Session Number 3233

Electrical Engineering Concept Demonstrations and Laboratories using a Power Relay System

Noel N. Schulz, Associate Professor, Mississippi State University
Yanfeng Gong, Graduate Student, Mississippi State University
Mike Collum, Schweitzer Engineering Laboratories

Abstract

Recent issues within the power industry, such as deregulation and California's energy problems, are creating a renewed interest in careers within power engineering careers. Many schools are seeing increases in the number of undergraduates in power engineering elective courses. However, at many universities the field of power engineering is seen as a mature field with no exciting problems to solve or work on in the 21st century.

This paper and presentation will outline a joint effort between Mississippi State University and Schweitzer Engineering Laboratories (SEL) to develop several demonstrations for introductory EE courses and laboratories for the first power engineering course using a microprocessor controlled relay set-up. The goal of the project is to provide other universities with a set of demonstrations and laboratories to help integrate other electrical engineering concepts into the power curriculum to show students that power really involves many areas of core electrical engineering. Two developed laboratories will be discussed and future plans for other demonstrations and laboratories will be outlined.

Goals of the Collaboration

The decline in university support for power engineering programs across the U.S. has caused a decrease in available engineers with training on basic principles in power engineering. Additionally many entering engineers perceive power engineering as a mature field that does not relate to new topics such as computer engineering, digital signal processing, and fiber optics communications.

While electric utilities have had lower levels of hiring over the last ten years, support industries for electric utilities are becoming more prevelant on campus. Companies need students with a strong background in power engineering fundamentals coupled with other areas of expertise such as controls, computers, electronics and communications. Some high-tech power-related companies such as SEL are finding it more and more difficult to identify qualified engineers for their entry level positions. In some cases, power-related industries hire non-power engineers and provide training on power topics to bring entry-level engineers up to speed. In the case of SEL, the challenge is even tougher as they try to identify candidates with additional training related to protection and relaying. SEL has been supportive of educational initiatives to help power programs across the U.S. and world. In the summer of 2000, SEL sponsored a teaching workshop at the IEEE Power Engineering Summer Meeting to help power faculty be better teachers and hopefully attract more students.

Faculty at MSU and engineers at SEL discussed how to solve the issues of workforce as well as educating all electrical and computer engineers about the next-generation of power challenges. Microprocessor-controlled relays and other protection equipment manufactured by SEL provide an excellent teaching platform for both power engineering as well as electrical engineering classrooms. Using a protection set-up, faculty members could demonstrate many key points in fundamental electrical engineering courses relating to topics such as circuits, signal processing, communications, microprocessors, and power engineering. Also using this set-up, laboratories could be performed to demonstrate concepts relating to circuits, electronics, computer engineering and signal processing. The educational goal for these demonstrations and labs is to provide a state-of-the-art, realistic platform for applications of electrical engineering and computer engineering concepts. The goal for SEL would be demonstration to a wide range of electrical and computer engineering students the high tech side of power engineering helping to increase interest in power engineering upper-level classes and eventually creating more power engineers. Besides these lower level demonstrations and labs, advanced labs and demonstrations could be developed for senior and graduate level classes to provide aids to faculty for advanced topics in protection.

Relay Test Equipment

SEL donated a relay test system to Mississippi State in the fall of 2001. The donation included two SEL-351S relays, a SEL-AMS Adaptive Multichannel Source, SEL-5401 software package, and cables and connectors for the system. The donated equipment set is valued at approximately $15,000. SEL personnel also provided MSU with training on the system. A picture of the set-up is shown in Figure 1. The relays and source are connected to a computer for configuration, demonstration and laboratory experiments.

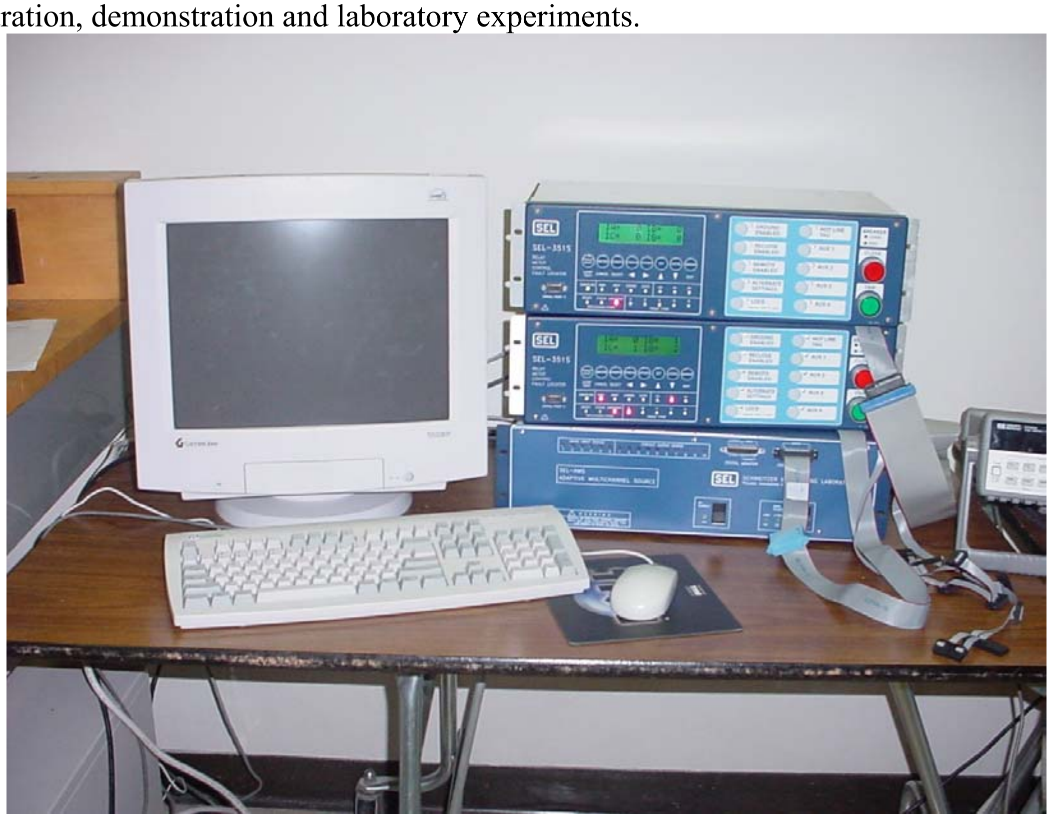

Figure 1: Relay Test System in Laboratory

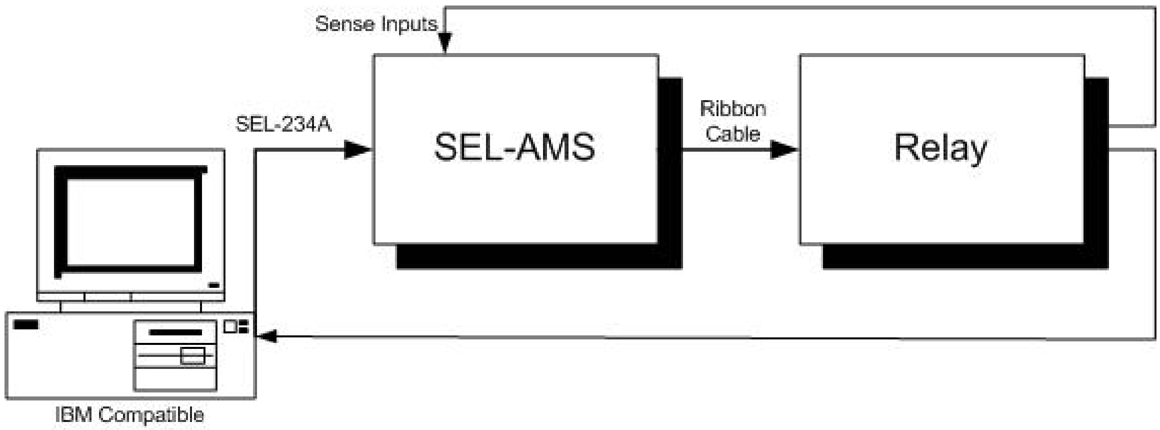

Figure 2 Interconnection diagram of testing system

Figure 2 shows a block diagram of the arrangement for the test set-up.

Protection and ECE

Since power faculty have little control on non-power required ECE core classes, it may be difficult to get other faculty to introduce topics that combine power and their subject within their classes. To solve this, the main emphasis in the required junior power course is to show the integration of all the ECE subjects within the power field with demonstrations and laboratories. We are also working with the “Introduction to ECE” first year course and “Circuits I” course to incorporate appropriate activities at these levels to demonstrate some power concepts very early on in the curriculum.

The protection test system provides many opportunities for demonstrating electrical and computer engineering concepts within one test set-up. This can be used to give students in various level classes a demonstration or laboratory to help reinforce concepts. Table 1 lists some of the topics available using the protection set-up.

Developed Labs and Future Plans

To date our collaborations have produced two laboratories for the first electric power course. This course is currently taught at a junior level at Mississippi State. These two labs are: Symmetrical Components Lab and Overcurrent Protection Lab. The current version of these laboratories is available at www.ece.msstate.edu/~schulz/protection. The symmetrical component lab gives students a chance to “play with” three phase voltages and currents and see their representation. Additionally the applications for the symmetrical component analysis are defined to help the students better understand the purposes for studying the topic. The students get a brief introduction in this class but will need a solid background for the senior level power electives. Figures 3 and 4 show several of the screen shots related to the symmetrical components lab.

Table 1: Connections between ECE Topics and Protection Test Set

ECE Topic	Related to Protection Set	Appropriate Course(s)
Circuits	- Three phase circuits (show voltages and currents - Simple fault analysis (RLC) - Phasor representations and applications	Intro to ECE: Applications Circuits: all Intro to Power: More Details
Electromagetics	- Current Transformers for sensing current	Intro to ECE: Applications Intro to Power: all
Controls	- Setting the various protection schemes - Based on a signal and logic, opening a circuit breaker	Intro to ECE: Applications Intro to Power: More Details, lab
Signal Processing	- Inputting signal to represent three phase quantities. - Evaluating signal to determine a fault as quickly as possible	Intro to ECE: Applications Intro to Power: More Details, lab
Communications	- Pilot schemes – relays talking to each other by fiber optics	Intro to ECE: Applications Intro to Power: More Details, lab
Digital Logic	- Can set up Boolean operations to determine control schemes	Intro to ECE: Applications Intro to Power: More Details, lab
Microprocessors	- Part of system, see controlling aspects	Intro to ECE: Applications Intro to Power: More Details, lab
Advanced Protection Concepts	- Different schemes	Senior power electives

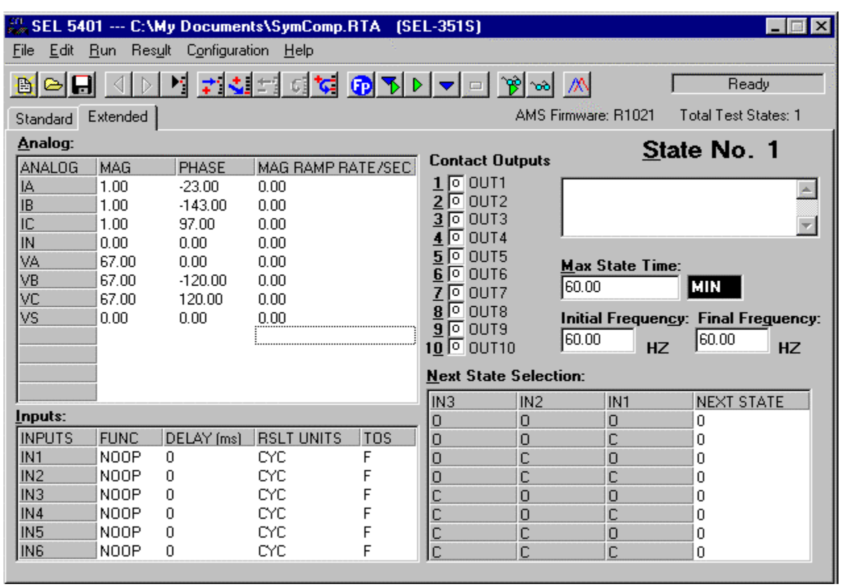

Figure 3: Screen shot of software noting output values for source voltages and currents.

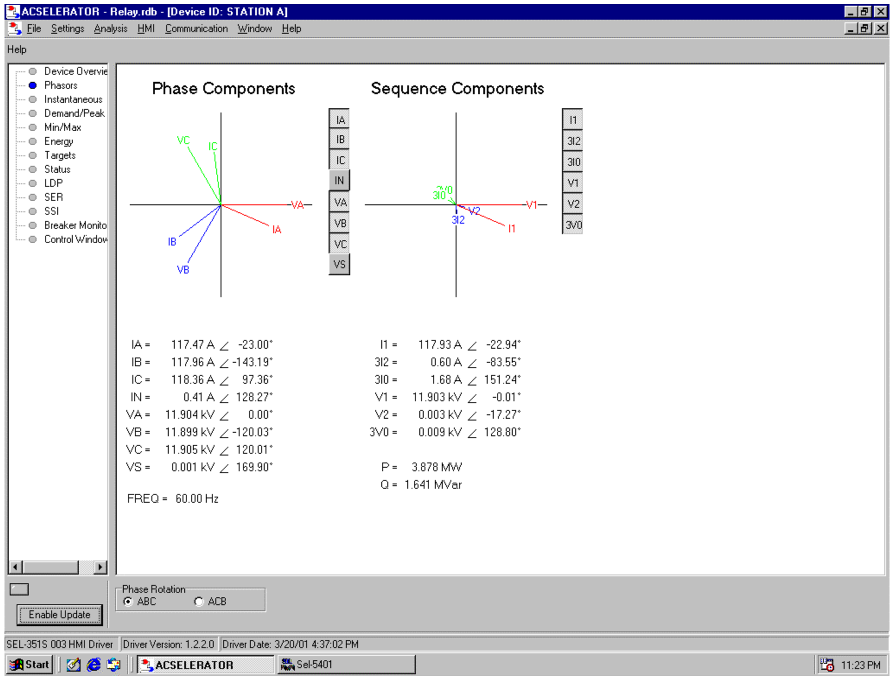

Figure 4: Phasor representations of the phase and sequence values.

The second lab for the introduction to power course relates to overcurrent protection. Most students can relate to fuses and circuit breakers within a home and this concept is extended for this laboratory. A brief background extends the power systems concepts covered in the classroom to help the students understand the issues related to how the relay test system works. Students are also introduced to the concept of time-delay overcurrent relays and how the magnitude of the fault impacts the timing for opening of the circuit breaker. This laboratory combines concepts related to logic, control, signal processing and circuits. Figures 5 and 6 show the screen shots related to this laboratory and show issues related to logic values (at the bottom) as well as the fault signals and reactions depending on the settings of the relays.

For the laboratory demonstrations it is suggested that up to four students participate in a lab exercise, with two being an optimal sized group. It is estimated that graduate teaching assistants can usually develop background on the relay test configuration in about two weeks and that a faculty member could become familiar with the test set up for a demonstration in approximately four hours or one afternoon.

Both laboratory exercises are being tested this semester with two classes: the junior-level introduction to power class and senior-level power engineering elective class. Both classes have performed the symmetrical components laboratory. The juniors had a very favorable response on the exercise based on informal exit surveys. Additionally the senior students were enthusiastic about the laboratory as it was presented at the same time as symmetrical components and introduction to fault studies in the classroom.

These two laboratories enable some advanced power systems topics to be introduced through a laboratory experience without taking too much time from course material. They also allow students to see the applications and understand where the fundamentals are used and why they are learning the topics within class.

Future planned laboratories and demonstrations include:

- "How it works" demonstration with broken and opened relays for Intro to ECE class
- Short circuit demonstration and/or laboratory for circuits class
- Microprocessor and Controls in Protection: demonstration for Intro to ECE class and lab in intro to power course
- Three phase and phasors demonstrations for circuits class
- Signal Processing and Communications Applications in Protection using a pilot scheme: demonstration for Intro to ECE class and lab in intro to power course
- Senior protection demonstrations/laboratories for general power systems class

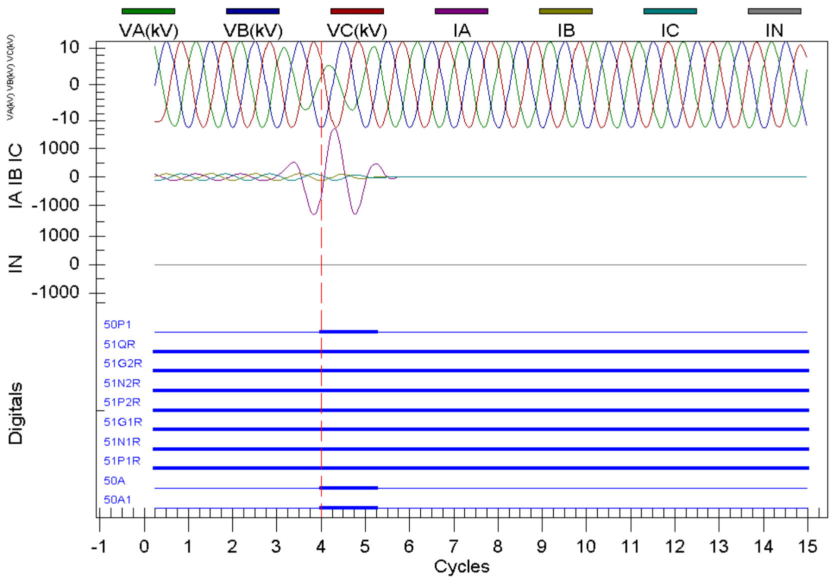

Figure 5 Instant overcurrent relay event report for one test scenario

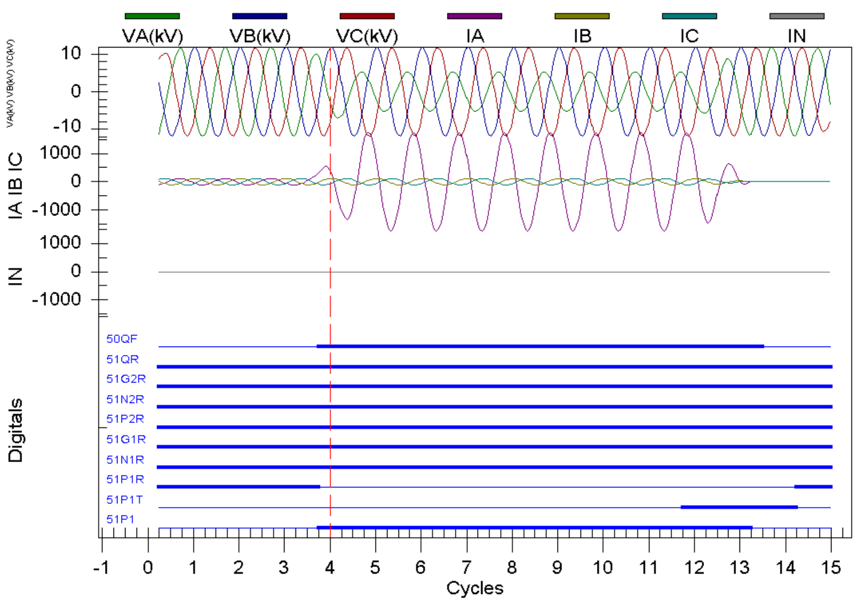

Figure 6 Instant overcurrent relay event report for second test scenario

Resource Materials

After development, testing and revisions, resource materials will be developed for each laboratory and demonstration for distribution via the web and through power meetings. Current plans include an instructor's manual including solutions and an information sheet to be distributed with each demonstration. The demonstration sheet would include one page that explains the relay and one page that explains the related demo. Four sheets will be designed – one for each level of student (freshman, sophomore, junior, senior). The sheets will include references and where to go to learn more. Besides the general information sheets for the demonstrations we are also developing two page handouts for the following topics as they relate to protection:

Sophomore Level
- Phasors
- Three Phase Circuits

Junior Level
- Digital Signal Processing
- Controls
- Communications
- Microprocessors

More updated information will be available as developed at www.ece.msstate.edu/~schulz/protection. SEL is willing to work with various universities to provide a test set-up. For more information, please contact one of the authors.

Summary

This paper has outlined a joint effort between Mississippi State and SEL to develop several educational modules to enable a protection set-up to be used to highlight and demonstrate ECE concepts within a power context. The goal of the project is to develop materials to enable faculty to easily incorporate this set-up into the classroom. Using these demonstrations and laboratories, we hope that more students will see the diverse opportunities with power engineering and choose a career in power engineering. The authors welcome suggestions and other collaborations related to this subject.

Acknowledgements:

The authors would like to thank Schweitzer Engineering Laboratory (SEL) and in particular, Ed Schweitzer, CEO for their support of educational activities at universities including the project to develop educational laboratories and demonstrations.

Biographical Information

Noel N. Schulz is currently an Associate Professor of Electrical and Computer Engineering at Mississippi State University. Prior to teaching at Mississippi State, she was on the faculty at Virginia Tech, the University of North Dakota, and Michigan Technological University. She is active in the IEEE Power Engineering Society and ASEE. E:mail: schulz@ece.msstate.edu

Yanfeng Gong received his BSEE degree from the Wuhan University, Wuhan, China, in 1998 and his MSEE from Michigan Technological University, Houghton, MI in 2002. He is currently a Ph.D. candidate at Mississippi State University, MS. His research interests include computer applications in electrical power systems and power system protection.

Mike Collum, P.E. started working with Schweitzer Engineering Laboratories, Inc. in 1997 as a field application engineer. He is currently the Regional Service Manager for the Southeast out of Tupelo, Mississippi. For 11 years prior to joining SEL, he was director of planning and protection for South Mississippi Electric Power Association. Mike graduated from Mississippi State University with a BSEE degree. He is a registered professional engineer in the State of Mississippi.