POM – OPM at American Transmission Co.

March 27, 2006

V&R Training, Los Angeles

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Operations Engineer

AMERICAN TRANSMISSION COMPANY®

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ATC Overview

- ATC owns and operates transmission assets in portions of Wisconsin, Michigan, Minnesota and Illinois
  - 9,100 miles of transmission lines, 480 substations
  - Serves electric needs of more than 5 million people

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Core business

- ATC is a private transmission-only company owned by 29 entities including investor-owned utilities, municipalities, municipal electric companies, electric cooperatives
- Does not own generation or distribution assets
- Ensures reliable operation of the transmission network
- Provides adequate infrastructure to meet the needs of all customers
  - invested more than $1 billion in infrastructure in first 6 years
  - 10-year plan outlines an additional $3 billion in investment
- Operates independently, providing service without discrimination between customers

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Use of POM-OPM in System Operations

- Reliability Analysis to support Real-time Operations and Outage Coordination Process
  - Impact of Market Operations and System Bias
  - Voltage Stability P-V Curve Analysis
  - Power Transfer Analysis with Visualization Tool Implemented for N-1, N-2, …, N-K
  - Emergency Mitigation Measure Process
- Transformer Maintenance Analysis to Support Asset Management Project Prioritization
- Future Work and Recommendations

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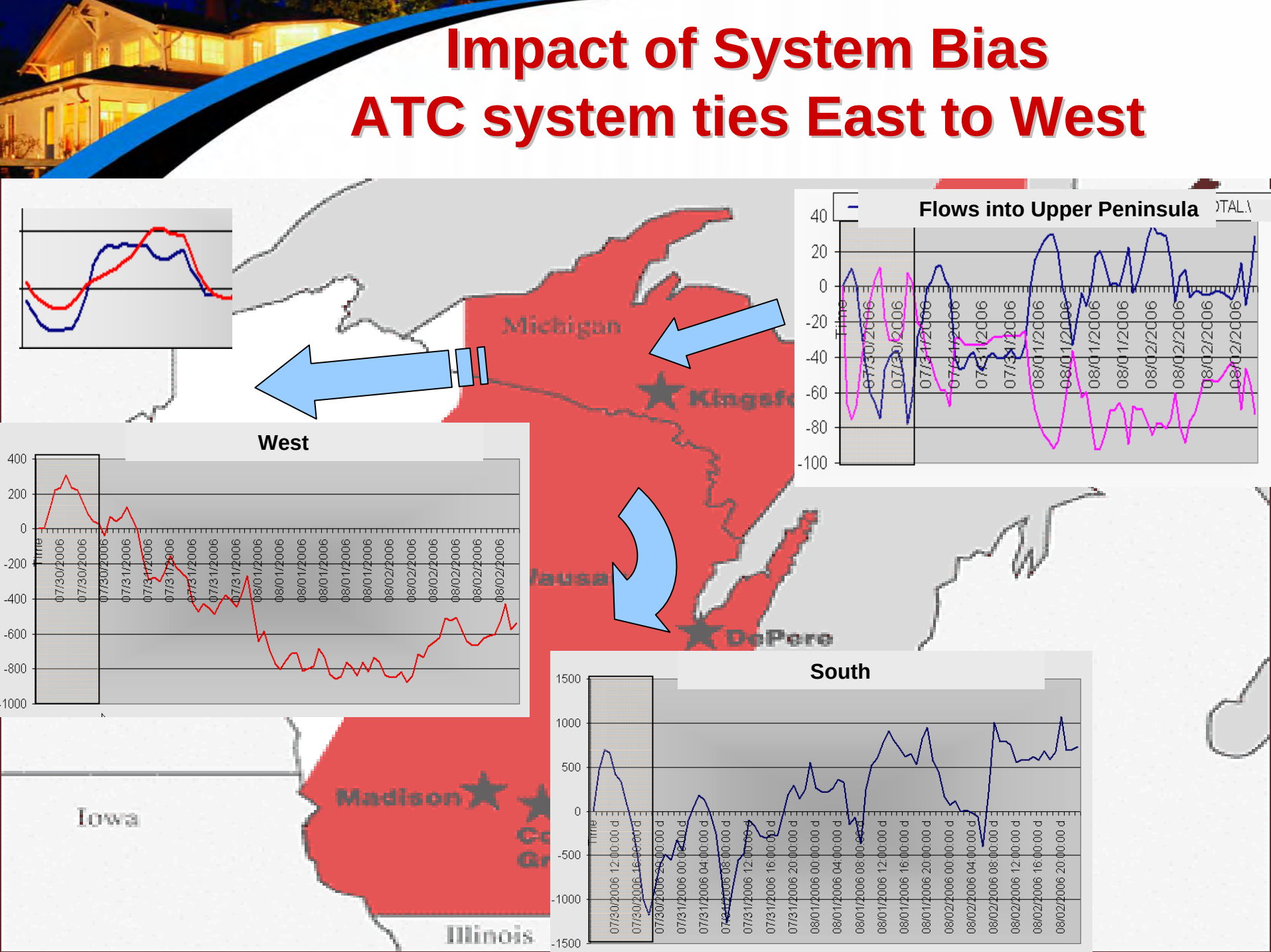
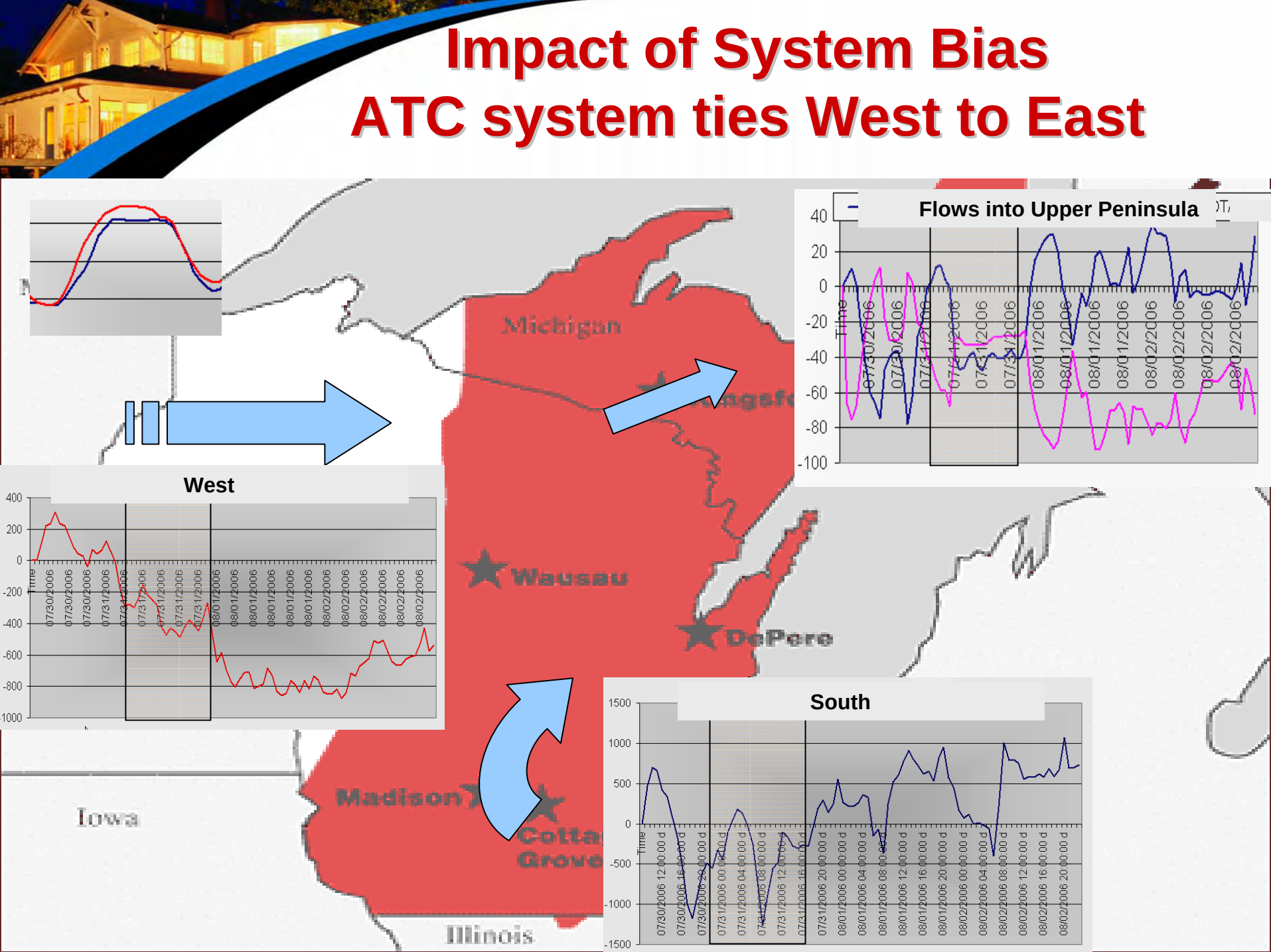
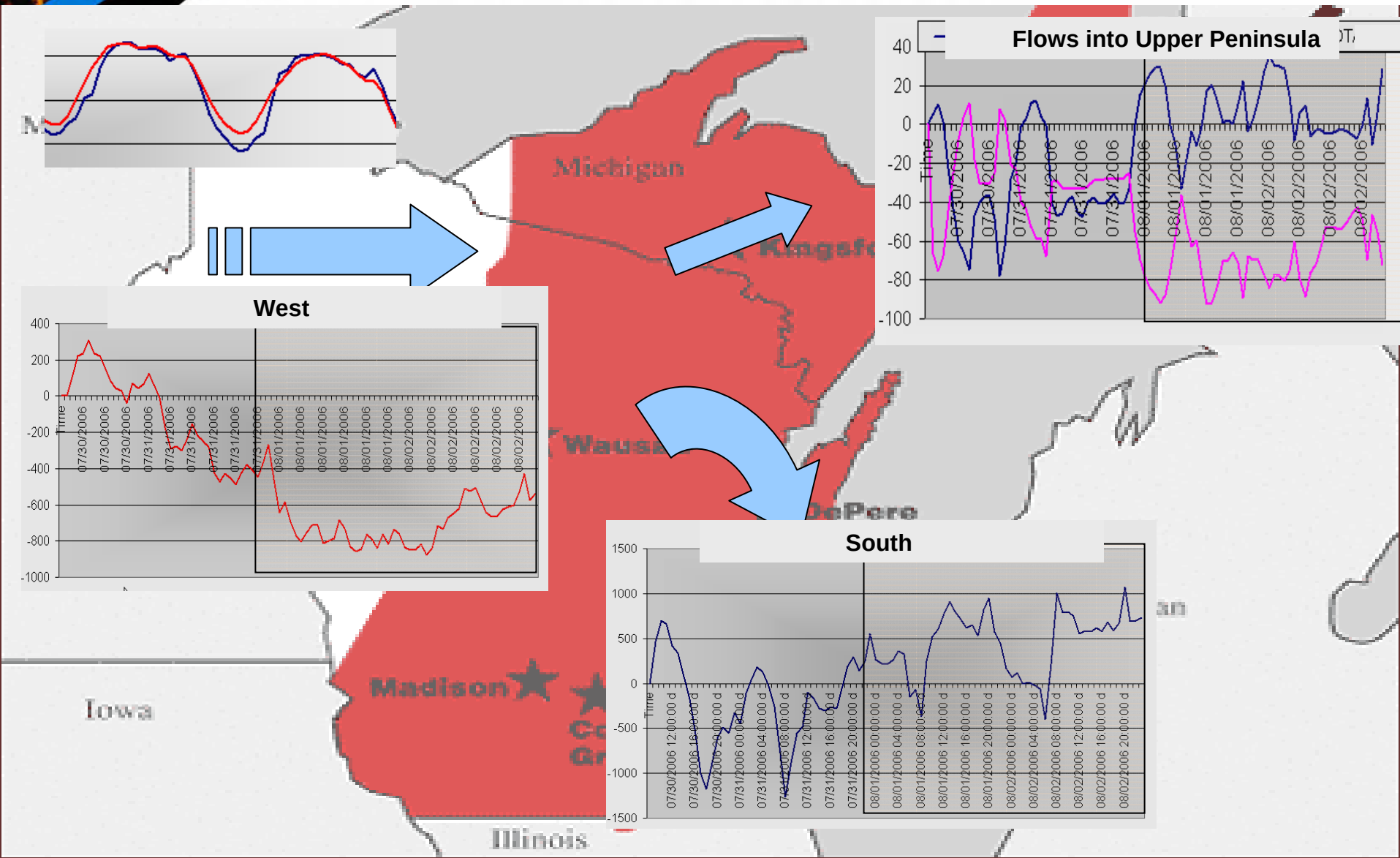
Impact of System Bias
ATC system ties East to West



Impact of System Bias
ATC system ties West to East



Impact of System Bias
ATC system ties "Through" Flow



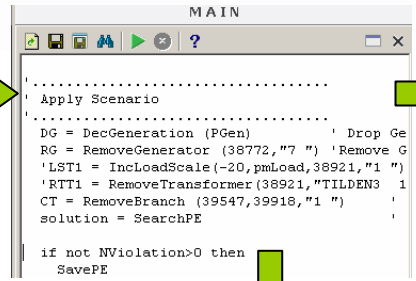
P-V Curve Analysis in Operations by using POM-OPM

Run P-V Curve Analysis for flowgates in ATC System sensitive to voltage collapse. Establish operating limits during different construction phases.

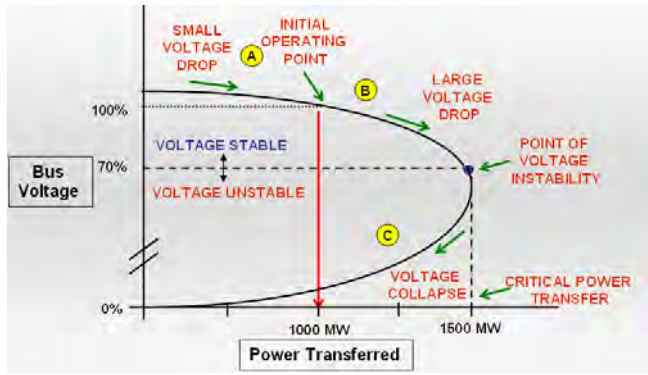
1. Develop PROJECT.prv
2. Use Advanced Mode – PV Script

1. EMS cases provided every "X" minutes
2.PSSE Planning Cases

Input



Output



- *If using real time cases to support Operations, verify the voltage contingencies identified by POM-OPM with AREVA Contingency Analysis Tool*
- *Compare the POM-OPM P-V curve results with other tools (i.e, PSSE Flow South P-V Curves)*
- *Establish P-V Curve Analysis process in Operations (for different flowgates that are subject to voltage collapse in ATC System)*

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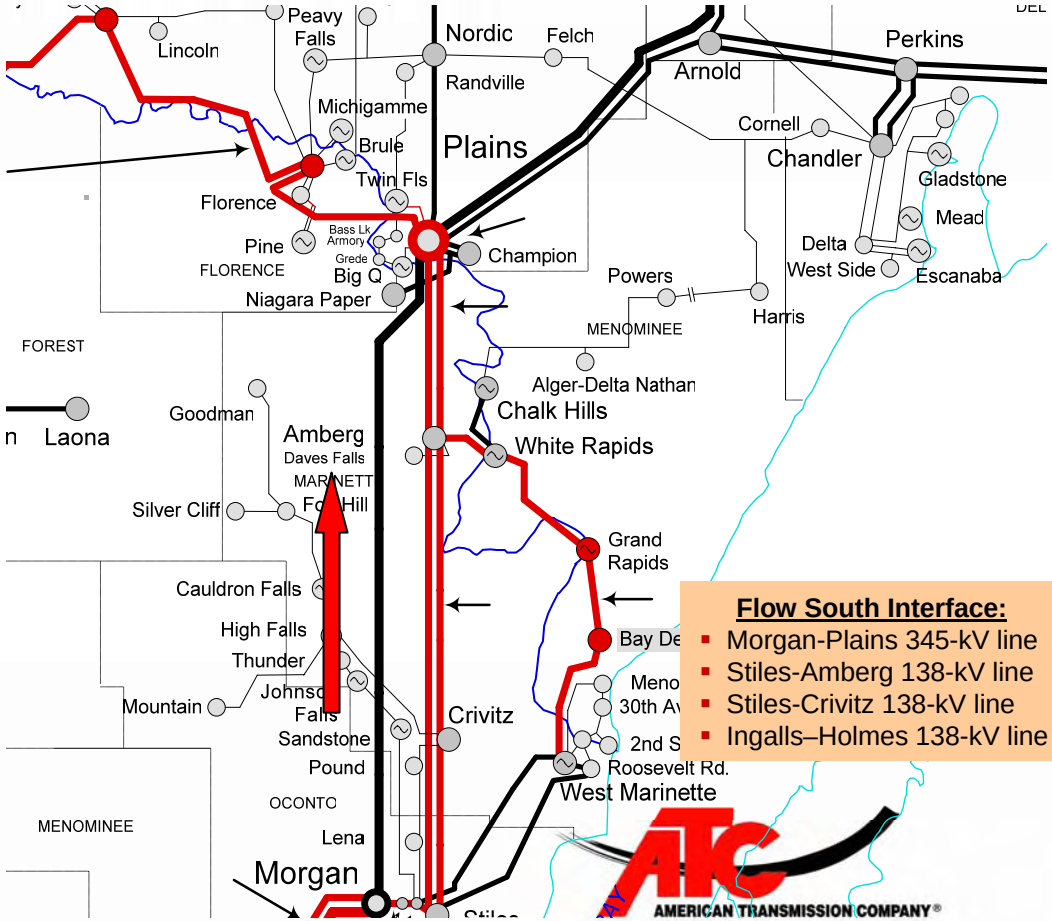
Flow South Reliability Improvement

ATC recently energized new power lines, completing a two-year project to upgrade 80-year-old facilities in Northern Wisconsin and Michigan.

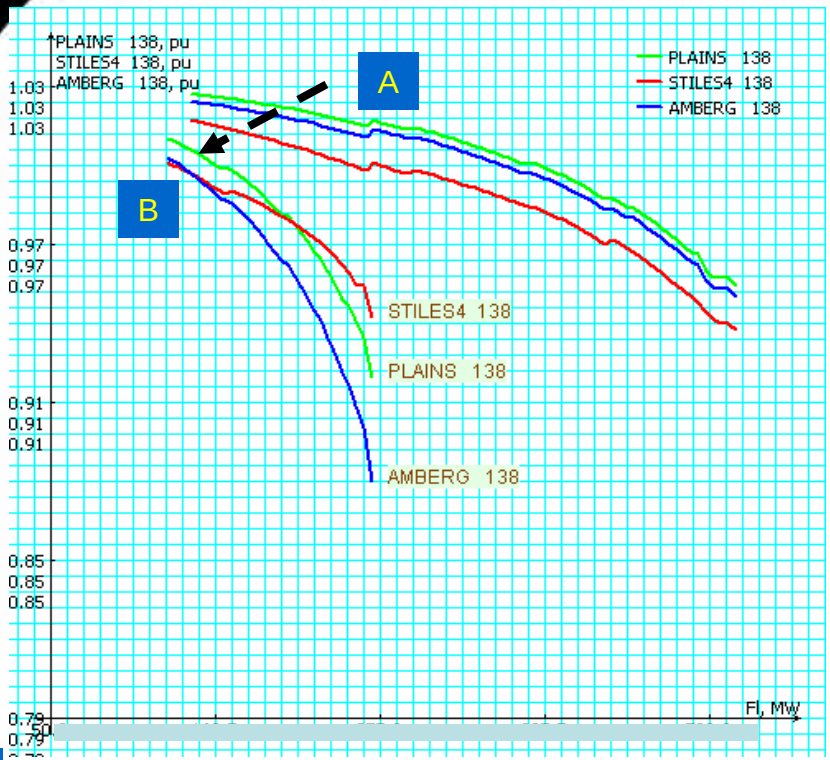
- Construction of Amberg-West Marinette 138-kV project
- Reconstruction of double-circuit Plains-Amberg 138-kV lines
- Amberg–Crivitz double-circuit 138-kV rebuild project
- Stiles– Crivitz and Stiles–Amberg construction project

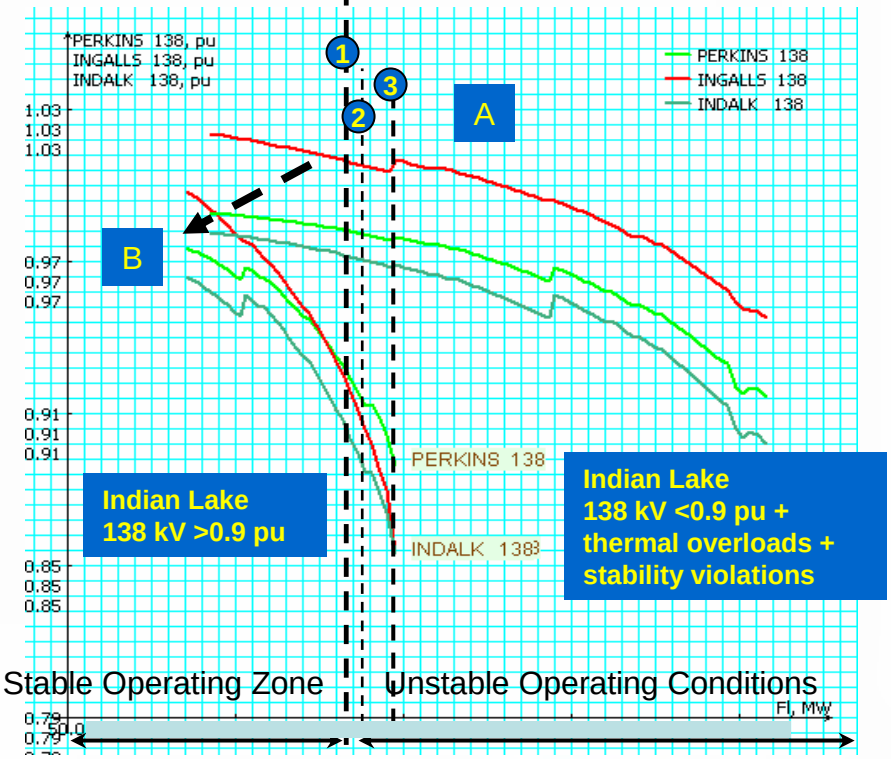


P-V Curve Analysis in Operations by using POM-OPM

Curves A: Base Case

Curves B: Contingency of Morgan – Plains 345 kV line (35321) applied





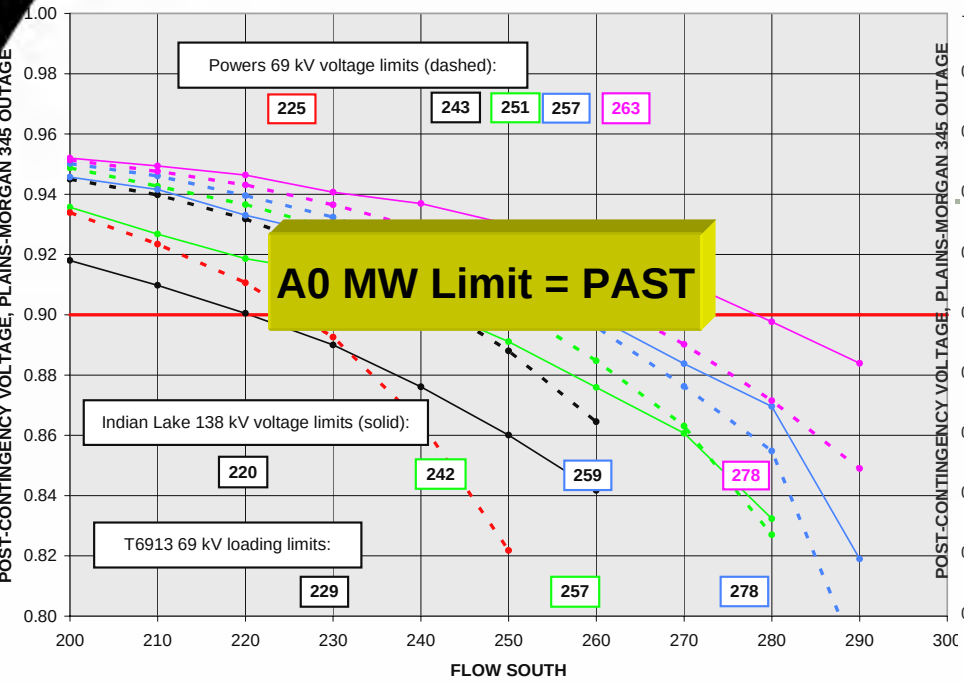
B

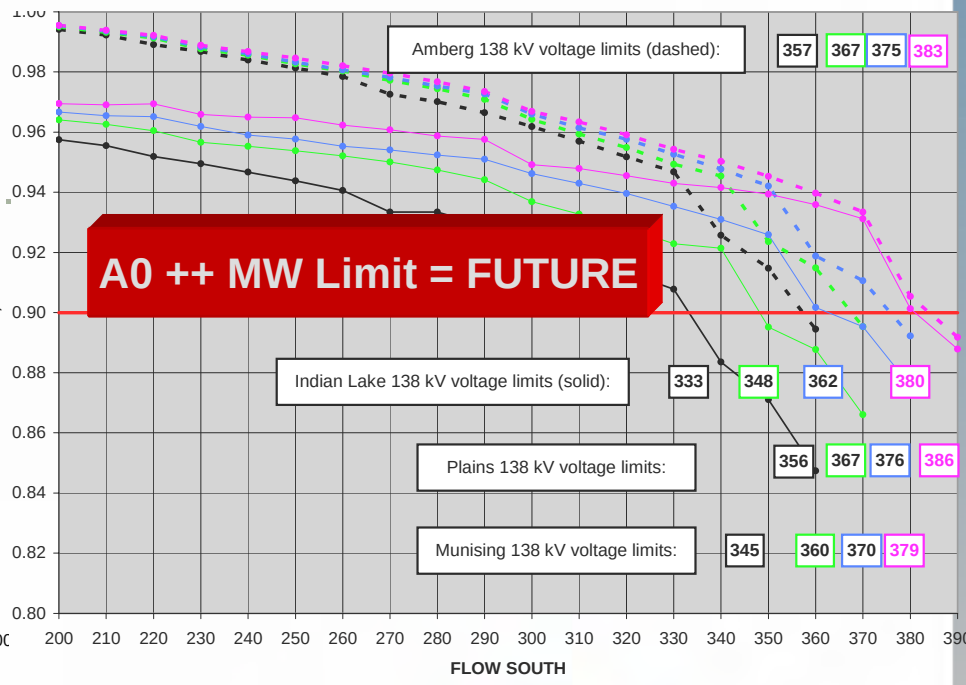
1. **Flow South pre CTG* Operating Limit = A1 MW**, Indian Lake 138 kV < 0.9 pu + Thermal Overload of Stiles–Oconto 138-kV line
2. Thermal Overload of Hiawatha 6913 69-kV line at Flow South pre CTG = **A2** MW
3. Stability Violation at Flow South pre CTG = **A3** MW

**CTG = Morgan – Plains 345 kV line (35321)*

Voltage Stability Limits Past and Future

The graphs show increased of the Flow South transfer capacity





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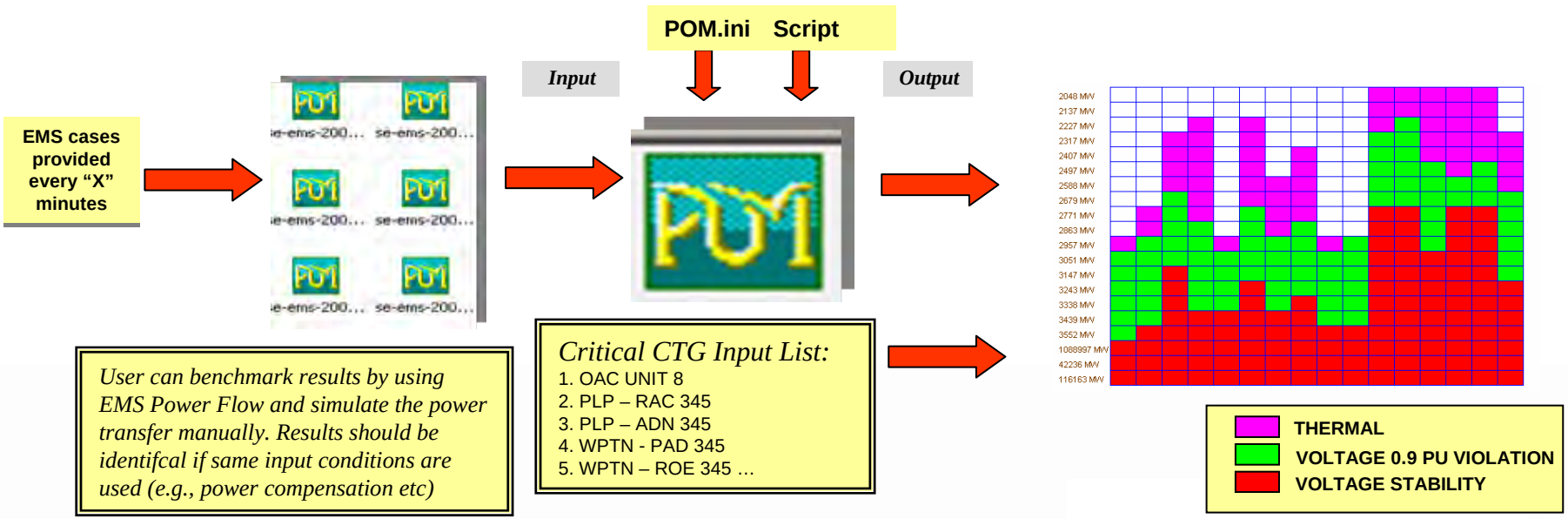
Power Transfer Analysis and N-K Visualization Tool Indicator

To evaluate “X Interface” and to provide System Operators at ATC with guidance (proposed Reliability Limits) as to possible system conditions that would warrant close observation of the Interface flows to ensure system reliability. Identify plans inclusive of emergency generation redispatch (and load curtailment as a last resort) that may guide operators during emergency conditions.



Power Transfer Analysis and N-K Visualization Tool Indicator

- Analyze the impact of “X Interface Imports and Exports” on the ATC transmission system
- Monitor the facilities 69 kV and higher in the ATC system
  - Thermal Violations (Summer Emergency Ratings)
  - Voltage Violations (0.9 – 1.1 pu)
  - Voltage Stability
- Identify critical N-1 and N-2 contingencies
- Run script (developed by Mark Povolotskiy) in POM and simulate power transfer by visualizing the output of contingencies tested
- Run P-V Curve Analysis for the sensitive (critical) buses that may be impacted by increased transfer
- Investigate possible IROLs for critical double contingencies
- Provide guidelines to System Operators

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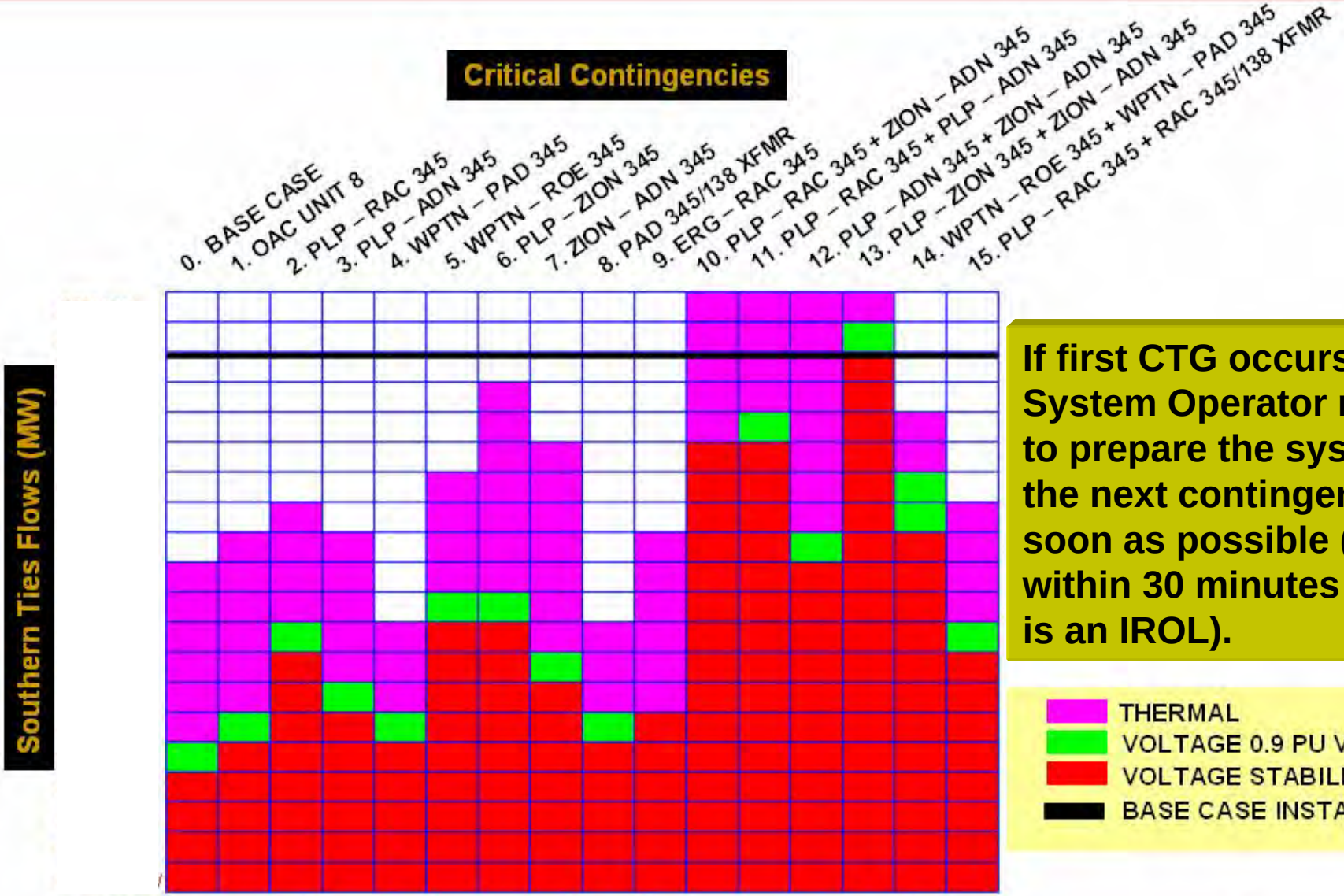
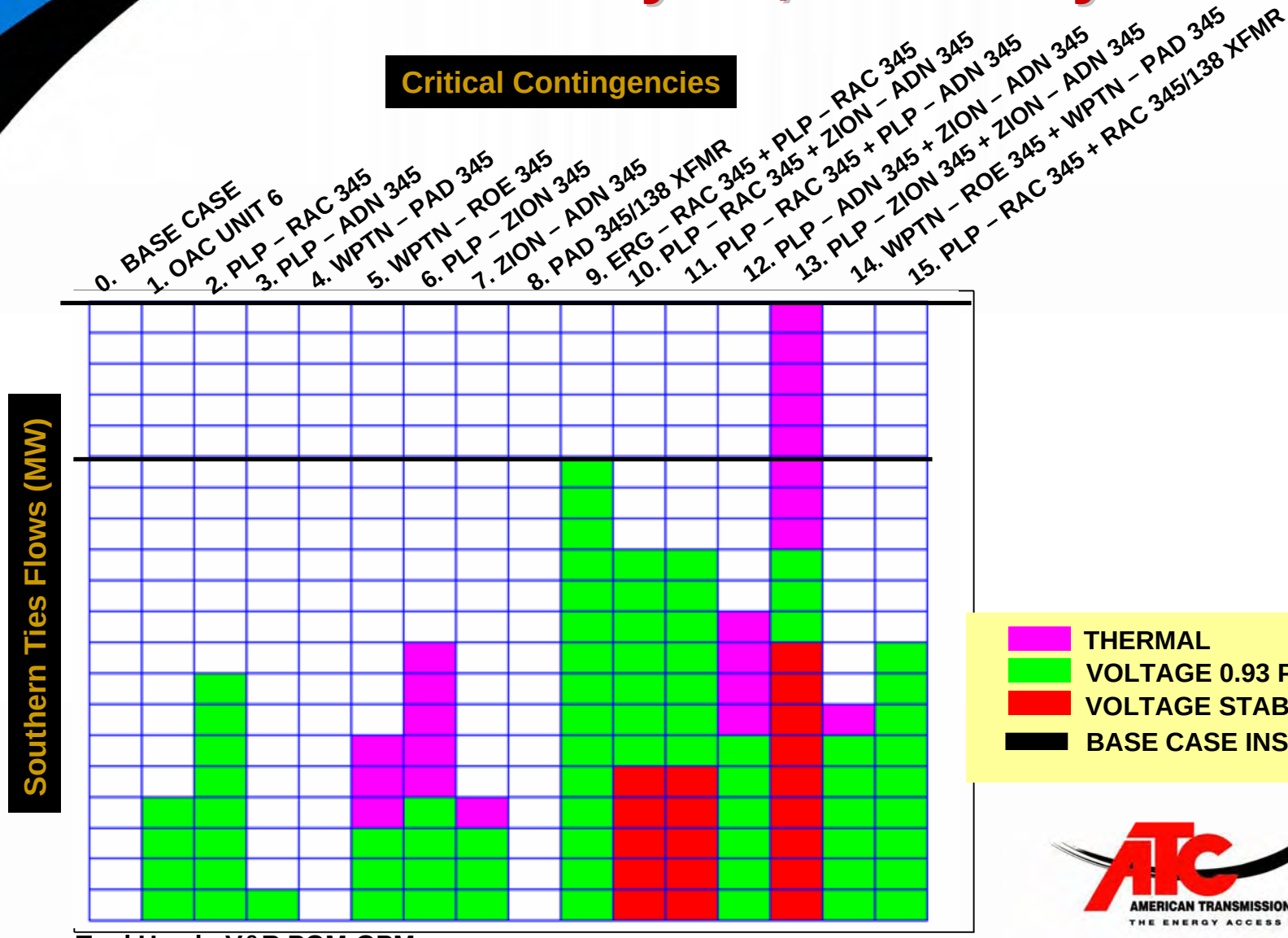
Example 1. Potential Loss of the Power Plant due to Lake Moss



If first CTG occurs, the System Operator needs to prepare the system for the next contingency as soon as possible (or within 30 minutes if this is an IROL).

Tool Used: V&R POM-OPM

Example 2. POM-OPM Transfer Analysis, February 2007



Tool Used: V&R POM-OPM

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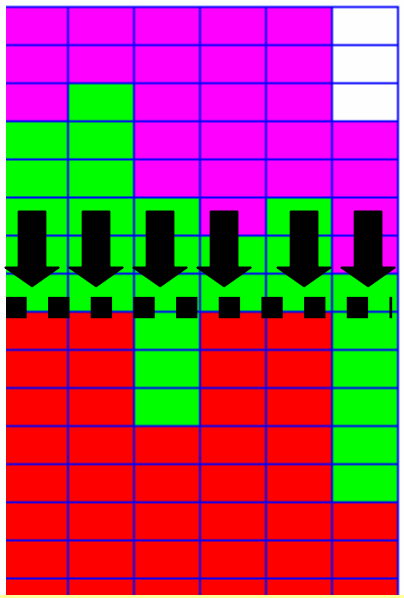
Impact of N-K CTGs on voltages in the area

Critical Contingencies

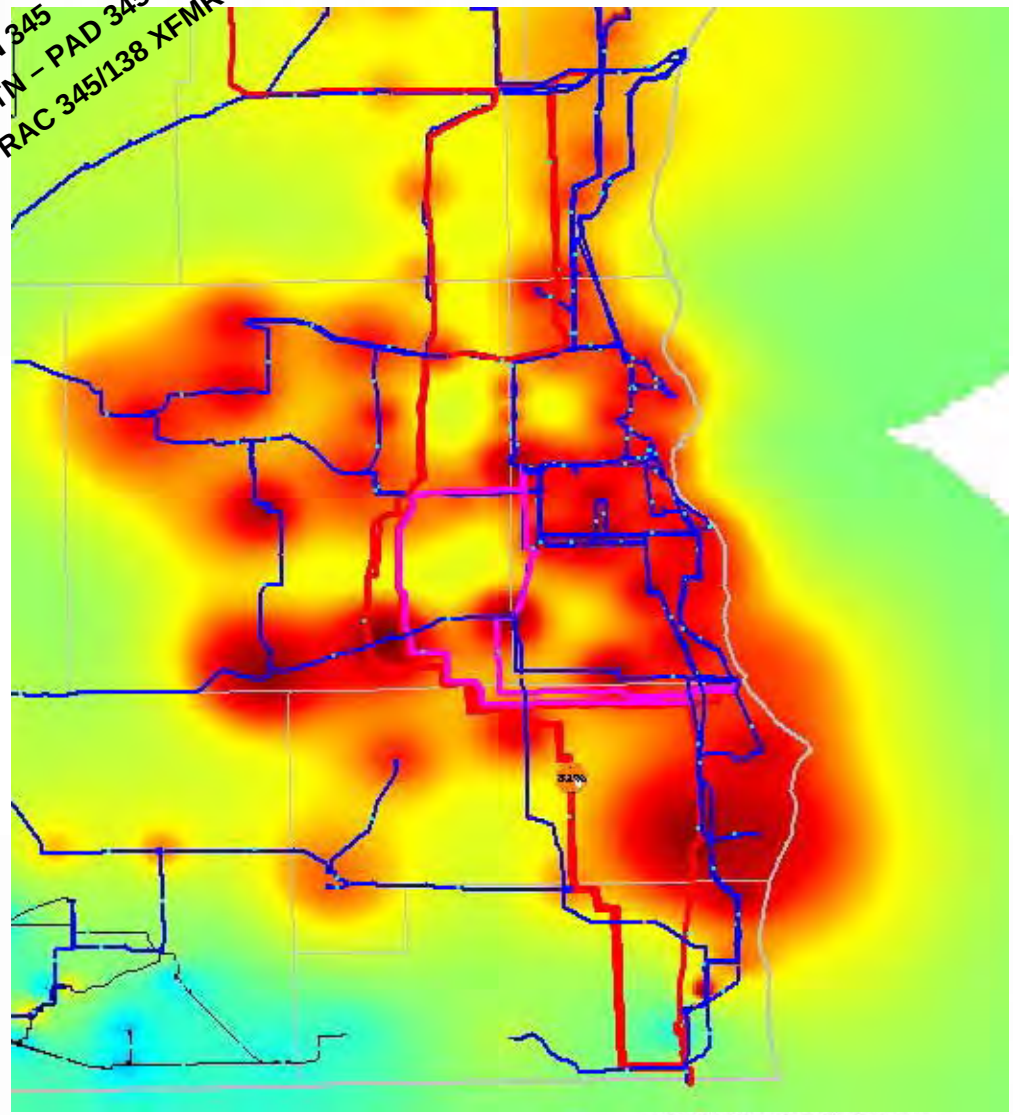
10. PLP – RAC 345 + ZION – ADN 345
11. PLP – RAC 345 + PLP – ADN 345
12. PLP – ADN 345 + ZION – ADN 345
13. PLP – ZION 345 + ZION – ADN 345
14. WPTN – ROE 345 + WPTN – PAD 345
15. PLP – RAC 345 + RAC 345/138 XFMR

Southern Ties Flows (MW)



- THERMAL
- VOLTAGE 0.9 PU VIOLATION
- VOLTAGE STABILITY
- BASE CASE INSTABILITY

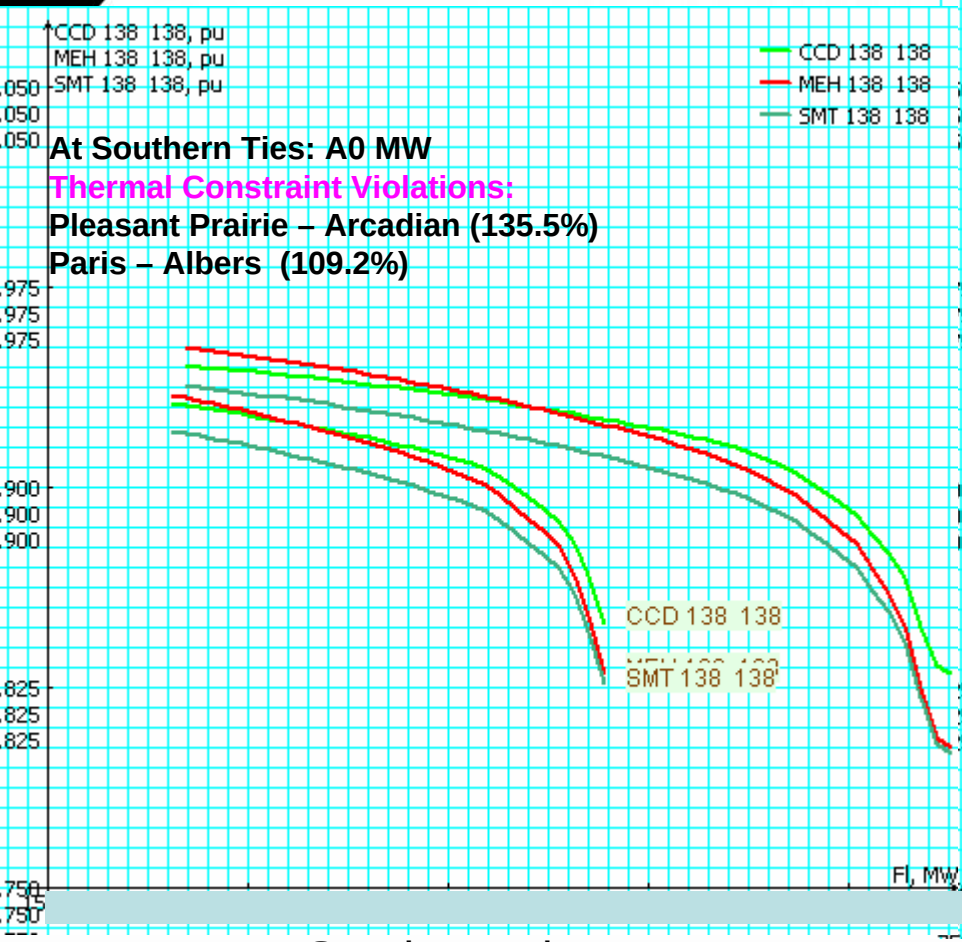
Tool Used: V&R POM-OPM



Tool Used: © 1997-2007 PowerWorld Corporation

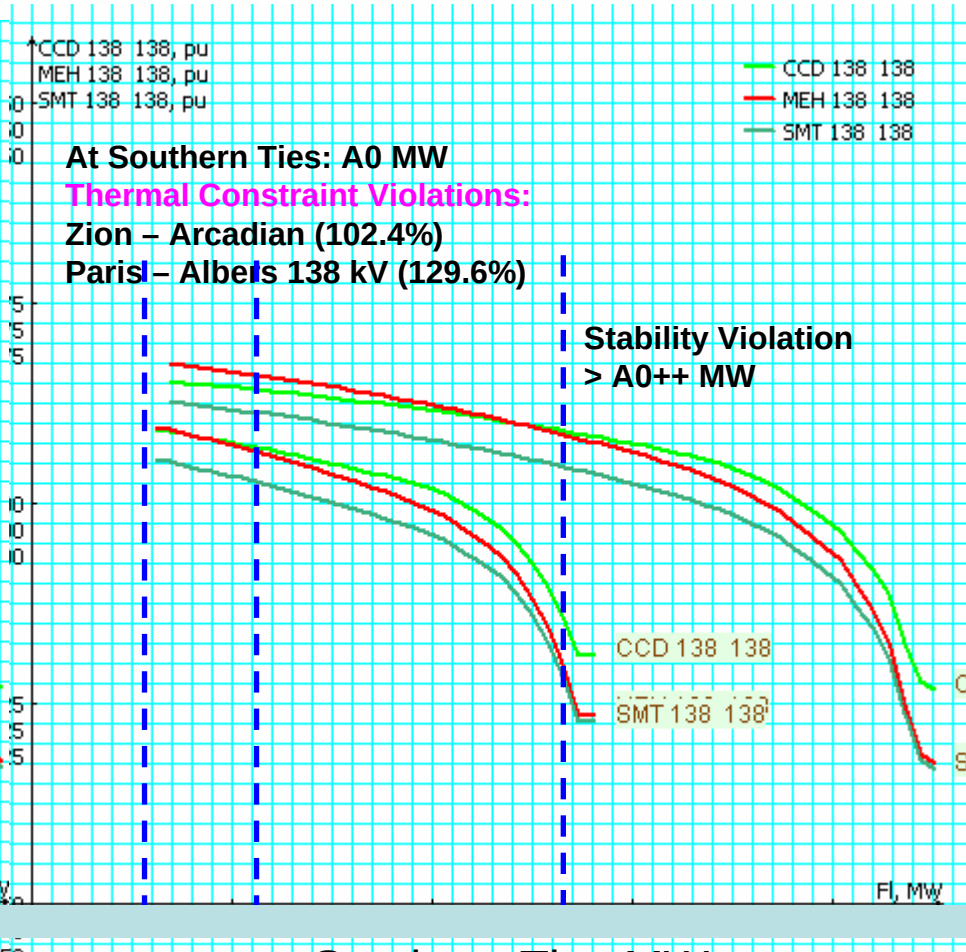
Voltage Stability Analysis

1. Base Case + 631 Out
2. Base Case + 631 Out + 2222 Out



Southern Ties MW

1. Base Case + 631 Out
2. Base Case + 631 Out + 612 Out



Southern Ties MW

Power Transfer Analysis and N-K Visualization Tool Indicator

Benefits:

- The POM-OPM Transfer Mode Analysis and new Visualization tool (POM-OPM script) provides near real time thermal, voltage violation, and voltage stability analysis
- The process quickly identifies reliability limits for “any existing critical Interface” as well as mitigation plan (generation redispatch and if in emergency – load shed recommendations) that can guide System Operators during different system conditions
- The present process simulates transfer scenarios by evaluating 15 critical N-1 and N-2 contingencies for South Interface
- N-1 and N-2 POM transfer analysis consistently shows same type of issues we are facing at the critical interfaces (confirmed with EMS study in real time)

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Use of OPM to support System Operations during System Emergencies

Develop mitigation scheme inclusive of load shed plan at ATC to support Real Time System Operations

EMS cases provided every "X" minutes

Input

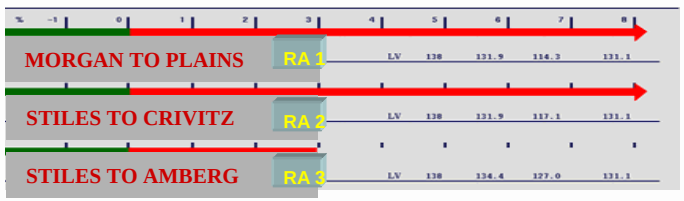
POM.ini

Mitigation

Output

- *If time allows validate the plan with AREVA Power Flow and Contingency Analysis Tool*
- *Provide Mitigation Plan to System Operators*

- *"NERC Standard EOP-003-0 – Load Shedding Plans. R8. Each Transmission Operator or Balancing Authority shall have plans for operator-controlled manual load shedding to respond to real-time emergency.*



- *Employ POM-OPM Software to determine which loads would be the best to curtail to mitigate transmission problems.*

- *The System Operator will curtail and restore the load by confirming selection on EMS Load Shed Application shown below*

EMS Network **Manual Load Curtailment**

Control Area 1

STATION	ACTUAL WATTS	ACTUAL VARS	BREAKER STATUS
RAW	30.3	25.9	☐
TIF	145.3	18.3	■
TOD	120.7	12.7	■
SPS	31.5	30.3	☐

Control Area 2

STATION	ACTUAL WATTS	ACTUAL VARS	BREAKER STATUS

Transformer Maintenance Prioritization Project

- Support Asset Management Decision Making Process by prioritizing transformer maintenance according to the reliability impact on transmission system
- Perform the N-2 contingency analysis by utilizing the primary list of transformers in combination with the rest of the elements in the system (Number of CTG screening = 100,000)
- Run POM to identify the following variables:
  - Number of contingencies causing violations
  - Thermal violations (and %)
  - Voltage Violation (and min pu voltage)
- Run OPM to identify load at risk for N-2 violations.
  - Record the cumulative amount of load (and after any N-2 contingency occurrence) necessary to alleviate all thermal, voltage violations, and voltage stability for each transformer in input list.

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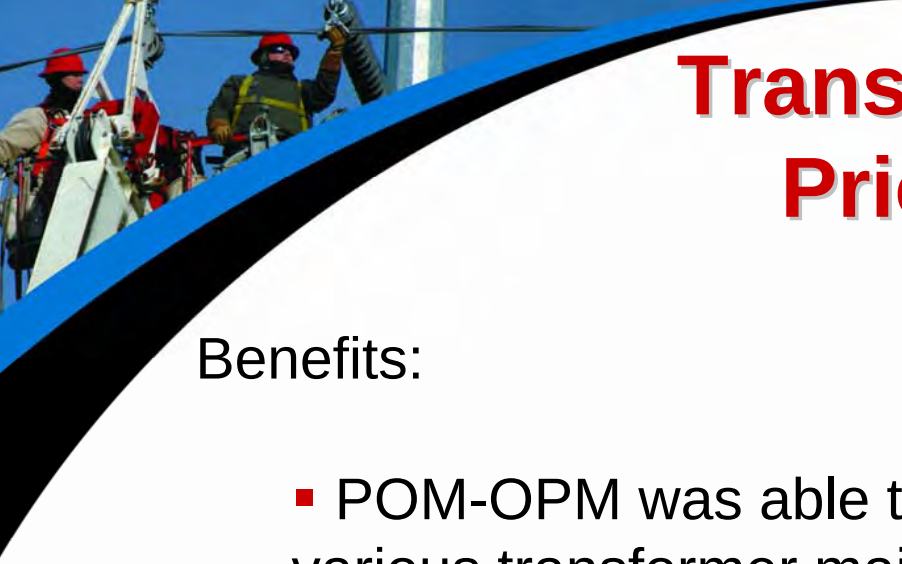

Transformer Maintenance Prioritization Project

Benefits:

- POM-OPM was able to provide quick answer for ranking various transformer maintenance projects based on as defined reliability criteria and its impact on the transmission system.

- POM-OPM was able to overcome the difficulty in simultaneously combining the list of N-1 and critical N-1, N-K and to calculate all contingencies simultaneously.

- POM-OPM proved to be a good tool for respecting the evaluation criteria defined in the asset management's corporate goal.

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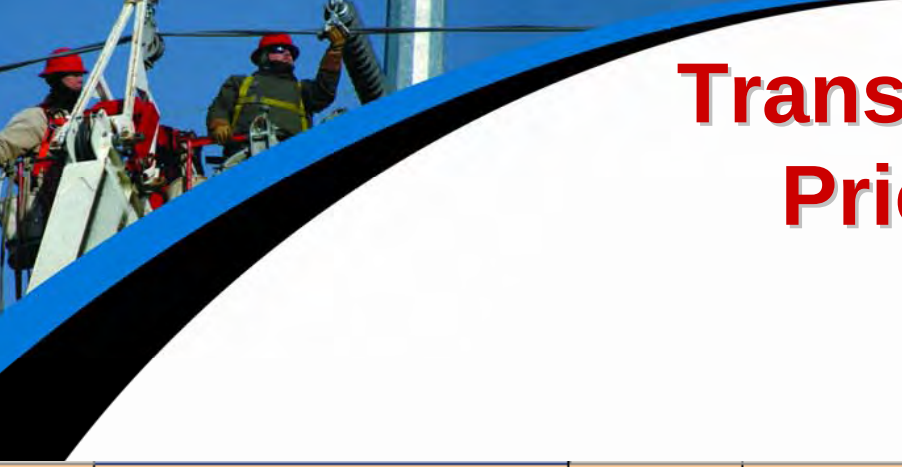

Transformer Maintenance Prioritization Project

CTG No.	Complex Contingency Name	Thermal CTG	Max % Post Ctg Thermal	Voltage CTG	Min Post CTG Voltage	Total CTG	Load Shed at Risk (MW)
1635	Special List of Transformers 21	2	115%	5	0.765 pu	7	69
1636	Special List of Transformers 22	13	116%	0	0	13	809
1637	Special List of Transformers 23	0	0	1	0.865 pu	1	8
1639	Special List of Transformers 24	1	136%	0	0	1	18
1641	Special List of Transformers 25	4	216%	3	0.611 pu	5	104
1642	Special List of Transformers 26	1	117%	2	0.888 pu	3	13
1646	Special List of Transformers 27	2	111%	0	0	2	256
1647	Special List of Transformers 28	3	120%	0	0	3	507
1648	Special List of Transformers 29	1	130%	0	0	1	20
1649	Special List of Transformers 30	1	130%	0	0	1	20
1650	Special List of Transformers 31	12	182%	22	0.704 pu	24	197
1651	Special List of Transformers 32	0	0	1	0.89 pu	1	0.1
1652	Special List of Transformers 33	0	0	1	0.89 pu	1	0.1
1653	Special List of Transformers 34	1	106%	0	0	1	0
1654	Special List of Transformers 35	5	120%	0	0	5	157
1655	Special List of Transformers 36	2	109%	0	0	2	43
1659	Special List of Transformers 37	2	110%	0	0	2	21
1660	Special List of Transformers 38	5	177%	1	0.721 pu	5	58
1661	Special List of Transformers 39	3	199%	1	0.870 pu	3	156
1662	Special List of Transformers 40	3	228%	1	0.865 pu	3	169

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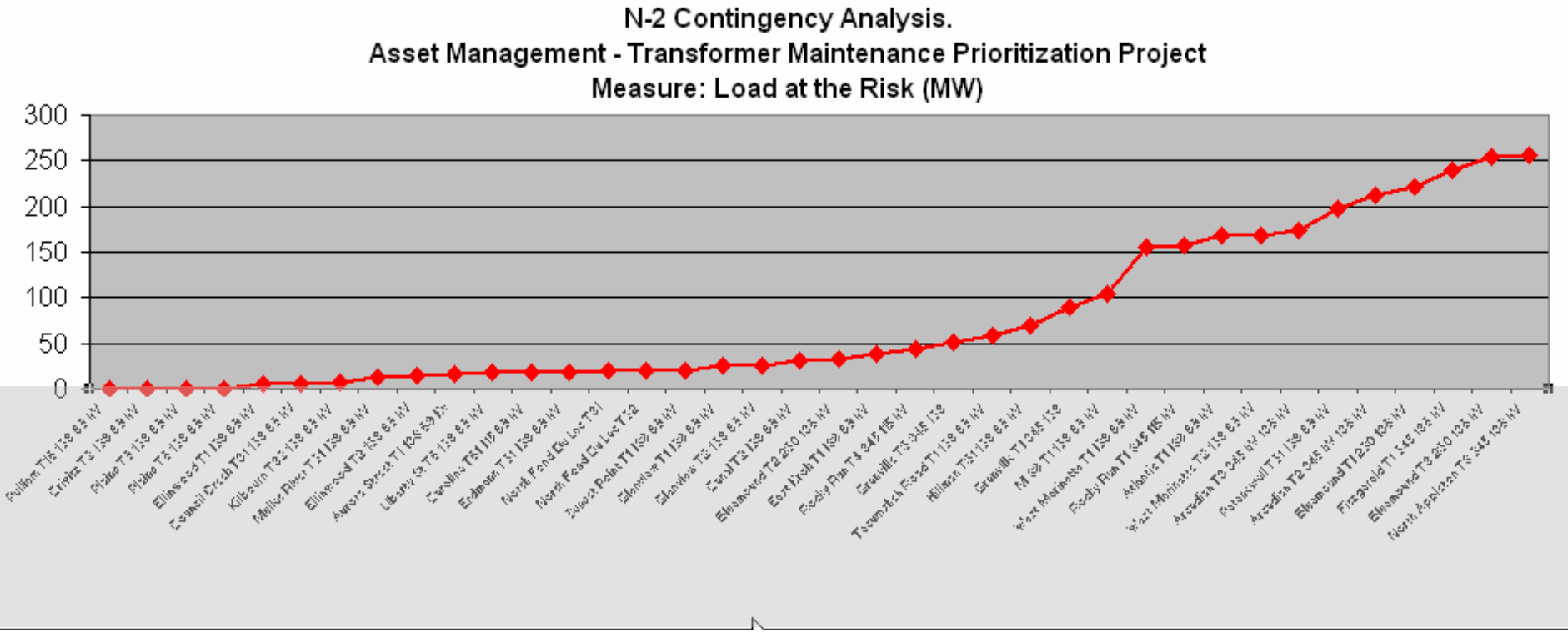
Transformer Maintenance Prioritization Project



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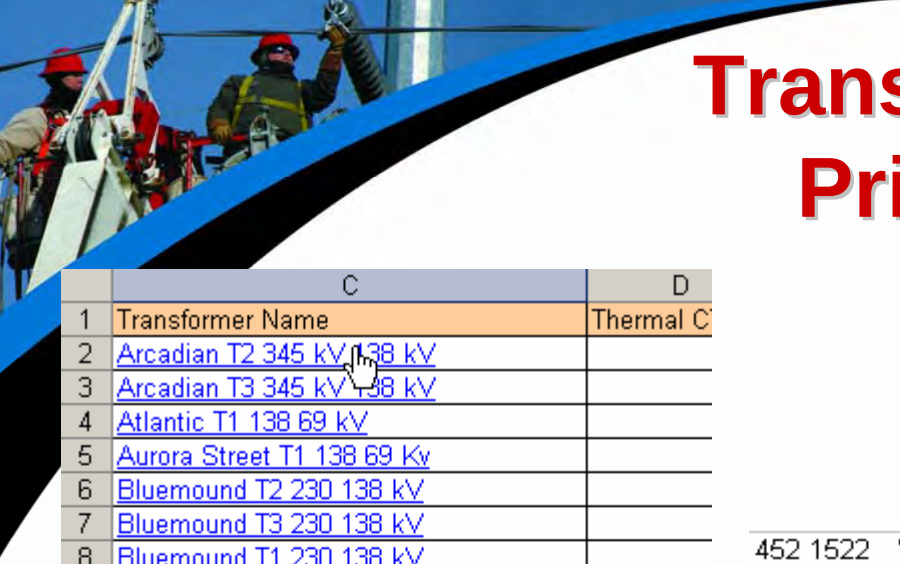
Transformer Maintenance Prioritization Project



	C	D
1	Transformer Name	Thermal C
2	Arcadian T2 345 kV 138 kV	
3	Arcadian T3 345 kV 138 kV	
4	Atlantic T1 138 69 kV	
5	Aurora Street T1 138 69 Kv	
6	Bluemound T2 230 138 kV	
7	Bluemound T3 230 138 kV	
8	Bluemound T1 230 138 kV	
9	Canal T2 138 69 kV	
10	Caroline T61 115 69 kV	
11	Council Creek T31 138 69 kV	
12	Crivitz T2 138 69 kV	
13	East Krok T1 138 69 kV	
14	Ellinwood T1 138 69 kV	
15	Ellinwood T2 138 69 kV	
16	Erdmann T31 138 69 kV	
17	Fitzgerald T1 345 138 kV	
18	Glenview T1 138 69 kV	
19	Glenview T2 138 69 kV	
20	Granville T3 345 138	
21	Granville T1 345 138	
22	Hillman T31 138 69 kV	
23	Kewaunee T10 345 138 kV	
24	Kilbourn T32 138 69 kV	
25	Liberty St T6 138 69 kV	
26	M 38 T1 138 69 kV	
27	Mullet River T31 138 69 kV	
28	North Appleton T3 345 138 kV	
29	North Appleton T1 345 138 kV	
30	North Fond Du Lac T31	
31	North Fond Du Lac T32	
32	Petenewell T31 138 69 kV	

Asc Summary | **Gen Summary** | Arcadian T2

452 1522 'xxxxx ' 345.00 - 'xxxxx ' 138.00 1
1604 Special List of Transformers Arcadian T2 345 kV 138 kV

Violations before Mitigation
Thermal Constraint Violations
9999 "xxxxx ' 138.00 - 1111 xxxxx ' 345.00 1 321.2 MVA (134.4%, 39250)

Remedial Actions
IncLoadScale -64.9, pmBus, 38541
IncLoadScale -62.8, pmBus, 38480
IncLoadScale -56.2, pmBus, 38482
IncLoadScale -18.6, pmBus, 38543
IncLoadScale -11.6, pmBus, 38481

Mitigation Successful

Asc Summary | Gen Summary | **Arcadian T2** | Arcadian T3 | Atlantic T1 | Aurora | Blue

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Future Work

- ATC currently utilizes 4 licenses of POM-OPM to support real-time operations.
- Voltage Stability Support to Real Time Operations
  - Investigating the calculation of dynamic Mvar reserve limits for one or more of the interfaces. Generator sensitivity analysis would help support this.
  - Modal analysis to identify critical load buses for P-V plots.
- Currently enhancing the process to utilize POM-OPM load shed tool to help mitigate system emergencies.
- Enhance the process of supporting Asset Management group in prioritizing the transformer maintenance work.
- POM-OPM real-time CIM Conversion Project (EPRI)

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Ideas for Improvement

- Compatibility with Real Time Energy Management System.
- Have ability to calculate LSF's and GSF's for selected flowgate
- Monitor generator Mvar reserves

  One of the NERC recommendations in Northeast Blackout Report - August 2003 is to have VAR-Management process in the place. Having ability to monitor generator Mvar reserves with respect to changes in Net Load (it could be system load or specifically defined zone in the system) would improve the ability to monitor the system changes. It would be preferable to have this monitoring system defined for Base Case and for Contingencies

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Ideas for Improvement

POM-OPM Remedial Action Result

- *Load Sorting Option Selected. OPM load shed recommendations are listed as follows:*

  IncLoadScale -5.434, pmBus, 39736
  IncLoadScale -13.321, pmBus, 39745
  IncLoadScale -4.341, pmBus, 39754
  IncLoadScale -1.021, pmBus, 39758
  IncLoadScale -0.556, pmBus, 39731

  Total ~ 24 MW

  Mitigation Successful

How can Operator interpret this output?

Use Bus Names instead of Bus Numbers

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Ideas for Improvement

If loss of Critical N-K Contingency results in loss of load in the system (or island creation) and no violations of any type in the rest of the system occurred POM should have ability to display (as a result) the following:

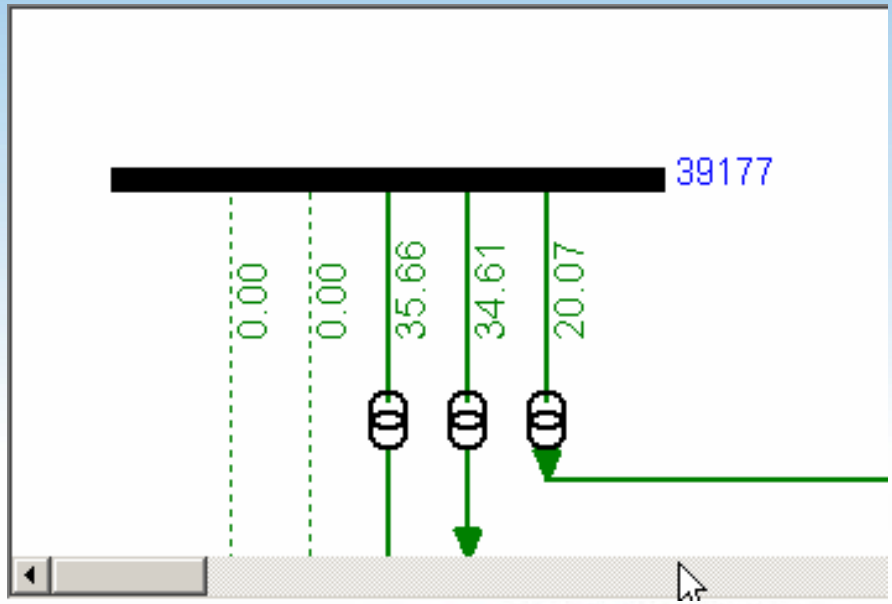
- Which buses (lines) in the system are disconnected
- How much load is lost

Case1. Remove two lines from Saukville to Cedarburg:

RemoveBranch 39177,39271,"1 "
RemoveBranch 39177,39288,"1 "

Iterations 2

Minimum VM 0.940 (38951)
Maximum VM 1.054 (39450)
Maximum S Br 84.4% (38888 - 39283 1)
Time 0.2 s



I appreciate Your Attention!

Any Questions?

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