INTRODUCING POWER ELECTRONICS IN ELECTRICAL AND COMPUTER ENGINEERING CURRICULUM

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Abstract

This paper presents the incorporation of Power Electronics as a new course in electrical and computer engineering curriculum at Grand Valley State University. The philosophy and necessity of this course in modern electrical and computer engineering curriculum are explained with a brief snapshot of the United States economic trends enforcing employment demand for power electronic engineers. The objectives, synopsis of course contents, laboratory development and course project structure are discussed. Student evaluation and lessons learned from a test run of this course as part II of EGR 680 (Design of Electrical Control Systems) offered in winter 2003 are summarized. The results of this test reveal some difficulties encountered and possible solutions while enhance the potential of power electronics as a new course at the school of engineering.

I INTRODUCTION

In recent decades, the focus of engineering curriculum has been displaced away from power engineering program. At the same time, research on power electronics is consistently enjoying rapid progress. In [1] B.K. Bose, has reported that the late 20th century is the era of power electronics and information. Truly power electronics and computer has achieved a revolutionary advancement in modern technology in every sphere of our day-to-day life. Sales of power electronics equipment exceed $60 billion each year and contribute to another $1 trillion sale in related hardware electronics [2-3]. Although these figures reflect the contribution of power electronics in modern economic trends, the power electronics industries, more generally, the power industries are facing an alarming shortfall [4] in quality workforce with appropriate blend of knowledge with other areas including software and information technology. This is partly due to lack of student interests in power engineering major.

United States is going to face a serious energy crisis if appropriate measures are not taken on time. Recent (2003) Department of Energy (DOE) statistics [5] show that about 91.7 % of our energy need comes from fossil fuel source including foreign petroleum or other sources detrimental to clean environment. To ensure continuity of required energy supply it is time to look for alternative energy sources. At the same time to leave a cleaner and safer environment free from pollutions for our future generation we must look for renewable and cleaner energy source. Recently, research trends have been showing significant interests on the renewable energy sources like hydrogen fuel-cells, photovoltaic-cells, bio-diesel, wind energy, hydro-electricity etc. Almost all of these energy sources have low efficiency and high cost, hence requires optimized operation with lower cost. Above all, some of these sources generate low level dc voltage which must be converted to higher level and appropriate frequency to supplement the utility supply. The integration, control strategy, efficient operation and application of these energy sources require expertise in Power Electronics and control systems.

Although Power Electronics is a well-established and important course in electrical engineering program in almost all of the universities in the United States, it was not being offered at the school of engineering until recently. In winter 2003 the author offered power electronics as a part of EGR 680 (Design of Electrical Control Systems) on test basis. Recently the base of a power electronics laboratory has been developed in the school of engineering at Grand Valley State University. This development was funded internally by Padnos College of Engineering and Computing. This paper presents the development of this course and relevant laboratory along with the findings and lessons learned from the test run.

The outline of this paper is as follows: Section II explains the contents and objectives of this course. Laboratory development and possible laboratory exercises are presented in Section III. Section IV explains the course project structure along with its contribution towards final grade. Results and lessons learned from the experimental run are explained in Section V. Section VI concludes this paper with a mention of future work.

II. COURSE OBJECTIVES AND CONTENTS

This course is designed to provide the basic foundation of power electronics technology. All of the modern electrical systems around us require power electronics for controlling the flow of electricity at high voltages or currents. From the simple acts of turning motors on and off to the more complex such as lighting a factory or controlling the flow of power on the nation's power grid, power electronic devices are at the core of these operations. This course provides students the necessary analysis and design tools to incorporate power electronics into a variety of high-power-level systems including heating and refrigeration systems, motor control, lighting, and fuel cells. Upon completing this course, students will:

1. be able to model semiconductor devices as power switches
2. be able to design systems to control electric power flow using semiconductor switches
3. be able to analyze and design power converters
4. be able to design ac and dc power supplies of variable voltage and frequencies
5. be able to describe the challenges and remedies associated with utility pollution

As opposed to traditional power electronics, this course is designed as a senior level elective and graduate level course. Students taking this course must have completed the basic electronic circuits and power system analysis course as prerequisites. At this stage of this new course the course contents include but not limited to:

a) Power switching devices (power BJT, MOSFET, IGBT, SCR etc.)
b) Rectifying circuits: uncontrolled, half-controlled, fully-controlled for passive and live load
c) AC voltage controllers
d) DC chopper circuits
e) Frequency converters: inverters, cycloconverters for variable frequency passive and live loads
f) Harmonic Analysis
g) Practical Applications

III. LABORATORY DEVELOPMENT AND EXERCISES

This course has been designed so that students can gain hands-on experience along with the design, analysis and simulation expertise as opposed to traditional power electronics course. Keeping this in mind the base of a new power electronics laboratory has been developed in the school of engineering. Currently, this lab is housed in Keller Engineering Laboratory building at Pew campus. PSPICE simulation software and MATLAB analysis tools are licensed to school of engineering and available for student use. Other development work was funded internally from the school of engineering and some equipment was collected as donations from International Rectifiers. Recently laboratory equipment was purchased from Sun Equipment Corporation to facilitate following laboratory exercises:

1. Single-phase, Half-wave rectifier circuit
2. Single-phase, Full-wave rectifier circuit
3. Single-phase, Half-wave controllable rectifier
4. Single-phase, Full-wave controllable rectifier
5. Single-phase, Half-cycle controllable ac circuit
6. Single-phase, Full-cycle controllable ac circuit
7. Three-phase, Half-wave rectifier circuit
8. Three-phase, Half-wave rectifier circuit
9. Three-phase, Half-wave controllable rectifier
10. Three-phase, Full-wave, Half-cycle controllable rectifier circuit
11. Three-phase, Full-wave, Full-cycle controllable rectifier circuit
12. Three-phase, Half-cycle controllable ac circuit
13. Three-phase, Full-cycle controllable ac circuit

The long-term goal of this laboratory development is to facilitate student and faculty research in future. Towards this goal new equipment will be acquired and laboratory facilities will be housed in the proposed John Kennedy Hall of Engineering in Pew campus.

IV. COURSE PROJECT

To enhance the hands-on experience this course has a design project. Students are required to analyze, design, simulate and built a completely functional system. The project is defined at the beginning of the semester. Students work in a group of three and present their work at the end of the semester. The goal of the design project is to explore students understanding of the fundamental power conversion principles, power circuit simulation capability and hands-on demonstration of circuit prototyping. The course project is worth 15% of the course grade. It will be graded based on the functionality of the built system. Students are required to present their project output in a poster session arranged for a technical audience.

V. EXPERIMENTAL RESULTS

This course had gained significant interests through a survey piloted in summer 2002 with practicing engineers and local industries. The Electrical and Computer Engineering curriculum committee at Grand Valley State University expressed their suggestions and incorporated them in the contents of this course through a series of meetings. As mentioned in Section I, this course was offered in winter 2003 on experimental basis. At that time it was taught as the second part of the course EGR 680 Design of Electrical Control Systems. Students were required to meet once in a week for 3 hours. The meeting activities included lecture, discussion, simulation, device testing and demonstration. Students were required to analyze, design and simulate two different power electronics converter circuits to control the speed of a dc motor from a 3-phase ac supply. Feedback from students to improve this course includes: 'need a lab', 'more hands-on activities', 'more applications of power circuits' etc. These lessons have been utilized during laboratory development phase as explained in Section III.

VI. CONCLUSIONS

Incorporation of Power Electronics as a new course in Electrical and Computer Engineering curriculum at Grand Valley State University has been presented in this paper. The urge to introduce this new course based on national energy and economic trends has been identified. Course content, laboratory development and project structure are explained. Results from local industry survey, curriculum committee discussions and a test run of this course has been understood and utilized to modify the course contents. The required course pre-requisite has been identified and is on the process of implementation. As expected, this is an ongoing process and Power Electronics will eventually evolve as a matured course with time for ECE curriculum at Grand Valle State University.

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