Effectively Teaching Power Flow Analysis Through the Use of a One-Line-Based Industrial Power Flow Program

Scott C. Dunning
University of Maine

Abstract

As multi-media software becomes the standard, commercial programmers are continually improving traditional engineering software. Unfortunately, many engineering schools are not familiar with the latest commercial programs. Thus, many topics are presented in equation form with minimal focus on actual application of the theory. Power flow analysis is often presented this way. Many schools present the theory and then ask students to write short programs in Basic or C which apply the theory. This paper presents an alternative approach to presenting power flow analysis utilizing available commercial software. The benefits of this approach are discussed along with a presentation of student feedback.

Background

Traditionally, power flow analysis has been introduced to students as a dry, mathematical derivation. The general power flow equations are derived in various texts. [1,2] So, faculty typically cover the derivation quickly in lecture and then present the iterative process.. Students are then required to develop a simple power flow program in a common computer language. This approach leaves students with a minimal understanding of how the modification of input parameters affects the output results and no experience with typical industry applications.

In the past, students on a cooperative experience with utilities have been required to perform power flow studies. Invariably, the students review the theory, read the software manual, then realize that they do not adequately understand load flow analysis. This leads to increased training time before the student can provide acceptable results.

At the University of Maine, the teaching approach to this topic was modified to alleviate these problems. First, a review of the software currently used by industry was completed. An informal survey of industrial firms and public utilities was performed to determine which products were the most widely used. Then, the most popular programs were compared to determine which program would be the most effective tool for teaching power flow analysis concepts. Desirable features were; user-friendliness, concise manual, program flexibility, easy data entry, and clear one-line representation.

Software Highlights

It was determined that EasyPower by Electrical Systems Analysis of Oregon was the best suited for power flow instruction. This program was originally developed jointly with General Electric Company. It is currently used by many industrial firms and utilities. Since the time of the survey, additional programs have come on the market that appear to have similar features to EasyPower.

There are several key features about EasyPower that made it a good choice for use in an educational curriculum. One feature is it's easy

user interface. All work is done on a one-line diagram. This is important because it provides an overview of the input data. Data entry is completed by choosing elements off a palette, placing them on the page and then entering the required information about the element. The program runs under Windows and allows for text editing and "click and drag" for all elements. This allows for a combination of data entry and one-line modification in one step. This is another important feature since it reduces the time required to enter data, draw the one-line and create different test cases.

Once the data entry is complete, users click on one button and can immediately see the power flows and bus voltages on the diagram. This is much more efficient than programs which just provide results tables. Also, when line limits and voltage limits are broken, the one line diagram highlights the problem. This prevents students from overlooking obvious system violations.

A third feature is quick convergence. The program uses an efficient algorithm which allows for quick convergence. This algorithm is very robust and will converge on a solution if it exists. There are several different algorithms currently being used in commercial software. It is advisable to offer students a robust algorithm to limit the amount of diverging cases. This leads to discouragement and lack of confidence in the software.

A fourth feature is ease of editing. Data modification is completed by double-clicking on the item in question and changing the parameter. Programs that require a Dos shell for editing are bulky and can be confusing.

Finally, the manual is well written.[3]. The author displays actual screen designs in the manual which makes makes for easy understanding.

Homework Applications

To introduce the students to the software, several homework problems were assigned for manual computation. Once the students completed the assignments, the instructor worked out the problems in lecture using the software. Problems were selected from the Stevenson's text, "Elements of Power Systems Analysis"[1]. This appeared to be quite effective since the students were able to see how easy the software solved the problems. The output from a sample problem is illustrated in Figure 1. As can be seen, the power flows are easily identified along with bus voltage and angle. Bus #3 would show up in red since its voltage is 7% below rating.

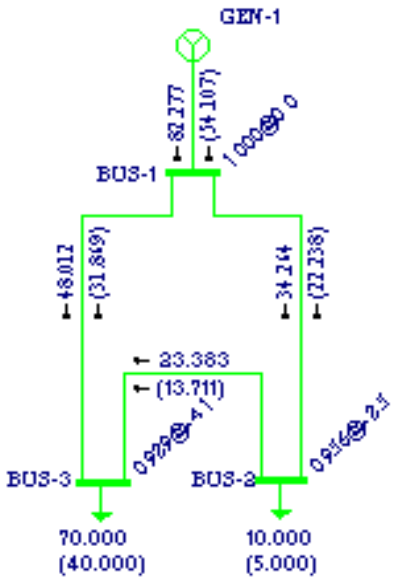

Figure 1 - Sample Output

To develop expertise with the software, further problems were assigned and the students were required to use the software to solve the problem. This allowed the students to learn program basics before trying to solve complicated system problems.

Final Project

To improve student's abilities to handle industrial problems, lectures emphasized industrial applications. Lectures included sample outputs from the software and students were asked to suggest approaches for correcting problems. This prepared them for a full scale project.
At this point a local paper company, Madison Paper, agreed to provide a copy of their system data for analysis. Madison was considering purchasing

the software and this provided an opportunity for students to develop a base data set for the company.

Students were then given the necessary data along with results from a previous study and asked to perform a complete power flow analysis. Students were required to identify problems with the current system configuration and make recommendations for system corrections.

Results

This curriculum change proved to be beneficial to both the students and Madison Paper Company. The students stated that they were very comfortable performing power system studies and many developed interest in performing them in the future. Madison Paper received the best student report and reported that they were quite satisfied with the results. As a result, this has been approved as a permanent curriculum change for teaching power flow analysis.

References

1. Stevenson, W. D. Jr., "*Elements of Power Systems Analysis*", McGraw-Hill Book Company, Inc.

2. Glover, J.D., Sarma M., "*Power System Analysis and Design*", Second Edition, PWS Publishing Company, Boston, MA, 1994

3. "*EasyPower Users Manual"*, Electrical Systems Analysis, Oregon City, OR

SCOTT C. DUNNING

Scott C. Dunning in an Assistant Professor of Electrical Engineering Technology at the University of Maine, Orono, Maine. He teaches undergraduate courses in electrical machinery and power systems. He received the BSEE and MSEE from the University of Maine. He is a licensed professional engineer in the state of Maine. He is currently Vice-Chair for the Executive Committee of the Institute of Electrical and Electronics Engineers in Maine (IEEE) and a Member of the Amercan Society for Engineering Education(ASEE).