

Visualization of Power Systems and Components (S-18)

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Project Overview

- Project goal was the development of enhanced visualization techniques for power systems and their components
 - Project also included an explicit human factor consideration of these techniques
- Industrial team members included AEP, Areva, ATC, Entergy, Exelon, ISO NE, PJM, PowerWorld, Southern, TVA, WAPA

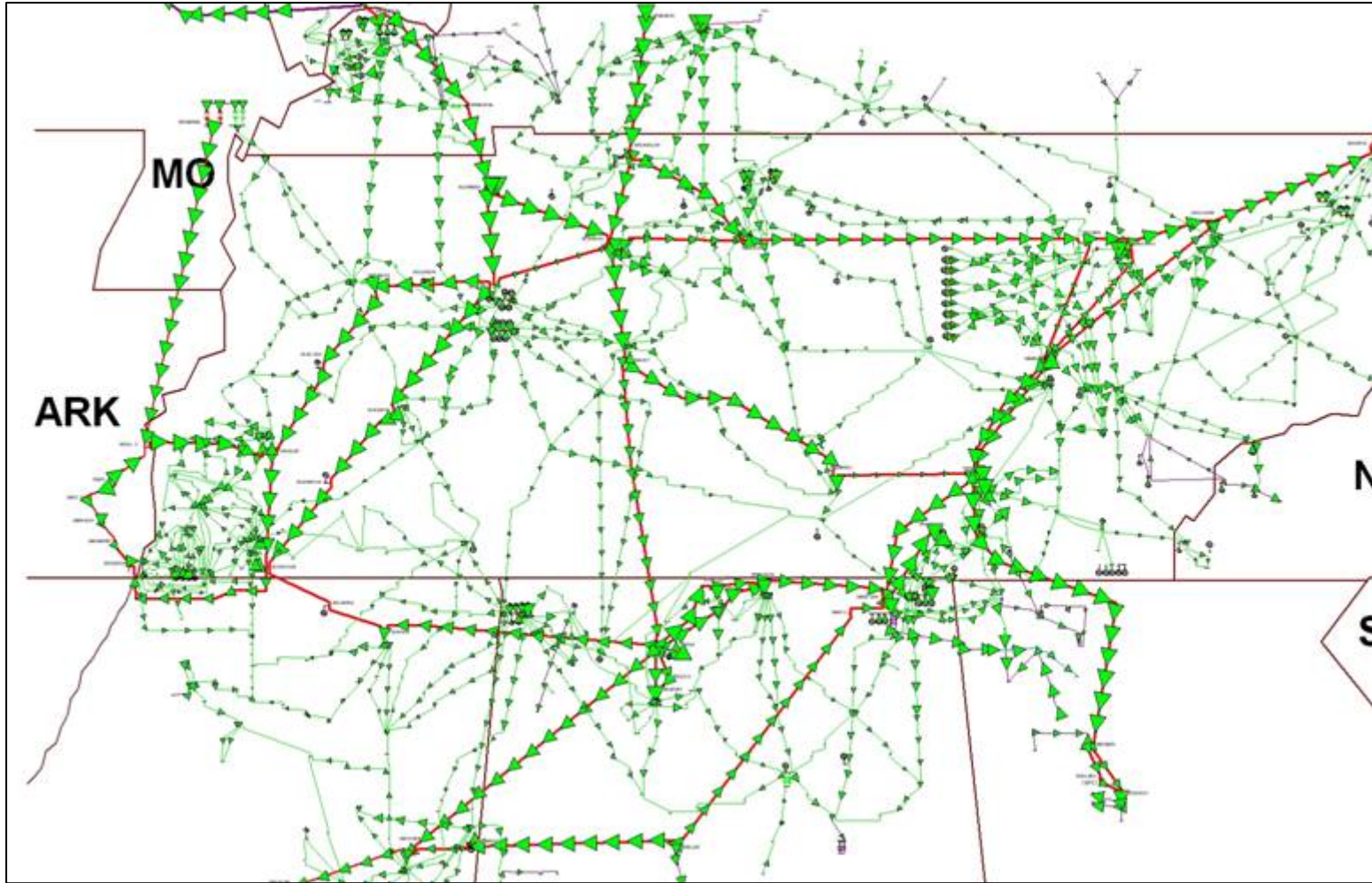
Key Results

- Improved 2D large-scale visualizations
 - Selective information highlighting, gauges for reactive power visualization, improved contouring algorithms, power injection contours, integrated weather/power system displays,
- Improved 3D large-scale visualizations
 - Display of contingency analysis results, state estimator residuals
- New component visualizations
 - 3D displays of generators and transformers
- Human factor studies results
 - Conducted experiments assessing line pie charts, animated line & PTDF flows, and 3D displays showing generator outputs and flows

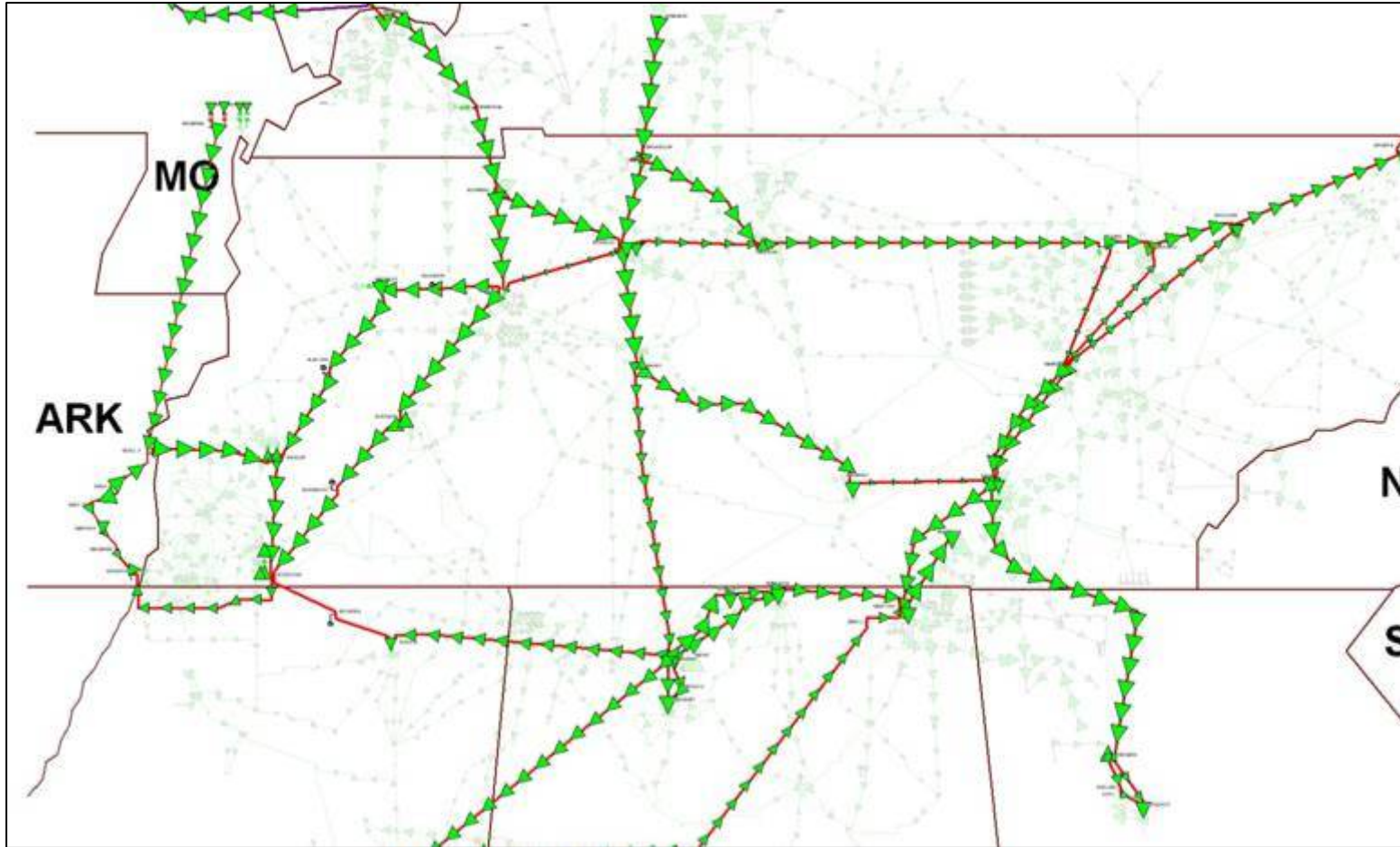
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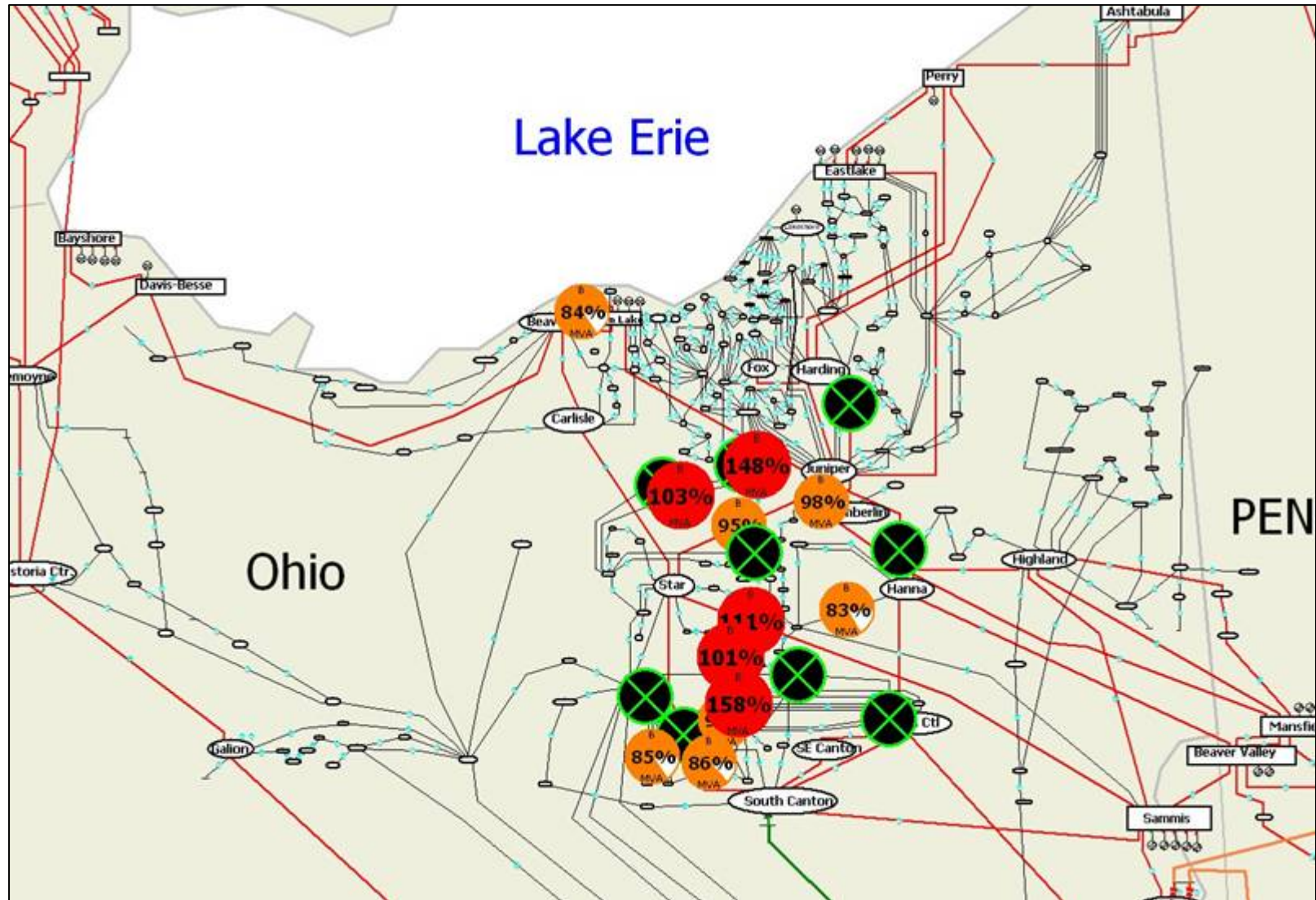
Need for Information Highlighting



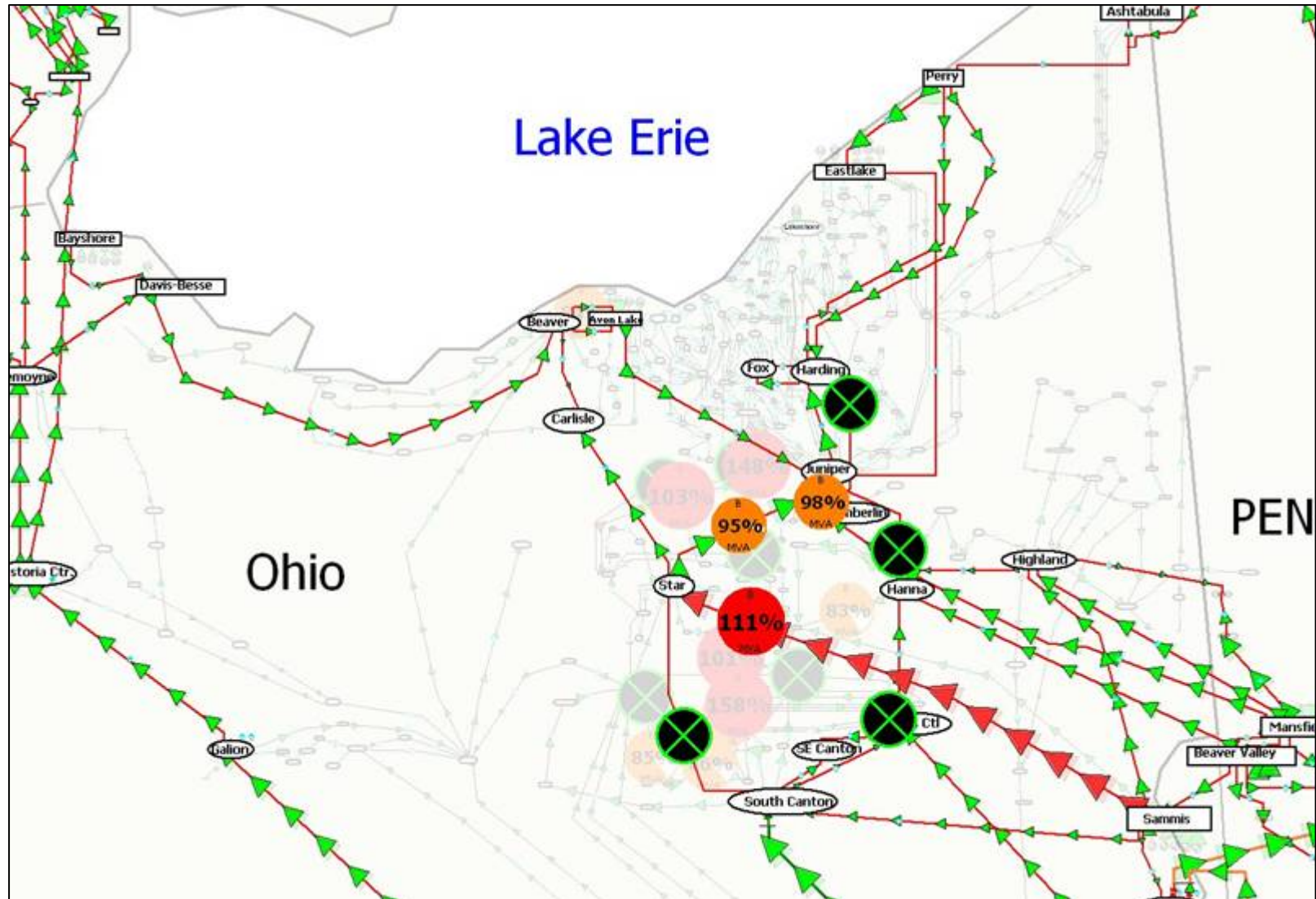
With Information Highlighting



8/14/03 Without Info Highlighting

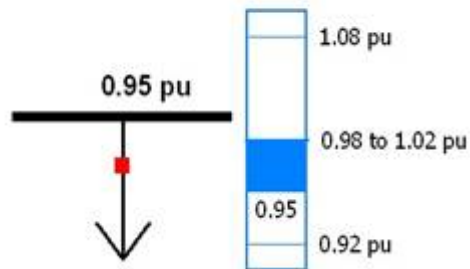
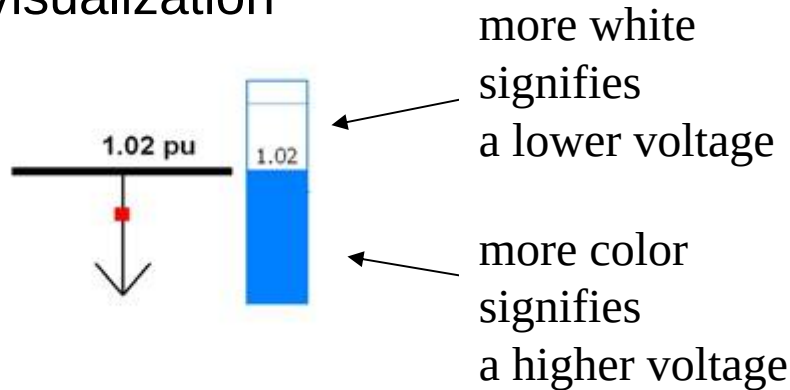


8/14/03 with Highlighting



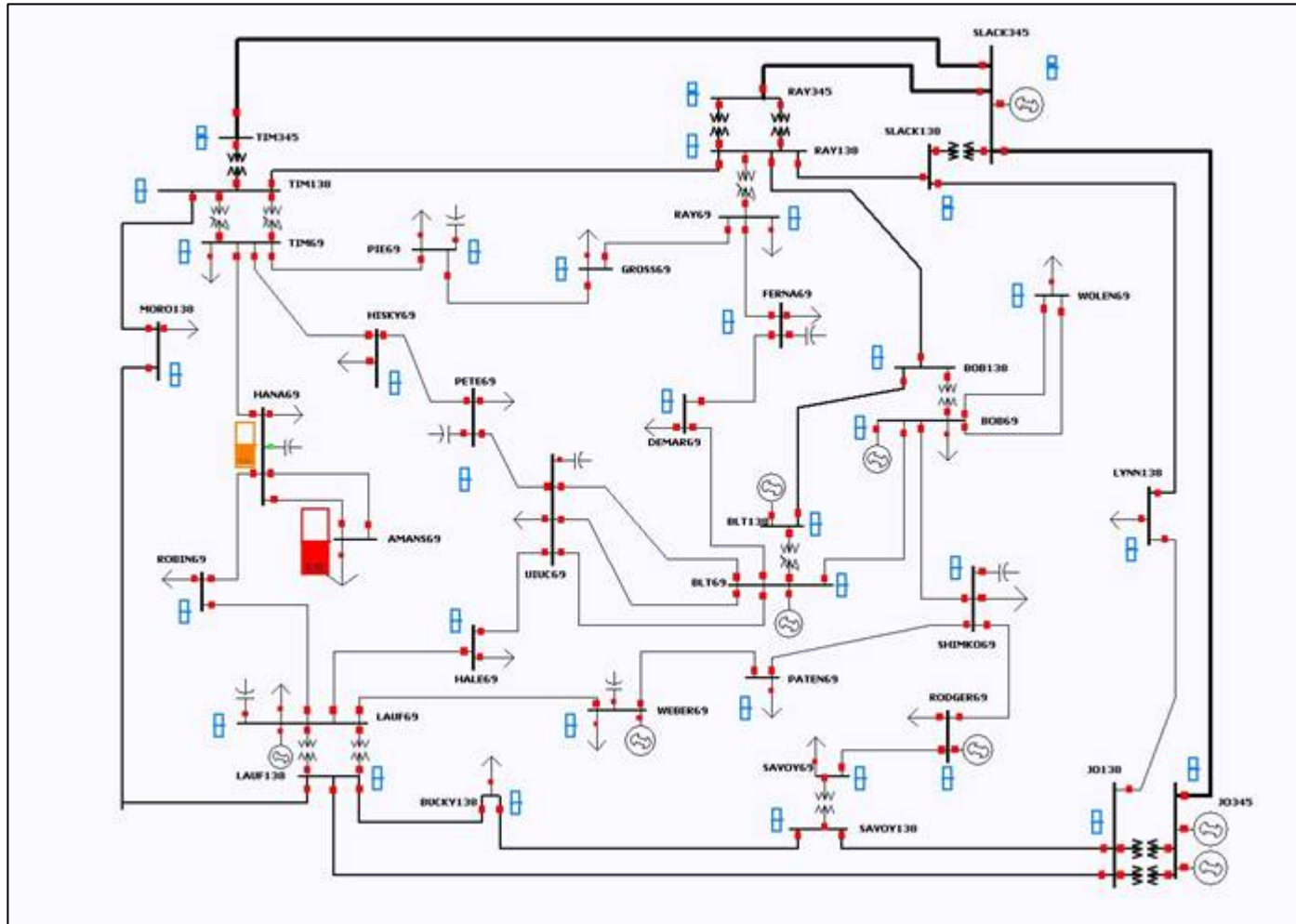
Application of Gauges

- Gauges can be used for the symbolic display of power system information
 - Project studied their use for voltage and reactive power visualization



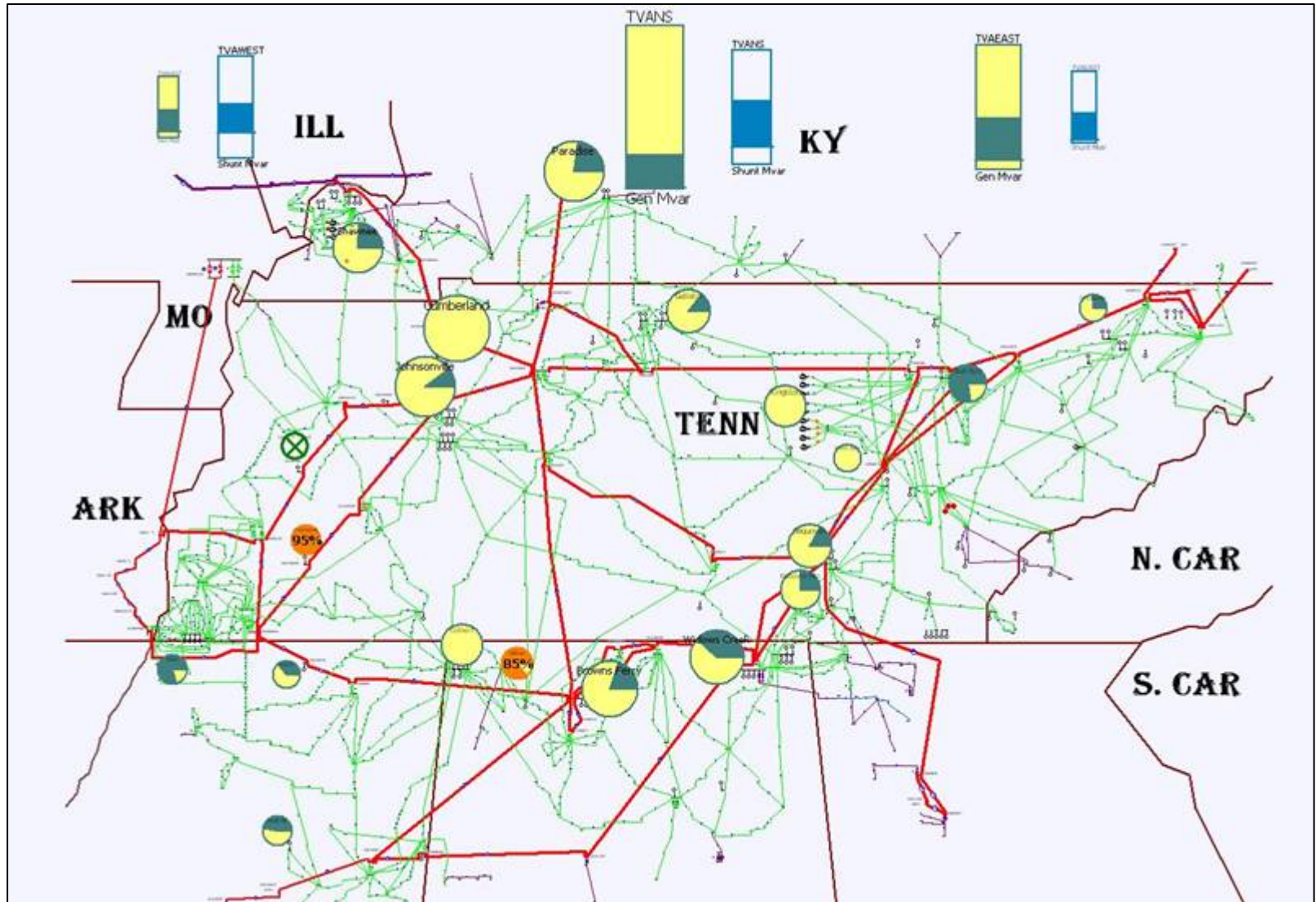
Center Filled Gauge

Application of Voltage Gauges



Gauges are probably not useful for system wide voltage displays

Reactive Power Visualization

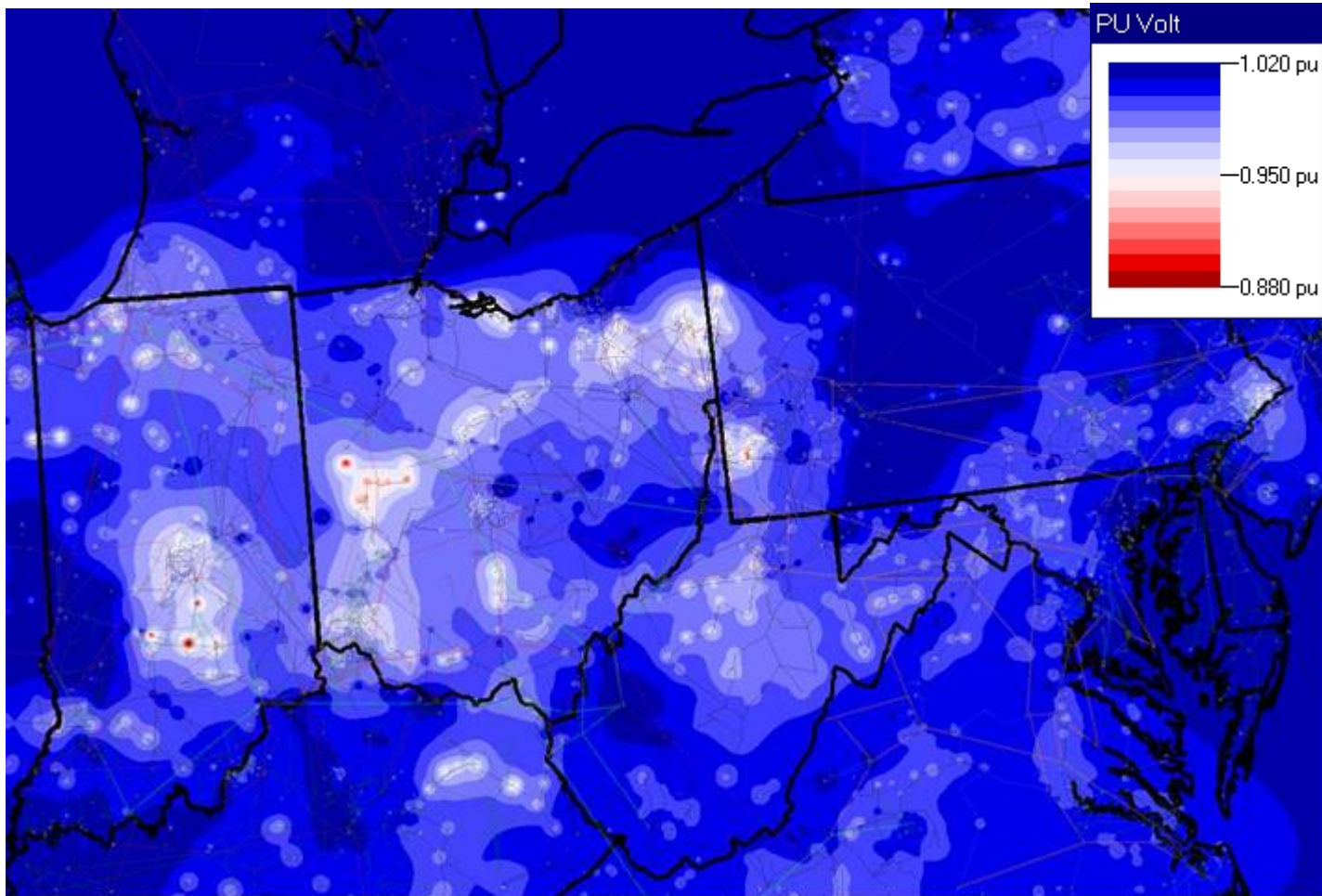


Contouring Applicatons

- Project developed improved contouring algorithms, particularly for highly zoomed displays
- Project also investigated the application of contouring to showing system-wide net power injections (power density contours)

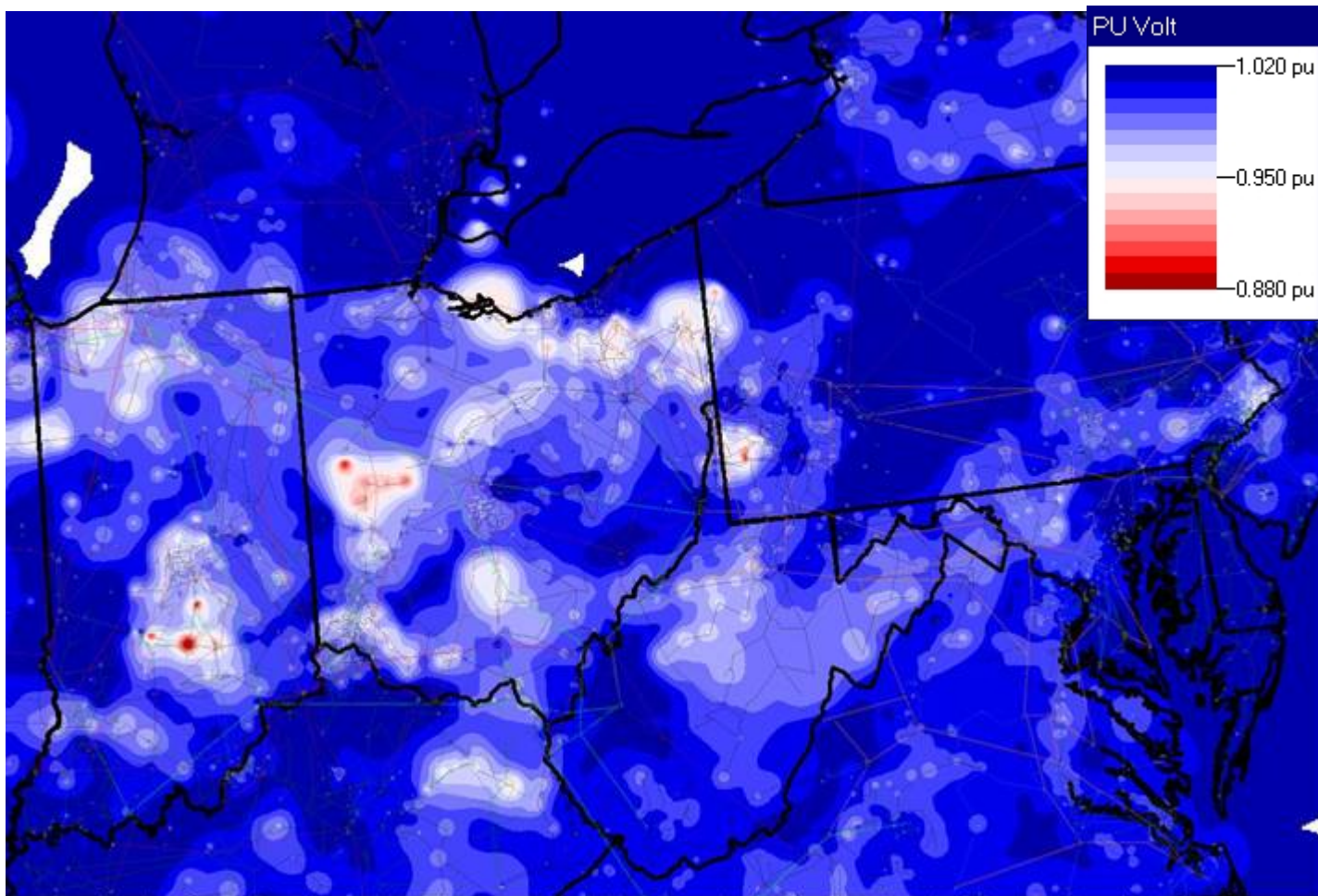
Contour Performance

- Pre-Blackout Ohio Region 115-230 kV Voltage Contour
- Before optimization contour can be created in about 14.2 sec.



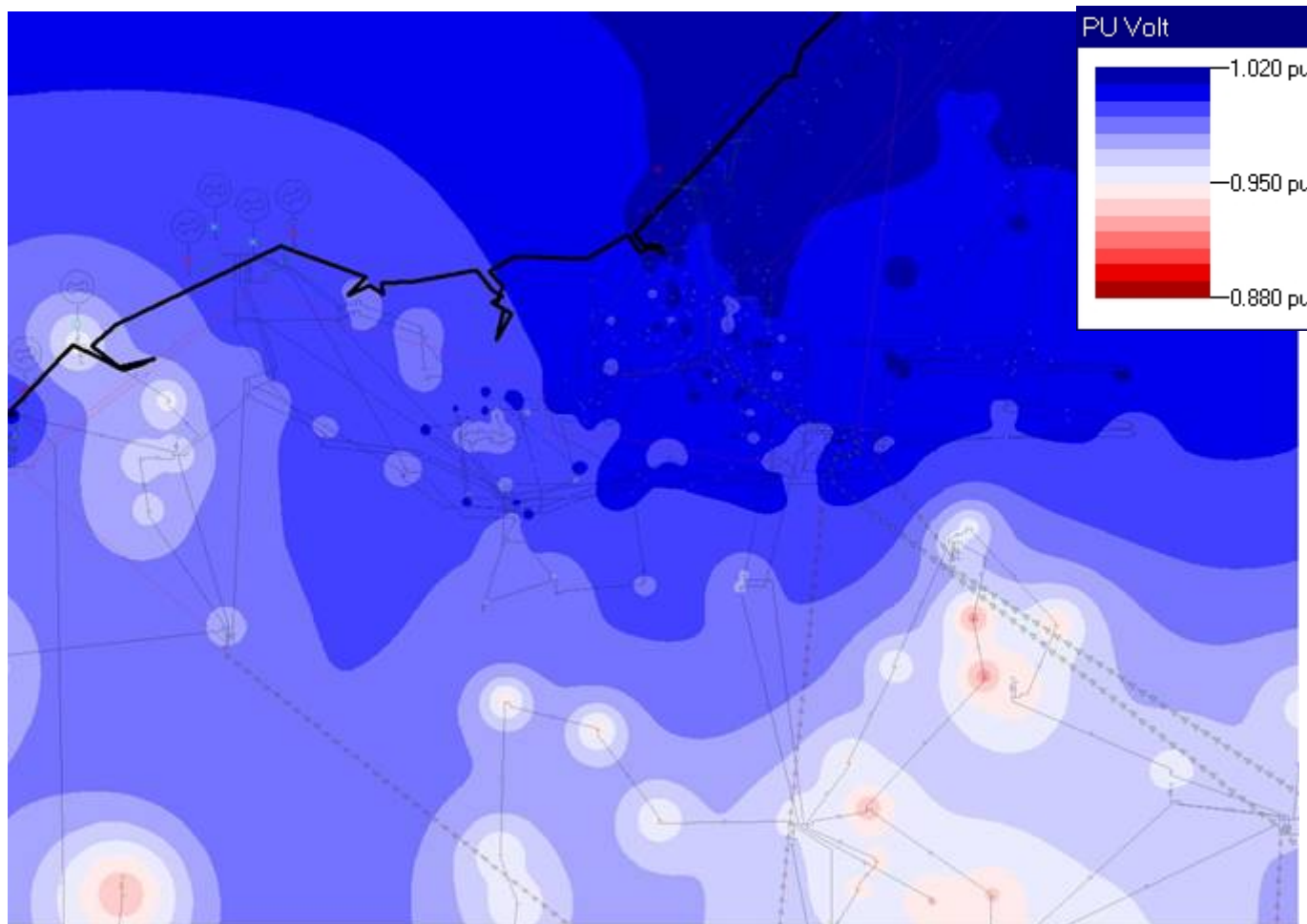
Contour Performance

- Pre-Blackout Ohio Region 115-230 kV Voltage Contour
- With optimization contour can be created in about 8.8 sec.



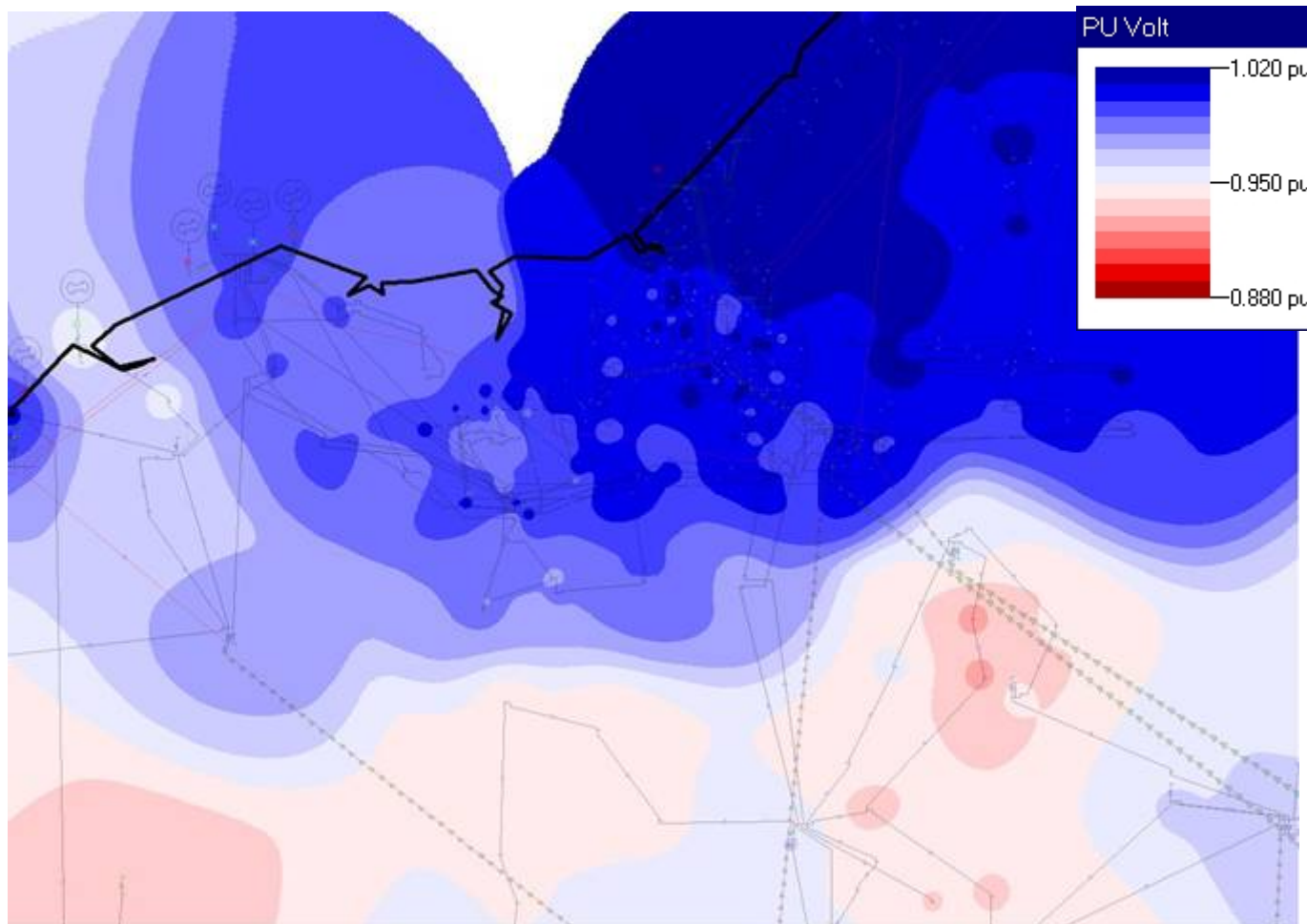
Zoomed View Without Optimization

- Pre-Blackout to Cleveland Voltage Contour
- Contour can be created in about 16.6 seconds



Zoomed View with Optimization

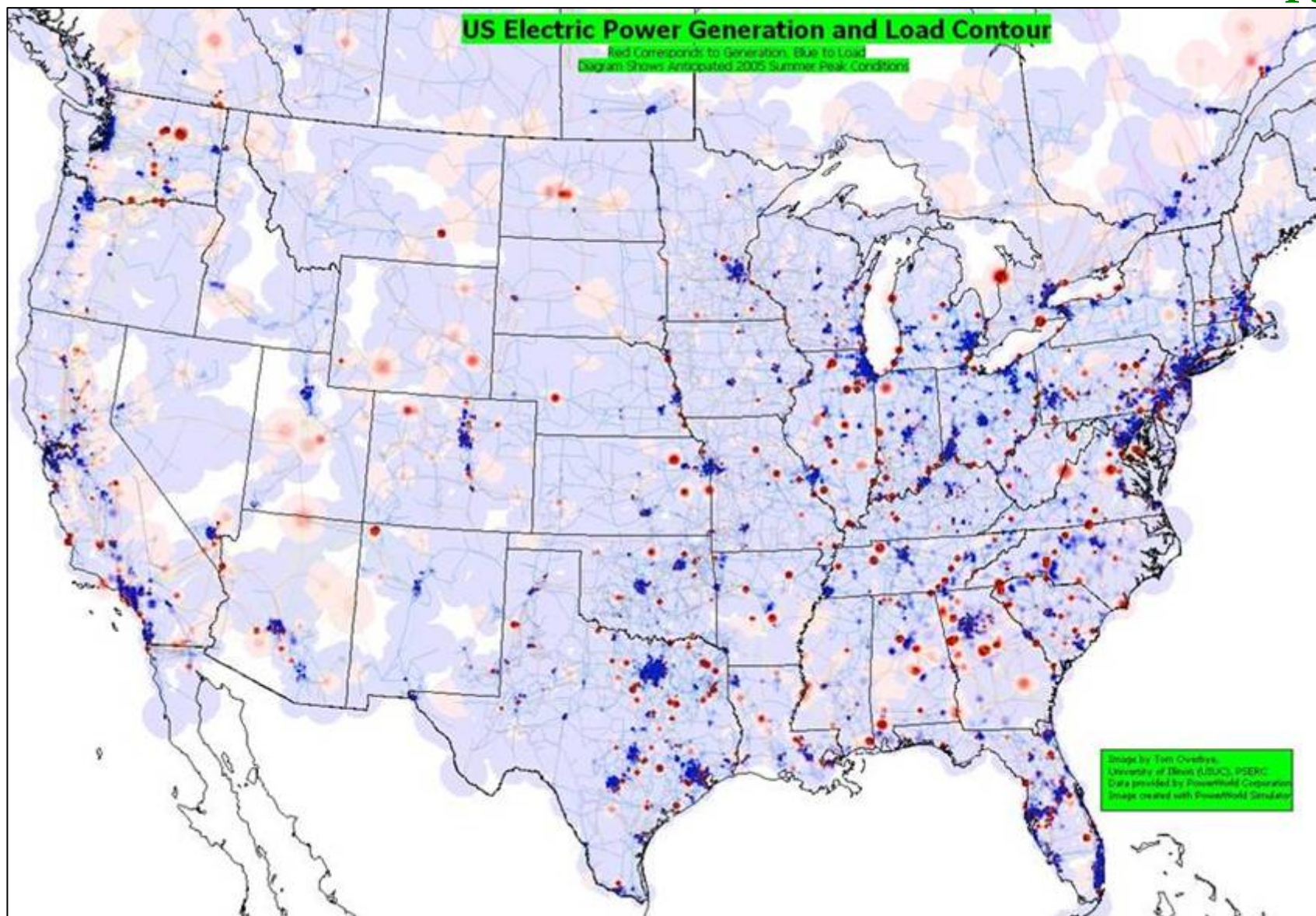
- Pre-Blackout to Cleveland Voltage Contour
- Contour can be created in about 3.9 seconds



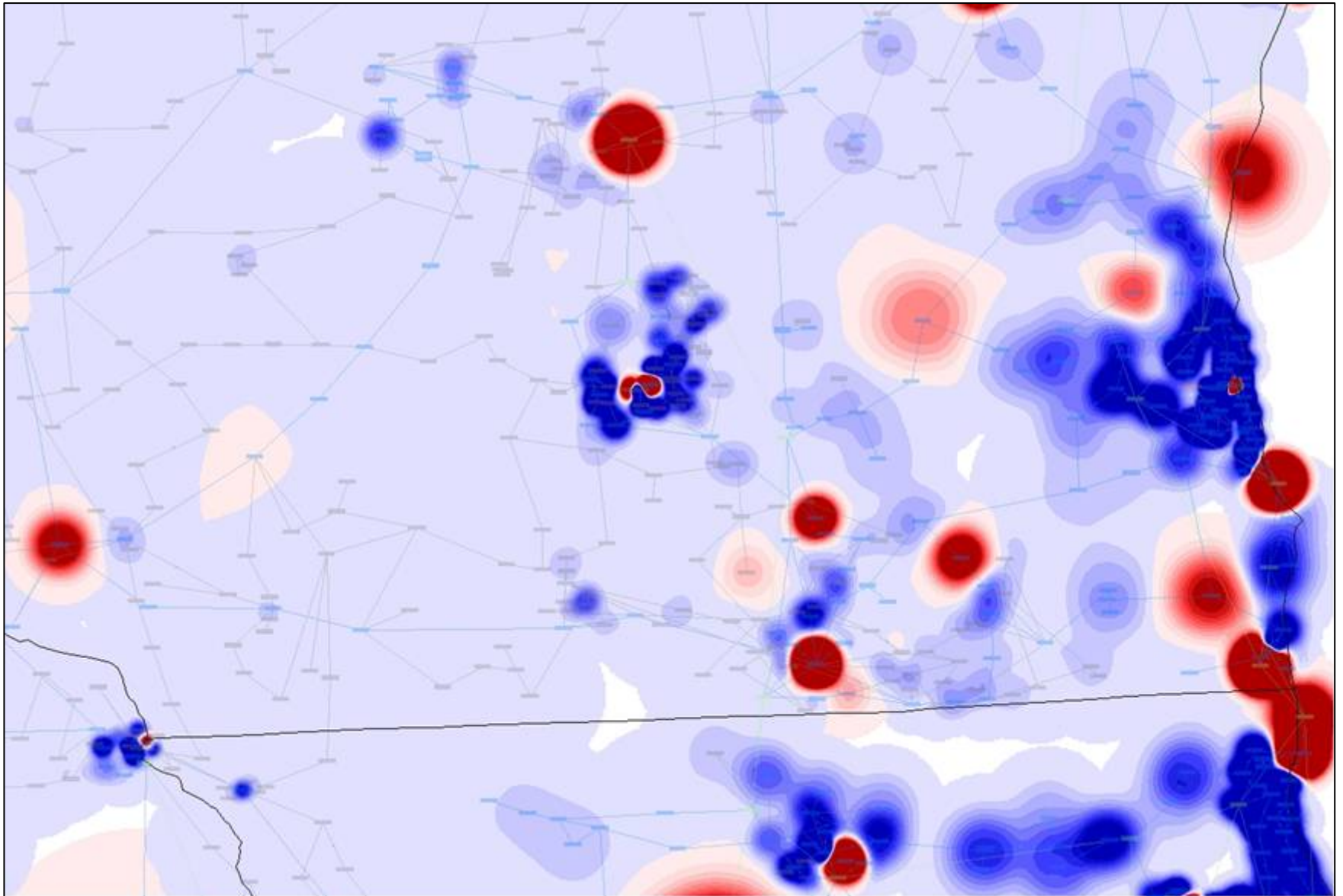
Power Density Contours



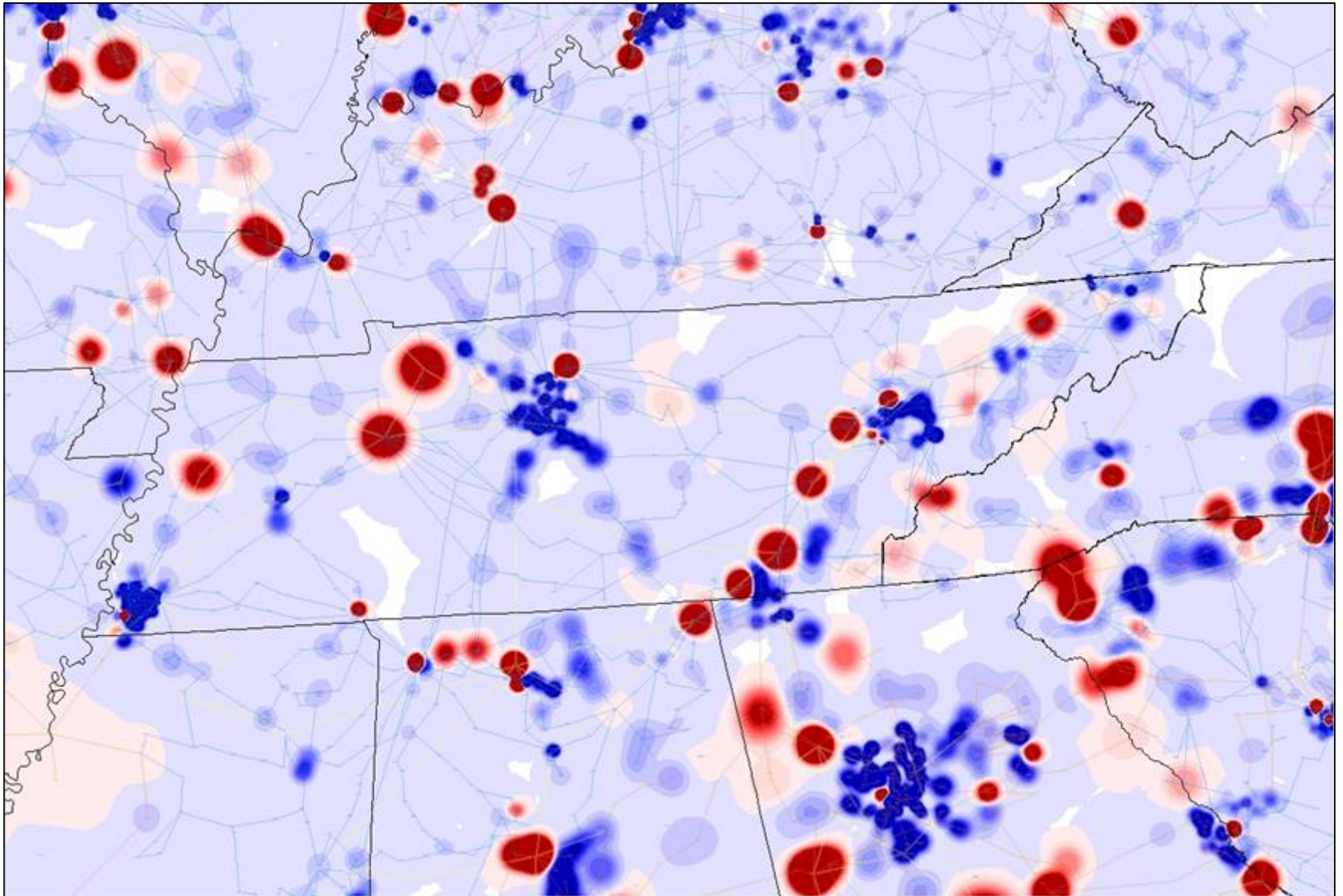
PSERC



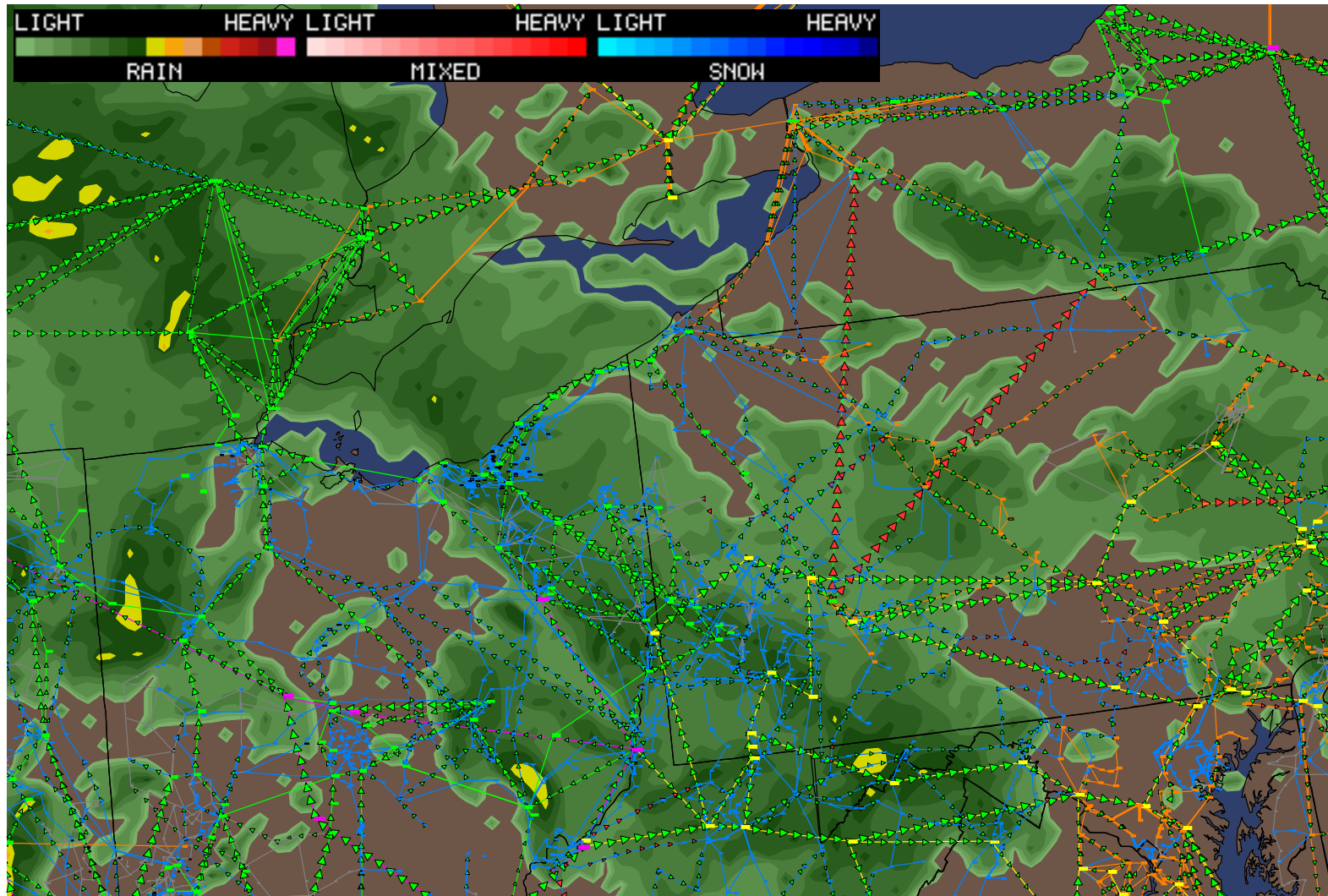
Zoomed View of Wisconsin



Zoomed View of Southeast



Integrated Display of Power Data with Weather Information

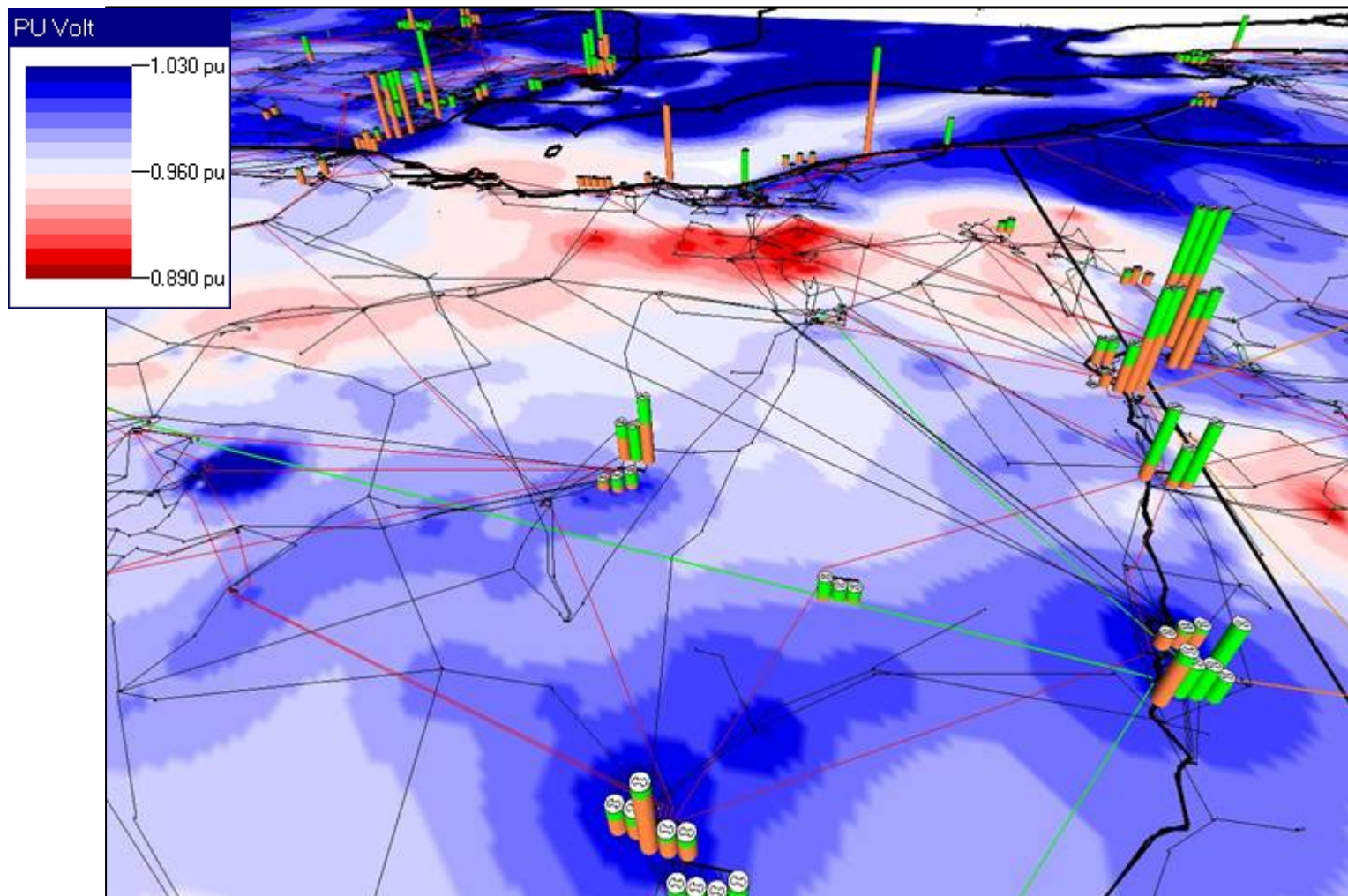


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Interactive 3D Displays

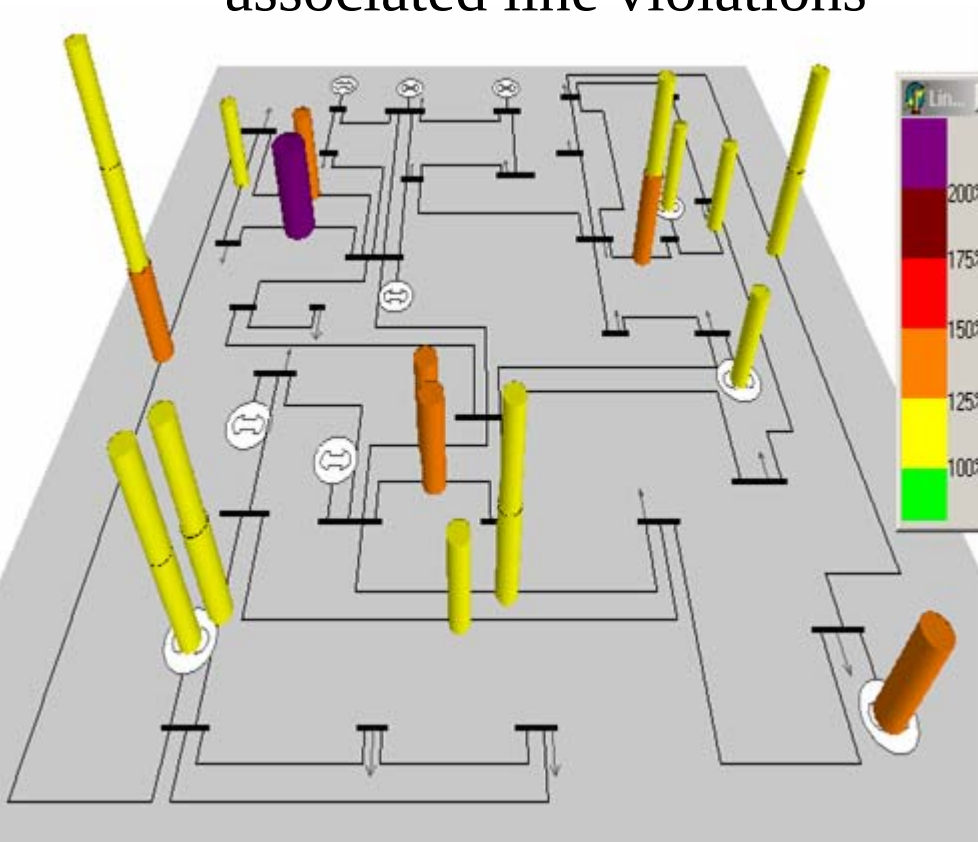
- Generator “cylinders” show their reactive power outputs and limits



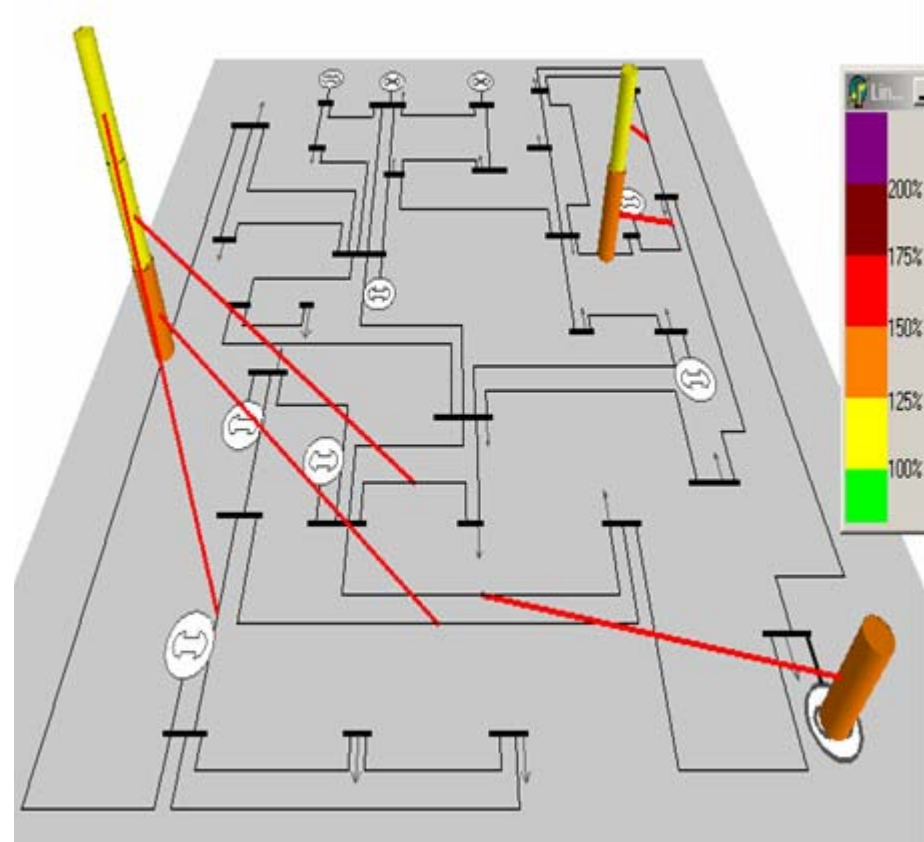


Display of Contingency Data

- Display maps geographic location of contingencies to the associated line violations



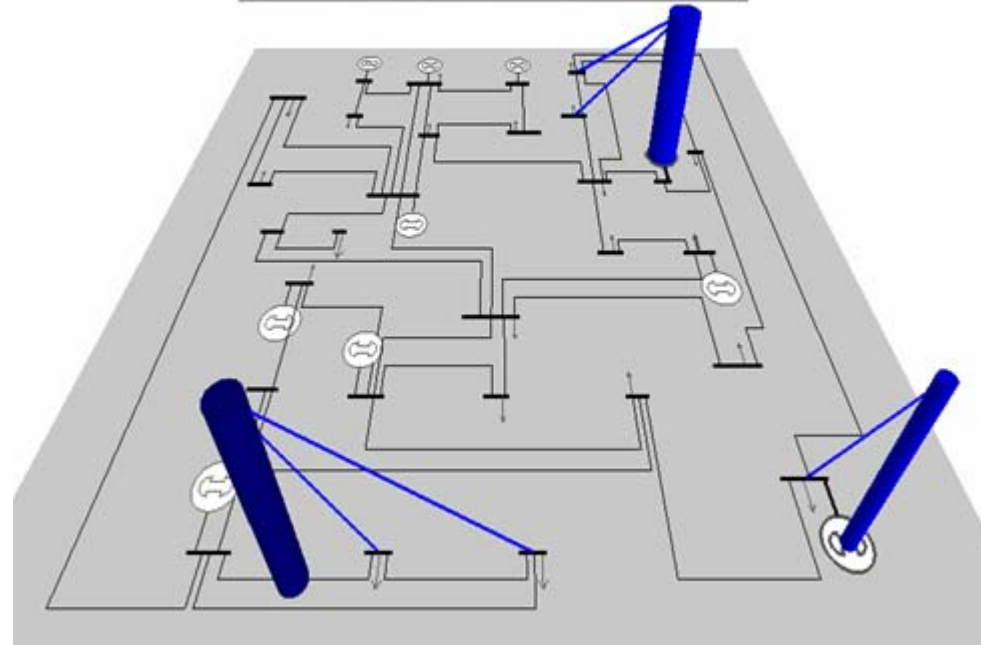
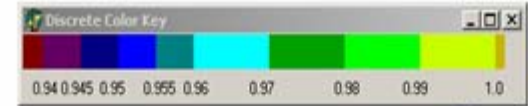
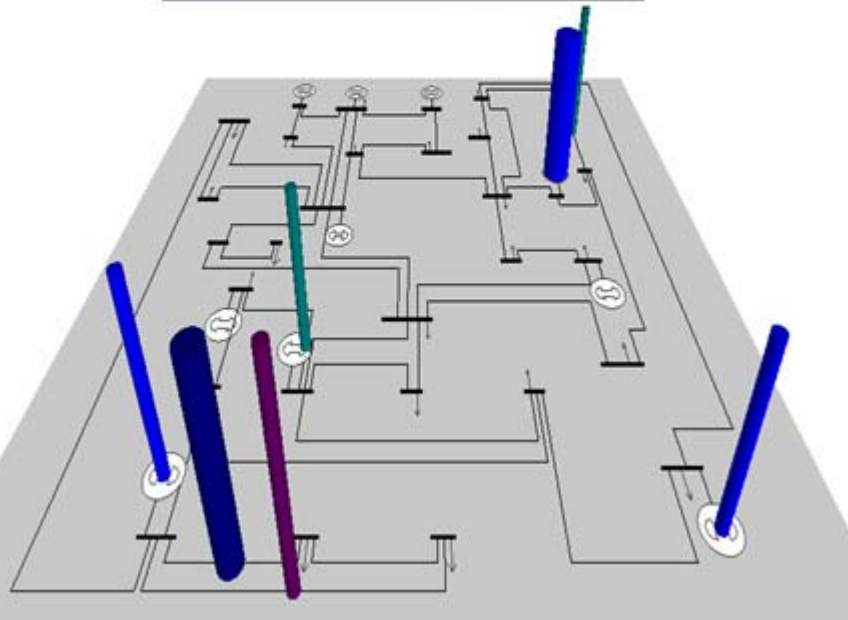
Overview Display



Detail Display

Display of Contingency Data

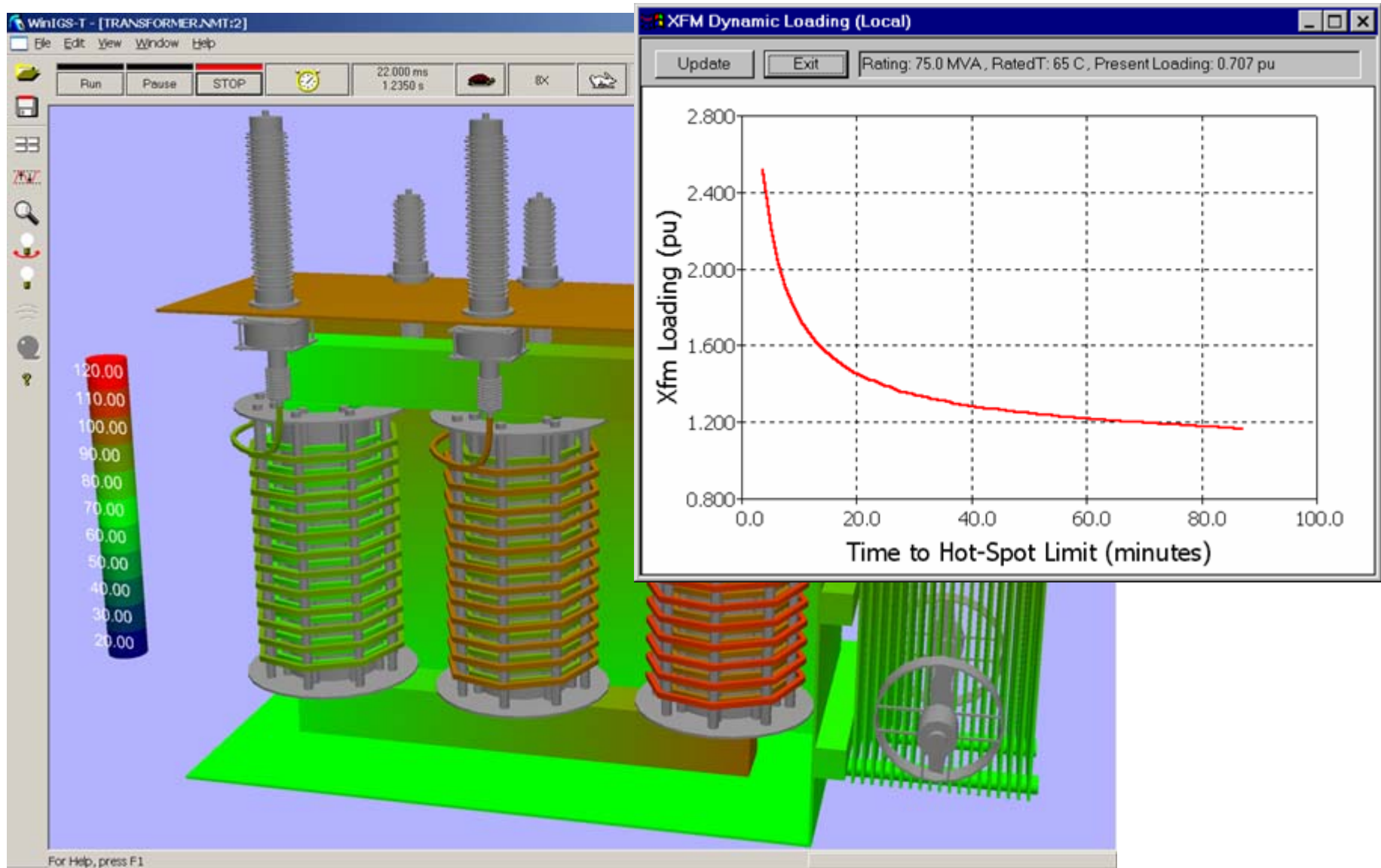
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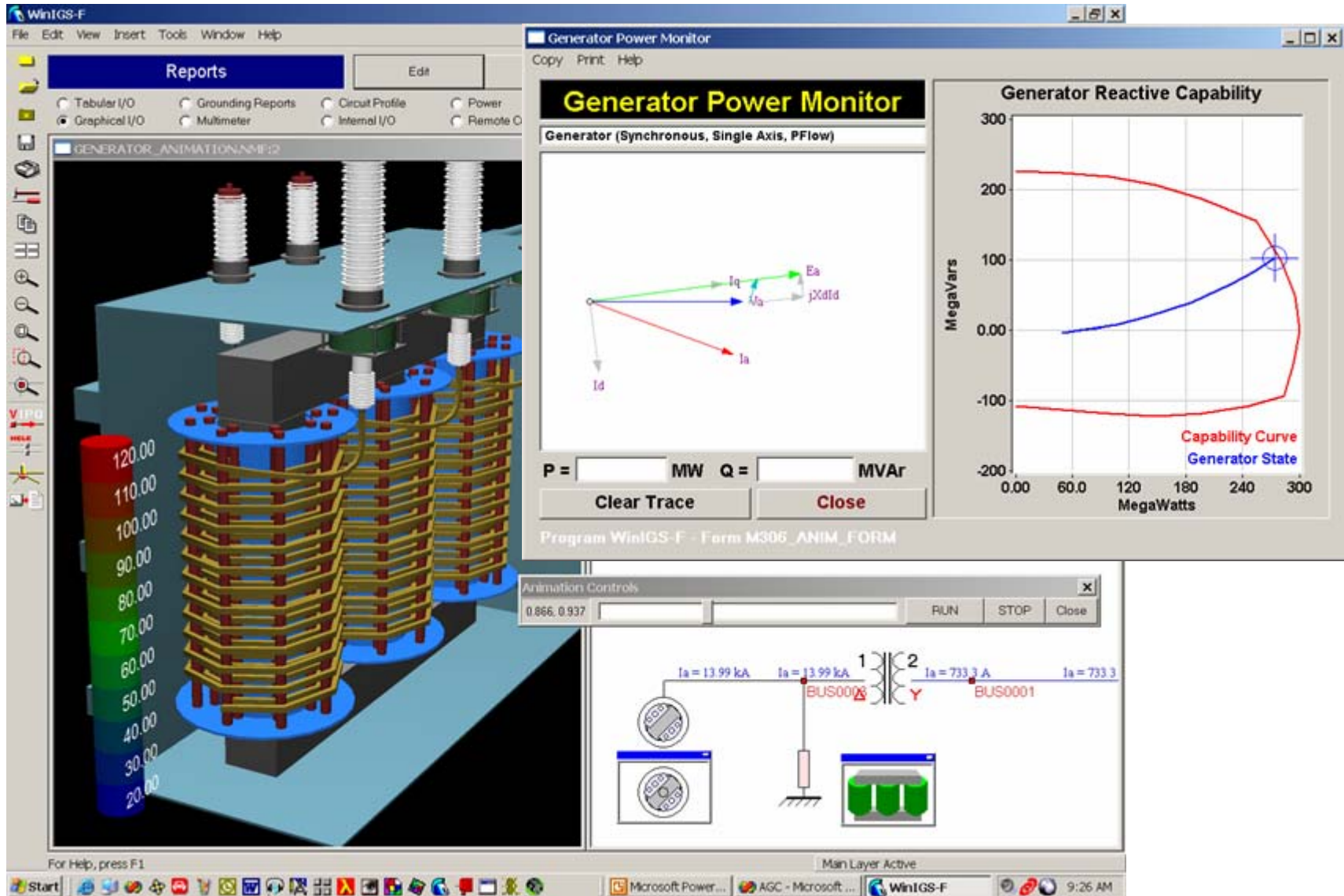
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Transformer Dynamic Loading



Generator and Transformer



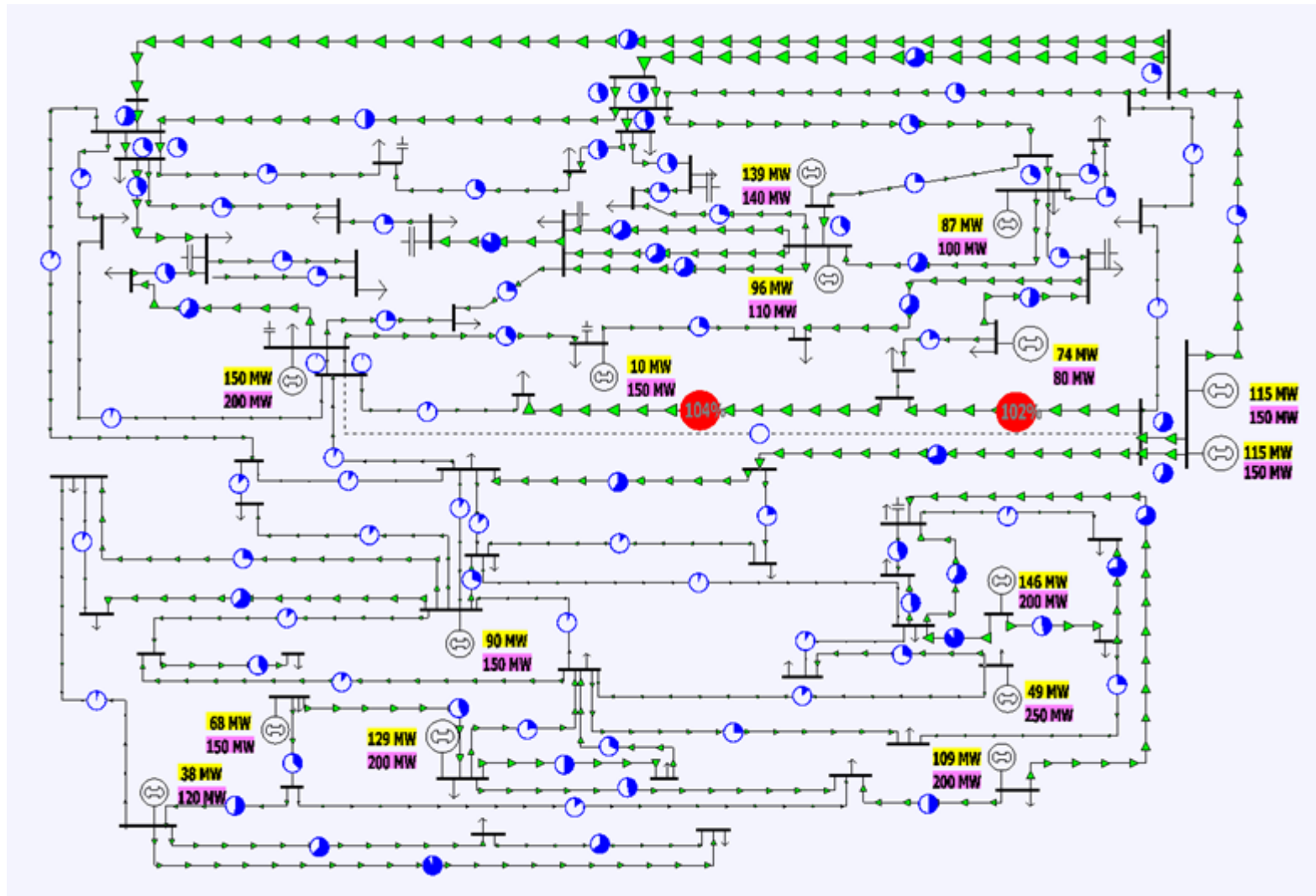
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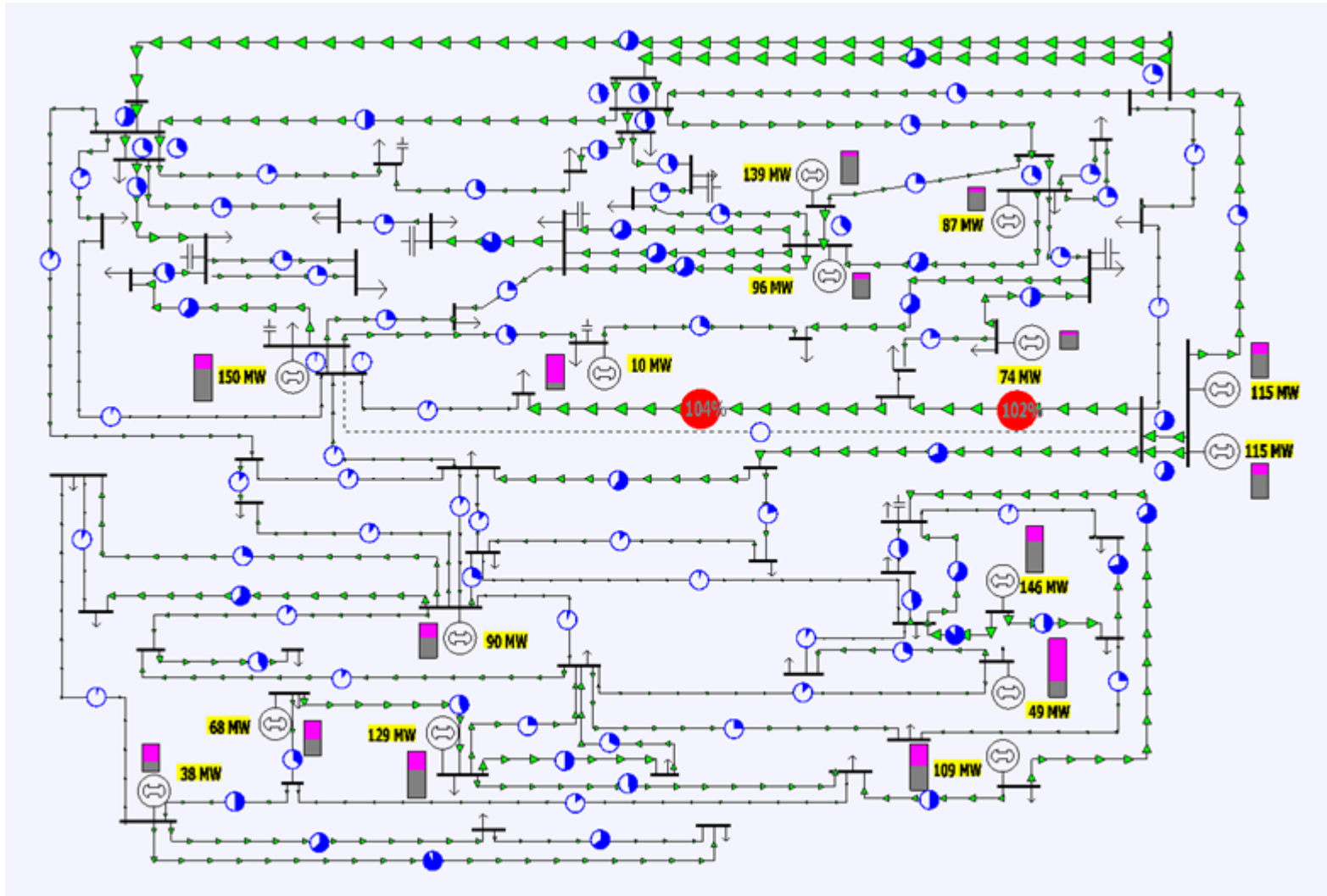
Human Factor Testing Results

- Bus voltage contour experiments indicate color contours help locating/solving problems
- Power flow animation experiments indicate animated flow arrows help with solving complex tasks
- PTDF experiments indicate animation is very helpful
- 3D experiments indicate 3D one-line can help people solve problems quicker and more accurately

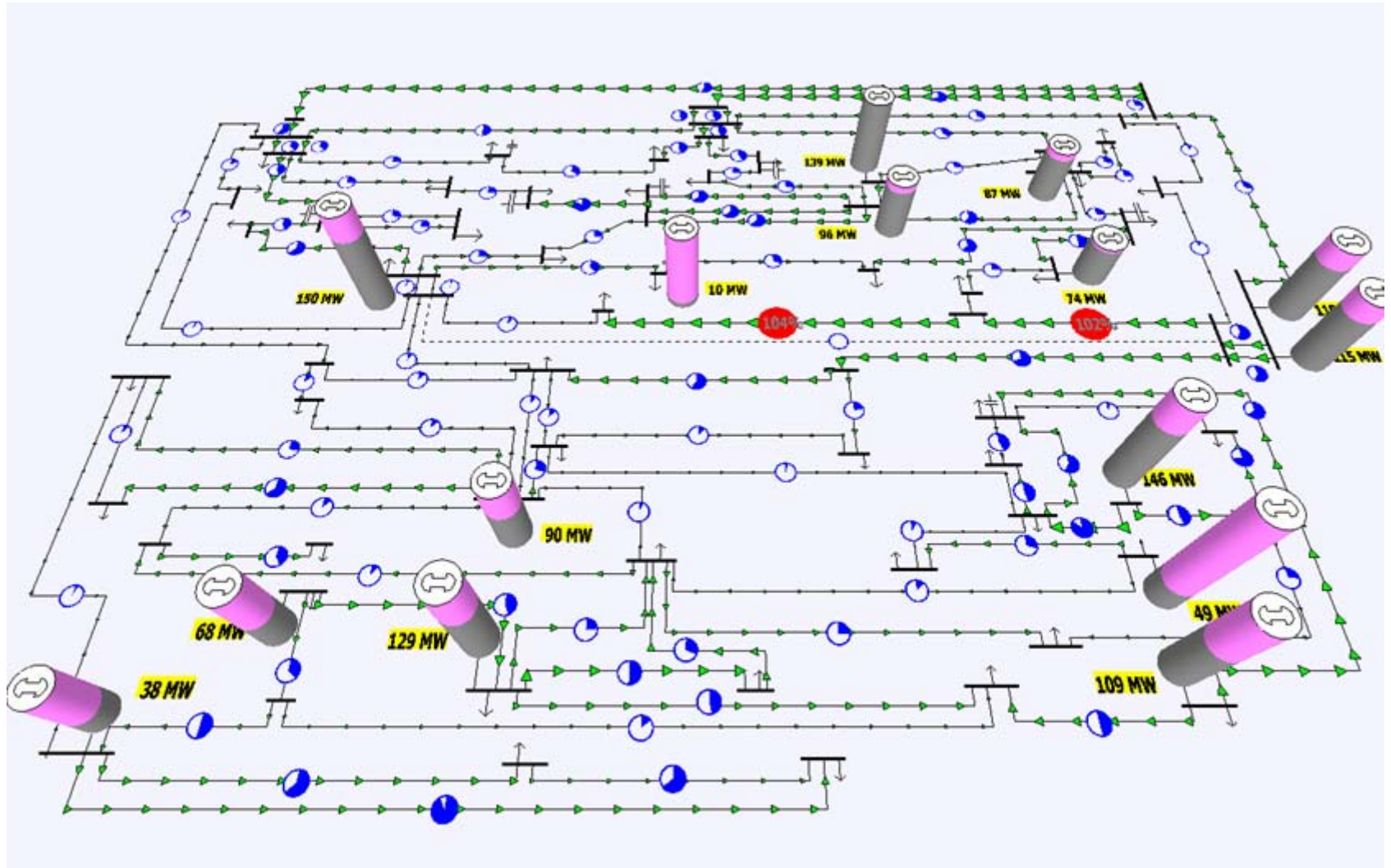
2D Numeric Representation



2D Symbolic Representation



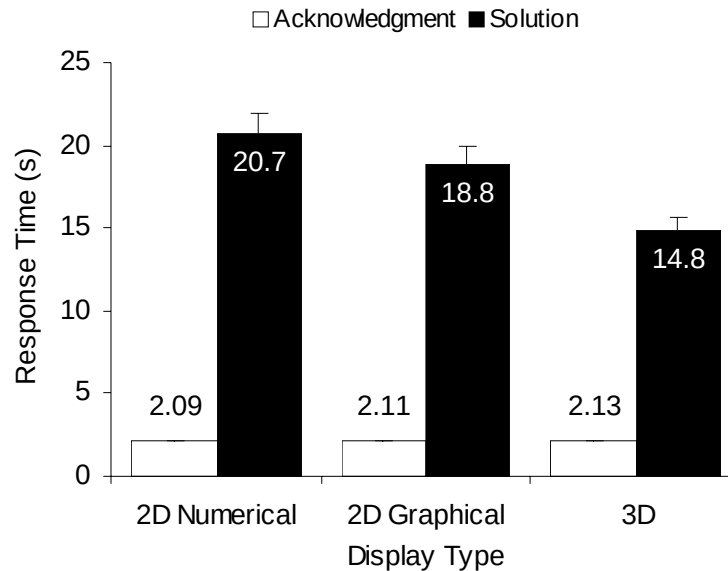
3D Symbolic Representation



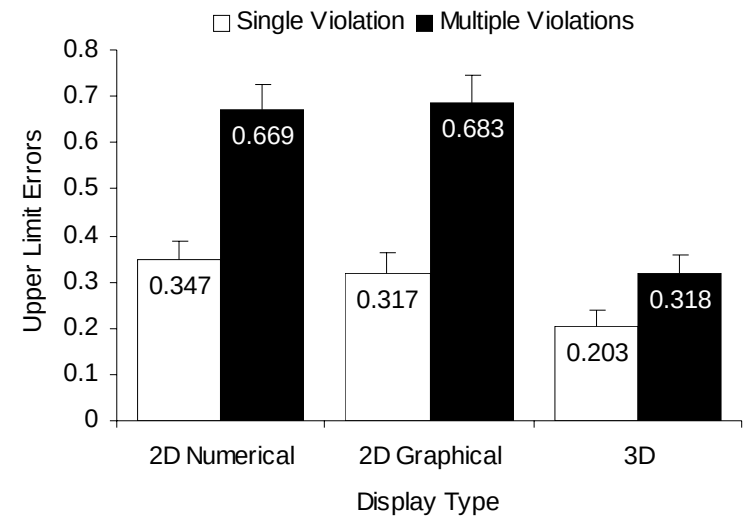
Experiment Results

3D Symbolic Display Resulted in Faster Response
with Fewer Errors

Solution Time



Average Errors per Trial



Moving Forward with S-25

- Project had significant accomplishments, but there is much more still to do. Some examples include
 - Wide-area visualizations of all pertinent system quantities using 2D and/or 3D
 - Incorporation of PMU and IED data into the visualizations
 - Enhanced integration of visualization into EMS applications such as alarming
 - Better methods for showing contingency analysis info
 - More human factors evaluation!
 - Industry support is crucial!!

Project Publications

- R.K. Klump, W. Wu, G. Dooley, "Displaying Aggregate Data, Interrelated Quantities, and Data Trends in Electric Power Systems," 36th Hawaii International Conference on System Sciences, Kona, HI, January 2003.
- T. J. Overbye, "Estimating the actual cost of transmission system congestion," accepted for presentation at 36th Hawaii International Conference on System Sciences, Kona, HI, January 2003.
- T.J. Overbye, D.A. Wiegmann, A.M. Rich, Y. Sun, "Human Factors Aspects of Power System Voltage Contour Visualizations", *IEEE Trans. on Power Systems*, vol. PWRS-18, pp. 76-82, February 2003.
- Y. Sun, T.J. Overbye, "Visualizations for power system contingency analysis transmission element loading data," *Proc. 35th North American Power Symposium*, Rolla, MO, pp. 629-635, October 2003.
- Y. Sun, T.J. Overbye, "Three dimensional visualizations for power system contingency analysis voltage data," *Proc. 6th International Conference on Advances in Power System Control, Operation and Management (APSCOM)*, Hong Kong, November 2003.
- T.J. Overbye, Y. Sun, R.P. Klump, J.D. Weber, "Interactive 3D visualization of power system information," *Electric Power Components & Systems*, pp. 1205-1215, December 2003.
- T.J. Overbye, X. Cheng, Y. Sun, "A comparison of the ac and dc power flow models for LMP calculations," *Proc. 37th Hawaii International Conference on System Sciences*, Kona, HI, January 2004.
- A.P.S. Meliopoulos, G.J. Cokkinides, T.J. Overbye, "Component monitoring and dynamic loading visualization for real time power flow model data," *Proc. 37th Hawaii International Conference on System Sciences*, Kona, HI, January 2004.
- Y. Sun, T.J. Overbye, "Visualizations for power system contingency analysis data," *IEEE Trans. on Power Systems*, vol. PWRS-19, pp. 1859-1866, November 2004.
- T.J. Overbye, D.A. Wiegmann, "Reducing the risk of major blackouts through improved power system visualization," *Proc. 2005 Power Systems Computational Conference (PSCC)*, Liege, Belgium, August 2005.
- D.A. Wiegmann, G.R. Essenberg, T.J. Overbye, Y. Sun, "Human factor aspects of power system flow animation," *IEEE Trans. on Power Systems*, vol. PWRS-20, pp. 1233-1240, August 2005.
- T.J. Overbye, "Power system visualization," *Automation of Electric Power Systems*, vol. 29, no. 16, August 2005.
- A. P. Sakis Meliopoulos and G. J. Cokkinides, Mike Ingram, Sandra Bell, Sherica Matthews, "Visualization and Animation of State Estimation Performance", *Proceedings of the 38st Annual Hawaii International Conference on System Sciences*, Big Island, Hawaii, January 3-6, 2005.

Questions?