AC 2008-614: POWER ENGINEERING TECHNOLOGY PROGRAM DEVELOPMENT

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Power Engineering Technology Program Development

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Abstract:

A major issue in the electric power industry is the staffing of the electric power infrastructure. As the Baby Boomer generation retires over the next decade as much as 75% of the current industry staff will have retired. This will affect hourly operations and maintenance personnel, engineering design staff and transmission and distribution professionals. The impending demand for power engineers has spurred the utility companies to work with the College of Applied Science to develop programs for new Engineering Technologists in Power Systems. A major goal of this paper is to describe and promote the topics that should be included in Power Engineering Technology Programs. The paper will focus on the technical description of a recently approved new Associate Degree in Power System Engineering Technology at the University of Cincinnati. This new program started in the fall of 2006, and was created largely due to the request from industry professionals. The program is jointly presented by the Electrical and Computer Engineering Technology, and Mechanical Engineering Technology departments at the University of Cincinnati. The paper also presents a proposed formation of an Energy Center which will extend the current associate level curriculum into a baccalaureate degree in Power Systems Engineering Technology. Other degrees including nuclear power, certificate programs, conferences and workshops will be offered.

Introduction:

Over the past three decades the utility industry has gone through the toughest times in the history of large scale centralized power production. The 1973 Clean Air Act required power companies to provide remedies for thermal pollution, air pollution, ground water contamination and soil contamination. This added significantly to the costs of traditional fossil fueled power plants and helped stimulate the growth in interest in building a large number of nuclear power plants.

In 1979 the accident at Three Mile Island halted the construction of every nuclear plant being built in the US as well as forcing utilities to scrap any plans to seek licensing to start building new plants. In the 1980s natural gas transmission was deregulated on a federal basis. This resulted in rapid growth in the sales and installation of a large number of combustion gas turbine peaking power stations. In addition to being a cleaner fuel, combustion turbine peaking stations were nowhere near as labor intensive as large scale fossil fueled power plants or nuclear power plants. This allowed the industry to keep pace with demand for power without any serious need for new staff.

All through this period in time the style of management, the regulatory world and national energy policy floated along without many upsets other than Chernobyl which again heightened the public's fears of nuclear power. Successful deregulation of the natural gas markets, led legislatures across the country begin a movement to deregulate the electric power market as well. Power marketers, arbitragers, venture capitalists and institutions with large power needs entered the electric power business.

The 2000 California energy crisis was followed by the huge blackout of the Northeast, and the rising drumbeat of climate change, global warming, carbon emissions, greenhouse gases, and a general public re-examination of how we make power, use power and distribute power.

Since 1973 for all intents and purposes the utility industry staff was frozen. The industry benefited from a workforce with deepening experience, seniority and problem solving skills. It is expected that by approximately 2012 75% of the current utility industry operations and maintenance workforce will have either retired or become eligible to retire. With no established pipeline of new workers the industry has called upon us to respond with programs in Power Engineering Technology.

The vast majority of the large scale base load power generation plants are over thirty years old. Many are almost fifty years old and the ability to continue to stretch new life out them is wearing thin. A whole new infrastructure needs to be built from power generation plants to switching stations and power transmission and distribution systems. This is the impetus along with industry inquiries that had UC create the new programs in Power Engineering Technology we will outline in the following sections.

Curriculum Outline:

Table 1 lists the curriculum plan for the Associate degree in power technology option. Total of one hundred quarter credit hours are required for this degree option. There are nine lecture courses with accompanying lab classes that are offered in the Electrical and Computer Engineering (ECET) department. Sum of the credit hours for these classes is 36 quarter credit. Mechanical Engineering Technology (MET) department is responsible for offering seven courses that sum up to twenty-eight quarter credit hours. One course for three credit hours entitled "Environmental Laws and Regulations" is offered by the Chemical Technology department (Chem Tech). The rest of the classes are supporting Math/Physics and Breath of Knowledge (BoK) general education classes.

FALL		WINTER		SPRING		SUMMER	
Courses	Cr. Hr.	Courses	Cr. Hr.	Courses	Cr. Hr.	Courses	Cr. Hr.
Alg. & Trig. I 32MATH178	4	Alg. & Trig. II 32MATH179	4	Calculus I 32MATH244	4		
Elements of EET 32ELTN102	3	**Circuit Analysis I 32ELTN142**	3	**Circuit Analysis II 32ELTN143**	3		
Elements ECET Lb 32ELTN112	1	**Circuit Analysis I Lb 32ELTN15**	1	**Circuit Analysis II Lb 32ELTN153**	1		
English Comp I 32ENGL101	3	English Comp II 32ENGL102	3	English Comp III 32ENGL103	3	Co-op	
Stationary Eng I 32ENGY101	3	Prin of Machin. 32MFTN132	3	**Digital Systems I 32ELTN141**	3		
Prof Devlpmt 1 36PD132	1	Prin Machin. Lab 32MFTN142	1	**Digital Sys I Lab 32ELTN151**	1		
		Stationary Eng II 32ENGY102	3	Stationary Eng III 32ENGY201	3		
	15		18		18		0
Courses	Cr. Hr.	Courses	Cr. Hr.	Courses	Cr. Hr.	Courses	Cr. Hr.
Physics I 32PHYS181	3			Physics II 32PHYS182	3	Env. Laws/Reg 32CHEN470	3
Physics I Lab 32PHYS186	1			Physics II Lab 32PHYS187	1	Energy Systems 32MET421	3
Survey of Econom. 32ECON286	3			Power Plant Tech 32MET420	3	**Flex Automation I 32ELTN415**	3
Electronics 32ELTN101	3	Co-op		**Topics of Appl Des. 32ELTN256**	3	**Flex Automation I Lab 32ELTN425**	1
Electronics Lab 32ELTN111	1			**Topics of Appl Des. Lab 32ELTN266**	1	H/SS Elec. - Ethics	3
Circuits III 32ELTN144	3			**Rotating Machinery 32ELTN416**	3	Speech 32COMM172	3
Circuits III Lab 32ELTN154	1			**Rotating Machinery Lab 32ELTN426**	1		
Stationary Eng IV 32ENGY202	3						
	18				15		16

Table 1- Course plan for the Power Engineering Technology Option to the ASEET Degree

Course Development and Content Descriptions:

In this section we will describe electrical and mechanical courses and expected learning outcomes. Learning outcomes for these classes were prepared by the faculty members for ABET Accreditation board visit to our college in fall 2006. We will first describe the Electrical courses followed by the Mechanical courses.

Persons employed in the power systems area must be able to understand three phase power generation and distribution. They must be able to perform basic analysis and further understand the control aspects of power generation systems and be prepared to manage and make design changes as well. The educational goal of our curriculum is introduce the concepts that will support the understanding of modern power systems. Graduates at the associate level will be able to perform many technical tasks in support of power generation and distribution. Those interested in pursuing further education with more advanced study leading to a bachelor degree in this field will find that the curriculum provides a strong foundation as well.

The study of circuit analysis supports understanding electrical phenomena and is particularly important to the understanding of power generation and distribution. Our curriculum provides a four course sequence in circuit analysis, beginning with an introductory course the first quarter of the freshman year and continuing through a course that covers three phase power systems, transformers and complex power, in the sophomore year. This sequence is supplemented with courses in rotating electric machinery, applied design and flexible automation. These courses provide the technical core for our ABET accredited associate degree in Electrical Engineering Technology with power systems technology. All courses consist of a three credit hours lecture with and accompanying three hour laboratory which serves to reinforce the concepts presented in the lecture with practical hands-on experiments.

Table 2 lists courses that are offered in the Electrical and Computer Engineering Technology (ECET) department for the Power System Technology program.

Courses	Cr. Hr.		Courses	Cr. Hr.
Elements of EET (32ELTN102)	3		Electronics (32ELTN101)	3
Elements ECET Lab (32ELTN112)	1		Electronics Lab (32ELTN111)	1
Circuit Analysis I (32ELTN142)	3		Flex Automation I (32ELTN415)	3
Circuit Analysis I Lab (32ELTN152)	1		Flex Automation I Lab (32ELTN425)	1
Circuit Analysis II (32ELTN143)	3		Rotating Machinery (32ELTN416)	3
Circuit Analysis II Lab (32ELTN153)	1		Rotating Machinery Lab (32ELTN426)	1
Circuits Analysis III (32ELTN144)	3		Topics of Applied Design (32ELTN256)	3
Circuits Analysis III Lab (32ELTN154)	1		Topics of Applied Des. Lab (32ELTN266)	1
Digital Systems I (32ELTN141)	3			
Digital Sys I Lab (32ELTN151)	1			

Table 2- Electrical Engineering Courses for the Power System Technology Program

Basic electrical principles and the means of performing analysis are introduced the very first quarter in Elements of Electrical Engineering Technology. This course called **Elements of EET** covers use of scientific calculators, and basic instrumentation as meters, power supplies and the oscilloscope [1]. Application of resistors and the color code are presented. Students are introduced to basic concepts of electrical phenomena and terminology and learn to perform simple calculations on resistor based circuits. Students learn Ohm's Law, Kirchoff's Voltage Law, and Kirchoff's Current Law. They will also learn how to combine resistors in series and in parallel. In lab, students learn to use a D.C. Power supply, a Digital Multimeter, a Function Generator, and an oscilloscope. They also learn to wire resistive circuits and make appropriate voltage and current measurements. Students also use the computer software program, Multisim, to analyze resistive networks. They learn to compose and write cogent laboratory reports.

Circuit Analysis I builds upon the fundamental concepts that were introduced in Elements of Electrical and Computer Engineering Technology [1]. Students learn how to apply mesh and nodal circuit analysis methods for DC circuits. Thevenin's theorem, Norton theorem, Superposition theorem and the Maximum Power Transfer theorem are used to analyze electrical networks as well. The accompanying laboratory course provides hands-on reinforcement of the principles that are presented in the lecture.

Circuit Analysis II covers many of the same analysis topics and methods that were introduced in Circuit Analysis I, but this time with respect to AC circuit quantities [1]. Reactance, impedance and admittance concepts are presented along with Phasors and complex number mathematics. Students will learn to analyze circuits containing real and reactive components in transient and steady states. They perform AC circuit analysis on circuits that contain resistors capacitors and inductors. In lab, students continue to apply the skills and tools that they learned in Elements of ECET, Circuit Analysis I and III classes.

Circuit Analysis III is the culmination of the formal circuit analysis sequence where three phase power systems, complex power, magnetic circuits and transformers are covered [1].
In this course methods of circuit analysis are applied to three phase voltage-load systems of both Wye and Delta configuration. The concepts of real and complex power are introduced and applied to single phase and three phase systems. Transformers and magnetic circuits are described and analyzed. Finally, classic low pass, high pass and bandpass filters are presented analyzed and designed. Various concepts of pulsed waveforms and corresponding circuit responses are also covered. In lab, students learn to use the D.C. and AC Power supplies on the Hampden stations. They learn to wire AC single phase series, parallel and series-parallel RLC circuits. They also learn how to connect three- phase Wye-Wye, Wye-Delta, Delta-Wye, and Delta-Delta circuits and take measurements. They will measure Real, Reactive, Apparent powers and calculate Power Factor. Students perform experiments for magnetic circuits and transformers. In addition they will learn how to draw the Bode Plot for finding the voltage gain magnitude and phase shift response of a passive filter.

In the **Electronics** course semiconductor concepts introduced [2]. Other concepts covered include the operation of the PN junction, bipolar transistors, half- wave and full-wave rectifier design and construction. Various transistor bias schemes are discussed, as well as standard BJT amplifier configurations. Amplifier characteristics such as gain and input and output impedances are presented in tabular form. In lab, students measure transistor amplifier characteristics such as input/output resistance and voltage gain of the CE and CC amplifier configurations.

Digital System I covers Number systems, Boolean algebra, logic concepts, and characterization of TTL and CMOS logic families [3]. Students learn the function of gates, latches, decoders, and bitable and their interconnection into combinational logic subsystems. They will learn the concept of two-state digital system. They will also study Boolean algebra and learn how to use it to reduce Boolean functions. They will also learn how the Small Scale Integrated (SSI) circuits such as Logic Gates and Medium Scale Integrated (MSI) such as Counters operate. In labs, students learn to wire Integrated Circuit (IC) chips and make appropriate Input/Output measurements. They will also use software tools such as Logic Converter and Karnaugh Map Minimizer.

Introduction to Programmable Logic Controller (PLC) architecture and programming based upon the Allen Bradley Small Logic Controller (SLC 503) series family of controllers are covered in **Flexible Automation I** course [4]. Students who enroll in the Flexible Automation I class have already completed the aforementioned electrical, electronics and digital courses. Students will learn how to configure the Allen Bradley SLC503 I/O ports and connect the input/output devices to the PLC I/O ports. They will learn to use normally open and normally closed switches and contacts in a PLC ladder logic diagram. They will convert Boolean equations and combinational logic diagrams to PLC ladder logic diagrams and vise versa. They will also study the use of timer and counter functions and utilize them in a control system. In lab, students will use Allen Bradley Small Logic Controller (SLC503) programmable logic controller stations to read input devices and control output devices. They will use the Allen Bradley RSLogix 500 software tool to write their PLC ladder logic. Students also use the LogixPro simulator program to simulate and analyze their routines prior to using AB RSLogix 500 to download their program into PLC memory.

Following completion of the circuit analysis sequence students take a course in the operation of rotating machinery. This course is Topics of **Rotating Electric Machinery** [5]. Three phase systems are reviewed and transformers are covered in more detail than was done in Circuit Analysis III. The operating principles of practical rotating machines are introduced. These machines include: DC generators and motors, three phase synchronous and induction motors and single phase motors. In labs, students take measurements of power, voltage and current quantities of machines under operating conditions. They are required to make observations of machine efficiencies under various loading conditions.

In addition to taking courses in circuits, machinery and controls we feel that it is important students be able to pull together much of what they have learned at the associate level so they see how their knowledge can be applied to a real project. **Topics of Applied Design** is intended for this purpose. The course serves as a capstone course at the associate level that requires students to apply the knowledge and analysis techniques they have learn thus far. Students work in teams on a project of some complexity such as a regulated power supply or RF circuit. The actual project can be changed each time the course is offered in order to keep the material fresh and relevant. Students are expected to make a complete design to the PC board layout level. Practical components and their limitations are discussed. This course requires students to consider projects from an overview perspective. It provides an introduction to tasks and skills such as writing Project proposals, Cost Estimating, Scheduling, Poster and Power point presentations, and report writing.

Table 3 lists courses that are offered in the Mechanical Engineering Technology (MET) department for the Power System Technology program.

Courses	Cr. Hr.		Courses	Cr. Hr.
Stationary Eng I 32ENGY101	3		Prin of Maching 32MFTN132	3
Stationary Eng II 32ENGY102	3		Prin of Maching Lab 32MFTN142	1
Stationary Eng III 32ENGY201	3		Power Plant Tech 32MET420	3
Stationary Eng IV 32ENGY202	3		Energy Systems 32MET421	3

Table 3 Mechanical Engineering Courses for the Power System technology Program

Stationary Engineering I provides the basic fundamental technical knowledge for high performance steam plant operation [6, 8]. This includes steam and its importance utility boilers for electrical power, combined cycle and cogeneration systems, fundamentals of steam generation, principles of heat transfer, super-heaters, nuclear steam generation, design and construction of boilers, fluidized bed boilers and combustion of fuels, maximum allowable working pressure, internal design pressure and boiler horsepower calculations.

Stationary Engineering II & III cover boiler settings, combustion systems and auxiliary equipment, hand firing, stokers, pulverized coal, fuel oil, gas, automatic operation of boilers, boiler accessories, operation and maintenance of boilers, instruments and automatic control systems pumps, and auxiliary steam plant equipment [6, 8]. Students will learn the methods for Minimum and Maximum hydrostatic test pressure calculations.

Stationary Engineering IV provides the fundamental technical knowledge of steam plant equipment for the Ohio State Stationary Engineer's Examination [6, 8]. Steam turbines and auxiliary equipment, environmental control systems, and Waste to energy plants, application of thermodynamics, fluid mechanics and heat transfer in power plant operation. Review of all power plant calculations and synthesis of Stationary Engineering I, II, III and IV.

Power Plant Technology is a study of power plant components: steam generators; turbines; feedwater heaters; cooling towers. Learn the analysis of combustion products and pollutants, air and water pollution control. Study the design and computer simulation of power generations systems [7].

Energy Systems Study and comparisons of alternative large-scale energy sources: fossil fuels, shale, synthetic fuels; biomass, wood, solar, wind, ocean, hydro, fission, fusion. Study the availability of resources, status of technology, costs and environmental effects [7].

Industry Feedback Actions and Future:

As more and more companies in the power industry have become aware of the impending rush to the exits of their baby boomer workforce they have started to take action. Leaders of the industry which is represented by the Electric Power Research Institute (EPRI) gathered together to develop an action plan. One action area was to create interest in careers in the industry early in a student’s education. To that end EPRI established the Center for Energy Workforce Development or CEWD. The CEWD’s mission is to develop programs targeted at middle school age students and their teachers to create a buzz for a career path in the power industry.

The utilities have also found allies in a number of rust belt states with needs for Adult Workforce Development to retrain displaced workers from outsourced manufacturing. For example the State of Ohio’s Department of Education has developed a series of documents outlining in detail the technical competencies required to fill jobs successfully as power plant operations personnel, power line workers, and nuclear plant operations personnel.
There are commercial utilities that have also partnered with community colleges, junior colleges and vocational and technical schools to start to develop the necessary programs to address this workforce need. This leads us to the present state of the program at the University of Cincinnati College of Applied Science’s Power Systems Technology Associate Degree and Energy Center.

Conclusion:

This paper demonstrates how critical it is that higher education institutions educate more power engineers. These young power engineers are going to replace the "baby boomer generation" engineers who have maintained infrastructure of power plants and power transmission systems. New power engineering programs similar to the one discussed in this paper are starting to be offered by universities and community colleges all over the United States of America. Students involved in these programs need to be familiar with mechanical and electrical devices used in the power plants to generate electricity as well as digital and electronics equipment used to control the generation and transmission of the electric power. Students who graduate from the program presented in this paper also gain valuable industrial programming knowledge that is necessary for programming control equipment.

Faculty members in the ECET and MET departments have had positive feedback from students who have completed their first co-op internship with utility companies. This Associate degree program will have its first Power System Technology graduate in fall 2008. Students currently enrolled in this program and people from the electric utility company have expressed their desire to see that we design a baccalaureate degree program for the Power System Technology. ECET and MET departments in the College of Applied Science (CAS) at the University of Cincinnati are currently exploring the possibility of offering BS degree in Power System Technology. This proposed program will also include courses in new energy, environmental and sustainability fields.

Bibliography

1. *Boylestad, Introductory Circuit Analysis, Eleventh Edition, 2005, Prentice-Hall Publishing Company, Upper Saddle River, NJ.*

2. *Thomas L. Floyd, Electronic Devices, Eighth Edition, 2007, Prentice-Hall Publishing Company, Upper Saddle River, NJ.*

3. *Kleitz, Digital Electronic, Seventh Edition, 2005, Prentice-Hall Publishing Company, Upper Saddle River, NJ.*

4. *Webb, John and Reis, Ronald, Programmable Logic Controller: Principals and Applications, Fifth Edition, 2002, Prentice-Hall Publishing Company, Upper Saddle River, NJ.*

5. *Charles Hubert, Electrical Machines, Second Edition, 2002, Prentice-Hall Publishing Company, Upper Saddle River, NJ.*

6. *Woodruff and Lammers, Steam; Steam Plant Operation; Eighth Edition, 2004; McGraw-Hill.*

7. *Babcock and Wilcox; Steam, Its Generation and Use; Paperback Edition 2007; Merchant Books.*

8. *Elliott, Chen and Swanekamp; Standard Handook of Powerplant Engineering; Elliott, Chen and Swanekamp; Second Edition, 1997; McGraw-Hill.*

Biography

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