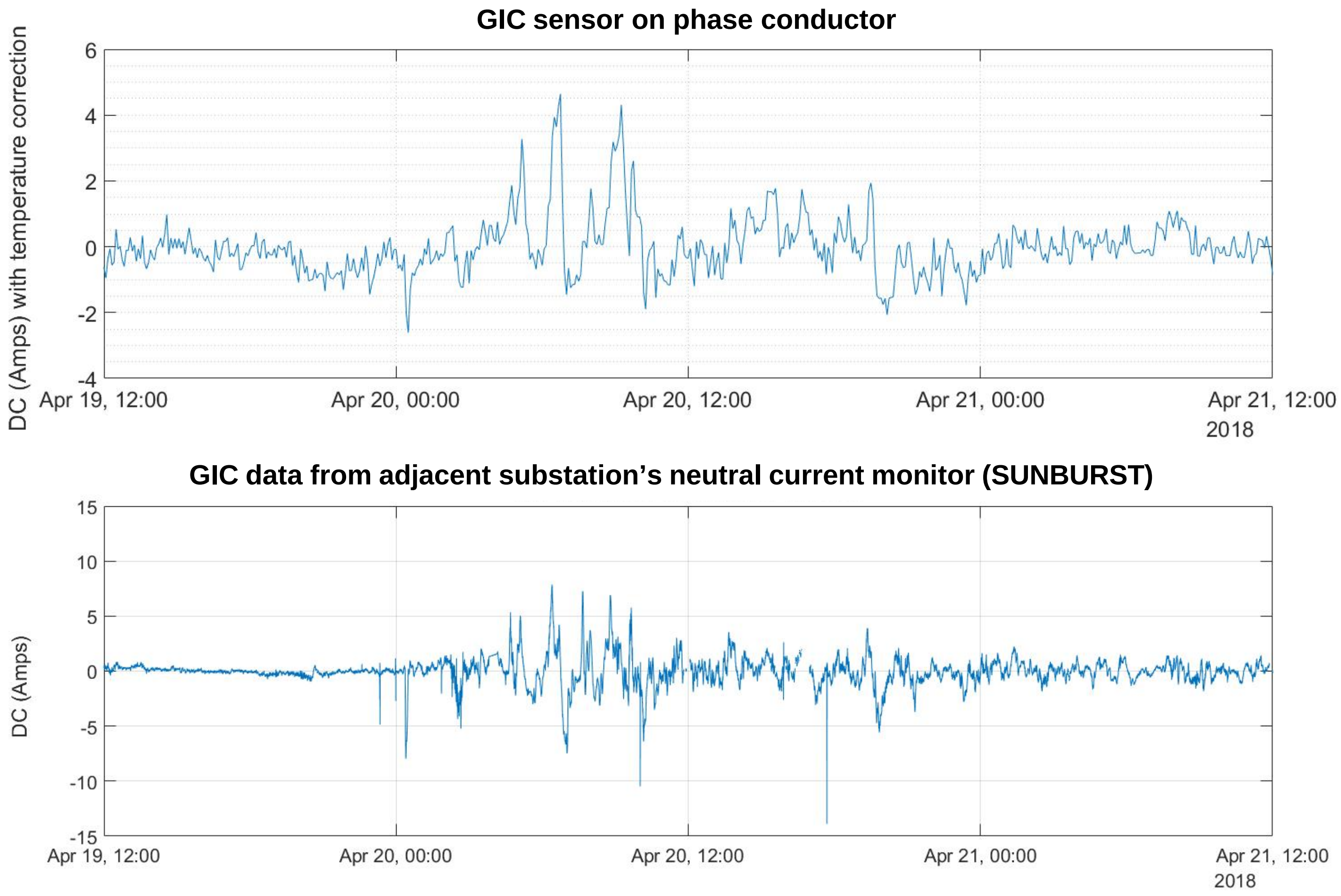
Monitoring Site 3

Location

- New York
- 230/69kV 170MVA Auto

Monitoring Status

- GIC Monitor on a phase of an incoming line
- Further GIC sensors planned for further lines and the transformer neutral



Monitoring Site 4

Location

- New York
- 115/13.8kV 250MVA GSU

Monitoring Status

- GIC Monitors on each HV phase of a GSU
- Four Vibration sensors on the tank

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Monitoring Site 5: Planned for 2018

Location

- Washington State
- 525/34.5kV 448MVA Auto

Monitoring Status

- GIC Monitors on 2 HV phases and one LV phase and neutral
- Possible vibration sensors

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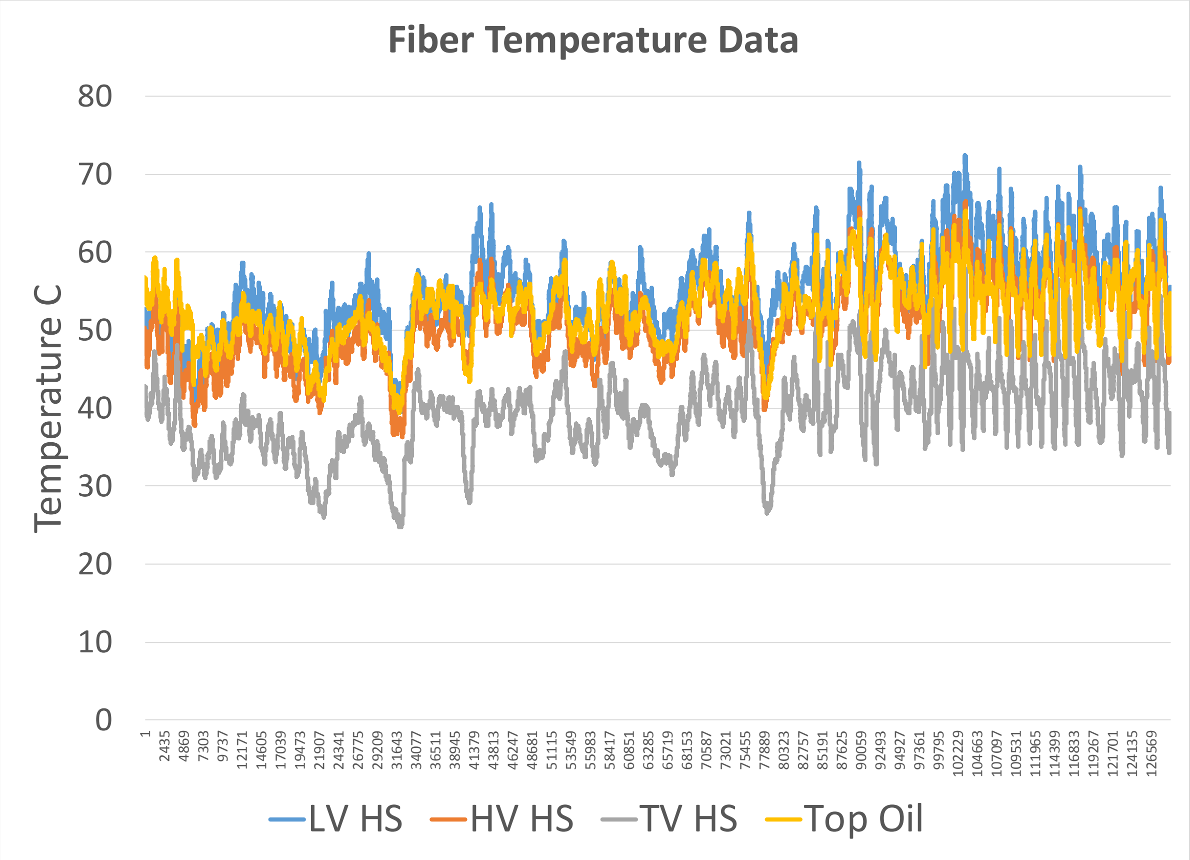
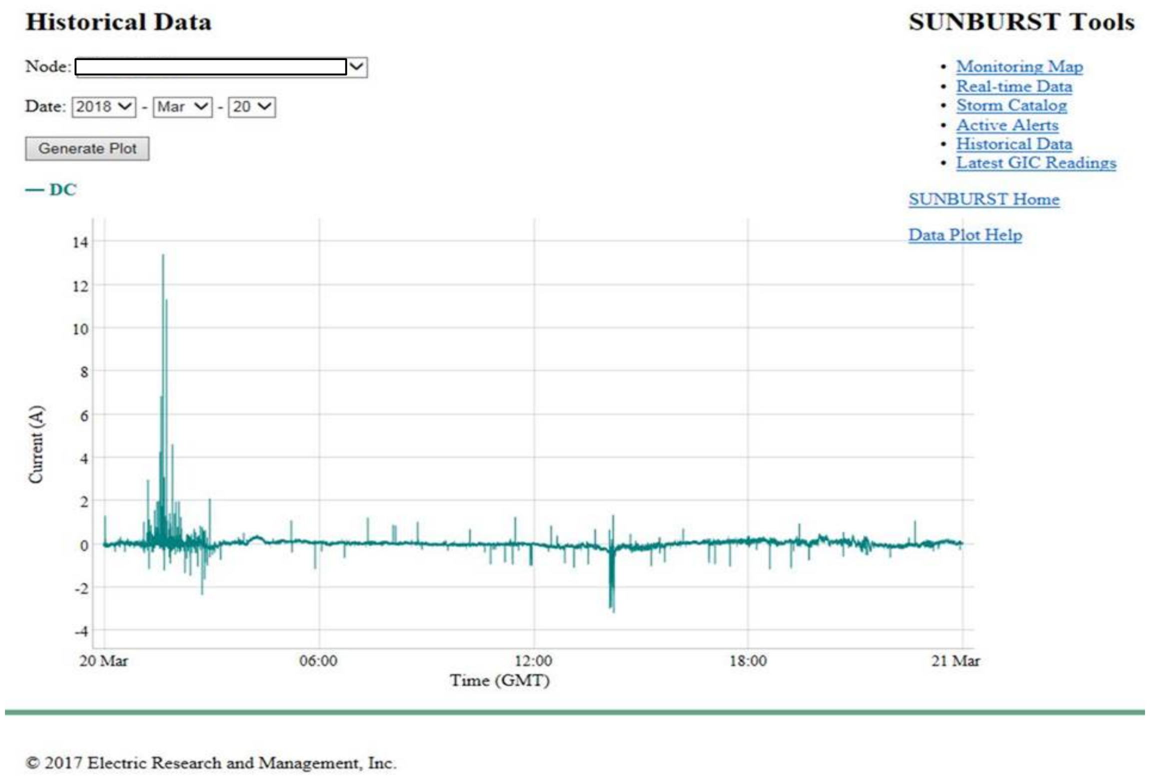
Have started collecting winding temperature data

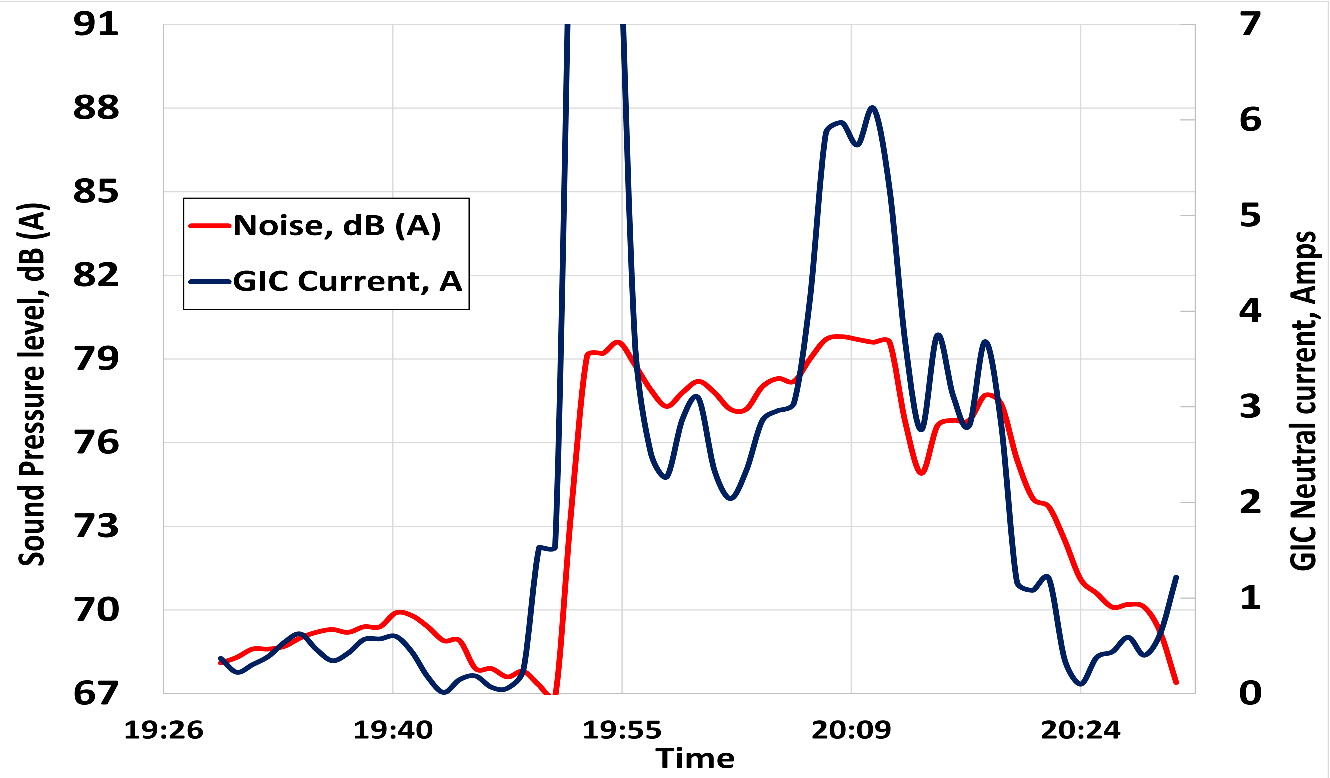
- 90 days of temperature data





Vibration Research Summary and Important Observations

- Sound and vibration levels increase at a much faster rate at low levels of GIC (a few Amps) and slow down considerably at higher levels of GIC; until it reaches core saturation
- Hence, screening using vibration is not feasible
- Vibration measurements on 6 different transformers that were exposed to the Halloween storm and 174 GMD events of K6-K8 show no vibration increase above typical levels
- Hence – there is no indication to-date that GIC events impact transformer mechanical integrity



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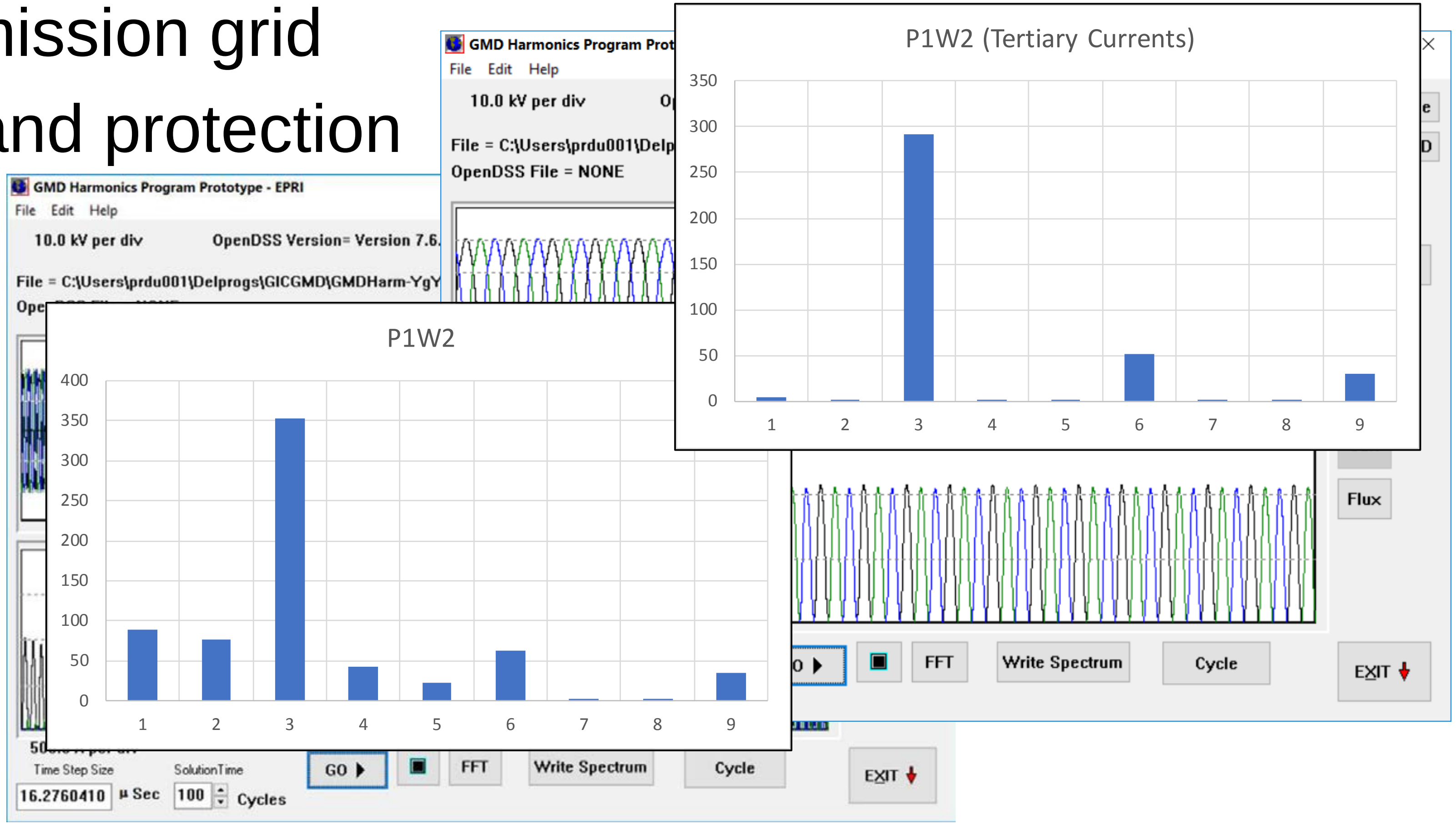
GMD Harmonic Tool

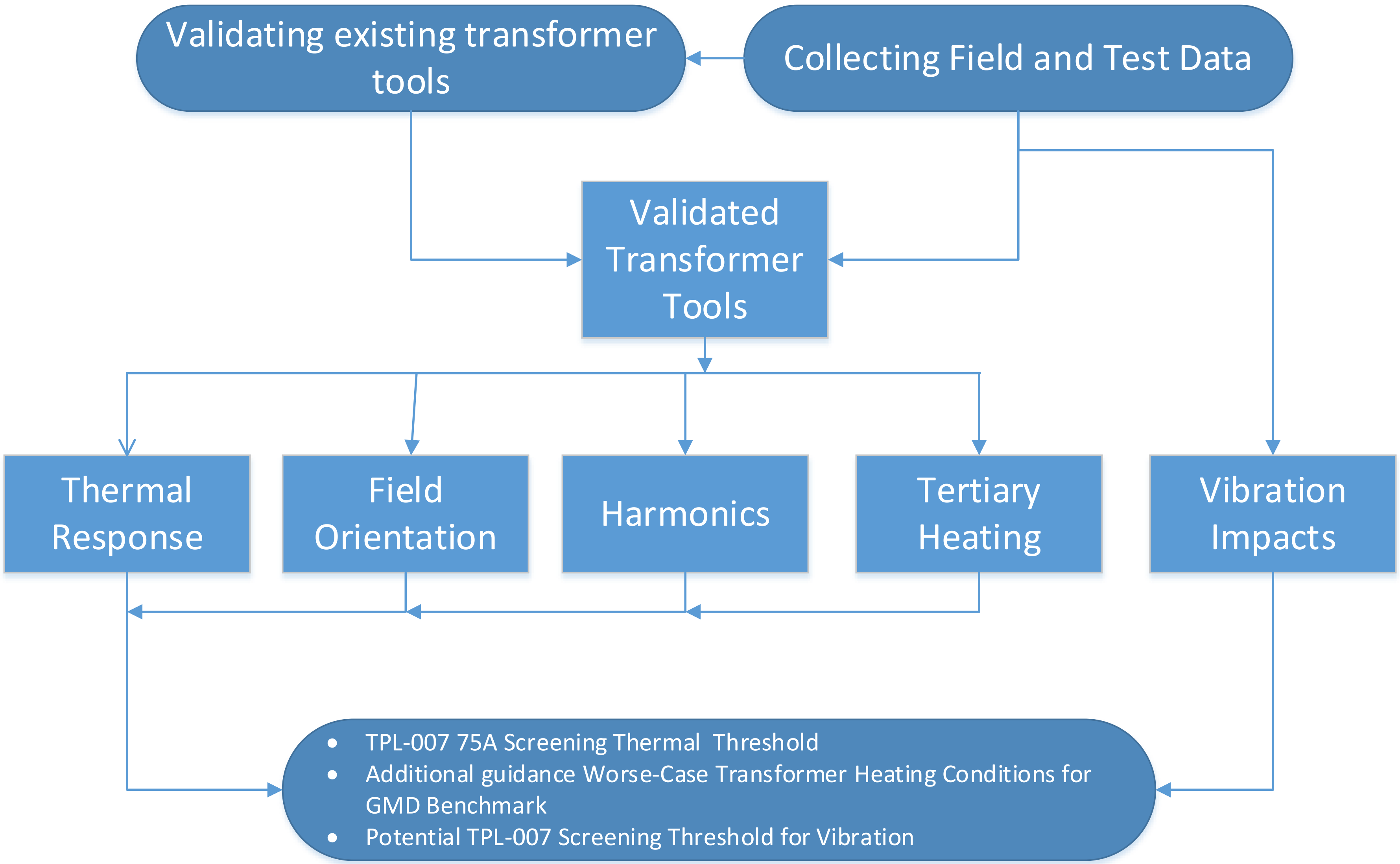
- Impacts of harmonics on the bulk power system.
  - Determine harmonic currents and voltages applied to equipment throughout the transmission grid
  - Evaluate equipment and protection systems.



- Determine generator stator currents
- Study harmonic currents on tertiary windings

Transformer Schedule and Work Plan Flow

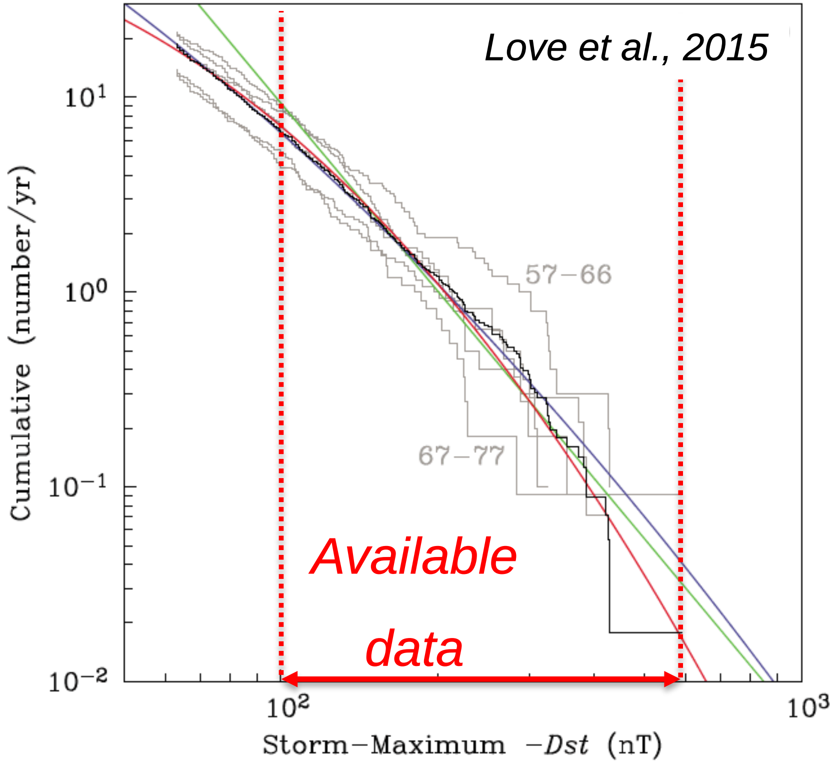
- Work Presently Underway
- Begun the process of examining field data and adding additional monitoring equipment
- Complete Tasks by Q4 2019



GMD Database Development

- Define List of Large GMD Events (i.e., time periods of interest)
  - All Dst ≦ -100 nT Magnetic Storms since 1980 (~ 230 events; Woodroffe 2016)
  - Severe and Extreme Storms (~10 including the Carrington Event, 1921 Railway Storm, 1989 Quebec Blackout Storm, etc.; same storms selected for Los Alamos funded study on GICs)
- Define Data Sources for the Study
  - Global Geomagnetic Indices: Kp, Dst, SYM-H/SMR
  - Auroral Indices: AE, AU, AL, Auroral oval latitude
  - Solar wind measurements: solar wind speed, Bz
  - Ground measurements:
    - Higher time resolution magnetometer measurements
    - E-field measurements
    - GIC measurements

Database being developed for Spatial Averaging and Latitude Scaling Research.



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Earth Conductivity – Unspecified Regions

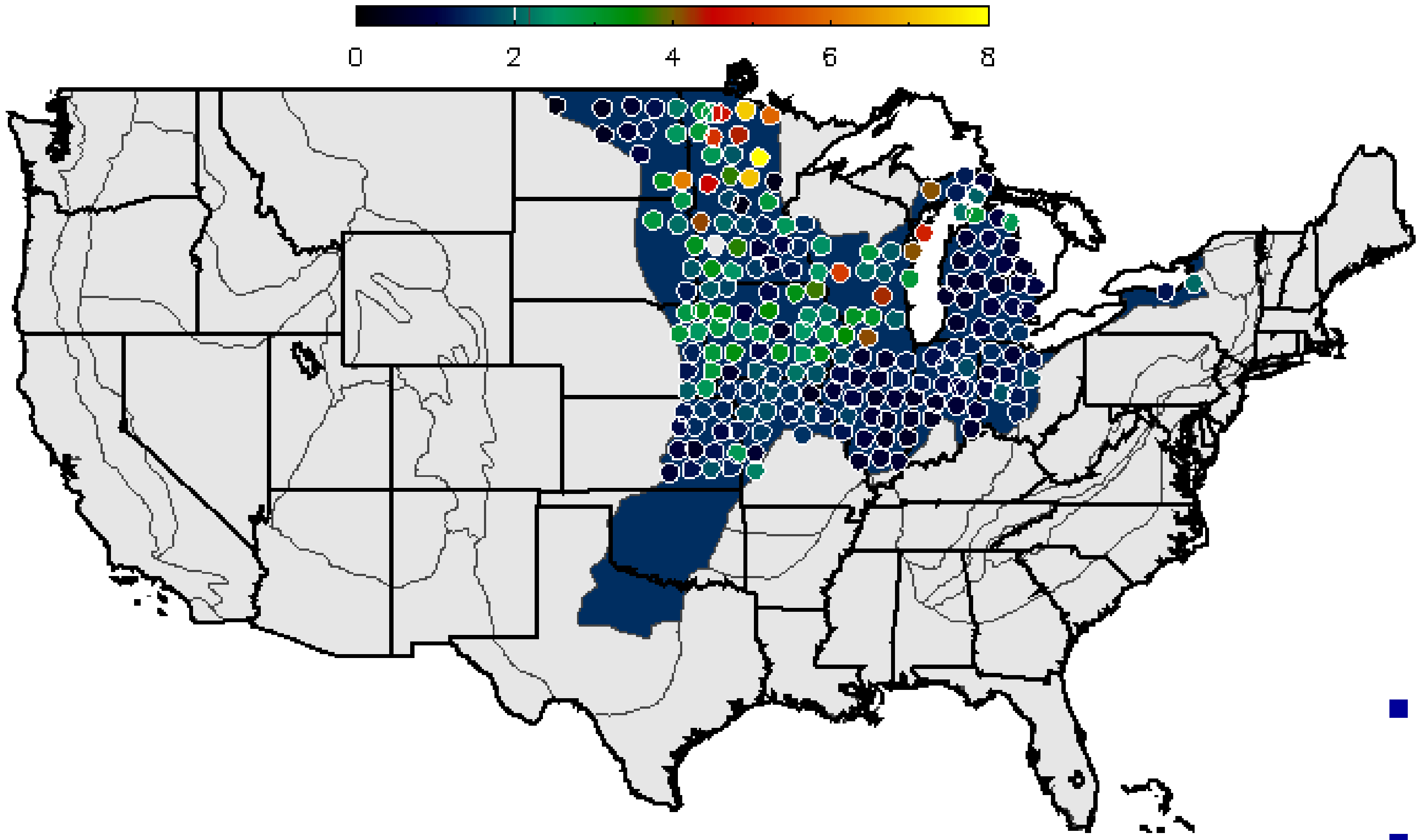
- There are several physiographic regions that did not have 1D models built specifically for them

(Lower Californian, Northern, Middle and Southern Rocky Mountains, Wyoming Basin, Ozark Plateau, Ouachita, and some parts of the New England physiographic regions).

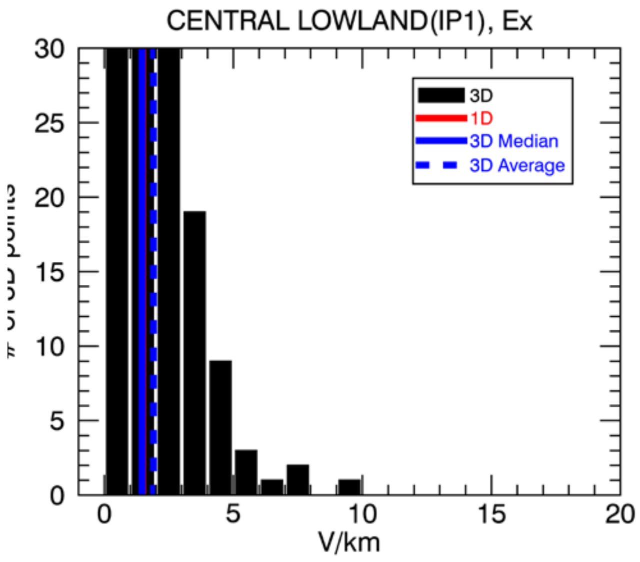
- These unspecified regions are being evaluated based on comparison with available 3D results

Guidance being provided in the interim for what beta scaling factor should be used for GMD vulnerability assessments for TPL-007.

Earth Conductivity – Model updates based on 3D EMTFs



Continuing to exam impact on GIC.



- 1D model updates are needed
- Boundaries need to be evaluated

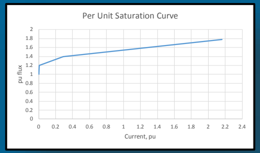
Use Magnetotelluric Measurement Data to Validate/Improve Earth Conductivity Models Technical Report – Q4 2018

Research Work Plan Tasks

Highest Priority

Improved Earth Conductivity Models

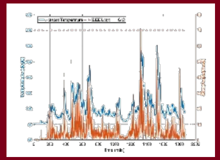
Improved Harmonic Analysis Capability



- EPRI Prioritization follows that of the FERC Directive
- Work on schedule to be completed in Q1 2020

Harmonic Impacts

Transformer Thermal Impacts



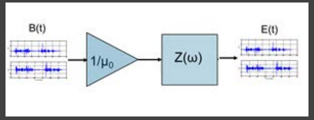
Spatial Averaging

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

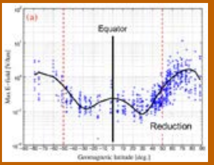
α= Geomagnetic Latitude Scaling Factors

β= Conductivity Scaling Factor

Geoelectric Field Evaluation



Latitude Scaling Factor



Lowest Priority

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Upcoming Reports/Tools

- Use Magnetotelluric Measurement Data to Validate/Improve Existing Earth Conductivity Models Available to Industry and Researchers Technical Report **Q4 2018**
- Harmonic beta version of the open source software tool **Q4 2018**
- Transformer Vibration Technical Report **Q4 2018**
- Database of localized extreme events, including ground-based and space-based data. The database will be made available to the public. **Q1 2019**
- Review of peer-reviewed research regarding the effects of geomagnetic latitude on geoelectric fields **Q2 2019**

Together…Shaping the Future of Electricity

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Link to Item 8.a

- Click here for Adam Schultz Presentation (Earthscope/USArray)
    - https://para1.coas.oregonstate.edu/drive/d/f/42676012734166305

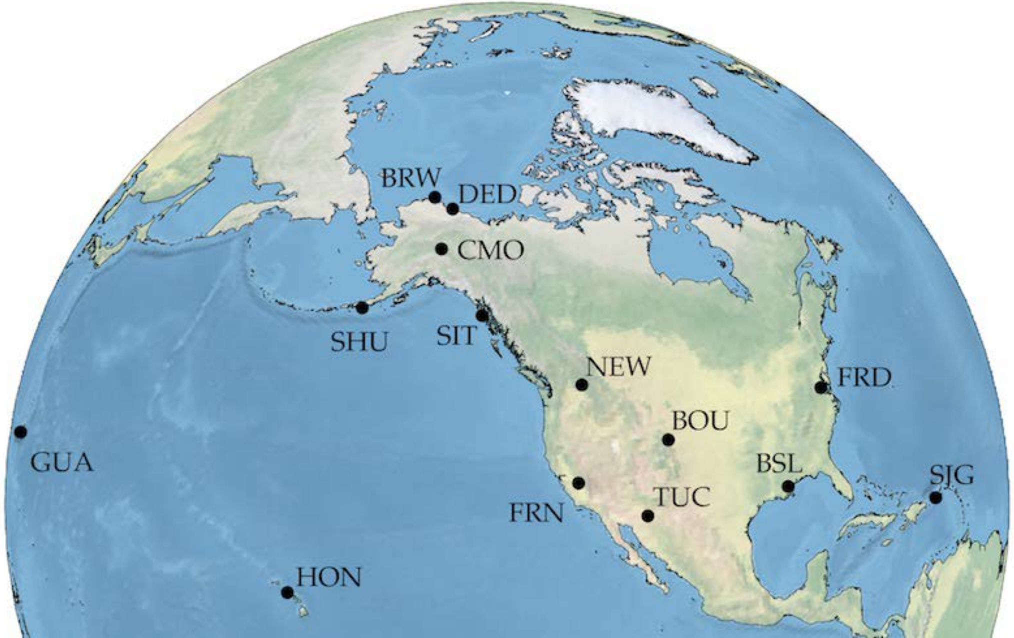
Update on work at the USGS Geomagnetism Program

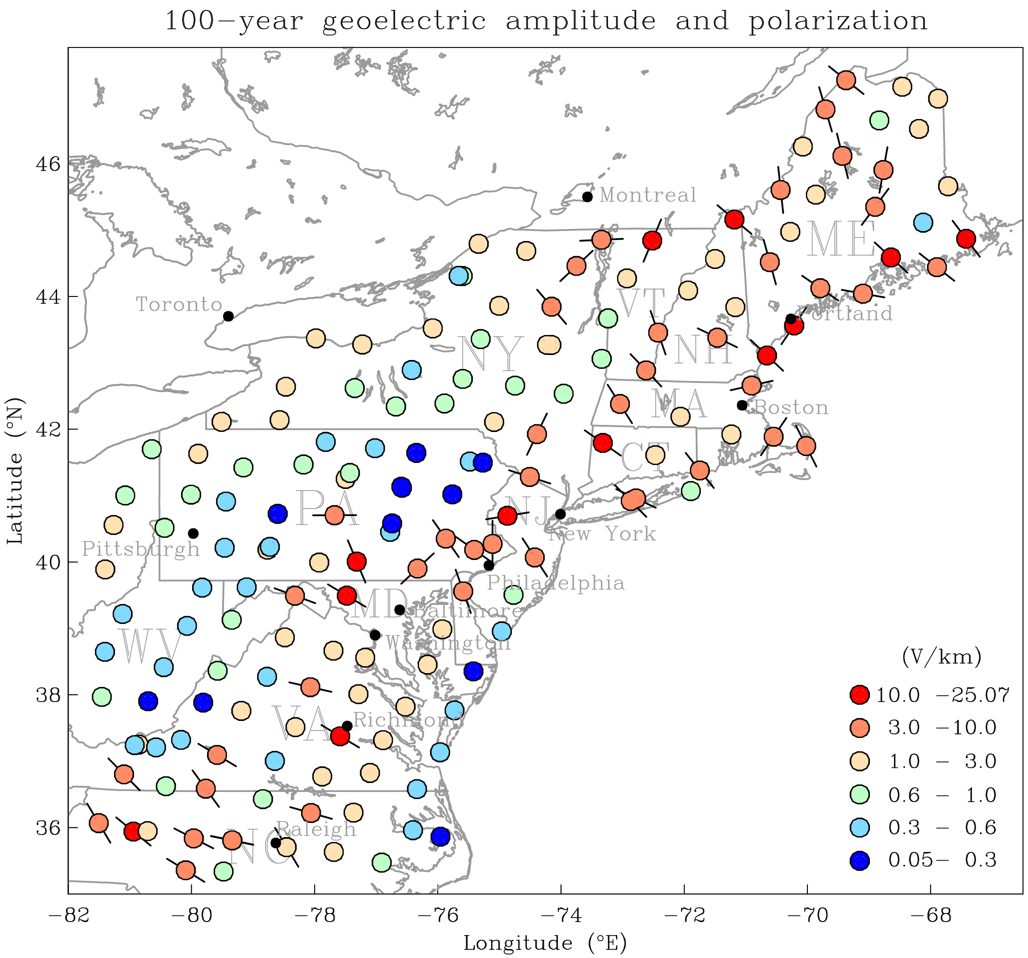
Jeffrey J. Love and Greg M. Lucas
U.S. Geological Survey
Geomagnetism Program

USGS Geomagnetism Program Summary
geomag.usgs.gov

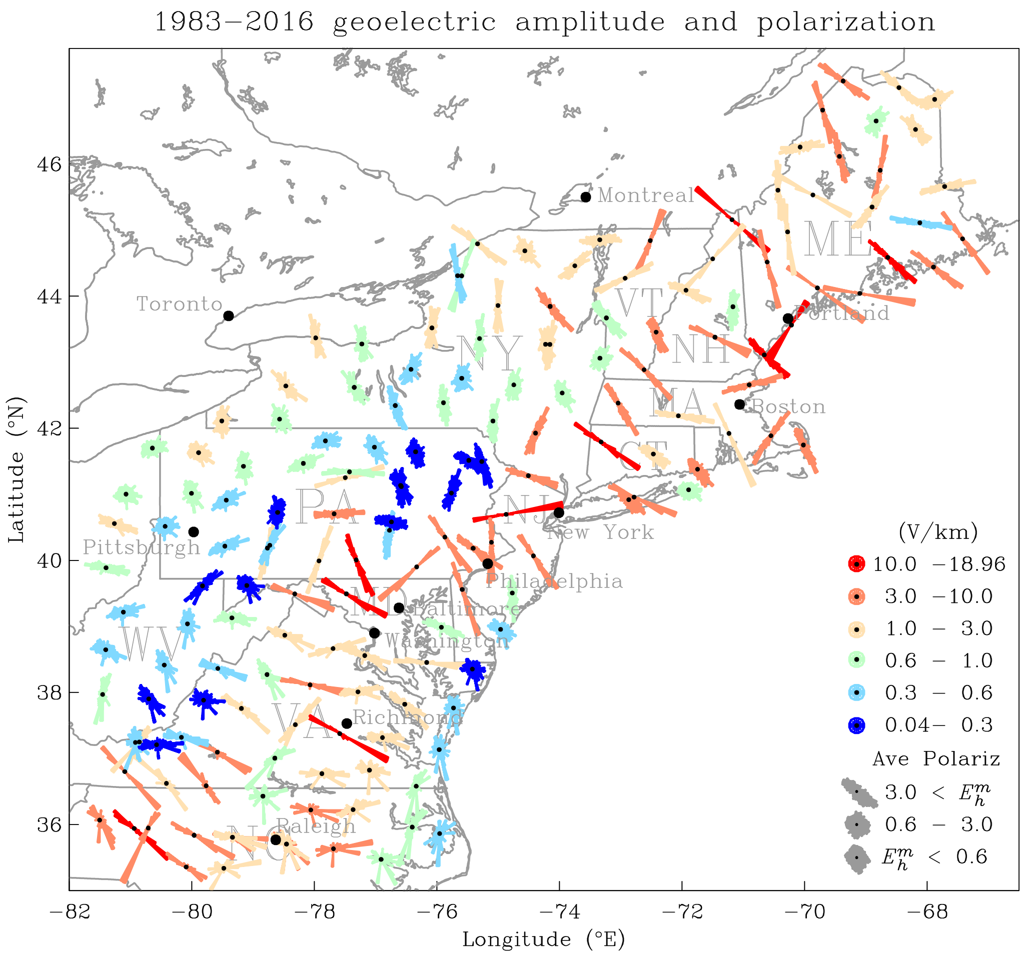
The USGS Geomagnetism Program stands ready (subject to budgetary and staffing challenges) to facilitate the collection, management, use, and dissemination of geomagnetic monitoring data and magnetotelluric survey data.

Contact:
Carol A. Finn
Geomagnetism Group Leader
cafinn@usgs.gov





100–year geoelectric amplitude and polarization
Latitude (°N)
Longitude (°E)
46
44
42
40
38
36
−82
−80
−78
−76
−74
−72
−70
−68
Montreal
Toronto
Portland
Boston
New York
Pittsburgh
Philadelphia
Baltimore
Washington
Richmond
Raleigh
ME
VT
NH
NY
MA
CT
NJ
PA
MD
WV
VA
NC
(V/km)
10.0 −25.07
3.0 −10.0
1.0 – 3.0
0.6 – 1.0
0.3 – 0.6
0.05– 0.3

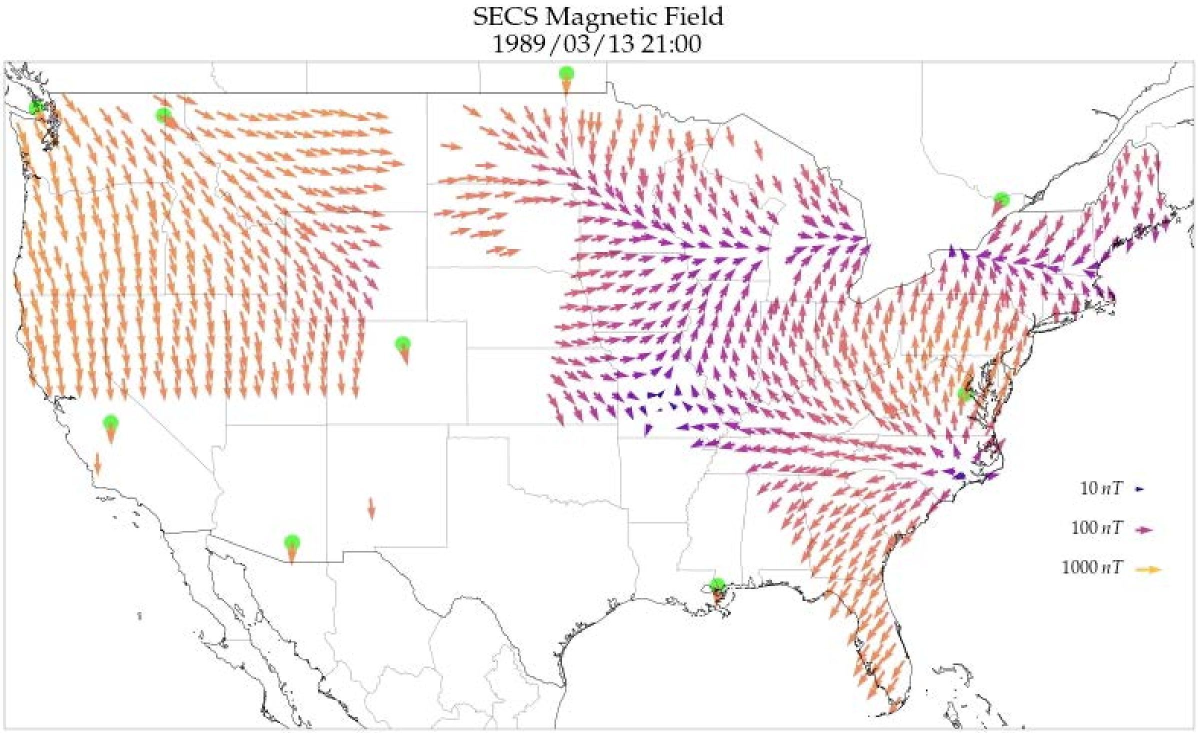


1983–2016 geoelectric amplitude and polarization
Latitude (°N)
Longitude (°E)
46
44
42
40
38
36
−82
−80
−78
−76
−74
−72
−70
−68
Montreal
Toronto
Portland
Boston
New York
Philadelphia
Pittsburgh
Baltimore
Washington
Richmond
Raleigh
ME
VT
NH
NY
MA
CT
NJ
PA
MD
WV
VA
NC
(V/km)
10.0 −18.96
3.0 −10.0
1.0 − 3.0
0.6 − 1.0
0.3 − 0.6
0.04− 0.3
Ave Polariz
3.0 < E_h^m
0.6 − 3.0
E_h^m < 0.6

USGS/NRCan Magnetic Fields

The magnetic field is only sampled at a few dozen observatories across North America.

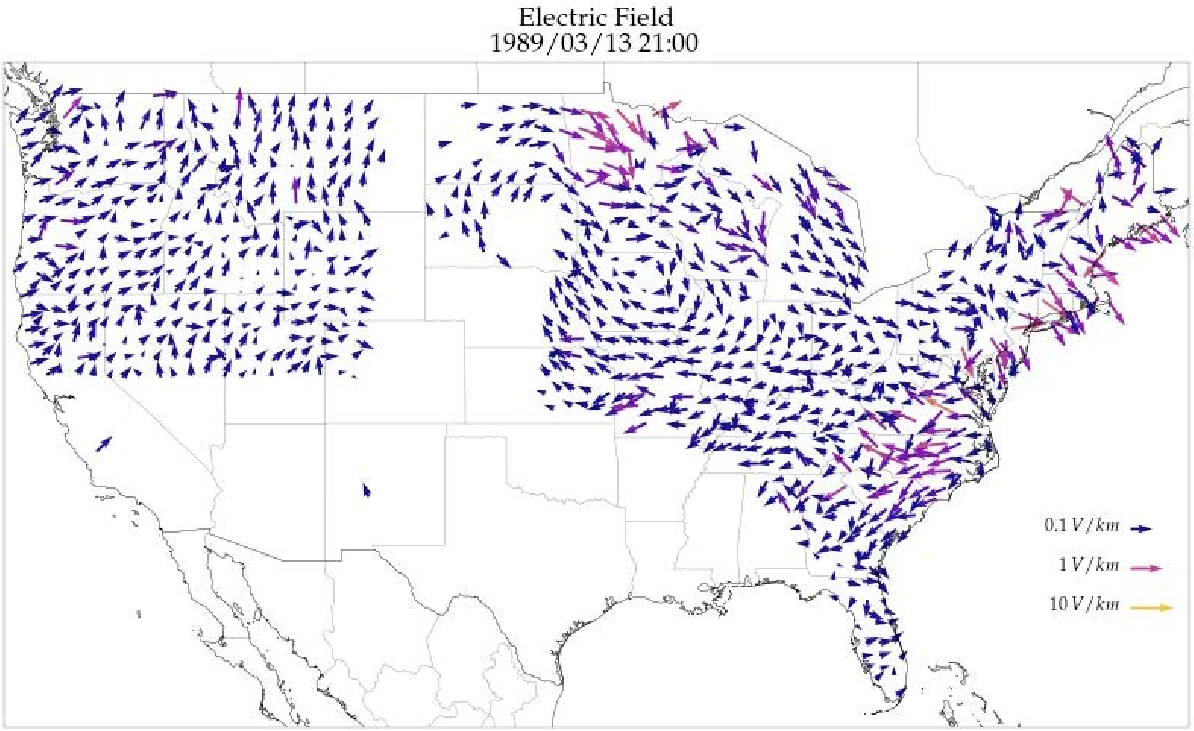
We use these high quality measurements to calculate a predicted time-series at each MT survey site.



Electric Fields at MT Survey Sites

Utilize the magnetic field time series to calculate a predicted electric field time-series at each MT survey site, using the full 3D impedance tensor.

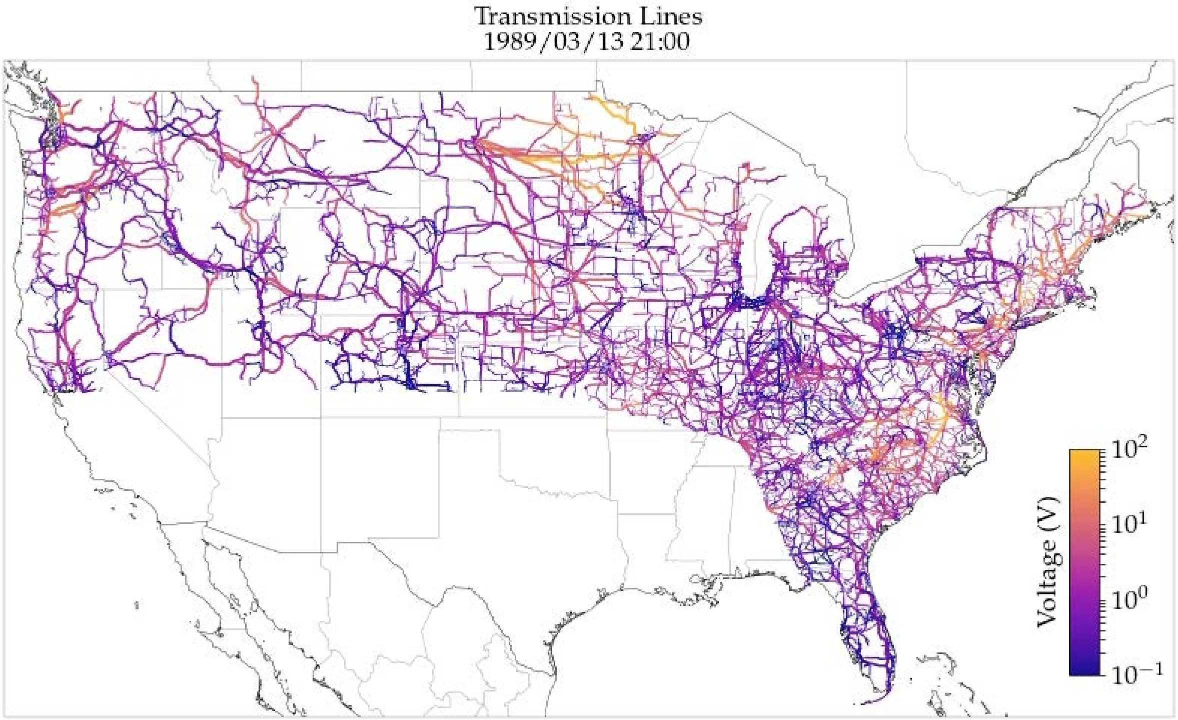
$$\vec{E} = \overleftrightarrow{Z} * \vec{B}$$



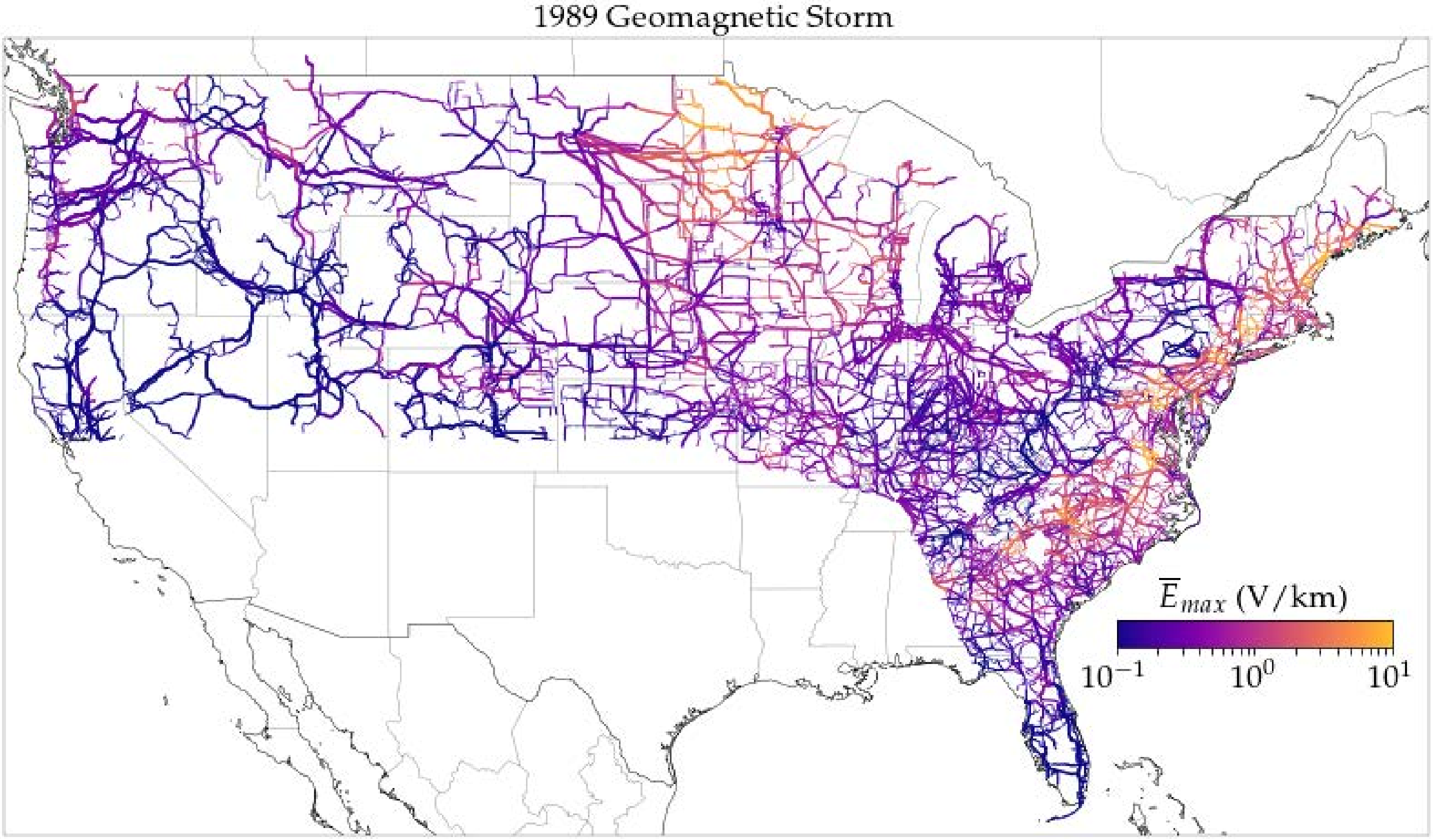
Voltages between Substations

Integrating the vector electric field along the transmission line to calculate a time-series of voltage between substations. This could be used as input for GIC models to calculate current flows.

$$V(t) = \int \vec{E}(t) \cdot d\vec{l}$$



Geoelectric Hazards



Summary

The data and codes are available to the community! Please get in touch with me if you have questions or want to collaborate.

Greg Lucas: glucas@usgs.gov

Open source code (with examples) for the community to use magnetic (B), electric (E), and impedance (Z) data.
https://github.com/greglucas/bezpy

Lucas, G. M., Love, J. J., & Kelbert, A. (2018). Calculation of voltages in electric power transmission lines during historic geomagnetic storms: An investigation using realistic earth impedances. Space Weather, 16, 181-195. https://doi.org/10.1002/2017SW001779

USGS Geomagnetism Program Summary
geomag.usgs.gov

The USGS Geomagnetism Program stands ready (subject to budgetary and staffing challenges) to facilitate the collection, management, use, and dissemination of geomagnetic monitoring data and magnetotelluric survey data.

Contact:

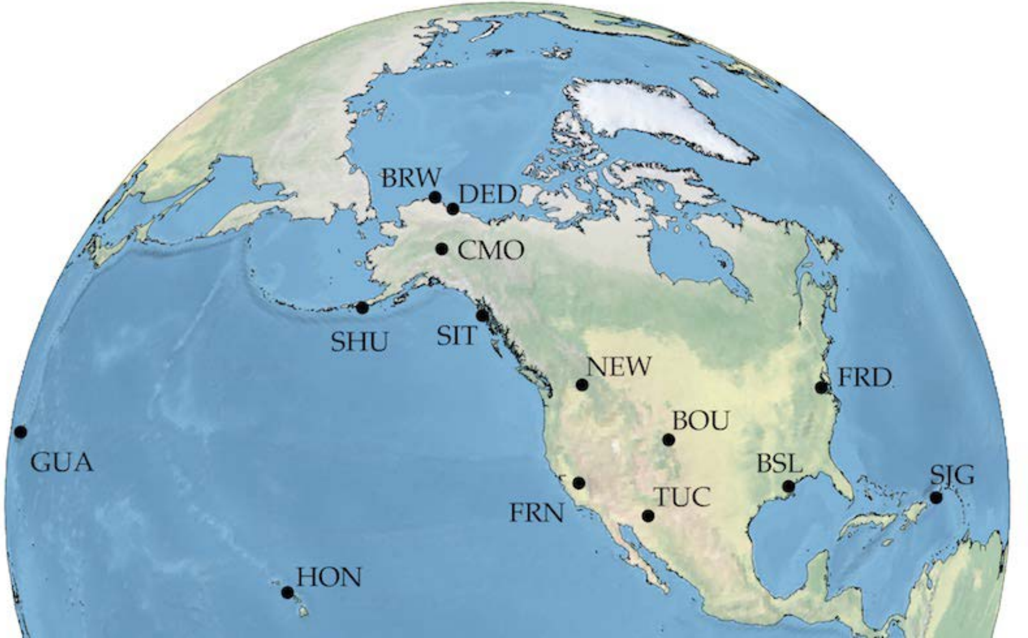
Carol A. Finn

Geomagnetism Group Leader

cafinn@usgs.gov

Jeffrey J. Love: jlove@usgs.gov

Greg M. Lucas: glucas@usgs.gov



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GMD Data Request

NERC Rules of Procedure Section 1600

Mark Olson, Senior Engineer
GMD Task Force Meeting
June 13, 2018

RELIABILITY | ACCOUNTABILITY

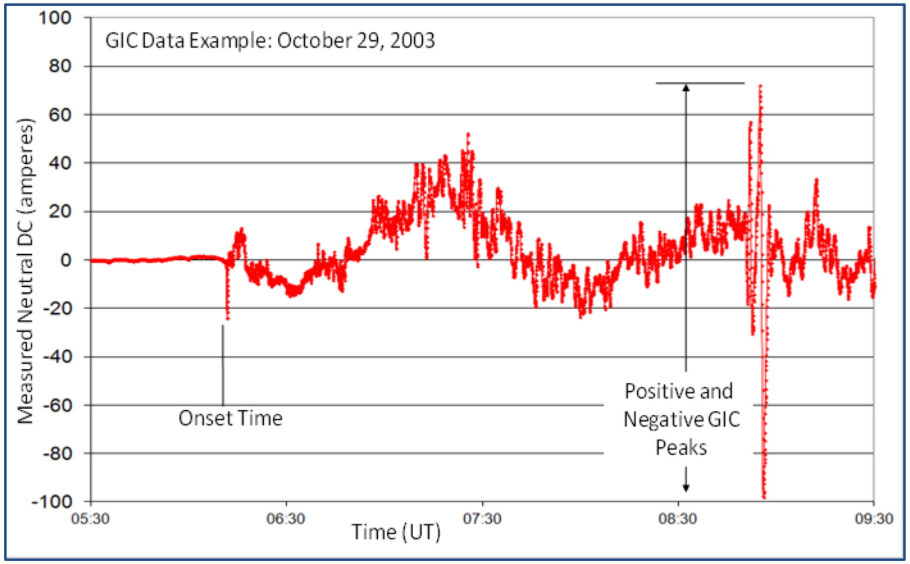



FERC Order No. 830

- In 2016 Federal Energy Regulatory Commission (FERC) directed actions to continue addressing risks from geomagnetic disturbances (GMD)
  - Implementation of GMD Vulnerability Assessments (TPL-007-1)
  - Revisions to TPL-007-1 (TPL-007-2 filed in January 2018)
  - Additional research
  - **Data collection**
- NERC developed a Rules of Procedure Section 1600 data request with GMD Task Force (GMDTF) and stakeholder input
- NERC, EPRI and GMDTF are conducting a research plan to meet Order No. 830 research objectives

Data Collection and Availability

- Order No. 830 directs NERC to collect GMD data to "improve our collective understanding" of GMD risk
  - Includes GIC and Magnetometer data
- NERC is to make data available to the public



GMD Data Request Overview

- Data will be collected for GMD events that meet or exceed K_P-7
  - Low burden on reporting entities: 200 events per 11-year solar cycle
  - NERC will designate specific collection periods (date/time)
- Transmission Owners and Generator Owners with GIC and/or magnetometer data are applicable reporting entities
  - Reports are not required for entities that do not collect data
  - Non-U.S. entities are not obligated to participate but are encouraged
  - Reporting on behalf of applicable entities is acceptable (e.g., EPRI)
- NERC will make data available to researchers

Development Steps

- September 2017 | Draft Presented at GMDTF Meeting
- December 2017 | Planning Committee Authorized Posting
- January – March 2018 | 45-day comment period
  - Comments were provided by over 30 stakeholders

- Comments, responses, and revisions to the GMD Data Request are posted on GMDTF Project Page

Data Request Status

- PC endorsed the GMD Data Request on June 5, 2018
- Next steps
  - August 2018 | Request NERC Board Approval
  - Q3 2018 | GMDTF and NERC Staff begin developing a Data Reporting Instructions (DRI)
- NERC staff will continue development of information technology application for collecting GMD Data

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Questions and Answers

Back-up Slides

Data Request Background

- NERC Rules of Procedure (RoP) Section 1600
  - *Within the United States, NERC and Regional Entities may request data or information that is necessary to meet their obligations under Section 215 of the Federal Power Act, as authorized by Section 39.2(d) of the Commission's regulations, 18 C.F.R. § 39.2(d).* (P 1601)
- Data Request Elements
  - Describe why the data is needed, its use and collection method
  - Identify functional entity(ies)
  - Estimate the burden on reporting entities
  - Establish reporting criteria or schedule
- Process
  - 45-day public comment period on NERC's request
  - NERC Board approval required to issue data request to entity(ies)

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What Data Will Be Requested

In addition, the Commission directs NERC, pursuant to Section 1600 of the NERC Rules of Procedure, to ***collect GIC monitoring and magnetometer data from registered entities****[*] for the period beginning May 2013, including both data existing as of the date of this order and new data going forward, and to make that information available.*

-Order No. 830 P 89

*does not apply to non-U.S. Entities

Order No. 830 on Data Confidentiality

…as a general matter, the Commission does not believe that GIC monitoring and magnetometer data should be treated as Confidential Information pursuant to the NERC Rules of Procedure. (P 89)

…Notwithstanding [the Commission's] findings here, to the extent any entity seeks confidential treatment of the data it provides to NERC, the burden rests on that entity to justify the confidential treatment. (P 95)

Basis for Data Confidentiality Approach

- Critical Energy Infrastructure Information is defined in NERC RoP Section 1501 as

  specific engineering, vulnerability, or detailed design information about proposed or existing Critical Infrastructure that (i) relates details about the production, generation, transportation, transmission, or distribution of energy; (ii) could be useful to a person in planning an attack on Critical Infrastructure; and (iii) <u>does not simply give the location of the Critical Infrastructure.</u>

- Data reporting requirement provides only general location information
  - Nearest tenth of a degree ~ 5-7 mile resolution

Purpose of Collecting GMD Data

[The Commission] also direct NERC, pursuant to Sections 1500 and 1600 of the NERC Rules of Procedure, to collect and make GIC monitoring and magnetometer data available. We determine that the dissemination of GIC monitoring and magnetometer data will facilitate a greater understanding of GMD events that, over time, will improve Reliability Standard TPL-007-1. The record in this proceeding supports the conclusion that access to GIC monitoring and magnetometer data will help facilitate GMD research, for example, by helping to validate GMD models.

- Order No. 830 P 93