EXPLORING PROBLEM BASED LEARNING IN A MULTIPURPOSE USE POWER ELECTRONICS LABORATORY

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***Abstract* – This work presents some results using the problem-based learning in power electronics disciplines. The power electronics curriculum develops the basic concepts of the field and applies them to modern industrial challenges to solve practical problems. The laboratory activities are planned to support three fundamental disciplines: frequency line converters, high frequency switching converters and motor control and drives. The methodology adopted is a cooperative experiential learning activity. The experience is based on a problem-based learning approach that motivates student learning and develops skills required by the student in a future professional capacity. Some equipment, computer and software provide the students modern tools necessary to analyze, design and build the circuitry. Computer simulations are used extensively to verify concepts and to enhance student's comprehension. In general, students feel they learn more effectively in a practice-oriented course. This laboratory significantly impacts many students who will take positions with organizations in the electrical/electronics industry, where the skills gained from laboratory experiences will be greatly valued.**

***Keywords* - Cooperative learning, experiential activity, problem-based learning, power electronics laboratory.**

I. INTRODUCTION

Power electronics is a science based in circuit theory and applied electronics, but it is essentially based in laboratory exploration. So laboratory activities are fundamental in this field for a better student comprehension. To develop student's skills it is necessary to plan some laboratory activities.

The power electronics laboratory is a multiuse undergraduate and graduate teaching facility designed to be both flexible and powerful. The equipment facilities allow students an opportunity to apply and integrate classroom knowledge in analysis, simulating, design and experiment topologies in the field of power electronics and related topics [1]. Students are exposed to software and modern tools necessary to analyze, design and build systems.

The laboratory is basically designed to support three fundamental disciplines: Power Electronics I (frequency line converters), Power Electronics II (high frequency switching converters) and Electrical Drives (motor control and drives).

The methodology adopted is the cooperative problem-based learning to develop student's design skills [2-7]. Essential elements of a well-structured formal cooperative learning group are considered along with the professor's role in structuring a problem-based cooperative learning group.

With the problem based learn methodology, students improving their skills in dealing with complex projects, linking theory to real world applications, and improving their problem-solving performance.

The power electronics laboratory is used as an educational workbench and in practical operational use. It is designed like a pedagogical tool, a research environment, and a fully operational data analysis system that is used not only in undergraduate engineering courses, but also in graduate study and general research [8].

The lab configuration allows the students to perform standard topologies experimentation or to provide a new design which novel topologies or theories can be analyzed and implemented.

After an experiment, the student does a primary simulation step, so that most mistakes and improper measurement settings are detected and immediately fed back [9, 10]. Computer simulation is used as a tool increasing student's abilities to comprehend the behavior of several power electronics circuits [11, 12]. Graphical capability of doing numerical computations reduces the effort needed to determine power-related quantities in nonlinear circuits. Fourier analysis capabilities enable harmonics to be investigated [13].

Experimental examples using digital oscilloscopes having print/plot capability and dedicated software are used to compare with computer simulations. A design project is used to integrate the materials taught in the lectures with experience gained in the laboratory sessions.

II. PROBLEM-BASED LEARNING

Problem-based learning (PBL) is the process of using a problem situation to focus the learning activities on a need-to-know basis. This contrasts with subject-based learning, where the student is presented with discipline-based material and is then given a problem (or example) of its use. PBL is ideal for engineering education as it encourages a multidisciplinary approach to problem solving (which is essential for modern engineering practice) and develops techniques and confidence in solving problems, which have not been encountered before [2].

Combining PBL with cooperative learning provides a mechanism for students to maximize their own and other group members' learning by working in teams to accomplish a common task or goal [2]. Cooperative learning develops personal skills including conflict resolution and social skills as well as developing interdependence and individual and group accountability [2, 4]. Learning in groups has the additional advantage of reducing the resource demand on the engineering department [2].

When implementing a PBL program it is important that the assessment requirements relate to the course objectives [2]. The power electronics course has two major objectives: first, that each group produces a working design; and secondly, that each group member is proficient in all aspects of the design process.

In the implemented course, there are two major items of assessment: an individual design report and a group presentation. The group presentation consists of each group demonstrating their working design in the final session allocated to the course. Part of this demonstration is an individual interview, which is used as an incentive to overcome the student's initial reluctance to cooperate and learn in groups. In this interview, detailed aspects of the hardware and software design are asked of randomly selected individuals from the group. The combined results from this interview are then allocated to the group as a whole. This ensures that the group is responsible for the learning of the individual and for ensuring that each member is performing as a member of the team.

The goal of the laboratory work is to provide the basis of electronic practical experience, i.e., the use of basic instruments and measurement techniques, the understanding of the methods used, and the validation of the obtained results [3-5].

III. FACILITIES

The Power Electronics Laboratory occupies an area of approximately 50 square meters. It has a principal bench for power electronics experiments and a secondary bench for computational support. The principal bench has capacity for eight students simultaneously working and the secondary bench for computational use with four microcomputers.

The Power Electronics Laboratory is equipped with two Tektronix TDS3012 color two channel oscilloscopes. Waveforms acquired by these oscilloscopes can be imported into some word-processing software to generate laboratory reports. Additionally, harmonics can be analyzed using specific software. Each oscilloscope has a set of differential voltage and current probe. AC and DC current probe capability is very useful and even magical to students who have not used a current probe before. The laboratory requires two high-power (~120V, 10A) power supply, some medium-power (~60V, ~3A) power supply, some true rms capability multimeters, and function generators. Fig. 1 shows some equipment used in the Lab.

In addition, for general purposes, the laboratory supports several electronics instruments and components used in any one of the standard undergraduate laboratories in the Department of Electrical and Telecommunications Engineering. Bench instruments include analog and digital oscilloscopes, voltmeters, amp meters, digital multimeters, triple power supplies, power analyzer, and others.

The chief support equipment in the current inventory includes adjustable autotransformers, drew press and an assortment of hand tools.

Fig. 1. Some equipment used in the Power Electronics Lab.

The four personal microcomputers are equipped with the principal software used in power electronics analysis like: Orcad Light Edition simulation set, PSim student version, some software for mathematical analysis, circuit drawing and waveform analysis and treatment. One microcomputer is equipped with the Orcad 10.5 full version and another with the PSim full version. They are used in more complex simulations and it is very helpful for graduate and research activities.

IV. SIMULATION TOOLS

The use of circuit simulators at the undergraduate level has afforded those who teach power electronics an additional and important tool to simplify teaching and to introduce students to real-world engineering problems [9].

In this approach, Orcad has been used as an instructional tool to analyze the electrical performance of power electronics circuits by feeding the simulator with the circuit topology of the converter, as well as the element values and the control signals [9-11].

Using the input data, the simulator generates the algebraic and integer-differential equations by applying Kirchhoff's laws at each node, solves them, and provides the specific output in the form of visual waveforms for the current and voltage everywhere in the circuit. Students are allowed to vary the circuit parameters and examine the effect of these changes on the electrical variables equivalent to the creation of a virtual laboratory where the computer screen replaces the oscilloscope in a real laboratory environment [9].

The approach, however, does not permit the student to design, using methodical steps, converter circuits to meet a set of design criteria. For this methodical design to take place, one needs to couple the strength of the circuit simulator in terms of its computational speed with the basic design equations that are derived in the literature for various converters. Only then, a circuit simulator can be used as both a tool for analysis and a design of power circuits.

Selecting Orcad rather than other circuit simulators is because it has an evaluation version of Capture-PSpice available to students at no cost through the OrCAD (Cadence Design Systems, Inc). Capture-PSpice outputs a text and a data file. The text file reports all the requested results and shows any errors that occur during simulation. The data file is used as an input to the graphic post processor program, a waveform analyzer known as Probe.

The latter contains analog operations and functions that can be used to calculate important parameters such as root-mean-square (rms) values, instantaneous power, maximum and minimum values, and average power.

A set of design criteria, such as the output voltage, the output power, and the maximum permissible ripple on the output voltage, are specified, and the design equations are used to generate the value of the elements in the design. Simulation will then run to compare the actual characteristics of the design with the required ones. Minor modifications can be brought to the elements to increase the overall accuracy.

All simulations in the undergraduate course are completed by using the evaluation version of PSpice, and active switches are treated as ideal or, when necessary, by a similar model contained in the software library.

V. DESIGN PROJECT

A design project is used to integrate the materials taught in the lectures with experience gained in the laboratory sessions. In order to be effective, the experimental work needs some previous theoretical preparation, and once the experiments are finished, further study to settle the concepts involved is advisable.

Students first perform hand calculations to determine appropriate components for their converter design. These components are then verified using computer simulations.

The project introduces students to the design and fabrication of magnetic components. They select the required magnetic cores based on specifications of their converters.

This approach has eased many experimental setups, eliminating some manual tedious data collection routines and allowing more time for efficient analysis of results, proposing new models for the assimilation of fundamental concepts, and offering modern resources for the elaboration of reports []14, 15.

It also serves to improve interpersonal skills of students by requiring them to work as a member of a team. Students are divided into groups of no more then three, but each is required to write his/her own report.

The design project assignment depending on the class and discipline, as examples, involves a complete controlled rectifier design, a single mode power supply design and a voltage source inverter design respectively in the three disciplines of the power electronics field: Power Electronics I, Power Electronics II and Electrical Drives.

In a design of a single mode power supply the students experience a complete system overview. They need design the input protection and filtering, the rectifier bridge, the switch technology, the power stage topology, the magnetic components, the control and the drive circuitry. Fig. 2 shows a block diagram of a single mode power supply system explored in Power Electronics II discipline.

The student should notice that each part of the circuit is essential for an adequate operation and it involves knowledge of some other subject. This experience changes the student vision of the discipline, the course and professional carrier.

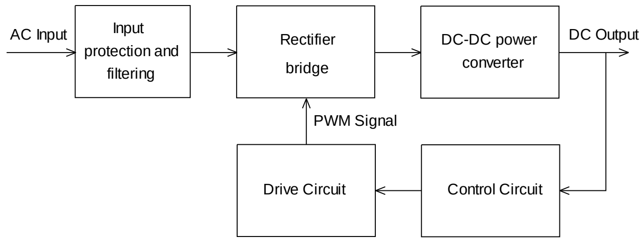

Fig. 2. Block diagram of the single mode power supply used as an example in a PBL exploration.

The major problem of this method is the spend time of the students without hands-on experience, but they are helped by the others one that have these skills.

Using this methodology the students gain experience in producing a prototype design, in much the same manner as would be occurring in an industrial setting.

VI. RESULTS

It has been four years since the new teaching approach was introduced and the power electronics laboratories were re-organized. Apart from having continuously improved the experiments, the changes, which have impacted the students' learning efficiency in the electrical engineering course, have been quantified.

Not many changes have been observed on the students' failure rates in the disciplines. A better assessment method would be through evaluation of experimental procedures proposed to each student in the Lab.

Some of their comments were really useful and relevant to the process: they all liked the new methodology, instruments and equipment used.

This method is now available to all electrical engineering students who are enrolled in any laboratory of power electronics field, giving them the opportunity to complement their practical skills, acquiring hands-on experience, developing their own designs.

The professional instruments and computational tools used in the laboratory have increased student's interest in the disciplines. Teamwork and creative learning are also objectives of the new methodology.

The lab was constrained to fit within a 2-h period. To enhance learning, the lab was designed to be hands-on. Selecting inexpensive equipment enabled the Lab to be performed by large numbers of students and easily implemented to other institutions.

From conversations with some students the authors can deduce that they find the interactive learning is a significant improvement over a traditional laboratory method. They say that this method permits them to monitor the evolution of their experimental work, so that they can validate their results in real time, and feel motivated to continue. Keeping students' motivation alive is a basic aspect in an engineering course. The response was positive, which will encourage the extension of the approach to other subjects.

Some of the students that experienced this type of methodology are thinking about entering at the master degree course in the field of power electronics. That is a big advantage because they have more skills to develop a practical dissertation compared to other students.

VII. CONCLUSION

Students learn, verify, and reinforce lecture concepts by performing switching power converter experiments in the laboratory sessions. It was adopted the problem-based cooperative learning methodology. With this approach, students can develop confidence and abilities needed in future capstone design courses and professional practice. The design experience develops the student's lifelong learning skills, self-evaluations, self-discovery, and peer instruction in the design's creation, critique, and justification. Students learn to learn from manufacturer datasheets and application notes. The experience, which would be difficult to complete individually, gives the students a sense of satisfaction and accomplishment that is often lacking in many engineering courses. Furthermore, the design experience motivates student learning and develops skills required by the student in a future professional capacity. Computer simulations are used extensively to verify concepts and to enhance student's comprehension. The experiment received a positive response from the students, having enhanced their understanding of the theoretical concepts analyzed in class. In general, students feel they learn more effectively in a practice-oriented course. The technique presented in this paper can be extended to other circuit design related courses.

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