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Development and Implementation of a Power and Energy Engineering Minor with Limited Resources: First Results and Lessons Learned

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Design, Development, and Implementation of a Power and Energy Engineering Minor with Limited Resources – First Results and Lessons Learned

1. Introduction Power and Energy Industry Needs, Current Status and Project Rationale

Enrollment in engineering programs, although increasing modestly over the past three decades, is still unable to keep pace with the industry needs and with number of engineers leaving the workforce, which is particularly truer in the power industry[1-4]. Indeed too few engineering students are studying or planning to study power engineering, further compounding to the problem of power engineers' shortages[1-5]. Preparing students for these career opportunities is a challenging task, further complicated because it must be accomplished using often limited resources and within very stringent time constraints of the already crowded curriculum[1, 5-8]. Moreover, there also are new challenges due to the grid transition to the future smart grids and to the increased use of renewable energy. Development and operation of the smart grids require engineers to have not only a solid power engineering background, but good understanding of auxiliary fields like information technology, cybersecurity, communication, controls or distributed generation. The smart grid initiative not only requires power engineers to have a good understanding of auxiliary fields, but also needs experts in these auxiliary fields to understand the basic operations, requirements and capabilities of the future power systems. There is great need in industry for such cross-trained professionals to meet challenges in modernizing the power grid. Training professionals and students in smart grids, alternative energy and distributed generation needs a creative curriculum that crosses traditional divisions based on disciplines[5,9-14].

Designing a novel power engineering curriculum consists of assessing regional industry needs, determining how effectively the existing curriculum meets industry needs, and identifying specific enhancements to properly align the program to the industry expectations[10-15]. However, the curriculum changes must fall within constrains established by the university and accreditation bodies[1-8]. Quite a few shortcomings of today's electrical engineering graduates entering the power industry were identified in literature[6-12]. Among others are needs for stronger technical knowledge, particularly in the area of general engineering, extended practical experience, and a need for increased professional awareness connectivity. Surveys targeting technical knowledge, in general engineering, in overall electrical engineering, or specifically in power engineering are showing while the graduates have adequate electrical engineering and power engineering knowledge[14,15], the non-electrical engineering skills are often not adequate. The specific non-electrical areas identified are in engineering mechanics, thermodynamics, heat transfer, and fluid mechanics, which are quite critical in renewable energy technology. There are also stronger desire from industry that their new hires to have more practical experience, defined as meaningful nonacademic engineering experience and in-depth familiarity with industry tools, software packages, standards and codes used in modern power and energy industries[14-20]. The industry feedback also puts emphasis on the value of co-operative education and internship programs as means of building practical industry experience. However, designing courses to include cross-disciplinary topics, such as smart grids (SGs), distributed generation or renewable energy systems (RES) or to keep students from diverse backgrounds engaged can be quite a challenge for instructors[14,19-28]. In our view, these curricular and pedagogical challenges can be addressed by bringing research topics, projects and integrated laboratory experiences into power and energy courses. One of the advantages of these approaches is that the impacts on the existing curriculum, space, equipment and financial requirements are minimal[23-25, 28].

This paper describes efforts being undertaken at our university to revise, revitalize and update the power engineering related-courses and laboratories and to establish a power engineering minor into the electrical engineering program. Another important goal, no discussed in this paper is to revitalize the sustainability and energy track in the graduate program. The logistics, approaches, curriculum developments, the scope, and the methodology that is adopted to develop and implement a successful and effective power engineering concentration are discussed here. Working very closely with industry representatives, students and alumni helped us in designing the curriculum, restructuring existing courses and laboratory facilities, developing new courses, while ensuring that the students are prepared for the real world problems and challenges of the 21st century. Another goal of this paper is to promote these efforts to all interested faculty, to get feedback, comments and suggestions to improve and optimize our enterprise. Modern power engineering education requires that the student get the opportunity to apply as many of the concepts presented in the theoretical and lecture portions of the course as allowable, and to acquire hands-on experience and receive training in practical aspects. Universities need and must respond to marketplace needs for engineers to design, plan, operate, and maintain power systems using leading-edge technologies. A particular attention must be given to the employers in the state or immediate region. This aspect of the power engineering education should continue, with an added emphasis on building stronger relationships with local industry and government.

2. Power Engineering Concentration Goals, Objectives and Structure

Our power engineering program aims to enhance student learning by introducing innovations in course design, teaching methods and learning resources that ensure students have the skills, knowledge and attributes they need to enter the power and energy engineering professions. Strong linkages to real world are formed through collaborative research projects, industry oriented courses to ensure student learning is industry-relevant and real-world focused. By making classroom experiences industry-relevant, interactive and student-centered, we should be able to influence, motivate and inspire student learning and interests. The development of new curricula and resources are based not only on technical requirements and current industry practices, but also of contemporary pedagogical approaches and active learning principles[14-28]. The major courses in any power engineering program need to include courses on basic power systems, electric machines, power system analysis, power electronics, power distribution, and an introductory smart grid course. These courses must include background topics and knowledge, proper assignments and real-world practical problems and projects. Students are asked to make teams and collaborate with their team members in doing the projects. For example, we decided to structure the energy conversion and electric machines course in such a way that it focused not only on transformers and steady-state DC and AC electric machines, tests and equivalent circuits, but also to include topics on machine starting and stopping, speed, torque, voltage or frequency control, and modern industry applications. Furthermore, electric machines are used today extensively with power electronics or microcontrollers in process control or renewable energy, which must be also included in the course content.

Under aging and quite ineffectual power distribution system, unprecedented initiatives have recently been instituted to ameliorate the electric grid with the smart grid initiatives. However, to develop, implement and teach a basic smart grid course is a challenge and complex enterprise, due to the lack of appropriate textbooks on the subject, highly interdisciplinary subject, lack of laboratory facilities, software or even availability of instructors and teaching assistants fully proficient in the smart grid technologies. While there are efforts in the literature and academia, regarding appropriate smart grids textbooks, to the best of authors' knowledge, there still appears to be a strong need to have an inherently interdisciplinary textbook with a balanced approach on the fundamentals that can used as an introductory course, with appropriate topics, examples and end-of-chapter exercises[21-25]. The current books on smart grids require significant efforts by the instructors for use in the class, and often advanced knowledge, not common to the students. It is our strong beliefs that the publication of appropriate smart grid textbooks has positive impacts on smart grids education. However, in order to upgrade, restructure and improve our power engineering courses, an integrative approach and co-active teaching methodologies are employed so that the course can effectively offer students a complete view of modern power industry.

3. Project Challenges and Project Development

Major challenges faced with this project are the lack of adequate laboratory facilities, software licenses, properly trained teaching assistants and longer time since such power engineering courses were offered. However, the project feedbacks from alumni and industry were overwhelmingly positive and supportive. We have also have to keep in mind that an upgrading or setting of a power engineering laboratory is an expensive enterprise and requires adequate laboratory facility. Those universities which have not completely abandoned power engineering laboratories are not always capable of implementing new and modern experiments or acquiring new equipment at an acceptable cost or having appropriate laboratory space[14-22]. Recent power industry developments demonstrate that technical understanding of power systems, underscored by hands-on laboratory experience, is even more important than some might have previously thought. The development of a power engineering laboratory requires reinforcement of various aspects of energy conversion concepts, smart control, or power electronics aspects. A versatile laboratory development, providing coverage separately or in combination, became a valuable asset, which can be used for various experiments, while emphasizing on different facets of power systems analysis, power electronics and control, machine characteristics or energy conversion concepts[12-22]. While most of the laboratory can support the energy conversion, the addition of power electronics and control modules, integrated with what is already in place, would vastly increase the laboratory versatility, functionality, and pedagogical values. To address these needs, we are designing our power engineering facility in an integrated and modular structure. Combining energy conversion, power systems, renewable energy, power electronics and control experiments in a versatile integrated laboratory is our current goals. Other questions we are addressing are how to improve and update the existing courses, what are the cortical topics needed to be included, what new courses are really important and need to be developed, and which are the courses that need to include semester projects or mini-projects, what is the most appropriate teaching methodology for each of the courses, and to what extent course materials must be covered. In our views all are critical questions that must be answered and handled properly in order to establish a strong and modern power engineering concentration.

3.1 Restructuring and Upgrading the Existing Power Engineering Courses

It is well-accepted that the educational requirements of a power engineering program or concentration need to be shaped, not only by the academic requirements but also by the industries who are hiring the graduates[5-15]. Doing so is the best means of assuring that our graduates have the skills necessary to succeed in their future workplace. They need to be well-trained, proficient in engineering, have good communication and management skills, and able to be successful with minimum supervision is a necessity, as there are quite often minimal resources in the form of experienced engineers to help train the new engineers. We had these in minds when we started to restructure and upgrade the existing courses, and to propose and develop a set of new courses as discussed in the following sections and subsections.

Electric Machines I: This 3-credit course is designed to provide foundations in the operation, principles, construction, performances and testing of major types of electrical machines, being offered once a year usually during the spring semester. Topics covered are the fundamentals of magnetic circuits, transformers and rotating electric machinery including both DC and AC machinery. In addition to that, we are also included comprehensive discussions of the control methods, techniques and most important applications for each of the major types of electric machines included in this course. The following topics are included in this course:

1. Introduction to Electric Machines, Review: Newton Laws, Electric Circuits, Phasors, and Electromagnetic Field Basics (1 week)
2. Power Electronics Basics and Magnetic Circuits (1 weeks)
3. Transformers (2 weeks)
4. AC Machinery Fundamentals (1 week)
5. Synchronous Generators and Motors (2 weeks)
6. Induction Motors, Drives, Their Control and Applications (2 weeks)
7. DC Electric Machines, Control, Starting and Matching (2 weeks)
8. Single-phase and Special Motors, Starting and Control (2 week)
9. Motor Applications, Standards and Codes (1 week)
10. Safety and Electric Hazards (1 week)

Electric Machines II: This course covers topics in steady state and dynamic characteristics of DC and AC machinery and energy conversion systems, control and protection. This course was offered only a couple of times, and not been offered since Fall 2000 semester. So far no decision was made regarding the status of this course. If the course remains as it is, a stronger emphasizes will be on topics related to the electric machine dynamic analysis, advanced control, design and modeling. However, the final decision on the course content is in stand-by, until after the feedbacks from the 2018 Spring semester industrial advisory board meeting. Any suggestions and recommendations from 2018 ASEE Conference audience are highly appreciated.

Power System Analysis: This course introduces student to power systems concepts, per unit concepts and notations, symmetrical components, and symmetrical and unsymmetrical faults on the transmission line. Selected textbook for this course is J.D. Glover, M. S. Sarma, and T.J. Overbye, Power System Analysis and Design (Fifth Edition, CENGAGE Learning, 2011) while recommended references are: A.R. Bergen and V. Vittal, Power System Analysis, Prentice Hall, 2000; and M. El-Hawary, Electrical Power Systems: Design and Analysis, IEEE PRESS, 1995. Instructors are providing lecture materials. The major course topics included are:

1. History and Structure of an Electrical Power System; Power System Representation;
2. Review of Phasors, Three Phase Systems, Per Phase Analysis Notes, Per Unit Analysis
3. Three-phase Transformers;
4. Synchronous Generators, Standalone and Grid Connected Operation;
5. Transmission Lines – Models and Analysis;
6. Network Calculations, Symmetrical Components;
7. Balanced and Unbalanced Faults
8. Introduction to Power-flow Studies
9. Introduction to Power System Operation and Control;
10. Power System Protection
11. Smart Grids Objectives and Architecture; Supervisory Control and Data Acquisition

Power System Design covers advanced topics in generation, distribution, and transmission related to power systems, including the synthesis of various design topics is treated. However this course was not offered for a long time. We are planning to change the course content and catalog number to be offered as a combined undergraduate and graduate course. The new course is focusing on *generation, power plant operation and control,* the topics include: power system concepts, generation characteristics, energy sources, economic dispatch, unit commitment, generation with limited energy supply, power transmission, power flow analysis, control of power generation, demand forecasting, and power system economics. The course changes were submitted and approved to the college and department curriculum committees. The restructured course delivery methods include lecture and workshops, where the basic knowledge is delivered to the students, guiding them to learn the required background knowledge more efficiently. On the other hand, during the workshops students learn professional software packages, standards and codes, how to conduct the projects, obtain relevant information and learn various facets of the course by doing real-world practical power engineering projects.

3.2 Proposed New Courses

Introduction to Energy System Engineering: This course is an introductory subject in electric power systems and energy conversion. Electric power has become increasingly important as a way of transmitting and transforming energy in industry, military and transportation uses, which include all electric transportation systems, electric and hybrid vehicles, battery powered factory transport, building and industrial energy systems, or distributed generation. Electric power systems are also at the heart of alternative energy systems, wind and solar electric, geothermal and small scale hydroelectric generation. The course is intended for all engineering students, and is offered as sophomore elective, having pre-requisites of certain engineering, math and physics courses. The course materials and the topics covered include:

- Fundamentals of energy-handling electric circuits, power electronic circuits; alternative current circuits and three-phase circuits
- Modeling of magnetic field devices and description of their behavior using appropriate models; Simplification of problems using transformation techniques;

- Analysis of power electric circuits, magnetic circuits, and elements of linear and rotating electric machinery;
- Use of lumped parameter electro-mechanics to understand power systems;
- Energy resources, power plant components and operation;
- Renewable energy, grid-integration;
- Models of synchronous, induction, and DC machinery;
- The interconnection of electric power apparatus and operation of power systems.

The course materials are useful to students who pursue careers in electric power systems.

Power Electronics: All good university power engineering programs include power electronics courses. However, one of the emerging technologies in electrical engineering where a continuous curriculum update is essential is power electronics and its applications. This area needs a basic understanding of electrical engineering fields and a good knowledge of the systems, in which power electronics converters are used. Furthermore, the field is characterized by that practical skills are being important in respect to understanding the system where power electronics is used in and realize it in practice. The course is designed to study of the capabilities and limitations of power semiconductor switching devices, analysis, design and simulation of common circuit topologies for power conditioning and processing, converters, and switch-mode power supplies. Power electronics applications are also discussed. This course covers the following topics:

1. Introduction to Power Electronics. Power Electronics Concepts and Components
2. Power Computations, Magnetic Circuits
3. Rectifiers (AC-DC Power Converters)
4. AC Voltage Controllers
5. DC-DC Converters, DC Power Supplies
6. Inverters (DC-AC Power Converters)
7. Resonant Converters
8. Drive Circuits, Snubbers and Thermal Considerations
9. Renewable Energy and Power Systems Applications

The textbook used for this course is D.W. Hart, Power Electronics, McGraw Hill, 2011, together with the author extended lecture notes, course materials, and application notes.

Renewable Energy Systems: It is a four credit-hour integrated lecture-laboratory course, which primarily focuses on wind energy conversion systems, solar-thermal and photovoltaic energy systems, marine energy, energy storage and fuel cells. To a lesser extend it focuses on other renewable energy sources and related technologies. This course is meant to enable the students to apply basic science knowledge to renewable energy systems. Wind and solar energy systems make up about 60% of the course since wind and solar energy represent the fastest growing areas of renewable energy in the past decade. Therefore the key areas that the course focuses are on the wind and solar energy sources and the related technologies. This course also presents tools and methods used to assess, analyze, harness and operate renewable energy sources. The role of new energy resource, technologies, and the effects of market forces on renewable energy and modern power systems are discussed in details. Grid integration of renewable energy systems and related issues are also presented and discussed. Discussions of economical aspects, environmental impacts of alternative energy and social policy are integral components of this course. This course will cover the following topics:

1. Energy Review; Overview of Renewable Energy; Electric Power Basics
2. Small Scale Distributed Generation
3. Wind Energy Resources
4. Wind Turbines
5. Electrical Aspects of Wind Energy Conversion
6. Solar Energy, Solar Concentrators
7. Solar Thermal Energy Systems
8. Photovoltaic Materials and Systems
9. Geothermal Energy
10. Hydro and Ocean Energy;
11. Other Renewable Energy Systems
12. Energy Storage, Batteries and Fuel Cells
13. Hybrid Power Systems and Grid Integration of Renewable Energy Systems
14. Environmental Aspects and Economics of Renewable Energy

There is no required textbook for this course. However, one of the authors is providing the students with comprehensive lecture notes, part of his Taylor and Francis Renewable Energy Systems future book. Recommended textbooks are: B. K. Hodge, Alternative Energy Systems & Applications, Wiley, 2010; Gilbert M. Masters, Renewable and Efficient Electric Power Systems, Wiley, 2013; and M.K. Patel, Wind and Solar Power Systems, CRC Press, 2006. After completing this course, the students are expected to be well rounded in general renewable energy systems, energy storage and energy conversion technologies. They are also expected to be quite skillful in analyzing and assessing wind or solar energy resources, analyzing and designing wind and solar energy systems. This course is planned to be offered for first time in Fall 2018 semester. In long run the course is also planned to be offered online, by adapting and using an e-Learning platform developed by the authors few years ago while working for another institution.

Power Distribution: This course is focusing on electric power distribution system analysis, design and operations, including load estimates and calculation, sub-transmission lines, distribution substations, feeder design considerations, voltage regulation, protection and reliability of power distribution systems. Special topics related to power distribution and advanced metering and monitoring infrastructure, distributed generation and smart grid application are also included here. Upon completion of this course, students are able to: analyze, simulate and model power distribution system components, to compute the electric performance of a part of the distribution system or a system component, preliminary cost-performance analysis of a small part of the distribution system, perform a preliminary design of a small part of the distribution system or a system component in order to achieve safe and economic operation, and have a good understanding of basic system protection issues, fault types, symmetrical components, thermal effects of fault currents, the operation of overcurrent protection devices, and the coordination of these devices in order to derive a reliable protection schemes. The selected course textbook is: T. Gönen, Electric Power Distribution System Engineering (3 ed.), CRC Press, 2014; and the authors is providing the students with extensive lecture notes and additional course materials. This is 3 credits combined undergraduate and graduate level course, with additional requirements and topics for graduate students. It is offered in the evening, in order to be also accessible to professionals. This course is covering the following topics:

1. Introduction. Review Phasors; Complex Power; Network Equations
2. Distribution System Planning and Automation
3. Electric Loads; Energy Demand
4. Power Distribution Transformers
5. Design of Sub-Transmission Lines and Distribution Substation
6. Design Considerations of Primary and Secondary Systems
7. Voltage Drop and Power Loss Calculations
8. Application of Capacitors to Distribution Systems, Short-circuit Calculations
9. Distribution System Voltage Regulation, Reliability and Protection
10. Power Quality, Standards and Smart Grid Distribution

Introduction to Smart Grids: The course is intended to provide the students with working knowledge of the fundamentals, design, analysis, and development of Smart Grid paradigm, offering an introduction to the basic concepts of power systems along with the inherent elements of computational intelligence, communication technology and decision support, automation and computational techniques needed to ensure that the Smart Grid guarantees adaptability and capability of handling new system, components, and interoperability with renewable energy, distributed generation and smart loads. The recommended textbooks are: J. Momoh, Smart Grid Fundamentals of Design and Analysis, Wiley, 2012; F. P. Sioshansi (ed.), Smart Grid: Integrating Renewable, Distributed & Efficient Energy, Academic Press/Elsevier, 2012; and A. Carvallo, The Advanced Smart Grid: Edge Power Driving Sustainability, Artech House, 2011, and instructor' lecture notes. The course goals are to give students good understanding of the smart grid architecture, structure, operation and management, the challenges and differences with the today power grid. This course involves the analysis of the future grid; smart grid concepts, as well as working knowledge of design, analysis, and development, from basic concepts of power systems to the concepts of the smart grids. Learning the materials in this course is an important step toward a rewarding career as a power engineer in the future power grid[20-23]. This is a combined senior undergraduate and graduate course, targeting not only electrical engineering students, but also professionals, students from computer science, computer engineering or mechanical engineering enrolled in dual programs. It is offered once a week in evening to be also accessible to professionals already working in power industries. Course schedule consists of ten units, covering critical aspects of the smart grids:

Unit One: Introduction to Power System Operation and Management
a. History of the Power Industry Present and Future Trends; Electric Utility Industry Structure
b. Basics of Power Systems, Load and Generation, Power Flow Analysis
c. Economic Dispatch and Unit Commitment Problems

Unit Two: Introduction to Smart Grid Structure, Architecture and Operation
a. General considerations for a Smart Grid, reasons, objectives, differences among utilities
b. Definition, Applications, Government and Industry; Standardization

Unit Three: Key Characteristics of Smart Grid

a. Elements of the power grid and measurement technologies: generation, transmission; Basic concepts of power, load models, power flow analysis; New technologies

b. Modularity; Common, reusable building blocks, Standardized interfaces

c. Smart Grid Models, Key Functions of a Smart Grid

Unit Four: Smart Grid Elements

a. Electric Grid; Smart Grid Control Elements

c. Communications Infrastructure

d. Smart Grid Control Layer

e. Smart Grid Applications Layer

Unit Five: Smart Grid Communications:

a. Two-way Digital Communications Paradigm

b. Network Architectures, IP-based Systems

c. Power Line and Wireless Communications

d. Advanced Metering Infrastructure

Unit Six: Demand Response

a. Definition, Applications, and State-of-the Art, Pricing and Energy Consumption Scheduling

b. Controllable Load Models, Dynamics, and Challenges

c. Demand Side Ancillary Services

d. Elements of computation and decision support tools, computational techniques

e. Aspects of energy management in the smart grid

Unit Seven: Renewable Energy Generation and Microgrids:

a. Elements of distributed energy resources, distributed generation and grid integration

b. Renewable energy resources: Wind and solar

c. Microgrid Architecture; Concepts of Micro-grid; design and analysis; distributed generation;

d. Tackling Intermittency, Distributed Storage and Reserves

Unit Eight: Wide Area Measurement:

a. Sensor networks; Phasor measurement

b. Communications infrastructure

c. Fault detection and self-healing systems; Applications and challenges

Unit Nine: Security and Privacy:

a. Cyber-security challenges in Smart Grid

b. Load Altering Attacks; False Data Injection Attacks

c. Defense Mechanisms; Privacy Challenges

Unit Ten: Economics and Market Operations, Standards and Codes

a. Energy, Power and Reserve Markets, Generation Firms

c. Locational Marginal Prices; Financial Transmission Rights

d. Policy and economic drives of the smart grid; environmental implications; sustainability issues; state of smart grid implementation

e. Interoperability, standards and cyber-security:

3.4 Unified Energy Conversion, Power Electronics, Renewable Energy and Power Engineering Laboratory

The role of laboratories in modern power engineering education is well accepted and established. Nevertheless laboratories and experimentation are an important part of the engineering curricula and education[17-20, 22-24]. In the past, undergraduate electrical power engineering education used the traditional electrical machine and high voltage laboratories. However, the fast development of computers and IT sectors shifted the engineering education, but especially the power engineering education towards the use of computers, simulation and multimedia instead of conventional laboratory settings. The main problem of power engineering education is the continuous and very dynamic technology development. The curricula must adapt to these technological developments and the laboratory education has to follow this trend as well. This suggests that laboratory instruction has great value as a component of power electronics, power systems, renewable energy or electric machines curriculum[17-19]. During the 2017 Spring semester an overall inventory and status of electric machines, power electronics and power system equipment and laboratory components were conducted, all components being tested and checked. Additional parts, components, data acquision and power electronics modules, rectifiers, DC-DC convertors, and DC-AC convertors were purchased and included in the workstations, thanks to a small internal grant and small donations from local industry. Four integrated electric machines and power electronics workstations are fully functional and are already employed in our integrated laboratory. The electrical machines, power electronics and energy conversion experiments include: single- and three-phase power measurement, transformers, DC machines, induction motors, synchronous motors, single-phase motors, DC-DC back, boost and back-boost converter, single- and three-phase rectifiers, inverters, drives and transmission lines. Additional workstations are in process to be set for 2018 Fall semester. A local network of eight desktops and a network workstation are in operation in the new integrated laboratory. Besides the MATLAB and LabVIEW we are planning to install a few free and open-source power oriented software packages, to be used in power distribution, power systems analysis and renewable energy technology courses. For the renewable energy laboratory components, we are planning to replicate the virtual laboratory units and integrated model previously developed by one of the authors. A set of emulators of major renewable energy systems, horizontal wind turbine, Savonius rotor, photovoltaic modules, a battery bank and a hybrid power system is designed and implemented. Each emulator is an interactive model of the actual renewable energy source, scaled up at the desired level, providing users a hands-on experience in renewable energy, offering real working environment at a minimal cost and space requirements, allowing a comprehensive design, learning and study of renewable energy systems and related issues. All units can be operated on-site or remote, through Moodle Learning Management System. This approach results in a significant reduction of computational, operation cost and administrative requirements. In addition, an e-Learning support platform for learning renewable energy theory, concepts and experimental procedures are also in process to be designed and implemented. The e-Learning support platform is also designed for presential, or for hybrid use and delivery

4. Project Summary and Future Developments

During the two semester period, since the project began, all existing power engineering courses, but one Electric Machines II were revised, ungraded and offered. For example, Electric

Machines I and Electric Machines Laboratory offered in 2017 Spring semester have an enrollment of 6 and 8 students, respectively. However, in second round, 2018 Spring semester the enrollment doubled, 12 and 13 students, respectively. During the same interval four new power engineering courses (power electronics, renewable energy, power distribution and smart grids) were proposed and approved by the department, college and university. Power Electronics course is also offered for the first time in 2018 Spring semester, with an enrollment of 15 undergraduate and graduate students, quite high enrollment at our college for a new course. The electric machines power electronics, renewable energy and energy conversion integrated, modular laboratory was established and in large part operational. Additional developments and laboratory expansion are planned next academic year. Several proposals were submitted (or are in the preparation phase) to the state and federal funding agencies. Contacts were established with local and state energy industry, with a combined support commitment of about $350,000 for the integrated power and utility laboratory and support for the sustainability and energy track in our graduate program. The next project phase consists of the restructuring of Electric Machines II course, focusing on the topics related to the dynamic aspects and advanced control methods. The course catalog number is also planned to be changed to a combined senior undergraduate and graduate course, depending on the future enrollment and feedback from local energy industry and alumni. We also are planning to propose and develop a new elective combined undergraduate/graduate course on Electrical Services and Protection. Future steps are also planned for the laboratory facility expansion, addition of new equipment, components and remote and online access. Last but not least we are also planning to propose a course on sustainable industrial energy systems, while a similar course was developed in the past by one of the authors. This course aims to train students in process integration methods and tools necessary for identifying and designing efficient industrial energy system solutions that contribute to sustainable development. Besides understanding technical and economic issues, students are achieving understanding of the impact of industrial processes on energy usage, the role that industrial energy systems with respect to meeting energy efficiency requirements, reducing energy consumptions and environmental impacts. The course addresses the use of appropriate methods to identify the cost-optimal mix of different process energy technologies to satisfy a given process demands and constrains. Aspects of the energy management, energy audit, life cycle assessment, analysis, procedures and practice are also discussed in this course. One important aspect is how future energy policy instruments is influencing the optimal solutions. Technical systems encountered in the course include heat exchange, boilers, heat pumps, combined heat and power systems, and thermal separation units.

5. Conclusions

Without any doubt, the future for power and energy engineering profession and industries are very bright. However, there are quite a few exciting and demanding challenges ahead for both education and industry. There are several critical challenges ahead facing future engineers: globalization, economic issues and more friendly environmental energy systems, rapid technological advancement, energy security needs and an aging infrastructure with the backbone more than half a century old system. Energy industry and power systems are now in full transition to the smart grids, extended use of distributed generation, alternative energy systems or the advanced electricity generation and storage technologies. The power and energy industry are looking for well-trained graduates with advanced engineering background to help manage the challenges faced by our energy and power sectors. Qualitative, in terms of increased demand for power engineering graduates and the salary range for the industry professionals indicates that there are long-term needs for quality power and energy engineering programs. As part of our project to revitalize the power engineering concentration at our university, we are upgrading, improving and start to offering the existing courses, proposing and developing new courses in power electronics, power distribution, renewable energy, smart grids, energy management and energy engineering. Other important project goal is the development and structuring of an integrated and modular energy conversion, electric machines, power electronics, power systems and renewable energy laboratory, aiming to give the students access to new experiments in a systemic approach, and professional power engineering software packages. Feedback from students, industry, alumni and Industrial Advisory Board will be used to improve concentration structure and content, course contents, equipment of the integrated laboratories and experiments. However, even though we are in an early project phase, we are confident that it is a success based on the enrollment trends, feedback and interest from students, alumni and local energy industry, and the full support from college and university. We are actively looking to engage others in this effort, any suggestions and recommendations from the audience and faculty with similar interests or involved in similar projects are highly appreciated and welcomed.

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