

A. Title Page

Implementation of Steady-State Power System Visualizations Using PowerWorld Simulator

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B. Statement of problem researched or creative activity

Most calculations for in-class power system analysis have been done by hand, engineering calculators and/or text-based programming software. Since late 1990s, several teaching approaches for power system analysis using power system simulation software have been developed. One of power system simulators, the PowerWorld software is utilized in this research because of the following reasons:

- It can support very powerful power system visualization techniques such as power flow animation, 3-D display and contouring [1-2].
- Currently it is one of the most commonly used power system simulators by many power utilities and in the electric power industry [3].
- It is relatively easy to teach students how to run power system cases because it provides the graphical user interface [4].

In [4], loads flow and fault analysis of a small-size power system using the PowerWorld simulator software version 10.0 was presented so that students could gain an understanding of the capabilities of this tool and obtain an “animated picture” of a typical power system.

In fact, a newly update version of PowerWorld software supports innovative and advanced visualization techniques that help students better understand what happens in a power system by graphically representing power system data. So this research introduces new power system visualization techniques such as animation, 3-D display and contouring.

C. Brief review of the research procedure utilized

1. Power System Visualization Techniques using PowerWorld - Animation

One critical key to understand the state of transmission system is to know power flows in MW, Mvar and percentage loading of transmission lines. However this can be quite difficult, particularly for large power systems. One technique is to use animation of flows to illustrate how power is actually flowing in a system. The flow of power into and out of buses is portrayed as colored arrows that move in the direction of the power transfer. The magnitude of each flow is indicated by the size of the arrows and the speed with which they move through the associated

equipment. Larger, faster-moving arrows symbolize larger power flows. The application can show real power flow (P) and reactive power flow (Q) either separately or simultaneously using different color schemes for each. Furthermore, it represents the difference in metered flow values at opposite ends of a transmission line by scaling the size and speed of the arrows along the line. This feature is important for visualizing the flow of reactive power. Additionally, the tool indicates device status using breaker-like symbols that appear solid when the device is closed and hollow when the device is open. See Figure 1.

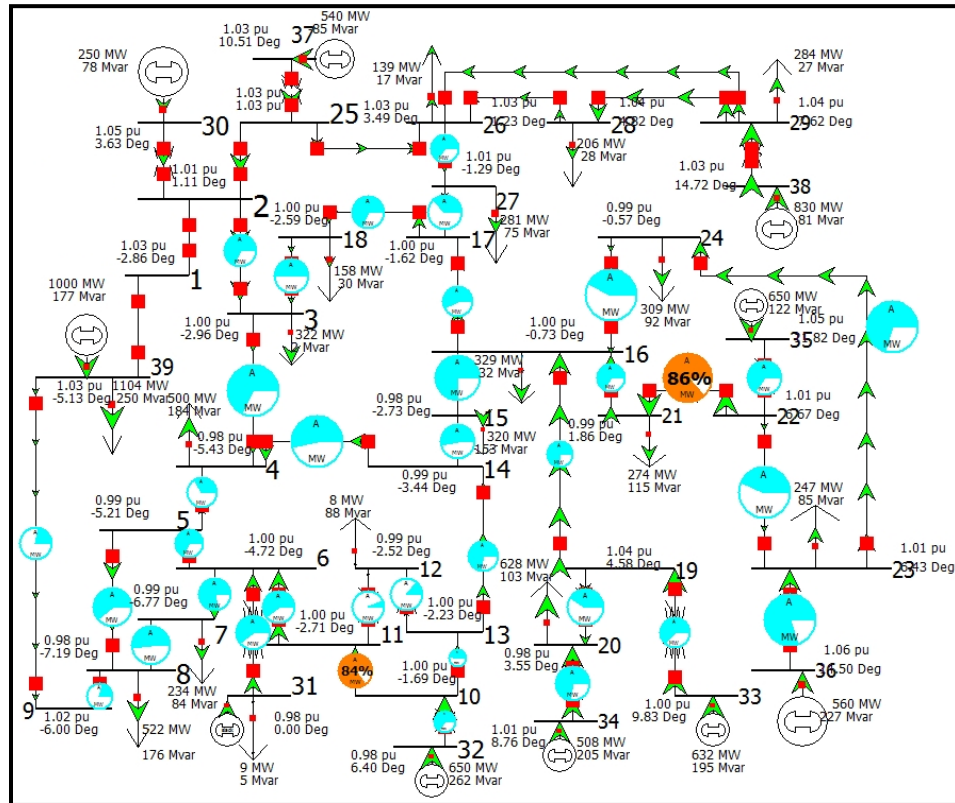


Figure 1. Animation of Power Flows on IEEE 39-bus System

2. Power System Visualization Techniques using PowerWorld - 3-D Display

Three-dimensional display can demonstrate how multiple types of quantities vary simultaneously. For example, Figure 2 uses a cylinder coincident with each generating unit and load. The height of the cylinder indicates the amounts of generating powers and capacities in MW and the amounts of load in MW and Mvar.

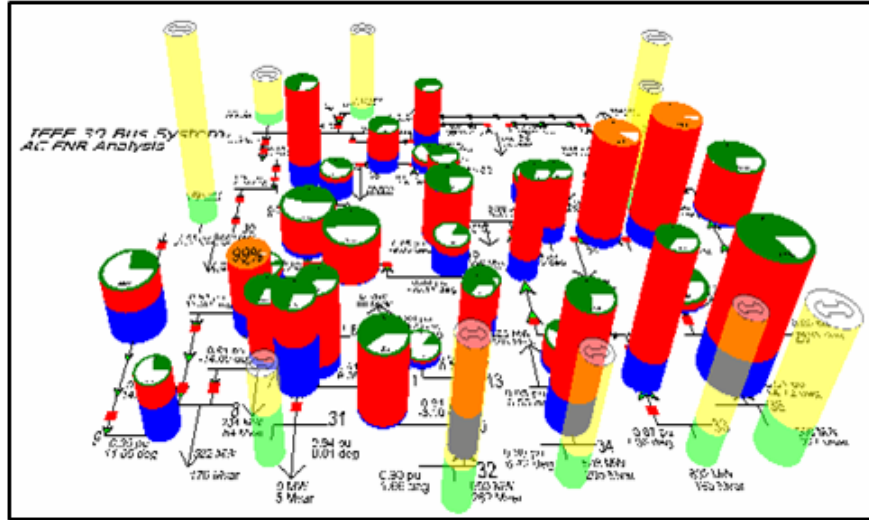


Figure 2. Three-Dimensional Display on IEEE 39-bus System

3. Power System Visualization Techniques using PowerWorld - Contouring

Contouring technique illustrates how a particular quantity varies with location. Since one-line diagrams usually reflect the geographic arrangement of system equipment, contour plots provide a valuable picture of how quantities such as voltage or transmission loadings vary across the system. This technique enables operators to pinpoint specific regions of concern when inspecting the system as a whole. See Figure 3.

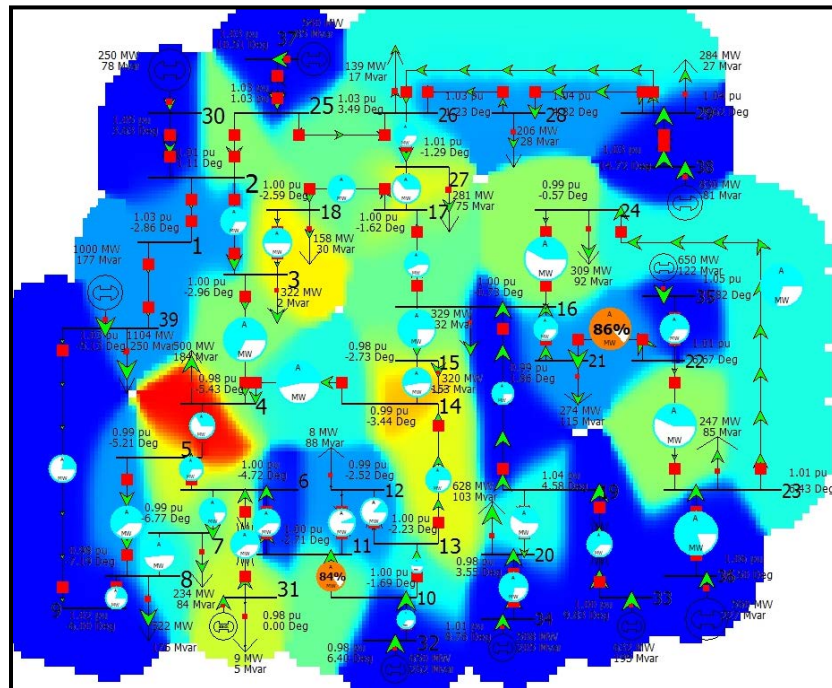


Figure 3. Contouring on IEEE 39-bus System

D. Summary of findings

Load flow analysis, one of the representative steady-state power system analyses, was performed using the PowerWorld simulator and simulation results using the advanced visualization techniques were incorporated into the power system course (ELEG 3163). The developed pedagogical procedure is shown as follows:

- Four-time classroom lectures on theoretical basics of load flow analysis
- Basic instructions and skills on how to run load flow cases on PowerWorld
- One take-home exam using their own personal computers
- Demonstration of simulation skills and results with a sample load flow case.

Upon completion of this course students were able to:

- a. Understand power system components and parameters such as generators, loads, bus voltage magnitudes and angles, line impedances and currents, real and reactive powers, bus admittance matrix, etc.
- b. Understand load flow methodology such as Gauss-Seidel method, Full Newton-Raphson method, Fast Newton-Raphson method and DC Power Flow method.
- c. Run small-size power system cases on PowerWorld and report the simulation results.
- d. Use some advanced visualization techniques such as animation, 3-D display and contouring of power flows.

The four items (a, b, c, and d) as shown above are the course outcomes to evaluate students' achievements. Students' performance for the outcome a, b, c and d was assessed based on their simulation results, demonstrations and discussions. The average grades on the power system simulation part are shown in the Table 1.

Table 1. Students' Performance for Expected Outcomes in Percentage Grade

Part a	Part b	Part c	Part d
83% / 100%	78% / 100%	88% / 100%	85% / 100%

E. Conclusions and recommendations

This research introduces the advanced power system visualization techniques supported by PowerWorld: animation, 3-D display and contouring of power flows. Such techniques were taught, practiced and discussed in the power system course (ELEG 3163) in order to visualize the results of load flow analysis. Students' performances showed that all expected course outcomes have been achieved.

REFERENCES

1. Thomas J. Overbye and Jamie D. Weber, "Visualization of Power System Data", Proceeding of the 33rd Annual International Conference on System Sciences, Hawaii, HI, January 4-7, 2000.
2. Y. Sun and T. J. Overbye, "Three Dimensional Visualizations for Power System Contingency Analysis Voltage Data", IEE APSCOM 2003 Conference, Hong Kong, November 11-14, 2003.
3. PowerWorld Simulator, PowerWorld Corporation at <http://www.powerworld.com>.
4. Frank Pietryga, "Animation of a power system using PowerWorld Simulator", ASEE 2006 Annual Conference, Chicago, Illinois, June 18-21, 2006.