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Experiments in Adopting Computer-Aided Learning in Electrical Engineering

Dr. Majid Poshtan, Cal Poly

Dr. Majid Poshtan obtained his PhD in EECE from Tulane University, New Orleans, USA in 2000. Dr. Poshtan has over 20 years of wide-ranging experience in EE academic and industry. He is an expert in electric power systems, transmission planning, short circuits studies and protection, condition monitoring of generators, induction motors, transformers and power cables, substation design, power system computer simulators, and Real Time simulator. Dr. Poshtan is currently a faculty member in California Polytechnic State University in San Luis Obispo, CA, USA.

Dr. Bridget Benson, California Polytechnic State University, San Luis Obispo

Bridget Benson received a Bachelor's degree in Computer Engineering at California Polytechnic State University San Luis Obipso in 2005, a Master's degree in Electrical and Computer Engineering at the University of California Santa Barbara in 2007 and a PhD degree in the Computer Science and Engineering at the University of California San Diego in 2010. She is currently an Assistant Professor in the Electrical Engineering Department at California Polytechnic State University San Luis Obipso. Her research interests span engineering education, embedded systems, and ecological monitoring.

Dr. Fred W DePiero, California Polytechnic State University, San Luis Obispo

Dr. Fred DePiero received his B.S. and M.S. degrees in Electrical Engineering from Michigan State University in 1985 and 1987. He then worked as a Development Associate at Oak Ridge National Laboratory until 1993. While there he was involved in a variety of real-time image processing projects and several laser-based ranging systems. Fred began working on his Ph.D. at the University of Tennessee while still at ORNL, and completed it in May 1996. Fred joined the faculty at CalPoly in September of 1996. He has developed CATE, the Circuit Analysis Tool for Education. Fred continues to pursue extensions and improvements to this system while using it in his courses.

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Introduction

Computer-Aided learning provides a means to enhance 3D visualizations, simulations of physical systems, and/or demonstrations of lengthy mathematical examples in a classroom environment [1-3]. This paper is about four experiments the authors conducting on adopting computer-aided learning tools in four undergraduate electrical engineering courses at 100, 200 and 300 levels at Cal Poly (California Polytechnic State University, SLO, USA). The goal of such efforts was to provide additional resources to the students beside the text to enhance the diversity of the learning process. The instructors have noticed anecdotal encouraging results from all experiments and have survey data from the third experiment illustrating adding computer-aided learning to the classroom was favored by students.

The computer software programs added to the courses were directly related to the subject and helped the students to cross check their answers obtained by mathematical equations from the text with the numerical results from the software. The software programs used in this research are provided by various sources and have different GUIs (Graphical User Interfaces), but they apply very similar numerical methods to solve differential equations in dynamic engineering problems. To get the results from the software programs, the students must build a virtual case compatible with the data provided in their assignments. The students must understand and define the topology of the electric circuit in the programs, plus they must input the relevant parameters and initial conditions before they could obtain any results. Most of the students were able to get comparable results from their hand calculation and the simulation, however, for the rest, the inconsistency of the two methods raised a flag. In such cases, the instructor checked the two results and helped the students to find possible errors.

Case 1

The first case was adopting a software, which comes in a CD with the textbook in the "Electric Power System Analysis" course. The student version of the software is also available for free from the publisher website for those who didn't purchase the book or bought a used book. The professional version of the software is for sale and is used by some electric power utilities. The method of teaching electric power systems is based on extensive use of the computer to apply the electric circuit theories in large-scale electric systems. A typical actual size power system may include about twenty thousand buses (nodes) and forty thousand lines (branches). Most problems and examples in the power system textbooks illustrate networks with a much smaller size, say a dozen electric nodes and branches. Even with such a smaller size, it is impossible to demonstrate a complete case on the classroom's whiteboard. A typical IEEE case study is shown in Figure 1.

A widespread practice when teaching this course is to assign a small size network for HW that can be calculated by hand and calculator, and a medium size network for a course project that can be calculated using computer software. The course project often asks the students to use the

software at the end of the term, which is too late for any extensive practices. This approach lacks teacher-student interaction and results in an incomplete project for most of the students.

To improve the quality of the assignments and foster learning of complex systems, the instructor adopted introducing computer-aided design within the lecture part of the course itself (akin to combining a traditional lecture with a traditional lab in a combined 'studio' course) and did so earlier in the course. The teaching was pedagogical in its principles and became popular among the students. Because of the usage of studio style for teaching this class, all of the students (instead of just a few) were able to learn how to use the computer software tools to complete the course assignment of modeling a complex power system.
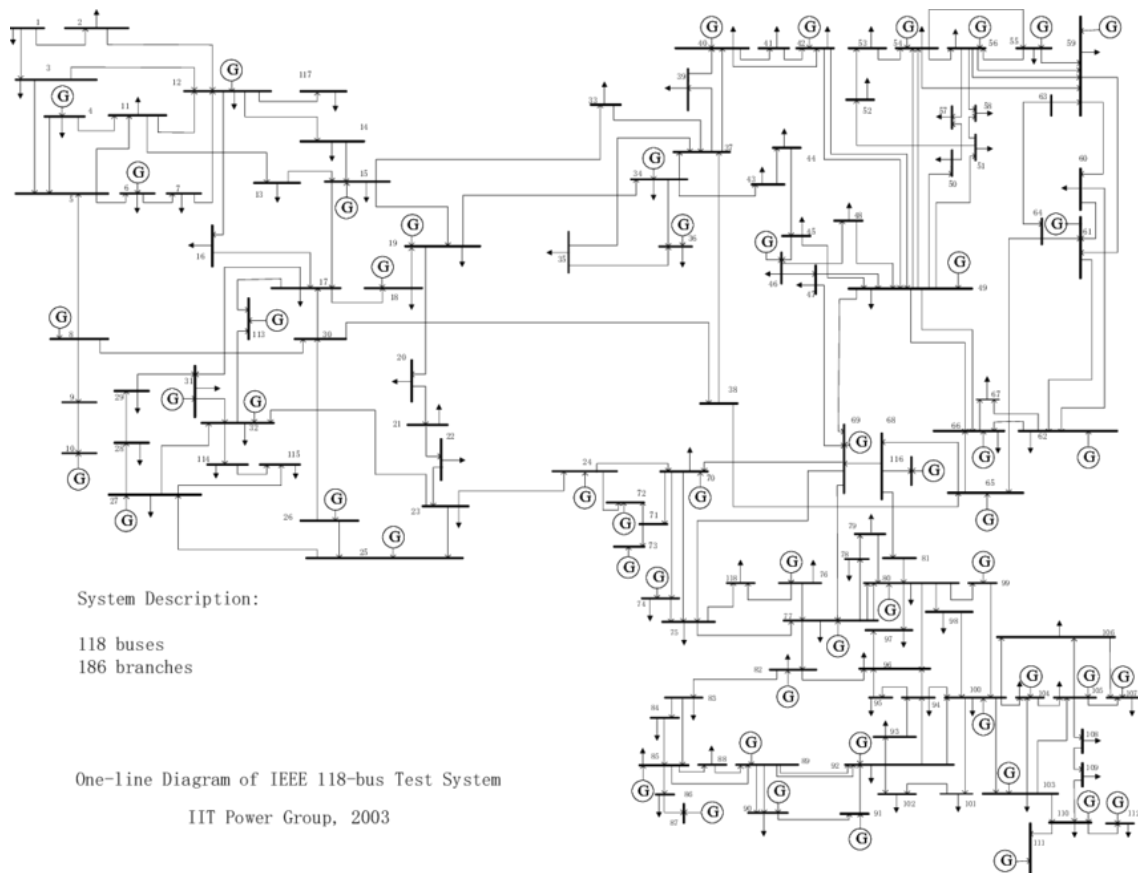

System Description:

118 buses
186 branches

One-line Diagram of IEEE 118-bus Test System

IIT Power Group, 2003

Fig.1: IEEE 118-Bus Electric Power Test System Case Study

Case 2

The second case was using a universal numerical simulator that is widely used in electrical engineering courses. The software was adopted in the "Electromagnetic Energy Conversion" course. This course is very different from the "Electric Power System Analysis" course explained in Case 1 because its content greatly deals with the physics of three-dimension electromagnetic fields. The course has a three-hour lab component as a co-requisite. The challenge in this course is about learning the dynamics of electric machines in their unstable

operation region. Not only is it difficult to study the theory of the transient stage of motors from starting point to their stable operating point, but also it is impossible to observe this phenomenon in the lab. The only existing method to observe the unstable behavior of the machine is by adopting a computer simulation with the results obtained from the lab. The result is shown in Figure 2.
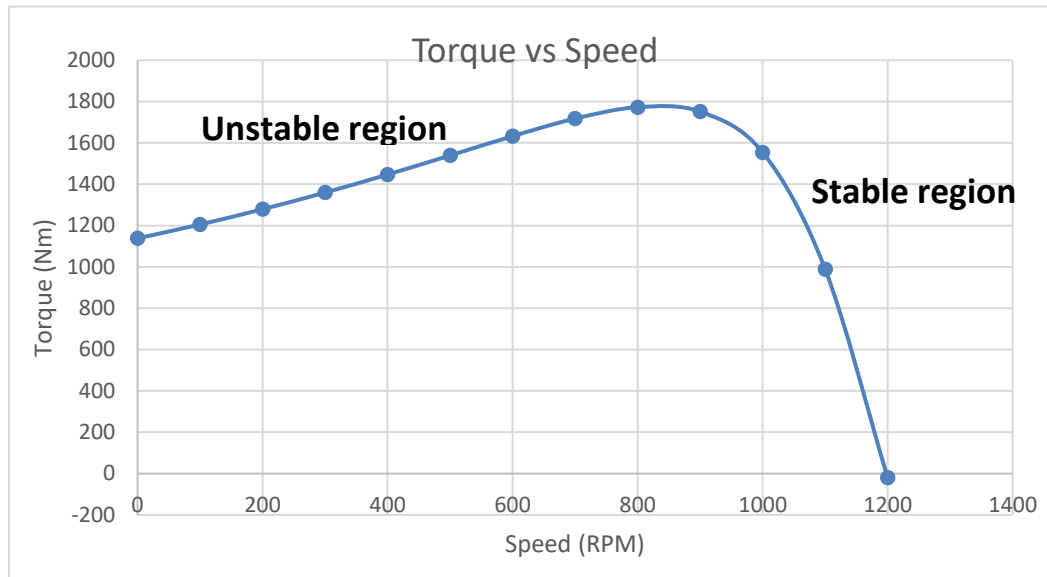

Fig.2: Combined Experimental and Simulation Result of a 350-Watts Induction Motor

The instructor used a combined demonstration of the course lab equipment and computer simulation to test a complete operation of an induction motor from its starting point to its stable operating point. Normally the students can see only observe the stable operating region in the lab (the end part of Figure 2), but with the addition of computer-aided learning, the students were able to use the data collected in the lab to run a simulation that would also show the Unstable region (the first part of Figure 2).

Case 3

The third case was using an online circuit analysis tool and free circuit simulation tool to reinforce circuit analysis techniques in an introductory "Electric Circuit Analysis" course. Introductory circuit analysis is typically taught as a 'chalk talk' where the instructor introduces circuit concepts and theorems on the black or white board and solves example circuits on the board using the concepts and theorems. Students then are assigned homework problems to solve by hand to practice these concepts. Instead of solely relying on chalkboard examples, the instructor asked her students to bring their laptops to class and introduced two software programs to the students to aid them in learning circuit analysis: CATE (The Circuit Analysis Tool for Education – a teaching and learning tool for linear circuit analysis (see Fig 3) and LTSpice (a free circuit simulation tool). These tools have been used by other instructors for Homework, Quizzes or outside of class practice (CATE) or in a laboratory environment (LTSpice) but have rarely been incorporated directly into the lecture. By incorporating the computer-aided learning

directly into the lecture, the students had the opportunity to practice circuit analysis at their own pace (CATE) and have a tool to instantly check if any of their hand-solved problems were correct (LTSpice). The students enjoyed the active learning aspect of the lecture course and became comfortable using the computer-aided tools inside and outside the classroom.
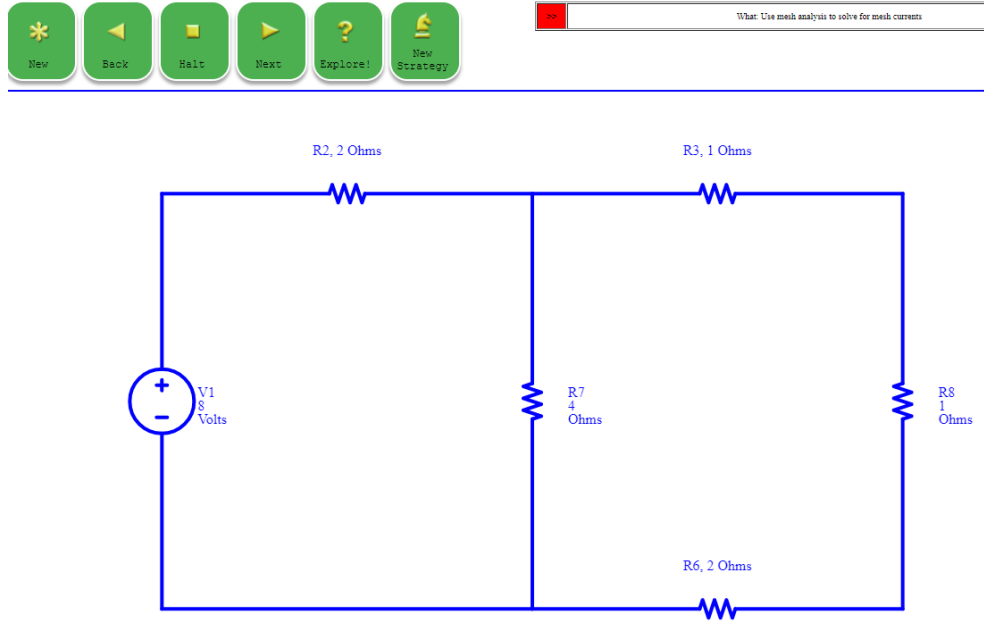

Fig.3: Example of CATE generated circuit for walking a student through mesh analysis

An anonymous survey handed out to the students at the end of class (course number EE 211) in Fall 2017 indicated that they found the class to be fun and preferred incorporating the computer-aided learning tools inside the classroom rather than using them solely outside of the classroom or in a separate laboratory environment (see Fig. 4). There were 24 students in the class, and 20 responded to the survey.
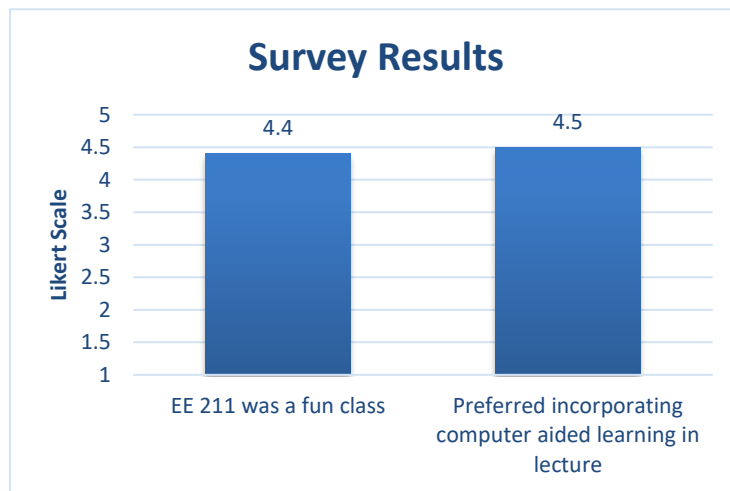

Fig.4: Average level of student agreement on a 5-point Likert scale (1=strongly disagree, 5 = strongly agree) to the given statements

Case 4

In a fourth effort, students were given weekly quiz problems outside of class using an online system. The students were encouraged to work together to solve the quiz problems, some of which were the same while other problems were distinct for each student.

This case also involved CATE, using it to generate many quiz problems for students. We set up an online system to administer weekly quizzes (assigning problems, controlling access, grading and tallying student scores). The quizzes were accomplished outside of class so as not to impact lecture time. Students were encouraged to work together. Each quiz included some problems that were common and others that were distinct. For the distinct problems, each student was asked the same question (e.g., Find a mesh current? What is the resistance seen by a source?) but they were given a different circuit. Circuit generation was constrained for example by requiring them to be solvable via mesh or nodal analyses with a specified number of unknowns. This helped throttle the complexity to provide more consistent problem difficulty.

A goal of this endeavor was to foster peer learning. Having some questions in common encouraged the students to compare results and work together. The frequent questions were intended to provide a high reward for relatively little effort in collaborating, with the hope that students might continue their collaboration for the more challenging distinct problems.

Conclusion

The authors were able to enhance their teaching material with educational computer programs in four different courses in the Electrical Engineering Department at Cal Poly, CA, USA. The embedded computer program helped the authors in such ways that were not possible before. The delivered material or the performed tasks/quizzes had difficulties in the traditional class environment. The usage of computer programs added graphics, speed, visual aid and diversity to the classes. This is more obvious in courses with roots in physics than in pure mathematics. The programs used in this paper were free and accessible to all faculty and students.

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