Successes with NSF CCLI-EMD and CCLI-ND Grants

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Abstract

This paper outlines how a real need in teaching, in our case in the areas of Power Electronics and Electric Drives, was recognized and articulated. To meet this need, this paper shows how the faculty resolve, the departmental encouragement, and the financial support from agencies such as NSF and NASA led to a successful conclusion in revitalizing these fields not only at the University of Minnesota but in creating a community of schools where it has met with equal success. Although our effort is specific to the fields of Power Electronics and Electric Drives, this presentation is generic and can apply to virtually any discipline.

Rationale for Change

Power electronics and electric drives are enabling technologies, crucial for industrial competitiveness. The industrial scene is changing as many of the items discussed in these courses are becoming commodity items being outsourced to low-wage areas of the globe. Therefore, the role of our future graduates would mainly be system integration where control would play a key role, based on solid understanding of the fundamentals. The courses in these areas, however, have not changed in decades and fail to deliver relevant information in light of the current industrial practices.

For example, power electronics courses fail to show the commonality between various topologies and do not include discussion of their feedback control, which is essential to their operation. Similarly, motor drives courses have traditionally emphasized the analysis of electric machines without any emphasis on their use in speed and position control applications.

No wonder that the enrollment in these courses have been declining to the point that several schools have eliminated them from their curriculum.

Faced with a similar situation, we at the University of Minnesota undertook an in-depth examination of how and what should be taught in these courses. This has led to the restructuring of these courses with the associated laboratories, which are described in the following sections.

Learning-Outcome Based Course Restructuring

The learning outcome of each course is solid understanding of fundamentals in a way that makes them relevant to current industrial practices and prepares students for a lifelong learning including graduate studies for a research-oriented career. In addition, we recognized that most interested undergraduate students take only one course in each of these areas. Perhaps, they should take only one course, thus allowing them to attend courses in complimentary fields such as digital control, applications of digital signal processors, and so on to receive a broader education.

In light of these objectives and constraints, we decided to offer only one course in each field at the undergraduate level, followed by a course that is mainly oriented towards graduate students. In the undergraduate course, we decided to present many more topics in an integrative manner with twice the in-depth knowledge. For example, students should be able to design feedback control in power electronics and electric drive systems.

Compared to a traditional course, presenting twice as many topics with twice the in-depth knowledge is a challenge that was met by following the steps listed below:

- Avoiding legacy topics that waste valuable time and provide misleading impression that they may still be applicable. As an example, various arrangements in dc machines as generators are omitted.
- Searching for commonality in various topologies to provide deeper physical understanding and to avoid repetition thus saving time. The example of this is the concept of a switching power-pole as the building block in power electronics converters.
- An applications-based top-down approach is followed to provide the rationale for discussing each topic. Moreover, fundamentals are presented in a way to provide seamless continuity to advanced topics.

  An example of this is the use of space vector theory, which is essential in describing how ac machines should be controlled dynamically in an optimal manner. This is a topic for the graduate course. However, simplifying the space vector theory in how it is presented and used in the undergraduate course to describe the steady state behavior of ac machines provides a seamless continuity to the graduate course and saves time.

- Topics are sequenced to build on the prior discussion and to maintain student interest.
- Easy-to-use simulation programs, such as PSpice, are used to avoid tedious calculations that provide no insight.
- Hardware laboratories are developed to reinforce recently-discussed topics in lectures, and to provide hands-on experience.
- Textbooks are written to support the above-mentioned approaches.

Proposal to NSF under the CCLI-EMD Program

Accomplishing the tasks listed above require faculty resolve and departmental support in allowing restructuring of courses and experimentation with fine tuning the syllabus. However, the development of hardware laboratories also requires funding for equipment and a graduate assistant to help with the development. To make these laboratories models for national dissemination, it was decided to prepare a CCLI-EMD proposal for a full-scale development. In preparing this NSF proposal, there were several aspects that were crucial to its eventual success:

- Addressing the need: Although we had an open mind for making necessary adjustments, we were absolutely convinced and extremely excited about the task at hand and had done our homework. For example, we proposed DSP-based, software reconfigurable laboratories based on the fact that most industrial drive systems are beginning to be digitally controlled.

- Support from Industry: We solicited many letters from leaders in industry and government laboratories that highlighted the problem, mainly the lack of adequately trained students. In addition to the mandatory matching funds from our university, we were successful in NASA supporting our development effort, contingent on the success of our NSF proposal. Although the funds promised by NASA were relatively small, its leveraging effect we believe was enormous.

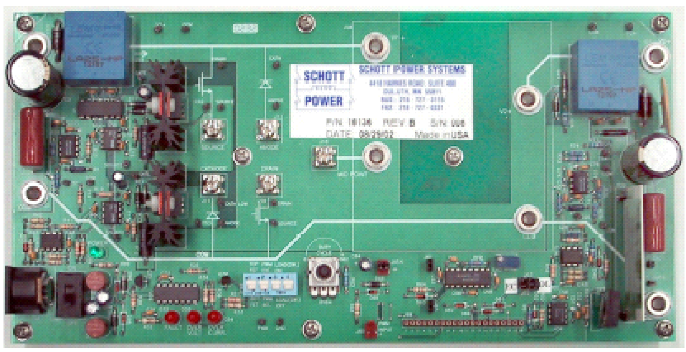
- Feedback Mechanism, Evaluation and Dissemination: It was proposed to hold workshops and seek other faculty feedback as the laboratory development proceeded. A carefully thought out evaluation plan was proposed. The workshops to seek feedback were to help in dissemination.

Our CCLI-EMD proposal "DSP-Based Software-Reconfigurable Laboratory to Nationally Revitalize Electric Drives and Power Electronics Curricula" was funded for the duration 5/31/2000 – 5/31/2003 for an amount of $276,292. A one year no-cost extension has subsequently been granted. Matching funds of 60 k$ were provided by the University of

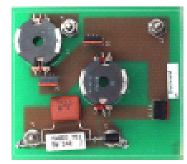
Minnesota. In addition, a grant of 30 k$ was received in support of this development from NASA.

Developing and Commercializing the Hardware Laboratories

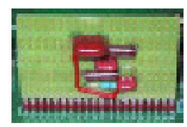
With the help of NSF CCLI-EMD funding and the NASA support, hardware laboratories have been developed. Some components of these laboratories are shown in Figs 1 through 3, which are commercialized for easy access to any school desiring to adapt these. Several universities have successfully received CCLI-A&I funding from NSF and more new proposals to do so have been submitted this year.



(a) Switching Power-Pole Board



(b) Magnetics Plug-In Board



(c) Feedback Control Plug-In Board

Figure 1 Commercialization of Power Electronics Lab Set-up.

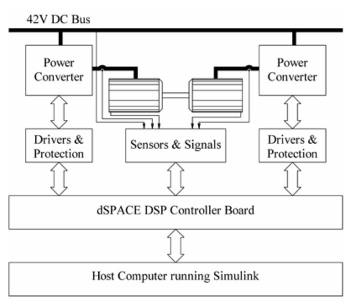


Figure 2 DSP-Controlled Drives Lab Arrangement.

(a) Drives Board

(b) Motor Set

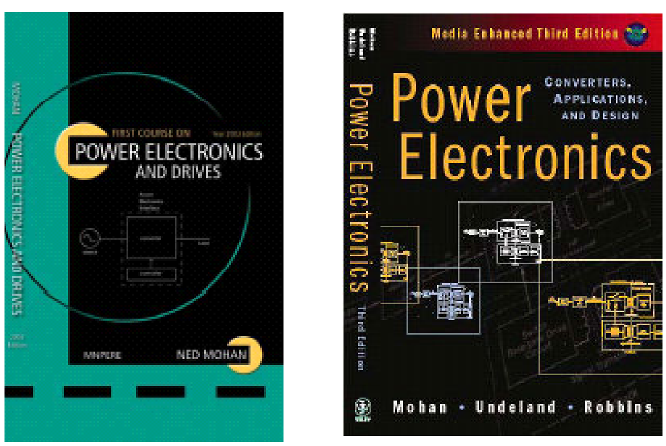
Figure 3 Commercialization of Drives Lab Set-up.

The experiments are developed for these two laboratories and are available at the following website for anyone to download and apply for the NSF CCLI-A&I funding: www.ece.umn.edu/groups/PowerElectronics_Drives. The homepage of this website is shown in Fig. 4.

Figure 4 Homepage of the Website for Developed Laboratories.

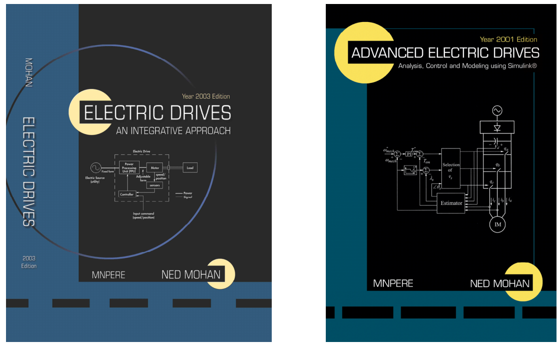
Publication of Textbooks

In parallel with the laboratory development supported by the NSF CCLI-EMD, it was recognized that the success in teaching these courses required textbooks that students can follow. This has led to writing of four textbooks, shown in Figs. 5 and 6, that have been published.



(a) Undergraduate (b) Graduate

Figure 5 Power Electronics Textbooks.



(a) Undergraduate (b) Graduate

Figure 6 Electric Drives Textbooks.

Faculty Workshops for Feedback, Evaluation and Dissemination

The feedback on laboratory development and course restructuring for revitalizing power electronics and electric drive curriculum nationwide has been accomplished by holding faculty workshops in 1997, 1998, 2002 and January 2003. These also served to disseminate these developments, as described by their agenda on the following workshop website: www.ece.umn.edu/groups/PowerElectronics_Drives.

Nationwide Dissemination through the CCLI-ND Funding

With the objective to reach 350 faculty members, and impact 10,000 undergraduate and 1,000 graduate students, a CCLI-ND proposal was prepared. Through this three-year continuing grant "State-of-the-Art Practices and Educational Materials for Revitalizing Power Electronics and Electric Drives Curricula" for an amount of $117,268, a workshop was held in July 2003 and another one during February 20-21, 2004 for which the website is the same as that listed above for the prior workshops.

Short Courses that include Distance Learning through the Internet

In addition to these faculty workshops, short courses are planned for practicing engineers, the primary objective of which is to disseminate these new educational developments that are equally beneficial to them. These short courses are also useful in soliciting the feedback from practicing engineers about the importance of various topics in our courses. To reach a wide spectrum of practicing engineers, a distance learning format is adopted where the material presented to in-class participants is also broadcast over the internet in real-time. This format has several advantages:

- Participants present in the classroom benefit by interacting with instructors and with each other.
- Participants over the internet can ask questions through e-mail that instructors can answer in real-time.

- All presentations are kept on the internet website for a few months that all participants can review at their convenience. Copies of these on DVDs can also be made available.

One such internet-based short course was held in November 2003, as described on the following website: www.ece.umn.edu/groups/PowerElectronics_Drives.

This was our first attempt in offering these short courses that included the use of internet. In doing so, only the in-person participants were able to view the laboratory displays and results. We are exploring ways to make these laboratories available through the internet where the participants can conduct the experiments remotely.

Increasing Student Enrollments

Since the course restructuring, the student enrollments have been increasing with the recent trends shown in Fig. 7. During the most recent semester (Fall'2003), the Electric Drives course had 75 students and the Power Electronics course had 50 students registered.

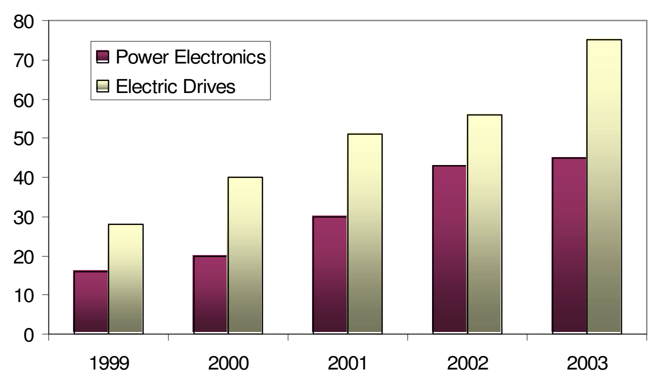


Figure 7 Trends in Student Enrollments at the University of Minnesota.

Conclusions

This paper outlines how a real need in teaching, in our case in the areas of Power Electronics and Electric Drives, was recognized and articulated. To meet this need, this paper shows how the faculty resolve, the departmental encouragement, and the financial support from agencies such as NSF and NASA led to a successful conclusion in revitalizing these fields not only at the University of Minnesota but in creating a community of schools where it has met with equal success.

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Biographies

Ned Mohan, William P. Robbins and Paul Imbertson are faculty members in the Department of Electrical and Computer Engineering at the University of Minnesota. Rajapandian Ayyanar is a faculty member in the Electrical Engineering Department at the Arizona State University. Ben Oni is a faculty member in the Electrical Engineering Department at the Tuskegee University.