

Data Visualization for Effective Grid Monitoring & Control in a Complex Operating Environment



Tom Overbye

Dept. of Electrical and Computer Engineering

University of Illinois at Urbana-Champaign

overbye@ece.uiuc.edu

June 2003



ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN



PSERC

Need for Better Power System Visualization

- Electric power industry is very competitive
- Size of power markets are much larger
- Amount of power system data has become overwhelming
- Audience interested in power issues is now much broader



Presentation Overview

- Goals of presentation are
 - to show how PSERC visualization research is rapidly being transferred to control centers
 - describe some of our ongoing research in developing new visualization techniques
 - describe our ongoing work in human factors assessment



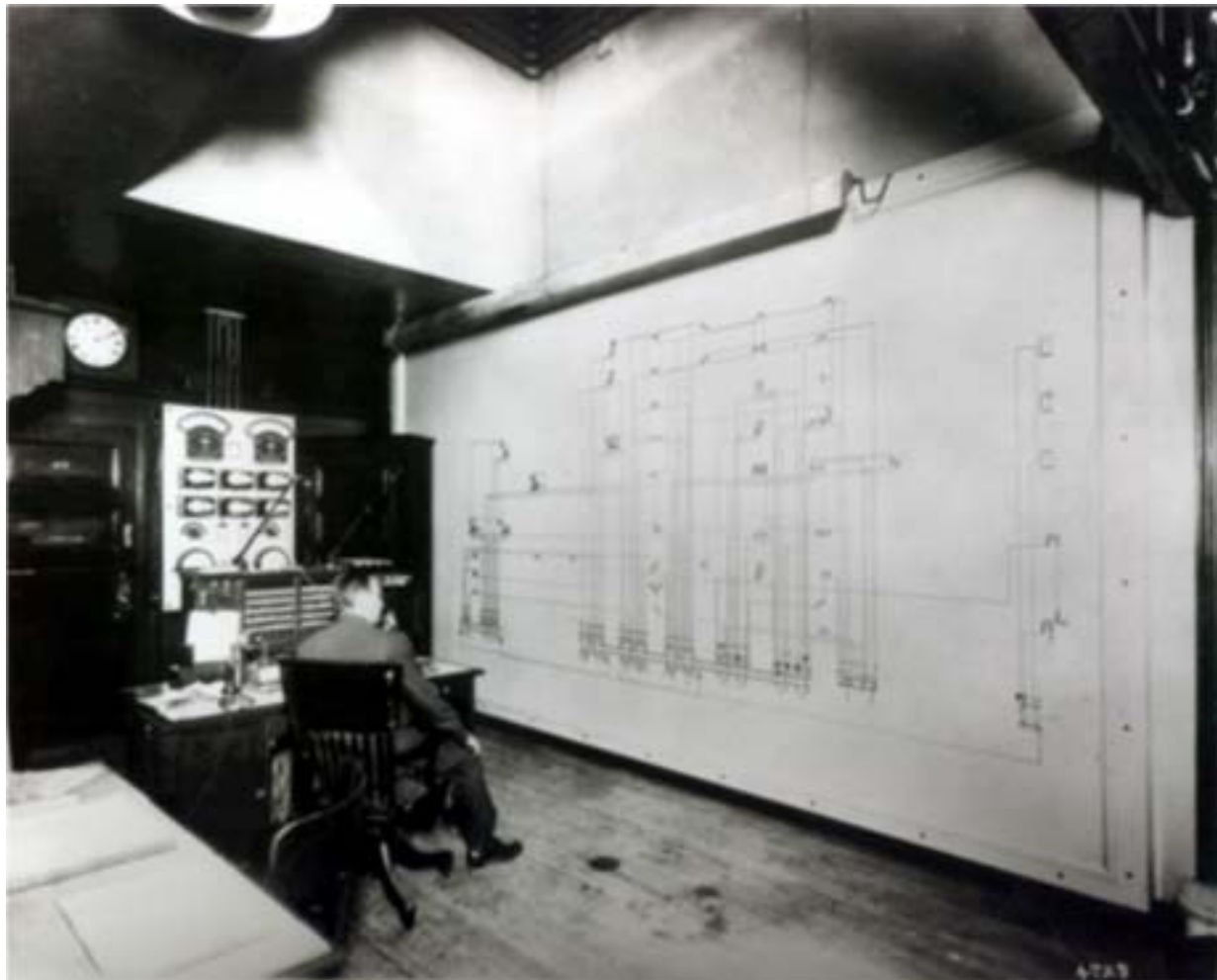
ComED Case Study

- ComED has been a long time PSERC member, with a long history of interest in our visualization research
- Three years ago they asked if our visualization technology could be implemented in their control center
 - we said yes, and with the help of PSERC member PowerWorld got an initial installation in about 6 months



Before PSERC

(actually, much before in 1919)



PSERC

A More Recent Before Shot



Motivation

- Mapboard Replacement
 - the mosaic mapboard was replaced in 1999 by 12 electrohome “cubes”
 - the displays initially put on the mapboard were unsatisfactory
- Progression of Data Requirements
 - amount of data the dispatchers must process is constantly increasing



New “Mapboard” with PSERC Developed Visualizations

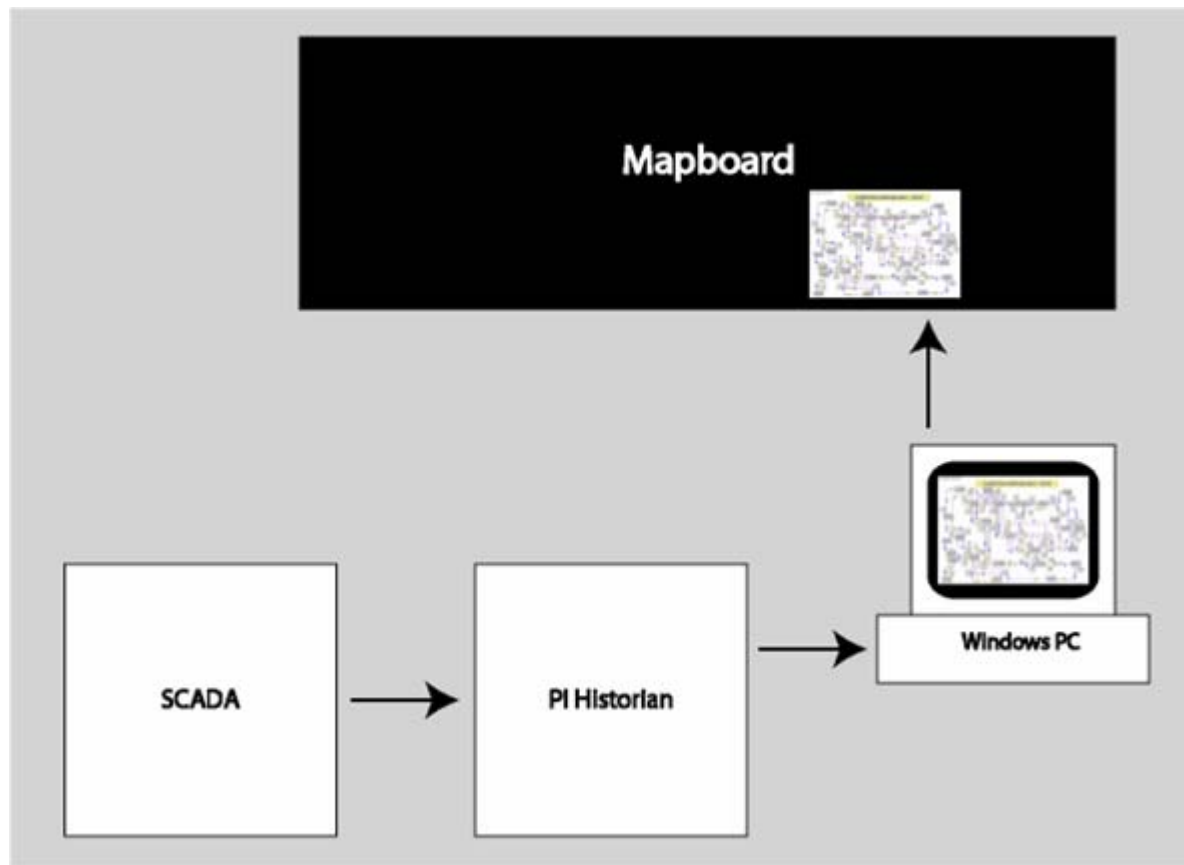


Data Pipeline is via PI

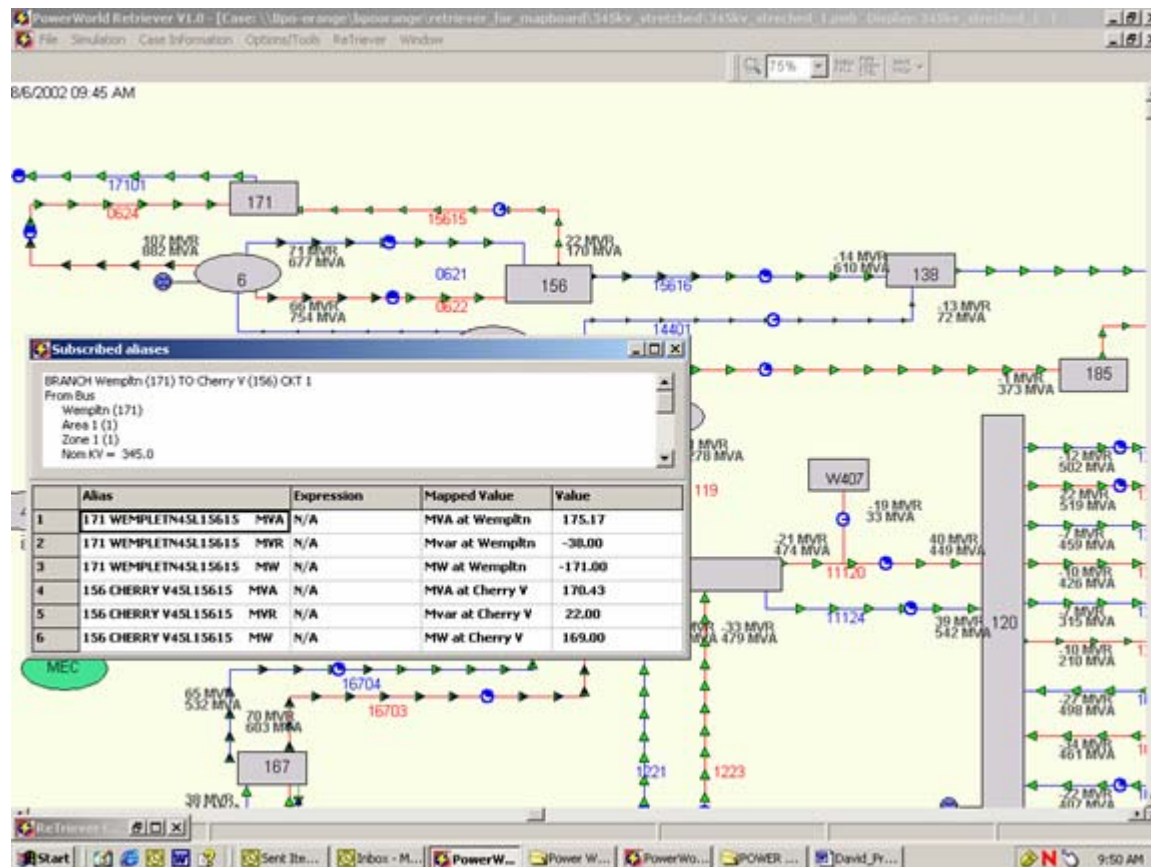
- ComED has been using the PI data archival system since mid 1998
- ComEd's Transmission and Distribution PI has about 250,000 points (Sept 2002)
- Selected data is visualized to the electronic displays using PowerWorld Retriever
- ComED worked with PSERC and PowerWorld to determine data to show



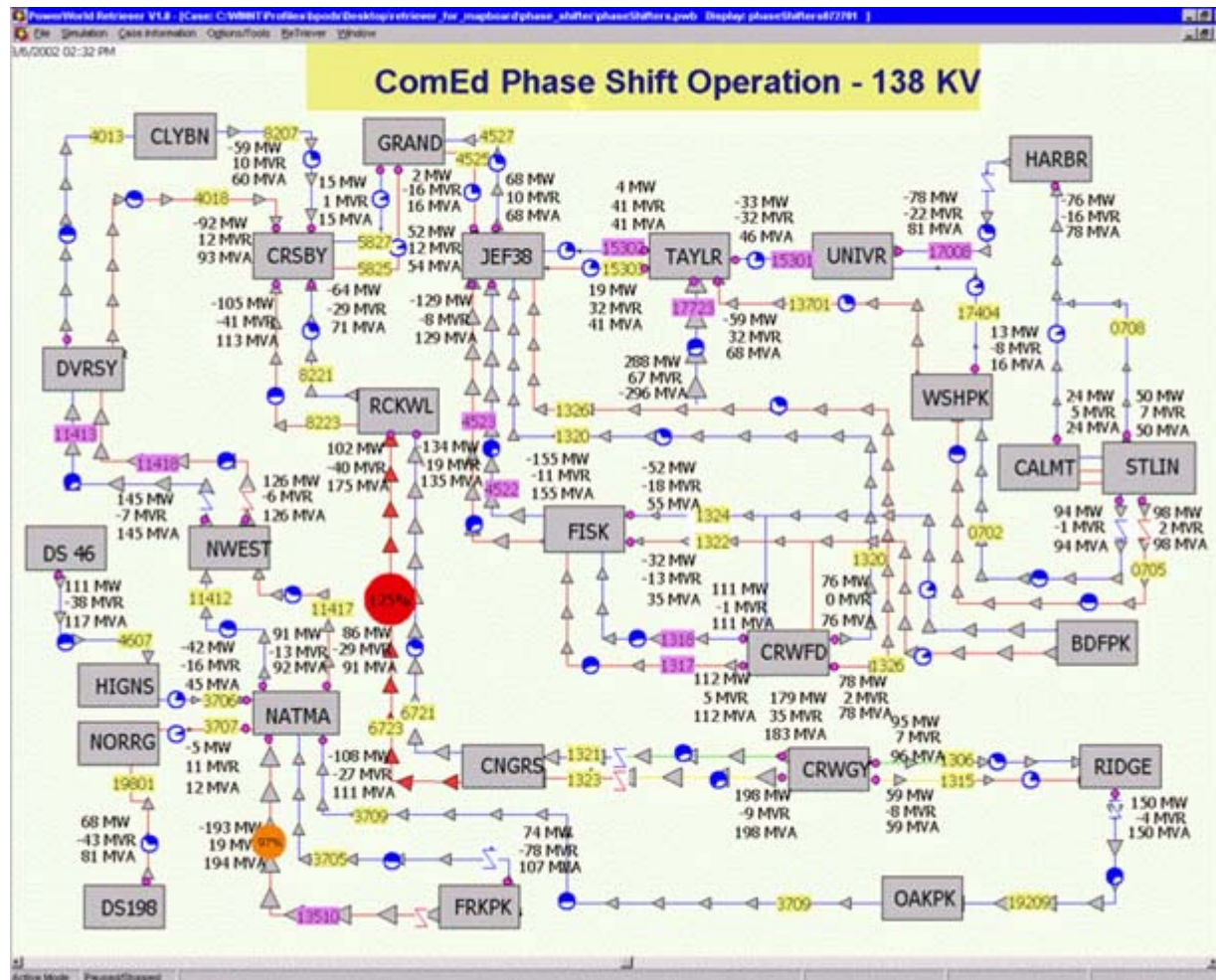
Data Flow



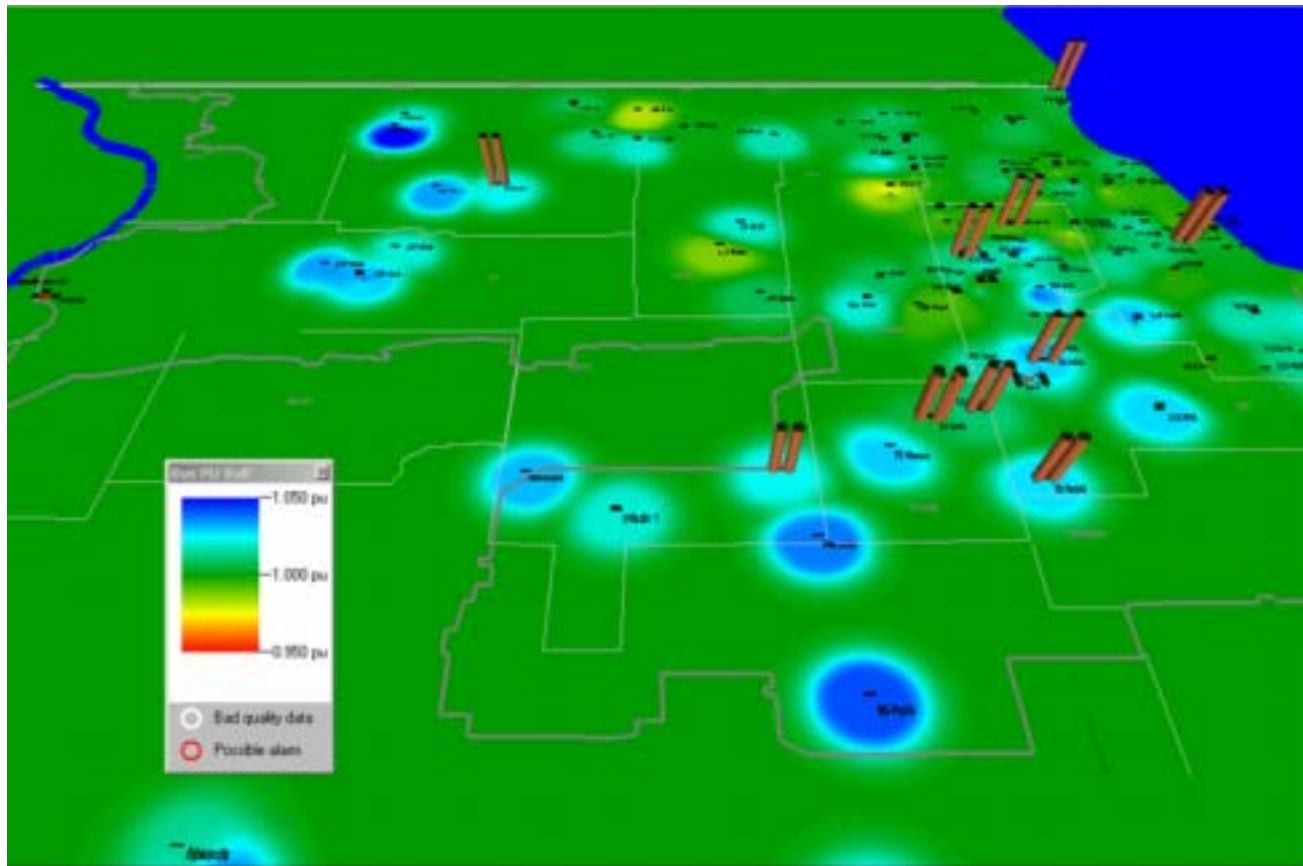
System Overview Display



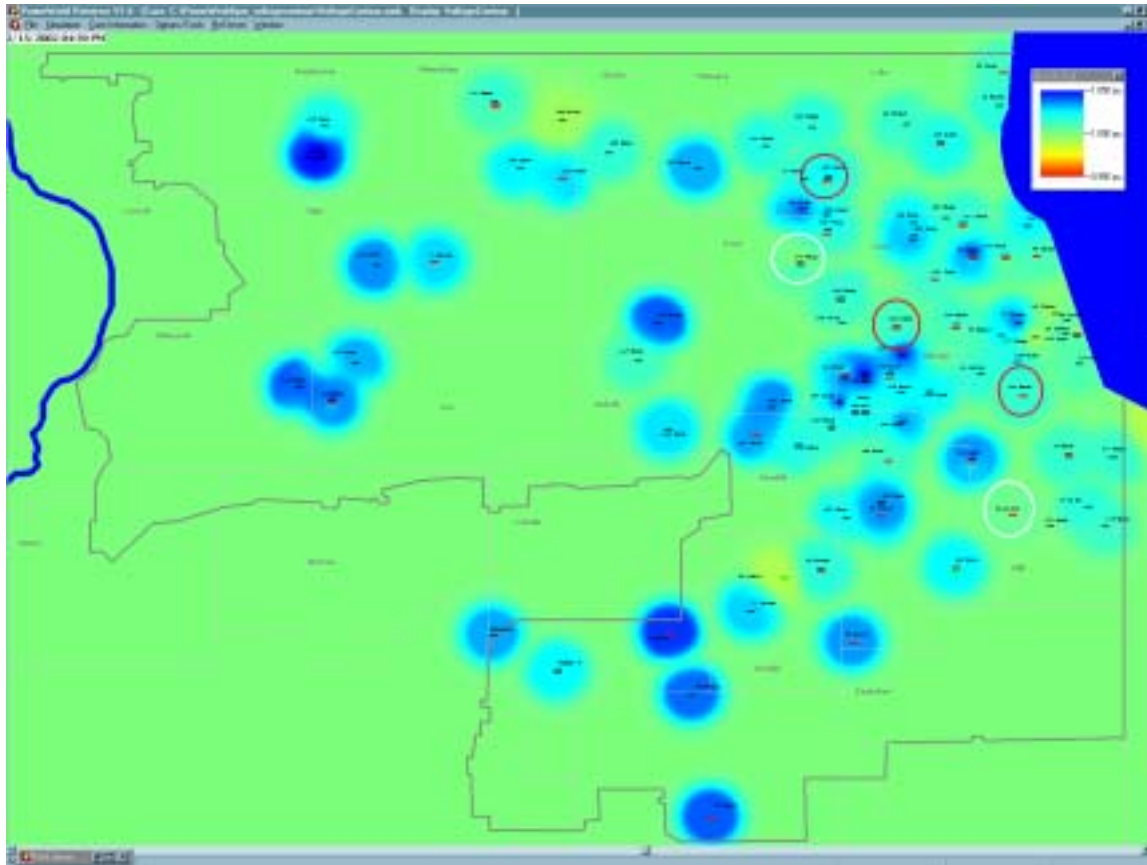
Animated arrows and dynamically sized pie charts are used to give an overview of the transmission system



Voltage Contours, both 2D and 3D



Highlighting Bad Data is Crucial

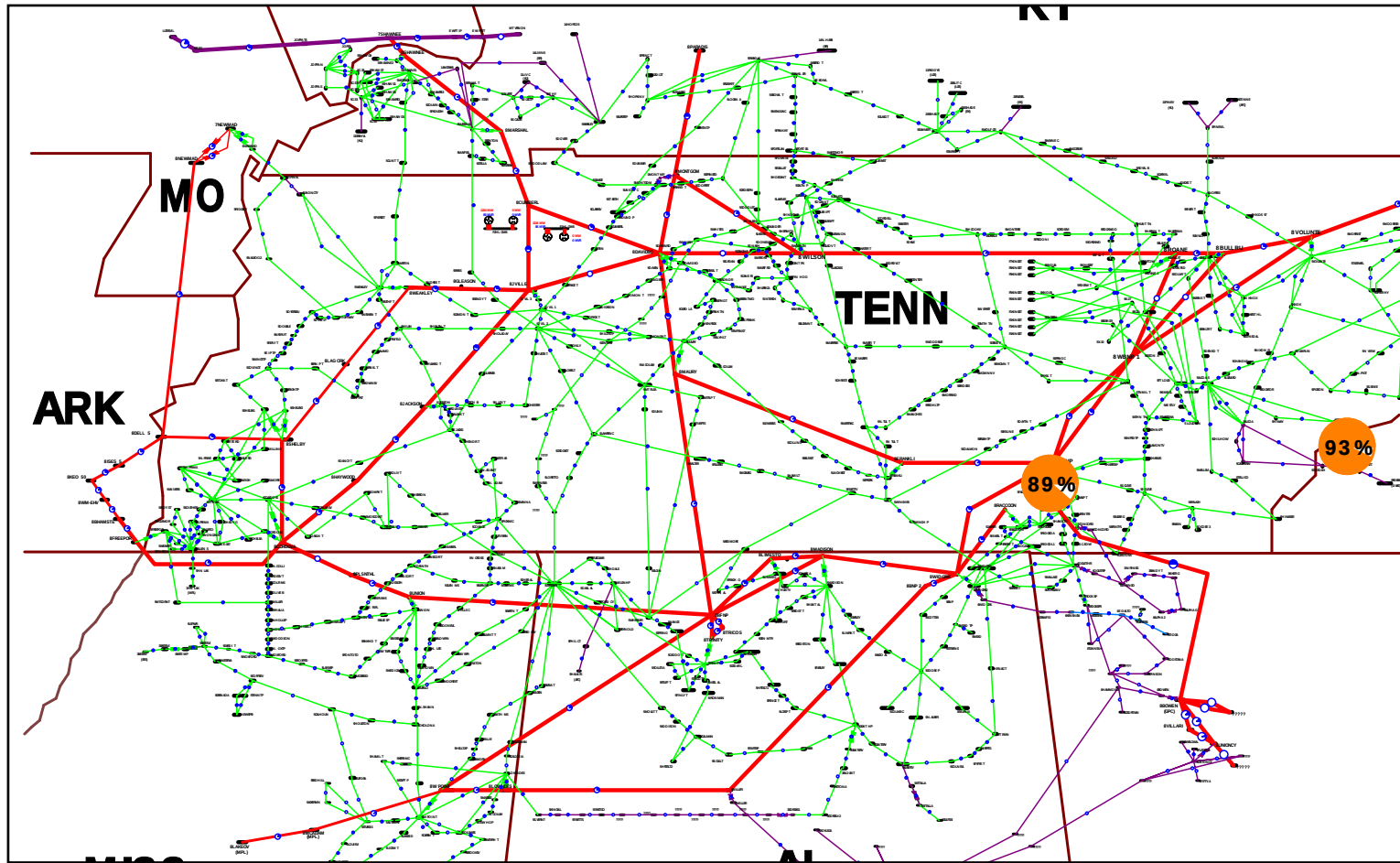


Additional Installations

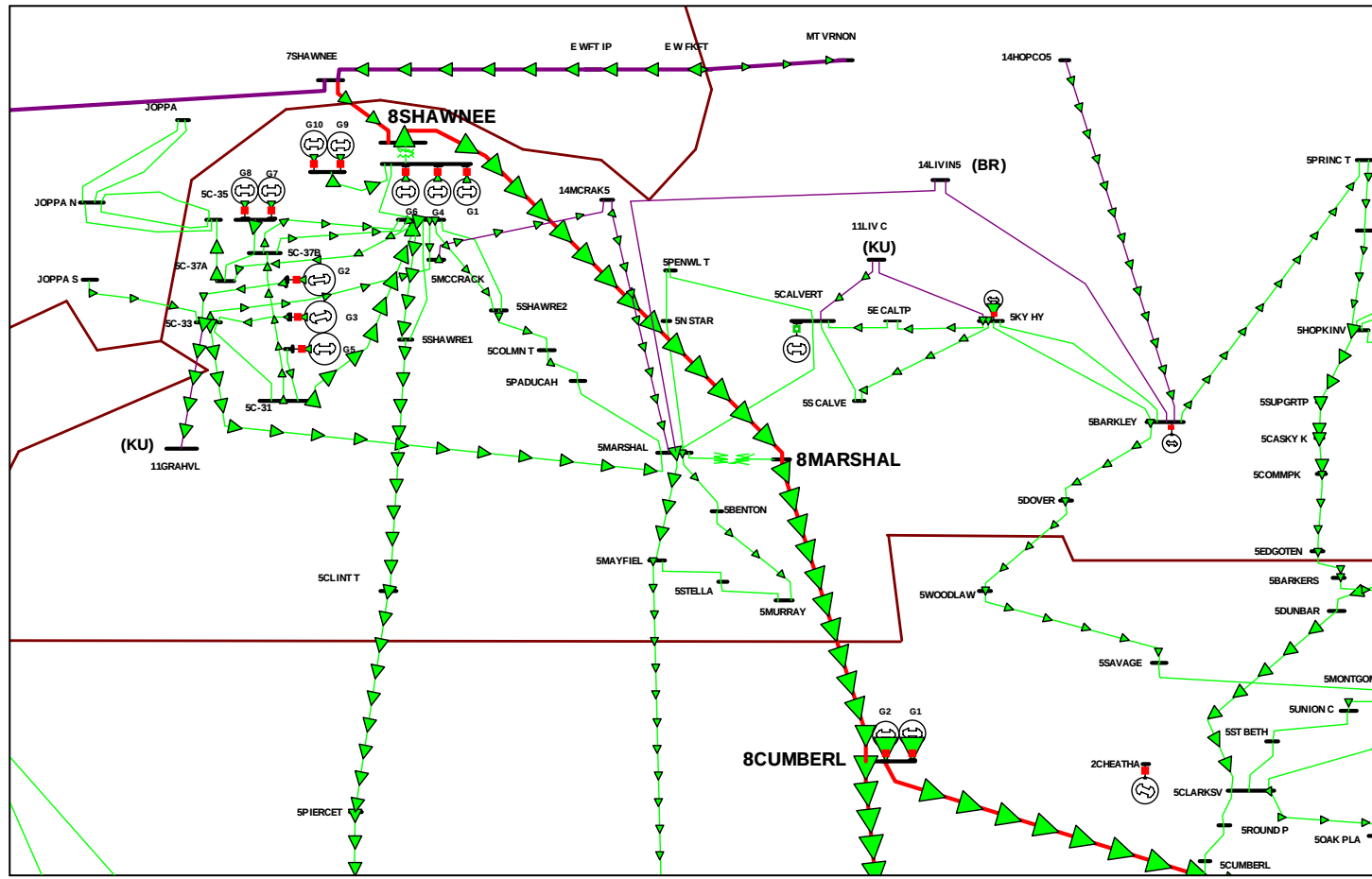
- Similar types of visualizations are currently in use at the TVA Control Center
- A project at another major PSERC member control center is scheduled to begin this month
- Four other PSERC member control centers are seriously considering this type of installation, including BPA



System with Dynamic Sized Pie Charts used to Indicate Loading



Animation of Line Flows (MW and/or Mvar)

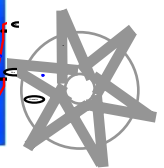
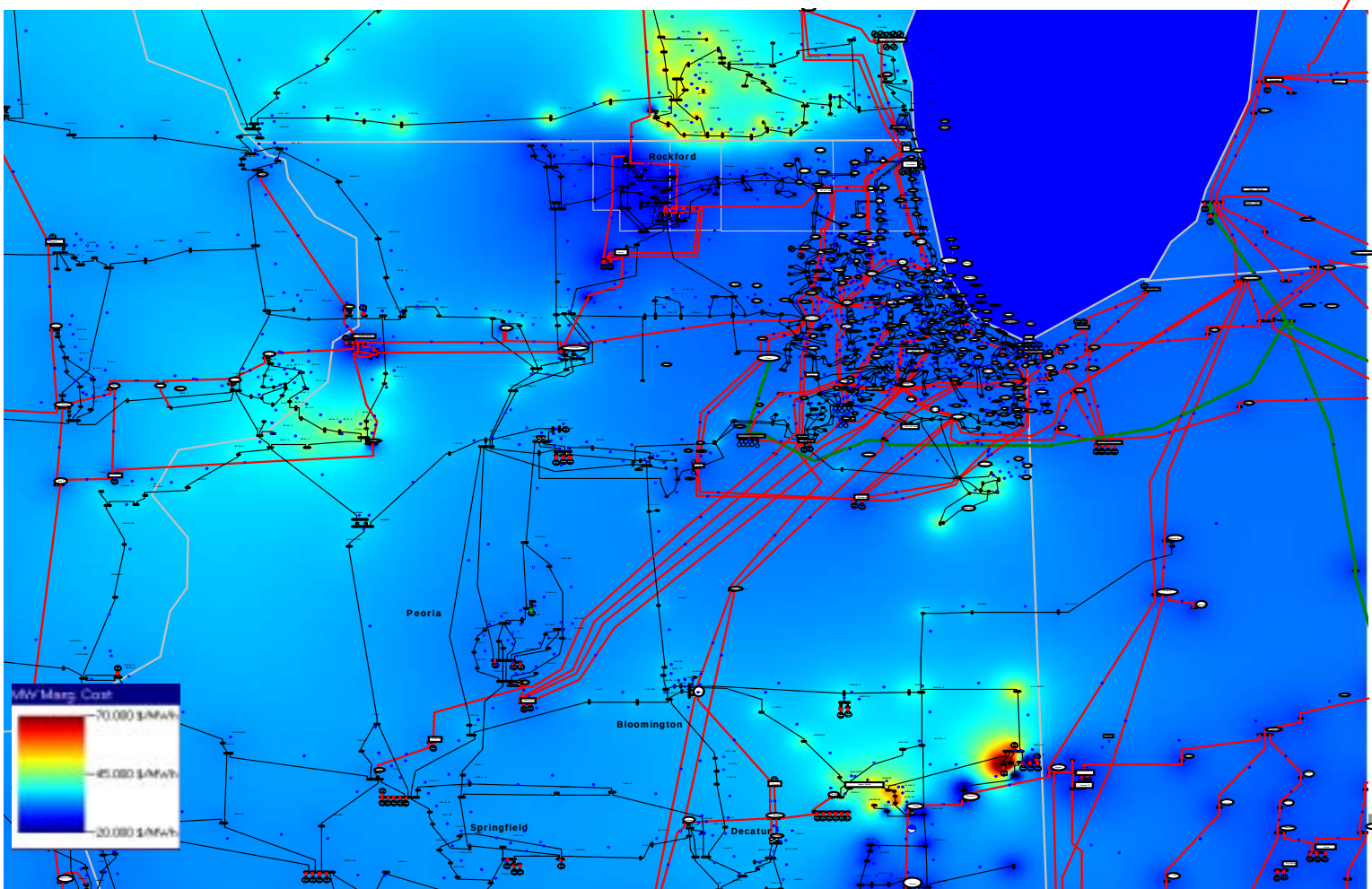


Contouring

- Contours can be effective for showing large amounts of spatial data
 - weather maps showing temperatures and weather radar images provide good examples
 - potential power system applications
 - bus voltage magnitudes and LMPs
 - percent loading and PTDFs on transmission lines
 - flowgate values
 - personally, I think discrete contours are best

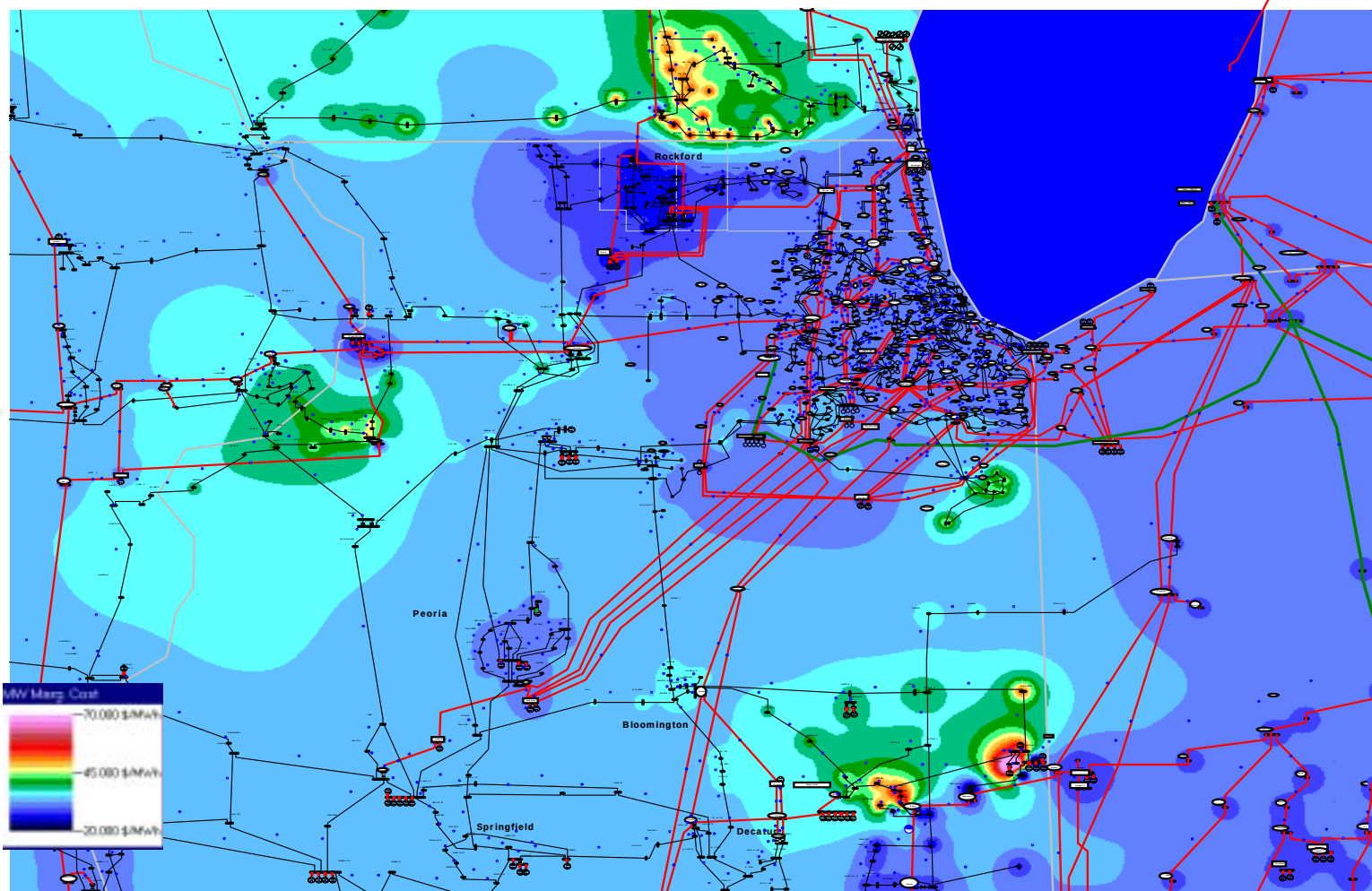


Continuous Contour of Bus LMPs



PSERC

Discrete Contour of Bus LMPs

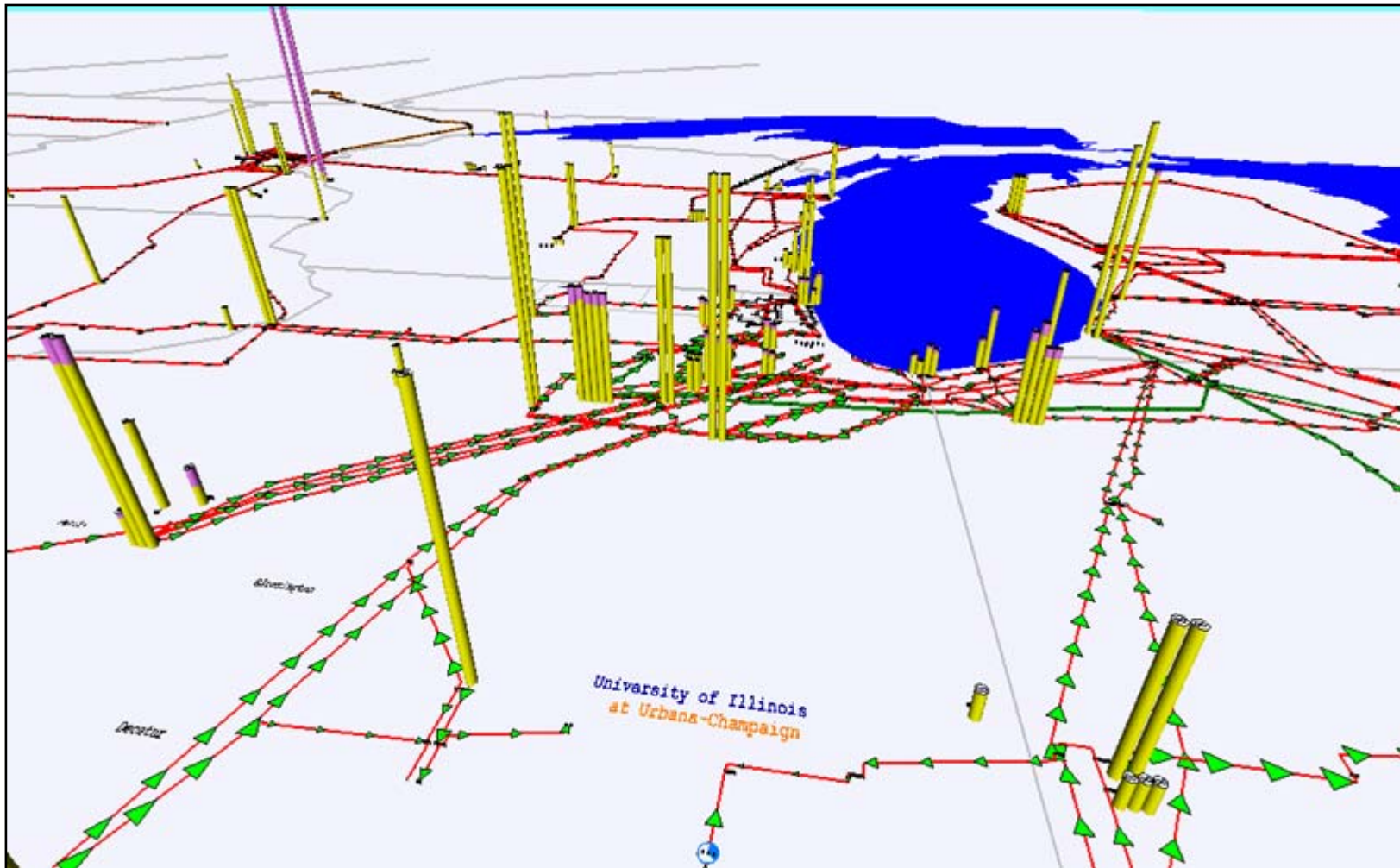


Interactive 3D Visualization

- Starting point is to re-map traditional one-line into 3D
 - builds upon the traditional 2D one-line, familiar to power system users
 - existing one-lines can be extended into 3D to highlight relationships between variables
 - existing 2D one-lines were redrawn using a 3D visualization language, OpenGL
 - easy navigation and interaction very important



3D View of Generation Sources in Midwest

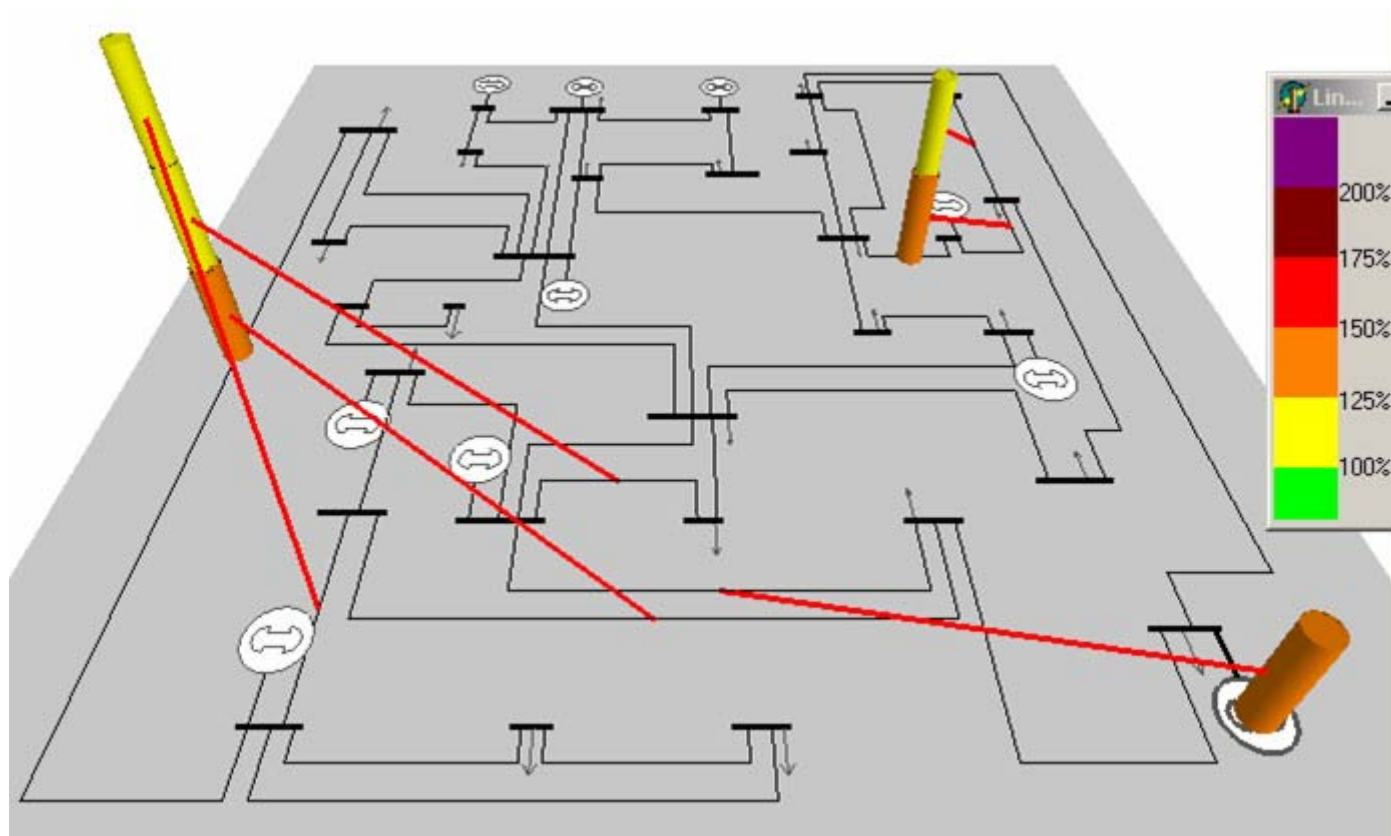


Visualization of Contingency Analysis Results

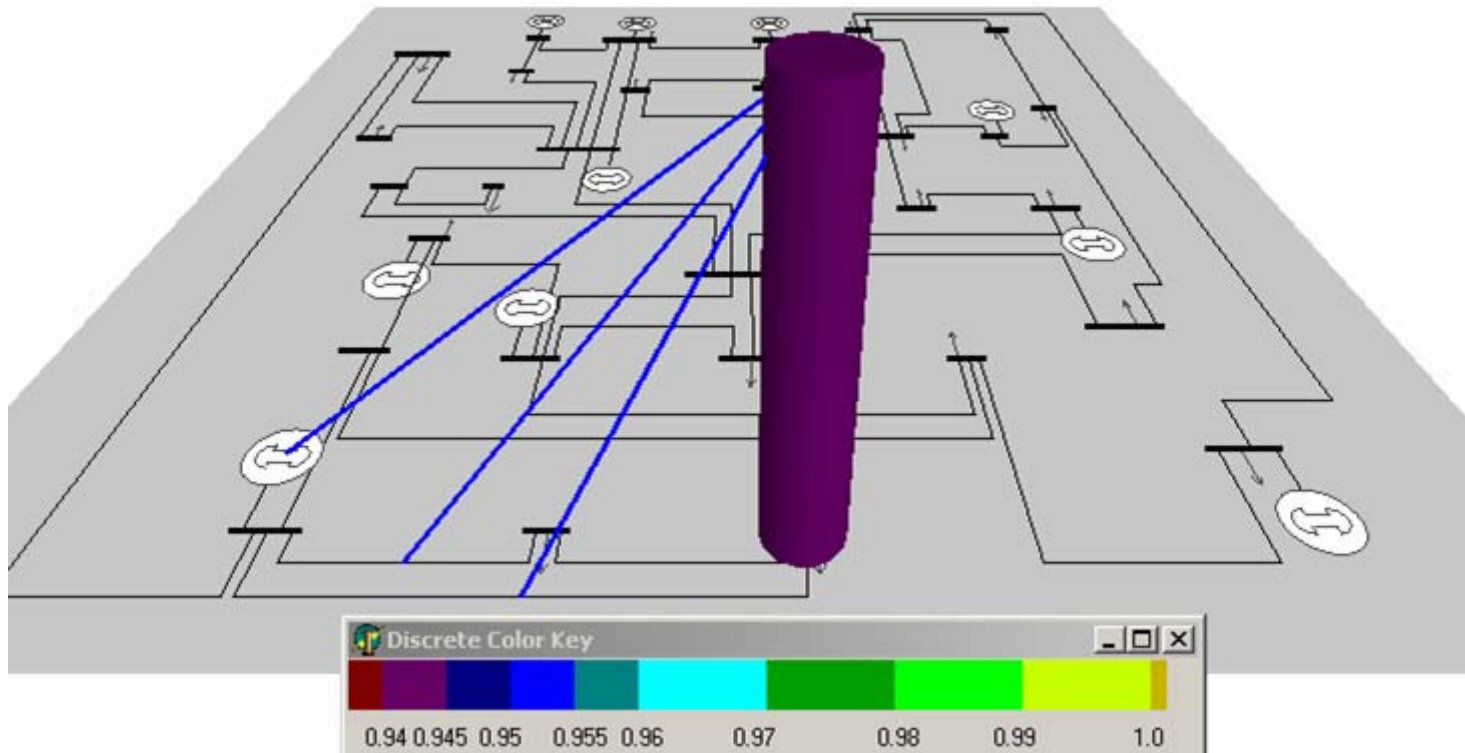
- Contingency analysis results can be presented in a 2D matrix format (contingencies versus violated elements)
 - but such an approach loses the geographic information for both the contingencies and the violated elements
- We are working on 3D approaches to supplement traditional 2D displays



Single Device Contingencies: Contingency to Violated Elements



Single Device Contingencies: Violated Element to Contingencies

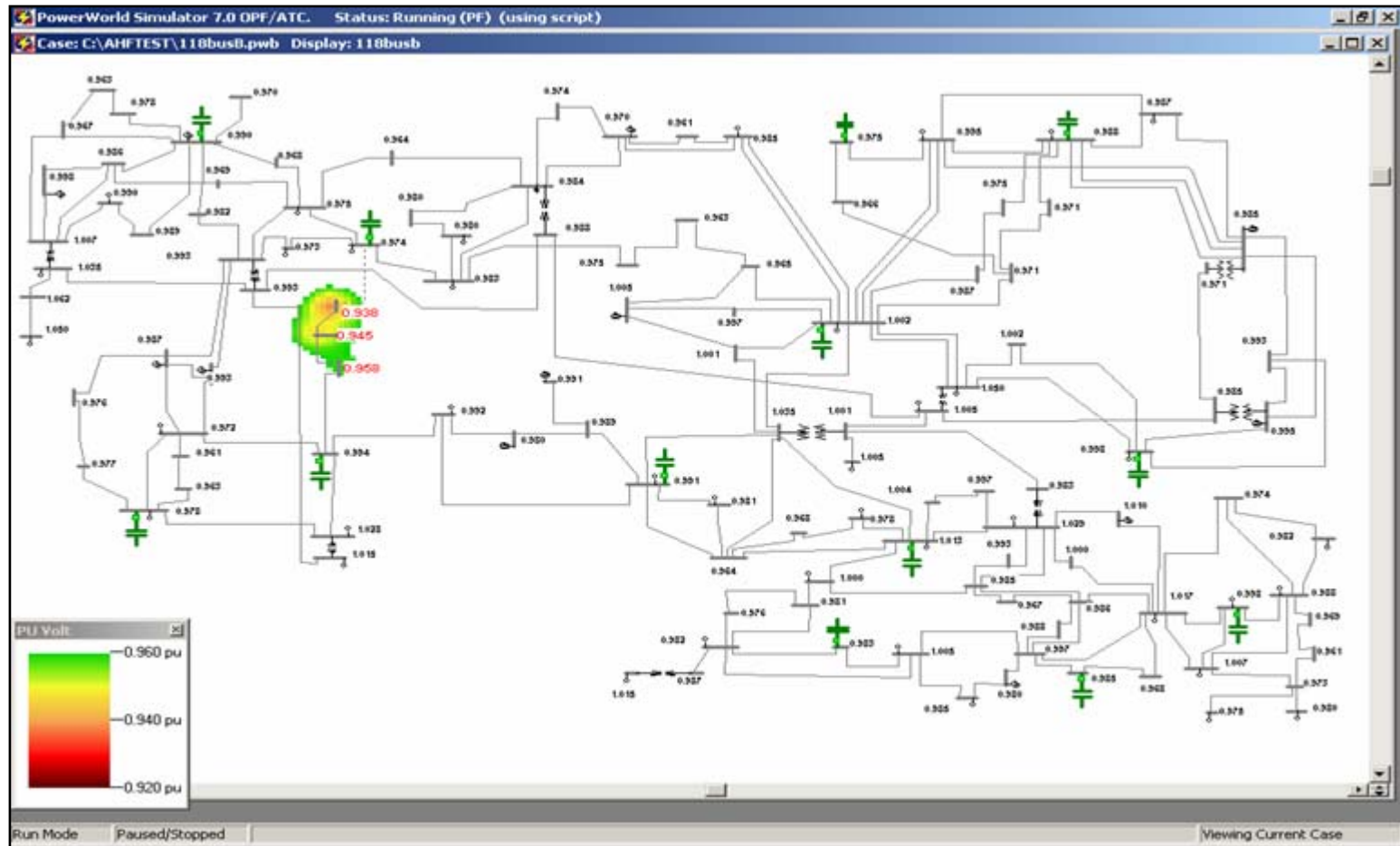


Formal Human Factors Tests are Ongoing

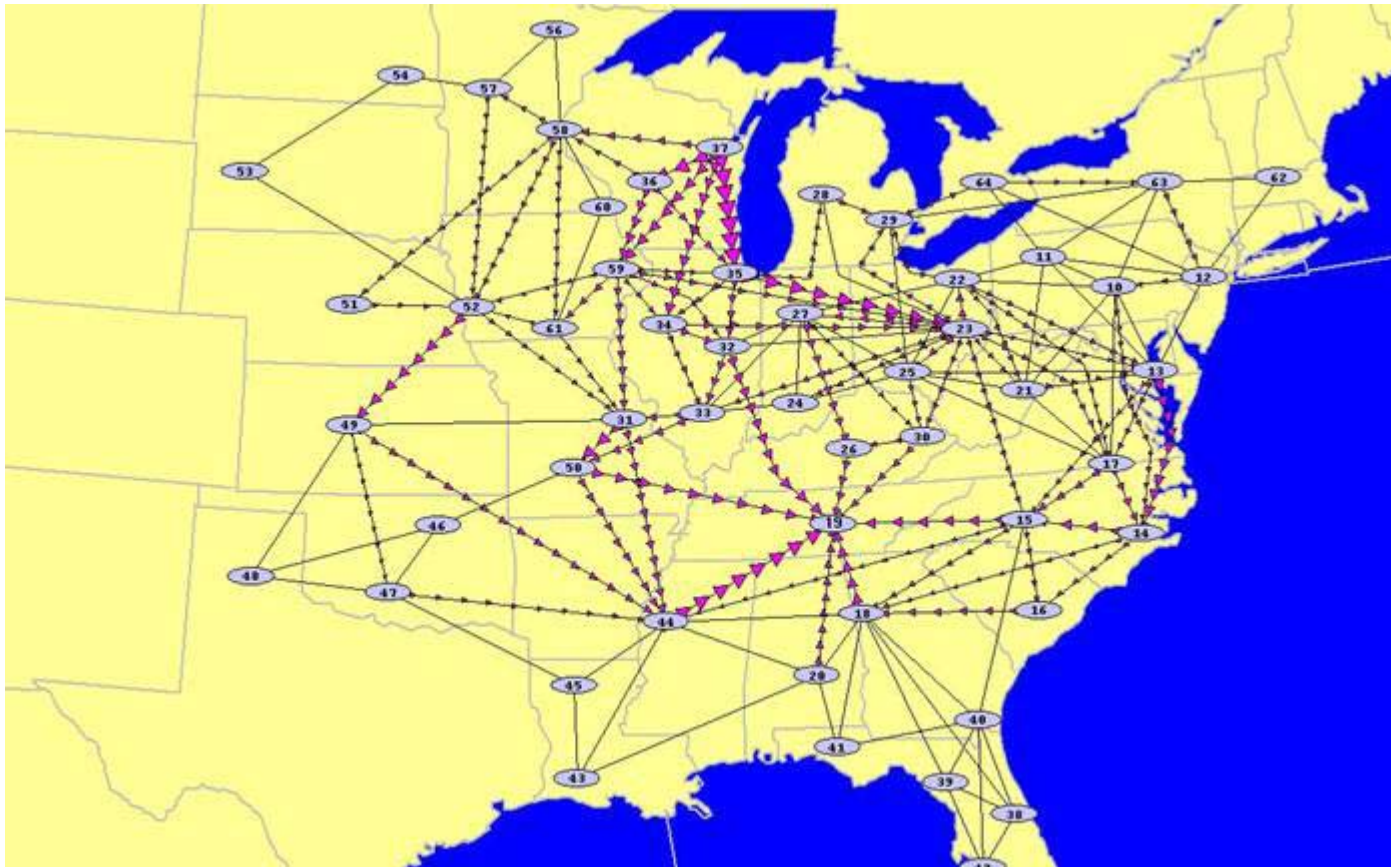
- Early experiments compared how quickly participants could acknowledge and resolve voltage violations on a one-line. One experiment tested 1) just voltage magnitudes, 2) just a color contour of voltage magnitudes, 3) a combination
- Use of color contouring was found to greatly aid in finding worst voltage violations



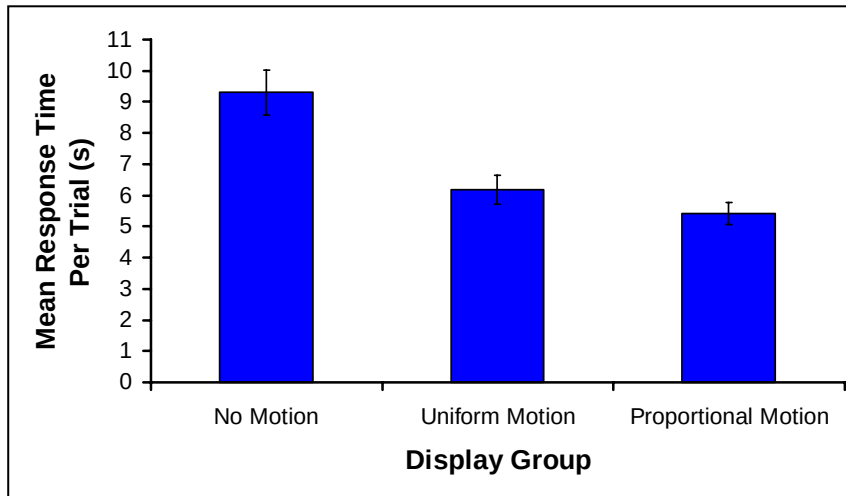
Sample Human Factors Display Screen



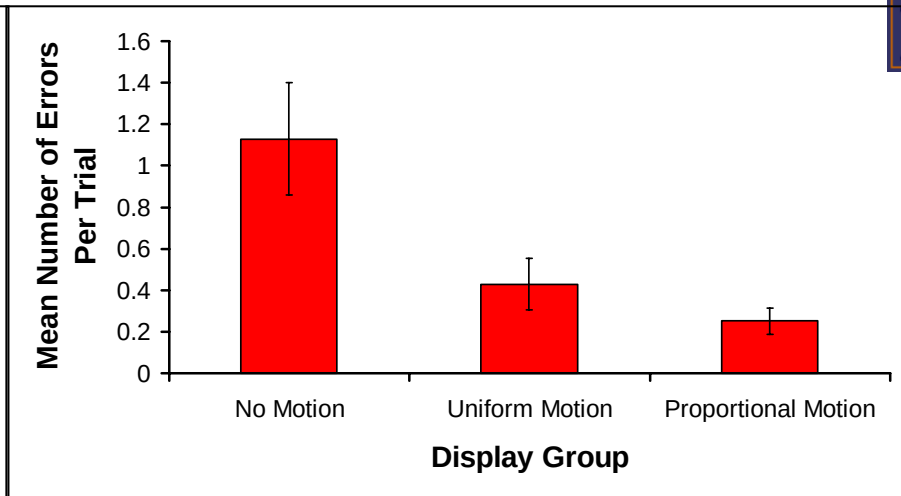
More Recent Tests have Looked at the Impact of Flow Animation



Animation Experiment Results



Time to Determine Buyer
and Seller



Accuracy of
Initial Selection

Conclusion

- PSERC developed visualizations are in control centers right now, with more installations likely to occur shortly
 - turn around time from university research to control center installation can be quite quick
- Research is ongoing to develop new techniques
- Formal human factors studies are being done