MERIT 2000 – A New Concept in Power Engineering Education

M. Kezunović A. Abur G. Huang
Texas A&M University
College Station, TX 77843-3128
USA

***Abstract*—** This paper suggests an extensive use of the simulation technology to enhance student's understanding of the fundamentals, as well as practical solutions while making this approach quite effective in reducing overall classroom teaching time. This is achieved by efficiently presenting and explaining the analytical and practical aspects of related phenomena through simulation, as well as by redistributing some of the teaching to the laboratory environment. This approach will make sure that an additional time in the curriculum is made available for introduction of the new topics that will reflect the multidisciplinary issues created by the changing environment.

1. INTRODUCTION

The current power engineering education has been influenced greatly by the difficulty of fully analyzing the large and complex power system. The curriculum has performed well in that it provides a solid background of traditional power system problems and classifies problems similar to the historical utility organization. The curriculum performs less satisfactory in that it: (1) is relatively inflexible in terms of adopting new technology developments, for example, advanced integrated control and protection concepts are difficult to include since one needs to have access to the equipment, or its models, and (2), tends to force onto the student a utility perspective of the power system as opposed to a manufacturing, customer or other industry player perspective. Software tools available to previous generations of educators were relatively limited in computational capabilities and many heuristic techniques were introduced into the curriculum. As computer speeds have improved dramatically in recent years, courses have been updated, but these modernizations have been ad hoc. New simulation tools have been added to courses without an opportunity for the student to understand fully the numerical techniques used. Power faculty are faced with a difficult choice between presenting small problems that students can grasp versus larger problems based on simulations which exhibit the true nature of the problem, but tend to overwhelm the student. A primary objective of this paper is to introduce a simulation environment concept that allows students to work at many levels of problem size and detail in a familiar and user-friendly framework.

2. CHANGING ENVIRONMENT

This paper is aimed at introducing a new concept in power engineering education for the 21st century, namely Multi-disciplinary Education Using Curriculum Re-engineering, Industry Partnership and Simulation Technology -**MERIT**. This concept is being now realized and deliverables are to be made available in the year 2000, hence, the project designation **MERIT 2000**.

The changes in the utility and manufacturing industry, as well as consulting and engineering services, are quite complex, but may be simplified for the purposes of recognizing some major impacts as follows:

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

The above "cause → effect" chart indicates that the industry has been driven by continuing de-regulation and increasing competition into a new paradigm of operation where the customer becomes the focus. This approach not only redefines who the customer is, but what the customer wants and what the options in achieving the goals of satisfying the customer are. An obvious consequence of this process is a need for a new profile of an engineer that can fit the new paradigm. There is a wide consensus that the existing power engineering education does not offer the required solution [1]. This conclusion coincides with the situation in the overall field of science, mathematics, engineering and technology [2]. As a result, the education process needs to "produce" an engineer with a new profile. This requires a new paradigm for power engineer education where the "customer focus" concept becomes a driving force for the education process as well. This is not meant to imply that any of the fundamental academic goals of providing quality education should be compromised in any way. On the contrary, it means that these goals should be reinforced, but achieved with a clear focus that the student and future employees of this student need to be attracted and satisfied with the educational process and its final results. This "customer focus" concept in education brings forward a competition between the power engineering education and other engineering programs at the same institution, as well as among power engineering programs at different educational institutions. This paper suggests that the **MERIT 2000** approach and its deliverables are an effective way to meet the new challenge of the educational needs in the changing environment.

IEEE Catalogue No: 98EX137
0-7803-4495-2/98/$10.00 1998 IEEE

The key strategy of the approach undertaken to develop the **MERIT 2000** concept is to assemble a team of faculty and advisors from industry representing different personal expertise, regional prospectives and professional interests. This strategy was pursued at the proposal preparation stage and will be continued throughout the project with a very clear goal to make the creation of the new education concept a joint effort between "producers" and "consumers" of the power engineers for the 21st century.

3. RESEARCH OBJECTIVES AND SIGNIFICANCE

The main objectives of this project are to:

- Create an example of a new re-engineered curriculum for undergraduate and graduate power engineering education [3].
- Involve various segments of the utility and manufacturing industry, as well as the consulting and engineering services in the process of defining multi-disciplinary needs and practical examples for the educational process [4].
- 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 [5].

The significance of the curriculum re-engineering should neither be under estimated nor overstated. It is our position that the curriculum has to be changed to accommodate the multi-disciplinary issues of the new industry paradigm such as, customer relationship, advanced technologies, changing social and engineering economic considerations, and new power system applications. At the same time, the fundamentals of power engineering education should be enhanced. Having a limited number of available university credit hours to implement the new concept, any major changes are quite difficult to incorporate. To perform this difficult task, the industry partnership and advanced simulation technology are viewed as important ingredients of a successful solution. The act of writing re-engineered curricula may not be an overly difficult task. However, the implementation part is what makes this project quite challenging. Again, the industry partnership is expected to produce the required advisor-ship and the new simulation technologies are expected to produce the required efficiency needed to achieve this goal.

The significance of the industry partnership should neither be downplayed nor exaggerated. It is extremely important to get an input from a vast segment of the industry representation to better understand what the new needs and expectations are. On the other hand, education is the main task of academic institutions, and those institutions should be able to stand up to this task and play a leading role in defining and implementing the required changes in the power engineering education. As a conclusion, the industry partnership is a necessary, but not a sufficient condition for a successful implementation of the proposed concept. Dedication and expertise of the educators, as well as support and commitment of the educational institutions are indeed also very important.

The significance of the simulation technology should neither be trivialized nor glorified. The modeling and simulation have always played a significant educational and practical role in the engineering disciplines. In fact, they have become indispensable in some very advanced and competitive industries such as auto, civil and aerospace. In the power industry, the modeling and simulation are moving into the main-stream of the practical engineering very fast [6]. The **MERIT 2000** concept is based on the fact that the advanced simulation technology can provide an efficient medium for teaching by allowing visualization of the phenomena to supplement understanding of the analytical approaches used to describe them, as well as facilitate the use of real life cases and studies to enhance the practical experience.

4. INDUSTRY AND UNIVERSITY PARTNERSHIP

The main philosophy behind the partnership in the **MERIT 2000** approach was to follow the existing trends in the partnership seen between various industries, as well as between industries and their customers. It is understood that a major advancement in the power engineering education can not be easily achieved by one school, or without the industry input. Hence, the approach taken was to make a team of two universities, four utilities and four vendors that will jointly participate in this project from the stage of the proposal writing to the stage of the final curriculum implementation.

The choice of utility advisors was carefully made based on the power system size, service area, role in the economy of a given region, versatility of its approaches in reaching de-regulation goals and increasing competitiveness, its recognized leadership in research and technical innovations, and its continued interest in, and support of, education. The selected utilities were quite excited and pleased to be approached with an invitation to participate that they not only agreed to offer the cash support for this project, but also designated their prominent representatives as an in-kind support to help create the proposal and closely participate in the project if awarded.

The project partnership would be incomplete if the vendors were not included. The vendors are, together with utilities, a major employer of the power engineering graduates, as well as the main contributors to the national economy and the overall competitiveness of the industry. The criterion for extending invitations to the vendors was similar as for the utilities. In addition, a detailed assessment of the vendors suitability to facilitate selection and evaluation of the simulation technology was performed.

Finally, the size and specialization of the selected utilities and vendors gives a unique cross-section of different aspects of the industry activity. This should assure that the educational concept includes concerns of power generation, transmission, distribution, wholesale and retail customers, as well as manufacturing, consulting, engineering, marketing and public relations segments of the industry.

Teaming up between Texas A&M University (TAMU) and Washington State University (WSU) is not a random match either. Both universities have long standing and recognized power programs. Both universities also have a strong relationship with utilities and vendors. In addition, both universities have demonstrated the dedication of their faculty and administration to support and further develop power engineering education program. In addition, the faculty mix of the two groups is quite representative of the senior faculty with well established teaching experience, faculty in their mid-career striving for further enhancement of their teaching skills, and junior faculty aiming at demonstrating their teaching ability as a part of satisfying the requirements to get tenured. This balance of the faculty goals and expertise is considered to be an important ingredient of the overall concept and its implementation approach.

5. NEW EDUCATION CONCEPT

The new concept is based on three pivotal components:

- Multi-disciplinary Approach
- Simulation Technology
- Innovative Teaching Methodology

A. Multi-Disciplinary Approach

The basic idea is to enhance the existing fundamental power core topics with the following additional topics:

- Customer Relationship (marketing, public relations, communication skills, environmental issues, team work, etc.)
- Advanced Technology (computers, communications, signal processing, power electronics, intelligent systems, etc.)
- Economic Considerations (multi-objective cost analysis, econometric approaches, cost and pricing issues, unbundling of services, etc.)
- New Applications (power quality, distribution and substation automation, FACT technology, renewable energy sources, use of power electronics, etc.)

To allow for dynamic changes in the curriculum needed to accommodate on-going changes in the industry, the core curriculum will be designed as a relatively fixed set of topics, while the new considerations will be added as a series of special topics that may be enhanced and changed as needed in the future. To make sure that the most recent developments in the industry are reflected in the curriculum, a percentage of the curriculum enhancements will be targeted for teaching by the experts from industry. In particular, it will be recommended that the experts from industry be selected to best fit the multi-disciplinary issues, which means that the choice will be both technical, non-technical and management profiles. A contact with other departments and colleges at both universities will be established to obtain advice when deciding on the teaching topics such as communication skills, team work, social impacts, marketing techniques, that are traditionally outside the engineering disciplines.

B. Simulation Technology

The use of the simulation environments available at related labs at both schools offers an advanced technology and a powerful methodology to be extensively explored in this project. Each of the fundamental power system topics will be re-examined to decide how the required modeling and related simulation can be utilized to enhance understanding of the fundamental phenomena and practical solutions. An inventory of the existing software that can be made readily available to the educational institutions will be made to determine its potential use in the educational process.

The emphasis will be placed on the capabilities of two state-of-the-art simulator environments readily available through EPRI and further developed and maintained by commercial vendors. The first simulation environment that will be explored is the digital simulator for relay testing presently available at Texas A&M University [7]. The second simulation environment that will be utilized is a training simulator for EMS personnel. This simulator has been developed by one of the co-principal investigators (Dr. A. Bose) and his students [8].

An attempt will be made to fully explore applicability of these simulators in the teaching process. This project will not be aimed at any major new developments of the simulator software or hardware. However, certain upgrades of the existing simulators will be considered as deemed appropriate. In particular, utility and vendor representatives will be consulted in performing these upgrades. Certain software packages presently offered by the participating vendors will be used if required and declared as readily available in the future at a university discount. A close look at the present development of EPRI workstations for power system engineering and design will also be taken [6].

C. Innovative Teaching Methodology

The main ingredient of the innovative teaching methodology will be an extensive use of digital simulators in the teaching process. Due to the fact that the core of these simulators are software packages located on a computer, a provision for running extensive simulations both using lap-top computers in the classroom and general purpose computers in the laboratory will be investigated. This will allow for redistribution of the teaching load in the classroom where the time required for presenting and understanding of theories and concepts will be reduced due to a well prepared set of visual demonstrations. Furthermore, detailed considerations and practical examples will be shown in the laboratory environment which will be turned into additional teaching time and self-learning experience.

Clearly, industry expects engineering students to have more training in communication skills, both verbal and writing, and teamwork. In addition, the abstraction skill to combine the practical data and physical phenomenon are also needed for practicing engineers. Accordingly, we propose to use the simulator environments as the teaching and training set-up. We will define the simulation exercises to be worked out on a rotational basis by different groups (teams) of students. Each team will be asked to run the assigned simulation cases, present them to the other teams until the other teams fully understand the fundamental issues and agree with the results. The teams will be asked to summarize the results and theoretical explanations, as well as teaching and learning experience into a written report. By this approach, the students will be more aware of the fundamental core knowledge and make sure that they understand the basics well enough to be confident and convincing, as well as to avoid an embarrassment for themselves. Also, group discussion will force team spirits and reports will make them aware of the need for communication skills. The whole process will improve their verbal and writing skill. All these activities will be closely supervised by teachers.

To make this innovative teaching methodology a reality, the power courses may be taught by a team of faculty as appears appropriate. Such arrangements are already tried at the participating universities and the department heads at both institutions have agreed to continue and expand this practice in the future, in particular during the demonstration phase of the project.

6. CURRICULUM ISSUES

The researchers envision several areas which must be addressed by the proposed multidisciplinary approach to power engineering education. Some of the areas given below have been identified in the initial contacts with the prospective industry advisors. These areas will be a starting point for further discussions on the curriculum issues. The areas below can eventually be combined or matched into a series of courses at the undergraduate and graduate level:

(1) **Energy Sources and Conversion.**

Traditional principles of energy conversion: steady-state operation of electric machines and power transformers. New sources of power: wind generators, fuel cells and solar cells. Advanced energy storage methods and concept of co-generation. Combining of the alternative energy sources, cogeneration, heat utilization factors and pollution control with the classical electromechanical conversion to demonstrate an integrated approach that has a high potential for achieving self-sustainable energy utilization with a cleaner environment as a result.

(2) **Power System Design, Analysis and Control.**

Traditional steady-state and transient analysis methods; system modeling, load flow, short-circuit and transient stability. Advanced control of power flow using FACTS devices, calculation of transmission and wheeling losses, voltage control and reactive power optimization, security constrained optimal power dispatch. Use of phasor measurements and wide area measurement systems for on-line stability monitoring and control.

(3) **Protective Relaying, Monitoring and Local Control.**

Traditional relaying principles, metering, data recording and substation control. Digital relay designs and related digital algorithms for relaying and fault locating. Traveling wave relays and fault locators. Synchronized sampling and its use in relaying, fault locating and stability monitoring. Adaptive and system wide relaying. Automated fault analysis and equipment diagnostics.

(4) **Advanced Technologies for Power System Automation and Control.**

Traditional SCADA systems and RTU designs. Advanced integrated/coordinated digital substation control and protection systems. The use of fiber optics, digital wide-band communications, local area networks and wide area networks. New transducers for voltage, current, temperature; new sensors for gas analysis, partial discharges and incipient faults. Application of intelligent systems and power electronics.

(5) **Power Quality Design and Assessment.**

Traditional study of the harmonics and their sources, as well as the mitigation techniques using passive and/or active filters. Advanced concepts in power quality assessment using signal processing and intelligent techniques to automatically detect, classify and characterize a variety of power quality disturbances. Modeling and analysis of power systems containing nonlinear devices and loads. The role of power electronics in the power quality related applications.

(6) **Distribution Systems and Automation.**

Traditional planning, operation and maintenance, distribution system power flow, capacitor placement and sizing, reconfiguration for loss minimization and load balancing. Advanced automation of switching sequences, meter readings, distributed voltage control, fault location, high impedance fault detection. Real-time pricing, customer information systems, outage management, geographic information systems, mapping/facilities management.

(7) **Deregulation and Market Competition.**

New concepts such as energy markets, competition, regulatory models, power pool arrangements, unbundling of services, pricing of auxiliary services. New service criteria reflecting market needs and engineering requirements; price competition indices and multi-objective analysis.

(8) **Standardization, Industry Recommendations, and Quality Assurance.**

New standards for data communication; ISO model and IEC standardization of communication protocols. New standards and recommendations for device interfacing; COMTRADE, Profibus, MMS, FMS. Power quality standards and recommendations. ISO 9000 series of quality assurance standards.

(9) **Social, Environmental and Economic Impacts.**

New approaches to the issues of the regulatory pact and the obligation to serve. Advanced emission control issues; environmental impacts, cost analysis of the environmental control. Power system management for both societal benefit and corporate profit.

(10) **Communication Skills, Team Work, Marketing Strategies.**

New requirements for communication skills aimed at presenting the cost benefits of the technical solutions to the managers and customers. Team work, behavioral patterns, leadership role. Marketing focuses on the customer needs, utility customer relationship; customer relationship between generation, transmission and distribution organizations.

Note, these areas include fundamental power engineering material (issues # 1-6), as well as additional considerations associated with the developments in deregulation and new technologies (issues # 7-10). The focus of this work will be to maintain a similar structure to the traditional power system education while adding the required new material through the efficiency of the case-based approaches discussed earlier. This approach will have the advantage of the ease of implementating of new topics into the current curriculum, as well as maintaining an emphasis on the power system engineering fundamentals.

7. PROJECT TASKS

The curriculum development is broken down into three major tasks which must be completed for each of the issues identified previously.

A. Task 1 (Year 1) - Initial Curriculum Design and Simulation Setup

The first year requires setting out the new curriculum through broad design of course materials. An initial meeting will be held where an outline of the concerns for each of the previously identified issues will be presented. A consensus on the required course changes at the two universities will be sought. This will require considerable brainstorming and debate in order to forge the material into appropriate courses.

It is not the objective of this first task, nor would it be possible, to reach complete consensus on material for each course. Instead, a broad and open curriculum will be pursued which forms a foundation upon which educators can add or remove case studies as they deem appropriate. In general, for each of the considered course material changes, the faculty involved in this project will need to: (a) select preliminary curriculum topics and simulation examples, (b) obtain feedback from industry advisors on this material, (c) define teaching and laboratory exercises based on this feedback, and (d) detail the curriculum topics and hourly schedule for both teaching and laboratory courses.

B. Task 2 (Year 2) - Simulation and Course Material Implementation

The second year will be an implementation phase. Again, each of the faculty will focus their efforts on particular curriculum issues.

For all of the course materials identified in Task 1, the implementation phase requires participants to: (a) collect data for practical examples, (b) implement simulation models for these case studies, (c) layout a teaching plan for faculty and industry participants, and (d) complete teaching and laboratory manuals.

C. Task 3 (Year 3) - Demonstration and Evaluation of the New Curriculum

The final year will be devoted to a demonstration of the new curriculum. All of the newly designed courses will be taught at a minimum of once at the universities. This task is considered extremely important as the only way to fully develop curriculum and evaluate improvements is through teaching.

Evaluation will be pursued from both educators and students. For educators in all courses, questionnaires will be designed to determine (a) the ease of teaching the new material, (b) the ability of the approach to adequately convey material based on tests and completed assignments, (c) an assessment of the students ability to learn in this environment, and (d) an assessment of the interest level of students in the courses. Students' course evaluations will be more extensive than the standardized department evaluations. Feedback will be required throughout the teaching of the course so that students can identify specific difficulties that can be corrected. Where possible, industry participants will be asked to observe the course presentations and provide feedback, as well as to teach specific practice-oriented issue.

8. EXPECTED DELIVERABLES AND DISSEMINATION Of PROJECT RESULTS

Project deliverables will fall into four general categories:

- Course syllabus with detailed description of the topics
- Teaching and laboratory manuals
- Modeling and simulation set-ups for teaching and laboratory experiments

- Project reports

Description of the courses will be very detailed, indicating the required prerequisites, hourly teaching subjects, modeling and simulation examples, topics suggested as a fixed part of the suggestion of topics that may be taught by the industry representatives or specialists outside engineering programs.

Teaching and laboratory manuals for the use of the simulation examples will be developed to guide teachers in determining the complexity and extent of the fundamental phenomena to be demonstrated.

Detailed descriptions of the software and hardware, as well as power system parameters and input data for the simulation experiments will be provided so that such experiments can be repeated by anyone interested.

Project reports will include periodic reports for each of the tasks, semi-annual reports, and a final report.

All of the written reports, together with detailed specification of the simulation environments and experiments will be made available through either an FTP site or an Internet WWW page. The Power Globe Facility will also be used for result dissemination. Detailed instructions of how to obtain the required simulation hardware and software will be included. Several journal and conference papers will be published outlining most important project contributions. A panel session at one of the IEEE Meetings will be proposed to make the other professionals aware of the project progress and results. Regular participation at the NSF/EPRI Workshop of all the contractors for this RFP is also planned.

9. ACKNOWLEDGEMENTS

This project is funded by the National Science Foundation, Grant No. ECS-96-19294. This project is a joint effort between Texas A&M University and Washington State University (Co-Principal Investigators A. Bose, K. Tomsovic and M. Venkatasubramanian).

10. CONCLUSIONS

This paper presents the most important aspects of the proposed work. The project has been initiated in May of 1997 and will last for three years. The results will be reported in some future papers.

11. REFERENCES

[1] NSF, *Proceedings of the Workshop on Innovative Power Engineering Education in a Changing Environment*, Arlington, Virginia, June 1995.

[2] NSF Directorate for Education and Human Resources, *Shaping the Future - New Expectations for Undergraduate Education in Science, Mathematics, Engineering and Technology*, NSF, June 1996.

[3] PES Power Engineering Education Committee, "Electric Power Engineering Curricula Content in the 21st Century," *IEEE PES Winter Meeting*, Paper No. 94 WM 113-1 PWRS, New York, February 1994.

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

[5] PES Power Engineering Education Committee, "Electric Power Engineering Education Resources 1991-92," *IEEE PES Winter Meeting*, Paper No. 94WM 138-8 PWRS, New York, February 1994.

[6] G. Ben-Yaacov, "ES Workstations: The Next Generation," *IEEE Computer Applications in Power*, April 1993.

[7] M. Kezunović, "Modular Simulators match Cost and Performance Criteria," *IEEE Computer Applications in Power*, April 1996.

[8] M. Prais, G. Zhang, Y. Chen, A. Bose, D. Curtice, "Operator Training Simulator: Algorithms and Test Results," *IEEE Transactions on Power Systems*, Vol. PWRS-4, No. 3, pp. 1156-1159, August 1989.

[9] M. Prais, C. Johnson, A. Bose and D. Curtice, "Operator Training Simulator: Component Models," *IEEE Transactions on Power Systems*, Vol. PWRS-4, No. 3, pp. 1160-1166, August 1989.

[10] M. Kezunović, J. Domaszewicz, V. Skendžić, M. Aganagic, J. K. Bladow, S.M. McKenna, D.M. Hamai, "Design, Implementation and Validation of a Real-Time Digital Simulator for Protection Relay Testing," *IEEE Transactions on Power Delivery*, Vol. 11, No. 1, pp. 158-164, January 1996.

[11] M. Kezunović, Q. Chen, "A Novel Approach for Interactive Protection System Simulation," *IEEE T&D Conference*, Los Angeles, California, September 1996.

[12] V. Kola, A. Bose, P. M. Anderson, "Power Plant Models for Operator Training Simulators," *IEEE Transactions on Power Systems*, Vol. PWRS-4, No. 2, pp. 559-565, May 1989.

[13] G. Zhang, A. Bose, "Scenario Building for Operator Training Simulators Using a Transient Stability Program," *IEEE Transactions on Power Systems*, Vol. PWRS-4, No. 4, pp. 1542-1549, October 1989.