cigré
21, rue d'Artois
F-75008 Paris

Session - 1998


LUC 1-04

# ADVANCED POWER ENGINEERING EDUCATION USING DIGITAL SIMULATION

by

M. KEZUNOVIĆ*
Texas A&M University

(United States)

**Summary** - This paper provides a view regarding new requirements for power engineering education as well as impact that those requirements may have on education in the future. An increased interaction between academia and industry is recognized to be one of the most important components of the future enhancements in the power engineering education. A recently funded project in the education area is used as an illustration of possible approaches to accommodating the required changes. Future use of the simulation technology in the education process is promoted as a powerful approach to the enhancements. An example of a consortium relationship with industry is discussed as a possible direction for long term industry involvement in the education process.

**Keywords:** Education-Power Systems-Power Electronics-Digital Simulation

## 1. INTRODUCTION

TAMU's Power Engineering Program offered through the Department of Electrical Engineering is an example of a well established power engineering education activity with over one hundred undergraduate and graduate students in attendance each year [1]. The traditional nature of TAMU's Power Engineering Program is representative of the power engineering education in the USA. The program includes both power systems and power electronics topics. It offers 5 standard undergradute courses (Power System Analysis I and II, Electromagnetic Energy Conversion, Electronic Drives, and Power Electronics) and over a dozen graduate courses in various areas of power system control and protection as well as power electronics and electronic drives. With ten Faculty engaged in the program, this makes this program one of the largest in the nation and hence a sizable experiment for the continuous justifying of its role and reinventing of the means of adjusting to the prevailing educational needs.

One of the main challenges that has greatly affected power engineering programs in the USA, such as the one at TAMU, is the introduction of the new paradigm in the utility industry: deregulation and increased competition. As a consequence, the National Science Foundation together with the Electric Power Research Institute issued a request for proposal (RFP) for projects to enhance power engineering education to accommodate the changes. Under this RFP, TAMU was awarded together with Washington State University, a joint project for the MERIT 2000 proposal [2]. The proposal has financial support and participation of four major utilities and four vendors. This provides for close cooperation between the researchers and industry representatives. This paper gives assessment of the emerging requirements and their impact on the education as seen from TAMU Power Engineering Program's prospective. Examples related to the possible approaches to the education enhancement are discussed. The goals of the MERIT 2000 project are introduced promoting the simulation technology as an important ingredient of the improvement process. The TAMU's model of cooperation with industry, as a way of continued probing of the possible directions for further changes, is also presented.

## 2. EMERGING REQUIREMENTS

Introduction of deregulation in the utility industry in the USA and other parts of the world has been observed by the academic institutions at different levels of interest. They are ranging from one extreme of denying that deregulation has any substantive potential impact on power engineering education to the other extreme of assuming that the power engineering education will have

* Dept. of Electrical Engineering, College Station, TEXAS 77843-3128

to be totally transformed. The midstream views were quite unanimous that a change is required, but there was no agreement as to what the extent of the change or its direction should be [3].

The TAMU's Power Systems Group has taken the view that the introduction of deregulation and industry competition may change the whole paradigm of power engineering education, and hence an urgent need to adjust to the new paradigm has been expressed through the MERIT 2000 project goals. The simplified model for the paradigm can be represented as given in Figure 1.

> De-regulation→Utility Competition→New Industry Paradigm (Customer Focus) →New Engineer Profile (Versatile Industry Needs) →New Student Profile (Multidisciplinary Education Goals) →New Education Paradigm (Customer Focus) →University Competition→ **MERIT 2000**

Figure 1. Model for the Change in the Paradigm.

The main shift in the paradigm has been from a limited scale competition in the industry in the past to the sweeping customer focused competition in the future. As a consequence, a major change in the education paradigm has been focused on moving from the traditional general service role to a new customer (student) focused competitive role. It needs to be recognized that this view of a competitive environment in the universities may not be universally acknowledged as a viable assessment of the needs and requirements. This paper makes this point of view as a premise for further presentation of some important issues.

As a consequence of the changes caused by deregulation and increased competition, a variety of distinct components of the competence profile for the technical staff have been recognized by the industry. These profile components are summarized in Table I pointing at the reasons for each of them.

As a result of the mentioned industry changes, a variety of the impacts of the changes on the power engineering education are discussed next.

## 3. IMPACTS ON POWER ENGINEERING EDUCATION

The competitive environment in the utility industry has produced a variety of strategies being developed by various Academic Institutions to cope with required adjustments. TAMUS's Power Engineering Program has defined the following three components of the strategy:

- Make appropriate changes in the curriculum
- Develop state of the art laboratory infrastructure
- Secure close ties with industry

Table I. New Components of the Industry Staff Profile Introduced by Increased Competition

| Profile Component | Competitive Reasons |
|---|---|
| Multidisciplinary Engineering Background | The industry is becoming technology driven with a strong emphasis on automation and cost reduction. |
| Customer Relation Skills | The industry is focusing more on the specific customer needs with a tendency to diversify services and maximize profits. |
| Team Work Attitude | The industry is expecting more coherent and flexible professional teams aimed at offering more efficient and profitable services. |
| Business Background | The industry is promoting a bottom line approach to any future investments targeting reduction in operating and capital cost. |
| International (Global) View | The industry is expanding its investments in the global international markets to diversify its financial portfolio. |

This section of the paper is devoted to discussion of some basic premises for each of the strategy components. The role of the simulation technology being a major ingredient of the strategy is also presented.

### 3.1 Changes in the Curriculum

Having in mind the new engineers' profile discussed in Table I, it was felt that the curriculum needs to be reengineered to include more interdisciplinary subjects and technology flavor [4]. A definite need to create an industry-like environment with enhanced interaction among students and extensive lab experience was also recognized. At the same time, it was important to preserve the core goal of teaching the power engineering fundamentals where new methodology for facilitating this teaching goal would need to be developed.

A lot of thought was given to the non-engineering skills and experiences such as personal communication, teamwork and customer relation that the engineers need to learn. It was concluded that these skills and experiences are very important and should be incorporated in the process of teaching rather than being taught as separate curriculum subjects. On the other hand, fundamental knowledge in the areas of business and marketing as well as social and political issues that may be of concern to the engineers working in a deregulated highly competitive market, was considered important but not fitting into the power engineering curriculum. It was decided that the students should be encouraged to take the courses in those areas offered by the departments specializing in those disciplines.

With the basic goals outlined, a single but very important question was identified: if there is a fixed number of credit hours available to teach the power engineering subjects, how can the enhanced breadth and the required depth of the fundamentals both be accommodated at the same time.

After an extensive search for an answer, it has been found that the introduction and extensive use of advanced simulation technologies may help in answering the above mentioned question. It was envisioned that the use of the simulation technology in both the classroom and in the labs can help in achieving some of the mentioned goals. While it can assist in reducing the time required to teach some of the subjects, it also allows for the additional time needed for introducing some new subjects. The areas of possible improvements and description of the intrinsic features coming from the use of the simulation technology are given in Table II.

Table II. The Benefits of Using Simulation Technology

| Possible Improvements | Intrinsic Features of the Simulation Technologies |
|---|---|
| Enhanced Understanding of the Fundamentals | Simulation enables sensitivity studies and detailed representation of complex phenomena which leads to better grasping of the fundamentals. |
| Joint Student Projects | Simulation requires selection of appropiate data, models, and engineering trade offs between performance and accuracy which can be defined as separate tasks for different individuals on the same project. |
| Industry-like Skills and Experiences | Simulation provides an ideal environment to study practical problems without requiring physical industrial installations. |
| Savings in Classroom Teaching Time for a Selected Topic | The process of writing the required equations to explain various complex issues can be readily simplified by visualizing the problems in a more efficient way using simulations. |

### 3.2 State of the Art Laboratory Infrastructure

The power engineering education, to be competitive, needs to familiarize students with laboratory facilities that they may use as they enter industry jobs. This goal is not new and was always a subject of great concern to the power engineering programs. However, the cost of providing elaborate laboratory infrastructure, matching the industry standards, was always excessive and for the most part not affordable for academic institutions.

The role of the simulation technology enabling construction of relatively low cost digital power system simulators can be explored in the future. This technology is quite affordable and can be conveniently implemented in the academic institutions since it only requires a computer, appropriate application software, and possibly some interfacing hardware.

A summary of the major developments in the simulator technology is given in Table III. Each of the new developments is correlated to the commercial products available on the US market today.

Table III. Summary of the Simulator Technology Developments

| New Simulator Technology Developments | Commercial Products |
|---|---|
| Application Programs for Planning and Engineering | Short Circuit, Load Flow, Transient Stability, Long-term Stability, Voltage Stability Programs |
| Operator Training Simulators | EMS functions including AGC, Economic Dispatch, State Estimation, Security Assessment |
| Open-Loop Simulators for Device Testing and Evaluation | Electromagnetic Transient Programs, Data File Replaying Programs, Programs for Automated Device Testing |
| Real-Time Simulators for Device In-the-Loop Testing and Evaluation | Real-time Electromagnetic Transient Program, Programs for Testing the Real Time Interaction Between Devices and Power Systems |

### 3.3 Close Ties with Industry

The importance of the interaction with industry has been recognized by TAMU's Power Engineering Program and others long ago [5]. Since the early 60's, the program had established formal ties with the utility industry in the state of Texas to facilitate support of the research activities. Up until today this connection has been maintained and produced some benefits for both parties.

In the context of the future relationship, in particular regarding the educational process and use of the simulator technology, several explicit areas of mutual benefits can be defined. The areas where industry can provide invaluable information for the educational process and university can provide a very important service to the industry, in reference to the use of the simulator technology, are summarized in Table IV. For each of the areas of cooperation, brief discussions of the reasons for interaction and related benefits are outlined.

Interestingly enough, one major research effort in the area of development of new digital simulators, that was undertaken jointly by TAMU and utility industry for the past ten years, has produced a variety of outcomes that can fit in all of the categories mentioned in Table IV. The simulator research funded by a number of utilities (Houston Lighting & Power, Florida Power and Light, Western Area Power Administration, Commonweath Edison, Pacific Gas and Electric, Bonneville Power Administration) and EPRI was aimed at developing both the real-time and open loop digital simulator configurations [6-8]. As a result of this development, a variety of sections of the actual power system were modeled using the data provided by the industry [9]. As a part of this activity, a number of useful tests on distance relays were performed to evaluate some of the products that the industry was already using or contemplating of using in the future [10,11]. As a result of this experience, a short course on advanced testing applications using digital simulators was defined and offered to the industry [1]. Finally, a number of research projects were initiated where digital simulators played an important role as an advanced experimental test bed [9-12].

Table IV. Areas of Mutually Beneficial Cooperation with Industry

| Areas of Cooperation | Mutual Benefits |
|---|---|
| Collection of Data for Practical Simulation Examples | The industry can provide data for practical problems, which in turn can be used to define important examples for the teaching process. |
| Advanced Testing Services Using Digital Simulators | The industry may use the university's advanced laboratory infrastructure for performing some specialized equipment tests, which produces a chance for students to learn practical applications. |
| Short Courses for Continuing Education with Hands-on Experience | The university can offer unique hands-on short courses for the industry exposing the industry staff to some state of the art equipment for experimental studies. |
| Research Project Requiring Advanced Experiments Using Digital Simulators | The university can engage in some practical research where the use of an advanced laboratory infrastructure enables some studies that may not be possible to carry by the industry. |

## 4. MEETING THE CHALLENGE FOR A CHANGE

This section describes some recent efforts at TAMU aimed at improving TAMU's ability to meet the challenge for a change. This discussion follows the three major strategy components mentioned

Table V. New Curriculum Issues

| Curriculum Issue | Subject to be Covered |
|---|---|
| Energy Sources and Conversion | Traditional principles of energy conversion; new sources of power; advanced energy storage and concept of cogeneration; self-sustainable energy utilization for cleaner environment |
| Power System Design, Analysis and Control | Traditional steady-state and transient analysis methods; advanced control devices; transferring capability analysis; use of wide area measurement systems |
| Protective Relaying, Monitoring and Local Control | Traditional principles and concepts; digital relaying; synchronized sampling applications; adaptive and system-wide relaying; automated fault analysis and equipment diagnostics |
| Advanced Technologies for Power System Automation and Control | Traditional SCADA and RTU designs; integrated/coordinated digital substation designs; use of fiber optics; advanced local and system-wide communications; new transducers, intelligent system applications |
| Power Quality Design and Assessment | Traditional study of harmonics and related mitigation techniques; advanced concepts of power quality assessment; the use of power electronics |
| Distribution Systems and Automation | Traditional functions; advanced automation; high impedance fault detection; fault location; real-time pricing; customer information systems; outage management |
| Deregulation and Market Competition | Traditional vs. new concepts; energy markets; power pool arrangements; unbundling of services; pricing of auxiliary services; new services |
| Standardization, Industry Recommendations and Quality Assurance | New standards for communications; device interfacing standards; power quality standards; ISO 9000 Series of quality assurance standards |
| Social, Environmental and Ecomonic Impact | Issues of the regulatory pact and the obligation to serve; emission control issues; environmental impacts; societal benefits and corporate profits |
| Communication Skills, Team Work, Marketing Strategies | Cost benefits of technical solutions; team work; behavioral patterns; leadership role; utility-customer relationship |

earlier, namely curriculum adjustment, development of laboratory infrastructure, and interaction with industry.

### 4.1 MERIT 2000 Project

The title of this NSF project suggest the basic goals of the effort: **M**ultidisciplinary **E**ducation Using Curriculum **R**e-engineering, **I**ndustry Partnership and Simulation **T**echnology [3].

The main objectives of the project are:

- Create an example of a new re-engineered curriculum for undergraduate and graduate power engineering education.
- Involve various segments of the utility and manufacturing industry, as well as the consulting and engineering services in the process of defining multidisciplinary needs and practical examples for the educational process.
- Exploit unique expertise of the university teams and industry advisors to explore the simulation technology and related benefits in implementing an efficient methodology for classroom and laboratory teaching.

The new education concept to be developed is based on variety of curriculum issues described in Table V.

### 4.2 Laboratory Infrastructure Project

TAMU's Power Program Faculty have recognized the need to enhance the laboratory and have submitted a bid for the Academic Research Infrastructure (ARI) Program of NSF.

The proposal was approved and a major grant for development of a Power Quality Laboratory has been obtained [13].

This laboratory has some generic features that can be used for teaching a number of courses. The features are listed in Table VI together with an explanation of how a feature may be used in the teaching process.

Table VI. Laboratory's Generic Features and Uses

| Feature | Uses |
|---|---|
| Power System Modeling | Modeling of power system components and sections |
| Digital Simulation | Simulation of power system phenomena such as faults and other disturbances |
| Programmable Signal Sources | Generation of power system wave forms through mathematical expressions |
| Data Recording and Monitoring | Capturing of field data for analysis of various phenomena |
| Signal Processing and Analysis | Analysis of the captured or simulated signals |

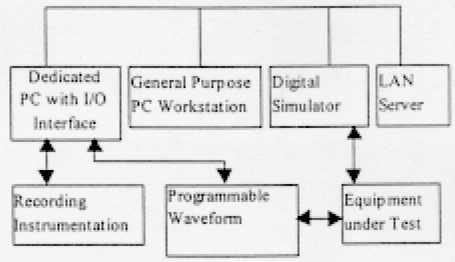


Figure 2. Arrangement of the Equipment in the Laboratory.

Arrangement of the computer equipment installed in the laboratory is given in Figure 2.

### 4.3 Interaction with Industry through EPPEI

As mentioned earlier, the Power Engineering Program at TAMU had established a tie with the industry through the Electric Power Institute formed in 1964. Recently, the Institute has changed its name into the Electric Power and Power Electronics Institute (EPPEI) to reflect broader scope of its activity. In addition, the Institute's mission has changed from a grant based program into a consortium type activity with an annual membership associated with a variety of services offered.

The list of basic membership options and related services is given in Table VII.

Table VII. EPPEI Membership Options and Related Services

| Membership Option | Related Services |
|---|---|
| Associate Member | • Use of the Laboratory Infrastructure for Various Studies<br>• Support of Students |
| Member | • Benefit of the Associate Member<br>• Participation in Defining Customized Short Courses |
| Industry Partner | • Benefit of the Member<br>• Facilitation of Joint Research Projects<br>• Reports on EPPEI Activities |

Even though the consortia and membership concept may look on the surface somewhat unrelated to the main discussion of the educational improvements using digital simulators, it is quite the opposite. The main activities in improving the teaching are dependent on availability of improving the teaching are dependent on availability of extensive simulation infrastructure. The ties with industry through the consortium are aimed at raising the funds for supporting and maintaining this infrastructure. At the same time, the exchange of information related to the services for testing, short courses and research projects enable the teachers and students to get involved in practical examples and activities.

## 5 CONCLUSIONS

This paper has presented some pointed arguments for the following conclusions:

- The educational paradigm has been changed by deregulation to include increased competition and more direct focus on a student as a customer.
- In a variety of new educational task, the change of the curriculum to accommodate simulation as the main teaching methodology is quite promising.
- The simulation activities and examples give students a chance to develop better understanding of the fundamentals as well as to develop communication skills and team work experiences.
- In order to utilize the simulation technology to a full extent, the teachers may have to develop rather extensive laboratory infrastructure which can be implemented at a moderate cost.
- The relationship with industry is very important since it can bring both financial support and practical experience needed to fully explain the capabilities of the simulator technology.

## 6 ACKNOWLEDGEMENTS

The Power Quality Lab Development was funded by the National Science Foundation Grant ESC-96-14540. The MERIT 2000 Power Engineering Education project is funded by the National Science Foundation Grant ECS-96-19294.

## REFERENCES

[1] Information about TAMU's Power Engineering Program: web site http://ee.tamu.edu/~eppe/.

[2] M. Kezunović, A. Abur, G. Huang, MERIT 2000 – A New Concept in Power Engineering Education, [International Conference on Energy Management and Power Delivery – EMPD'98, Singapore, March 1998].

[3] NSF, Proceedings of the Workshop on Innovative Power Engineering Education in a Changing Environment, Arlington, Virginia, October 1997.

[4] PES Power Engineering Education Committee, Electric Power Engineering Curricula Content in the 21st Century, [IEEE PES Winter Meeting, Paper No. 94 WM113-1 PWRS, New York, February 1994].

[5] H.K. Amchin, Increased Industry/University Interactions, A Solution for Today's Power Engineering Education Problem, [IEEE Transactions on Power System, Vol. PWRS-2, No. 4, November 1987].

[6] M. Kezunović, A. Abur, Lj. Kojović, V. Skendžić, H. Singh, DYNA-TEST Simulator for Relay Testing, Part II: Performance Evaluation, [IEEE Transactions on Power Delivery, Vol. 7, No. 3, pp. 1097-1103, July 1992].

[7] M. Kezunović, S.M. McKenna, Real-Time Digital Simulator for Protective Relay Testing, [IEEE Computer Applications in Power, Vol. 7, No.3, pp. 30-35, July 1994].

[8] M. Kezunović, Modular Simulators Match Cost and Performance Criteria, [IEEE Computer Applications in Power, April 1996].

[9] M. Kezunović, A. Abur, Protective Relay Workstation Applications of Digital Simulators for Protective Relay Studies: System Requirement Specifications, [Final Report, EPRI Project 3192-01, Phase I, EPRI TR 102781, October 1993].

[10] M. Kezunović, Y.Q. Xia, Y. Guo, C.W. Fromen, D.R. Sevcik, Distance Relay Application Testing Using a Digital Simulator, [IEEE Transactions on Power Delivery, Vol. 12, No. 1, pp. 72-82, January 1997.

[11] M. Kezunović, Y.Q. Xia, Y. Guo, C.W. Fromen, D.R. Sevcik, An Advanced Method for Testing of Distance Relay Operating Characteristic, [IEEE Transactions on Power Delivery, Vol. 11, No. 1, pp. 149-157, January 1996].

[12] S.M. McKenna, D. Hamai, M. Kezunović, A. Gopalakrishnan, Transmission Line Modeling Requirements for Digital Simulator Applications in Testing New Fault Location Algorithms, [Second International Conference on Digital Power System Simulators (ICDS '97), Montreal, Canada, May 1997].

[13] A. Abur, M. Kezunović, A Simulator and Testing Laboratory for Addressing Power Quality Issues in Power Systems, [IEEE PES Winter Meeting, Orlando, Florida, February 1997].