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Future Directions in Electric Power Engineering Education

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Electric power engineering graduates of the future will face increasingly complex technological, economic and environmental challenges. Power engineering degree programs will be expected to provide adequate preparation. This paper suggests degree program topics to address expected power system development in the areas of traditional power engineering, computer applications and communications.

I. INTRODUCTION

ELECTRIC power engineering graduates of the future will confront increasingly difficult problems as practicing professionals. These problems will arise because of ever more stringent environmental constraints and economic considerations. As today's technological solutions become insufficient to solve tomorrow's problems, power engineers will be expected to create new and more sophisticated solutions to those problems.

Engineering education in general and electric power engineering education in particular must provide graduates with the tools with which to embark on a life-long path of continuing self improvement and self education. This must be accomplished at the same time that students learn specific skills which enhance their employability immediately upon graduation.

The electrical engineering department at the University of Alaska Fairbanks approaches the challenges outlined above by providing a substantial laboratory or hands-on experience for students while, at the same time, requiring mastery of a rigorous theoretical base. At the undegraduate level, students choose between electric power, computer engineering and communications options. These options allow added educational depth in the subject of choice while still requiring background in a broad range of engineering topics. An unusual feature of the program is the existence of 'open laboratories' for undergraduates, in which students, when they become qualified to use the facilities, have 24 hour access to laboratories appropriate to their course work. The fact that this system is successful speaks well for the quality and integrity of our students.

II. GENERAL DISCUSSION OF THE PRESENT ELECTRIC POWER CURRICULUM

A general overview of the electric power option at the University of Alaska Fairbanks (UAF) may be helpful at this point. Accreditation Board for Engineering and Technology (ABET) accreditation requirements continue to be met. This covers mathematics, basic sciences, engineering sciences, engineering design, humanities and social sciences, laboratory experience, computer-based experience, written and oral communication skills development, and ethical, social, economic and safety considerations in engineering practice.

Electrical engineering courses begin in the second semester of the program with an introduction to circuit analysis and characteristics of passive and, to a slight degree, active devices. The third and fourth semesters each contain a four-credit course including a laboratory, covering network analysis, electronics (both analog and digital) and energy conversion. The fifth and sixth semesters include a three-credit course in circuit theory, a three-credit course in signal analysis, two four-credit courses (each including a laboratory) in physical electronics and electronic circuit design and a four-credit automatic control systems course. These courses are required for all electrical engineering undergraduates. In addition, the electrical machinery course and the two power courses described in Section III are taken in the fifth, sixth and seventh semesters, respectively. In the seventh and eighth semesters, power option students are required to take an applied electromagnetics course with an accompanying laboratory providing hands-on experience with several impedance bridges, an admittance meter, network analyzer and an S—parameter analyzer. In addition, they are required to take a four-credit digital systems analysis and design course, including a laboratory, which provides a background, from a software/

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firmware/hardware perspective, to analyze and design various classes of algorithmic state machinery ranging from the simple gate to microcomputer implementation of automata. This includes assembly language programming of microprocessors. The eighth semester also includes two electrical engineering elective courses. One of these must be a design elective, including more than 50% design. Power option students are encouraged to take additional courses in communication systems and digital systems. Some elect to take an additional electric power course, even though these are at the graduate level.

III. SPECIFICS OF THE PRESENT ELECTRIC POWER COURSES AT UAF

Electric power option undergraduate students are presently required to complete a four-credit course in electrical machinery (required of all electrical engineering majors). In addition, as noted in Section II, two four-credit electric power courses are required. All above courses have weekly three-hour sessions. Laboratory projects require written reports.

The electrical machinery course covers the following topics: magnetic circuits, review of three-phase power, basic machine concepts, synchronous machines, induction machines, single phase machines and DC machines. Laboratory projects include: (1) three-phase voltages, power measurement and power factor correction, (2) three-phase transformer connections, waveshapes and harmonics, (3) transformer equivalent circuit and parameter evaluation, (4) synchronous generator connected to an infinite bus, (5) parallel synchronous generators operating as an isolated system, (6) synchronous machine open circuit and short circuit characteristics, (7) synchronous machine transient behavior, and (8) autotransformers and open delta transformer connections, (9) induction motor torque-speed characteristics, (10) no-load and locked-rotor induction motor tests, and (11) DC motor characteristics.

The first electric power course lists the electrical machinery course as a prerequisite. Course topics include: steady-state single-phase and three-phase AC systems, determination of transmission line series impedance and shunt capacitance, transmission line equivalent circuits, reactive compensation, one-line and impedance diagrams, per unit representation, bus admittance and impedance matrices, power flow and power flow control, economic despatch and transmission loss coordination. Laboratory topics include: (1) measuring real and reactive power in a three-phase system using three wattmeters, (2) methods for determining phase sequence, (3) instrument transformer characteristics and applications, (4) three-phase transformer capability to supply a single phase load, (5) overhead line simulation, (6) circle diagrams for overhead line, (7) simulation of parallel underground and overhead lines and use of phase shifting transformers, and (8) computer based power flow case studies.

The second required undergraduate power course currently includes the following topics: symmetric fault studies, symmetrical components and unbalanced faults, fault analysis computer program and applications, power system overcurrent and overvoltage protection (including relaying, circuit breakers, fuses, reclosers, sectionalizers and overcurrent device coordination as sub-topics), power system transients, insulation coordination, static var compensation, power system stability, the National Electrical Code and the National Electrical Safety Code. Laboratory topics include: (1) electric power quality definitions and measurement, (2) breadboarding and testing a symmetrical component RC-active filter, (3) measuring sequence components, (4) application of a fault analysis computer program, (5) lighting system design, (6) overcurrent relay testing and coordination design, (7) line-open fault measurement and analysis, (8) National Electrical Code review, (9) National Electrical Safety Code review, and (10) application of a power system transient stability analysis computer program. Field trips to local utility generating facilities, substations and a supervisory control and data acquisition (SCADA) center are a part of both courses. In addition, both power courses require a written summary or critique of a recently published power engineering journal article as well as an oral class presentation of that summary. This encourages further development of writing and speaking skills as well as an increased awareness of current power engineering research topics.

Material for the two required electric power courses is selected from a variety of references. A partial list is provided at the end of this paper [1–15].

IV. WHY SHOULD POWER ENGINEERS UNDERSTAND COMMUNICATION SYSTEMS?

Communications is broadly defined as the exchange of information—whether the information is telephone conversations, broadcast television, data from the Voyager planetary probe, or the state of a relay switch in a power system. Information exchange is becoming more and more important and pervasive in our society. The recent explosion of facsimile or fax machines has demonstrated the adage that once a means of communicating becomes available, new uses will be developed to utilize this means. Offices will be connected with ISDN—Integrated Services Digital Network, whereby voice and data traffic will be brought into the office on the same digital line. This will of course require digitizing voice, a practice in standard usage among the many new long distance phone carriers. Local Area Networks (LANs) are becoming standard in many work environments. Distributed processing in small personal computers is replacing the central structure of a single mainframe. All of these personal computers, however, need to access common data banks or be able to communicate with each other. This provides a basis for development of the network which forms a means of communications between computers whether located in the same room or across the world. Telephone wires, microwave repeater stations, satellite links, and fiber optic lines are all commonplace and are the media over which the information, to be communicated, is carried.

Communication systems are thoroughly integrated into our daily lives. They are common in our homes, our offices, and in electric power systems. A basic understanding of a communications system is important to any engineer who relies on that system to perform his or her job.

Electric power engineers do not necessarily need to be able to design communication systems, but they must be able to specify the salient parameters of the information they need communicated. These initial parameters are:

1. The data rate
2. The acceptable error rate.
3. The distance of the communication link.

The design of the communication system can then proceed, with a watchful eye toward the prediction of services expansion—either higher data rates or new paths.

Although a communication systems course is not presently required for the power option, many power option students take an elective course which includes the above considerations. Power option students may also take a communications-based design elective. This course allows the student to work on the design of a communication network of personal interest, e.g. a communication network for a regional power utility, or for a trans-Alaska pipeline. In the future, it may be appropriate to require such a course, along the lines of Carlson [16] or Schwartz [17] for communications systems basics or Stallings [18] for communication network design.

V. WHY ARE DIGITAL SYSTEMS IMPORTANT TO POWER ENGINEERS

Digital systems and the techniques of digital analysis and control have become pervasive throughout all types of engineering but especially throughout the field of electrical engineering. Communications, instrumentation, process control, signal and data analysis, circuit design, and power systems are some areas of electrical engineering that have analog (continuous) foundations which have now been or are being redefined in terms of discrete values and processes. Digital processes have become as common and basic for electrical engineers as Ohm's Law or calculus but, unfortunately, not yet as well understood. Nevertheless, the digital revolution will continue and the electrical engineering education community has responsibility for keeping abreast of these changes and their impact on all areas of electrical engineering.

Digital design, *per se*, is still such a relatively new area that many techniques for accomplishing the design are not well structured or, rather, do not present a stable horizon. New or revised techniques for state machinery design are developed annually; in addition, familiarity with software packages as well as the advances in computer speed, graphics, interfaces, memory capacity and access times create such a flux of development that many techniques are outdated by the time they are disseminated. This scenario can be very frustrating to the engineer for several reasons. It is a credo of the engineer to be familiar with available tools and techniques and to be aware of the advances of the field. However, technological horizons often change so rapidly that the engineer simply cannot wait for the end product, whatever that may be, but must identify and put to use the best material available at the time. The problem becomes one of defining what is best—best supported, best functionality, least errors, etc. It can be frustrating to make a major purchase of some tool knowing that by the time it is received, the tool may have been updated to such extent that it has become outmoded.

Fortunately, because of buyer demand, the industry has a commitment to upward compatibility so that, in general, what is outdated may not be totally obsolete. Still, it may be frustrating to the more senior engineer who knows a problem solution and has developed a resistance to new routes. Then too, the novice engineer, with little experience for guidance, may be at a loss as to how to best choose a particular product from a seeming deluge of information. Therefore, the engineering educator must teach not only theory, but the techniques for realizing a particular solution or product and, not stopping there, the trends of product development.

The digital revolution is occurring for many reasons: digitization improves a signal-to-noise ratio; digital process control is more exact and predictable; digital signals and data are more quantifiable; certain preferred digital control and analysis techniques are not realizable in the analog domain; integrated circuitry allows fabrication of entire functions on a chip; computer modeling allows the design and simulation of complete systems. However, the most important reason for the digital revolution lies in the proliferation of personal computers with a computing base equal to that of mainframe computers of ten years ago as well as the immense software (program) base which is available for problem solving, system modeling and computer aided design.

Thus, there are two areas in which the engineering education community must respond in order to insure that students are prepared to function and lead in the changes that are upon us. First, the curriculum must recognize the infusion of digital techniques into the various aspects of engineering and, in that recognition, support the students' need to understand the revolution that is occurring. This may be accomplished by an early, introductory course which acquaints the student with basic concepts of digitization (analog—digital and digital-analog conversion), basic digital machinery (combinational and sequential logic) and concludes with an introduction to microprocessors and the role of integrated circuitry in the realization of digital (state) machinery. Second, the institution must provide adequate access to computer work-stations (personal computers) with which to exploit the sophisticated software available for problem solving, system and process modeling and Computer Aided Design/Manufacturing (CAD/CAM).

VI. THE FUTURE

The present electrical engineering curriculum at UAF, and the electric power option in particular, evolved in part as a response to requirements of the Alaskan engineering job market. The areas of power, communications and digital systems have been most important to the state's technological infrastructure. In addition to the state-of-the-art, there is a 'third world' aspect to Alaska for which our graduates must be prepared. A graduate may find himself or herself in a situation in which he or she is the only electrical engineer in a remote utility or at a remote job site. In situations like this, it is important to be able to draw upon a practical background and solve problems that may not have traditional solutions. These situations may require expertise outside the usual boundaries of electrical engineering. But while our graduates are preparing to meet Alaska's needs, they are also being prepared for the best research laboratories and graduate schools. In order to accomplish this, our curriculum continues its evolution along with the electrical engineering field and, thus, our graduates are able to function well in new learning situations as well as the job market.

In the context of changing requirements for electrical engineers, what are important traits for engineers? Initiative, a flair for innovation, a strong grasp on engineering fundamentals, good written and oral communication skills, a curious mind and a willingness to continue the life-long learning process are characteristics that come to mind. How are these instilled in engineering students? What areas of the curriculum should be strengthened? What existing areas may be deleted? These are questions which must be asked and answered on a regular basis.

UAF has recently adopted a core curriculum that will be implemented in September 1991. In general, the goal of the new core is to ensure that the Baccalaureate experience has common standards. Those standards include a more focused 'perspective on human conditions' which recognizes that Alaska has a global position and a broader responsibility than to just the state and the nation—asengineers do. The definition of engineering generally includes the effect of utilizing technology to improve the human condition whereby the engineer is forced to ask and answer basic questions about ethical and philosophical ramifications and consequences of a proposed design. A major feature of the new core is the specific requirement for written and oral communication—intensive components within the upper division courses in each major. This requirement is consistent with the engineer's role as a communicator and encourages expansion of the electrical engineering department's current efforts to utilize laboratory and design courses to teach oral and written communication.

There are practical limits to what may be accomplished in an eight-semester undergraduate degree program and most programs are already saturated in terms of amount of work required. Because of this, if new material is to be added, old material must be deleted or presented more efficiently. It is inevitable that new material will be added to continuously evolving electrical power engineering curricula. It would take a functioning crystal ball to accurately predict what these new topics will be. At this time, however, it seems likely that increased emphasis on data communications and digital systems will be required in the next decade. Also, it appears inevitable that expert or adaptive systems will be integrated into electric utilities within the next few years. In addition, modern linear and nonlinear control techniques and system modelling and simulation methods will likely become even more important as power systems continue to expand in size and complexity. System analyses will become more critical as social and economic costs of electric power service interruptions escalate. Regardless of the new areas of power engineering that emerge, graduates that are well versed in fundamentals will be better able to continue their self-education and work with new technologies.

REFERENCES

1. W. D. Stevenson, Jr., *Elements of Power System Analysis, 4th Ed.*, McGraw-Hill, New York (1982).
2. J. D. Glover and M. Sarma, *Power System Analysis and Design*, PWS Publishers, Boston (1987).
3. C. A. Gross, *Power System Analysis, 2nd Ed.*, John Wiley & Sons, New York (1986).
4. *National Electrical Code 1990*, National Fire Protection Association, Quincey (1989).
5. *National Electrical Safety Code 1990*, ANSI C2-1990, The Institute of Electrical and Electronics Engineers, Inc., New York (1989).

6. T. Gonen, *Modern Power System Analysis*, John Wiley and Sons, New York (1988).
7. R. L. Bean, *et al., Transformers*, McGraw-Hill, New York (1959).
8. P. M. Anderson, *Analysis of Faulted Power Systems*, Iowa State University Press, Ames (1973).
9. *Applied Protective Relaying*, Westinghouse Electric Corporation, Coral Springs (1979).
10. J. L. Blackburn, *Protective Relaying Principles and Applications*, Marcel Dekker, Inc., New York (1987).
11. J. R. Neuenswander, *Modern Power Systems*, International Textbook Co., New York (1971).
12. *IEEE Guide for Safety in AC Substation Grounding*, ANSI/IEEE Std 80–1986, The Institute of Electrical and Electronics Engineers, Inc. (1986).
13. *IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems* (Green Book), ANSI/IEEE Std 142-1982, The Institute of Electrical and Electronics Engineers, Inc., New York (1982).
14. *IES Lighting Handbook*, 1981 Reference Volume, Illuminating Engineering Society of North America, New York (1981).
15. *IES Lighting Handbook*, 1981 Application Volume, Illuminating Engineering Society of North America, New York (1981).
16. A. B. Carlson, *Communicating Systems*, McGraw-Hill, New York (1986).
17. M. Schwartz, *Information Transmission, Modulation, and Noise*, McGraw-Hill, New York (1990).
18. W. Stallings, *Data and Computer Communications*, Macmillan, New York (1988).