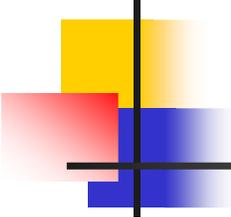


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NE Blackout of August 14th 2003

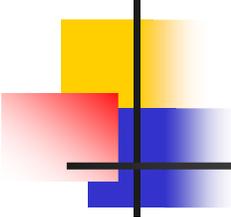
- Overview of What Happened
- Causes of Blackout
- Contributing Factors
- Key Recommendations



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□ Statistics

- 50 Million people blacked out
- 62,000 MW of load initially interrupted
 - Approximately 11% of Eastern Interconnection
- 531+ generating units at 261 plants tripped
- Over 100 transmission lines tripped
- 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

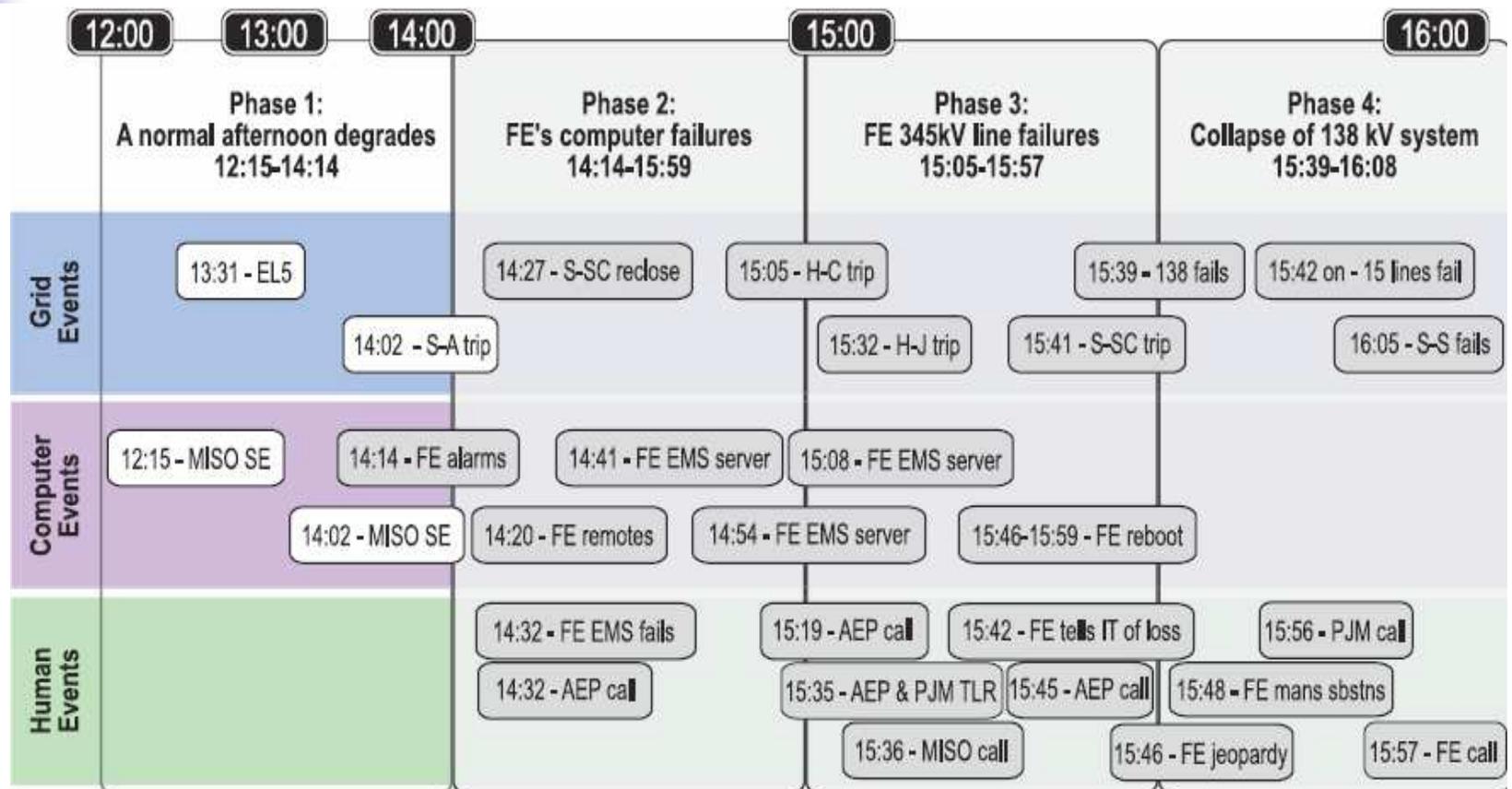


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- 12:15 MISO's State Estimator Mismatch
 - Bloomington – Denois Creek 230 kV Outage
 - Line status not linked to state estimator

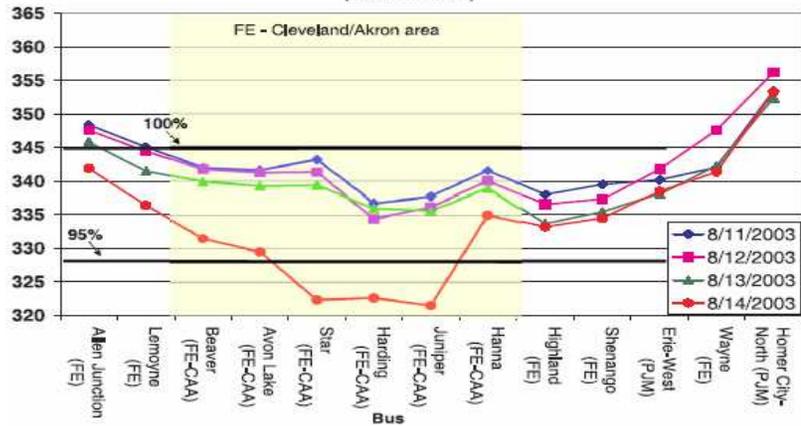
- 14:02 Stuart – Atlanta 345 kV line outage
 - Causes problem with MISO's state estimator

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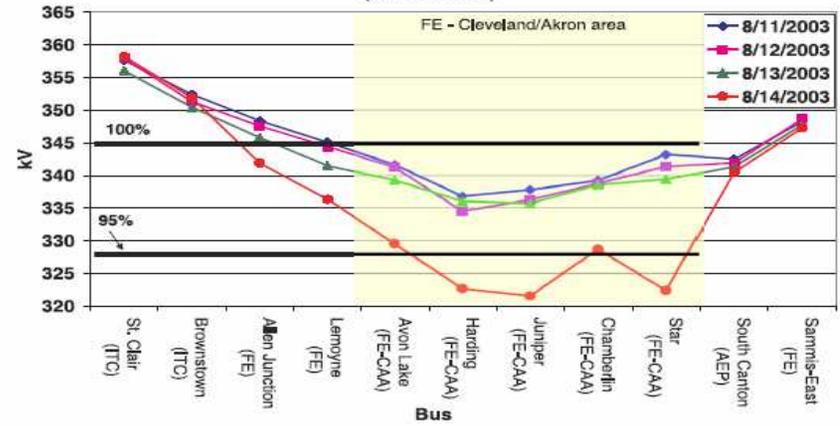


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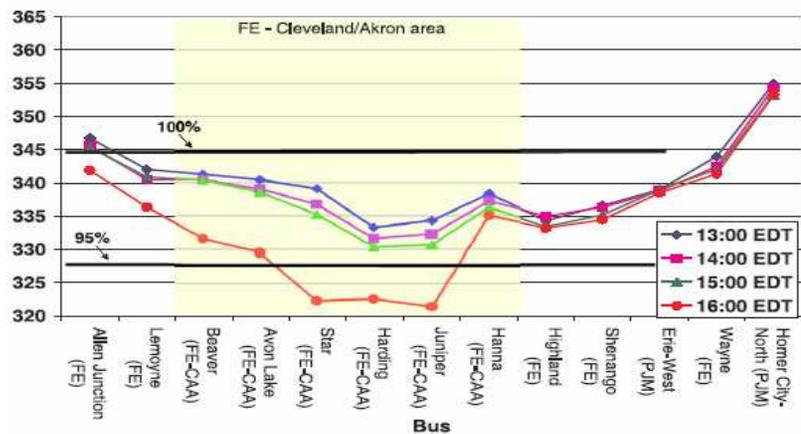
West-East 345kV Actual (Measured) Voltages Leading up to August 14th
(4:00 PM EDT)



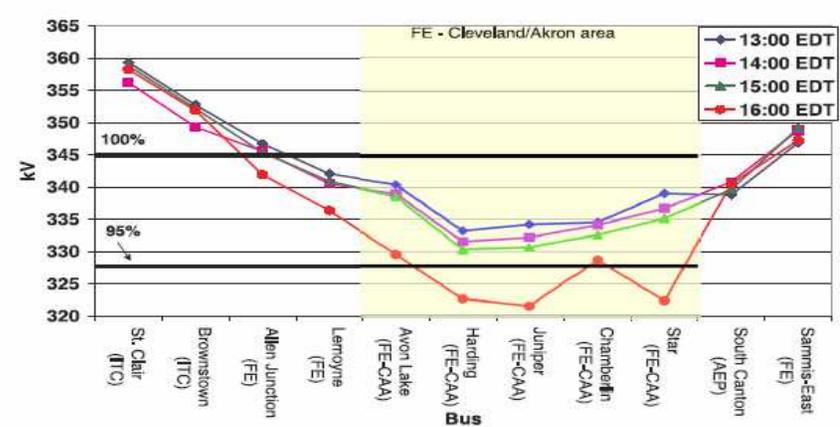
North-South 345kV Actual (Measured) Voltages Leading up to August 14th
(4:00 PM EDT)



Hourly West-East 345kV Actual (Measured) Voltages on August 14th

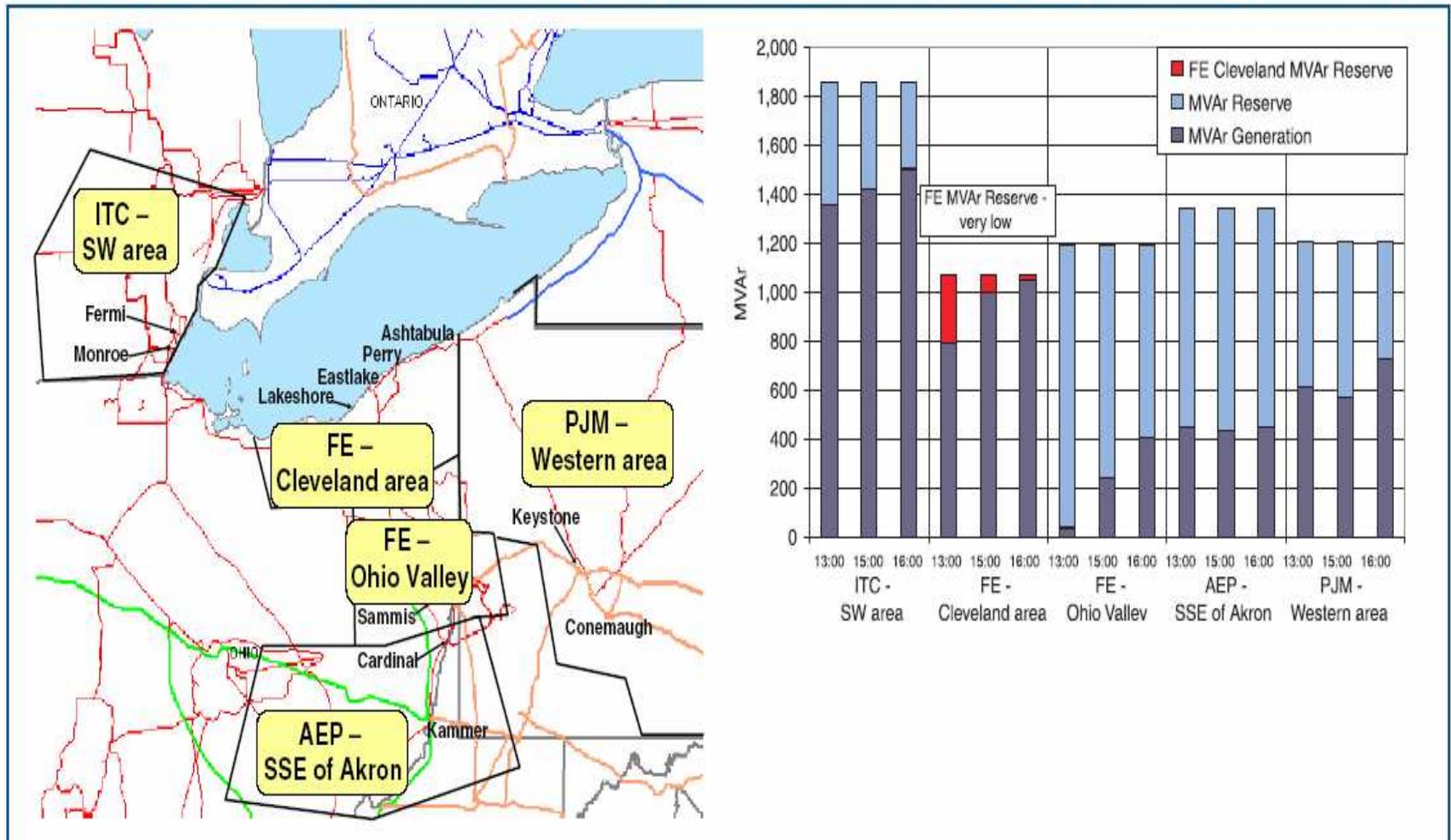


Hourly North-South 345kV Actual (Measured) Voltages on August 14th



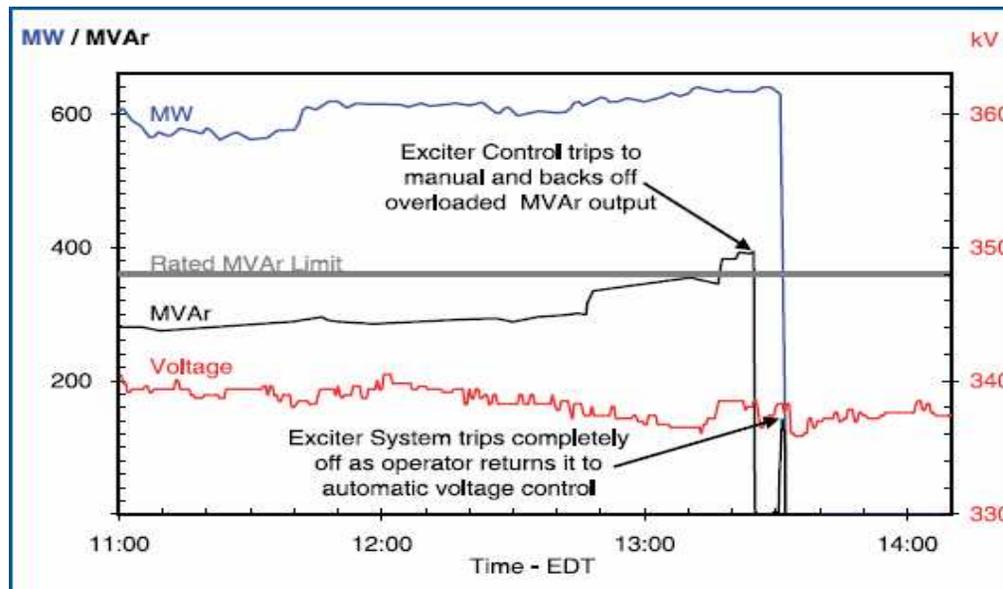
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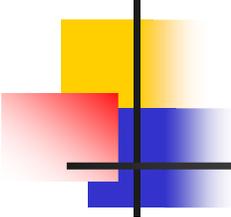
Figure 4.8. Reactive Reserves Around Ohio on August 14, 2003, for Representative Generators in the Area



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- 13:31 East Lake 5 Unit trips
 - Operator intervention coupled with exciter problem
 - Key generator outage in Cleveland area causes increased loading on FE's 345 kV system





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FE Computer Failures

- 14:14 FE alarm and logging software failed
- 14:20 Several FE remote EMS consoles failed
- 14:41 FE control system server failed
- 14:54 FE back-up computer failed

Other Events

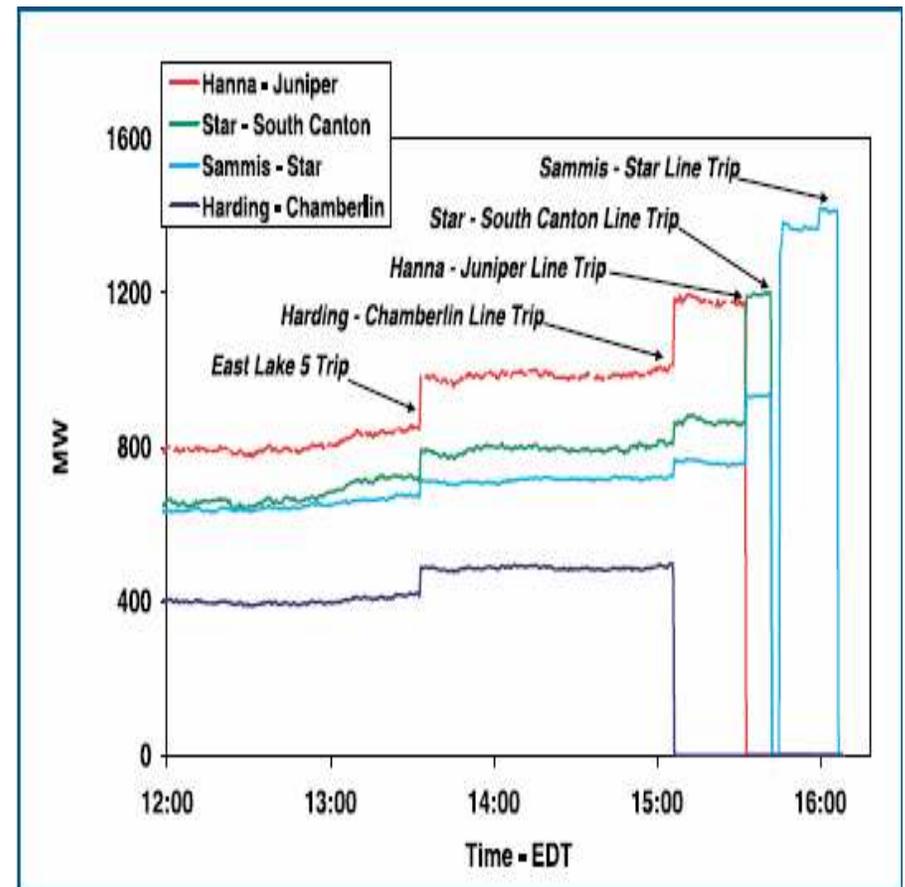
- 14:27 Star – South Canton 345 kV line relayed
- 14:32 AEP called FE regarding Star – South Canton
FE had no alarm or log of this line trip

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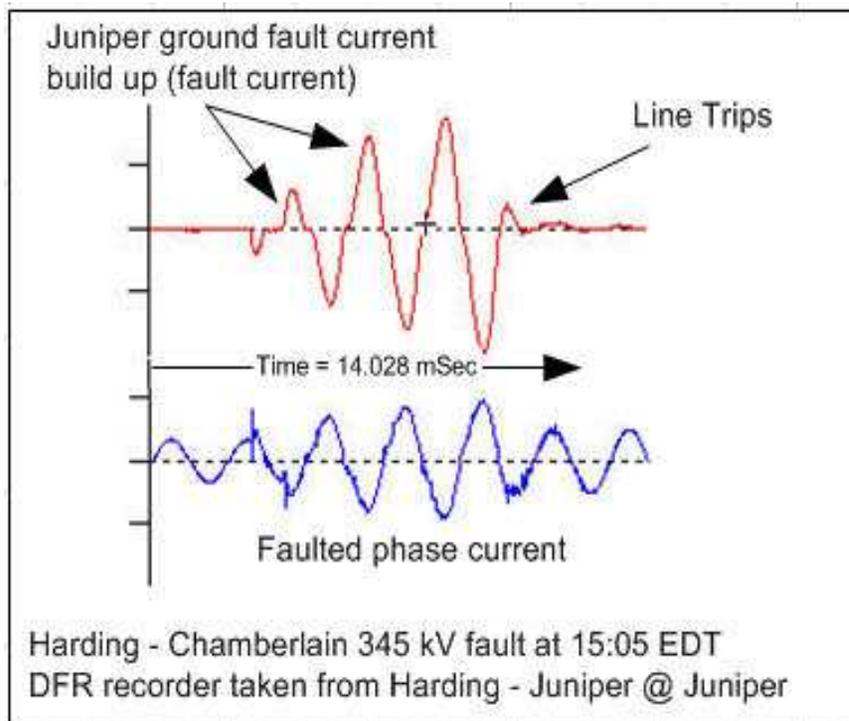
FE 345 kV line failures

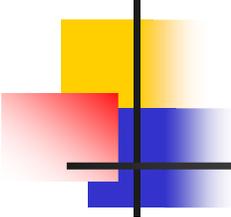
- 15:05 Harding – Chamberlain line trip
- 15:32 Hanna – Juniper line trip
- 15:41 Star – South Canton line trip

These lines tripped by gnd relay due to tree contact



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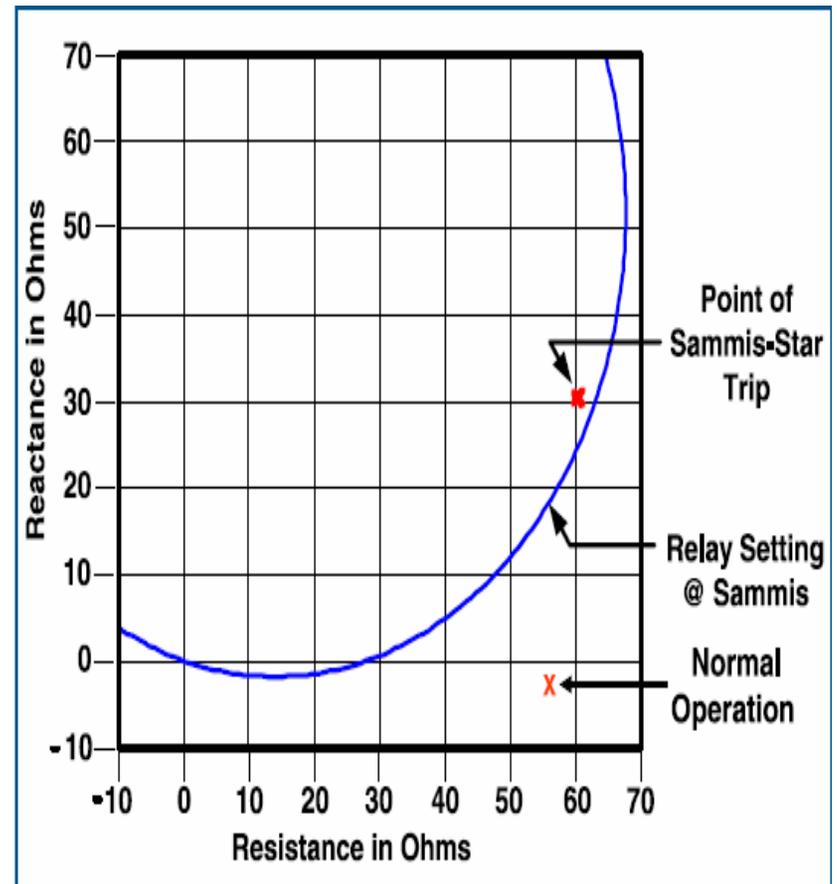
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Situational Awareness and Reliability Coordination

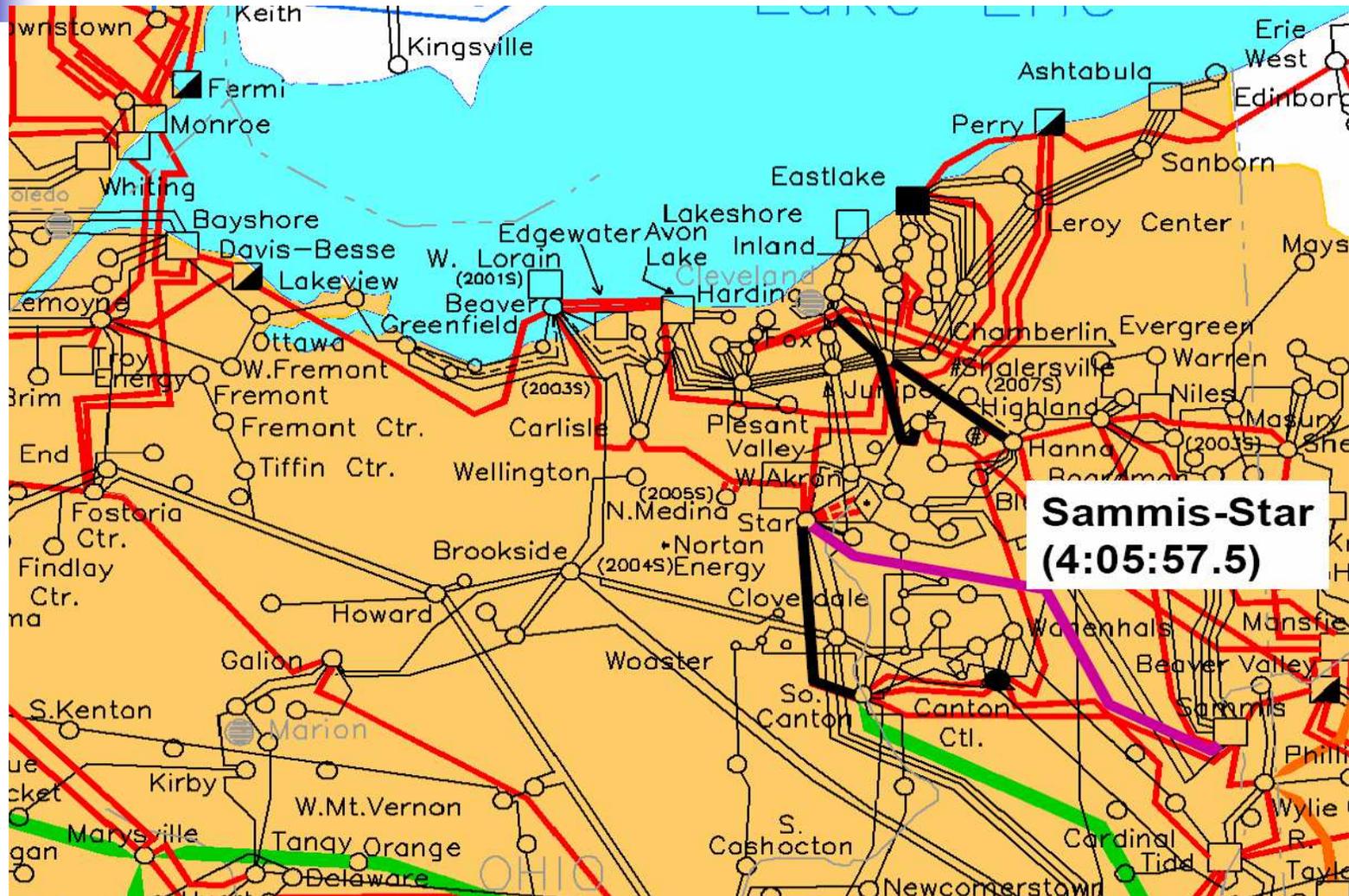
- FE was not aware of outages until 15:45 despite calls
- AEP called FE back regarding 14:27 operation of Star – South Canton line – disbelief
- 15:35 AEP asked PJM to work on 350 MW TLR to relieve overload on Star – South Canton line
- 15:36 MISO called FE regarding loss of the Hanna – Juniper 345 kV line
- 15:42 Calls from IT staff regarding failure of alarms

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- 16:05:57 Sammis – Star line trips
- Zone 3 relay initiation
- Load encroachment
- 120% of emergency rating
- 1500 MW of load shedding prior to Sammis – Star would have prevented disturbance



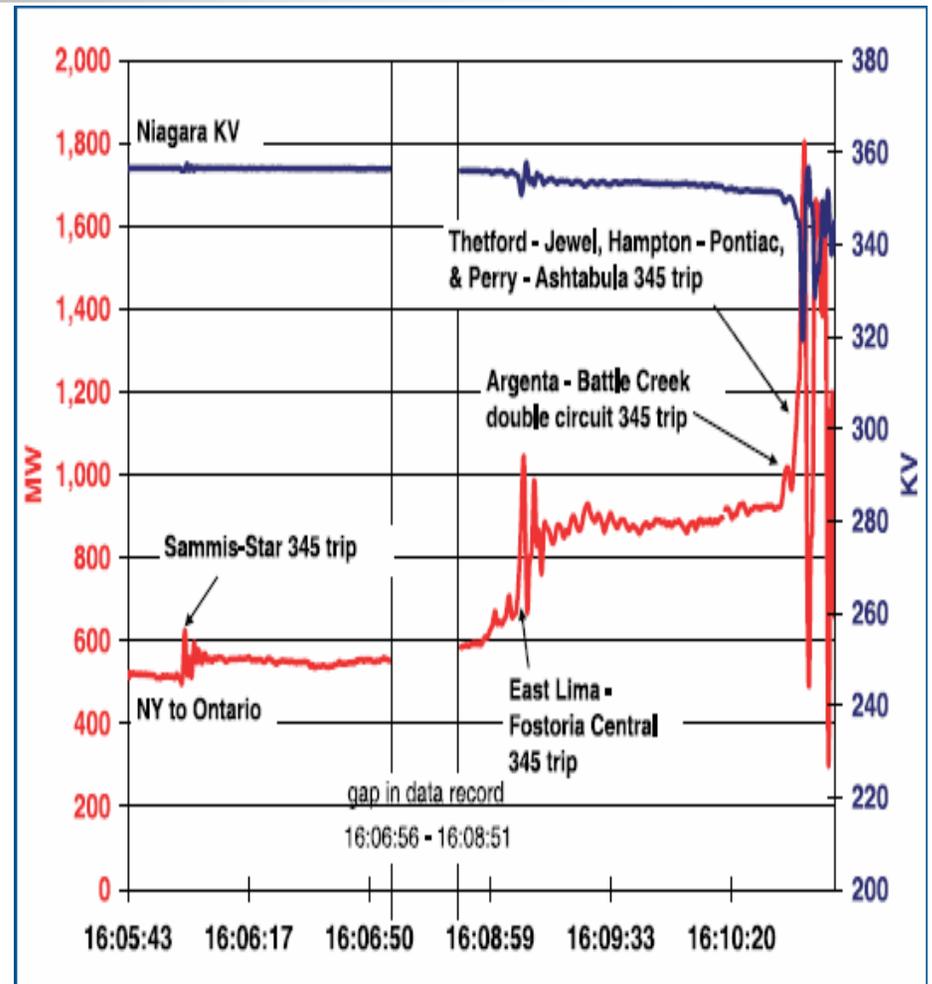
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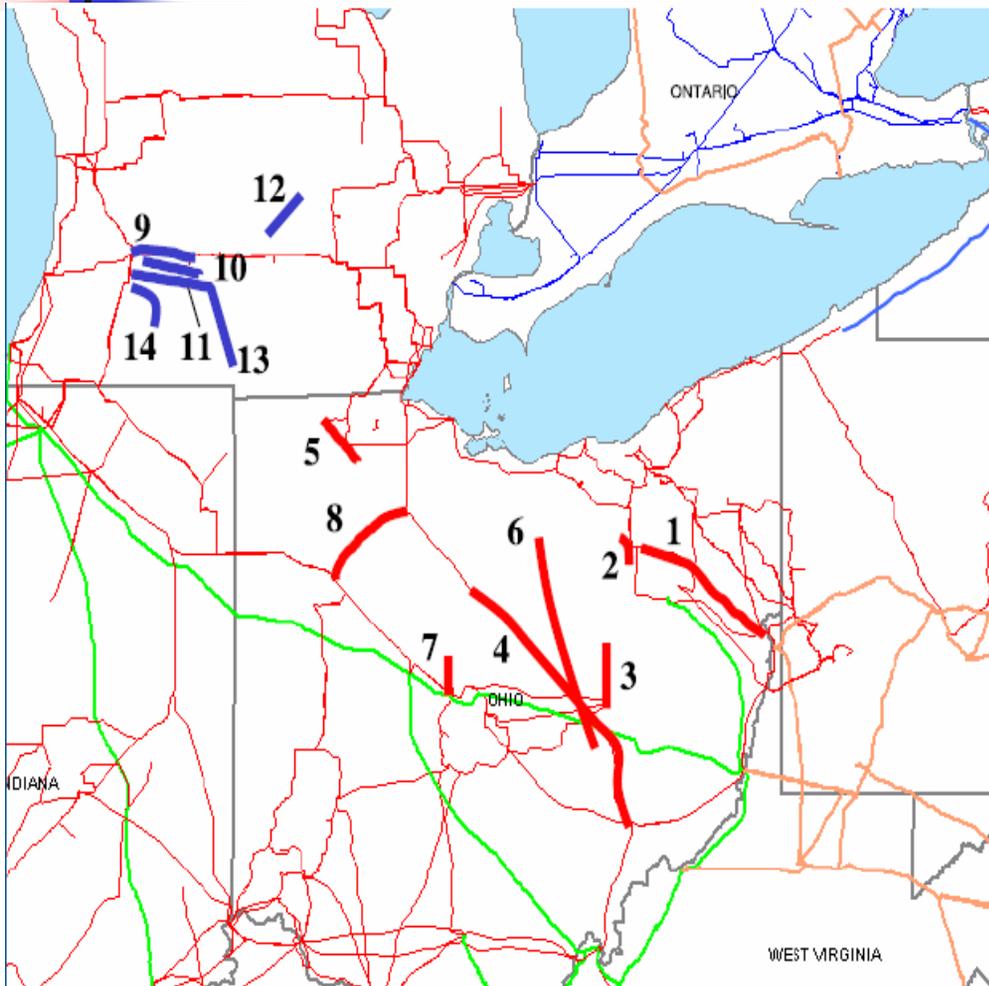
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Cascade Phase

- 16:08:59 Galion – Ohio Central – Muskingum tripped
- 16:09:06 East Lima – Fostoria Central line tripped
- Significant power swings – system poorly damped and barely stable
- Zone 3 relay operations



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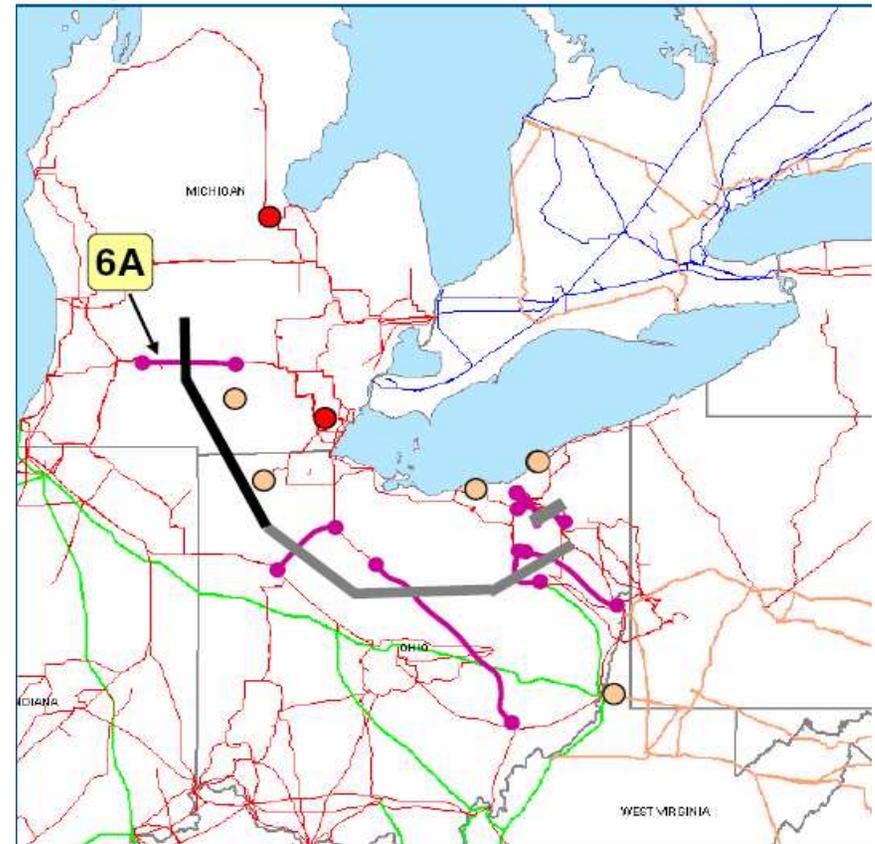
	Zone 3 Tripped Lines	State	Trip Time (EDT)
1	Sammis - Star (345 kV)	Ohio	16:05:57.504
2	Star (138/69 kV) Transformer # 6 Star - Dale (69kV)	Ohio	16:06:01
3	Ohio CTL - Wooster (138 kV)	Ohio	16:08:58
4	Galion - Ohio CTL - Muskingum (345 kV) @ Muskingum	Ohio	16:08:59.158
5	Richland - Wauseon - Midway (138 kV)	Ohio	16:09:00
6	Academia - Howard (138 kV) Philo - Howard (138 kV)	Ohio	16:09:05
7	Tangy - Kirby (138 kV) Tangy - Crissinger (138 kV)	Ohio	16:09:06
8	E. Lima - Fostoria (345 kV)	Ohio	16:09:06.311
9	Argenta - Battle Ck (345 kV)	Michigan	16:10:36.230
10	Argenta - Tompkins (345 kV) Battle Ck - Oneida	Michigan	16:10:36.310
11	Argenta - Verona (138 kV)	Michigan	16:10:37.550
12	Delhi - Island Road (138 kV)	Michigan	16:10:37.870
13	Verona - Batavia (138 kV)	Michigan	16:10:37.900
14	Argenta - Morrow (138 kV)	Michigan	16:10:38.350

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High Speed Cascade

- 16:10:36 Argenta – Battlecreek 345 kV line trip
- 16:10:36 Argenta – Tompkins 345 kV line trip
- 16:10:36 Battlecreek – Oneida 345 kV line trip
- Sumpter Units trip
- MCV Units trip
- 70 degree phase angle

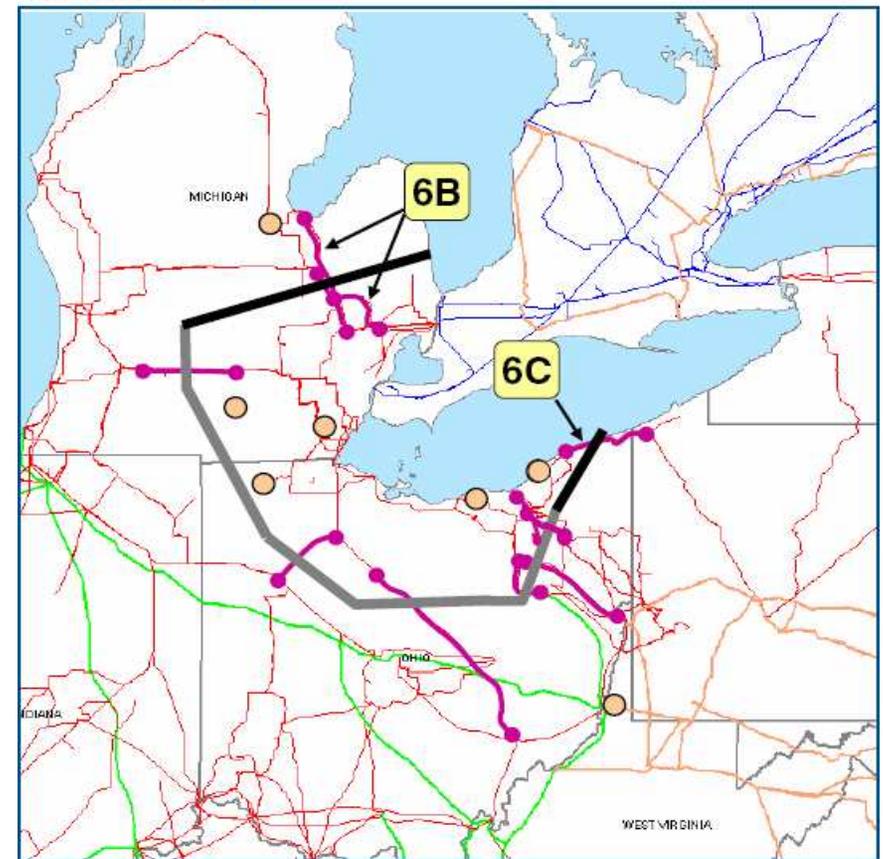
Figure 6.11. Transmission and Generation Trips in Michigan, 16:10:36 to 16:10:37 EDT



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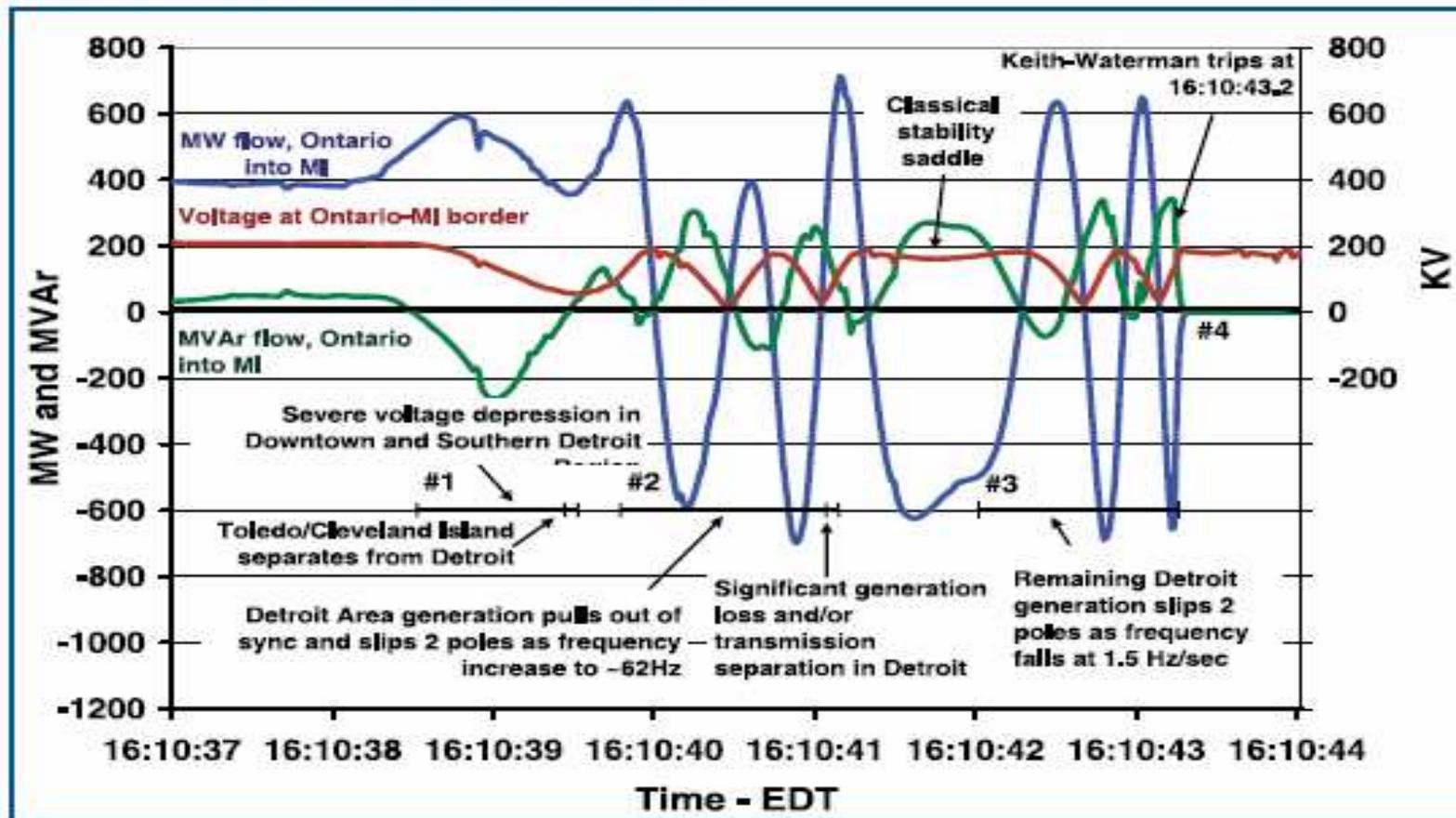
- 16:10:38 Hampton – Pontiac 345 kV line trip
- 16:10:38 Thetford – Jewell 345 kV line trip
- 16:10:38 Erie West – Ashtabula – Perry 345 kV line trip
- Cleveland separated from Pennsylvania
- 3700 MW swing from Michigan/Ohio thru Pennsylvania, New York, Ontario into Michigan !!!

Figure 6.15. Michigan Lines Trip and Ohio Separates from Pennsylvania, 16:10:36 to 16:10:38.6 EDT



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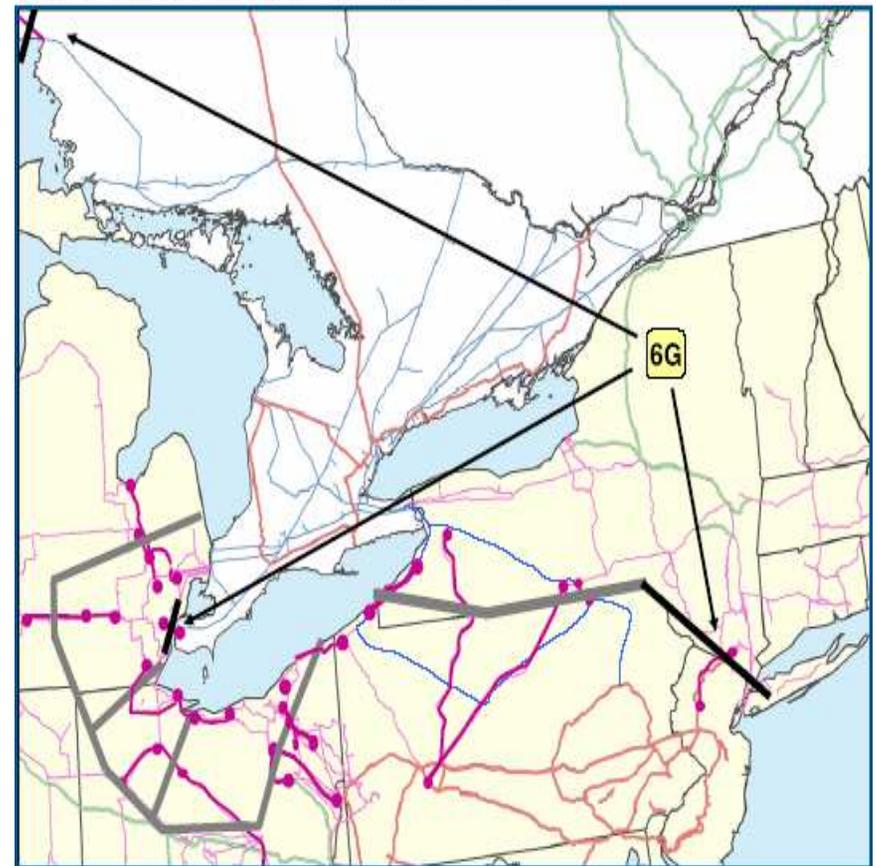
Figure 6.19. Generators Under Stress in Detroit, as Seen from Keith PSDR



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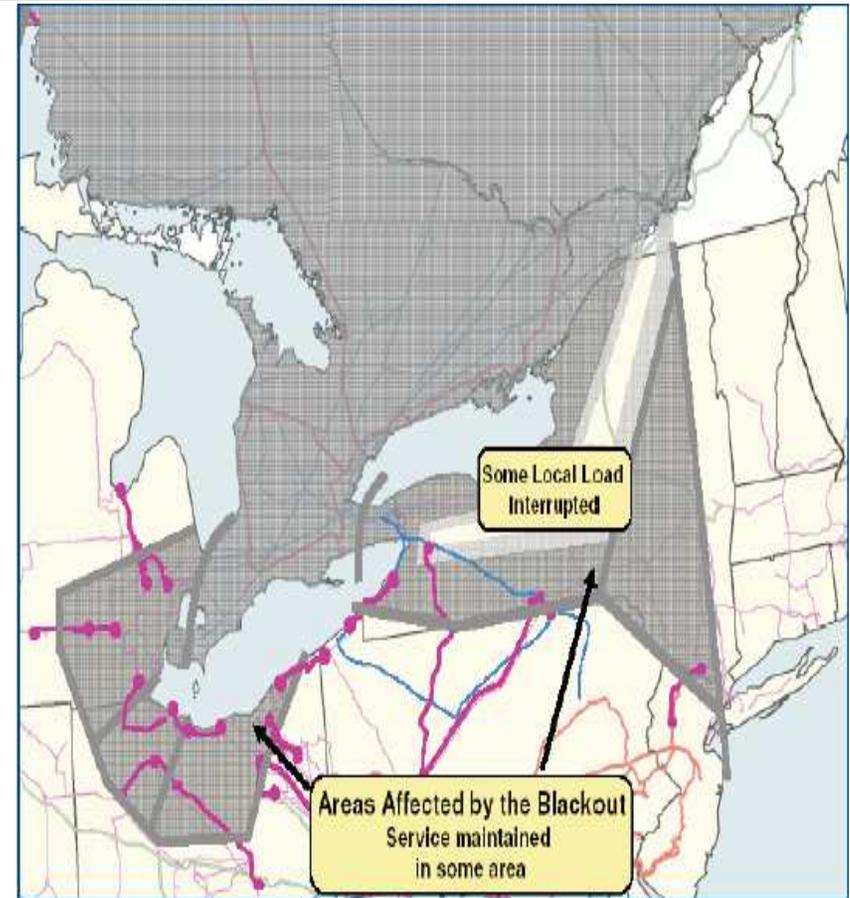
- 16:10:43 Keith – Waterman 230 kV line trip
- 16:10:45 Wawa – Marathon 230 kV line trip
- 16:10:45 Branchburg – Ramapo 500 kV line trip
- Northeast Island formed!

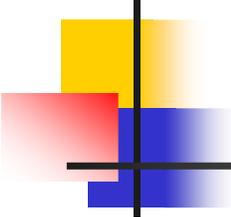
Figure 6.21. Northeast Separates from Eastern Interconnection, 16:10:45 EDT



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- 16:13 Cascade complete
- 25,588 MW load shed by underfrequency relays
- 18,448 MW load shed by UFLS in NE Island
- Uncoordinated tripping of generators by frequency and voltage

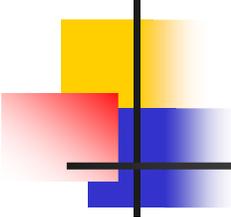




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Key Recommendations

- 44 recommendations from task force; 14 recommendations from NERC
- Make reliability standards mandatory
- Shield operators who initiate load shedding
- Strengthen institutional framework for reliability mgt
- Correct the direct causes of the NE blackout
- Strengthen the NERC Compliance Enforcement Prog.
- Support and strengthen NERC's Reliability Readiness Audit Program



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- Improve near-term and long-term training and certification requirements for operators
- Establish clear definitions for *normal, alert and emergency* conditions
- Make more effective and wider use of system protection measures
- Evaluate and adopt better real-time tools for operators
- Develop enforceable standards for t-line ratings
- Strengthen reactive power and voltage control pract.