

# Methods and Approaches for Developing the Future Leaders of the Electric Power and Energy Industries

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# Methods and Approaches for Developing the Future Leaders of the Electric Power and Energy Industries

## Abstract

Strong growth in the global demand for electric power is projected for the next half-century and beyond, providing tremendous opportunities for companies that are leaders in the electric power sector. They are all preparing for the impact of workforce and technology development neglect that was dominant in their industries in the 1980s and 1990s. In a landmark study from 2010 by the IEEE Power & Energy Society's Engineering Workforce Collaborative, the need was identified nationally to double the number of electric power engineering students at the B.S., M.S., and Ph.D. levels based on aging workforce demographics in the electric power sector. In a similar regional effort in 2006, the Three Rivers Workforce Investment Board presented results of a study designed to raise awareness of the aging workforce issue facing Southwestern Pennsylvania (SWPA). Utilizing data from the U.S. Census Bureau along with a survey of 1,500 regional employees, results indicate that the vast majority of SWPA employees in energy-related areas will be eligible to retire in less than 20 years. More alarming is that there is a significant deficit of employees aged 22-34 available to replace these employees upon retiring.

Universities and engineering schools across the United States are developing a new sense of purpose in the field of electric power engineering. Being driven by the aging workforce demographics in the industry a need for new innovations, as well as recent government funding for modernized educational programs and research activities, electric power is in the midst of a revolutionary period of advancement. This article presents a university program model, under development since 2007, which fosters continual classroom number growth, as well as international reputation as research partnerships develop outside the United States.

A review of new and revised curriculum development at the undergraduate and graduate levels will be explained including the details of both the undergraduate and newly developed graduate certificate program within the engineering school. The greatest assessment of an undergraduate program's effectiveness is to monitor growth in classroom numbers, number of students acquiring the certificates, and placement rate of graduating seniors. Trends of these metrics will be provided. To accommodate working professionals enrolled in the graduate certificate program, *real-time* distance learning principles will be explained. Not to be confused with traditional distance learning where lectures are pre-recorded, *real-time* distance learning allows professionals to attend lectures from any location if constrained by work related activities.

Fresh, relevant, and challenging research projects funded by internationally recognized organizations and government entities has been shown to attract and solidify within the student mindset that there are critical needs and purpose. Overviews of industry and government collaborations will show how industry involvement will help drive program expansion at all levels. These program partners, who attend the university's annual electric power industry conference (EPIC), understand the need to invest in students to get a return in their investment – that is, future employees. Growth metrics in EPIC annually are an indicator that the university program is providing a positive service to students, industry, and bridging communication between students and industry representatives to fill the needs in the electric power sector.

#### Introduction

Universities and engineering schools across the U.S. are developing a new sense of purpose in the field of electric power engineering. Bolstered by an invigorating job market, being driven by aging workforce demographics in the industry a need for new innovations, as well as recent government funding for modernized educational programs and research activities, electric power is in the midst of a revolutionary period of advancement.

As an example of this resurgence, the University of Pittsburgh has developed an electric power initiative over the past several years in collaboration with industry, government, and other constituents to provide innovative education and collaborative research programs in the areas of electric power and energy engineering.[1] Working together with industry partners, along with strong government sponsorship and other constituency support, the university is contributing to solutions that address the aging workforce issue in the electric power and energy sector through modernized educational programs, as well as to advances in technology development, basic and applied research, and outreach.

Specifically in the area of electric power engineering education, concentrations have been developed at both the undergraduate and graduate levels. The curriculum consists of a strong set of courses addressing the core principals in electric power, while being augmented with new offerings in emerging technology areas. Through strong industry collaborations that contribute to course development, the program is not only educating the next generation of power engineers, but developing the future leaders of the electric power industry.

The initiative establishes a model program for the resurgence and sustainability of universitybased electric power engineering programs in the U.S. In addition to the strong educational programs in electric power, the graduate research program has advanced significantly over the past four years and includes research and development efforts in emerging areas such as advanced power electronics and control technologies, power conversion systems, renewable energy systems and integration, materials development, smart grid technologies and applications, energy storage, energy efficiency, and microgrid developments.

Current industry partners providing various means of support to the initiative include regional, national, and international organizations such as ABB Corporate Research, BPL Global, DNV-KEMA, Eaton Corporation, FirstEnergy, Mitsubishi Electric, Pitt-Ohio Express, Siemens Energy, and Westinghouse Electric. Many other industry organizations are engaged with the program as well, through activities such as recruiting power engineering students, and power and energy initiative-related events on campus including the annual Electric Power Industry Conference. In addition to industry involvement in the research programs, support is provided from several different offices of the U.S. Department of Energy – the Offices of Electricity Delivery and Energy Reliability (OEDER), Energy Efficiency and Renewable Energy (EERE), National Energy Technology Labs (NETL), the Advanced Research Program for Energy (ARPA-E), the National Science Foundation (NSF), the U.S. Department of Commerce, the Commonwealth of Pennsylvania's Department of Community and Economic Development, and others. Key foundation constituents include the Heinz Endowments [2] and the Richard King Mellon Foundation [3].

Throughout this article, the approaches taken, centered upon industry and government involvement, to expand a new electric power program within *five years* will be thoroughly explored while providing methods of assessments and statistics to show that our methodologies are effective for educating and training the next generation of power engineering professionals.

#### Background

Strong growth in the global demand for electric power is projected for the next half-century and beyond. This growth will provide tremendous opportunities for companies that are leaders in the chain of industries that generate, transmit and distribute electric power.

While great opportunities await these companies, they are all preparing for the impact of workforce and technology development neglect that was dominant in their industries in the 1980s and 1990s. In 2006, the Three Rivers Workforce Investment Board (TRWIB) presented the results of a landmark study designed to raise awareness and understanding of the aging workforce issue facing Southwestern Pennsylvania (SWPA).[4] The study utilized Local Employment Dynamics (LED) data from the U.S. Census Bureau along with a survey of 1,500 regional employers and input from industry experts and workforce specialists. Report findings focused on those regional industries that include the highest percentage of older workers. A chart showing the age distribution in SWPA is shown in Figure 1.



Figure 1. Energy Workforce Age Distribution in SWPA [4]

This data indicates that the vast majority of SWPA employees in energy-related areas including utilities, will be eligible to retire in less than 20 years and that there are minimal employees aged 22-34 to fill the gap once these employees retire. The results of another survey provided by the Center for Energy Workforce Development (CEWD) in 2008 showed that approximately 50% of all then-current employees will be eligible for retirement within 10 years. The survey also indicated that nearly 45% of the eligible retirement age employees may need to be replaced by as early as 2013. [5]

While a detailed study of the age distribution of engineering employees within these regional industries does not exist, representatives of key energy industry sectors (coal mining and production, nuclear energy, gas exploration, electric utilities and electrical equipment suppliers) have all indicated to the school of engineering personnel that up to half of their engineering workforce will be eligible for retirement within the next decade. This coincides with similar studies conducted on a national scale, including the recent landmark report by the IEEE Power & Energy Engineering Workforce Collaborative (PWC).[6, 7] That report indicates that nearly 50% of all electric power industry technical personnel will be eligible for retirement within the next five to ten years, and establishes an action plan to address this critical need within the university education and research communities, as well as through K-12 outreach programs.

To further support the claim of a *national* workforce development issue within the power & energy sector, a survey was conducted by the IEEE Power Engineering Education Committee in 2006 providing national statistics from 115 U.S. schools and 10 Canadian schools. [8] An updated report is planned to come out in the fall of 2014. Figure 2 provides the national average funding amounts and Figure 3 provides the national average of graduate students per institution. The important point to note is the lack of investment in the discipline during the 1990s. These results are staggering compared to the estimated number of engineering replacements required as indicated in [6].



Figure 2. Institution and Average Funding from Government and All Sources - 115 U.S. and 10 Canadian Schools [8]



Figure 3. Average Number of Graduate Students per Institution - 115 U.S. and 10 Canadian Schools [8]

Five priority actions were set by the PWC committee in 2009 including: 1) To double the production of undergraduate and graduate students in power engineering; 2) Provide \$4 million in funding for undergraduate power engineering scholarships; 3) Create 2,000 internship and cooperative opportunities for electrical engineering students; 4) Hire 80 new faculty members

over the next five years to replace retiring faculty, to increase enrollments, and to broaden educational offerings, and 5) Raise annual non-equipment funding of university power engineering research from \$50 million to \$100 million over the next five to eight years. [6] Today, the efforts of the IEEE workforce collaborative have resulted in a nationally based scholarship opportunity for prospective electric power engineering graduates at the bachelors level, through the IEEE PES Scholarship Plus program as indicated in Figure 4. [9]



Figure 4. PES Scholarships Awarded 2012-2013[9]

To further address this engineering workforce gap in the *local* SWPA region, many regional industry companies have solicited the Swanson School of Engineering at the University of Pittsburgh to develop the following programs:

- Introduction of new undergraduate and graduate certificate and concentration programs in electric power engineering, nuclear engineering, and mining engineering. The programs require students to complete 4 to 5 courses specific to these fields at the undergraduate level, and also include extensive curriculum and courses at the graduate level.
- To provide the curriculum for these programs, the school has initiated the development and delivery of 31 new courses in the electric power and energy fields. These courses have enrolled over 4,000 students (electric power, nuclear, and mining) and 400 certificates have been awarded since the programs were initiated beginning in the fall 2007 through fall 2013.
- Strong research components in all three of these engineering areas have also rapidly developed, with advanced work in future directions of energy supply, delivery, and end-use; including areas such as advanced power electronics, smart grids, microgrids, renewable and clean energy integration, energy efficiency, energy storage, advanced energy materials, and other emerging areas.

### Program Goals, Vision, and Leadership

Through these programs, examples are being established for the region and the nation in terms of fostering technical advances, training a highly skilled workforce, and integrating university research with industry needs for future growth. A primary goal is to educate thousands of students in energy-related courses and research projects over the next two decades and beyond, including undergraduate, graduate and post-doctoral candidates. These graduates represent the next generation of power industry professionals and leaders, and will have an important impact on the continued energy leadership of the region and the nation. Moreover, this kind of student output will address the predicted shortfall in energy workers.

Thus, the university programs provide two important elements that are critical to meeting these needs throughout the region and as a national energy center: world-class intellectual capital on the academic side that is focused in a few key areas of electric power and energy research and technology development; and workforce development programs that are training high-level scientists and engineers to work in the energy fields that are important to the country's future. The intellectual and educational power provided through these programs are catalysts for the transformational change necessary to enhance continued growth and success for the university community and the local region in its leadership activities in the search for energy independence and efficiency. The vision for the programs is to provide continued excellence as a leader in education, a pioneer in research, and a partner in economic development with regional, national, and international scope.

### Industry Involvement – Foundation of Quality Education and Depths in Research

One of the strengths of the Electric Power Initiative has been the formation of strong partnerships with key industry organizations. A model example for these collaborations has been the partnership in electric power systems engineering with Eaton Corporation's Electric Sector, headquartered in the Pittsburgh region. Established in 2009 with an initial five year agreement, the partnership consists of funding and in-kind contributions from Eaton, and includes seven key activities that are clearly identified and measured for performance.[10] These include support for curriculum development and adjunct teaching, senior design projects and advisory, research and technology development, community outreach, recruiting and undergraduate co-operative education assignments, graduate student internships, and equipment for a new power systems laboratory that is planned for completion in the spring of 2014. More details on this laboratory will be provided later in the article. This partnership has been a mutually beneficial success for both the university and for Eaton in many ways, with nearly all of the original performance objectives having already been met or overwhelming exceeded, along with the continued fostering of a powerful relationship that is having impact on the region's leadership in the power and energy sector. And while the collaboration is held up as a model program, it is one of several industry partnerships that have been successfully established in the past several years at the university, each with a unique scope and set of objectives.

Other examples of major power industry leaders with significant collaboration activities with the school include ABB U.S. Corporate Research through funded development efforts on concepts for medium voltage direct current (MVDC) infrastructure; Siemens Energy T&D Service

Solutions division through contributions with the Power System Simulator for Engineering (PSS/E) analysis suite, an annual graduate student scholarship fund, and research efforts in Flexible AC Transmission Systems (FACTS); Mitsubishi Electric Power Products, Inc. with activities related to power electronics technologies, specifically, High Voltage Direct Current (HVDC), as well as adjunct teaching contributions; and Westinghouse Electric Co. through support of smart grid technology investigations, along with its strong role in the nuclear engineering program at the university.

Additional energy industry-related collaborations are underway to help expand programmatic pursuits including CONSOL Energy through their support of the mining engineering programs, and others from the power T&D sector including ANSYS, Curtiss-Wright, Clean-Line Energy, Duquesne Light, DNV-KEMA, Emerson Process Management, GE Power Conversion, Lockheed Martin, and RAND Corporation. Most have a strong regional presence as well as national and international operations that are beginning to allow the partnerships with the university to further expand in terms of the opportunities, depth, and global engagement.

Further, not only have these companies provided funding and support in various ways for research and development, but in all cases the educational programs that are being developed have had significant input and participation from many of these industrial partners. Indeed, most of the new courses that are currently being introduced are often first taught by industry experts serving as adjunct professors within the school of engineering. Many of the new courses are also being offered through state-of-the art distance learning techniques, allowing more opportunities for greater diversity in overall student participation. All of these efforts in both education and research will be sustainable through the continued support of the industry partners.

## **Educational Program Developments**

One of the themes of the electric power program is to develop the "next generation" of engineers, scientists, and leaders in the electric power and energy sector, and one avenue for achieving this is through education. An overview is provided here of the educational programs including curriculum development, requirements for receiving the electric power engineering concentration, various statistics that project program growth for the future, as well as a briefing on a new state-of-the-art power systems laboratory sponsored by Eaton Corporation through the partnership described previously.

#### Undergraduate Student Opportunities: Courses, Research Opportunities, & CO-OP

Starting in 2007, an electric power engineering concentration was developed at the undergraduate level. Prospective students must take two required core courses and have the option of selecting two electives from a variety of options. The two required courses include Power System Engineering & Analysis I and Linear Control Systems. In power system engineering & analysis I, students learn the fundamentals of three-phase power, power transformers, transmission line modeling and design, symmetrical components, and elementary power flow analysis. Software capabilities implemented throughout the class include the Power System Simulator for Engineering (PSS/E) providing hands-on experience with industry standard modeling and simulation tools. In linear control systems, system stability is strongly emphasized

and methods for predicting instability (root locus, Nyquist criterion, Bode plots) as well as core design fundamentals of PID controllers. A computer lab component is associated with the course where students use Matlab/Simulink and specific toolboxes to complete assigned tasks.

The electives at the undergraduate level include Electric Machines with an associated machines lab component (including the use of ANSYS finite element products); Power Generation, Operation, & Control; Electrical Distribution Engineering and Smart Grids; Construction and Cost of Electrical Supply; Power Electronics; Thermodynamics; and Introduction to Nuclear Engineering. It's important to note that the engineering school has an entire undergraduate and graduate program in nuclear engineering developed with the support of Westinghouse Electric Co., which provides cross-disciplinary course opportunities for students in electric power who are interested in careers on the generation side of the business, and vice-versa.

To date, nearly one-third of all graduating electrical engineers in the undergraduate program have completed the electric power concentration, with 100% post-graduation placement either in industry or a funded graduate program position. Statistical results are provided in Figure 5 showing a stable 30% each year accept for 2007-2008 when the electric power program was launched at the university. The course enrollments are excellent, with an average of more than 40 students in both of the required courses previously listed, and typically more than 20 to 25 students enrolling in each of the electives (Figure 6 and 7).



Figure 5. Undergraduate Electric Power Concentration Certificates Awarded from 2008 through 2012

The undergraduate students who declare electric power as their concentration of choice often perform an investigation in a power related area for their capstone senior design project, which is often sponsored through an industry partner of the program, such as Eaton Corporation who sponsors several projects each term. In addition, a series of undergraduate student projects over the past several years in the area of solar energy generation have been inspired and advised by Dr. John A. Swanson, founder of ANSYS. The most recent of these includes the installation of a solar power array on the roof of the school of engineering, the first solar array of its kind on campus. The installation is designed to provide hands-on research for the new electric power systems lab. The solar panels will supply both electricity and power generation data to the facility. As the lab grows, faculty and students will explore integrating other power generation resources such as wind. A photo of the new solar array is shown in Figure 8.



Figure 6. Course Enrollments in the Fall Term for Courses Contributing to the Undergraduate Electric Power Concentration Certificate



Figure 7. Course Enrollments in the Spring Term for Courses Contributing to the Undergraduate Electric Power Concentration Certificate



Figure 8. New Roof Top Solar Panel Installation

Undergraduates are also encouraged to pursue research opportunities with various power engineering related faculty and work alongside one of the full time graduate students in the program. All of the undergraduates who have taken advantage of this option and have later gone on to pursue advanced degrees, have transitioned into the graduate program smoothly with the capability of "hitting the ground running" from the start of their graduate careers. Two of the program's undergraduate researchers were award recipients of the inaugural IEEE PES Scholarship Plus program while three more were selected for the current academic year awards. An undergraduate project team recently won a national competition related to smart grid research sponsored by the Transatlantic Climate Bridge Initiative, a program designed to foster German-U.S. cooperation on environmental and energy concerns [11], as well as a prize student poster award at the 2012 IEEE PES Transmission & Distribution Conference and Exposition.

Many of the undergraduate students working on the electric power concentration are also pursuing their degrees through the school's co-operative education program. Many of them are working in their co-operative rotational assignments at regional power and energy related companies, including utilities such as FirstEnergy and various manufacturing organizations. This provides not only further training for these students with practical workforce knowledge and hands-on skills, but also brings a sharpened focus to the classroom. A large percentage of co-op students remain with the same company for all three of their assignment rotations, with the vast majority being offered full time positions at that company upon completion of their B.S. degrees. Students who complete the co-op program, the electric power concentration, and perform their capstone senior design project all in the power area, have become very highly recruited by employers regionally and around the country. Table I shows the longevity of our co-op program and the number of students recruited for positions in Power & Energy related companies well before the development of the Electric Power Initiative at the university.

POWER & ENERGY RELATED UNDERGRADUATE CO-OP STATISTICS						
Company	No.	Established	Company	No.	Established	
ABB	9	1998	Emerson	48	2006	
ANSYS Inc	213	1990	First Energy Corporation	74	1987	
Curtiss-Wright EMD	223	1991	GE Energy	12	2009	
Duquesne Light Company	6		Mitsubishi Electric	2	2010	
DOE NETL	8	2005	Siemens Industry	42	2002	
Eaton Corporation	199	1990	Westinghouse Electric	73	1998	

TABLE I er & Energy Related Undergraduate CO-OP Statisti

Graduate Student Opportunities: Courses, Distance Learning, and New Certificate Program

At the graduate program level, traditional power engineering courses are taught with continuous introduction of modern course developments that are relevant for future grid innovation. The core traditional courses include Power System Engineering & Analysis II, Power System Transients I & II, Power Electronics Devices and Circuits, and Power System Stability. New graduate course introductions over the past several years that are now part of the graduate curriculum have included Advanced Power Electronics (FACTS & HVDC Systems), Renewable & Alternative Energy Systems, and Smart Grid Technologies & Applications. In addition, several more new courses are in development including Electrical Distribution System Engineering & Analysis II, Power & Energy Industry Practices, Substation Automation and Protective Relaying, as well as others in the areas of power electronics and renewable energy systems. Some of the formal course descriptions are found below. Note that a "special topics"

course can be offered up to as many as three times, with the option of transitioning to a permanent course at any point during that period.

#### ECE 2774: Power Systems Engineering and Analysis II

Steady state phenomena, matrix transformations, system parameters, system unbalances, digital methods, and numerical analysis techniques applied to load flow, state estimators, and fault studies in the large power systems.

#### ECE 2777: Power System Transients I

Lumped parameter analysis, switching transients in AC/DC systems, arc modeling, damping, current suppression, traveling wave phenomena, line discontinuities, ferroresonance, and transient recovery voltage.

#### ECE 2250: Power Electronics Circuits and Applications

The key element in the field of power electronics is the switching converter. The objective of this course is to cover the fundamental concepts in the field in sufficient depth to allow students to analyze and design power electronics circuits. The course covers DC-DC converters (also known as choppers or switching regulators) and DC-AC converters (also known as inverters).

#### ECE 2646: Linear System Theory

Linear spaces and operators, mathematical descriptions of linear systems, controllability and observability, irreducible realization of rational transfer-function matrices, canonical forms, state feedback and state estimators, stability.

#### ECE 2795: Special Topics – Renewable and Alternative Energy Systems

Full life cycle assessment of current portfolios of generation (i.e. coal, nuclear, natural gas, hydro), storage and grid-integration options, environmental impacts and types including technologies and regulations in place to control impacts; along with renewable and alternative forms of generation (e.g. wind, solar, fuel cells, etc.), tradeoffs and challenges associated with moving to these alternatives and the various impacts; and technologies, markets, and policy.

#### ECE 2795: Special Topics – Advanced Power Electronics, FACTS and HVDC Technologies

Large-scale power electronics systems, circuits, and devices, with emphasis on utility scale FACTS and HVDC technologies and applications; control and operation, conversion techniques, engineering studies, turnkey project implementation and specifications, standards.

#### ECE-2795: Special Topics – Smart Grid Technologies and Applications

Emerging technologies dedicated to reliably, efficiently and safely managing electric power across utility, commercial, industrial, and residential networks. Application of smart grid technologies from power generation through power consumption including grid automation, smart meters, demand response, communication and control, monitoring and diagnostics, relaying, electric vehicle integration, grid connectivity, renewable energy, cyber security, microgrids, and business processes and markets.

#### ECE-3776: Power System Stability and Control

The power system model for stability studies, response to disturbances, the behavior of machines, the effect of excitation, and mathematical techniques for stability studies

Recommended electrical engineering program electives that complement the power curriculum included Optimization Methods, Stochastic Processes, Embedded Systems and other graduate level controls and electronics area courses. As with the undergraduate power courses, the

application of industry standard tools have been incorporated into the graduate curriculum, including PSS/E for stability courses, PSCAD/EMTDC for transients courses, ANSYS for electric machines and power electronics courses, Matlab/Simulink for control courses and other programs, providing students with a distinct advantage to prospective power industry employers.

The graduate program enrollments are strong, with an average of 20 or more students per class, some hosting more than 30 students in a given course as shown in Figure 9. The graduate level students are comprised of both full-time students pursuing their M.S. and Ph.D. degrees, as well as a strong resurgence of part-time industry based students from local power and energy related companies. This revitalized graduate curriculum has become very attractive to employers seeking to provide further training for their workforce, and for professionals who desire to obtain their advanced degrees on a part-time basis.



Figure 9. Course Enrollments in the Fall/Spring Term for Courses Contributing to the Graduate Electric Power Concentration Certificate

In order to better serve the part-time industry student demographic, plans are currently being completed for a post-baccalaureate certificate in electric power engineering. The certificate will consist of a subset of five of the graduate level electric power courses, and will be offered via synchronous (live) distance learning. The selection of courses is left up to the student (in consultation with the Program Coordinator) in order to allow the student to tailor the program of study to the area of greatest applicability to his/her job/career objectives. This certificate, and the 15 credits earned, could also be applied to students who wish to continue on to complete a full M.S. or Ph.D. degree.

The synchronous distance learning has many advantages for part-time industry students and their employers. There are no geographic boundaries, course participation for distance students is live via web-based connections – providing real-time interaction with the course instructor and the in-classroom students – and all of the certificate courses will be offered in new state-of-the-art distance learning facilities. A photo of one of the new distance learning classroom facilities located in the engineering hall is shown in Figure 10.



Figure 10. New Distance Learning Classroom Facility

In order to meet the requirements of the Graduate-Level Certificate in Electric Power Engineering, the student must successfully complete five of the courses listed in Table II. Table III indicates which courses are offered every semester, so that the student may plan his or her entire academic schedule.

TABLE II
COURSE SELECTIONS FOR GRADUATE-LEVEL CERTIFICATE PROGRAM IN ELECTRIC POWER ENGINEERING

Course No.	Prerequisite	Course Name	Term Offered	Instructor
ECE 2774	ECE 1769 or equivalent	Power System Engineering & Analysis II	Spring	ECE Faculty
ECE 2777	ECE 1769 or equivalent	Power System Transients 1	Fall 2014 EO	Adjunct Lecturer
ECE 2250	ECE 0257 or equivalent	Power Electronics Circuits & Applications	Spring	ECE Faculty
ECE 2646	None	Linear System Theory	Fall	ECE Faculty
ECE 2795	None	Special Topics: Renewable & Alternative Energy Systems	Summer 2014 EO	ECE Faculty
ECE 2795	None	Special Topics: Smart Grid Technologies and Applications	Fall 2014 EO	ECE Faculty
ECE 2795	None	Special Topics: Advanced Power Electronics - FACTS & HVDC Technologies	Fall 2013 EO	ECE Faculty

 TABLE III

 DISTANCE LEARNING COURSE SEQUENCE THROUGH 2015

Term	Courses to be offered	
Fall 2013	ECE 2646 Linear System Theory	
	ECE 2795 Advanced Power Electronics - FACTS & HVDC Technologies	
Spring 2014	ECE 2774 Power System Engineering & Analysis II	
	ECE 2250 Power Electronics Circuits & Applications	
Summer 2014	ECE 2795 Special Topics: Renewable & Alternative Energy Systems	
Fall 2014	ECE 2777 Power System Transients 1	
	ECE 2646 Linear System Theory	
	ECE 2795 Smart Grid Technologies and Applications	
Spring 2015	ECE 2774 Power System Engineering & Analysis II	
	ECE 2250 Power Electronics Circuits & Applications	
Summer 2015	ECE 2795: New Course to be developed	
Fall 2015	ECE 2646 Linear System Theory	
	ECE 2795 Advanced Power Electronics - FACTS & HVDC Technologies	

Both formative and substantive evaluations of the program will be conducted using Table IV. The program will be assessed against its objectives and outcome criteria as follows:

- Number of applications and enrollments and the extent to which we are able to meet enrollment projections.
- Quality of admitted students, e.g., B.S. degree in what field, previous university attended, undergrad GPA, etc.
- Quality of work and academic outcomes
- Student satisfaction, as evidenced by student course evaluations and results of the graduation survey.
- Employment outcomes and satisfaction

While the initial target audience of the program will be regional organizations and students, long-term plans provide tremendous growth opportunities for wider spread national and even international participation. The certificate option also fills a void for many industry workers in the power sector and their employers, who which to obtain further specific training in electric power engineering areas, but without a commitment to a full M.S. or Ph.D. degree. The certificate will be a recognized and official programmatic accomplishment that will be valuable to both the student and the employer. It is highly anticipated that this certificate program will be attractive to individual students at varying levels of career development, and to employers who may wish to have one or potentially groups of employees gain advanced education and training in electric power engineering, at a lesser financial and time commitment than full degrees.

Learning Outcomes	Assessment Methods	Standards of Comparison	Interpretation of Results
What will students know and be able to do when they graduate?	How will the outcome be measured? Who will be assessed, when, and how often?	How well should students be able to do on the assessment?	What do the data show?
Knowledge of key Power Systems concepts, to include concepts from at least two of the following areas: power system engineering & analysis, power system transients, renewable/ alternative energy systems, and smart grid technologies.	• Selected embedded assessments (exams, projects, etc.) within applicable coursework, to include ECE 2774, ECE 2777, or ECE 2795.	• At least 90% of students should be able to earn the equivalent of a B or better on embedded assessments.	To be determined
Introduction and coverage of emerging, leading-edge, contemporary technologies applicable to Electric Power Engineering.	• Selected embedded assessments (exams, projects, etc.) within ECE 2795.	• At least 90% of students should be able to earn the equivalent of a B or better on embedded assessments	
Knowledge, understanding, and application of IEEE standards for electric power.	• Selected embedded assessments (exams, projects, etc.) within ECE 2795.	• At least 90% of students should be able to earn the equivalent of a B or better on embedded assessments.	
Knowledge, understanding, and application of current US energy policy, as informed by the DOE's annual energy outlook report and its implications.	• Selected embedded assessments (exams, projects, etc.) within ECE 2795.	• At least 90% of students should be able to earn the equivalent of a B or better on embedded assessments.	

#### TABLE IV Assessment Matrix for Graduate Certificate Procham

#### **Research Program Developments and State-of-the-Art Laboratories**

Another component of the research program developments includes a new power systems laboratory that is planned to be completed by February 2014, supported by in-kind equipment contributions from Eaton Corporation. The new lab will provide state-of-the-art research facilities for faculty and graduate studies, as well as capabilities for hands-on learning associated with new course developments at the undergraduate and graduate level in power engineering. A 3D rendering of the laboratory, industrial grade hardware, and top view of the laboratory are found in Figures 11 and 12.



Figure 11. Electric Power Systems Laboratory: 3-D Rendering and Sample Hardware [12]



Figure 12. Electric Power Systems Laboratory: Top View

Beginning with the government programs, there are three multiple year projects funded through the U.S. Department of Energy (DOE). The first project is through the Advanced Research Program Agency for Energy (ARPA-E) as part of the ARPA-E Solar ADEPT (Agile Delivery of Electric Power Technologies) program and is focused on magnetic technology for high frequency mega-watt scale power converters. [13] Along with the technical design, economic evaluation to existing benchmarks is critical for the feasibility of the converters.

A second project with the DOE is through the Office of Energy Efficiency and Renewable Energy (EERE) as part of EERE's program on U.S. Off-Shore Wind: Removing Market Barriers, and is entitled the National Off-shore Wind Energy Grid Integration Study. [14] The project team is determining the optimal placement and integration methods for wind turbines along the perimeter shores of the United States. A map of the United States showing high potential areas for both onshore and offshore wind generation is shown in Figure 13.



Figure 13. National Onshore and Offshore Wind Generation Capacity [15]

The third DOE project, through the Office of Electricity Delivery & Energy Reliability (OEDER) is part of the national program on Workforce Training for the Electric Power Sector. [16] Two universities (one being the article authors) are partnering on this effort through a project entitled the Keystone Smart Grids Fellowship program which is developing curriculum, offering seminars and workshops, and other outreach components to train educators at all levels, with a focus on secondary education, in exposing power engineering and emerging smart grid principles to the next generation of potential students. As part of this effort, the graduate students in the research group are currently developing an introduction to energy and electricity based curriculum at the middle school level, which is planned to be offered a second time next year in cooperation with Aquinas Academy of Pittsburgh, a local K-12 school in Gibsonia, PA.

In addition to these activities, a new and exciting opportunity is developing in the local region through the DOE's National Energy Technology Laboratory (NETL). Through the NETL Regional University Alliance (RUA), a new grid technologies collaborative (GTC) has been established with faculty and student representatives from the five RUA institutions. [17] The GTC is working on concepts for the development of next generation power converter technologies for various applications at utility scale levels associated with clean energy integration, energy storage, and other emerging applications. Through NETL's support, this newly established GTC team positions the regional alliance as a formidable partner for future opportunities with government funding agencies and industry.

Through the Eaton partnership previously highlighted, the collaboration has also cultivated new and continuing research related to power systems, power quality, energy efficiency, and alternative energy systems. Senior design projects and graduate student research projects have been sponsored by and conducted at Eaton's Power System Experience Center (PSEC) in

Warrendale, PA, where students utilize Eaton's state-of-the-art facilities for their studies and work on the development of power quality equipment and technologies. Recently, several projects at the PSEC have focused on photovoltaic applications, data center power supply concepts, and electric vehicle charging technologies, with students also making trips to other Eaton facilities to perform the work, including operations in Asheville, North Carolina.

One of the core facets of the research program is centered upon direct current (DC) based systems and networks. These systems, currently, require a number of power conversion stages because most generation sources produce AC power being delivered to an increasing market of DC loads. These DC loads find themselves in the transportation and IT infrastructure markets, to name a few. ABB Corporate Research has partnered with the university in this area to begin investigating Medium Voltage Direct Current (MVDC) technology, which is a DC collection platform for interconnecting many forms of renewables and loads. The idea originated from the use of DC on shipboard applications and a means for improving system efficiency by reducing the number of power conversions necessary to interconnect DC equipment into AC networks. Figure 14 shows a one-line representation of one of the medium voltage DC architectures being developed.



Figure 14. Example Medium Voltage DC Architecture One-line Diagram [18]

Siemens Energy, another strong sponsor and advocate of the program, selected the university partner from only a handful of institutions across the United States and Canada. As part of this relationship, Siemens has provided the engineering school with full professional versions of its Power System Simulator for Engineering (PSS/E) software. Siemens also established a graduate fellowship at the school and access for faculty and students to attend Siemens' Power Technologies International courses, which provide up-to-date training in power system analysis and planning. To date, graduate students engaged in research activities with Siemens have developed closed-loop control system models to facilitate mathematical analysis and to promote operational efficiency of the dynamic bidding process in electricity market behavior. Another project also is looking at using their SVC Plus with energy storage FACTS technology in weak AC grid scenarios (formed through high wind penetration areas) compared to traditional technologies such as synchronous condensers.

Recently, another new corporate agreement has been created with Mitsubishi Electric Company (Japan) to investigate advances in areas of power electronics (specifically HVDC). A number of recent electrical engineering graduates with the electric power concentration have been employed by Mitsubishi Electric Power Products over the past several years.

While these represent a number of exciting research programs currently underway, new projects continue to develop to provide more graduate students opportunities to pursue their advanced degrees through funded graduate student research fellowships, as well as to provide new opportunities for faculty.

# Additional Outreach Activities: Electric Power Industry Conference and National Ambassadors Program

The university program is very much engaged in various outreach activities. One of the highlights each year is the annual Electric Power Industry Conference (EPIC). The conference was initiated as an opportunity for expanded networking between electric power and energy engineering students and professionals within the electric power and energy industry sector. As time has progressed, the conference has expanded, allowing opportunities to showcase relevant university research, to invite feedback from the professional community, to highlight trends and emerging technologies within the industry, and to provide a forum for discussion of regional developments related to energy. Several purposes benefit attendees including industry-university collaborations and networking, as well as industry-to-industry relationship development. Bringing these communities together, along with relevant government organizations represented at the conference, such as the Dept. of Energy, provides a tremendous opportunity to develop regional partnerships that can bring national contributions.

The EPIC event was established in 2006, hosting five industry participants (at the time only regional electric utilities) and approximately 40 attendees among students and faculty. The original conference was hosted in a classroom setting and while small, created the right environment to establish the dialogue and networking that was recognized as having potential to be expanded upon in future years. Also at this first event, each industry attended eventually hired one of the students in attendance that very next year either as a full time employee, summer intern, or cooperative program student. The conference has grown tremendously since then and has expanded to be held over two days with keynote addresses, industry-government-academic panel sessions, invited technical paper presentations, graduate student research poster sessions and mini-symposium, and workshops on specific on-going grants or potential research focus areas, and a popular evening networking event and exhibit. The 2013 two-day event included 39 organizations represented, approximately 227 attendees, 25 exhibitors, and 10 corporate sponsors. The two keynote speakers included Patricia Hoffmann – Assistant Secretary of the U.S. Department of Energy, Office of Electricity Delivery and Energy Reliability, and Revathi Advaithi – President, Electrical Sector – Americas, Eaton. Figure 15 shows the trends in company attendance for the annual event and a photo of students and industry attendees from a recent conference.



Figure 15. Growth in the Number of Companies Attending EPIC since 2006

Another recent example of the program's outreach component is participation in the newly established National Academies of Sciences and Engineering (NAS and NAE) Energy Ambassador Program.[19] This is a pilot program for which the local region was selected due to its national position as an energy capital and leader, with eventual national program development based on outcomes of the pilot. The goals of this National Academies endeavor are to provide innovative outreach and education on science and engineering for community and opinion leaders, students at all education levels, and others; and to build on the respect people hold for scientists and engineers and to address the need for a greater popular understanding of scientific issues, with energy as the initial focal topic. The program was launched in the fall of 2012.

These are just two examples of the many outreach activities being performed in the energy area. In addition, faculty and graduate students routinely volunteer their time on a continuing basis to deliver seminars and support other educational events at local high schools and middle schools, in an effort to introduce and attract young people to careers in the science, technology, engineering, and math (STEM) disciplines.

#### Conclusions

The electric power program described has been established as a model program nationwide for the resurgence and sustainability of university education and research activities in electric power engineering, with strong industry collaborations, core government interaction, and key foundation support. The University of Pittsburgh Swanson School of Engineering is engaged deeply throughout the regional area with industry partners, and at the national leadership level through various government and professional society participation in the electric power sector, and is well-positioned to support the emerging electric power and energy infrastructure and technology development revolution. There has never been a more exciting and dynamic time to be a part of the electric power and energy sector, with abundant opportunities to redefine our nation's future and to be at the forefront of the new 'energy economy' that is taking place. The challenges ahead are unprecedented, and the opportunities are robust and abundant. The 'next generation' of professionals are needed to bring innovation, creativity, and solutions to this emerging environment, and universities are at the forefront of developing these future leaders of the electric power and energy sector through advanced education, research, and outreach programs.

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