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An Enhanced Approach for the Power System Course Using a Computer-Based Visualization Tool for Steady-State Power System Simulation

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An Enhanced Approach for the Power System Course Using a Computer-Based Visualization Tool for Steady-State Power System Simulation

Abstract

This paper proposes an enhanced approach for the power engineering course, as part of the undergraduate electrical engineering curriculum, using the PowerWorld power system simulator. In order to assist students' better understanding of complex phenomena in power systems, steady-state power system analysis using the advanced visualization techniques was performed. The visualization techniques helped students better understand the power system analysis problems as a supplement to traditional lectures. This paper introduces such advanced power system visualization techniques as animation, 3-D display, contouring of power flows and map data projections. Those techniques were applied in the power system course (ELEG 3163) of the electrical engineering department at Arkansas Tech University. Students' outcomes and evaluation of this class supported the learning effectiveness of this course.

Introduction

Traditionally 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 and some simulators have been utilized in new power system courses. In [1], 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 and "animated picture" of a typical power system. In [2], a new power system analysis software program using the C# software and MATLAB software was designed and developed to allow students to enhance their understanding of the power system analysis concepts. Reference [3] discusses the course contents and pedagogical approach employed to deliver the new power system course using the Power System Simulator for Engineering (ESS/E) that aids power system studies. Each of software has its own advantages and disadvantages when it is used as an effective learning tool in power system courses. However, in this paper, the PowerWorld software is utilized as a power system analysis tool because of the following reasons:

- It can support very powerful power system visualization techniques such as power flow animation, 3-D display and contouring and map data projections [4-6]
- Currently it is one of the most commonly used power system simulator by many power utilities and in the electric power industry [7]
- It is relatively easy to teach students how to run simple power system cases and even complex real-life power system cases [1].

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 paper introduces new power system visualization techniques such as animation and contouring of power flows and map data projections. Such useful techniques were explored by students in the power system course (ELEG 3163) at Arkansas Tech University. This paper also discusses students' evaluation of this course to show that this proposed pedagogical approach using the advanced power system visualization techniques is very effective.

Power System Visualization Techniques using PowerWorld

1. Animation

One critical key to understand the state of transmission system is to know power flows in MW and 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 (P) and reactive power (Q) flows 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 particularly 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.

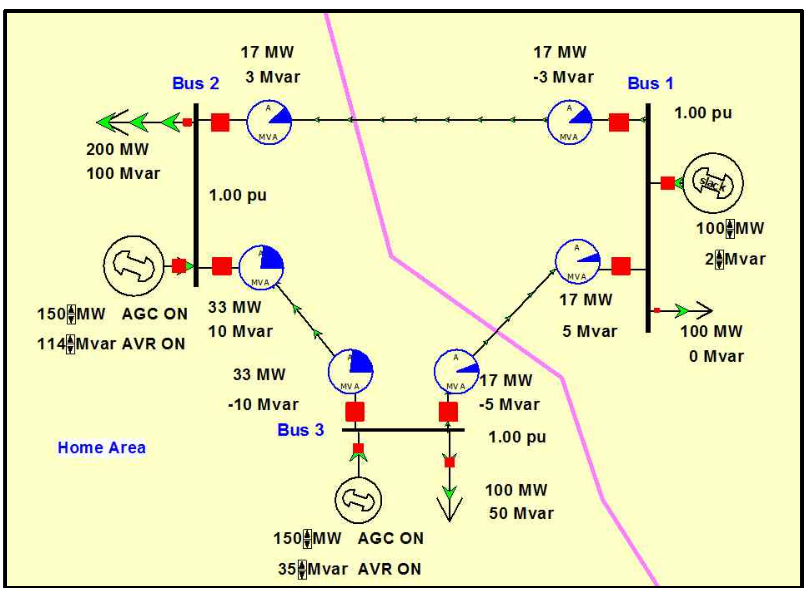

Figure 1. Example of Animation of Power Flows

2. 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. The height of the cylinder indicates the amounts of generating power and two different kinds of reserves each generator provides. Three-dimensional display also can identify critical regions and help focus problem-solving strategies.

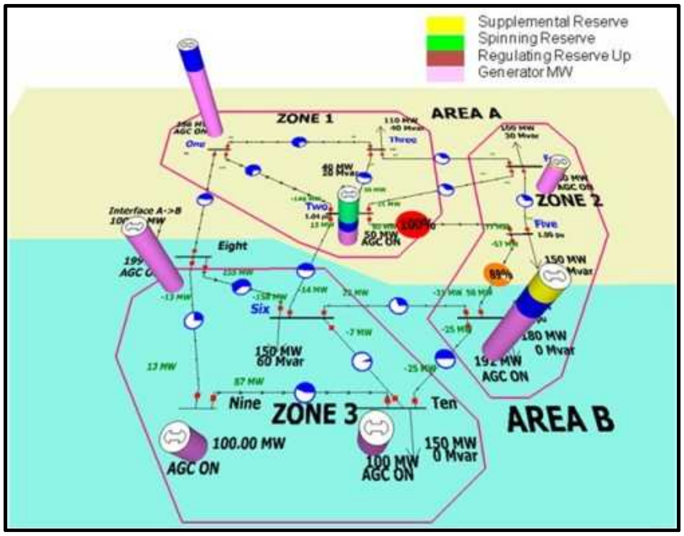

Figure 2. Example of 3-D Display

3. 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 students to pinpoint specific regions of concern when inspecting the system as a whole. Figure 3 shows a contour plot of bus voltage superimposed on a transmission system map.

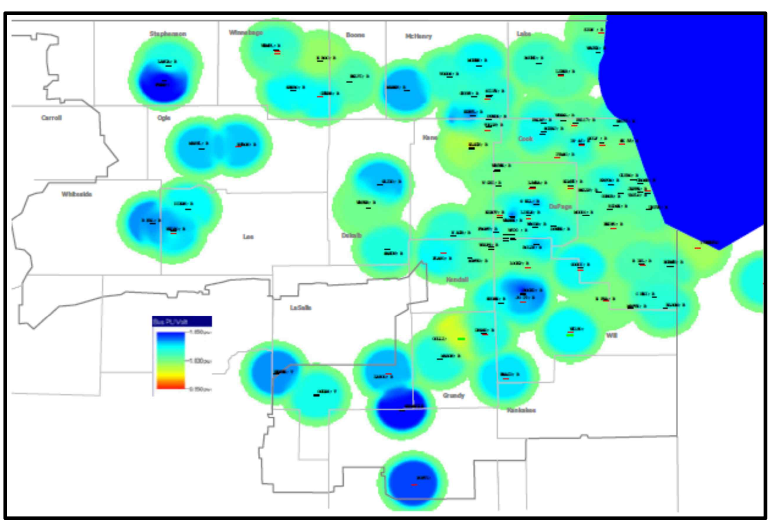

Figure 3. Example of Contouring

4. Map Data Projection

Basically one-line diagrams are used to build a power system on PowerWorld. A one-line diagram consists of symbols representing buses, generators, loads, transmission lines, transformers, switches and circuit brakers, etc. Buses can be arranged geographically; in fact, the PowerWorld software provides a tool for automatically placing buses on the one-line diagram based on their geographic coordinates. Figure 4 shows the one-line diagram and power flows projected on a middle-east U.S. map. Such map-projected one-line diagrams also allow students to pan the view port to display different regions of the system, and to zoom the view port to display a wider area or to examine a particular region more closely.

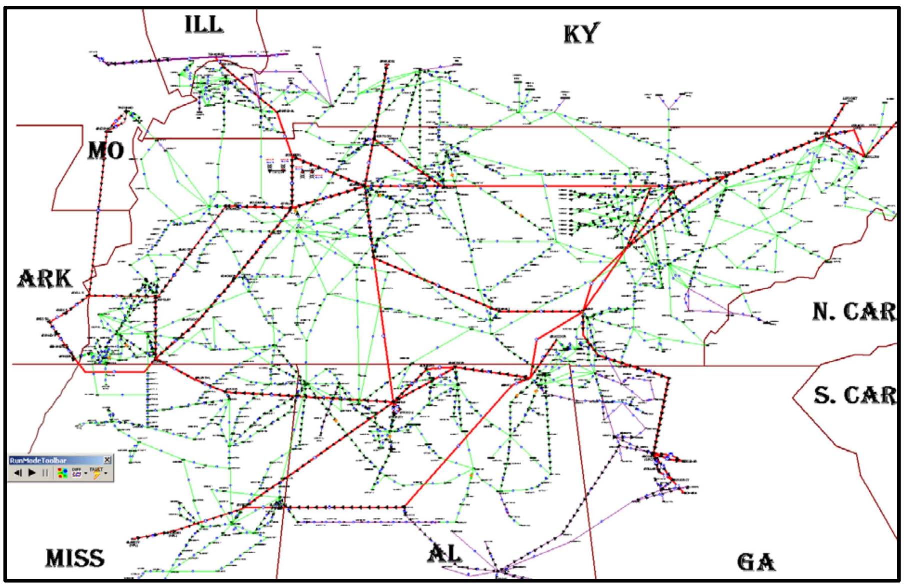

Figure 4. Example of One-line Diagram Projected on U. S. Map

Course Design and Students' Evaluation Results

1. Course Design

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 Electric Power Systems course (ELEG 3163), which is an undergraduate senior course.
The developed pedagogical procedure is shown as follows:

a. Some classroom lectures on theoretical basics of load flow analysis were delivered by traditional lectures.
b. Basic instructions and skills on how to run load flow cases on PowerWorld were introduced. Teaching assistants sometimes helped students learn and train the PowerWorld simulation.
c. Students were required to complete a take-home exam on such simulation using their own personal computers

d. Students were required to demonstrate their simulation skills and results with a sample load flow case.
e. Students were put into small groups and shared their experience with classmates and discussed about the results. Such group activities really worked. They were able to analyze the given sample power system in a comprehensive way just like professional power system operators.

2. Students' Outcomes

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, contouring of power flows and map data projections.

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 The Expected Outcomes in Percentage Grade

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

3. Students' Course Evaluation

Overall students' course evaluation for this course was 4.88 /5.0. Specifically, Almost students very positively responded to the inquiry of "the instructional aids were beneficial". The assessment in this part was 4.94/5.0, greater than overall assessment value.
More than 70% students, 18 students out of total enrolled 24 students, positively commented on the power system analysis using PowerWorld with the advanced visualization techniques. These results indicate that this course was successfully designed and the expected outcomes were well achieved by students.

Conclusion

This paper introduces the advanced power system visualization techniques supported by PowerWorld. Those techniques were applied in the power system course of the electrical engineering department at the Arkansas Tech University. This course covered the theories of load flow analyses and how to utilize the PowerWorld software for the analysis in a sophisticated manner. Achievements of the course outcomes and students' evaluation results show that the proposed pedagogical method using PowerWorld with the advanced visualization techniques was effectively and successfully applied.

Acknowledgements

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