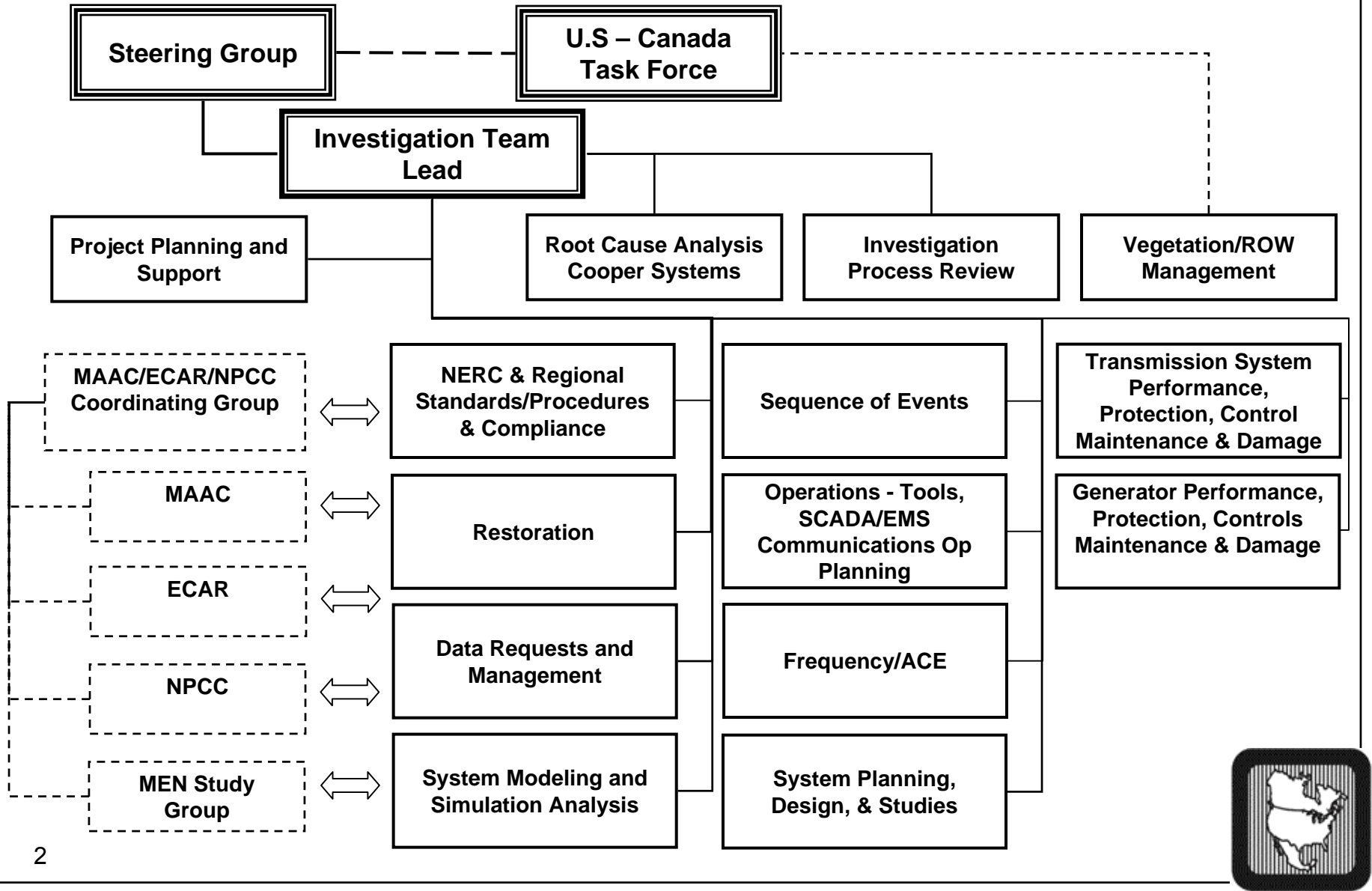


An aerial night photograph of a city skyline, likely New York City, with numerous skyscrapers illuminated against a dark sky. The lights from the buildings reflect on the water in the foreground. The overall color palette is dominated by dark blues and purples, with bright white and yellow lights from the buildings.

August 14, 2003 Blackout

Gerry Cauley
Director – Standards
North American Electric Reliability Council

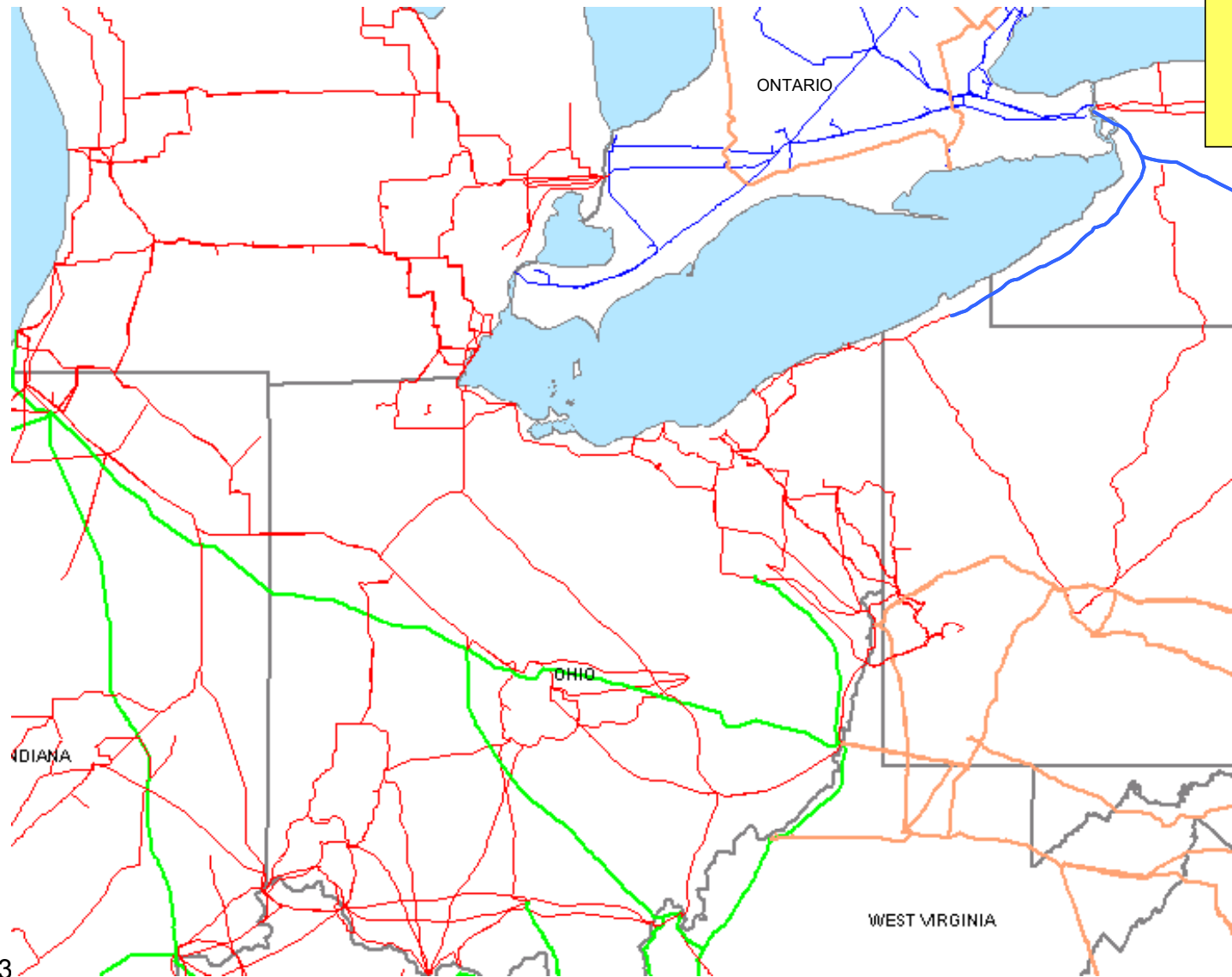
Investigation Organization Overview



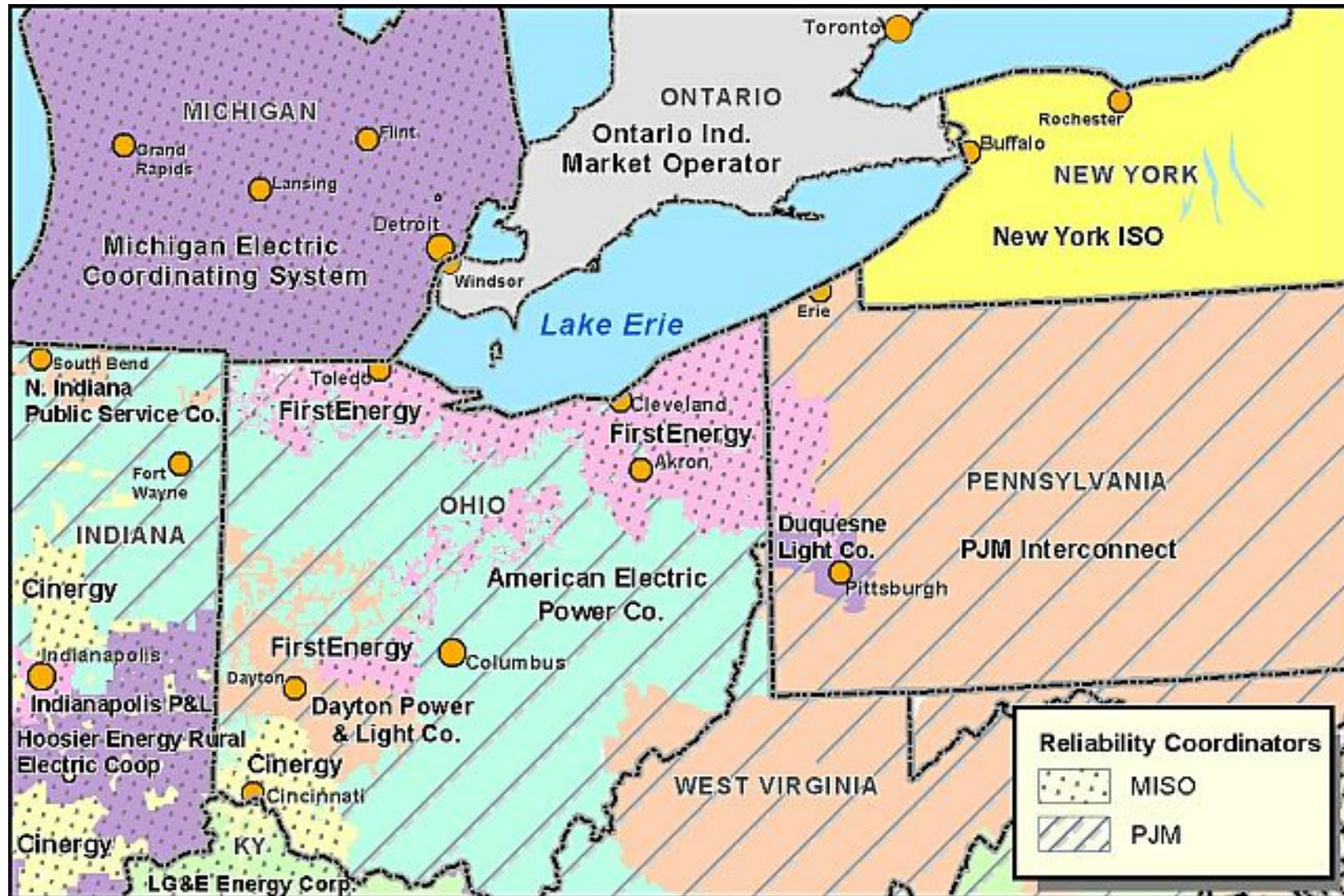
Transmission Map Key

Transmission Lines

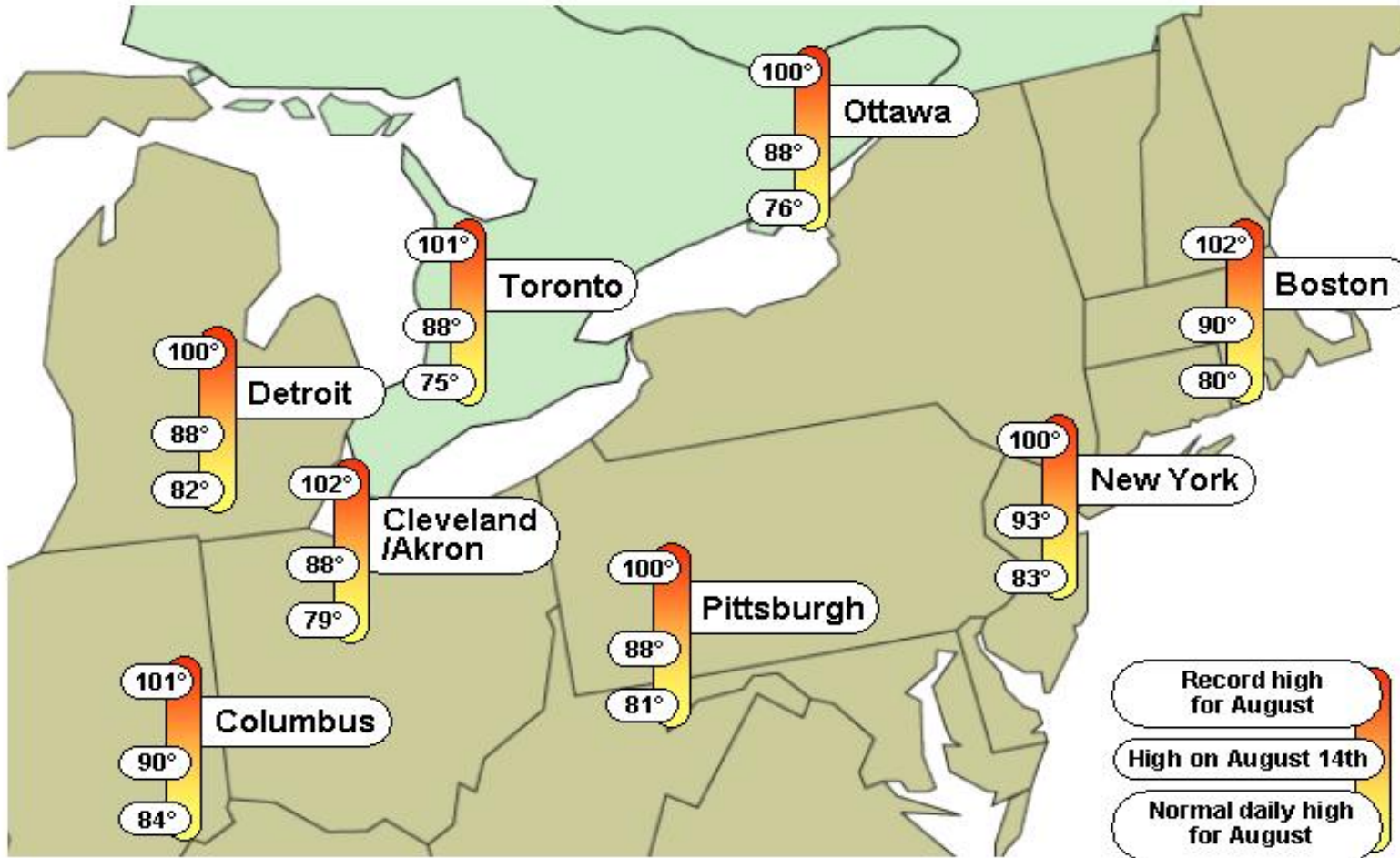
- 765 kV
- 500 kV
- 345 kV
- 230 kV



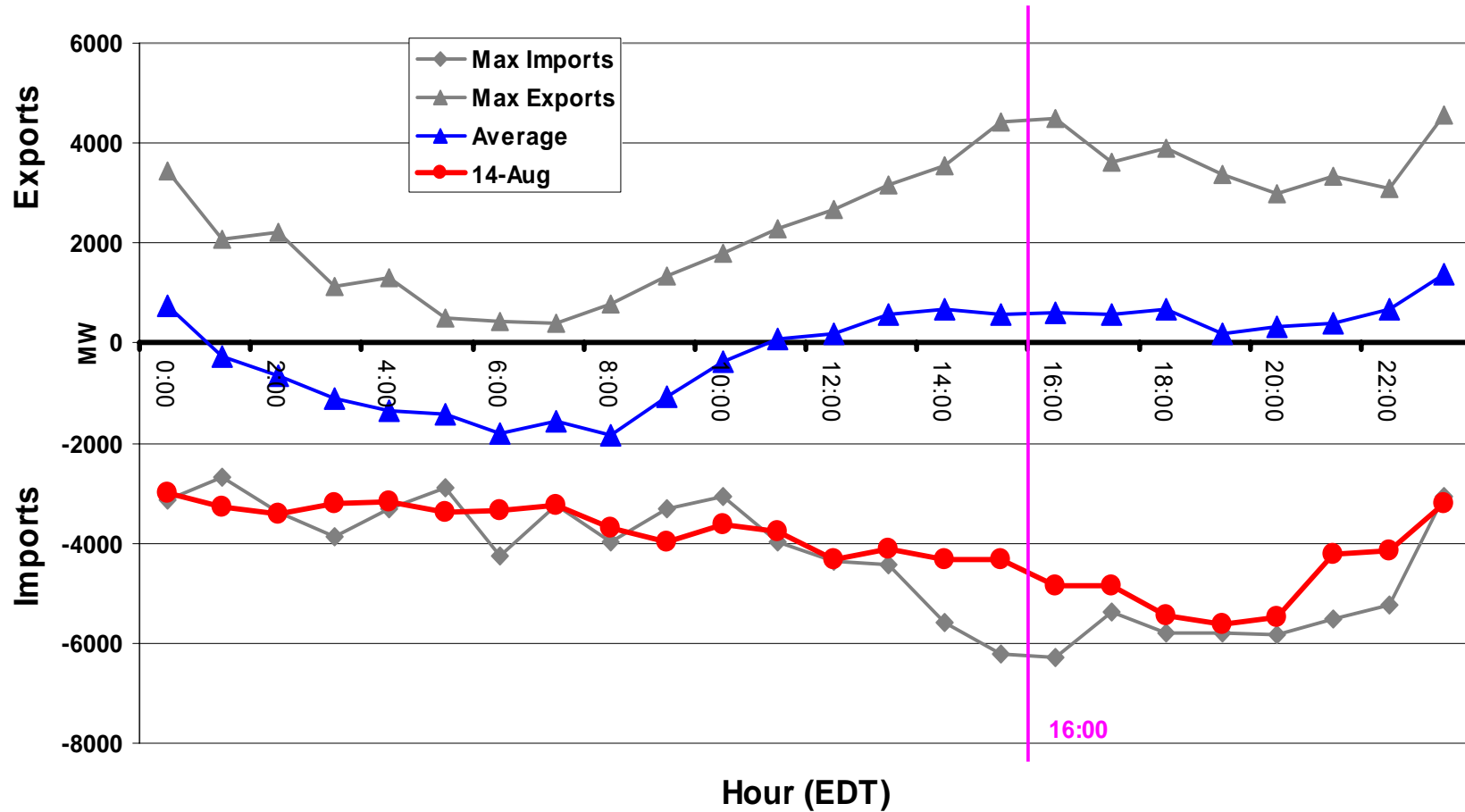
Footprints of Reliability Coordinators in Midwest



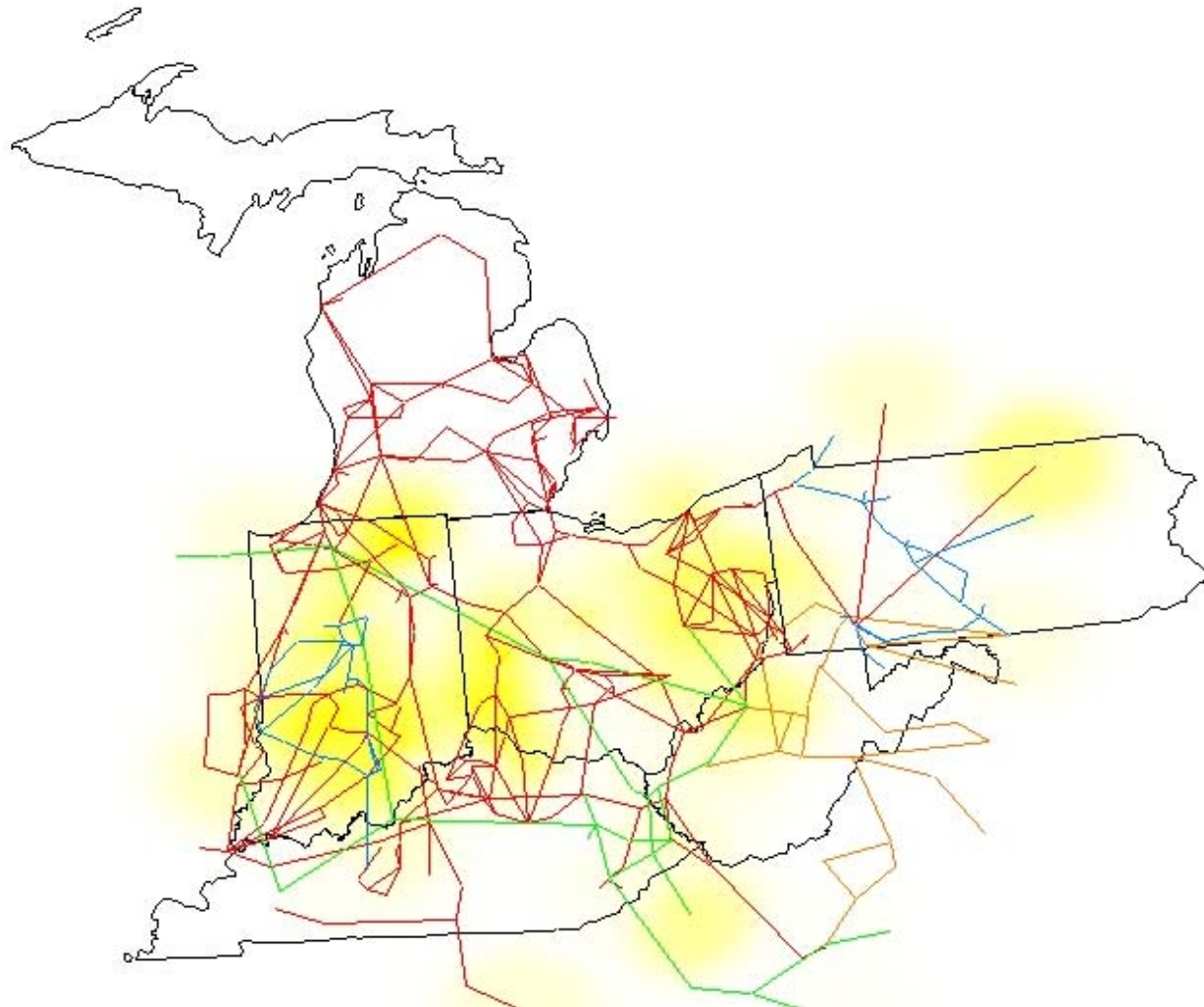
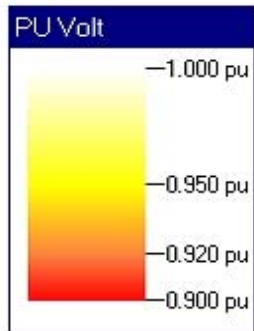
Warm But Not Unusual for August



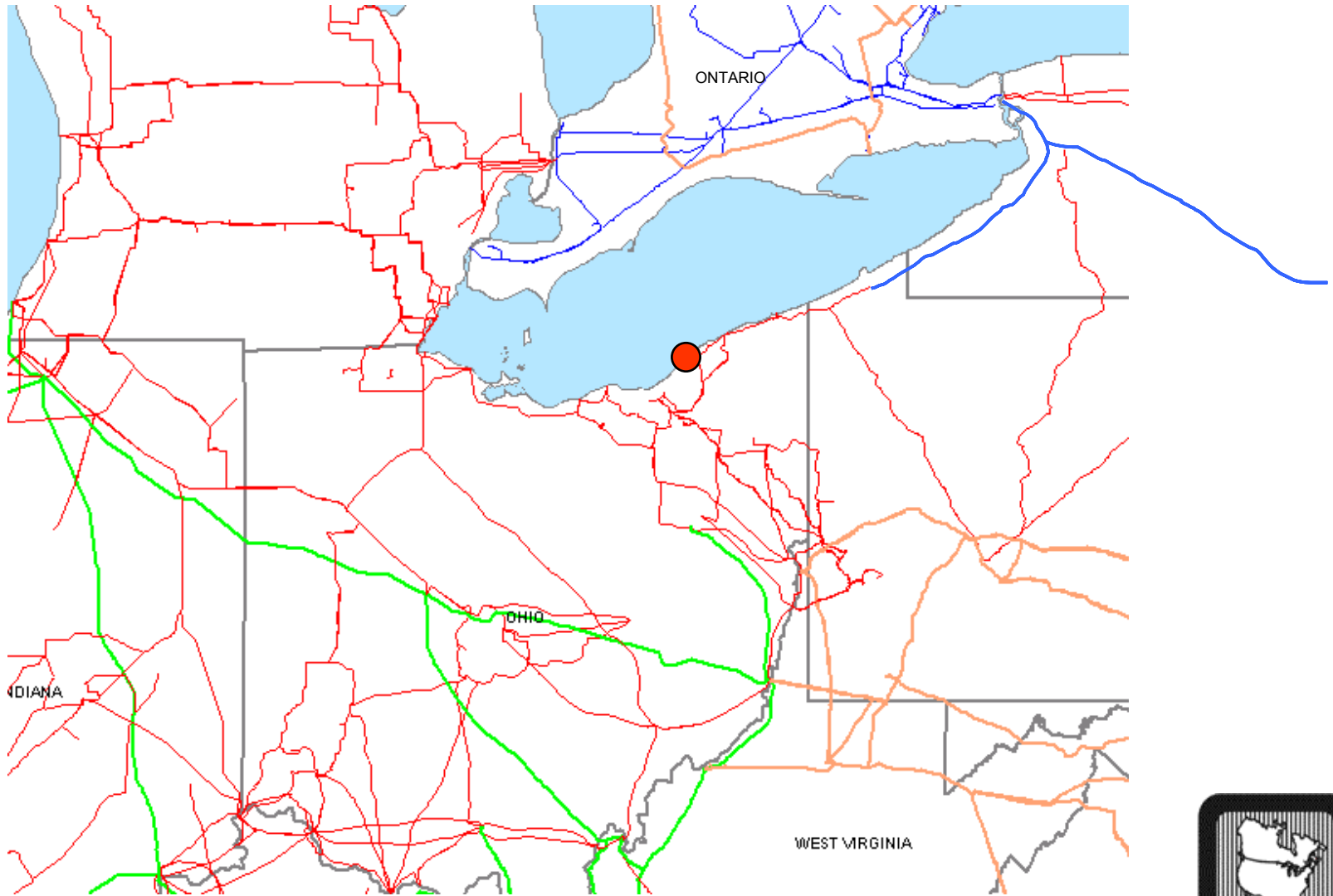
August 14 Imports to Northeast (Except ISO-NE, and Maritimes) Compared to 6/1 to 8/13/2003



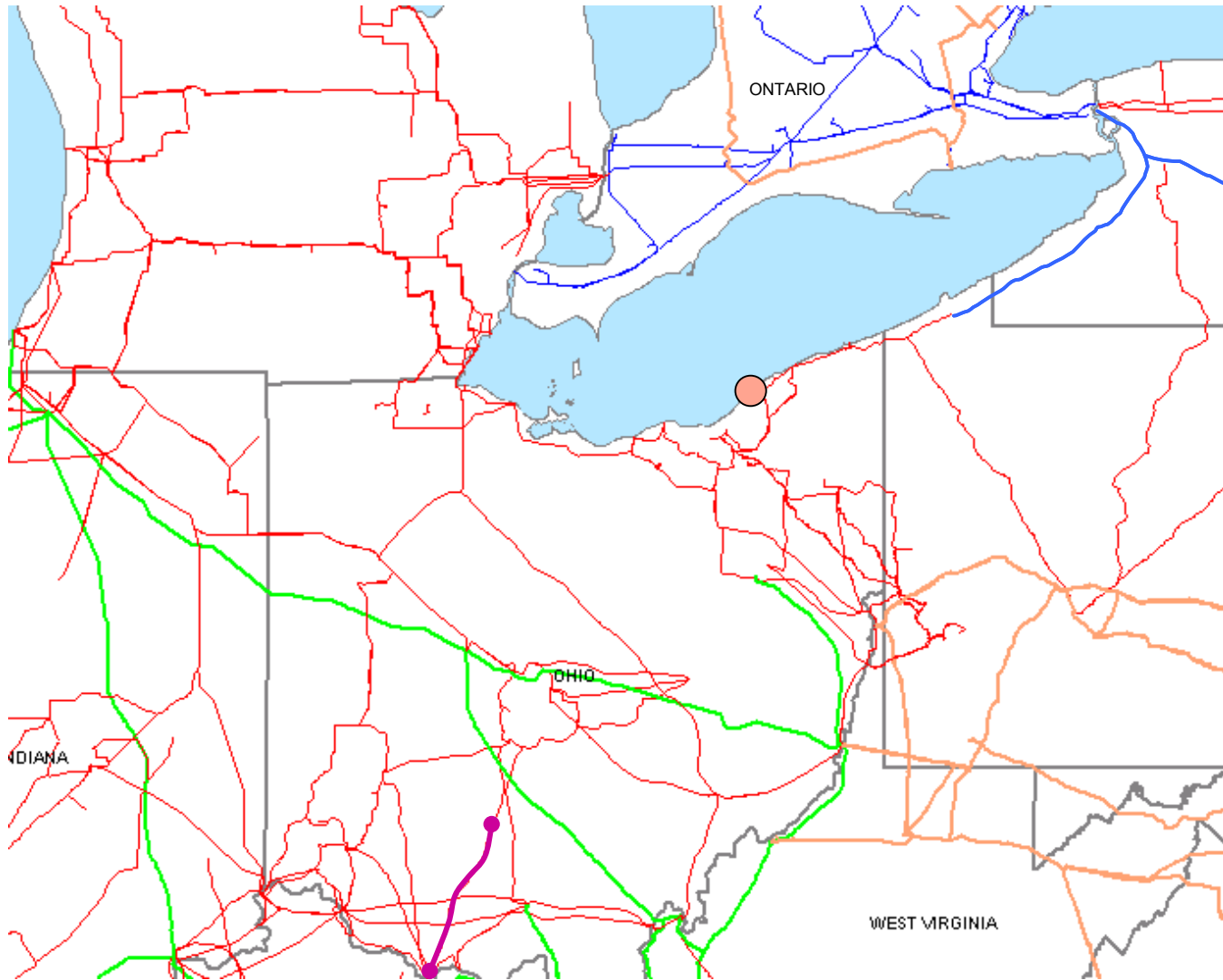
Voltages Prior to 15:05 EDT August 14



East Lake 5 Trip: 1:31:34 PM



Stuart Atlanta Trip: 2:02 PM



MISO State Estimator and Reliability Analysis

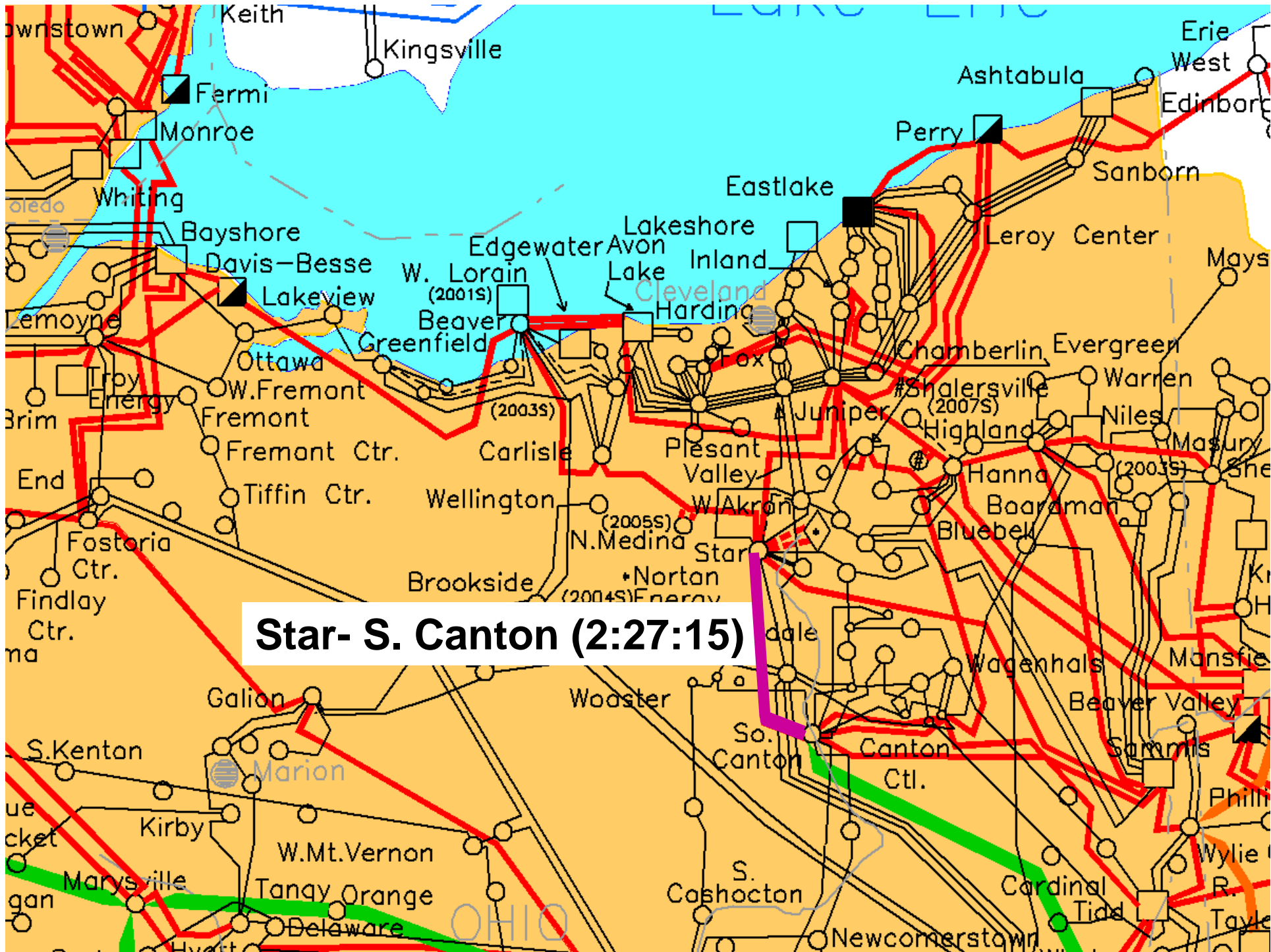
- MISO state estimator and contingency analysis ineffective from 12:37 to 16:04
 - State estimator not solving due to missing information on lines out in Cinergy then DPL
 - Human error in not resetting SE automatic trigger
- Using Flowgate Monitoring tool to monitor conditions on previously identified critical flowgates



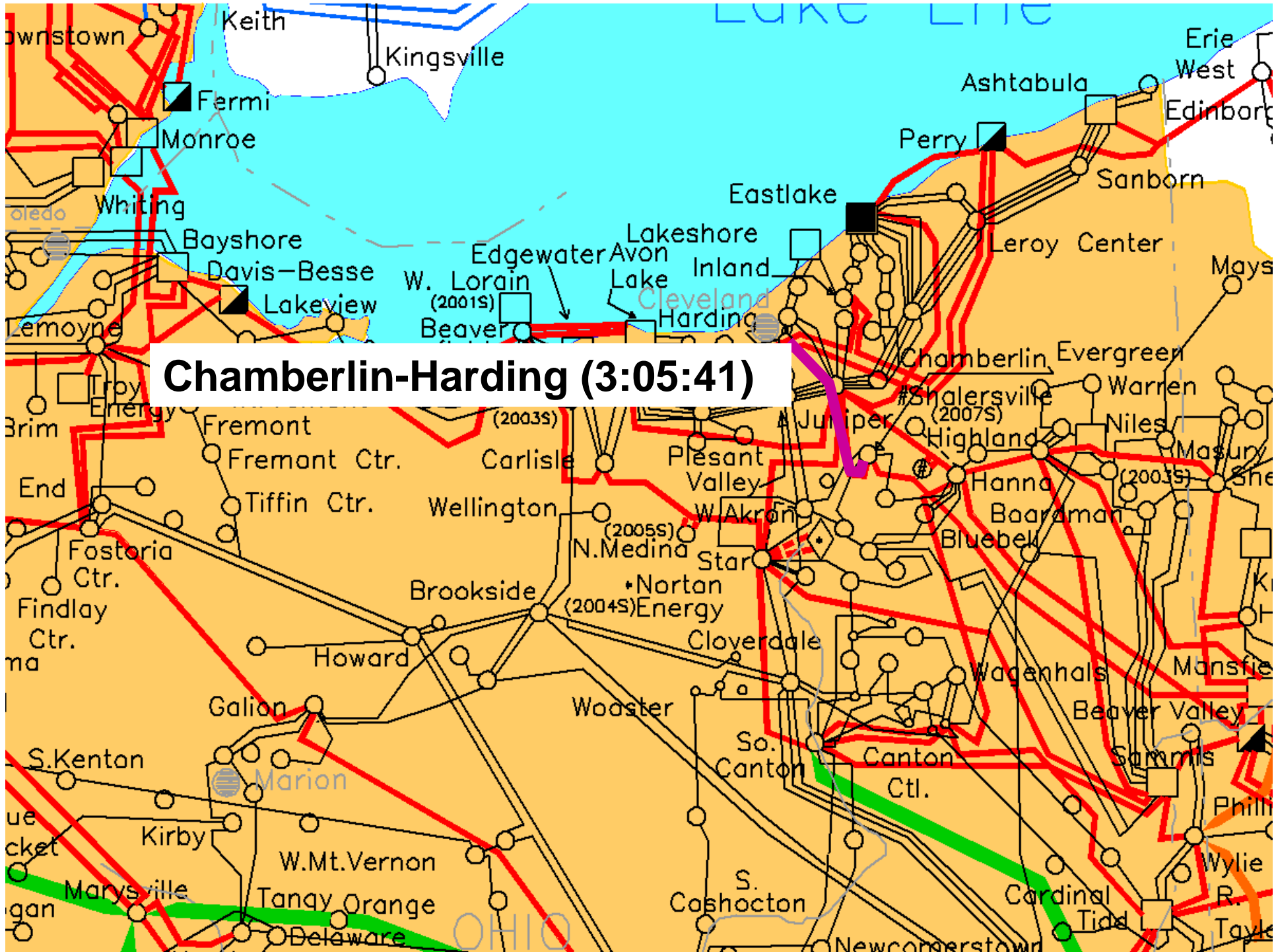
FirstEnergy Computer Failures

- 14:14 Alarm logger fails and operators are not aware
 - No further alarms to FE operators
- 14:20 Several remote consoles fail
- 14:41 EMS server hosting alarm processor and other functions fails to backup
- 14:54 Backup server fails
 - EMS continues to function but with very degraded performance (59 second refresh)
 - FE system data passed normally to others: MISO and AEP
 - AGC function degraded and strip charts flat-lined
- 15:08 IT warm reboot of EMS appears to work but alarm process not tested and still in failed condition
- No contingency analysis of events during the day including loss of East Lake 5 and subsequent line trips





Star- S. Canton (2:27:15)

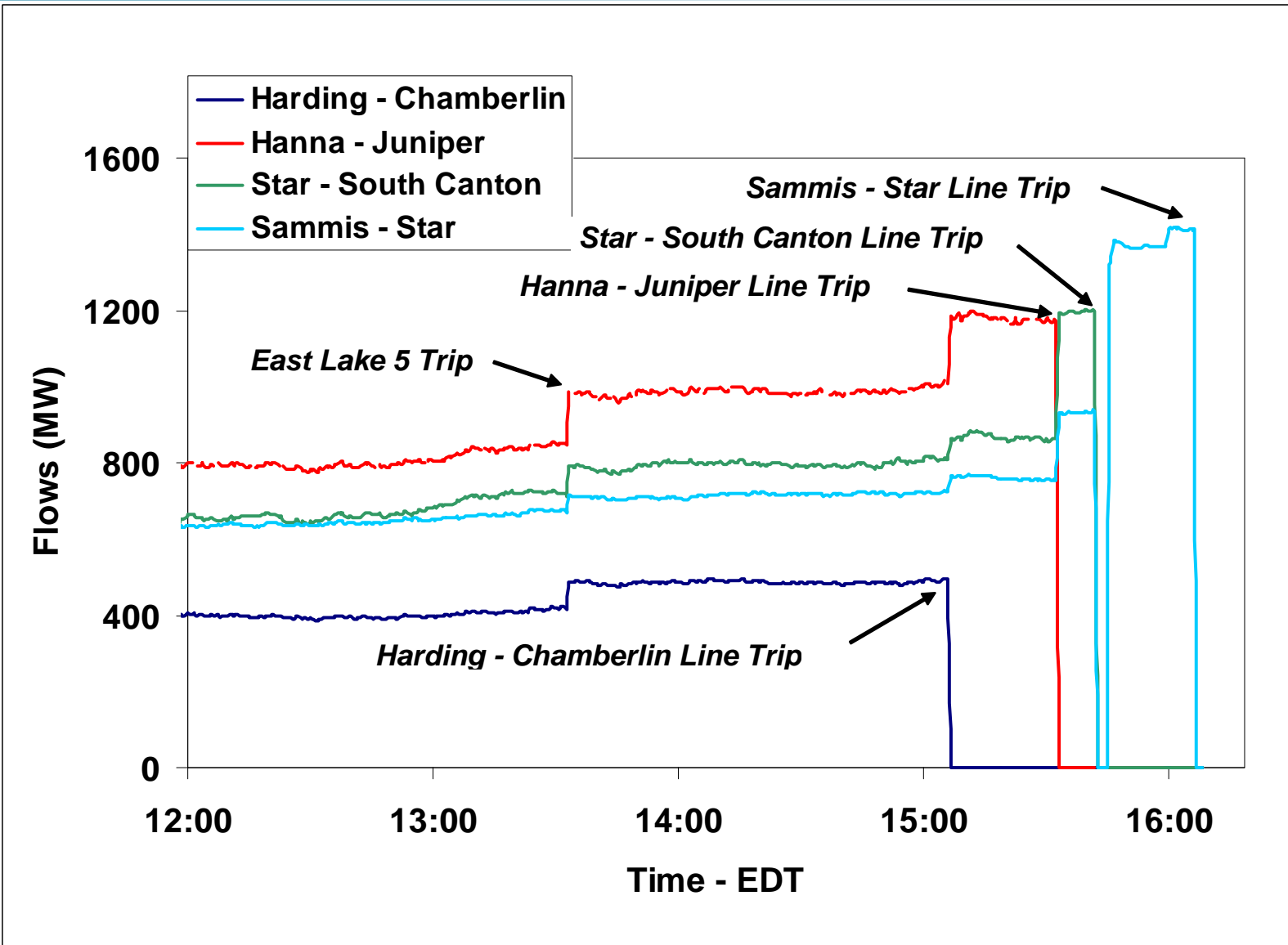


Chamberlin-Harding (3:05:41)

Hanna - Juniper Tree Contact Insufficient Clearance with Trees



Actual Loading on Critical Lines



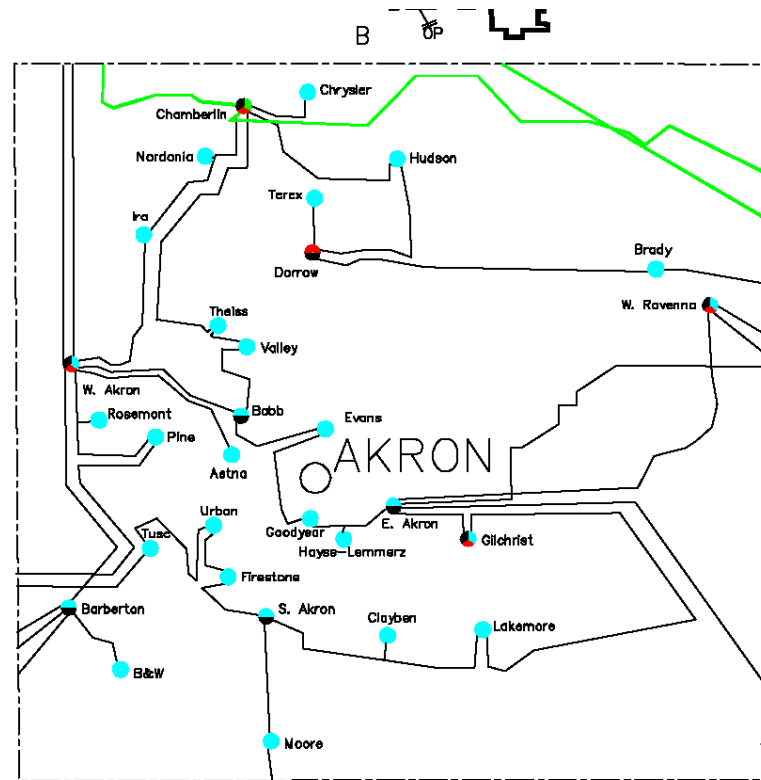
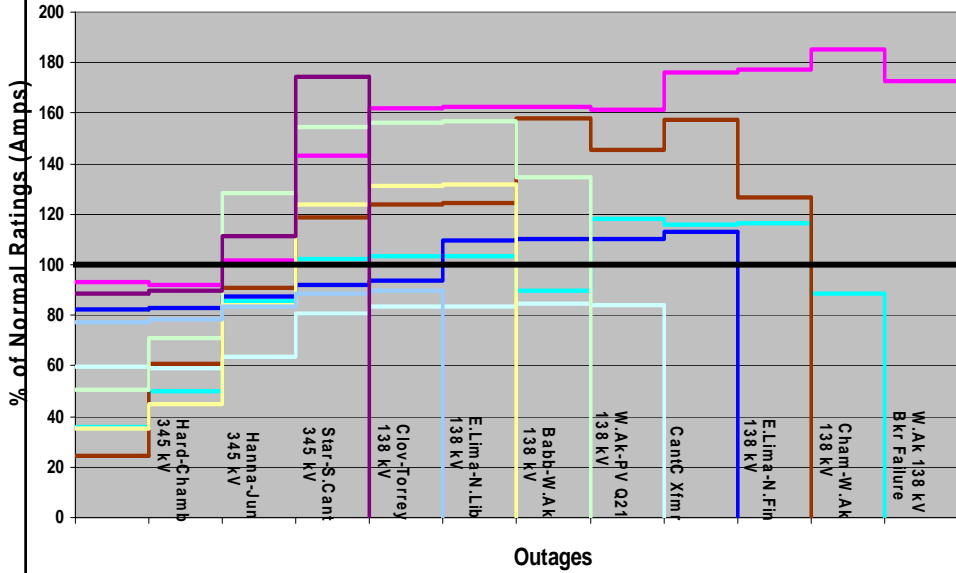
Phone Calls to FirstEnergy

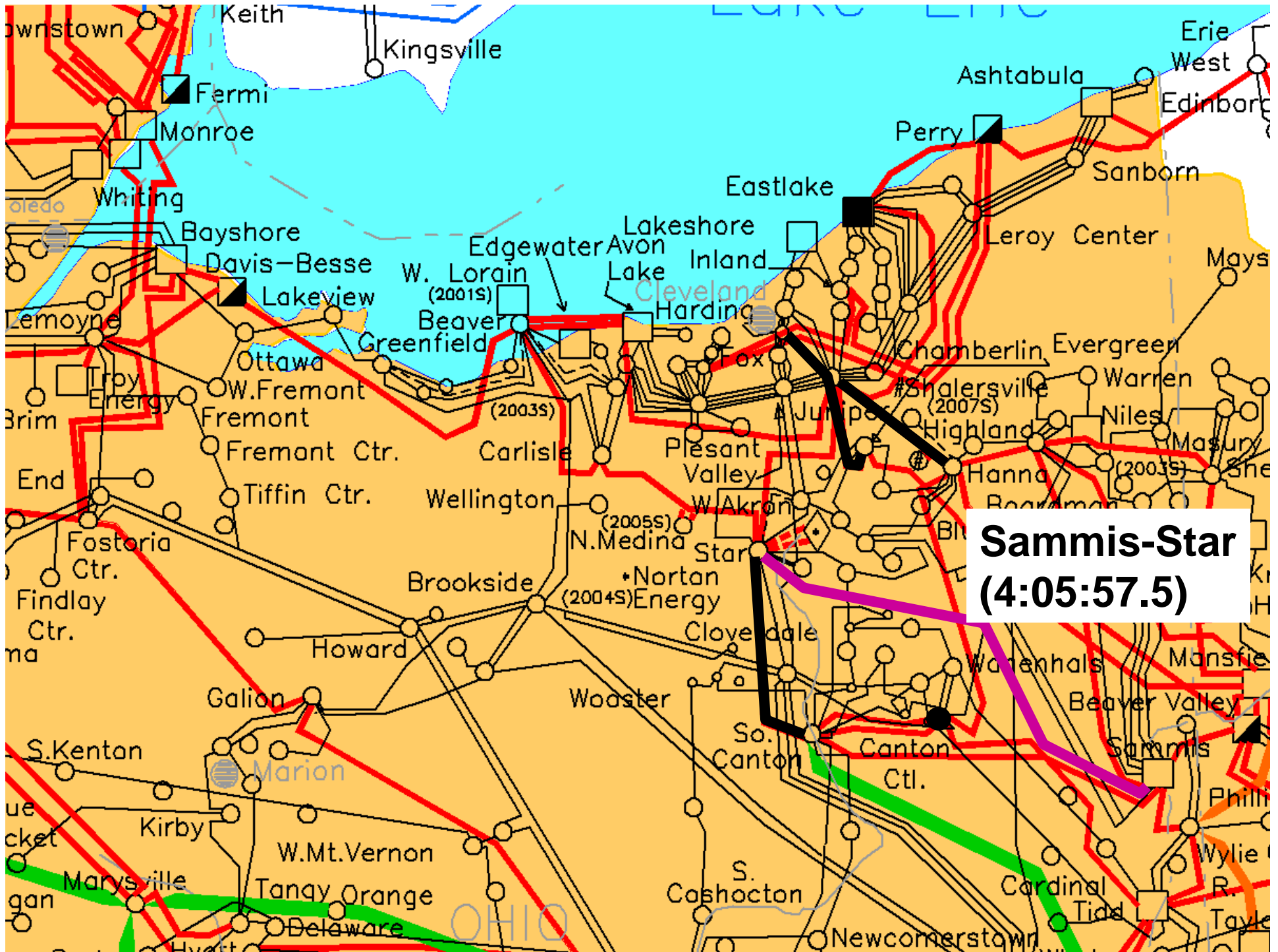
- FE received calls from MISO, AEP, and PJM indicating problems on the FE system but did not recognize evolving emergency
 - 14:32 AEP calls regarding trip and reclose of Star-S. Canton
 - 15:19 AEP calls again confirming Star-S. Canton trip and reclose
 - 15:35 Calls received about “spikes” seen on system
 - **15:36** MISO calls FE regarding contingency overload on Star-Juniper for loss of **Hanna-Juniper**
 - 15:45 FE tree trimming crew calls in regarding Hanna-Juniper flashover to a tree
 - PJM called MISO at 15:48 and FE at 15:56 regarding overloads on FE system



138 kV Lines Overload and Cascade Near Akron

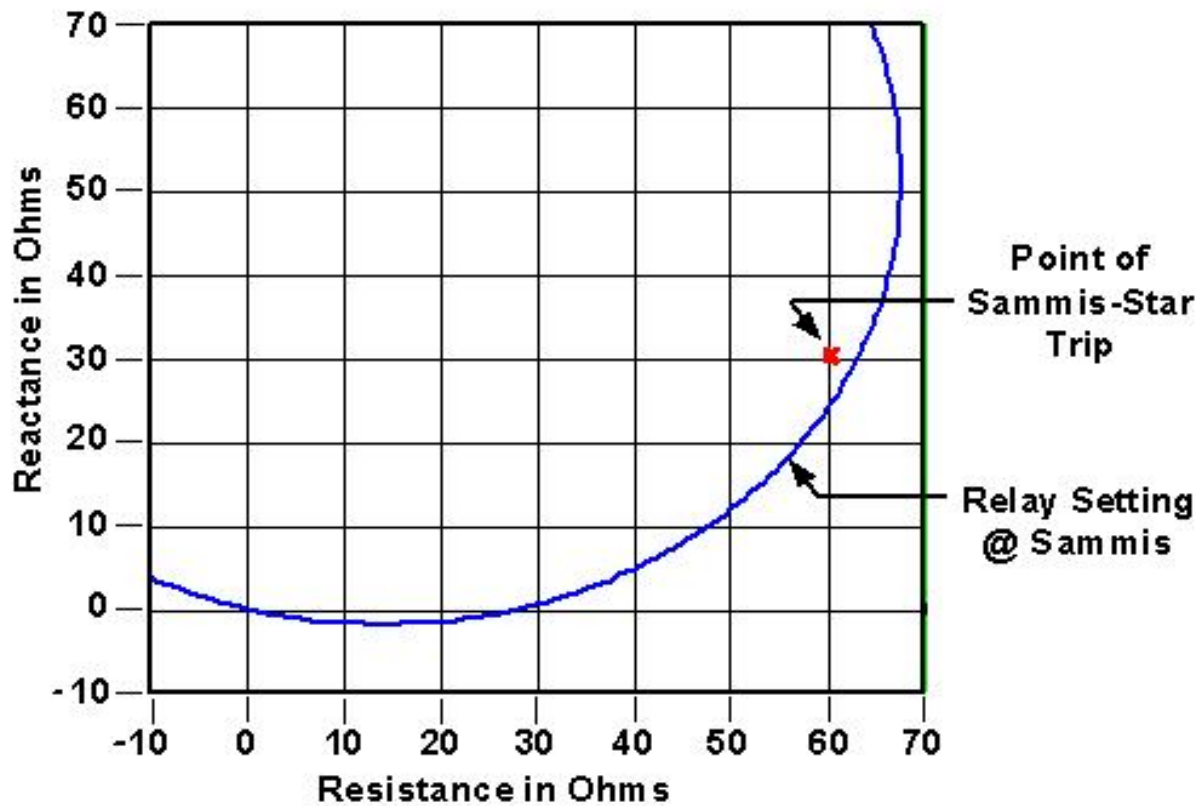
Simulated 138 kV Line Loadings



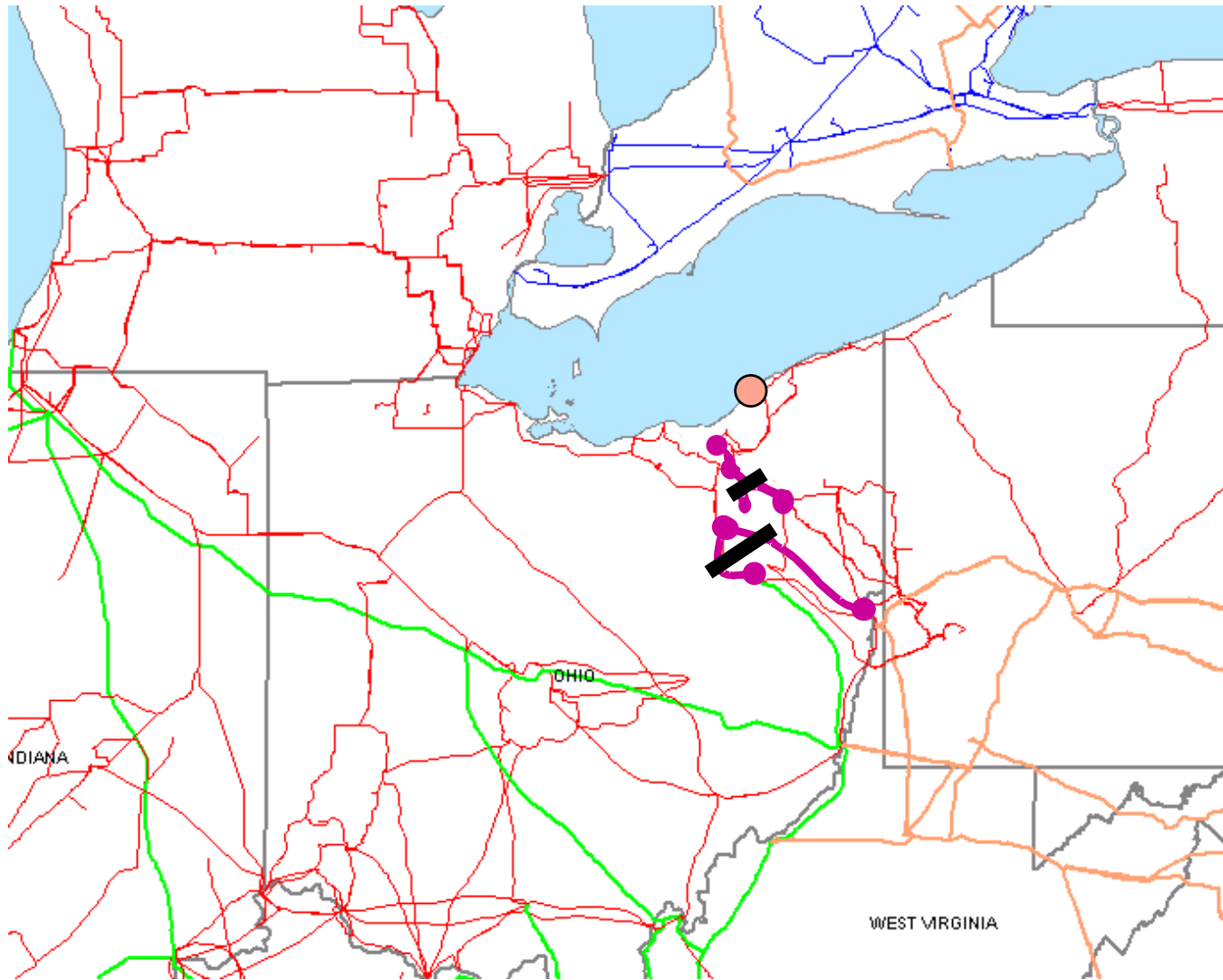


Sammis-Star
(4:05:57.5)

Sammis-Star Zone 3 Relay Operates on Steady State Overload



Last Major Path to Cleveland Blocked after Loss of Sammis-Star 4:05:57.5 PM



Blackout Root Cause Group 1

FirstEnergy Lack of Situational Awareness

- Did not ensure a reliable system after contingencies occurred because it did not have an effective contingency analysis capability
- Did not have effective procedures to ensure operators were aware of the status of critical monitoring tools
- Did not have effective procedures to test monitoring tools after repairs
- Did not have additional high level monitoring tools after alarm system failed



Blackout Out Root Cause Group 2

FirstEnergy Ineffective Vegetation Management

- Did not adequately manage ground clearance (tree clearance) in its transmission rights of way



Blackout Cause Group 3

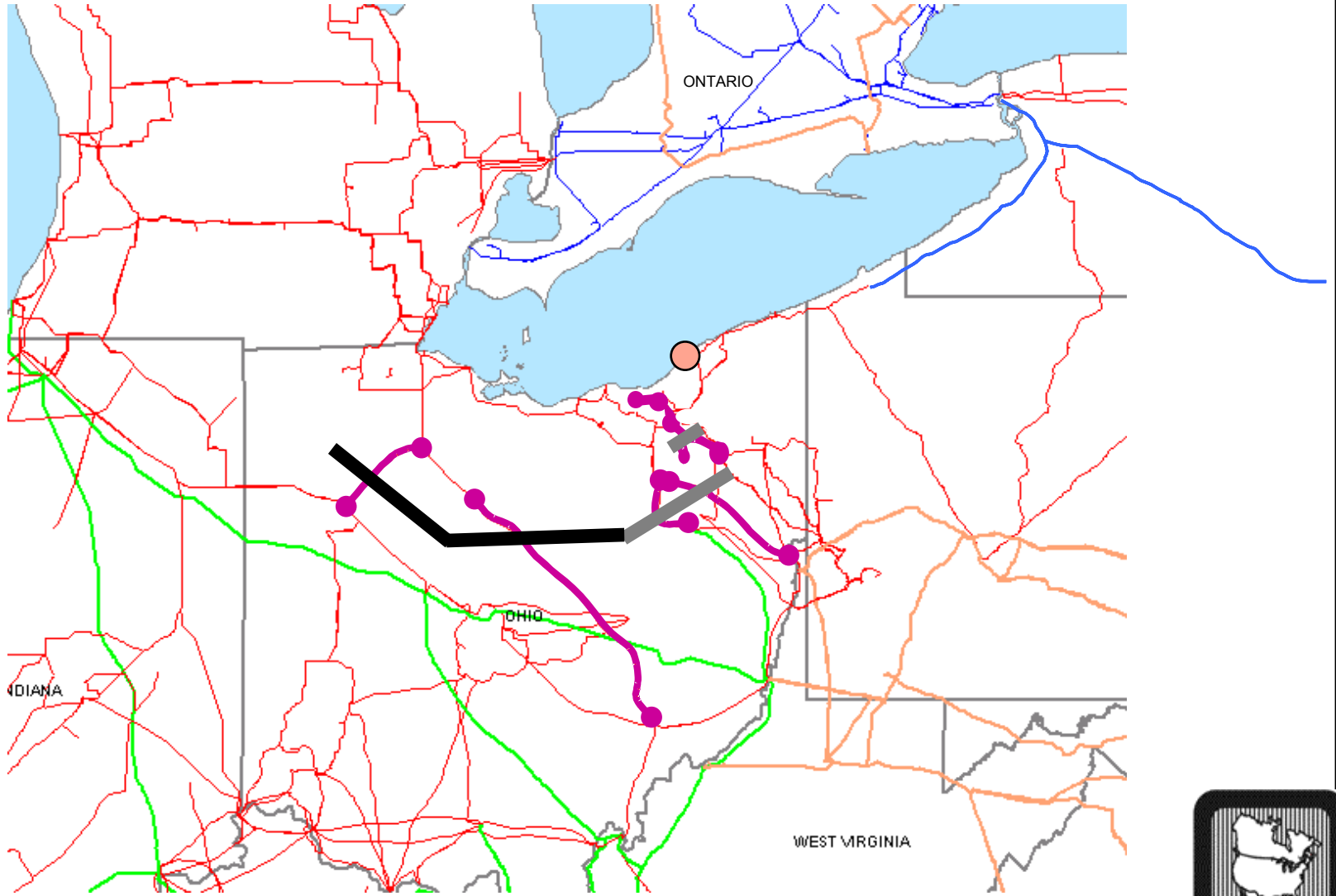
Reliability Coordinator Ineffective Diagnostics

- Reliability Coordinator (MISO for FE)
 - State estimator failed due to a data error.
 - Flowgate monitoring tool didn't have real-time line information to detect growing overloads
 - Operators couldn't easily link breaker status to line status to understand changing conditions.
 - Did not declare emergency or take any action
- PJM & MISO ineffective procedures & wide grid visibility to coordinate problems affecting their common boundaries

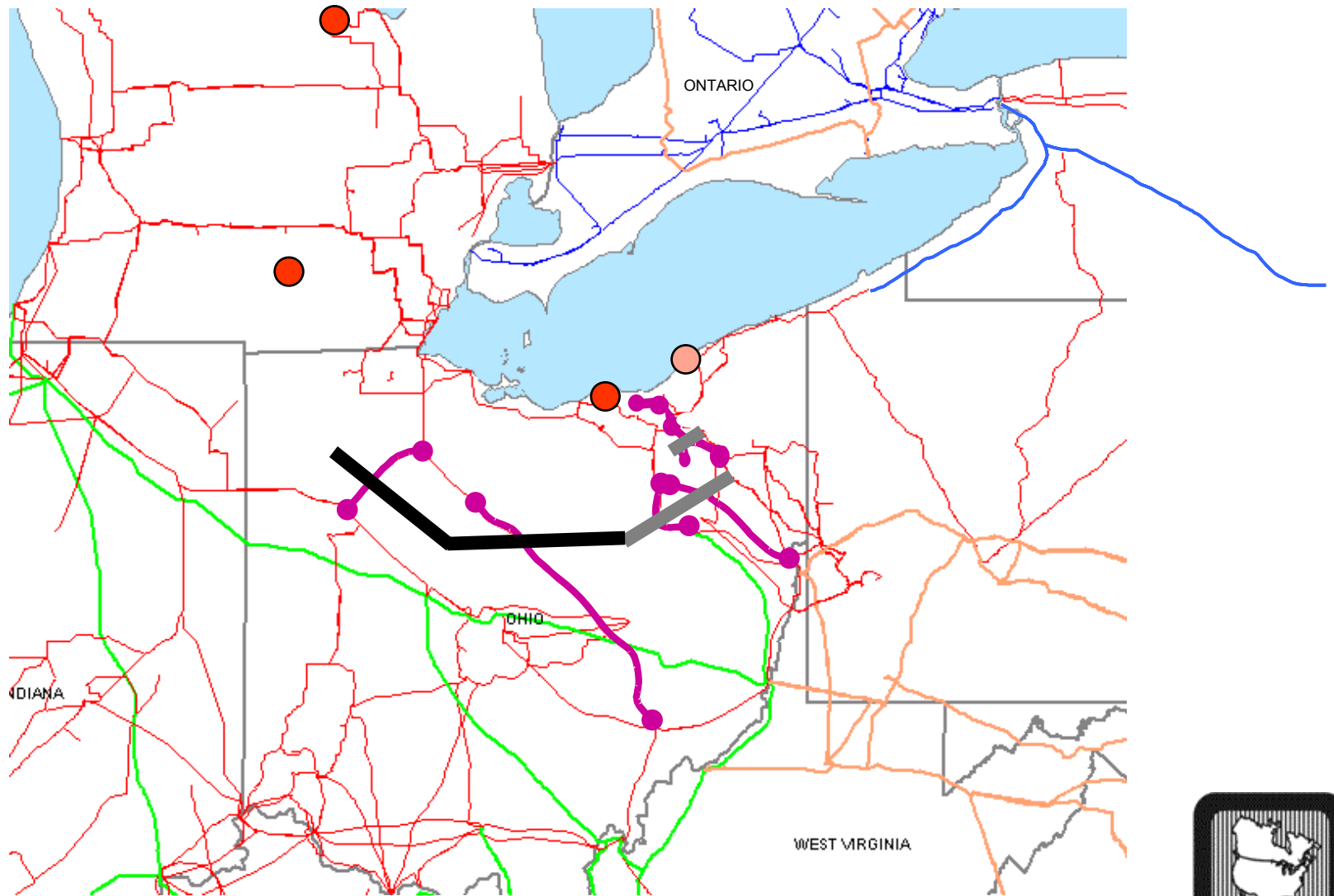


345 kV Lines Trip Across Ohio to West

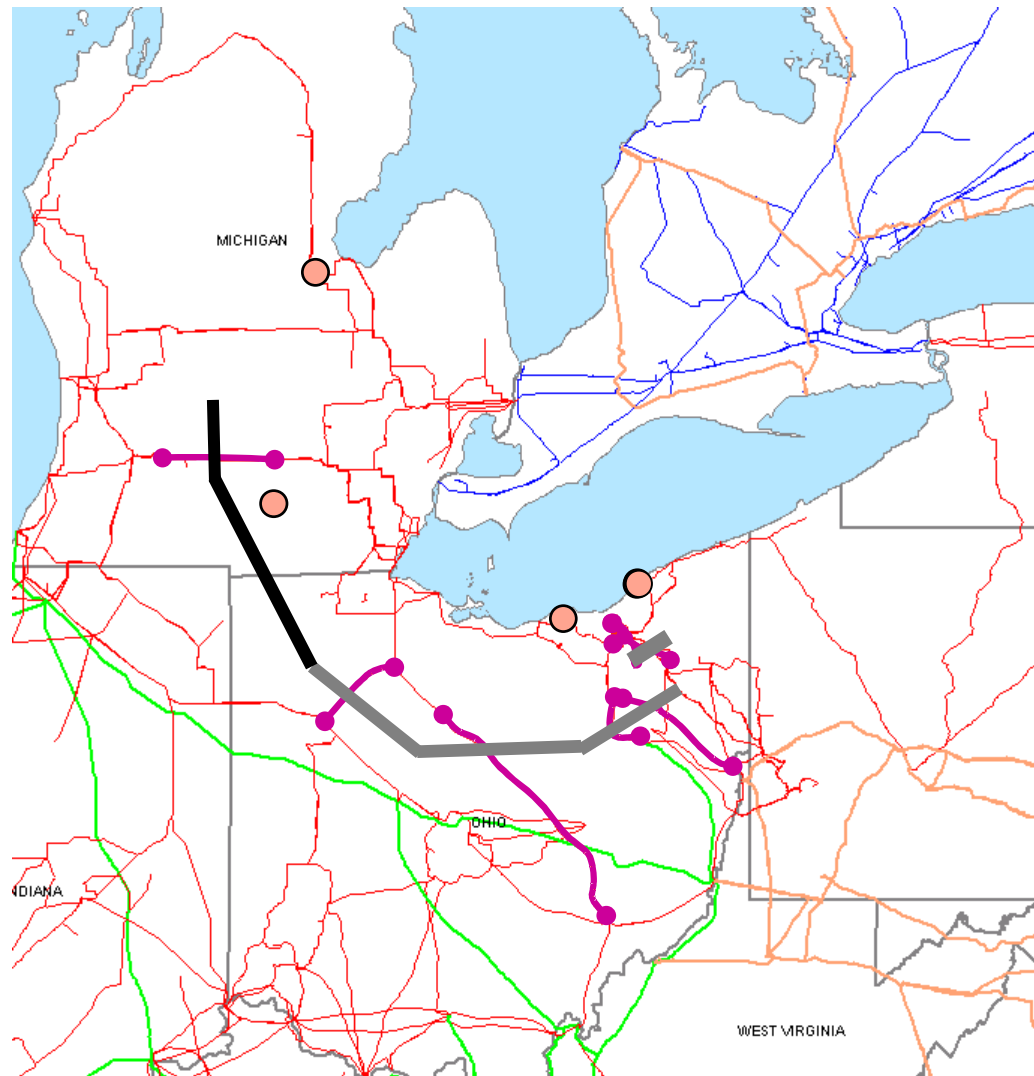
4:08:59 - 4:09:07 PM



Generation Trips 4:09:08 – 4:10:27 PM

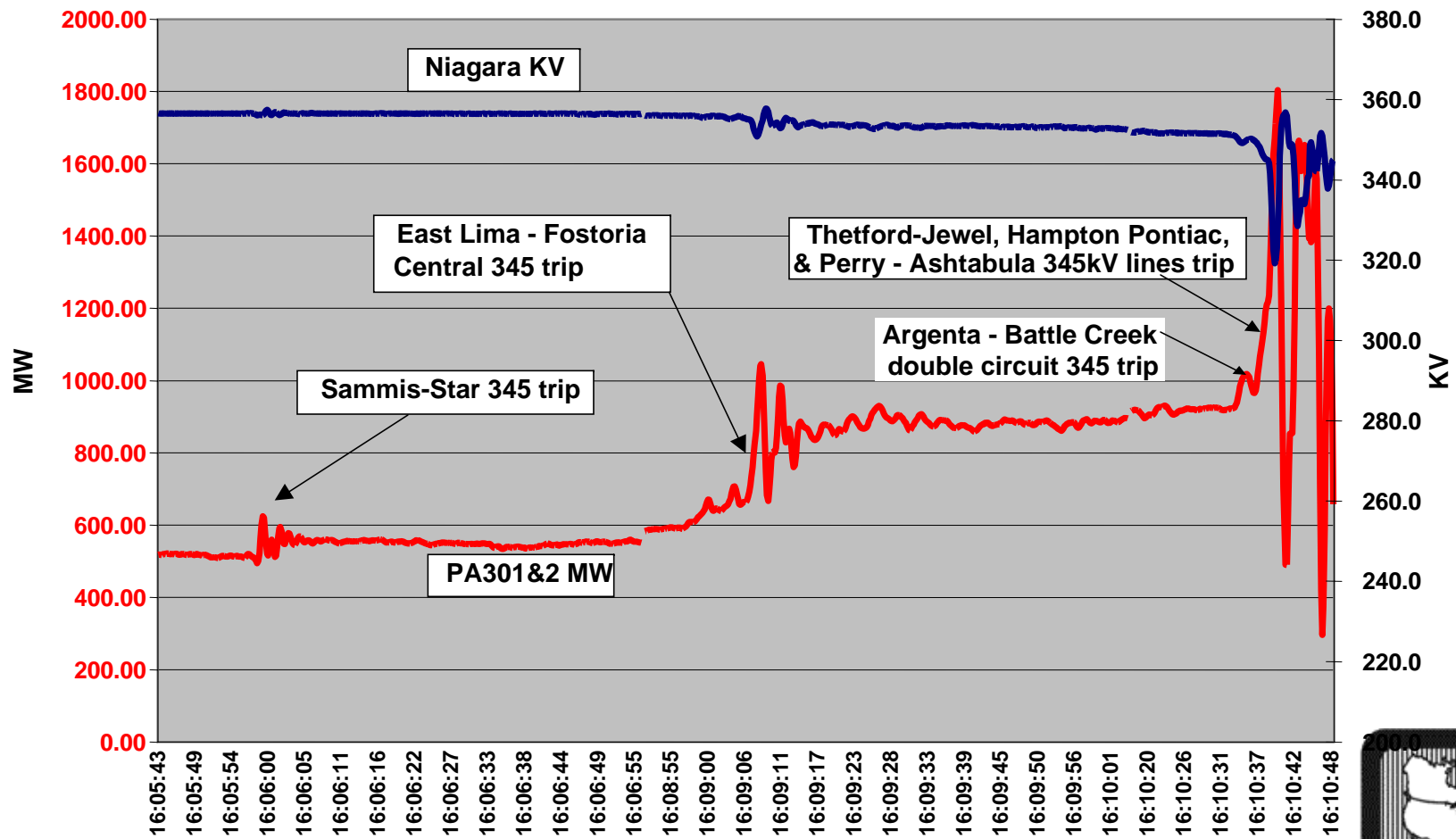


345 kV Transmission Cascade Moves North into Michigan 4:10:36 – 4:10:37 PM

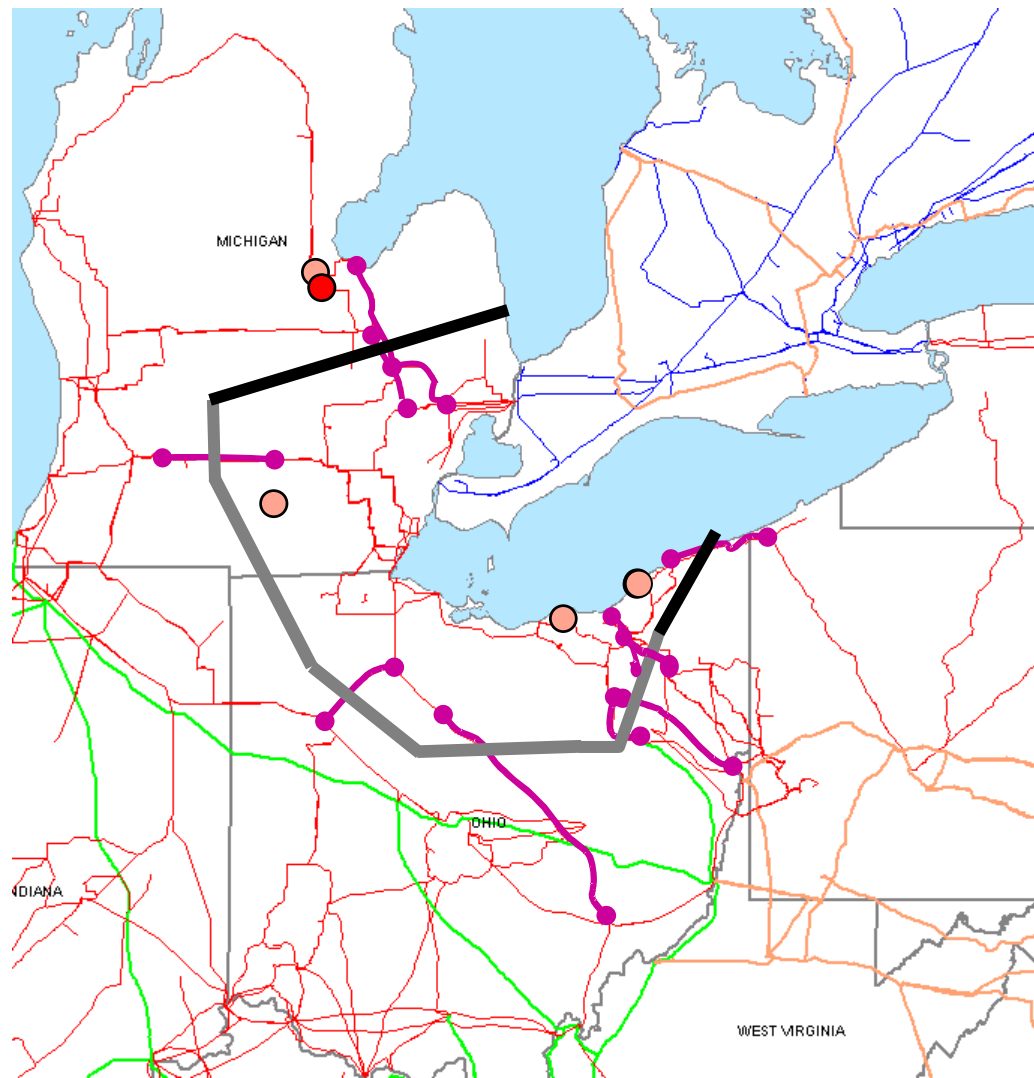


NY to Ontario 345kV Line Flows at Niagara Progressively Worsening Stability Conditions

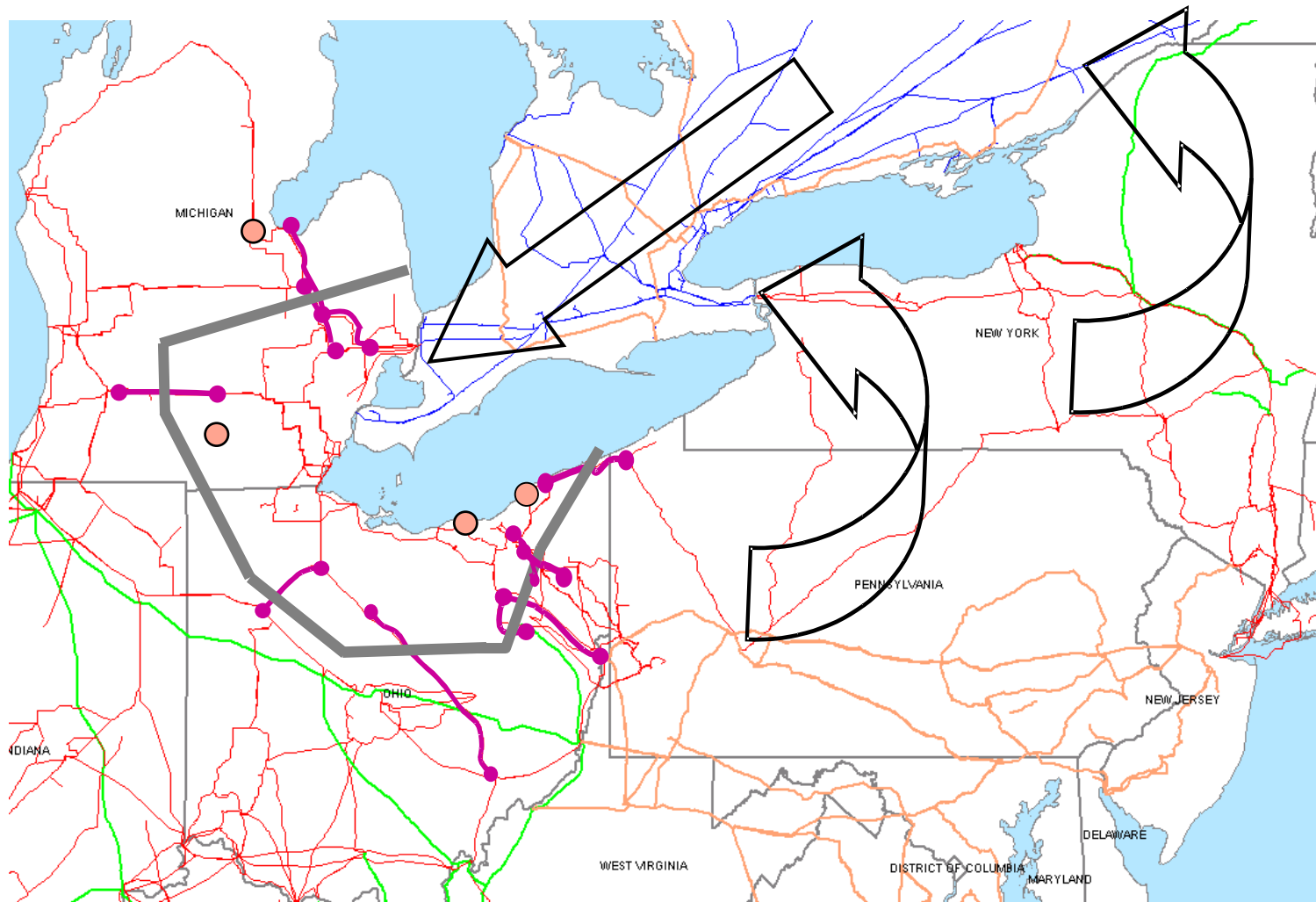
New York to Ontario 345 kV Line Flow at Niagara
(does not include 230 kV line flow)



Northern Ohio and Eastern Michigan Served Only from Ontario after 4:10:37.5 – 4:10:38.6 PM

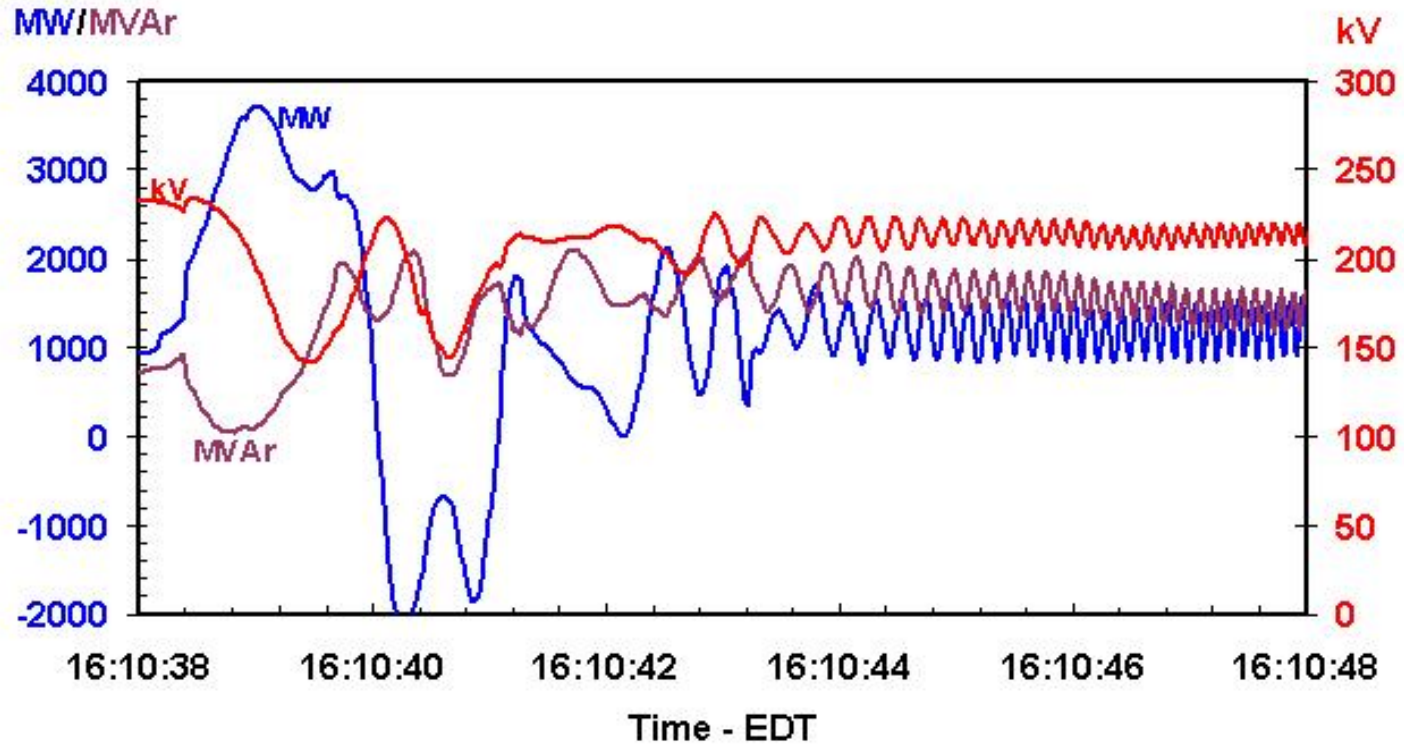


Power Transfers Shift at 4:10:38.6 PM

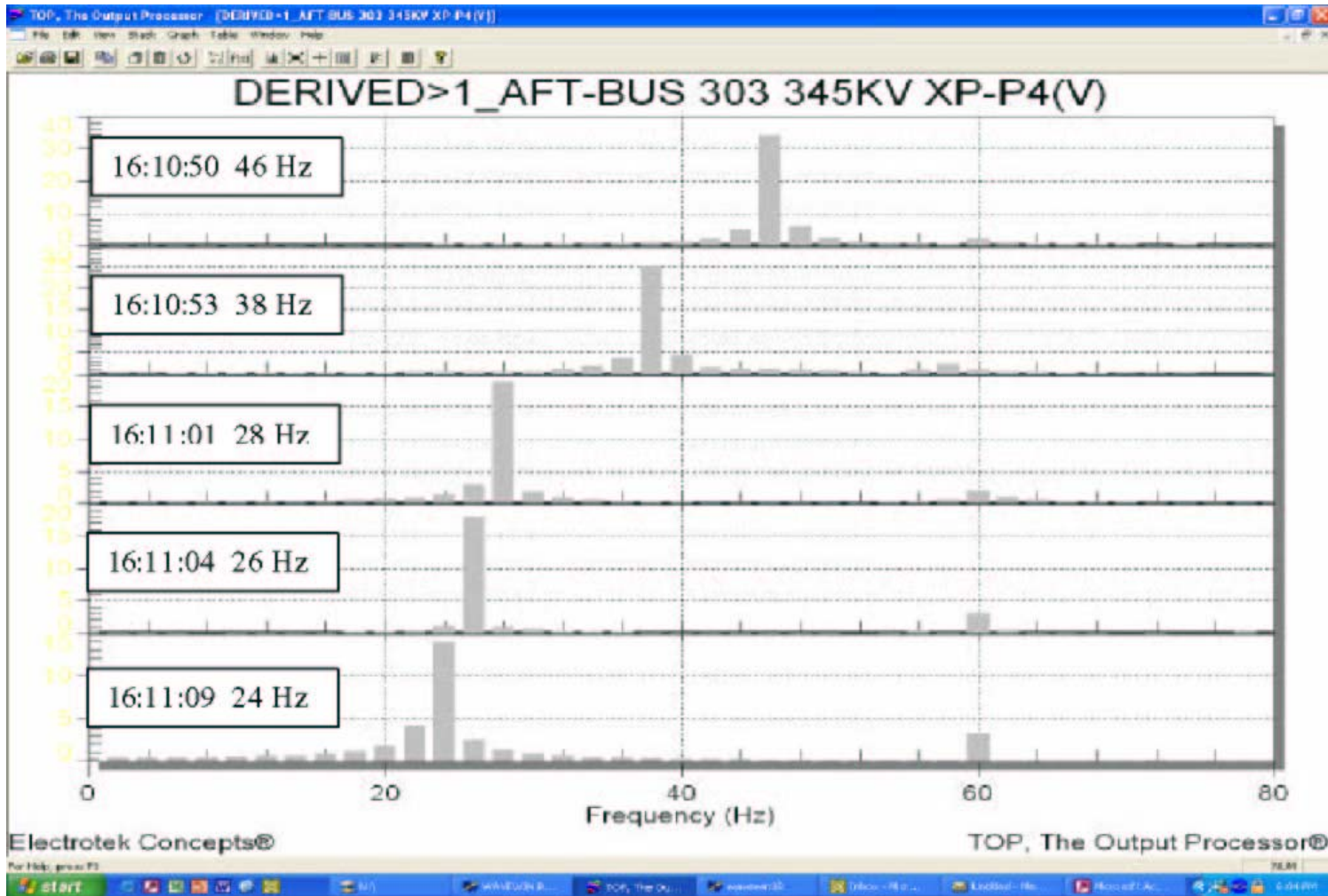


Eastern Eastern Michigan (Detroit) Unstable Voltage and Frequency Collapse and Pole Slipping

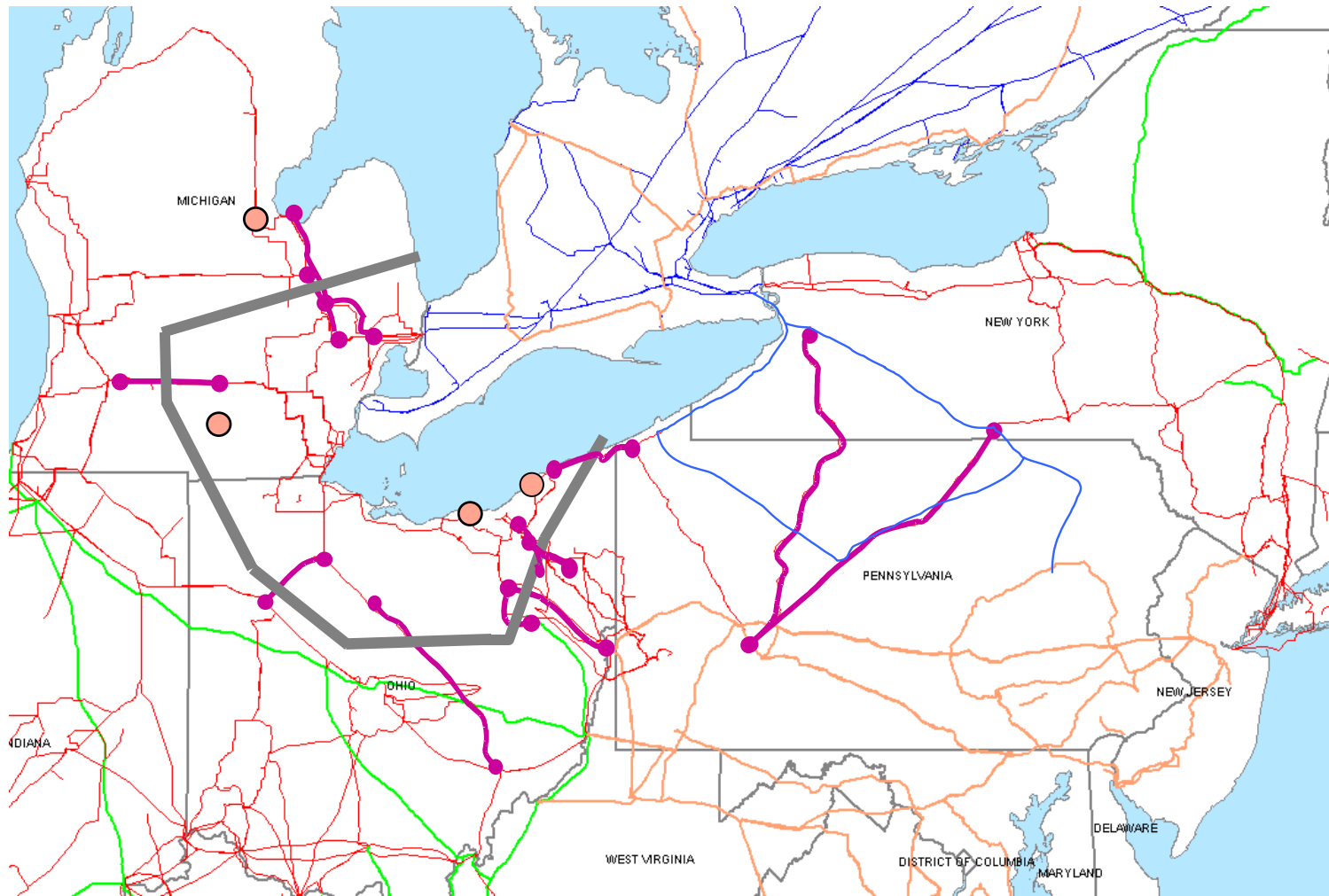
Ontario – Michigan Interface Flow and Voltages Beginning 16:10:38



Severe Under Frequency Condition

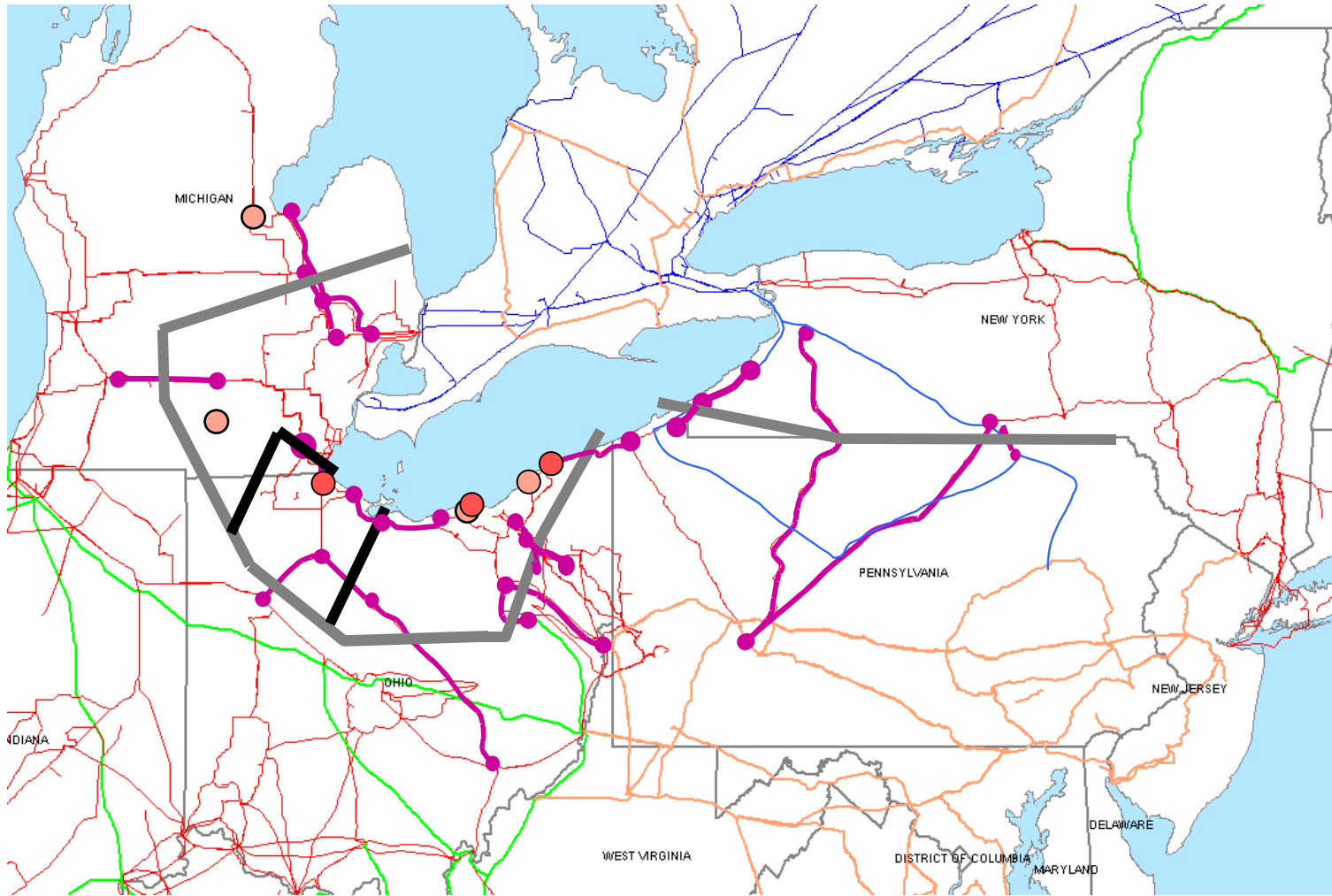


Power Surge on PJM – NY Ties 4:10:39 PM

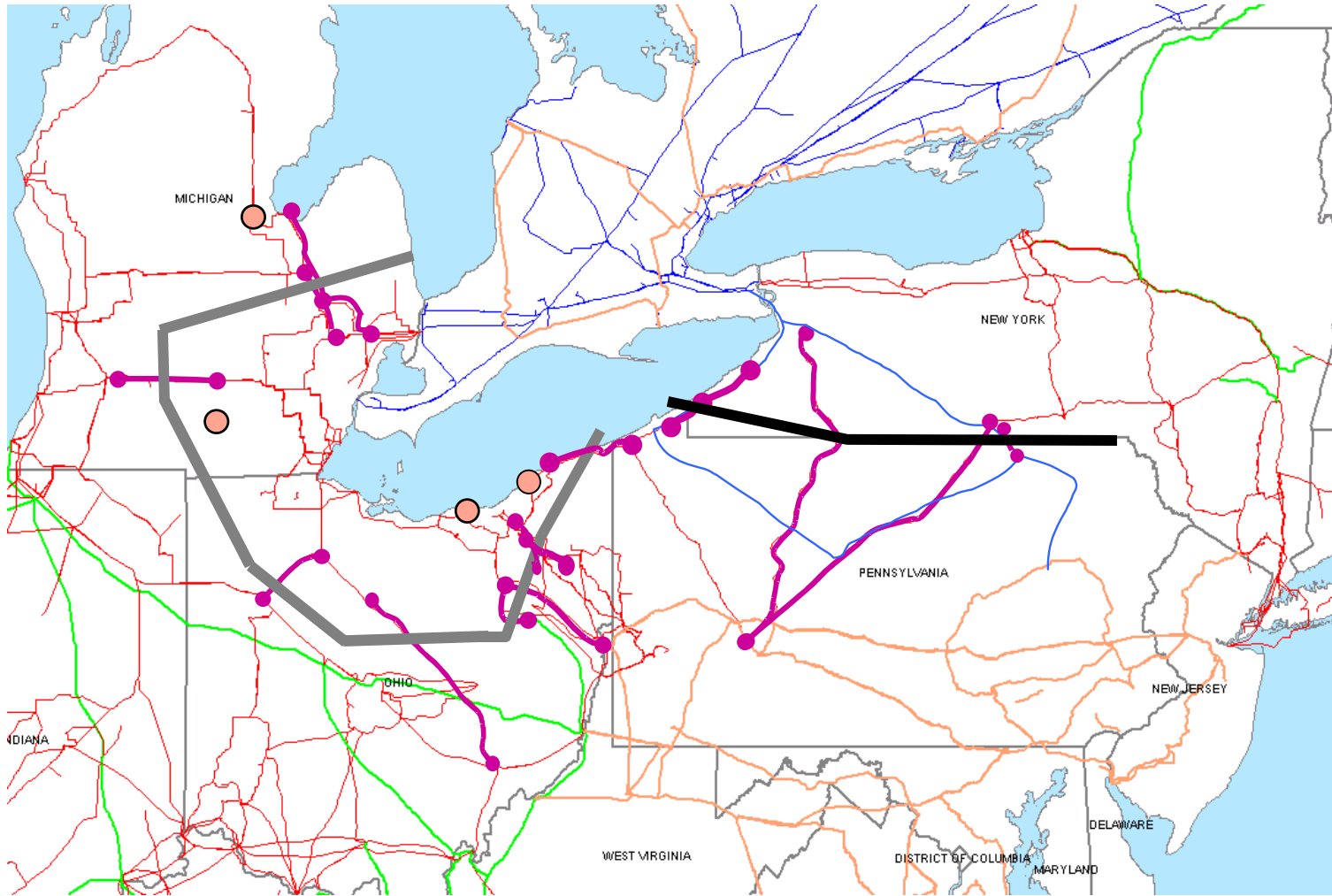


Cleveland – Toledo Island 4:10:39 - 4:10:46 PM

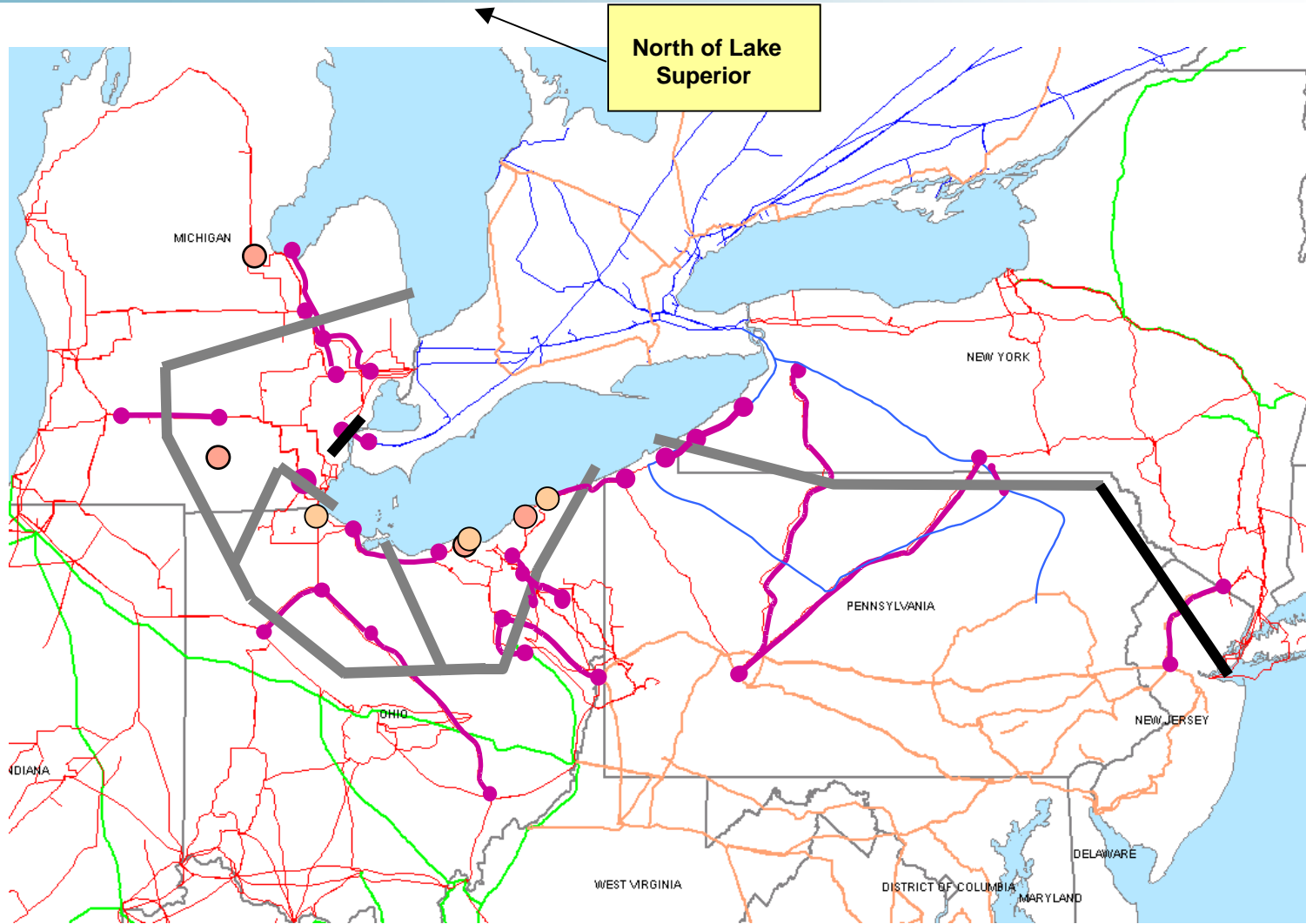
Cleveland Blacks Out



PJM – NY Separating 4:10:44 PM

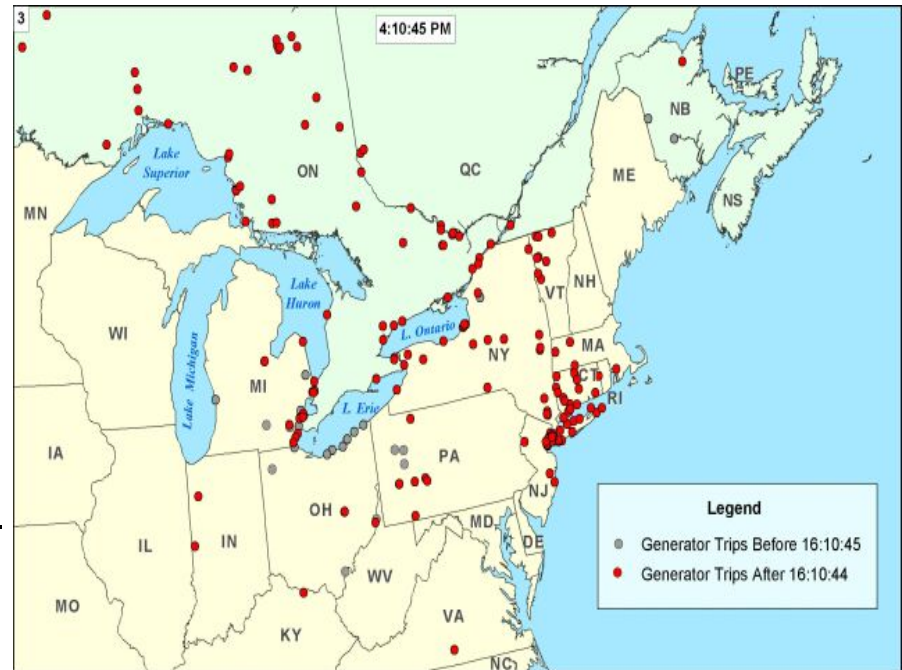


Northeast Completes Separation from Eastern Interconnection 4:10:43 – 4:10:45 PM



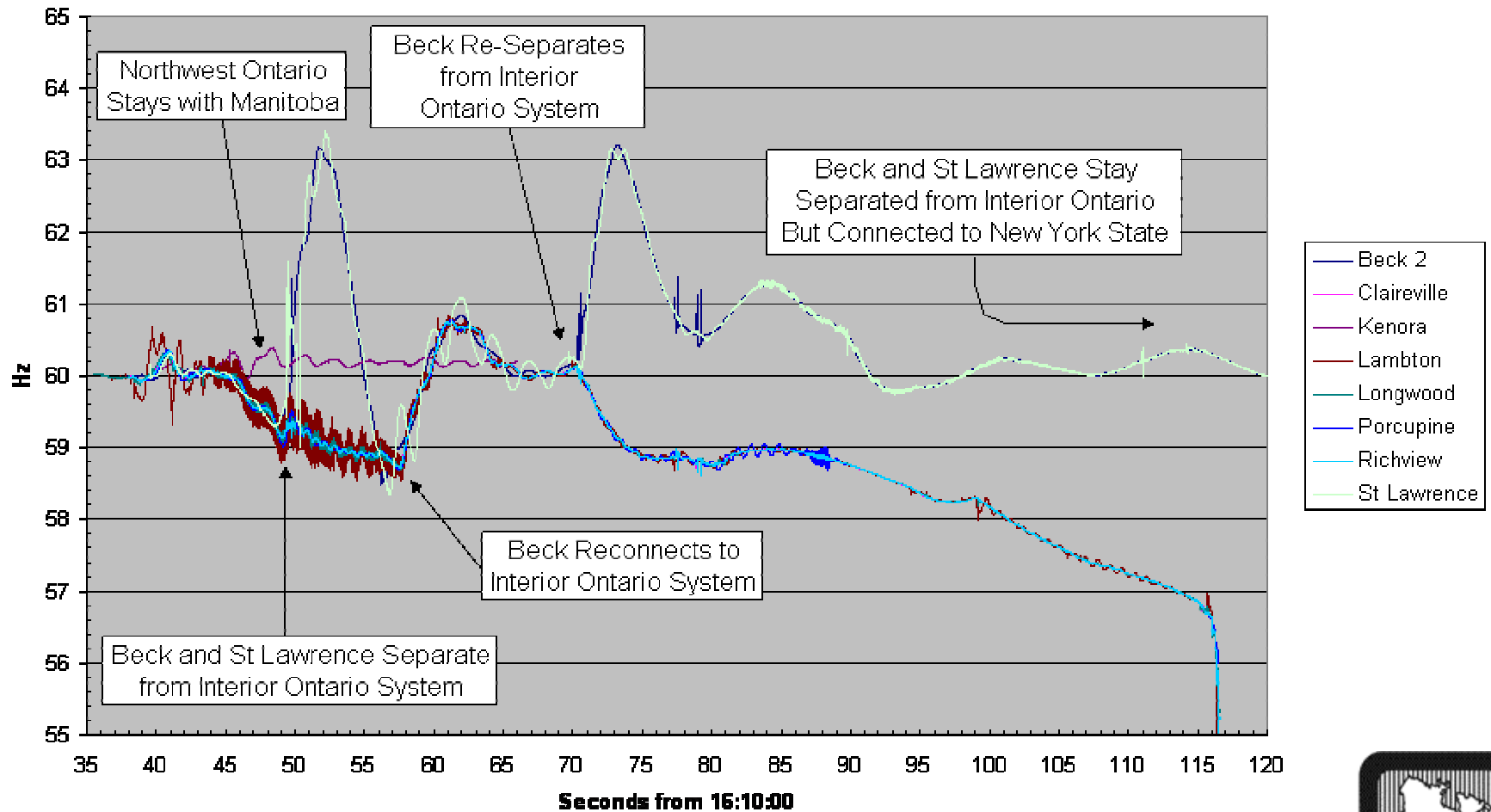
Power plants affected

1. 531 units shut down at 263 plants
2. Trip causes:
 1. Excitation system overload or extreme low voltage – 35%
 2. Generator protection or control system action – 34%
 3. Consequential result of the broken transmission system – 31%
3. Some prolonged out-of-step conditions are evident
4. To date, little damage has been discovered as a result of the cascade

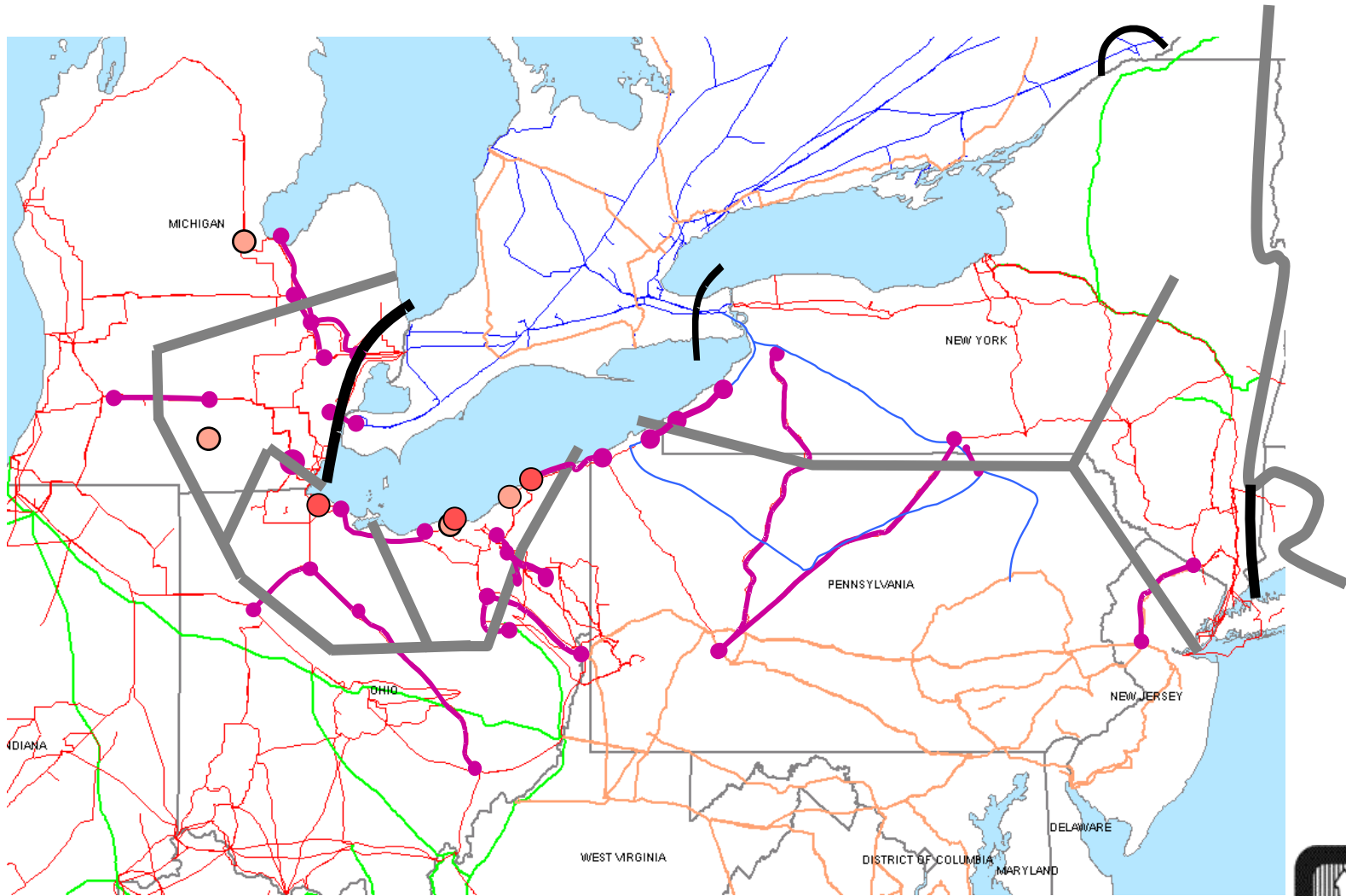


Frequency in Ontario and New York

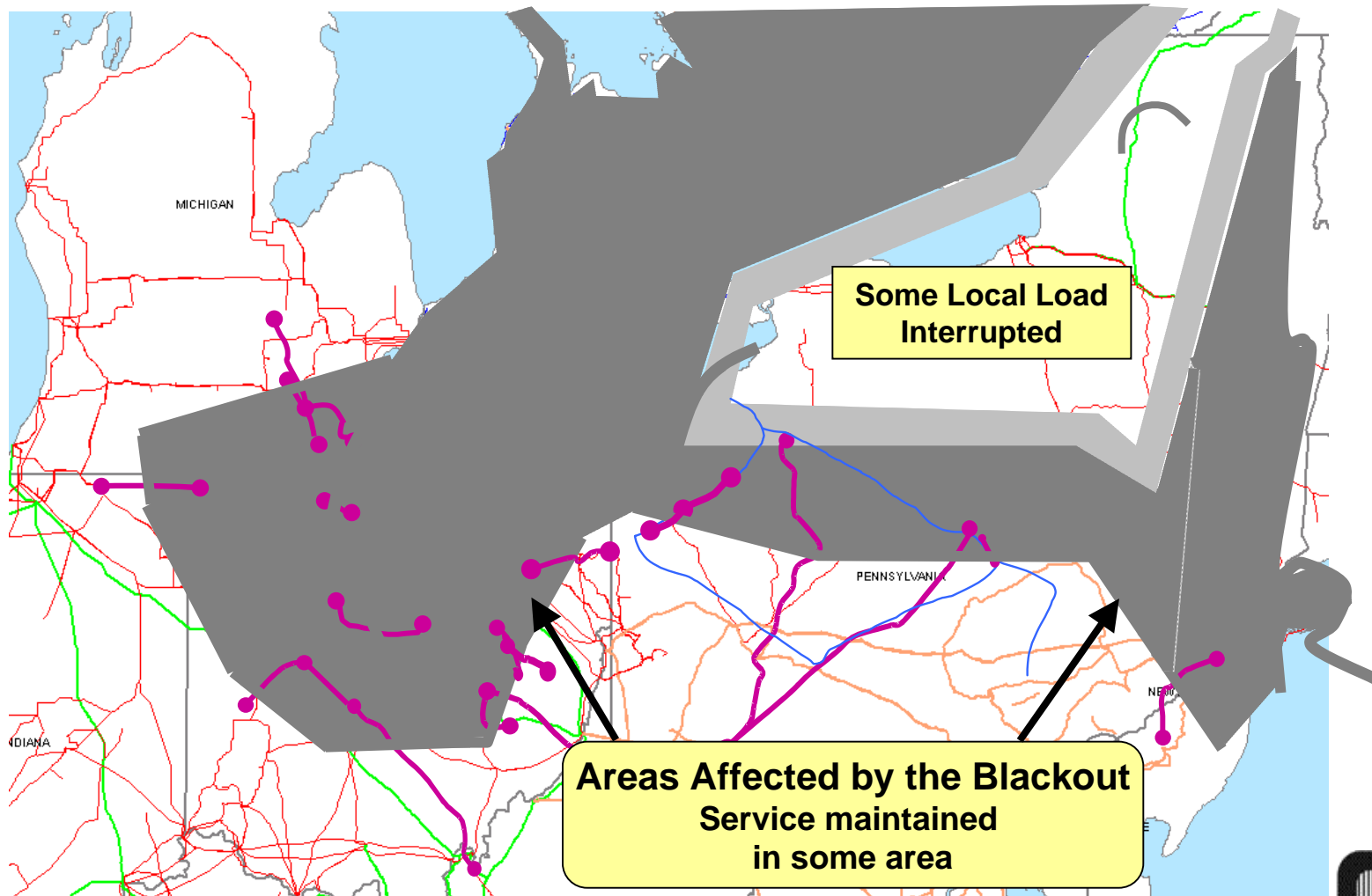
**Frequency Separation
Interior Ontario and Northern New York**



Island Breaks Up: 4:10:46 – 4:13 PM



End of the Cascade



When the Cascade Was Over

- 50 million people
8 states and 2 provinces
- 60-65,000 MW of load
initially interrupted
 - Approximately 11% of Eastern Interconnection
- Sammis – Star trip at 4:06 PM – Blackout
essentially complete by 4:13 PM
- High speed cascading lasted approximately
12 seconds
- Thousands of discrete events to evaluate
 - Time stamping - critical

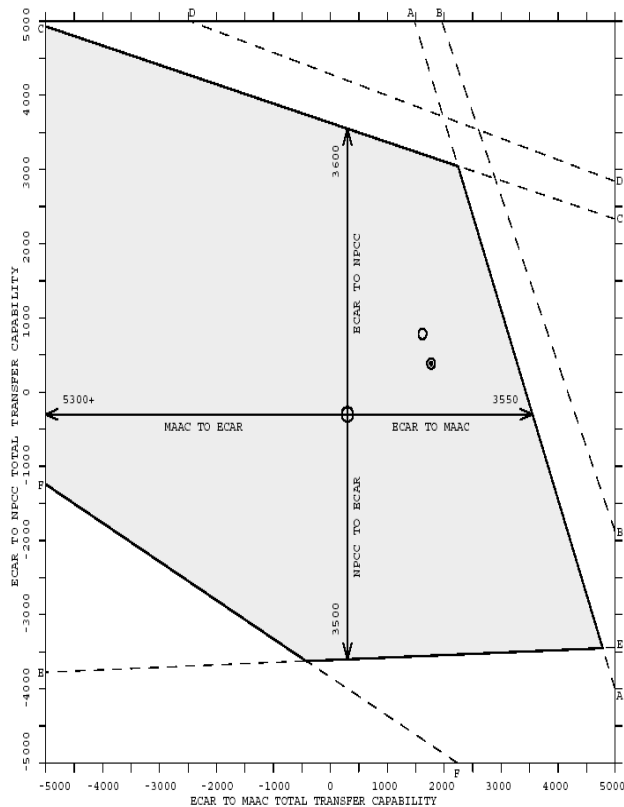


Other Key Findings of Investigation

- Compliance with reliability rules requires objective measurements and firm actions to resolve violations
- NERC policies were not sufficiently specific regarding reliability coordinator and control area functions, responsibilities, authorities, tools
- Problems from prior wide-area blackouts are being repeated: trees, operator tools, training



Other Key Findings of Investigation



- System planning and design studies, operations planning, facilities ratings, and modeling data accuracy were ineffective preparations for 8/14 event
- Power system in northeastern Ohio was being operated with insufficient reactive margins to meet NERC criteria
- Protection and controls could be more effectively used to slow or minimize spread of cascade



Corrective Actions

- FirstEnergy

- Voltage criteria and reactive resources
- Operational preparedness and action plan
- Emergency response capabilities and preparedness
- Control center and operator training

- MISO

- Reliability tools
- Visualization tools
- Operator training
- Communications protocols
- Operating agreements

- PJM

- Communications protocols



NERC Strategic Initiatives



- Performance reviews
- Readiness audits
- Vegetation-related outage reporting
- Recommendations implementation tracking



NERC Technical Initiatives

- Operator and reliability coordinator emergency response training
- Reactive power and voltage control
- Cascade mitigation
- Reliability coordinator and control area functions, authorities, and requirements
- Real-time operating tools
- Restoration review
- Time-synchronized measurements for disturbance analysis and operations
- Reevaluate system design, planning and operating criteria
- System modeling and data exchange standards

