

EPRI GMD Research Update:

Furthering the Research of GMD Impacts on the Bulk Power System

Bob Arritt, PE

Transmission and Substations Area
San Antonio, TX
12 February 2019



GMD Research Portfolio

New GMD Supplemental Project

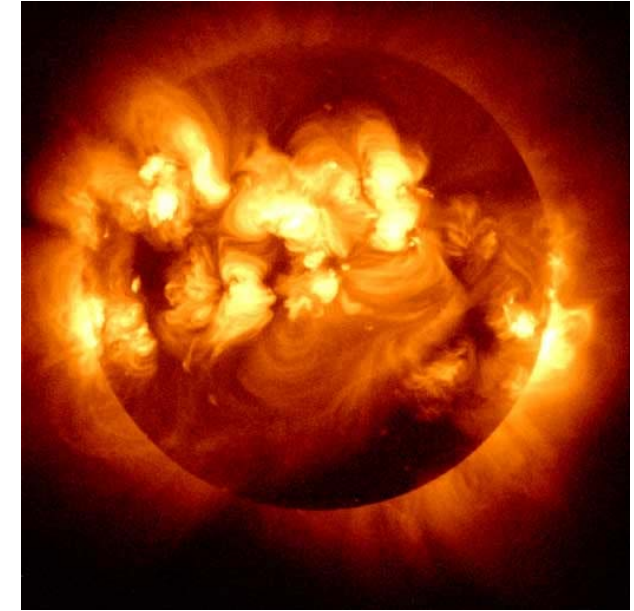
- Benchmark GMD Event
- Transformer Assessment
- GMD Harmonics Assessment

ARP – GMD Vulnerability Assessments

- GMD Assessment Guidelines
- Commercial Planning Tools
- Road Map for Future Assessment Methods/Tools

SUNBURST & Adv. Sensors

- GIC Monitoring (neutral and line)
- Magnetometers
- Data Analytics



Supplemental Newly Released Material

- Improve Harmonics Analysis Capability Tool Product ID# 3002014854
- Tool Evaluation and Electric Field Estimate Benchmarking Results Product ID# 3002014853
- Use of Magnetotelluric Measurement Data to Validate/Improve Existing Earth Conductivity Models Product ID# 3002014856
- Transformer Vibration Analysis Product ID# 3002014855

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Impact of Geomagnetically Induced Currents on Transformer Tank Vibrations

Transformer Vibration Analysis

3002014855

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Tool Evaluation and Electric Field Estimate Benchmarking Results

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Use of Magnetotelluric Measurement Data to Validate/Improve Existing Earth Conductivity Models

3002014856

The screenshot displays the GIC harm software interface. The main window shows a system-level analysis of a transformer tank vibration, with a list of components (reactors, capacitors, and shunts) and their status. A dialog box titled "About" is open, providing details about the software version and license.

About

EPRI | ELECTRIC POWER
RESEARCH INSTITUTE

GIC harm
Version 0.0

OpenDSS engine:
Version 7.6.5.86
(64-bit build)

License:

EPRI GIC harm (GIC harm) Version 0.0
Electric Power Research Institute, Inc. (EPRI)
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OK

GMD Harmonic Research

- GMD harmonic assessments—provide guidance and tools to address GMD-related harmonics
 - Develop models and methods to improve capability of performing harmonic assessments of benchmark GMD events.
- Impacts of harmonics on the bulk power system.

FERC Order 830 P68. “... Accordingly, we direct NERC to address the effects of harmonics, including tertiary winding harmonic heating and any other effects on transformers, as part of the GMD research work plan.”

FERC Order 830 P68 Footnote 101. “... collaborating with researchers to examine more complex GMD vulnerability issues, such as harmonics and mitigation assessment techniques, to enhance the modeling capabilities of the industry”

Transformer level analysis

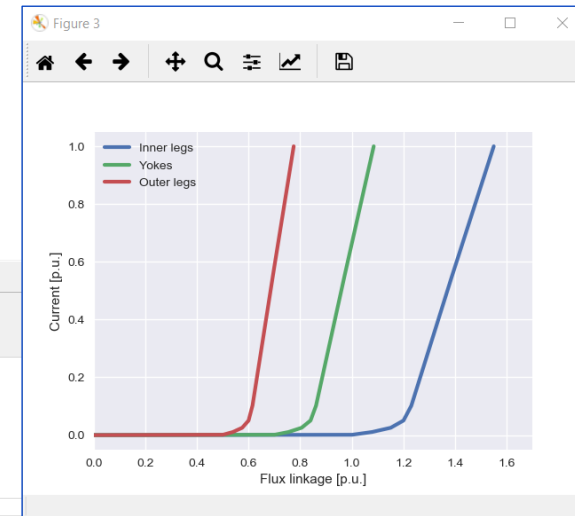
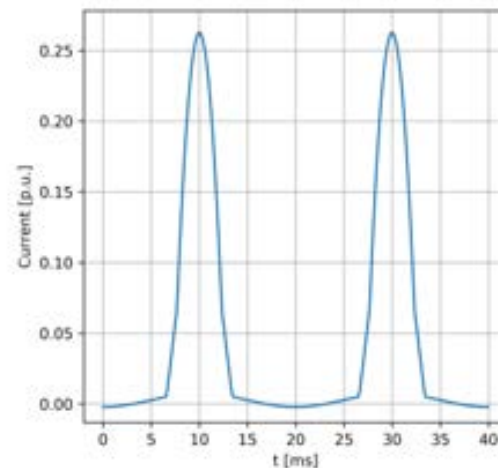
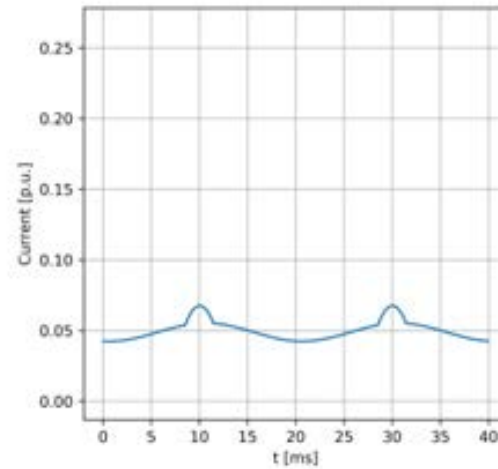
Core topology options:

- 3 single-phase, 3-leg, 5-leg, shell-form

Analysis options:

- Excitation currents per phase for a given GIC level:
 - Waveforms
 - Spectra

Magnetizing
Current 40A GIC



Transformer details

Core Type: 5 legged

MVA rating: 370.00

kV rating HV/LV: 400 / 20

V HV/LV [p.u.]: 1.00 / 1.00

Frequency: 60 Hz

Cross-sectional area (w.r.t. main leg)

Yoke [p.u.]: 0.70

Outer leg [p.u.]: 0.50

GIC [p.u.]: 0.030

Sweep details

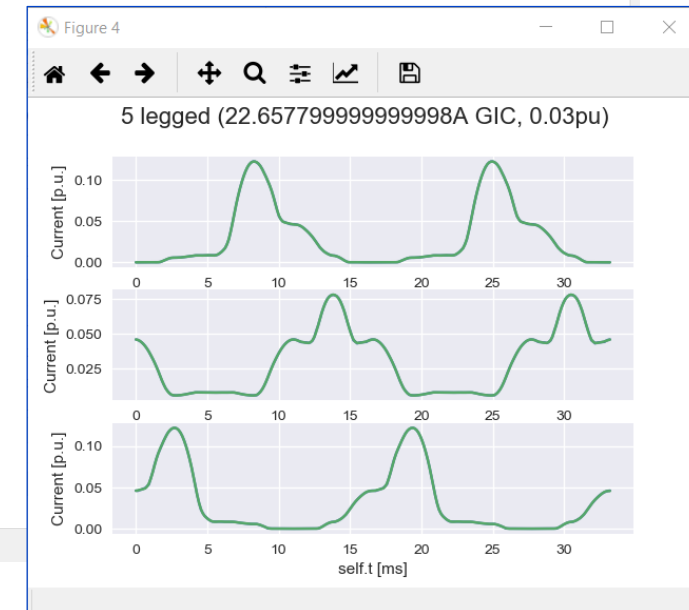
Start [p.u.]: 0.000

End [p.u.]: 0.300

Steps: 100

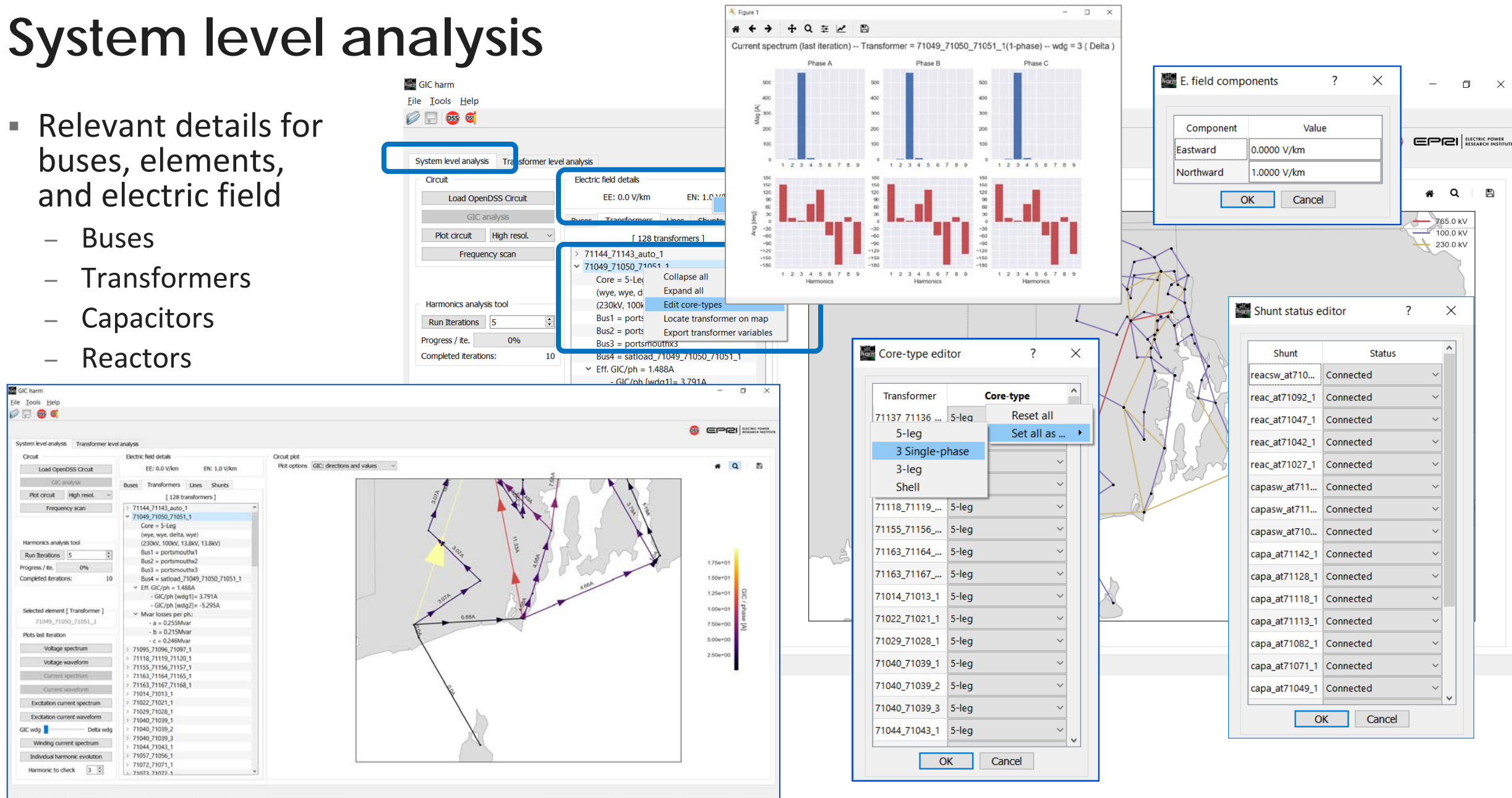
Progress: 0%

Create Run Run sweep Export

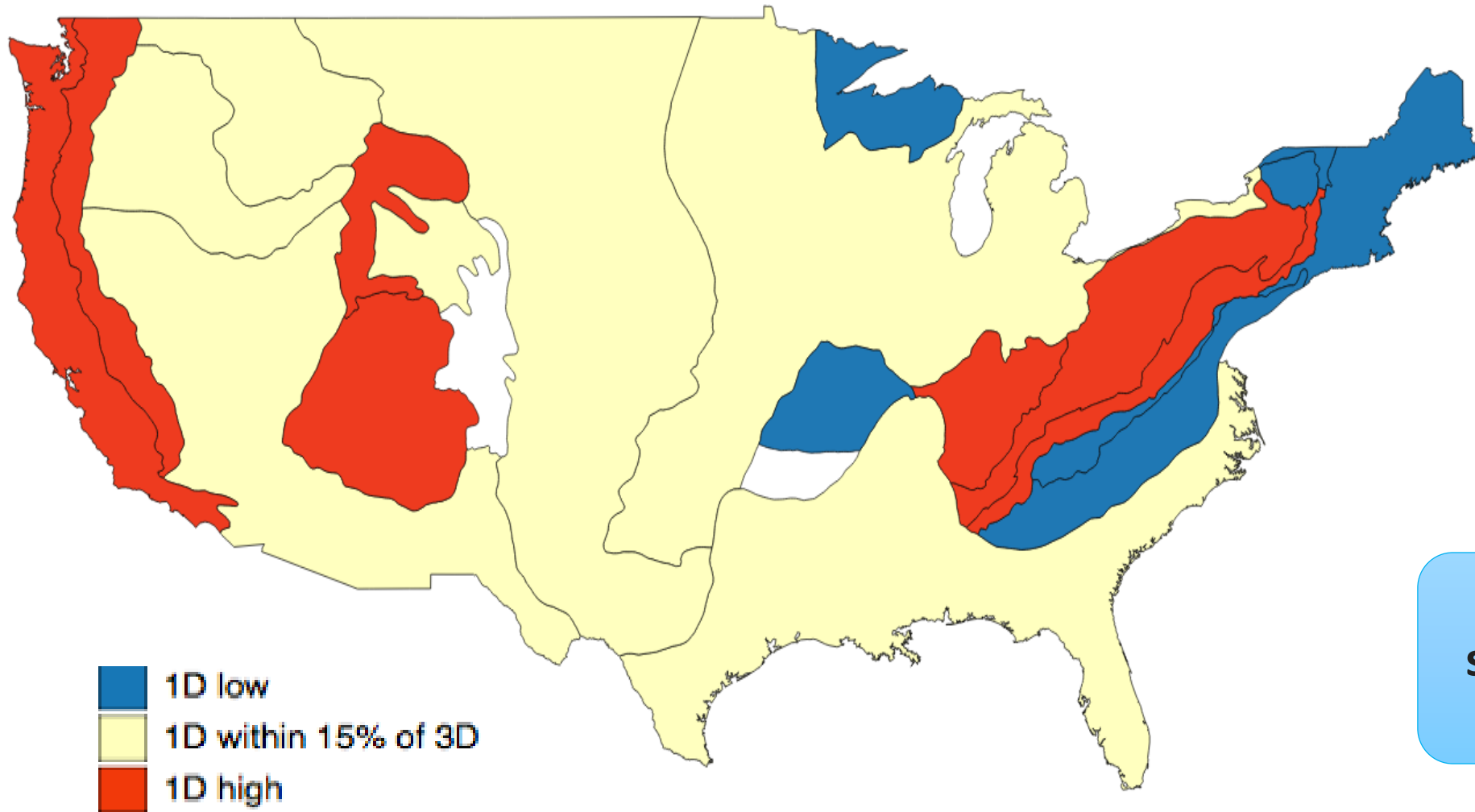


System level analysis

- Relevant details for buses, elements, and electric field
 - Buses
 - Transformers
 - Capacitors
 - Reactors



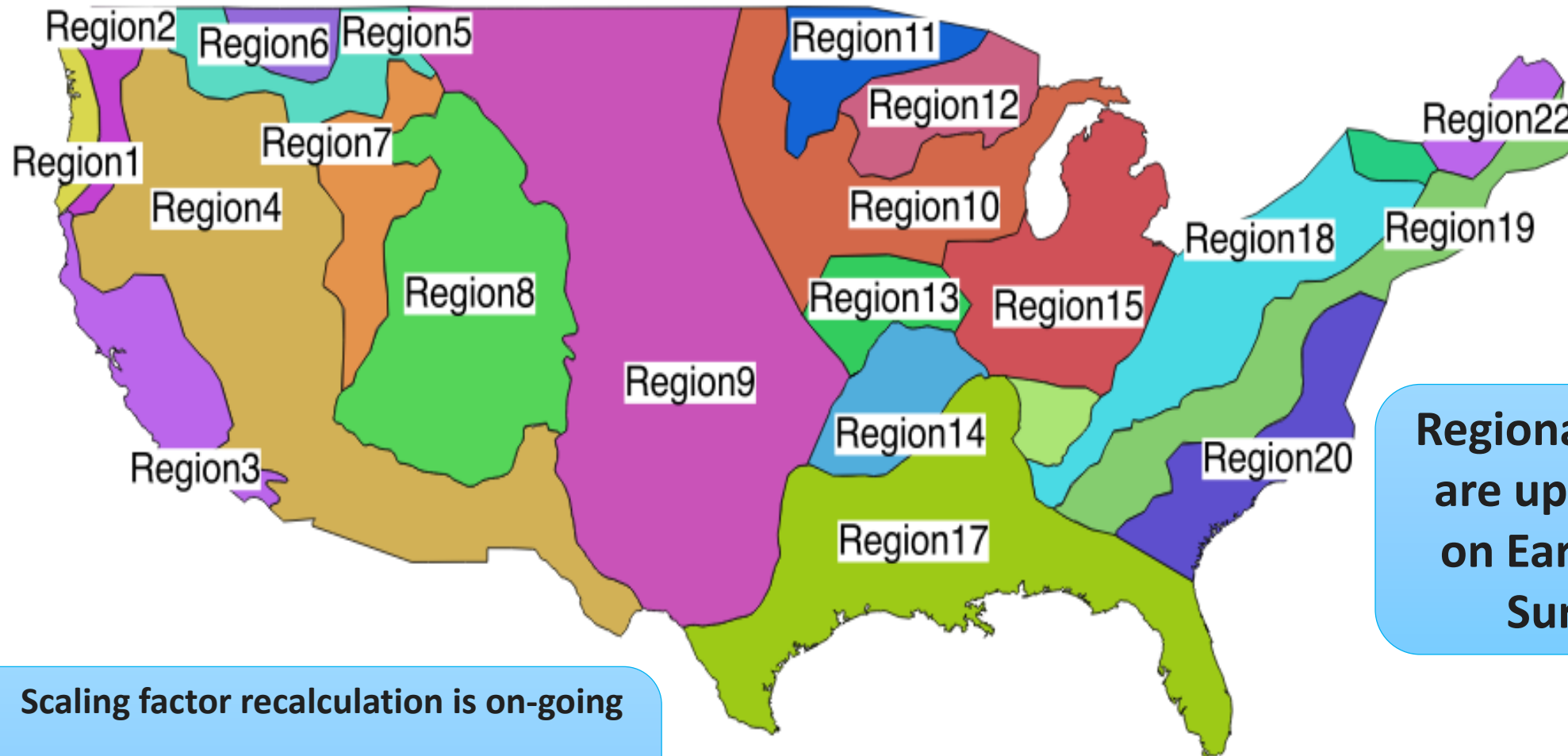
Earth Conductivity Research Comparisons – Original 1D models to new MT data



- Examining the observed differences between 1D and 3D representations of ground response approaches.

**Adding new data,
some areas are high
or low.**

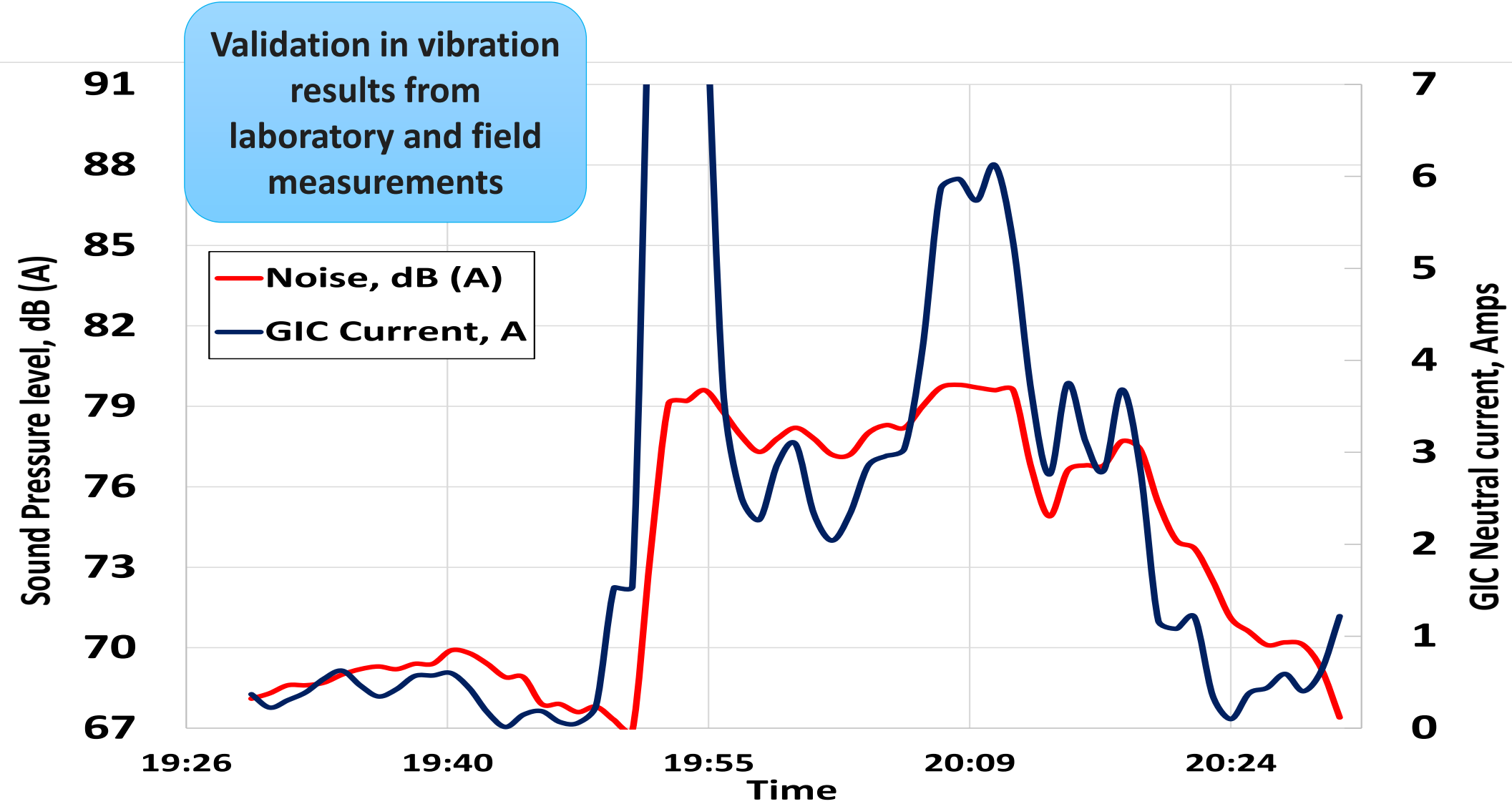
Updated 1D models



**Regional boundaries
are updated based
on Earthscope MT
Survey data**

- **Scaling factor recalculation is on-going**
- **Working with a member utility to compare model results with GIC measurements**

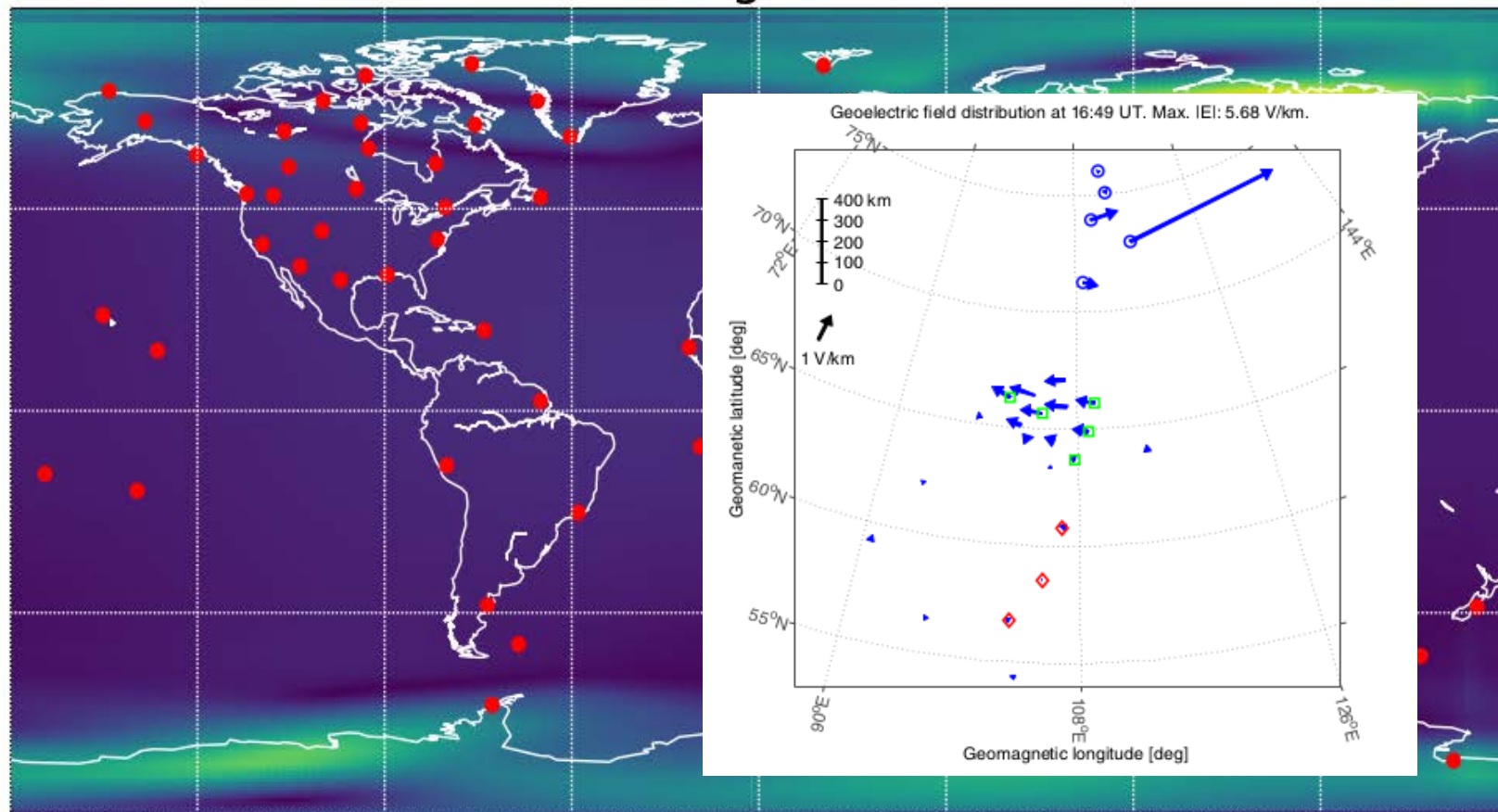
Studies on the saturation of noise and vibration with GIC currents



Localized Geoelectric Field Enhancements

- Have developed comprehensive data set to support GMD analyses.
- Using historical data and Magnetohydrodynamic MHD simulations, we can interpolate magnetic field values between observatories

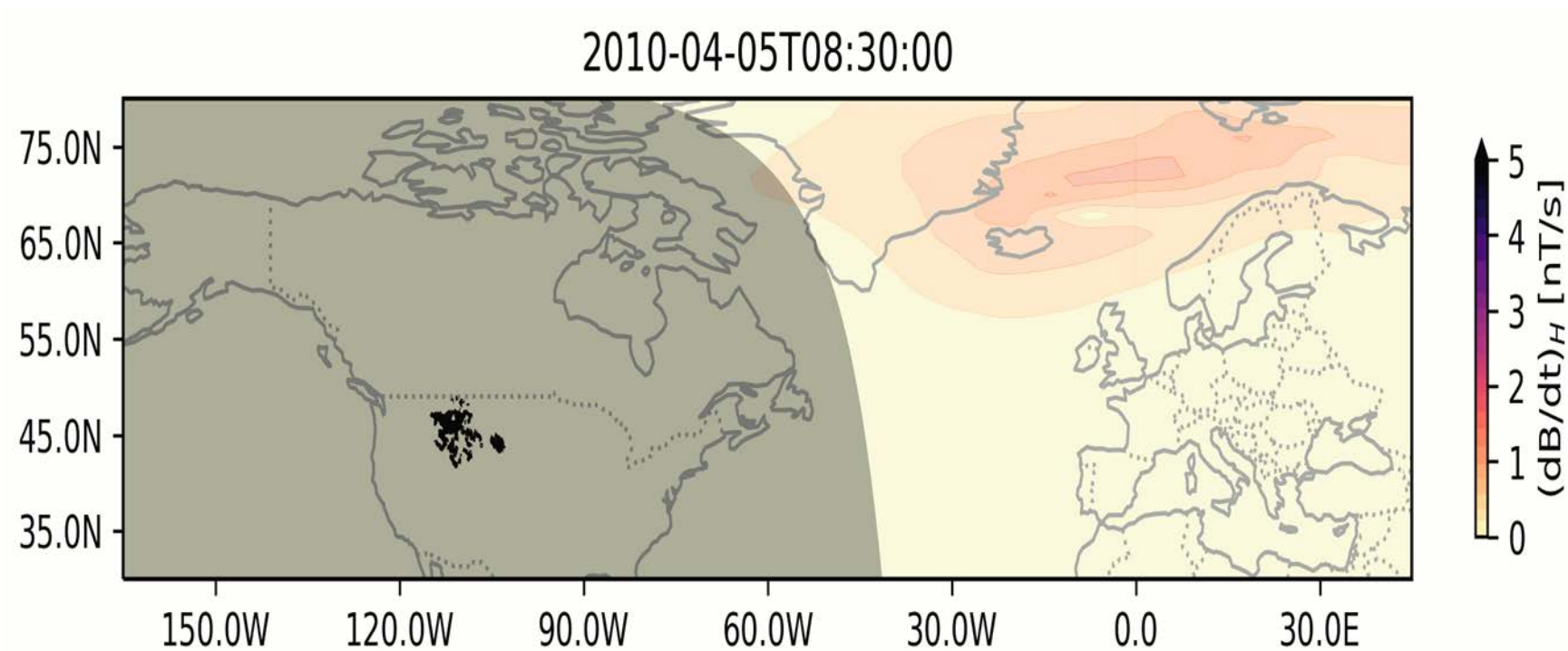
Intermagnet Sites



Data Set providing Ground Truth for Modeling

Geomagnetic Latitude Boundary Movement

- During geomagnetic storms, the auroral oval moves south, causing larger induced surface electric fields.
- Using historical data and Magnetohydrodynamic (MHD) simulations to show the extent of this southward motion for extreme events.



Data Set providing Validation for Modeling

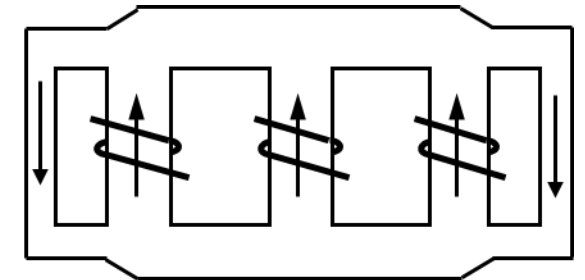
Next Steps

- EPRI will continue to perform long-term monitoring of large power transformers in the field.
- Upcoming Reports
 - Review of GMD Event Description White Paper and Supporting Peer-Reviewed Papers
 - Analysis of 10-20 localized extreme events and the associated MHD simulations
 - Developed database and derived products, including processed and corrected time series and APIs, will be made available and documented in the technical report.
 - Develop Guidance for Validation of GIC Models using Earth Conductivity Models
- Next Workshop August 13th Chicago, IL

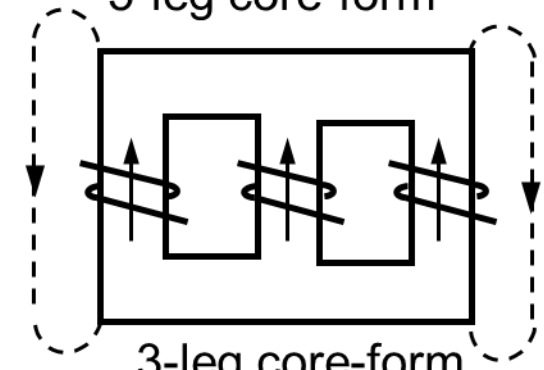
P40.023A Update: Special Studies

Factors Influencing k-factor

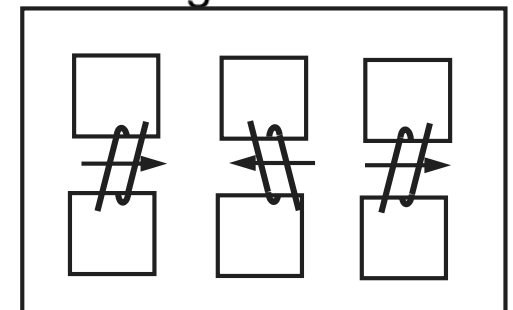
- Literature review shows that the following parameters influence the reactive power absorption of a transformer saturated due to GIC
 - Outer limb area (less impacted by yoke cross-section area)
 - Unsaturated stray flux inductance (airgap and tank reluctance)
 - Knee point of the core saturation characteristics
 - Air-core inductance (typically between 0.3-0.8pu)
 - Applied ac voltage
- Five-limb
 - Outer limb area (less impacted by yoke cross-section area)
 - Unsaturated stray flux inductance (airgap and tank reluctance)
 - Knee point of the core saturation characteristics
 - Air-core inductance (typically between 0.3-0.8pu)
 - Applied ac voltage
- Three-limb
 - Applied ac voltage
 - Stray flux inductance (high sensitivity), airgap and tank reluctance
 - Core saturation knee point
 - Non-uniform three-phase air-path stray fluxes
- Shell-type (similar behavior to single-phase)
 - Applied ac voltage
 - Yoke cross-section area
 - Stray flux inductance



5-leg core-form

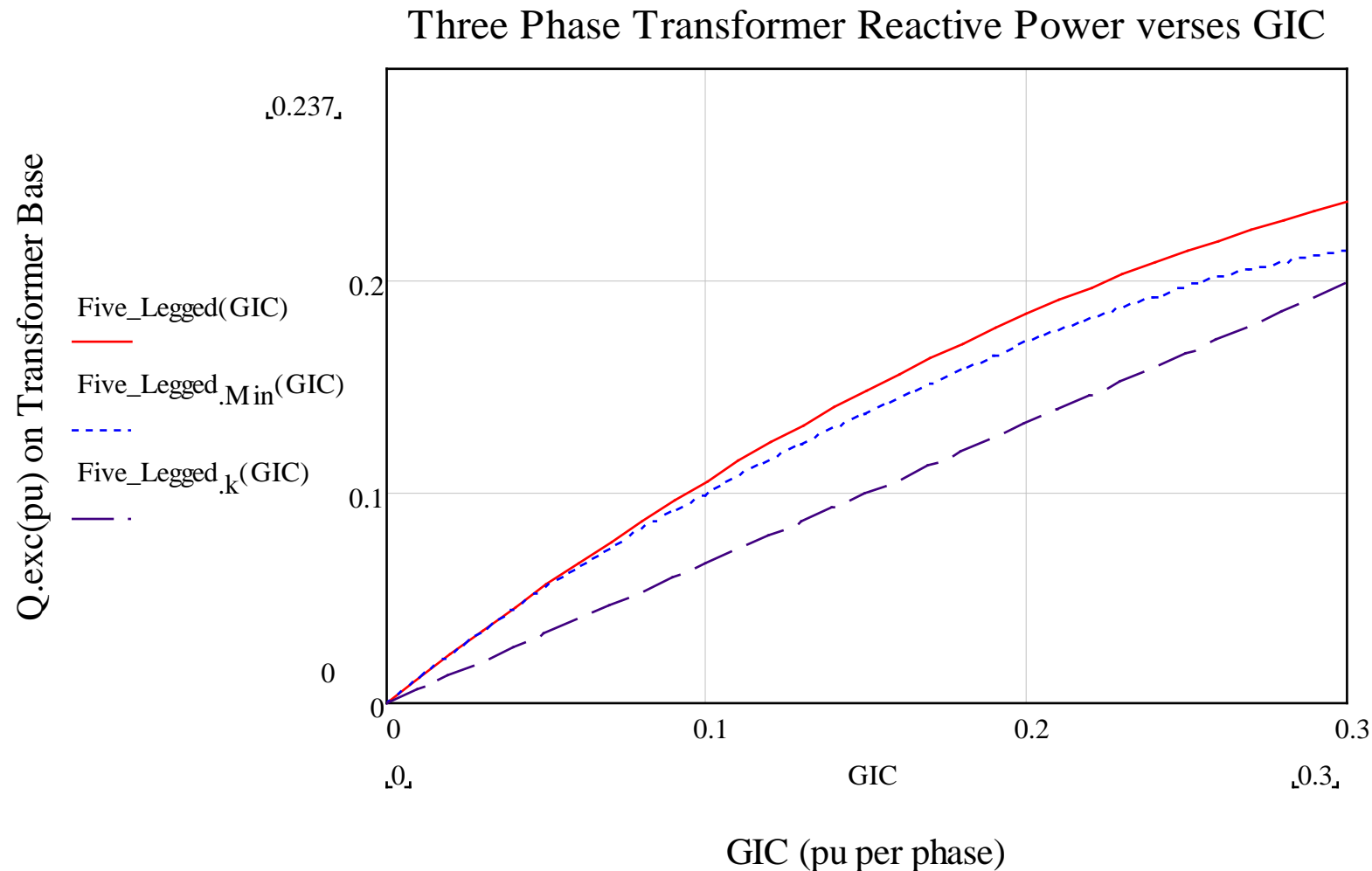


3-leg core-form

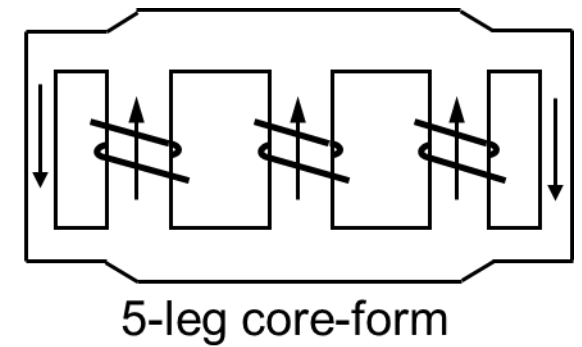


conventional shell form

Q-GIC characteristics of a 5-legged transformer under changing yoke and return leg cross-section area

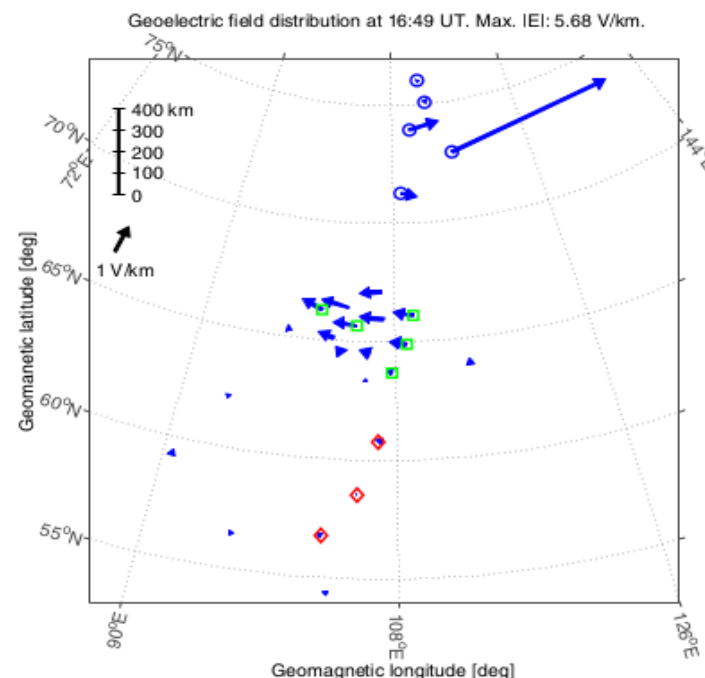
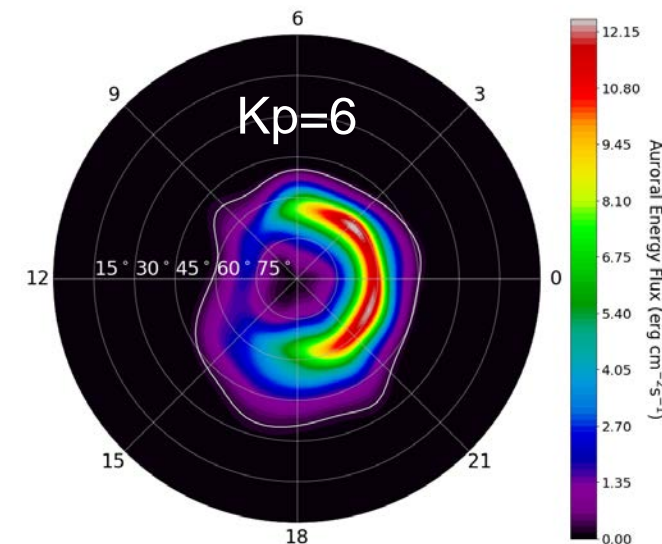


Provide k-factor ranges for various core sizes



2019 Project Proposals

- Update to the EPRI GMD Vulnerability Assessment and Planning Guide
 - Continue refinement of the k-factor results
- GMD Planning Software Benchmarking
 - Benchmarking the GIC simulation of non-uniform electric fields
 - EPRI would be generating a generic non-uniform electric field to be simulated in the GMD planning software tools.
 - To ensure accuracy and consistency across platforms, and coordinate individually with each vendor in a confidential matter and adjust where needed.
 - Goal is to allow vendors to expand their capabilities and to ensure accuracy across multiple platforms



2019 Project Proposals – EPRI Operations Guide

Proposed – EPRI GMD Operations Manual Table of Contents

- Preparation
 - System studies
 - Modeling uncertainties
 - GIC monitoring
 - Using the results to select the most strategic locations to monitor
- 2-3 day NOAA Alert \geq k7
 - Assess system configuration against planning configuration
 - Safe posture
- During event if still \geq K7 for x time
 - Actions to take with monitored GIC
 - Sophisticated monitoring infrastructure
 - Nominal monitoring infrastructure
 - Minimal/non-existent monitoring infrastructure
 - Monitor var reserves
 - Reliability issues – PT/CT calibration
 - State estimator
 - PMU issues
 - Emergency operation (not n-1)
 - Load shedding
 - GIC redirection
 - Account for ambient temperature discount on at-risk transformers.
 - Time of day consideration (Result of GMD supplemental work)
 - Leverage DGA monitoring – primarily to assess transformer condition.
 - Recognize sub-storm waveforms, etc.

P40.23A – GMD Vulnerability Assessments

Ultimate Research Value Proposition

- R&D Gap/Goal: Enhancing methods/tools to accurately conduct GMD vulnerability assessments.
- Value: Improved understanding of reactive power demands of transformers during GMD events will result in enhanced reliability of the bulk electric system.

2018 Projects Goals

- Provide an improvement or better understanding of the “k-factor” used in power flow simulations.
- Models will be further developed based on the research conducted which will assist in understanding the dependency between the level of GIC and transformer type on k-factors.

Project Set	Project	Deliverable Title - Full	Deliverable Title - Short	Project ID #
40.023A	GMD Planning Study Application Guide	GMD Planning Study Application Guide	GMD Planning Guide Update	3002013590
40.023A	GMD Planning Study Application Guide	Modeling of GMD Related Reactive Power Losses	Three-Phase Transformer K-Factor Analysis	3002014847



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