

# **Electrical Energy Engineering Education for 21<sup>st</sup> Century**

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*Unprecedented scientific advances present challenges and opportunities for professionals, research and educators alike. Energy industry is the prosperous society cornerstone all crucial socio-economic functions depend on a reliable energy infrastructure. There is growing recognition need to improve, restructure, and revitalize energy engineering curricula. The issues surrounding this theme are receiving significant interests form faculty and often administration. Energy industry professionals are required to have significant techno- scientific capabilities, deep interdisciplinary understandings, and soft engineering skills. However, how and which are the best approaches to educate future engineers, remain an open question. In addition of teaching the traditional courses in power engineering educators must include new topics, e.g. renewable energy, smart grids, or energy management, to mention a few of them while still ensuring a four-year graduation timeframe. A well-designed engineering curriculum must offer a judicious balance between the basic science and mathematics, energy engineering foundations, and hands-on experience, project, communication, management, or economics. The paper is proposing to discuss some of the energy engineering education challenges, issues and opportunities.*

*Keywords: energy engineering, education, curriculum, power and energy minor*

## **INTRODUCTION**

Unprecedented technological and scientific advances in power and energy engineering presents interesting challenges and opportunities for professionals, research and engineering educators alike. Electrical energy industry is the cornerstone of a prosperous society, all critical socio-economic functions depending on the secure and reliable power and energy infrastructures. Due to the increased complexity and technology advancements in all power and energy industry sectors (generation, transmission, distribution, control, protection, costumer participation, economics, etc.), there are growing needs for graduates to be specialized in such engineering areas. Electrical energy and power engineering education have undergone significant changes over the last two decades, together with an increased student interests into such programs. Such engineering programs have been revived in many universities in the U.S. and in other countries. Today, with the renewed interests and often support from industries and governments,

energy engineering programs are being rebuilt and expand with a strong interdisciplinary curricula fueled mainly by the industry needs. Moreover, recent changes into the power and electrical energy industrial sectors, restructuring the utilities, smart grid, and low-carbon economy require graduates with a broader understanding of technology, economics, and social contexts, as well as to have soft engineering skills (NAE, 2008, Energy Independence and Security Act of 2007, Kezunovic et al., 2012, Zinaman et al., 2015, Belu, 2019d). There is growing recognition of the needs to improve, restructure and reform electrical energy engineering curricula. The issues surrounding this theme are receiving significant interests from faculty, industry professionals and often administration (Heydt et al., 2000, Berry et al, 2003, Sauer et al., 2005, Crow et al., 2005, Ray & Wayno, 2005, Reed, 2008, Reed and Strachina, 2010, Belu, 2019d, Belu, 2020c). Electrical energy professionals are required to have significant scientific capabilities, deep interdisciplinary understandings, and soft engineering skills, e.g. self-learning abilities, communication or interpersonal competence. However, how and which are the best approaches to better educate the next generation of power engineers, remain an open question. The fresh graduates need enhanced knowledge and skills in leadership, communication, economics, data analysis, management, in addition to those in engineering, mathematics, physics, circuit analysis, energy conversion, signals and systems, which are the pillars of engineering education (Heydt et al., 2009, Bose et al., 2009, Dias et al., 2004, Fehr, 2008, Russel, 2010, Hardgraft, 2017, Parvania & Merrill, 2018, Belu, 2019d). The requirements for such skills and knowledge are in large part a consequence of the evolution and changes into electrical energy systems, from the today centralized grid structure, generation and control, unidirectional power flows to a new structure, the smart grid, in which significant distributed generation is located at transmission and distribution levels. In addition of teaching traditional power engineering courses, new courses and topics must be included into curriculum, such as renewable energy systems, advanced power electronics, smart grids, distributed generation, energy storage, energy management, to mention a few of them while still ensuring a four-year graduation timeframe. There are also increased demands for continuous education of the professionals, engineers and technicians in these emerging energy technology areas. A well-designed electrical energy engineering curriculum must offer a judicious balance between the basic sciences, strong electrical engineering foundations, laboratory and hands-on experience, design work, communication skills, management, economics and humanities. This paper is proposing to discuss some of the energy engineering education challenges, issues and opportunities.

### **Power and Energy Engineering Trends, Challenges and Opportunities**

The modern power system has changed significantly from the very modest beginnings to very complex and large systems, which are perhaps the largest enterprise ever built by humans. Mo Power systems are facing structural changes including among others, market liberalization, integration of renewable energy sources and customer participation. The power system connects nowadays every single house to each other and to the power stations together within a country or region. Furthermore, states and countries are interconnected together so that whole continents are joined together to enable smooth, secure and economical production and transfer of electric energy. This huge system needs very efficient automation, management and control systems with real-time communication connections over long distances. In the same time, the unprecedented economy globalization has amplified the impacts of technology and science discoveries on the modern societies in ways that have not been predicted. The connectivity provided by the internet and communication technologies has generated new products, services, business market opportunities, making in the same time available workforce that is often well-educated and cheap. This is likely to have profound impacts on the wealth distribution in developed and developing countries, and changes into the socio-economic structure of countries where the population general wellbeing has been taken for granted. Modern energy industries are going through an evolutionary period and these new technologies are changing the way the electricity is generated, transmitted, delivered and used. The power and energy industries have many new applications in the forefront. The education and research are playing essential roles into any nation prosperity is not debated, but there are arguments that how specifically the presence of knowledge and expertise that determines how well off the societies are.

Environmental concerns, the demands for higher and higher power generation, and steady progress in electricity market deregulation have created interests in environmentally conscious distributed power generation and renewable energy sources. Of particular interest are renewable energy sources such as wind, solar energy systems, fuel cells and distributed generation devices with near zero emissions of hazardous pollutants. These generation systems are used in various configurations, as stand-alone units, in microgrids or grid-connected. Given the rapid progress in renewable energy and distributed generation technologies, there is a greater need for trained professionals and engineers with adequate knowledge to be able to plan, design and operate such systems, and perform analytic evaluation of their impact on power systems (Belu, 2019d, Belu, 2020c). The integration of intermittent energy sources in the power system creates manifold challenges, which are not yet overcome. Breakthroughs in system design, transfer and energy storage technologies, as well as economic organization are needed. The renewable energy generation nature contradicts the conventional power system structure with large centralized power plants. On the one hand, decentralized generation suggests shifting to small-scale systems, whereas the intermittent generation nature favors large-scale systems. However, there are several advantages of the small-scale systems that should lead to research efforts in several directions, e.g. microgrids, a promising approach for increasing the supply autonomy and security. Microgrids require new control architectures requesting research into that direction. Another highly important technology that requires research is decentralized energy storage. A major goal of research on energy storage should lie in trying to achieve cost reductions. While technologies set limits for arbitrarily high renewable energy shares, the regulatory framework and individual incentives are already allowing increasing the use of photovoltaics and decentralized energy storage. However, the major challenges are thus not only technology driven.

It is worth to notice that a widely accepted new fundamental power system design does not exist yet. Discussions are largely limited to individual proposals and demonstrations. The path which will finally be chosen is not obvious at the moment. However, the U.S. Energy Independence and Security Act of 2007 indicated that it is the U.S. policy to support the modernization of the transmission and distribution system to maintain a reliable and secure electricity infrastructure to meet further demand growth and achieve the following characteristics and functionalities: 1) Increased use of digital information and controls technology to improve reliability, security, and efficiency of the electric grid; 2) Dynamic optimization of grid operations and resources, with full cyber-security; 3) Deployment and integration of distributed generation, including renewable energy; 4) Development and incorporation of demand response, demand-side and energy-efficiency resources; 5) Deployment of smart technologies for metering, power grid communications, and distribution automation; 6) Integration of smart appliances and consumer devices; 7) Deployment and integration of advanced energy storage and peak-shaving technologies; 8) Provision to consumers of timely information and control options; 9) Development of standards for communication and interoperability of appliances and equipment connected to the electric grid; and 10) Identification and lowering of unreasonable or unnecessary barriers to adoption of smart grid technologies, practices, and services. During the last decades major changes have happened in the way electricity market is running. Earlier it was a monopoly where only few, usually state or municipality owned companies, energy market being now deregulated and privatized. In addition to the energy business the second important area where power engineering skills are needed is industrial production. Power systems have a large variety of components, generators, transformers, cables, relays and substations. In addition, the electricity end-use may require high power equipment e.g. power supplies, frequency converters and several types of electric machines. Their design and manufacturing offers scores of jobs for power engineers and technicians. Industry in this area is very international and typically it exports a large part of the products. Further, certain companies, manufacturers, suppliers, consultants that have not traditionally been engaged in the electric power and energy industries are finding new markets in this growing and dynamic space. Through the revolutionary changes occurring in the electric power, new products, technologies, and skills are needed and are finding their way into the smart grid. The potential is tremendous, whether in the areas of communications, devices, or advanced products, or applied knowledge; they can gain great value from employee training through such a modernized program.

Power quality is another rapidly evolving field within power engineering involving the analysis, modeling, and mitigation of the difficulties related to voltage and current distortions, protection and related issues in power systems. This area also are requiring a suitable workforce, trained professionals and engineers able to conduct and perform research, operate and manage power systems, and to ensure power quality as required and prescribed by standards and codes. Most of the potential effects, form power quality on the power grid are from power electronic systems and nonlinear loads, e.g. harmonics, voltage variations, transients, are power quality events. Power quality is also increasingly important for customer side, because there are increased uses of the sensitivity loads and microprocessor-based equipment, affected by even minor power quality events. Power quality touches many areas relevant to energy and power systems: applied mathematics, power electronics, management, economic analysis, reliability, and power distribution among others. Thus, the power quality multidisciplinary nature presents an opportunity to integrate various power systems research aspects. The power quality research and related-education activities are prepare a new kind of power engineer, able to meet the energy challenges of the 21st century. Power quality are linking power systems, power electronics and contemporary energy and power issues in order to create an integrated perspective of today energy and power systems. Current research plans are centered on the power quality impact of integrating alternate energy sources to the power distribution systems. The educational aspect can provide alternatives for a renovation of energy education by implementing power quality activities in the power engineering curriculum.

The education of engineers and the existence of a well-prepared technical workforce are therefore critical to every nation to ensure the prosperity of their citizens. Engineers and scientists have always learned and tried to tackle new challenges or to find solutions of the problems. However, the unprecedented availability of tools, computers and equipment to do almost everything are suggesting that engineering educators must rethink how students are prepared and educated in their disciplines (Fehr, 2008, Reed & Stanchina, 2010, Schulz, 2011, Hardgraft, 2017, Belu, 2019d, Belu, 2020c). The new software tools, computer programs, Internet and software packages can do virtually anything, from simple calculations, to simulating complex systems, to design a complete engineered system, online teaching, are empowering the engineers and students, alike to do more than his or her predecessors could ever imagine. These tools and equipment are requiring not only that an engineer knows how to use them, but they are also requiring him or her to be able to assess what tool is appropriate for a given task and then to be able to evaluate the result in critical ways. While teaching students on the fundamentals of the applied sciences is at the core of modern engineering education, re-examining how the fundamentals of engineering sciences are taught to students is needed and is a must. Knowing the scale of phenomena and the distribution of knowledge over multi-scales are critical and essential attributes. In addition to these changes into the technical skills and fundamental knowledge engineers must possess, their non-technical professional skills must be suited for the modern way of doing engineering and to the modern engineering business. One of the drivers for power engineering education at the graduate level is the pertinence and excitement of research projects. However, the long term research work on more difficult topics tends to be more motivational for graduate students and to encourage undergraduate students to pursue graduate studies in power and energy engineering. A full list of grand challenges is too expensive to produce, but a sampling below illustrates the types of material that excite and may serve to recruit) students. The new attractive research power and energy areas are including the followings. There are strong interests in conducting research to effectively develop and design commercial super-conductivity applications in underground transmission, solving the greatest problems of power electronics, the increase junction voltages well beyond the kV levels (Dias et al., 2004, Sen, 2007, Fehr, 2008, Jennings, 2009, Pahwa et al., 2005,). Another research hot topic focusses on the applications of the smart advanced sensors and information processing technology in the future smart grid operation and management, smart microgrid protection and control. There strong research on the robust grid integration of renewable energy systems, developing and setting DC nanogrids, expanding the DC power distribution, developing new protection and control schemes for DC networks etc. (Russel, 2010, Mohan, 2011, Singh, 2012, Chowdhury et al., 2013, Reed G. & Stanchina, 2010, Ilić, 2010, Kuznovic, 2010, Schulz, 2011, Belu, 2011, Belu, 2019d, Belu, 2020c).

## POWER AND ENERGY ENGINEERING EDUCATION STATUS AND CHALLENGES

Over the years, engineering curricula across the United States and in many other countries have undergone rather substantial changes. Today, traditional curriculum needs for engineers that seek specialization in electric power or energy areas have been well defined and fairly stable over the last few decades. This seems quite logical, as the engineering profession has itself undergone significant changes, driven primarily by technological developments, economic and societal needs. But in recent years, not all changes in the engineering curricula have mirrored changes in the profession or industries. In fact, some changes have worked in opposition to meeting industry's needs of the education system by narrowing the scope of education while industry wants more breadth. Due to the pressure to reduce the credit hour requirement of the baccalaureate degree, all U.S. electrical engineering programs have reduced their credit hour requirements over the past decade. Most of the BSEE programs required over 150 credits until 1980, 136 semester credits before 2000, and about 28 credits from 2001 (Se, 2007, Fehr, 2008, Belu, 2020c). Similar trends can be found at many other countries universities. Designing a model curriculum for energy engineering consisted with the industry needs, must assess how effectively the existing curriculum meets industry needs, then identifying the specific enhancements to the existing curriculum to align better the academic programs to the industry expectations. However, the existing engineering curricula are still giving the impression that power and energy systems, control theory and power electronics on one hand and computing, information technology and communication networks on the other, are continuing to evolve in parallel tracks. The myths are that the application space is irrelevant in the study of communication and computer networks, and that control techniques, power electronics and power system applications are using the communications and computations as commodities. Noticing that, grid and power system operations are vitally dependent on sharing data, information and communication, and must be reflected into our courses and into non direct related power engineering course contents. Power and energy engineering have now commoditized the network and computation solutions, finding the off-the-shelves products that are fitting the day needs, by defining a logical mapping between desired functions, capabilities and communications standards.

Teaching and research in electrical power engineering has a long history as one of the first electrical engineering field. Power and energy engineering is still the cornerstone of the modern society, e.g. efficient generation, transfer, distribution and the use of electricity. The peculiar electricity nature is that it is very difficult to store it in large quantities, which would have energetic importance. Therefore, from the very beginning efficient and secure power distribution has been a key element in the development of societies. The workforce demand in the electrical power industry is also evolving in agreement with the significant changes and evolutions into the technology and industry. In order to be a successful proficient power and energy engineer in the 21<sup>st</sup> century, one must have multiple skills in cross disciplinary areas. The energy industry demands power engineering education to be broaden into a cross function of areas, such as networking, control, energy management, data analytics, cybersecurity and business to match the technical engineering ingenuity with the smart grid dynamics (Lozano & Lozano, 2014,, Malkki et al., 2015, Hardgraft 2017, Chicco et al., 2018, Parvania & Merrill, 2018, Belu, 2018, Belu, 2019a, Belu, 2019b, Belu, 2019c, Belu, 2020a). The smart grid has many obstacles to overcome, such as, pricing structure, agreement on information protocol, continuing standardization, development of low-cost smart appliances and numerous commercial issues. Traditional the electric power engineering mainly consists of the following conceptual areas: power generation; transmission and distribution; AC circuits, including three-phase theory; electric machinery; modern concepts in generation, fuel utilization, sustainability, and the environment; power quality; power protection; power systems analysis, and power electronics.

For various reasons, these engineering areas tend to attract a limited, modest attention in most undergraduate engineering programs. On the other hand, undergraduate students themselves are often unsure of their areas of interests, being a quite clear impression, among many educators and faculty that power and energy engineering programs continue to capture a lower percentage of the undergraduate engineering students. Recent or older published data are estimating that about 10% or even lower percentage of all electrical engineering students in the USA are in the power and energy engineering

programs at universities and colleges that are offering power and energy engineering electives, minors or programs. In UE, Japan, India and China, some of the EE programs are more traditional structured, and the power and energy engineering areas have higher enrollments, but not significantly higher. However, there are few particularly brighter areas into the undergraduate and graduate power engineering education picture. Many universities now have active power and energy engineering programs in which local and regional industry, utilities and corporations participates with the university to support graduate and undergraduate students, while industry-relevant topics are brought to the campus, and hiring programs are in effect. National Science Foundation and the Electric Power Research Institute continue to support research programs for power and energy engineering. Some of these funds form an important part of university research and educational infrastructure budgets in power and energy engineering. This program impacts not only U.S. programs but also international students who populate these programs. Encouragingly industry and academia are in close agreement on the key issues and what needs to be done. The universities welcome closer collaboration with industry, ensuring that the graduates can apply their knowledge effectively in real engineering settings, the opportunity to develop and implement new courses and programs. It is essential that we provide the right conditions in university engineering departments for such university/industry partnerships, as well as new approaches to learning and teaching, to flourish.

### **A NEW POWER AND ENERGY ENGINEERING MINOR**

Electrical engineering problems are complex, being even truer in power and energy engineering, with the dynamic behavior of the grid and a large number of components and states. It is difficult for the teacher, who is limited to verbal description and static pictures, to explain complicated materials e.g. complex parameter dependencies or, as often encountered in electric machines, power system analysis, renewable energy conversion or for example in power electronics circuitry, where current conduction which is dependent on switching states. Restructuring and reshaping of the electric power systems, in the context of smart grid paradigm and the rapid drive towards the integration of distributed generation and renewable energy systems have highlighted also the needs for power system education for non-engineers. During the 2017-2018 academic year, we proposed the department and the college curriculum committees approved to establish a minor in power and energy engineering. This initiative was strongly supported by the industrial advisory board and by our major industry sponsors, e.g. Entergy. 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 (Fehr, 2008, Reed & Stanchina, 2010, Ilic, 2010, Belu, 2011, Schulz, 2011, Belu, 2019a, Belu, 2019b, Belu, 2019c, Belu, 2019d, Belu, 2020a, Belu, 2020b). We have also have to keep in mind that an upgrading of a power engineering laboratory is an expensive enterprise and requires adequate laboratory facility, space and support. 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. A versatile laboratory, 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. 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. Questions we are addressing are: how to improve and update the existing courses, what are the critical topics needed to be included, what new courses are important and need to be developed, and which are the courses that need to include projects, what is the most appropriate teaching methodology for each of the courses, and to what extent course materials must be covered. All being critical questions that must be answered and handled properly in order to establish a modern power engineering concentration. 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. Doing so is the best means of assuring that our graduates have the skills necessary to succeed in their future workplace, e.g. proficient in engineering, having good communication and management skills, and being 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, propose and develop new courses.

### **Electric Machines I**

This 3-credit course is designed to provide foundations in the operation, principles, construction, performances and testing of major 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, 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.

### **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. Any suggestions and recommendations from audience are highly appreciated.

### **Power System Analysis**

This course introduces student to power systems concepts, per unit concepts and notations, power flow analysis methods, faults, symmetrical components, and symmetrical and unsymmetrical faults on the transmission line.

### **Power System Design**

It 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 changing the course content and catalog number to be offered as a combined undergraduate and graduate course. It is focusing on *power generation, 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, power system security, control of power generation, demand forecasting, and power system economics.

The proposed new courses included into power and energy engineering minor are discussed here:

### **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 converting energy in industry and transportation uses, which include also topics related to the electric transportation systems, batteries, fuel cells, energy storage devices, distributed generation and power system applications. Electric systems are also at the heart of alternative energy systems, e.g. wind and solar energy. The course is intended for all engineering students, and is offered as sophomore elective, having pre-requisites of certain engineering, math and physics courses.

### **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. This topic needs a good understanding of electrical engineering and 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 devices, analysis, design and analysis of common circuit topologies for power conditioning and processing, converters, switch-mode power supplies and applications.

### **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. This course enables the students to apply basic science knowledge to renewable energy systems. The role of new energy resources, technologies, and the effects of market forces are discussed in details. Grid integration of renewable energy and related issues are also discussed, as well as the economic aspects, environmental impacts of alternative energy and social policy are integral course components.

### **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. Upon completion of this course, students are able to: analyze and model power distribution system components, to compute the electric performance of a part of the power distribution or a system component, cost-performance analysis, 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 deep understanding of protection issues, faults, 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.

### **Introduction to Smart Grids**

The course is intended to provide the students with knowledge of the fundamentals, design, analysis of smart grid (SG) paradigm, offering an introduction to the power system concepts along with the inherent elements of computational intelligence, communication 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 goals are to give the students good understanding of SG architecture, structure, operation and management. This is a combined undergraduate and graduate course, targeting not only electrical engineering students, but also professionals and students from computer sciences, computer engineering and mechanical engineering, enrolled in dual programs.

## **A UNIFIED INTEGRATED 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. In the past, undergraduate electrical power engineering education used the traditional electrical machine and high voltage laboratories. However, fast developments of computers and IT sectors shifted the engineering education, as well as energy engineering education towards the use of computers, simulation and multimedia instead of conventional settings. The main problem of power engineering education is the continuous and very dynamic technology developments. 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 even a greater value as a component of power and energy engineering curriculum. During



the 2017-2018 academic year an overall inventory and status of electric machines, power electronics and power system equipment and components were conducted, components tested and checked. Additional parts, components, data acquisition and power electronics modules, rectifiers, DC-DC convertors, and DC-AC convertors are planned to be purchased, thanks to donations from local industry. Four integrated electric machines and power electronics workstations are functional and are already employed in our integrated laboratory. The energy conversion and power electronics experiments will include: single- and three-phase power measurement, transformers, DC machines, induction and synchronous motors, alternators, single-phase motors, DC-DC convertors, rectifiers, inverters and drives. Additional workstations are in process to be set for Fall 2021 semester. A local network of eight desktops and a network workstation will be in operation in the integrated laboratory. For the renewable energy laboratory components, we are planning to replicate the virtual laboratory units and integrated models developed by the author for other institution. Emulators of major renewable energy systems, wind turbines, Savonius rotor, photovoltaic module, battery bank and a fuel cell stack are designed and will be implemented. Each emulator is an interactive model of the actual renewable energy source, scaled up at the desired level. 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, online or hybrid use. Contacts were also established with local utilities and energy industry for the integrated power and utility laboratory support.

## CONCLUSIONS

This paper is giving a brief discussion of the issues, challenges and opportunities offered by power and energy engineering education. In order to face the modern energy issues, research studies are needed on areas such as improved energy utilization, energy policy issues, alternate energy sources, distributed generation and the economic impact of deregulation related to reliability concerns. The objective is to maintain a reliable, secure, efficient and economic viable power supply, by addressing any future shortage of conventional energy sources and the current needs for more efficient and environmental friendly ways to produce, transfer and use energy. For example, renewable energy sources and distributed generation appear to be one of the effective solution for sustainable development and a serious alternative for the protection of environment. In view of the changing nature of energy and power systems, there are critical needs for professionals and engineers that can deal with current and future energy challenges and are able to operate modern power and energy systems. On the other and, the recent changes to the electric power industry through deregulation and restructuring have had considerable effects on power and energy engineering education, both domestically and internationally. In the light of these changes, there is even more imperative need for industry-academia collaboration in the power and energy engineering education. While, the industry benefits by having access to a larger pool of qualified power engineers with practical experiences, the academia can increase the revenue, decrease financial burden on the departments or colleges and can have access to better experimental, research and laboratory infrastructure. Contrary to the misperception and believes by many students, the power and energy industries are introducing advanced and intelligent technologies and equipment, such as: design of advanced and intelligent control systems, system optimization, economic dispatch, open-access transmission systems, advance power electronics equipment, energy economics, renewable energy applications, energy policy issues, advanced communication and monitoring, smart metering, improving system reliability and security, equipment design and protection. The extended power and energy engineering education, minors or certificate programs, online and e-Learning formats are fitting quite well into the conventional academic models that are established at U.S. universities. Additionally, it can be adapted rather easily to fit other electrical engineering sub-disciplines, programs or other engineering areas. The robustness and versatility of this engineering education approach is long overdue and promises to address the engineering manpower concerns already being experienced by U.S. industry. In this paper, we are also discussed our approach to establish and structure a power and energy minor, and any feedback, comments and suggestions from faculty, instructors, educators, researchers and professionals are highly appreciated. It is the authors'

strongly believe that such discussions and feedback from other educators, professionals and researchers are improving the program quality, course contents, experiments, laboratory structure or project topics, while in the same time advancing the power and energy engineering education through the introduction of new topics, new or updated laboratory experiments or new applications, as well the development of new course materials, helping the instructors, especially the younger ones interested in education research and teaching in this complex engineering area.

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