2006-1767: ANIMATION OF A POWER SYSTEM USING POWERWORLD SIMULATOR

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Animation of a Power System Using PowerWorld Simulator

Abstract

During the junior year, the electrical engineering technology students are required to complete an introductory course in power systems analysis and design. Historically, this course was presented without requiring the use of the personal computer. This past year, the PowerWorld Simulator software [1], packaged with the text book [2] was incorporated. With the power system analysis software, the student was given the capability to model complex power systems consisting of generators, transmission lines, and rotating/non-rotating loads. The software was capable of performing a load flow analysis of a power system. Also, the students could analyze various types of faults for determination of proper circuit breaker selection and bracing of bus work and cabling. Traditionally, calculations for load flow and fault current analysis of small power systems have been done by hand and/or modern scientific calculators. With the use of the animated simulation tool, the students obtained a good “feel” of what was happening within the complex power system. While teaching this course, the instructor has not abandoned the presentation of the hand calculations of these quantities. Basic power system analysis calculations are still presented, but concepts are enhanced with the use of the simulation tool. The students gain an appreciable understanding of the capabilities of the PowerWorld Simulator after the typical hand calculations are presented in class.

This paper will examine the analysis (load flow and fault) of a simple power system using the PowerWorld Simulator software. The graphical results from the analysis will be presented so that one may gain an understanding of the capabilities of this tool and obtain an “animated picture” of a typical power system in the United States.

Creation of the One-Line Diagram of the Power System

With this software tool, the students use the provided graphical user interface (GUI) to draw the power system being analyzed. Included in the library are symbols for generators, buses, circuit breakers, transmission lines, filters, and 3 phase loads (rotating and static). The modeled power system for this paper is depicted in Figure 1. The system consists of (3) 22 kV buses, (2) generators, (3) transmission lines, (9) circuit breakers, (1) static load, and (1) power factor correction capacitor (PFC). Text fields have been provided to allow for displaying actual electrical quantities on the one-line diagram. For example, the per unit (PU) voltages and phase angles (degrees) are provided for each voltage bus. The actual power outputs (real and imaginary) are displayed for each of the generators. The actual power flows (real and imaginary) are provided for all transmission lines. The ratings of the connected load and PFC are included on the one-line as well. By careful creation of the power system one-line diagram using PowerWorld Simulator, the diagram becomes the actual report for describing the results of the simulation.

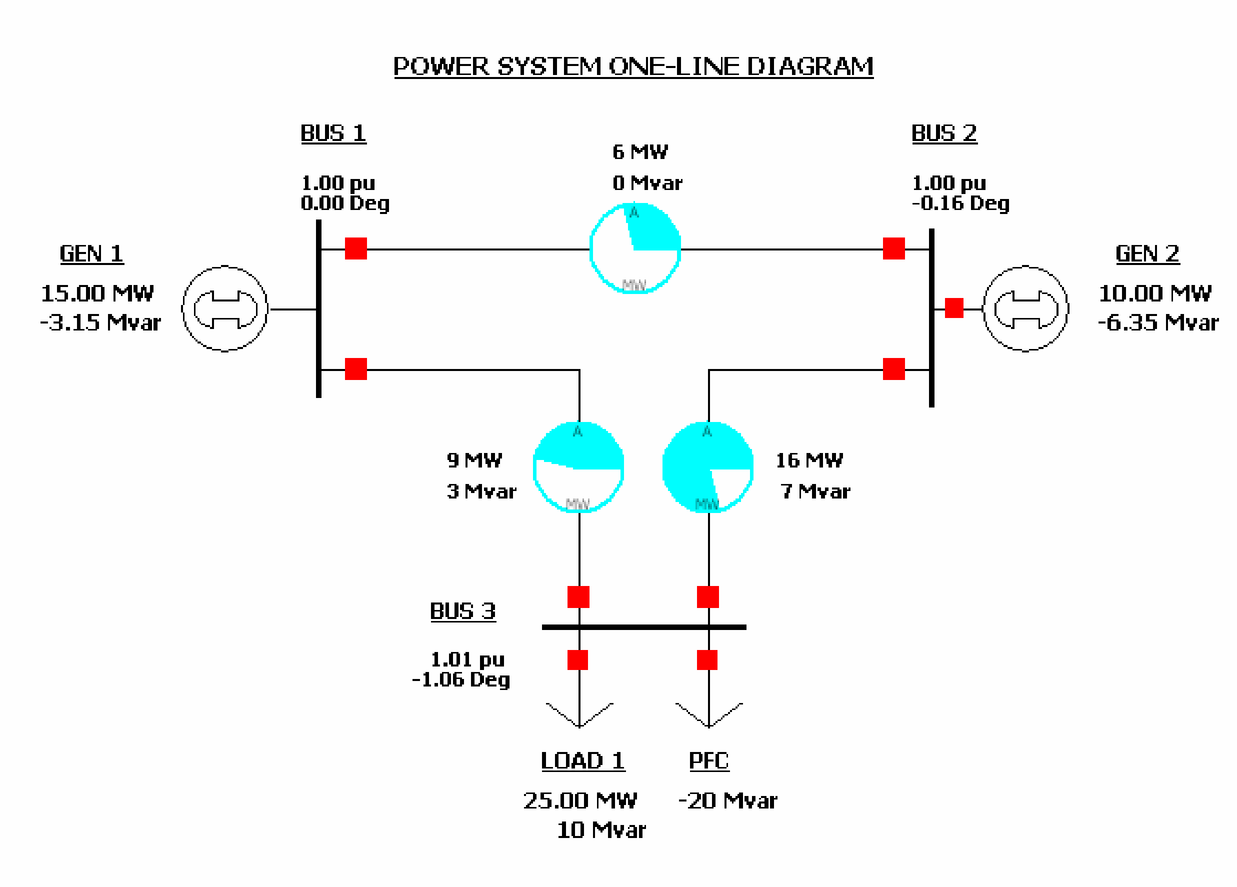

FIGURE 1 One-Line Diagram of Simulated Power System

Load Flow Analysis

After the one-line diagram of the power system is completed, the student invokes the simulation menu and chooses the type of load flow (Newton-Raphson, Gauss-Seidel, etc.) to be performed on the network. The appropriate power flow equations are solved and the voltages (magnitude and angle) are determined for each bus. The resulting power flows are shown as triangles, green for real power and blue for imaginary power. The movement of the triangles along the transmission lines depicts actual direction of real and imaginary power flow. The triangles are scaled to show the magnitude of the powers flowing on each transmission line.

Load Flow Analysis Results

A Newton-Raphson load flow analysis was performed on the power system described in Figure 1. The animated results of this load flow are shown in Figure 2. Generator 1 was set up to be the slack generator (i.e. 1 PU output voltage at 0 ° phase angle). The connected load was 25 MW and 10 MVAR (inductive). The resulting bus voltages and phase angles are shown on the one-line diagram. The resulting power flows for each transmission line feeding the connected load are also displayed. The pie charts associated with each transmission line, provide the student with an indication of transmission line loading. For this example, the resistance of each transmission line was not included, only the reactive component. The power flows (real and imaginary) for this example are in the same direction.

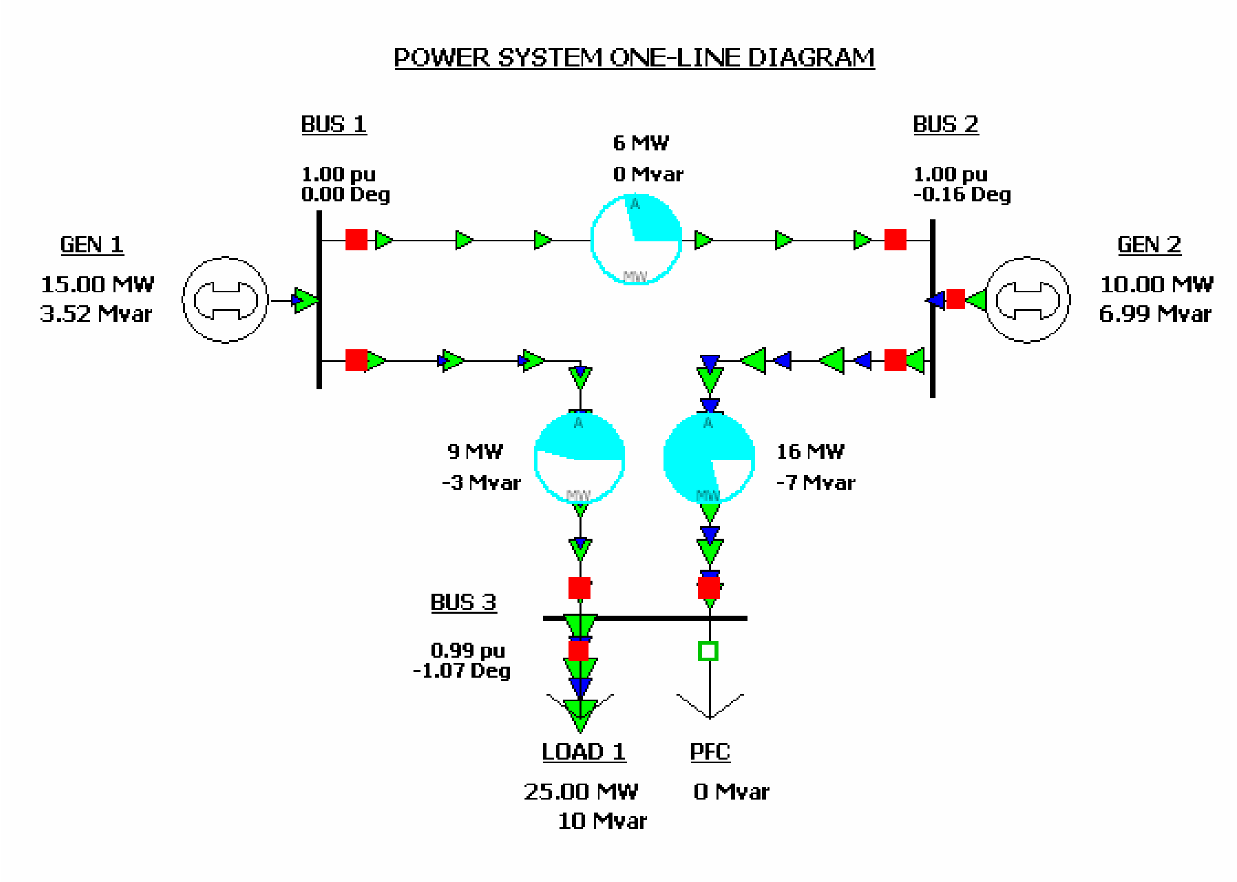

FIGURE 2 Simulation Results Using a Newton-Raphson Load Analysis

Load Flow Analysis Results with Power Factor Correction (PFC)

For this analysis, a power factor correction capacitor (PFC) rated at 20 MVAR (capacitive) was connected to the load BUS 3. The purpose of the capacitor was to increase the voltage at load BUS 3 by providing leading VARs to the power system network. The results of this simulation are depicted in Figure 3. It is easily determined from the results that the capacitor provides all of the necessary VARs to the power system network. The power flows (real and imaginary) are now opposing one another on the 2 transmission lines feeding the connected load. Also, some of the capacitive VARs are consumed by the connected load, the remaining VARs are provided to the power system network. The voltage at the load BUS 3 is increased. The student may easily switch between the 2 cases presented by opening/closing the circuit breaker associated with the PFC. With the simulator in animation mode, this is accomplished by clicking the red square associated with the PFC. All results are immediately displayed on the power system one-line diagram.

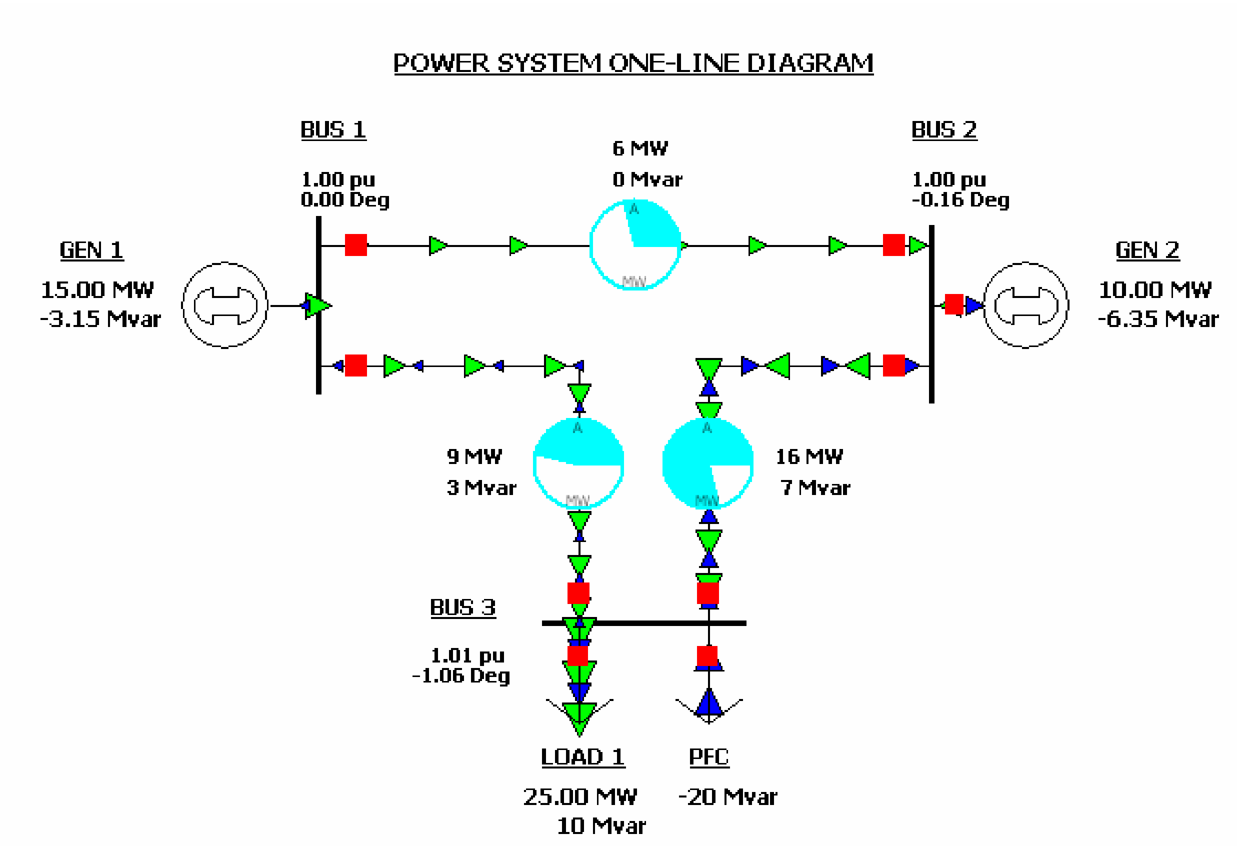

FIGURE 3 Simulation Results with added Power Factor Correction Capacitor (PFC)

Short Circuit Analysis

The PowerWorld Simulator tool also allows the student to perform an animated short circuit fault current analysis on the power system network. The provided fault calculations include balanced three-phase, single line to ground, double line to ground, or line to line faults. The appropriate short circuit sequence networks are solved and the voltages (magnitude and angle) are determined for each voltage bus. The resulting fault current flows are shown as triangles. The triangles are scaled to show the magnitude of the fault current contribution from each machine and transmission line.

Short Circuit Analysis Results

A three-phase short circuit analysis was performed on BUS 2 of the power system described in Figure 1. The animated results of this short circuit analysis are shown in Figure 4. A bolted three-phase fault was applied to BUS 2. The resulting fault currents that flow in the power system network are displayed on the one-line diagram including the contributions from all other connected equipment. Also, the resulting voltages (magnitude and phase angle) at each bus are shown. The total three-phase fault current at BUS 2 is 4, 942 Amperes. Generator 2 contributed 2, 472 Amperes to the fault, and the transmission lines connected to BUS 2 contributed 2, 470 amperes.

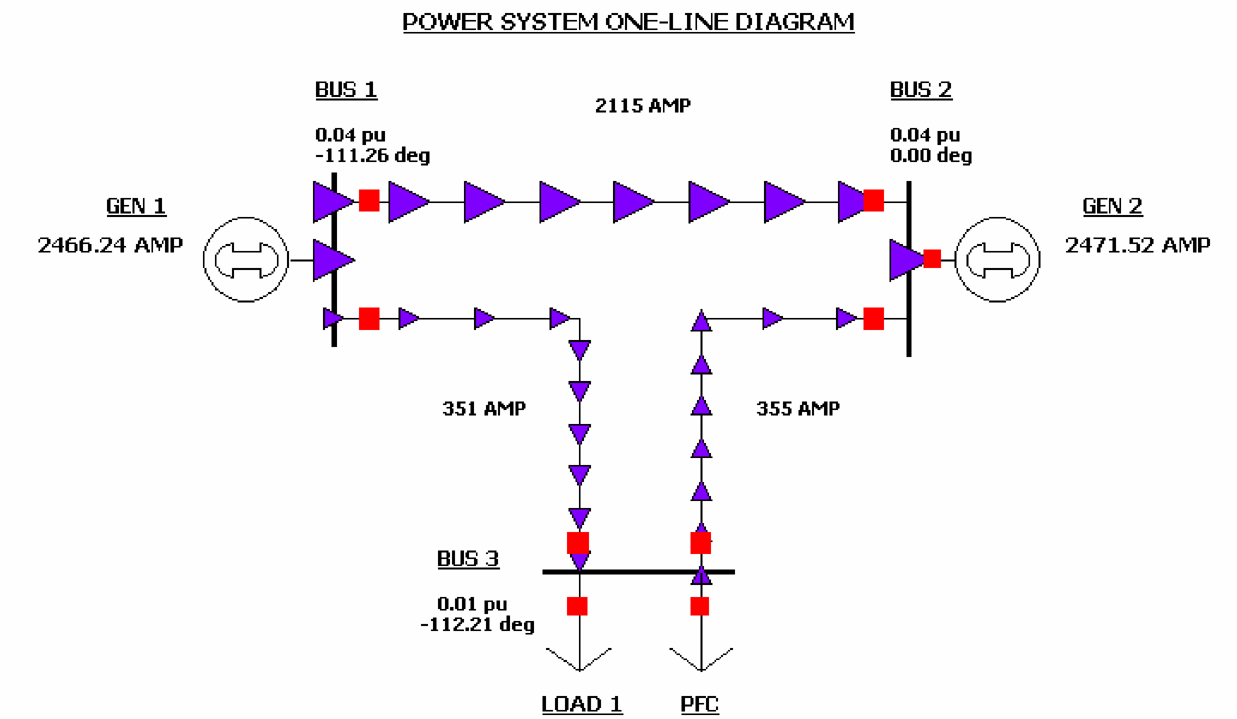

FIGURE 4 Three-phase Short Circuit Analysis of Power System

Inclusion in the Power System Curriculum

The PowerWorld simulator tool was incorporated into the Power Systems 1 curriculum several different ways which included classroom demonstrations, take home quizzes, and small group projects. Many sample load flow and short circuit analysis problems were demonstrated to the classs during the laboratory period accompanying the course. The students were required to complete several assignments using the simulation tool on their own personal computers. One particular assignment consisted of calculating the load flow solution of a simple 3 bus network by hand. Then, it was required to use the simulator tool to solve the network and compare the results to the hand calculated solution. During the latter part of the semester, students were put into small groups and given actual power system applications to model using the simulator tool. Each group worked on a unique application and was required to complete a one-line diagram of their system, present the power flow data in the traditional tabular format, and present the data with the animated format. In all cases, the power flow data was best understood with the animated format available with the PowerWorld simulator tool.

Conclusions

In this paper, the author has presented a load flow and short circuit analysis of a simple 3 bus power system using a new software tool, PowerWorld Simulator. The simulator tool greatly enhances the student's ability to visualize power flows and short circuit current contributions in a power system network. The presented analysis was created using the student version of PowerWorld simulator that is limited to 12 buses. The full version is relatively inexpensive and gives the user the capability to model much larger and complex power system networks.

Although no formal data was collected regarding the students' responses to this new tool, the course evaluations were very favorable with the introduction of the simulation tool to the curriculum. At least 75% of the students who registered for the Power Systems 1 course enrolled in the follow-up course, Power Systems 2.

Bibliography

1. PowerWorld Corporation, Champain, IL. PowerWorld Simulator Version 10.0 http://www.powerworld.com

2. "Power System Analysis and Design", Third Edition, by J. Duncan Glover & Mulukutla S. Sarma.