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A MULTI-INSTITUTIONAL COOPERATIVE APPROACH TO POWER ENGINEERING EDUCATION

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ABSTRACT

This paper describes the multi-institutional cooperative effort between the University of Missouri-Rolla, Kansas State University, and the University of Arkansas to develop two new courses in flexible power system control.

1. INTRODUCTION

In 1995, a trio of schools, the University of Missouri-Rolla, Kansas State University, and University of Arkansas, submitted a proposal to the National Science Foundation to develop a series of two courses on flexible power system control which would be taught simultaneously at all three campuses. The multi-institutional team of researchers will cultivate and disseminate the experience of the researchers to enhance each school's power engineering program. This cooperation will foster an environment in which students will learn not only the technological aspects of the material, but also the communication skills required to collaborate with other future engineers using electronic media.

This collaborative effort is a product of each school's struggle to meet the demands of coping with the rapid changes in structure, regulation, and technologies in the electric power industry. As the industry changes to meet the demands of a competitive environment, the need for engineers capable of meeting the challenges of the upcoming decades is increasing. However, a traditional power engineering education is not sufficient to prepare the nation's future engineers with the skills they will need to excel. There is an overall consensus among educators and industry that there is a need for significant change in power engineering education [1].

Industry deregulation will require power engineers to work in an environment which requires "mobility, empowerment, self-directed teams, cross-training, telecommuting, virtual offices, [and] reengineering [2]. The collaboration stresses several novel features which will address the future needs of graduates. Specifically, graduates will need a competitive technological education as well as an education in some of the "softer" aspects, such as communication (both oral and written), team work skills, and experience with electronic media. The collaborative effort between the trio of schools will promote advances in each of these areas. These advances will be discussed in greater detail in subsequent sections.

2. TECHNOLOGICAL COMPONENT

The challenge of supplying the nation with reliable, high-quality electrical energy at a reasonable cost is at the heart of the nation's economy. The electric power system is one

of the nation's oldest infrastructures, and the infrastructure most closely tied with the gross domestic product. However, the demographics of power generation, transmission, and distribution are changing dramatically in both the operating and business sectors of the electric utility industry.

Several new flexible control strategies hold considerable promise for maintaining a high degree of power quality and reliability under a deregulated environment. At the distribution level, flexible control strategies involve computerized automation of system control devices such as capacitor banks, under load tap changing transformers (ULTCs), and voltage regulators. In the transmission system, a new method of achieving this control is through the use of power electronics-based Flexible AC Transmission System (FACTS) devices. As utilities move progressively toward a deregulated environment, heavier reliance is being placed on flexible control strategies. Since the composition and nature of power engineering is changing dramatically, new engineering graduates from a traditional power engineering curriculum are faced with technological and economic problems for which they are unprepared.

To expose students to these new control strategies, the three universities have banded together to offer two new courses, which are taught simultaneously at each of the three sites. This enhances the educational experience of all of the students by relying not only on the experience of on-site faculty, but also on the experience of the researchers at the participating universities. The two course sequence is divided into a course on flexible distribution system control and a course on flexible transmission system control.

2.1. A Course in Flexible Control of Distribution Systems

The first course introduces the concept of flexible control as applied to distribution systems. Pahwa and Olejniczak have primary responsibility for this course. The course cover the following topics:

1. Introduction to distribution automation and allied systems
2. Control functions and their cost-benefit evaluation
3. Location of outages and restoration of service
4. Reconfiguration of system for loss reduction
5. Control of ULTCs and capacitors for voltage and VAR management
6. Introduction to solid-state synchronous voltage sources for the distribution system
7. Global feeder applications
8. Electric power quality

2.2. A Course in Flexible Control of Transmission Systems

The second course covers the topics of transmission system flexible control. Sudhoff, Crow, and Starrett have primary responsibility for this course. The course covers the following topics:

1. Overview of power transmission system limitations
2. Traditional approaches to power system control during steady-state, transient, and dynamic time frames
3. Introduction to FACTS Topologies
 - (a) StatCom
 - (b) TCSC
 - (c) UPFC
4. Development of power system application modelling techniques
5. Power system applications of FACTS devices

3. THE VIRTUAL CLASSROOM

As team structures are increasingly emphasized in industry, engineering classrooms around the nation are being modified to reflect this trend. The multi-institutional nature of this effort offers a unique opportunity to explore the use of the virtual classroom. As teams are comprised of students from the three universities and off-campus sites, students will have to rely heavily on electronic communication methods to correspond with teammates. This mode of communication is being rapidly adopted by many industries, as electronic communication can now encompass not only text communication, but graphics, sound, and video images as well.

The main technical obstacle to be overcome for this project is a live multi-way video link between the four campuses, with four different levels of capability. One of the least expensive means to accomplish such a connection is using the ISDN telephone service. There were two obstacles to utilizing such a service for this project. First, was the fact that a direct ISDN connection only works between two sites - not multiple sites. Secondly was the fact that only the KSU and UA sites have ISDN service available. The first of these difficulties, that is the two site limitation, was overcome by utilizing an ISDN bridge. This is a phone service facility which is specifically designed to link multiple ISDN sites. In this case, the bridge site was located in Topeka, Kansas. The second problem which had to be solved was connecting UMR to the bridge without paying for an ISDN line to be run to the UMR campus, which would be quite expensive. Instead of installing an ISDN line, use was made of a dedicated fiber optic network which links all campuses of the University of Missouri system - namely UMSL (St Louis), UMKC (Kansas City), UMC (Columbia), and UMR (Rolla). In particular, the fiber optic link was used to connect UMR to UMC, at which point the video information was converted to ISDN format and interfaced to the bridge in Topeka. With proper configuration, it is possible to automate all functions at UMC so that no UMC personnel are required to make the connection. Using an ISDN connection, each campus is free to utilize the most convenient hardware. For example, the UMR and UA campuses make use of a formal study designed for distance education projects whereas KSU makes use of a standard classroom using a PicturTel Elmo video conferencing system, thus avoiding studio costs. The total costs of a 128 Kb/s ISDN interconnection on an hourly basis is as follows:

Topeka Bridge:	\$60.00
UMR Studio Costs:	
(Two Camera Production)	\$23.00
(Taping Charge):	\$6.25
UMR/UMC Link:	\$7.00
UMC/Topeka ISDN Line:	\$12.00
UA Studio Costs:	\$102.73
UA/Topeka ISDN Line:	\$9.58
KSU/Topeka ISDN Line:	\$15.00

The instructors are developing course materials which will augment the traditional approach of bound paper textbooks. A *hyper-textbook* using HTML will be developed. This is a virtual textbook, one which resides on a computer and may be accessed by Netscape, Mosaic, or any other World-Wide-Web browser. The basic hypertext is the same as any bound paper textbook. It contains explanatory text, discussion, equations, figures, etc. The hyper-textbook, however, could also include links to additional examples, case-studies, lengthy derivations, problem solutions, animated simulation "movies," and links to similar topics elsewhere on the WWW. In addition, in a hyper-document, the reader can click on the reference number, and immediately be linked with the title, authors, and abstract of the reference. In addition, (copyright permission pending) copies of the reference paper may be scanned and included. The conversion from bound paper text to hypertext can be accomplished in several ways. The authors have experimented with the software *latex2html* which converts LaTeX documents into corresponding *.html files. Equations are converted into *.gif files. Figures (stored as *.gif) files may also be inserted, but this must be done manually. The *.html documents must usually be "prettied" up, but this software does a pretty good job at producing a rough draft of a hyper-document.

Another advantage of hypertextbooks is that the readers will always have up-to-date information. Unlike a bound paper textbook which must go into additional editions or printing to modify or update the material, a hypertextbook can be modified immediately by the authors. In addition, many of the links are to information which is timely and updated regularly. For example, when the large blackout occurred in the western United States and Canada on July 2, 1996, EPRI produced a web page specifically detailing the incidents leading up to and following the blackout. This link could be easily added at the appropriate place in the hypertext. Additionally, EPRI supports a Daily News Service Page in which news articles pertaining to electric utilities and power are catalogued and summarized. This is an excellent resource to provide students at the start of their power careers.

4. STUDENT CONSULTING TEAMS

The career path of power engineers into the twenty-first century is undergoing major changes. This becomes more apparent as utility companies continue to demand quick, low-cost solutions, with a maximum payback period of three to five years versus 20 to 30 years. Future power engineers must be team oriented, seek continuous learning, develop new products and services, and be able to find better, faster, cheaper, and safer ways to deliver electric power.

As the electric utility industry continues to exercise the economic benefits of restructuring/downsizing, corporations will be hesitant to employ the number of engineers they had had in the past. When large projects arise, independent engineering contractors or consultants will often be utilized. In fact, consulting and engineering services com-

panies are the largest single employment market for the engineering profession [2]. To this end, students who elect to participate in either of the two developed courses will be expected to perform all course requirements as if they were in a consulting environment. The instructors will assign homework projects individually and in a team environment. This method is a recommended and proven pedagogical tool which lends itself to the integration and documentation of design into each course. This method also allows interaction among other groups formed in the class. The instructors will assign projects which are initially closed-ended and evolve to those where many solutions exist. This forces the student to think and justify the tradeoffs involved in reaching a sound technical and economical solution. Other favorable attributes of the consulting environment include: (i) providing the students an opportunity to write proposals, present oral design reviews, and write final reports, (ii) encouraging professional and responsible behavior, and (iii) offering a "real world" experience for the students.

Students can also actively participate in the use of electronic multi-media to correspond with their classmates at the other universities. For example, a team member working on one aspect of a class exercise may send his/her design specifications to a teammate in the form of a Matlab *.m file via e-mail. The teammate can then use and modify the *.m file and relay the results to the other teammates. Final project reports are also required via HTML documents, with links to the design, analysis, and demonstration results. It is expected that most communication between students and faculty will take place via e-mail and electronic bulletin boards set up for the course, thus students at remote campuses will not be at a disadvantage for not having direct contact with the teaching faculty. Questions can be posted on the bulletin board and then answered by the faculty, for the benefit of all students. Homework assignments, solutions, and announcements can also be posted in the same manner.

5. INTERACTIVE COMPUTER EXERCISES AND DESIGN

In order to give students as much experience with flexible power system controllers as possible, one key feature of the new courses will be extensive use of interactive computer simulations. These simulations are being developed for implementation on a Matlab/Simulink platform. This platform is graphical in nature and highly interactive. It is also widely available. Students are provided with the basic component simulations of the various controllers studied in the courses. Using these building blocks, the students will be able to investigate controller performance as a function of parameters, control algorithms, and operating point, and will be able to investigate controller performance from a variety of viewpoints.

To illustrate an example of a student exercise for the transmission course, consider a power system consisting of an isolated local bus connected to the utility grid through a long line. In such situations, the local bus may experience severe voltage dips. This is shown in Figure 1 which depicts system performance during startup of a large induction motor at the local bus. Variables shown are the bus voltage magnitude V_t , motor speed ω_r , and the motor electromagnetic torque T_e . Initially, the bus voltage is nearly one per unit (p.u.). One-half second into the study, the induction motor load is started. As a result, the bus voltage becomes severely depressed for six seconds. It remains depressed even after the induction motor reaches rated speed.

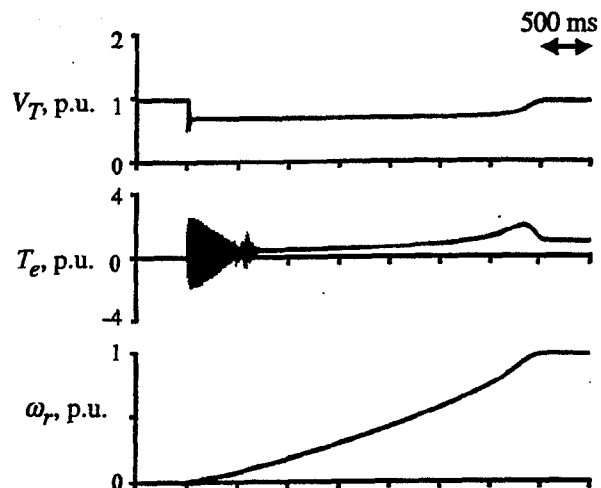


Figure 1. System performance during large induction motor start-up with StatCom off line

To alleviate this problem, students will investigate corrective control strategies using conventional solutions, as well as FACTS solutions such as a TCSC and a StatCom. Figure 2 depicts the system during the induction motor start up when a 48-pulse StatCom is placed at the local bus. With the StatCom in place, the voltage is maintained at exactly one p.u., except for brief excursions when the motor is initially connected and when the motor reaches rated speed. The motor also reaches rated speed much more quickly since the bus voltage is maintained. Students will use the interactive simulation to choose the StatCom control parameters in order to minimize the voltage excursion during the induction motor startup subject to the practical limits of the StatCom.

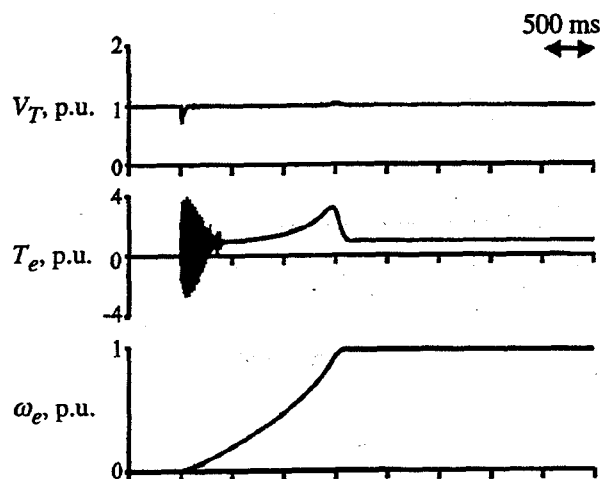


Figure 2. System performance during large induction motor start-up with StatCom on line

6. CONCLUSIONS

Video-linked, multimedia classrooms are becoming increasingly popular for providing off-campus students access to courses and credit towards continuing education. Cooperation between universities is a natural progression of this trend. This approach enhances the education experience of students at each of the schools by relying not only on the experience of the on-site faculty, but also upon the experience of researchers at other institutions. Many benefits result from this arrangements. These include: expansion of the power engineering course offerings at the participating universities which results in a stronger curriculum with more variety; minimal additional faculty workload allocation thus leveraging manpower; and large economies of scale realized via the multi-institutional format such that a national and global impact can be realized. This effort benefits power engineering students by providing them with the tools they will need to be competitive in the deregulated power industry.

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