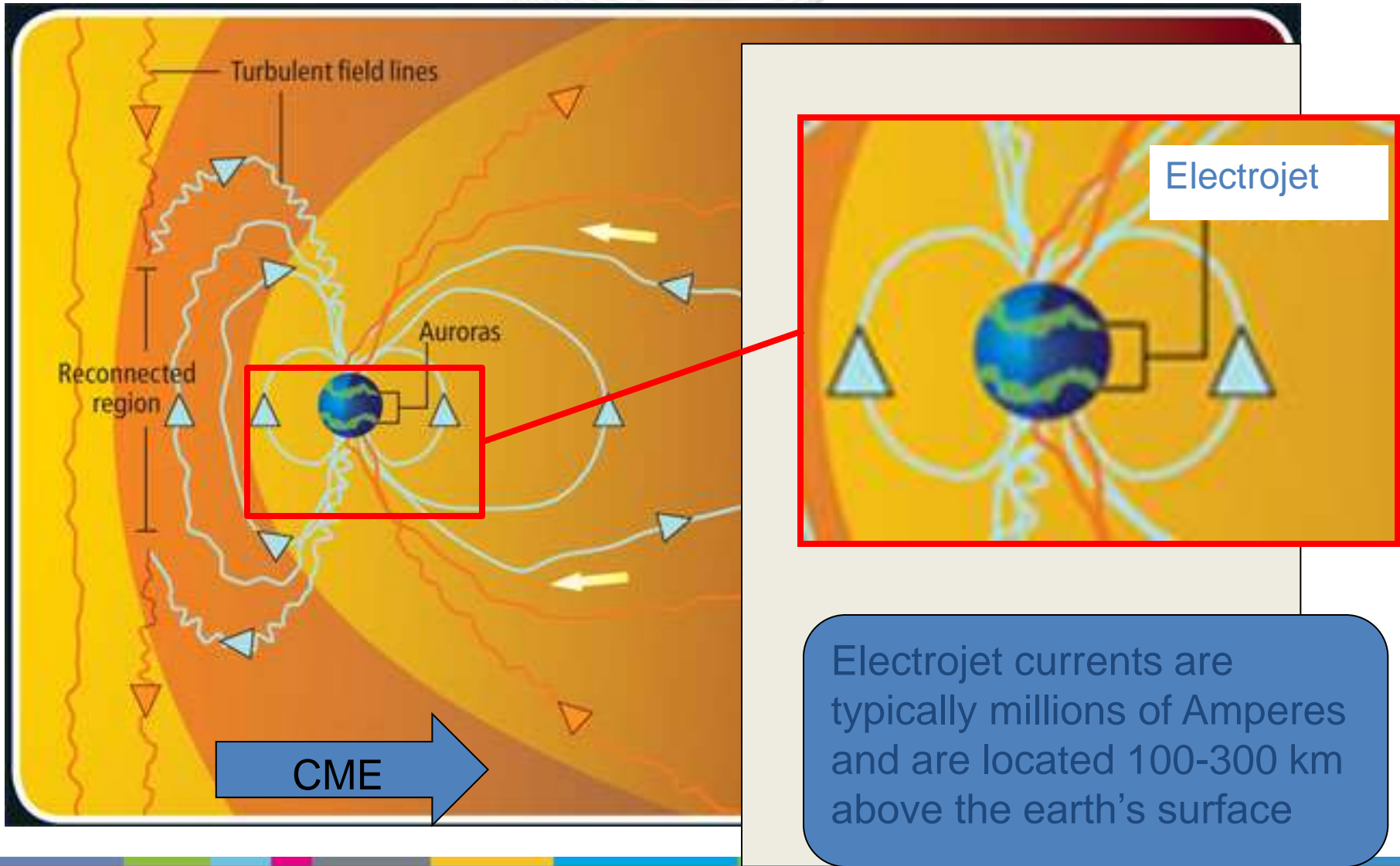


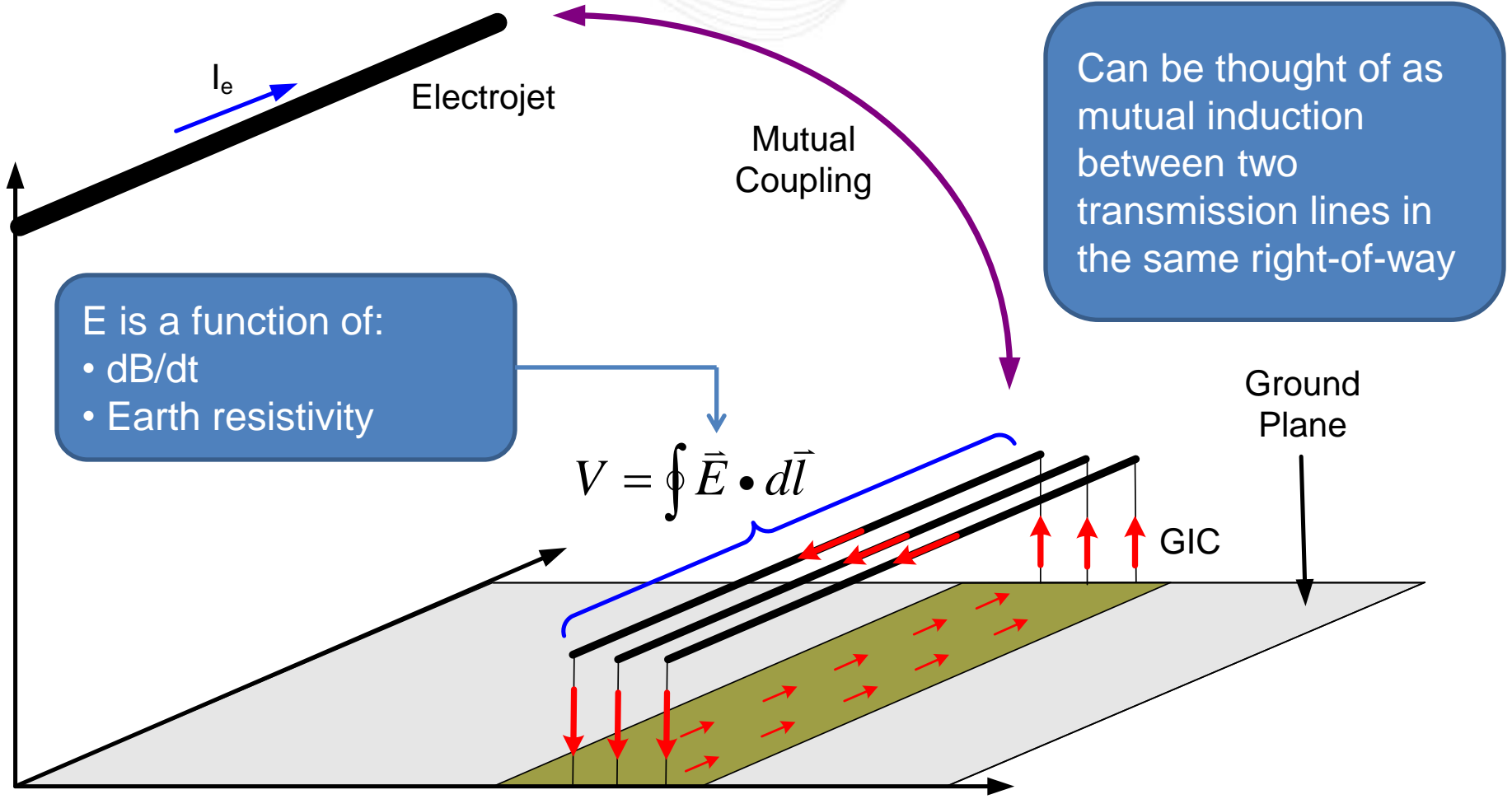
Space Weather Power System Impacts and PJM Response

AAS/SWF Space Weather Briefing
November 20, 2014

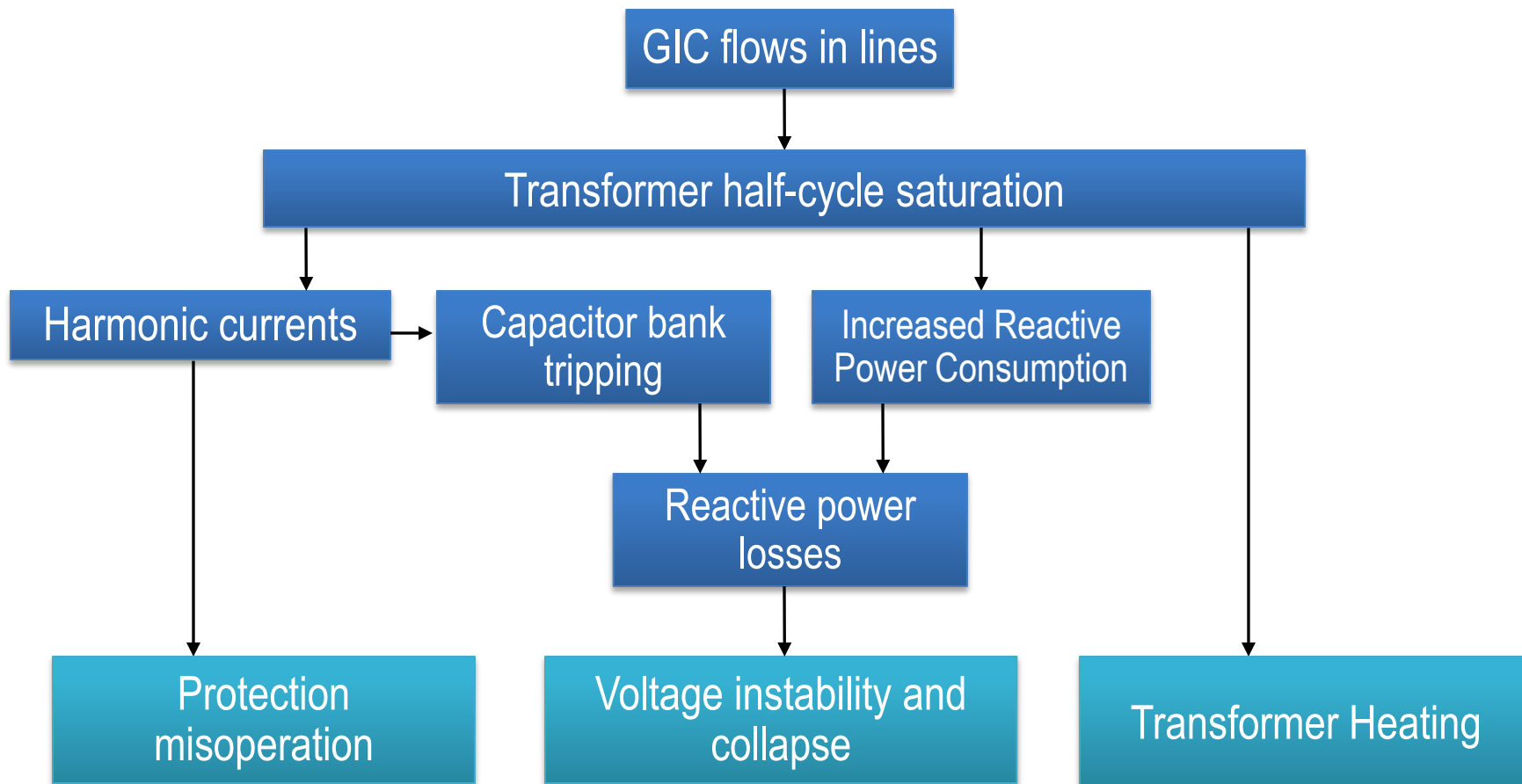
Frank J. Koza
Executive Director, Infrastructure Planning
PJM Interconnection



Electrojet currents are typically millions of Amperes and are located 100-300 km above the earth's surface



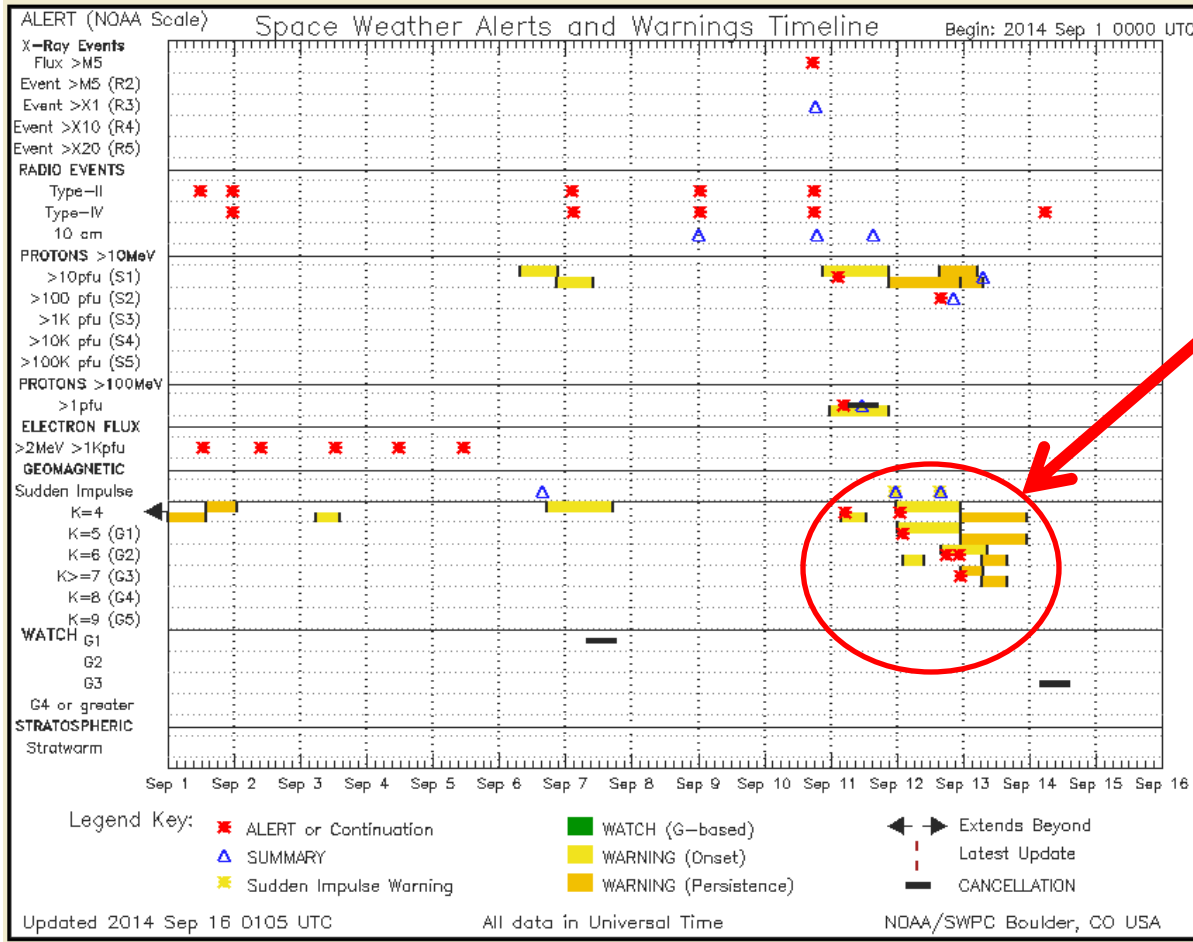
Induced Currents are “Quasi-dc” (mHz)



- Prepare (before the event)
 - Alerts/Warnings issues by SWPC 1-3 days in advance and monitored by PJM.
 - Include Intensity (K-scale) and latitudes impacted
 - Notify members and neighbors as needed.
 - Perform sensitivity studies ensure adequate system resiliency for future operating periods
 - Screen for loss of EHV capacitors, loss of major generating sites such as Artificial Island, loss of EHV transformers, etc.
 - Schedule additional generation if needed.
 - Potentially delay/defer/restore transmission and generation outages

- Monitor (during the event)
 - GIC Detectors are in place at ~50 locations to watch for GMD impacts in real time.
 - Adjust/operate more conservatively based on system conditions.
 - Coordinate with members, neighbors, etc. as the situation dictates.

- September 11 -- SWPC issued a K-4 warning for latitudes above 65-degrees (Alaska/Canada) for September 12-13
- News reports and media pick up on it
 - “Giant Magnetic Explosion on the sun racing toward earth”
 - “Keep your flashlights handy”
 - “Extreme sun storm heading toward earth”
 - Some scientists warning storms could take the grid down for an extended periods.
- Members and government agencies (i.e. FERC) asking if PJM is prepared and will there be major impacts.
- PJM procedures trigger at a K-5, but we did put out communications to members based on media reports and the questions we were being asked through non-operations channels.



Multiple CMEs strike the Earth and SWPC predictions were very accurate

SWPC Message:

Issue Time: 2014 Sep 12 0221 UTC

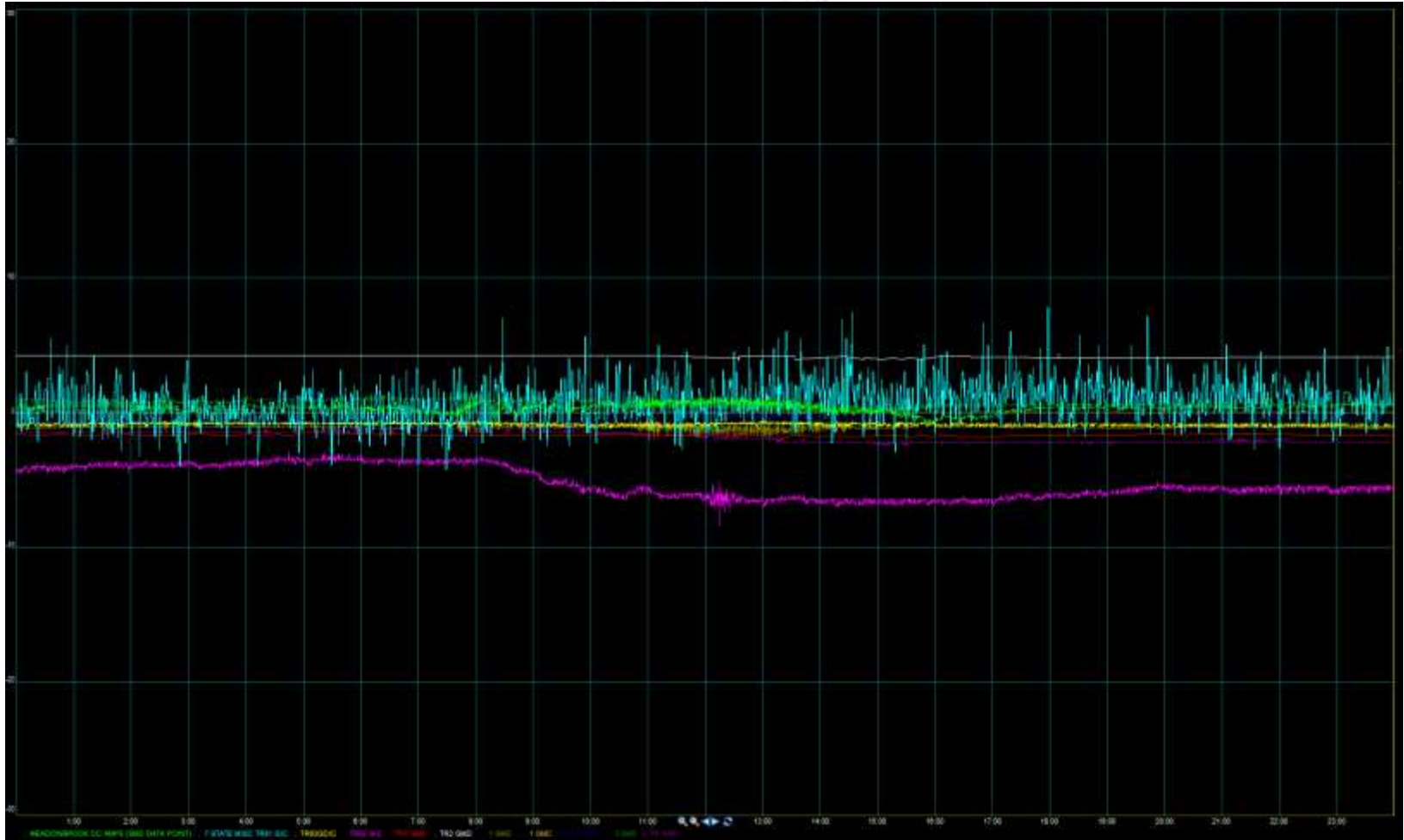
WARNING: Geomagnetic K-Index of 6 expected

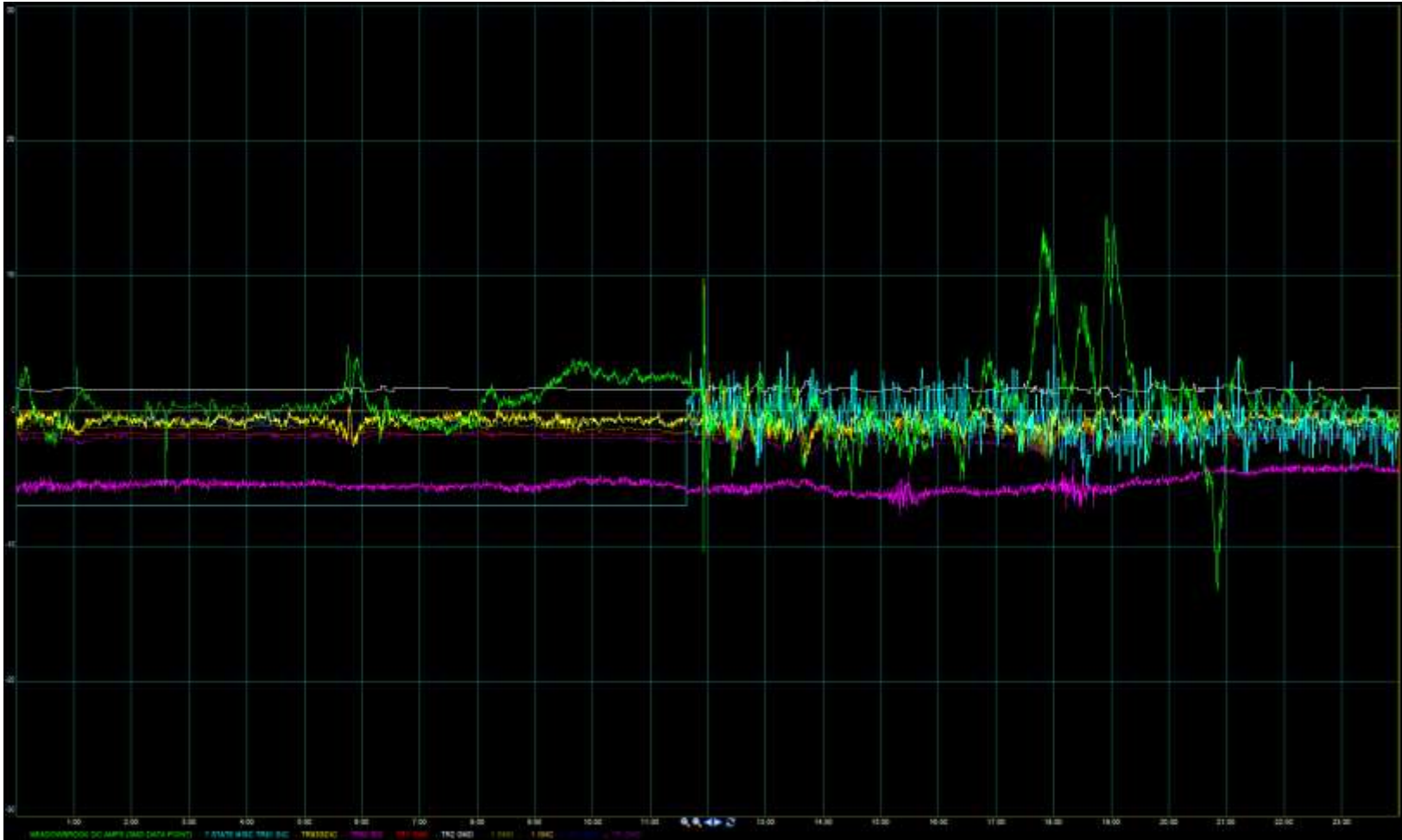
Valid From: 2014 Sep 12 0220 UTC
 Valid To: 2014 Sep 12 1000 UTC

NOAA Scale: G2 - Moderate
 Potential Impacts: Area of impact primarily poleward of 55 degrees Geomagnetic Latitude.

Induced Currents - Power grid fluctuations can occur. High-latitude power systems may experience voltage alarms.

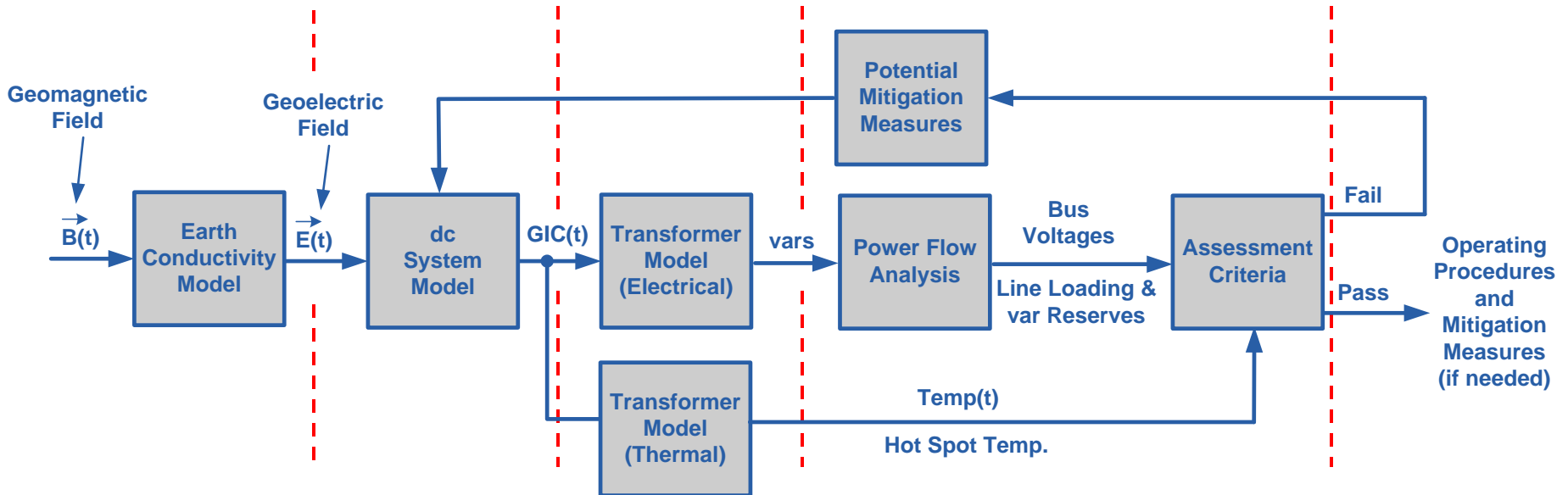
North of PJM System





GMD Standard TPL-007

GMD Reference Storm	GIC Application Guide	Transformer Modeling Guide	GMD Planning Guide	GIC Mitigation Guide
				Operating Procedure Template



- PJM
 - Operational procedures in place since after the 1989 Hydro Quebec blackout
 - PJM members have installed ~50 GIC detectors around the system and the data is telemetered into PJM
 - AEP is about to install a number of magnetometers with which to validate models. Dominion has implemented design changes to enhance GMD protection on capacitors and transformers
 - PJM and our members collaborated to do a GIC calculation study of the PJM system (AEP and ComEd have also done studies)
 - PJM, Dominion, AEP to participate with NASA on a research program to use ground measurement devices to validate electric field models
- Industry
 - Awareness is increasing and a number of systems are installing detectors. GIC calculation is now included in power analysis software
 - American Transmission (Wisconsin) is installing a prototype GIC blocking device
 - NERC standard will require network analysis and transformer thermal assessment