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# Collaborative Distance Education in Power Engineering

M. L. Crow, A. Pahwa, S. K. Starrett, K. J. Olejniczak, and S. D. Sudhoff

**Abstract**—This paper presents a perspective on offering “shared-courses,” or courses simultaneously offered at two or more universities via various distance educational frameworks. Over a three year duration, two senior/graduate level courses were jointly developed and offered to the students at the University of Missouri-Rolla, the University of Arkansas, Kansas State University, and Purdue University. This paper discusses the various distance educational technologies including two-way audio/visual via ISDN line, video-tapes, and web-based conferencing. Both instructor and student reactions to these mediums are included. Pedagogical methods appropriate for these mediums are outlined. The paper concludes with recommendations and strategies for engineering institutions who would like to “course-share” with other universities and industry.

**Index Terms**—Curriculum development, distance education, multi-institution collaboration.

## I. INTRODUCTION

**P**OWER engineering technology is expanding at an ever increasing rate. Recent advances in electronic materials have ignited surges in the application of high power electronic devices for many applications in both machines and drives and utility power systems. Increasing public awareness has increased the emphasis on alternate energy sources and energy storage. Recent utility restructuring has altered the power systems engineering arena in both planning and operation. Power engineering education must also expand to encompass these new areas.

However, due to the increased emphasis on computer and communications engineering in the past two decades, many electrical engineering departments have significantly reduced or eliminated their power engineering program. Of the remaining power engineering programs in the US, many currently have only one or two faculty whose primary teaching and research emphasis area is power engineering. Increasingly, a small power engineering faculty is no longer sufficient to cover all of the timely and relevant topics in power engineering. These faculty are frequently burdened with the task of teaching and advising students in areas of power engineering outside of their expertise.

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Unlike urban campuses which often have access to well-qualified adjunct faculty, land grant institutions tend to be geographically remote and are not able to take advantage of a large industrial base. One method of compensating for this mismatch between manpower and educational needs is to combine efforts between institutions by “course-sharing.” In this manner, power engineering programs at cooperating institutions may exploit the expertise of numerous faculty and offer a much wider range of courses to students. The Internet has provided an excellent means by which the students at numerous schools can interact in a “virtual classroom” setting.

This paper discusses the collaborative efforts of power engineering faculty at four institutions: University of Arkansas, Kansas State University, University of Missouri-Rolla, and Purdue. The faculty involved developed and offered a series of two senior/graduate level courses in flexible power system control which were offered simultaneously to the students at the four campuses. The developed courses were offered over a four semester time span and utilized a variety of interaction technologies. It is the intent of this paper to share with other educators some of the tools and techniques the authors developed for multi-institution course sharing. In this paper, the authors describe the pros and cons of the various interaction technologies, the student and faculty reactions to the shared courses, and some of the logistical problems encountered. Course-sharing is a very powerful method of providing upper-level students with a wide array of electives and experiences.

## II. COURSE CONTENT

The team of faculty from the four collaborating institutions developed two courses in flexible control of power systems. The first course to be developed was entitled “Flexible Control of Distribution Systems” taught by Prof. Pahwa and Olejniczak. The distribution course outline is given in Table I. The second course developed was entitled “Flexible Control of Transmission Systems” taught by Prof. Crow, Starrett, and Sudhoff. The transmission course outline is given in Table II. Since the students at the participating universities had diverse backgrounds, the only prerequisite for the courses was an undergraduate course in power engineering (which could be a systems course or an energy conversion course).

The URL for the main web site under which all material may be found is: [http://www.ece.umn.edu/~power/Flex\\_Cont.html](http://www.ece.umn.edu/~power/Flex_Cont.html).

Each course web site contained the course syllabus, an electronic bulletin board, homework assignments, the course notes in either html, pdf, or postscript form for printing,

TABLE I  
SYLLABUS FOR FLEXIBLE CONTROL OF DISTRIBUTION SYSTEMS

Distribution automation
Economic analysis
Outage location
Cold load pick up
System restoration
Voltage and VAR management
Power Quality
Custom power controllers
Shunt compensated controllers
Series compensated controllers
Unified power flow controller
Application studies

announcements, the other students' names, e-mail, and URL's, the instructors' names, e-mail, and URLS, and the hyper-textbook. Since textbooks are not available in the topic areas of the courses, the authors are developing a hyper-textbook for the courses. Each hyper-textbook, which is accessed using a web-browser, is similar to a conventional textbook, except it contains active links by which the reader can navigate the material. One of the advantages of a hyper-textbook over a conventional textbook is that the authors can update the textbook on-line by adding links to timely articles or other web sites on recent blackouts, deregulation, or mergers.

### III. COURSE SHARING CRITERIA

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. Prior to choosing a technological medium for sharing the developed courses, the faculty team identified and prioritized a number of criteria. These criteria and their rankings are given in Fig. 1. The faculty team experimented with different methods of classroom delivery each of the four semesters the courses were offered. Each semester a different technology or mix of technologies was used in order to optimally address the prioritized items. Both student and faculty reactions to each medium were assessed at the end of the semester.

Both student/faculty interaction and classroom flexibility were rated as being highly desirable. Well-known pedagogical guidelines assert that students learn more effectively in a relationship where there is a high-level of active interaction between the student and the instructor [1]. This fosters an environment where the students feel the instructor is responsive to their learning rates, styles, and differences. The instructor is able to respond in a timely manner to questions and concerns and also allows students to interject their own thoughts and experiences. Many current distance-learning technologies are passive in that the communication typically flows only one way—from the instructor to the student, and there is either no feedback or delayed feedback from the student.

Classroom flexibility is especially desirable in engineering classrooms where the instructor uses different mediums of

TABLE II  
SYLLABUS FOR FLEXIBLE CONTROL OF TRANSMISSION SYSTEMS

Traditional approaches to power system control
Steady-state control
Transient stability
Dynamic stability
FACTS topologies
Shunt compensated controllers
Series compensated controllers
Unified power flow controller
Power system applications
System based modeling
Power flow control
Subsynchronous oscillation mitigation
Dynamic voltage control
Transient stability improvement

	desirable	very desirable	highly desirable
Real-time student/faculty interaction			X
Collaboration between students	X		
Cost effectiveness		X	
Flexibility of lecture format			X
Ease of use	X		

Fig. 1. Course criteria.

instruction, such as demonstrations, computer simulations, and student presentations in addition to the traditional lecture format. Since a large component of the developed courses were case studies and design projects, the instructors felt it was highly desirable to be able to work through detailed examples during the class period.

Cost effectiveness of the distance technology medium was rated as being a very desirable trait. Although the faculty team had initial funding from the National Science Foundation (through the Combined Research and Curriculum Development Program) for the collaboration, continuation of the courses beyond the award termination was intended. Therefore, the costs associated with the course-sharing were targeted to be low enough to be carried by the departments of the participating institutions over the long term, such that the classes could be shared between institutions perpetually.

Although not rated as highly as student/faculty interaction, student/student interaction was felt to be a desirable aspect of the virtual classroom. It is becoming common practice in engineering classrooms to have students work in team on class projects to help prepare them for the industry environment, where teamwork is a necessity. The advantages of team work are well documented and help students development skills in time management, speech, and communication. Course-sharing

between institutions is a good opportunity for students to learn to work together using electronic media, such as e-mail and the internet.

Another desirable feature was ease of use of the technology. It was desirable to find a medium to which the faculty at each of the four institutions had access. It was also important that the students felt comfortable as well using the technology for presentations and student/faculty interaction.

#### IV. THE "VIRTUAL CLASSROOM"

In order to achieve the most effective presentation, in the presence of geographical, cost, time, and technology constraints, the faculty team experimented with four different approaches to promote course sharing between the four participating universities. In particular, the four approaches were: i) video tape technology by mail, ii) live audio and video via an integrated service digital network (ISDN), iii) data conferencing in conjunction with teleconferencing, and iv) a mixture of video tape by mail and data conferencing. In the following section, the authors address the trials and tribulations of their experiences with each of the aforementioned methods of course-sharing. Each of these alternative methodologies will be examined in detail and will be compared and contrasted from a cost and pedagogical point of view based on their experiences.

##### A. Video-Tape by Mail

The distribution course was the first course to be offered jointly between universities. During the first semester all courses were video-taped and then were sent via express mail to the other sites. Video-taping a course offers the instructor a wide range of flexibility in preparing and presenting the lecture material. Most forms of media presentation such as blackboard presentation, overheads, computer simulations, etc., are amenable to a video-taped format. With a two- or three-camera production, the instructor may use the blackboard or may write on the desktop using the overhead camera. The instructors also had access to "picture-in-picture (PIP)" and "chroma-key" alternatives. With PIP, both camera angles are captured and presented simultaneously on the monitor giving the viewer both the face shot of the instructor and the overhead shot of the desktop. Chroma-key is a technique of blowing up one camera shot to be the background of the other. In this way, the instructor could stand in "front" of the slides or computer simulation and use his/her hands and body to highlight points of importance, similar to the way a weather forecaster does during the evening news. This gives the student the advantage of seeing both the instructor and the lecture material simultaneously.

The primary disadvantages of video-taping a course is that there is limited student/faculty interaction. Although each campus had on-site students, there was little classroom discussion. On-site students are typically reluctant to ask questions or make comments when they know their discussion will be preserved on tape. Thus, lectures had a tendency to be passive and sometimes uninteresting due to limited participation from students. This reluctance can be mitigated over time by the instructor by continually asking questions and encouraging student responses. Off-site students also benefit from the

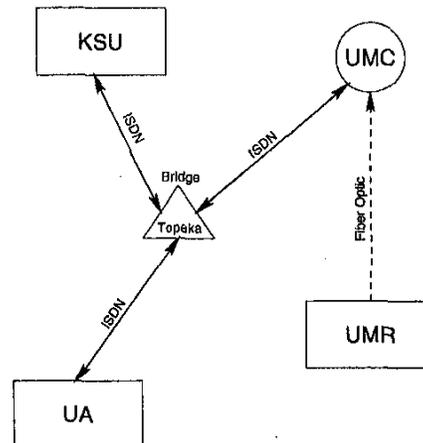


Fig. 2. Video conferencing connection.

discussion between the on-site students and the instructor, because they are far less likely to contact the instructor directly than on-site students. The authors found that typically only one student from each site would contact the instructor (usually via e-mail) and this student would report back to all students at the site. One method the instructors tried to get more interaction was to post all questions and answers to both an electronic bulletin board and to distribute all e-mail via a class listserv. The students did not utilize the bulletin board extensively, but they used e-mail correspondence considerably.

Another disadvantage with video-tapes is the high production cost associated with each lecture, due to the costs of production (number of cameras, PIP, etc.) and technical personnel required.

##### B. Video Conferencing

In the second semester of the project, the transmission course was offered with real-time audio and video via an ISDN connection. The primary advantage of the two-way audio and video is that students had real-time interaction with the instructor and each other.

The main technical obstacle to be overcome for this project was the live multiway video link between the three campuses (Purdue was not yet involved with the project), with three different levels of capability. One of the least expensive means to accomplish such a connection is using the ISDN telephone service. However, there were several obstacles in utilizing such a service for this project. First, was the fact that a direct ISDN connection only works between two sites—not multiple sites. Second was the fact that only the KSU and UA sites had ISDN service available.

The first of these difficulties, that of the two site limitation, was overcome by utilizing a 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 to be solved was connecting UM-Rolla to the bridge without paying for an ISDN line to be run to the UM-Rolla campus, which would have been quite expensive. Instead of installing an ISDN line, use was made of a dedicated fiber optic network which links all of

the campuses of the University of Missouri system—namely UMSL (St. Louis), UMKC (Kansas City), UMC (Columbia), and UM-Rolla (Rolla). In particular, the fiber optic link was used to connect UM-Rolla to UMC, at which point the video information was converted to ISDN format and interfaced with 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. The ISDN connection between universities is shown in Fig. 2.

Using an ISDN connection, each campus is free to utilize the most convenient hardware. For example, the UM-Rolla and UA campuses made use of a formal studio designed for distance education projects, whereas KSU made use of a standard classroom using a PicturTel™ video conferencing system. The three way connection had distinctly lower resolution due to the bridge bottleneck, than did a two way connection. The three way connection also decreased the reliability of the interconnection.

As a result of the decreased resolution, it became difficult for students to take notes during class. Many movements became blurry or choppy and the resolution of the instructor's handwriting was poor and fine lines on graphs or simulations became unreadable. To compensate for this disadvantage, the instructors prepared all class notes in advance using PowerPoint™ or similar package and then posted the notes on the web site for the students to download prior to class. Students were then able to follow along and make addendums to their notes during class.

### C. Data Conferencing

The distribution course was taught for the second time using a web-based on-line interactive component, where course lectures and presentations were delivered on-line via the internet using a data conferencing medium (such as FarSite™). Data conferencing is a term to describe the sharing of computer data among several computers. FarSite is a commercially available data conferencing package which the consortium members elected to use in creating the virtual classroom. The software was installed locally on each personal computer to enable a connection to the server. The FarSite server was installed on a UNIX machine in the Electrical and Computer Engineering Department at Kansas State University. The data conferencing software can be accessed through a Java-enabled worldwide-web browser such as Netscape. An attendee can initiate a conference, join a conference already in progress, or manage other functions of the conference through a web-site. The attendees can either go "free-form" using the whiteboard function of the conference, or open a prepared workbook. A workbook is a presentation that has been prepared in advance on one of many available platforms (such as PowerPoint). Once the workbook is opened and shared with the conference, any of the attendees may access the workbook. All attendees see the same workbook and the same page. The software has a pointer, a highlighter, a text tool to enter text, and a freehand tool for writing on the slides. Any addition, such as text or highlighting, made by any attendee appears on all attendees workbooks. Audio is provided by a same-time teleconference. The data conference can be held such that each student has the workbook loaded on his/her own PC, or the class the view a projection of the computer screen. This format allows each student the ability to write or draw on the

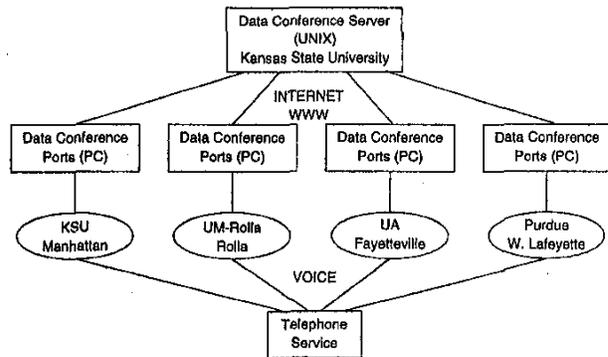


Fig. 3. Data conferencing connection.

screen to make a point or ask a question, much like they might do in a regular classroom setting. The structure of the data conference is shown in Fig. 3.

One advantage of this technology is that students can also prepare workbooks for their homework or project assignments and then present it to all the students, both on- and off-site. Such an activity encourages class participation and discussions by the students. Once again, the instructor must work to get off-site students to participate in class. Since the off-site students cannot see the instructor, they often do not feel the same rapport as on-site students do. Several of the instructors developed classroom activities which encouraged the students to utilize the drawing tools and to respond to questions, which enhanced the quality of the instruction.

One disadvantage of the data-conferencing is that it was difficult to work through lengthy problems using the text or drawing tools, so some of the problems worked in class lost some of the feeling of "discovery" since they had been worked out in the notes in advance. Similarly, it was not possible to run through real-time computer simulations in class, since the workbooks are static. Since the class is web-based however, animations can be made available on the class web-site and may be accessed during class for demonstration purposes.

In the fourth semester of the project, the instructors used a combination of video tapes and data conferencing. Video tapes were made of lectures related to standard course material or classes requiring considerable problem solving or computer demonstrations. These tapes were watched by students twice a week. The "live" data-conferencing classes were then used once a week to discuss the material presented in the two previous tapes and to discuss project work. The tapes were prepared ahead of time to allow each site to remain synchronized as teaching duties transferred from one instructor to another. The video tapes were also made available as a reference for students to review as they worked on course projects.

### D. Other Considerations

Some of the difficulties the faculty team had to overcome had little to do with the interaction medium, but rather with discrepancies between universities. Each institution had course numbers assigned individually, so students were able to register and pay tuition directly to their home university, even if

the instructors were at a different institution. The faculty at the home institution acted as facilitator by proctoring exams, etc. The lecturing faculty sent all homework, project, and exam scores to each faculty so that grade sheets could be filled out at the end of the semester. Homeworks and projects were submitted via e-mail or FAX.

In order to share courses in real-time, the courses at the participating universities must start at the same time. Throughout the duration of the project, all courses were offered on a Monday-Wednesday-Friday schedule at 10:30 a.m. Typically in the US, most institutions start their MWF classes on the hour or half-hour, so at most a shared course would overlap two scheduled course hours.

Another logistical problem was coordinating the first and last day of class and scheduled holiday breaks. For example, each institution had Spring Break scheduled for a different week. The authors' solution to this problem was to have the faculty at the school not on break lecture during that week and to video-tape the lectures. The video tapes were then sent to the students who missed those classes. Since no break was taken during the semester, no lectures were given the last week of class. Another difficulty the authors faced was that the state of Indiana does not observe daylight savings, so the class time at Purdue University changed by an hour in the middle of the semester. The students at Purdue were aware of this difficulty during registration so that it did not cause a scheduling problem for them.

One of the biggest advantages of course-sharing is the interaction between the involved faculty members. All of the instructors for each course attended each class and frequently initiated or participated in lively discussions about the topics. The students gained considerable insight into the material by listening to, and participating in, the discussions between the faculty.

## V. REACTIONS

The students' reactions to course sharing have been mixed. The majority of students had a positive response to being able to learn material from these courses to which they would not otherwise have access. The students' reactions to the different technologies were also mixed. In general, the students disliked video tapes, but they were willing to accept them in the absence of a better alternative. The reaction to the video conferencing (two way audio/video via ISDN line) was negative; this was primarily due to the poor quality of the video. Most students preferred data conferencing since it provides much better picture quality. The students were initially uneasy about not being able to see the instructor, but with time they became more comfortable with this format. They preferred data conferencing to video tapes.

The instructors reactions have also been mixed. Frequently, the instructors felt frustrated by the difficulty of getting students to interact during class. Off-site students were initially reluctant to speak or ask questions. This problem was addressed by giving interactive assignments (both formal assignments and in-class "mini" assignments) in which students had to respond verbally. Over the course of the semester students became more

comfortable with the novelty of both the video-conferencing and data-conferencing setups. This was further enhanced by having all instructors attend class and verbally participate as well.

The authors also attempted to have students work in project teams. The intent was to have students from different schools work together on a project. This was more difficult to implement than anticipated, due to the unequal numbers of students at the institutions, varying levels of expertise with html and computer capabilities (i.e. Windows versus Unix). Students were sometimes frustrated when they were asked to work with software with which they were not familiar and the instructor was at another institution.

## VI. RECOMMENDATIONS

Student participation and interaction is crucial to developing a "virtual classroom" experience. Following are some of the techniques that were utilized to encourage active student participation both in and out of the classroom.

- Early in the semester have the students and faculty introduce themselves and "play" with the technology.
- Encourage local students offline to prepare and ask questions in class.
- Have group exercises in-class at each site and have sites report to each other.
- Require students to present reports and project work to the class using the technology.
- Have students anonymously "peer review" each other's work and make positive suggestions.
- Present figures and data live and have students explain what is happening, answer questions, or "vote" on correct answers.
- Leave blanks in the course notes to require students to write down essential details during lecture to keep their attention directed.
- When e-mail questions are sent directly to the instructor, forward the question and answer to all students via the listserve.

## VII. CONCLUSIONS

Course-sharing can be an exciting way to increase the breadth of upper level power engineering courses. This approach enables students to have access to a wider range of expertise and material than they would have otherwise. Data-conferencing is a good medium for offering both real-time student/faculty and student/student interaction in a cost-effective manner. Data-conferencing can be augmented by video tapes when necessary for lengthy derivations, problems, or computer demonstrations. Student communication is best encouraged by having the faculty at the involved institutions attend and participate in the lectures.

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