AC 2011-554: ELECTRIC ENERGY AND POWER EDUCATIONAL PROGRAMS DEVELOPMENT SYMPOSIUM

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BIOGRAPHICAL INFORMATION

S. Hossein Mousavinezhad, Ph.D. Professor and Chair, Department of Electrical Engineering and Computer Science, Idaho State University Dr. Mousavinezhad is an active member of IEEE and ASEE having chaired sessions in national and regional conferences. He is an ABET Program Evaluator (PEV) for Electrical Engineering and Computer Engineering. He was General Chair of the IEEE 2009 International Electro Information Technology Conference, June 7-9 hosted by University of Windsor and 2002/2003 ASEE ECE Division Chair. He is IEEE Education Society Membership Development Chair and Van Valkenburg Early Career Teaching Award Chair. He was the ECE Program Chair of the 2002 ASEE Annual Conference, Montreal, Quebec, June 16-19. Professor Mousavinezhad received Michigan State University ECE Department's Distinguished Alumni Award, May 2009, ASEE ECE Division's 2007 Meritorious Service Award, ASEE/NCS Distinguished Service Award, April 6, 2002, for significant and sustained leadership. In 1994 he received ASEE Zone II Outstanding Campus Representative Award. He is also a Senior Member of IEEE, has been a reviewer for IEEE Transactions including the Transactions on Education. His teaching and research interests include digital signal processing (DSP) and Bioelectromagnetics. He has been a reviewer for engineering textbooks including "DSP First" by McClellan, Schafer, and Yoder, published by Prentice Hall, 1998 and Signal Processing First, Prentice Hall, 2003. He is on the Board of Directors of ECEDHA and Awards Chair. Hossein is a member of the Editorial Advisory Board of the international research journal Integrated Computer-Aided Engineering. Professor Mousavinezhad was founding general chair of the First IEEE Electro Information (eit) Technology Conference, June 8-11, 2000, in Chicago. This regional/national conference, sponsored by IEEE Region IV, is bringing together researchers in the ECE field covering such ECE research topics as Wavelet Transforms, Soft Computing, Power & Energy, Intelligent Control, Wireless Communications, and Fuzzy Logic. Keynote/Invited speakers included Drs. H. Adeli, M. Sloan, M. J. T. Smith, and L. Zadeh. He was part of the group promoting economic development in Michigan, MEDC and was responsible for bringing Innovation Forums to Western Michigan University, January 21, 1999. These forums were a series of meetings and seminars focused on university and industry collaboration initiated by the Michigan Governor. The Forums were sponsored by the Kellogg and Dow Foundations and were designed for finding strategies to create more Hi-Tech jobs in the State. As part of his responsibilities as Professor and Chair of the ECE Department at Western Michigan University, he prepared ABET reports for the two programs offered by the Department (EE and CpE.) The graduate programs offered by the ECE Department grew and he was responsible for initiating the first MSEE program in 1987. A new ECE Ph.D. program was offered starting Fall 2002. In addition to administrative responsibilities, he has managed to teach undergraduate/graduate courses in his research area of Digital Signal Processing, he is co-PIs for DSP and globalization grants funded by NSF. He has received other NSF and government grants in addition to equipment grants from Texas Instruments in support of his teaching/research activities in the DSP field. During May 2009, he received Michigan State University's Electrical and Computer Engineering John D. Ryder Distinguished Alumni Award for contributions in furthering the mission of the departmentwhich is to provide undergraduate and graduate education characterized by quality, access, and relevance, and to develop distinctive research programs in electro-sciences, systems, and computer engineering, with the promise of sustained excellence as measured in scholarship, external investment, reputation, and impact.

T.E. Schlesinger is the David Edward Schramm Professor and Head of Electrical and Computer Engineering at Carnegie Mellon University. Prior to this he was the Director of the Data Storage Systems Center, Associate Department Head in ECE, and was the founding co-director of the General Motors Collaborative Research Laboratory at CMU. He is currently the Director of the DARPA MISCIC Center at CMU. He received a B.Sc. degree in Physics from the University of Toronto in 1980 and an M.S. and Ph.D. degrees in Applied Physics from the California Institute of Technology in 1982 and 1985 respectively. His research interests are in the areas of solid state electronic and optical devices, nanotechnology, and information storage systems. He has received a number of awards and honors including; the Carnegie Institute of Technology George Tallman Ladd Award for research, and the Benjamin Richard Teare Award for Teaching, a Presidential Young Investigator Award, 1999 and 1998 R&D 100 Awards for his work on nuclear detectors and electro-optic device technology and the Carnegie Science Center 1998 "Scientist" award. He is a Fellow of the IEEE and the SPIE, is President of the ECE Department Heads' Association, and a member of the International Advisory Panel for the A*STAR Graduate Academy in Singapore. He has published over two hundred fifty archival journal publications and invited and contributed conference presentations and holds twelve patents.

Michael Lightner (Fellow, IEEE, AIMBE) is Professor and Chair of Electrical, Computer, and Energy Engineering at the University of Colorado, Boulder. He co-directs the Rehabilitation Engineering and Research Center on Advancing Cognitive Technologies. At Boulder he has served as Associate Dean of Academic Affairs and Associate Executive Director of the Coleman Institute for Cognitive Disabilities, He served as the 2006 President of IEEE and continues to serve on the Publications Service and Products Board, the Education Activities Board, the IEEE Committee on Earth Observations and the IEEE Cloud Computing Initiative. He is also a member of the ABET Board of Directors

MARK J. T. SMITH received the B.S. degree from MIT and the M.S. and Ph.D. degrees from the Georgia Institute of Technology all in electrical engineering. He joined the faculty at Georgia Tech in 1984 and later served as the Executive Assistant to the President of the Institute from 1997 until 2001. In January, 2003, he joined Purdue University as Head of the School of Electrical and Computer Engineering. Presently he serves as Dean of the Graduate School and holds the Michael J. & Katherine R. Birck endowed professorship. Dr. Smith is a Fellow of the IEEE and a former IEEE Distinguished Lecturer in Signal Processing. He has authored many papers in the areas of speech and image processing, and is the co-author of two introductory books: "Introduction to Digital Signal Processing" and "Digital Filtering." He is also co-editor of the book titled "Wavelets and Subband Transforms: Design and Applications," and the co-author of the textbook titled "A Study Guide for Digital Image Processing." Dr. Smith is a past Chairman of the IEEE Digital Signal Processing Technical Committee in the IEEE Signal Processing Society (SPS), a former member of the SPS Board of Governors, a former member of the MIPS Advisory Board of the National Science Foundation, and a past president of the Electrical and Computer Engineering Department Heads Association (ECEDHA). Currently he is a member of the IEEE Committee on Engineering Accreditation Activities (CEAA), a member of the International Engineering Consortium (IEC) Board, and member of the National Academies Board of Army Science and Technology.

Dr. Langis Roy is a Professor of Electrical Engineering and Associate Dean of the Faculty of Graduate and Postdoctoral Affairs at Carleton University (Ottawa, Canada). His research interests are in microwave electronics, integrated active antennas and electromagnetics. Dr. Roy has been a faculty member since 1993. He was Chair of Carleton's Department of Electronics from 2003 to 2009 and Chair of the Canadian Heads of Electrical and Computer Engineering (CHECE) in 2010, also serving on ECEDHA's Board of Directors. In 2005/06, he was a Visiting Professor at the VTT Micromodules Research Center (Oulu, Finland) and an Invited Professor at the INSA Electrical and Computer Engineering Department (Toulouse, France). In 2009/10 he was an Invited Researcher at the Institute of Electronics and Telecommunications Research - IETR (University of Rennes, France).

Barry J. Sullivan is Director of Program Development for the International Engineering Consortium. Prior to joining the IEC, he spent nine years at Ameritech, where he served as Director of Emerging Technologies. He has developed and delivered continuing education courses in communications technologies, and he guided the technology strategy for a start-up company delivering packet voice services. He was a full-time member of the faculty of the Department of Electrical Engineering and Computer Science at Northwestern University for more than six years, and has taught there as an adjunct faculty member. He also worked as a member of technical staff at Bell Laboratories. He received the B.S.E.E. and M.S. degrees from Marquette University, and the Ph.D. degree from Princeton University, all in electrical engineering. Dr. Sullivan has served as an associate editor of the IEEE Transactions on Signal Processing, publications chair of the International Conference on Acoustics, Speech, and Signal Processing, and local arrangements chair for the Digital Signal Processing Workshop. He is also editor of THE BRIDGE, the magazine of Eta Kappa Nu. He has published over forty papers on topics in signal reconstruction and image processing.

S. S. (Mani) Venkata is an Affiliate Professor of Electrical Engineering at the University of Washington (UW), Seattle, Washington since Janaury 2008. He is also President, Venkata Consulting Solutions Inc. and associated with KEMA Inc. as a subconsultant. Before joining the UW, he was Dean and Distinguished Professor of Wallace H. Coulter School of Engineering at Clarkson University, Potsdam, New York. During 2003 he was Palmer Chair Professor of Electrical and Computer Engineering Department at Iowa State University, Ames, Iowa. From 1996 to 2002 he was Professor and Chairman of the department at ISU. Before joining ISU, he taught at the University of Washington, Seattle, West Virginia University, and the University of Massachusetts, Lowell for 25 years. He received his B.S.E.E and M.S.E.E. degrees from India, and his Ph.D. degree from the University of South Carolina, Columbia in 1971.

Prof. Venkata has conducted research, design and development work for the more than 25 utilities and power related industries for the past 43 years. Venkata has published and/or presented over 300 publications in refereed journals and conference proceedings, and a co-author of the book Introduction to Electric Energy Systems Prentice-Hall Publications, 1987. He is a registered professional engineer in the states of Washington and West Virginia.

Dr. Venkata is a Fellow of the IEEE. He was a member of the PES Executive Committee and Governing Board for four years, as the Vice-President of Publications, member of the Finance Committee, the Long Range Planning Committee, and Technical Activities Advisory Board during 2004-2007. His past activities include serving as the Chair of the Power Engineering Education Committee, as the Regional 6 Representative and Seattle Student Chapter Chair. At the Technical Committee levels, he chaired several subcommittees, working groups and task forces. He was also the Vice-Chair of the 1992 Summer Power meeting. At the IEEE level, he represented the PES as the TAB Periodicals Committee member. He had also served as the Seattle Section Chair, and the Student Branch Advisor.

In 1996 he received the Outstanding Power Engineering Educator Award from the IEEE Power Engineering Society. He also received the Third Millennium Award from the IEEE in 2000.

Anthony Kuh received the B.S. degree in Electrical Engineering and Computer Science from the University of California , Berkeley in 1979, M.S. degree in Electrical Engineering from Stanford University in 1980, and the Ph.D. degree in Electrical Engineering from Princeton University in 1987. He worked at AT&T Bell Laboratories from 1979 to 1982 and has been with the University of Hawaii since 1986. He is currently a Professor of Electrical Engineering Department at the University of Hawaii . From 1999 to 2002 he served as Chair of the Electrical Engineering Department . He also helped to form the Hawaii Center for Advanced Communications (HCAC) and served as interim director from 2000 to 2001. During the 2003-2004 academic year he was a visiting faculty member at Imperial College, London where he received a distinguished Fulbright scholar's award Dr. Kuh's research interests are in the areas of machine learning and neural networks, adaptive signal processing, sensor networks, and communication networks. Dr. Kuh was a recipient of the NSF Presidential Young Investigator Award in 1988. He was elected Fellow of the Institute of Electrical and Electronics Engineers (IEEE) in 1998 for his contributions to analysis of neural network models and their applications to signal processing. He has been an associate editor for IEEE Transactions on Circuits and Systems, from 1990 - 1991, 1995 -1997, 2002-2004, and 2005-2007. From 1990-1995 he served on the IEEE Neural Network Council Administrative Committee representing the Information Theory Society. He served as a member of the Neural Networks for Signal Processing Committee in the IEEE Signal Processing Society from 1998 - 2001. He also co-chaired the 1993 International Symposium on Nonlinear Theory and Its Applications held in Honolulu . He has served as local arrangements chair for the 1997 NOLTA Symposium, 1999 NOLTA Symposium, 2000 ISPACS Symposium, and the 2002 World Congress on Computational Intelligence all held in Hawaii . He is also serving as the technical co-chair for the 2007 ICASSP to be held in Honolulu . His research interests are in machine learning (learning theory, kernel machines, reinforcement learning), adaptive signal processing, and sensor networks.

Electric Energy and Power Educational Programs Development Workshop

ABSTRACT

There has been much discussion recently regarding the issues involved in education and research programs in the area of electric power and energy. This discussion has included the topics of reforming electric energy systems curricula both at undergraduate and graduate levels. The Electrical and Computer Engineering Department Heads Association (ECEDHA) and other interested government and industry groups are developing workshops and special sessions at key conference venues to focus on topics that include: sustainable and renewable energy sources, smart grids, energy storage, efficiency, plug-in hybrid electric vehicles, and climate change. ECEDHA with the support of the National Science Foundation is establishing a workshop series on these issues aimed at department chairs and faculty members who are interested in developing educational and research programs in this critical area within Electrical and Computer Engineering (ECE). Without question a safe, dependable, secure, reliable and affordable supply of electric power is a fundamental requirement for national economic health. The corporations involved in the development and operation of the smart grid face increasing challenges in meeting the growing demand for electricity in the context of sustainable energy. The grid must be developed to accommodate new energy sources, including solar, wind, wave and other renewable sources, and support new demand patterns arising from the presence of plug-in electric vehicles and energy storage systems. Industry must have access to the trained engineers who will integrate information and communications technologies into the new generations of the grid to deliver electricity more efficiently, reliably, and securely. As a result, future electric power engineers will require knowledge of topics that may be outside those offered in traditional “power” programs, including communications and network security, sensor integration, public policy, and software development. The ECE department heads have recognized the need to update and upgrade programs in power engineering and closely related fields. The workshop described in this paper brought together a diverse set of academic, government/NGO and industry participants to address a range of issues including curriculum changes, faculty development and student recruitment. Participants also discussed the role of power electronic technologies, planning, automation and control to achieve smart grid performance goals.

INTRODUCTION

The first ECEDHA Energy and Power Educational Programs Development Workshop funded by the National Science Foundation with additional support from the Government of Canada and organized by the Electrical and Computer Engineering Department Heads Association was held in Arlington, VA, October 31- November 2, 2010. A pre-workshop meeting of academic specialists on the future of energy and power education took place before the workshop on October 30 as a brainstorming session in advance of the workshop discussions. The impetus for this workshop originated during discussion sessions held at recent ECEDHA annual meetings. These discussions recognized the importance of electric power education and research in university curricula and reflected the concern in industry regarding the future workforce in this critical field.

Many universities are introducing innovative programs to attract more students to pursue undergraduate/graduate studies in power and energy systems and related areas including power electronics, signal processing and computer network security issues for emerging smart grid applications. One such program is offered by the research group led by Professor Ned Mohan of the University of Minnesota.[1] Many faculty members and department heads attend annual workshops organized by this group at the University of Minnesota. In 2010, the ECEDHA Board of Directors decided to seek funding to organize workshops for educators and industry participants to exchange ideas and discuss important issues on workforce and curriculum development in electric energy and power systems.

Background Information

The electric power grid is a fundamental system within a nation's critical infrastructure. A safe, reliable, secure and affordable supply of electric power is a basic requirement for economic health. Canada and the United States have a common interest in this area through a shared power grid with interconnections spanning the US-Canadian border.

The power and energy utilities that operate this grid face increasing challenges in providing a reliable supply of electricity to meet growing demand. The existing grid infrastructure is aging with many components approaching the end of their life cycle after decades of service. In addition, the power grid must grow and evolve to accommodate renewable/sustainable and variable energy sources on the generation side, and to support dramatically different demand profiles from new uses such as plug-in electric vehicles on the load side.

At the same time, the impending retirement of many industry veterans creates an urgent need to prepare the next generation of professionals to maintain the vitality of the industry. The Center for Energy Workforce Development estimates that roughly 45% of engineering positions at electric utilities could become vacant by 2013.[2] The North American Electric Reliability Corporation (NERC) has identified the aging workforce and the potential loss of expertise due to retirement as a challenge to future reliability of the electricity supply.[3]

The power industry will need more than just replacements for retiring engineers to meet its challenges. "Smart grid" technologies offer the potential for utilities to deliver electricity more efficiently and effectively by integrating information and communication technologies into the next-generation grid. This requires knowledge of topics outside the traditional power engineering curriculum including communications, sensor integration, policy, software development and security.[4]

Universities have similar workforce issues in the area of electric power engineering. After highlighting the challenge of an aging workforce in its 2006 report, the NERC noted a parallel "decline in the number of college professors able to teach power systems engineering and related subjects" in its 2007 report.[5] A report by the U.S. Power and Engineering Workforce Collaborative indicates that the situation will grow worse if left unchecked, as about thirty percent of the full-time power engineering faculty members are likely to retire in the next five years.[6] The U.S. Department of Energy recognized the importance of replacing retiring faculty in this area in a report to the U.S. Congress:

> "Today, the power engineering education system in the United States is at a critical decision point. Without strong support for strategic research in power systems

engineering and without qualified replacements for retiring faculty, the strength of our Nation's university-based power engineering programs will wane, and along with them, the foundation for innovation in the power sector to meet our energy challenges in the 21st century."[7]

Workshop Goal

Individuals and organizations have launched several initiatives to improve the state of power engineering education. The scale of the demand for workforce replenishment and rejuvenation requires a broad response from the academic community, however, and as noted by the U.S. Power and Engineering Workforce Collaborative, the industry must "communicate with college deans and department chairs about strategic corporate and industry challenges, innovations needed by industry, importance of educating students to become power and energy engineers, and the need to hire new faculty."[8]

The ECEDHA Board of Directors recognized the need to update and upgrade programs in power and energy in light of new technologies and requirements for the electric power grid including issues associated with policy and regulations. The workshop described in this paper is the first in a series conceived to develop, implement and evaluate responses to this need. These workshops bring together diverse sets of academic and industry participants from Canada and the United States to address a range of issues including curriculum changes, faculty development and student recruitment.

The goal of the workshop is to identify actions that will create a strong academic foundation for educating the next generation of power engineering professionals and supporting the industry through fundamental research in relevant disciplines. These actions will enable a broad response from ECEDHA member institutions in Canada and the United States through strengthening of existing power engineering programs and establishing new ones. In addition, the workshop identified areas where greater North American regulatory cooperation is needed to ensure orderly deployment of the smart grid (i.e. market rules, safety standards, etc.) and its underlying educational programs (i.e. accreditation).

Workshop Organizer

ECEDHA is composed of heads or chairs of departments at universities in the United States and Canada offering accredited programs in electrical and/or computer engineering or other related fields. ECEDHA's purpose is threefold: advance the field of engineering education; catalyze the exchange of ideas and best practices; and improve communication with engineering professionals, industry, government, and others. With a strong need by the industry for the next generation of power engineering professionals, ECEDHA provides the necessary link to the leaders formulating the university curricula and working to achieve support to further research in this area.

Attendees at the workshop were a combination of individuals from industry and government invited by the workshop organizers, as well as delegates nominated by ECEDHA member institutions. Workshop attendees were invited based on their qualifications to contribute to a lively discussion and analysis of the current state of power engineering programs, the educational requirements for the next generation of power engineers, and steps to bridge the gap between the two.

Workshop Agenda

The workshop program was organized to enable participants to assess gaps and deficiencies in the current state of power engineering and actions to correct them. The first day of the workshop was comprised of invited panels and individual speakers, featuring experts from industry and academia. Presentations ranged from the "traditional" power engineering topics to the emerging needs to educate students in policy issues, demand response, software modeling, security, and the development of the grid into a cyber-physical system. During the morning of the second day the workshop participants broke into discussion groups to address pre-assigned topics. Following the working meetings of the breakout groups, all workshop participants reconvened in a single meeting and breakout group leaders reported their preliminary conclusions. Finally, the breakout groups were charged to discuss and prepare reports on the most important lessons learned. These reports were presented at the ECEDHA Annual Conference in March 2011, and the final report for this workshop was distributed to the ECEDHA membership, as well as posted on the ECEDHA web site.

Sessions within the workshop included keynote presentations, panel discussions, and workshop discussions by representatives of government and industry presenting the present and future energy systems landscape, the needs for faculty development, the expectations of students, the needs of facilities development and the needs of industry.

Day One Program

- Keynote speakers from National Science Foundation, University of Washington, GE Energy, U.S. Department of Energy, and Pepco Holdings
- Industry panel on "Next-Generation Grid Technologies" with panelists from Hydro One (Ontario), Hawaiian Electric, GE Energy, and HP Enterprise Services
- Academic panel on "State of Energy & Power Education" with panelists from Arizona State University, University of Western Ontario, Washington State University, Georgia Institute of Technology, and Carnegie Mellon University
- IEEE-PES Power and Energy Engineering Workforce Panel

Day Two Program

- Summary of pre-workshop meeting of fifteen academic specialists on the future of power and energy education
- Workshop sessions on curriculum development, facilities planning, industry research areas, faculty development, workforce development, student expectations & recruiting, K-12 outreach
- Keynote speaker from University of Minnesota
- Workshop readouts and final report preparation

Workshop Reports

<u>Curriculum Development</u>

The ECE curriculum should be the impetus for future developments in electric energy systems. The nature of the problems facing energy systems now and in the future will require a methodology incorporating many different application-specific approaches. Challenging controls problems in complex interconnections will demand a "system of systems" approach; the modern ECE curriculum is uniquely positioned to provide this emphasis.

Solutions provided should not be "course" based but should instead integrate topics and techniques throughout the ECE curriculum. Universities should adopt strategies that are appropriate to their individual missions and student populations.

The following key points were developed in the discussion by all meeting attendees.

- The ECE curriculum should be positioned as the leading engineering curriculum for future developments in electric energy.
- Different universities will specialize or emphasize energy systems to greater or lesser extent as appropriate to their mission and objectives.
- A key component of curriculum development will be to ensure that students understand that sustainable electric energy systems are an essential component of ECE. This should be visible to students early in their education. Students should see the societal benefits and impact of these topics.
- Propagation of the concept of "course in a box" and similar inexpensive techniques to cover the field are not suitable to address the energy area in a comprehensive education and research-oriented program.
- An introductory course in "**Fundamentals of Electrical Energy Systems Engineering"** is envisioned to
  - Equip graduating engineers for day-to-day life relating to energy
  - Stress basic energy fundamentals, generation, utilization, environment
  - Be tailored to local needs and placed in the program according to local requirements
- There should be mechanisms such as project courses for students to develop a **system of systems** approach – for example, projects involving power, power electronics, communication and computation.
- Incorporation of a **system of systems** approach should be encouraged in capstone design courses.
- A second course in **"Energy System Design"** is envisioned to
  - Provide the ability to understand and design energy systems in a complex, multi-topical context
  - Stress the integration of energy, controls, power electronics, communications and hardware

- Include a capstone design project or an actual course
- Contain a strong emphasis on multiple systems orientation
- Be tailored to local requirements

Facilities Planning

Improved laboratory facilities to support education and research are essential to meeting the need for updated power engineering programs. The capital investment required for these facilities can reach $150K for a full-blown research lab in power computing, and much more for high voltage or power semiconductors. Research labs for smart grid, systems and economics, sustainable energy systems, and high-power electronics may be somewhat less expensive to equip.

Instructional labs will also require significant investment. A typical figure for undergraduate core course laboratory facilities is $1000 – $3000/student. A more hardware-centric education will require greater capital investment. High-voltage engineering is particularly expensive. Many areas related to energy systems do not require “traditional” high-voltage equipment, although lab facilities for these areas do require NSF and industry support.

Approaching industry for help in developing facilities in partnership with NSF can help the funding challenge for new or improved lab facilities. In addition, there is a developing availability of integrated and scaled systems to allow for teaching of energy systems concepts to mitigate cost and space requirements. Other means of cost mitigation include

- Using local utilities as a resource for students to see/experience hardware systems;
- Developing non-proprietary software for real-time simulation;
- Developing regional facilities among a number of universities with virtual laboratory capabilities for remote access;
- Developing shared “common space” for all departments interested in energy systems engineering.

Industry Needs: Research

Due to technological innovations, deregulation and other related issues, the electrical energy industry is undergoing rapid transformations. Consequently, future energy systems will be radically different from their legacy counterparts. Universities must recognize this fact and transform their educational programs accordingly. Success in these programs, for the most part, is measured by the quality of research undertaken by them. It is also clear that research in energy systems is not focused for the “traditional customer” (utilities) alone. The following recommendations were made at the conclusion of the subject workshop as next steps:

- Recognize importance of properly showing value of research developments.
- Conduct NSF/EPRI Workshops to focus attention on topics of importance.
- Pursue NSF support for developing research laboratories in energy systems. This is an area where North American universities have lost their edge in some of these areas (e.g., high voltage). Use of the campus as a “test bed”.

- Stimulate initiatives with ambitious goals to encourage research funding for universities.

Research in electric energy can be broadly classified into three major areas: basic research (theory), applied research (applications) and hardware and software (computation). The following topics were identified as potential areas of research needs, opportunities and challenges as it pertains to successful development of energy systems of the 21st century. However, this list is by no means comprehensive or complete.

- Topical Areas:
  - Focus for "islands" and micro grid vs. continental issues
  - Integration of sustainable resources
  - Electrification of transportation
  - Portable power
  - Wireless delivery of power
  - Energy efficiency
  - Automation of large integrated systems
  - Security and reliability
  - Move from preventive to corrective control (including policy component)
  - Energy systems monitoring for system state and predictive capabilities
  - How to take research to scale?

In summary, educational programs (both graduate and undergraduate) development in North American universities should consider these recommendations before embarking upon curricular and other pertinent changes.

<u>Faculty Development</u>

The issue of strong faculty development in the area of power and energy is both challenging and complex, while being critical to the deployment of updated programs. The challenges have been mentioned before: the aging professorate and the changing nature of the field have resulted in a present shortage of qualified faculty and an inadequate pipeline for renewal. This is compounded by the fact that many universities over the previous two decades scaled back their energy systems facilities and now are ill-equipped to attract new faculty into a suitable research/teaching environment. The situation is further complicated by the multi-disciplinary requirements of future energy systems programs and corresponding skill requirements of new faculty. Nonetheless, tremendous opportunities do exist in the current transformational context of power and energy. It was against this backdrop that the workshop breakout session produced the following recommendations:

- Priority should be placed on attracting young people to this field. Making a difference is important to young people and emphasizing the many opportunities for doing so can be used as an attractor. ECE heads need to understand the "new culture" of power engineering and promote it effectively.

- Additional ways to attract/recruit and train new faculty should include: (1) ensuring that the aging professorate encourages the next generation of energy professors; (2) ensuring that PhD students who are interested in faculty careers are developed with a focus in energy systems; and (3) cultivating multi-university projects and using them to identify potential new faculty.
- In conjunction with the above, additional resources should be made available. These should not only be in the form of ECE hiring budgets, but also as project seed grants and infrastructure, especially for multi-disciplinary efforts. Sharing of educational resources using cyber infrastructure would be helpful and should be encouraged.
- Collaborative/team efforts and mentoring should be recognized as key attributes of future faculty development in a broad field such as this. Without a truly rich and supportive working environment it will be impossible to achieve the levels of competency that the new power and energy programs demand. Furthermore, this approach needs to be communicated to new hires and a reward mechanism needs to be established.
- Special attention should be paid to the career path of new hires, as promotion and tenure issues may arise given the breadth (versus depth in some cases) of energy systems.
- General hiring recommendation: Dedicated searches should be pursued, as these generally produce better results than cluster hires.

Industry Needs: Workforce Development

As the impending retirement of many industry veterans threatens the vitality and reliability of the power/energy industry, the need to increase the numbers of skilled entrants into the workforce is of tremendous importance. It is well recognized that industry will need more than just replacements for retiring engineers to meet its challenges. Indeed, the integration of information and communication technologies within next-generation power infrastructure will require future professionals to have knowledge extending beyond the traditional power engineering boundaries (i.e. communications/sensor integration, distributed control, policy, software and security). The IEEE/PES Workforce Collaborative has already made substantial progress in addressing these challenges and reported its work in a previous workshop session. Building on its findings and gathering input from a broader cross section of attendees, this session produced the following recommendations:

- Relevant organizations (ECEDHA, IEEE/PES, etc.) should be working to create a single collaborative voice to advocate for power and energy engineering education and research. Building awareness, advertising available programs and highlighting industry opportunities would be possible elements of such a collaborative. Web-based resources would be extremely useful in this regard.
- Ways to strengthen/retain engineering talent in this area should include: (1) providing a biennial survey of power engineering programs; (2) offering scholarships in power and energy for undergraduates; and (3) aligning efforts with "women in non-traditional positions" initiatives.

- In conjunction with the efforts on curriculum development, emphasis needs to be placed on broadening the scope of power and energy to include more cyber-physical systems oriented efforts.
- A greater interaction between industry and universities should take place, with features including: industrial speakers spending time on campus; industrial presence on advisory boards; trips to industrial facilities; industrial based case studies and senior design projects; industrial participation in advanced electives; industry student internships; faculty sabbatical leave/summer work in industry; flexible certificate programs for continuing education; and increased collaborative research.

Student Expectations & Recruiting, K-12 Outreach

Energy Systems should be a very "attractive" topic to students given the impact, societal need, and aspects of sustainability that it represents. These societal need and sustainability aspects provide a direct connection with environmental and global climate concerns which can in turn be attractive to a more diverse student population. Energy Systems offers a unique topical area that will showcase ECE programs in a favorable light to prospective students seeking a career field that can "make a difference".

The following actions are recommended:

- Host engineering open houses and summer programs that emphasize aspects of energy systems
- Target middle school or earlier – High school may be "too late"
- Target parents – understand opportunities (education and jobs) in energy systems
- Target high school counselors and science and math teachers
- Host "competition" through IEEE/PES that is energy systems focused
- Develop and expand energy-related student projects, such as projects supported by NREL to put windmills in schools. DOE, EPRI, State Energy Offices, local utilities and NSF are other agencies that can be considered in developing such programs.
- Ensure information about energy systems appears on ECE departmental websites to rebadge ECE to make it more attractive to prospective students.

IEEE-PES Power and Energy Engineering Workforce Panel

This panel presented the possible role of ECE departments in addressing future power engineering workforce issues. The presentations began with a discussion of the opportunities for collaboration between traditional electric power engineers and other ECE disciplines. The emerging smart grid concept includes virtually all other areas of ECE – communications, computing, control, signal processing, nanotechnologies, physical electronics, circuits, electromagnetics, and material science.

With the focus on renewable sources, electrification of transportation, intelligent metering, customer demand response, wireless interfaces, applications that require collaboration between multiple ECE disciplines abound. These energy-based technologies are being driven by a growing population and energy density requirements, the cost of energy in terms of pollutants and scarcity of resources, dependence on imported oil, environmental constraints on CO_2 emissions and air quality concerns.

In addition, the need to have a secure electric energy infrastructure and a vibrant investment market have escalated the need for advances in these new technologies on a global scale. The country of Korea has initiated a major initiative to create products that enable the smart grid in homes, business, on the road, and in the electric generation/transmission and distribution arenas. They have recently signed a memorandum of understanding with the State of Illinois to stimulate collaboration between Korea and the U.S. to leverage resources to create new market opportunities.

Features of this smart grid and its opportunity to create jobs include access to information, decentralized vs. centralized control, interoperability, cyber security, communications, privacy, investment cost, risk, grid stability, reliability, protection and operating with two-way power flow. The components of a smart grid include automatic controls, information technology, standards, power electronics, computer engineering, marketing, economics, systems theory, energy conversion, public policy, signal processing, transmission and distribution engineering and engineering physics. This means that ECE curricula need to examine if the following areas are adequately addressed: direct digital control, power system dynamics and stability, power quality and signal analysis, middleware migration, environmental and policy issues, reliability and risk assessment, economic analysis, energy markets, and new concepts of power system protection. Electric power and energy is a tremendous opportunity for ECE growth. This energy nucleus is surrounded by information and communication technology, materials, life sciences, production, transportation, and nanotechnologies.

A recent US workforce survey (2007 – 2009) of 55 electric and gas utilities, electric cooperatives totaling about half of all US electric and gas employees indicates that half of all engineers will need to be replaced by 2014. This is based on a current average age of about 50. In addition, the need for faculty to train new graduate students and teach courses in this area is critical to achieve the needed increase in new engineering talent. For example, university research is critical to the production of new PhD graduates who will become the new faculty at our universities. Therefore, increasing funding for university research is key to replacing the aging faculty.

In response to this projected need, the IEEE Power and Energy Society (PES) has created the Power and Energy Engineering Workforce Collaborative (http://www.ieee-pes.org/workforce).

This collaborative has the following five-year goals:

- Double the number of power engineering BS graduates
- Provide $4M in new undergraduate engineering scholarships per year
- Create 2,000 internships in the US per year

- Hire 80 new power faculty members in the US
- Raise university research funding to $50M per year
- Create five university centers of excellence to conduct power research and education

A major scholarship program is being developed by the IEEE/PES to make progress toward these goals. In addition, activities to promote student participation at IEEE meetings and K-12 interest are being enhanced. Some resources that can assist departments in this process include the following:

- PES-Careers for U.S. and Canada (www.pes-careers.org)
- NSF workshop report (http://www.ieee-pes.org/workforce/workforce-collaborative)
- Collaborative Action Plan: (http://www.ieee-pes.org/workforce/workforce-collaborative)
- The Center for Energy Workforce Development (www.cewd.org)
- Power Systems Engineering Research Center (PSERC) (www.pserc.org)
- Coming new gateway for students on PES website

The technologies needed for this growing area include all IEEE societies and all ECE disciplines. ECE department heads have a rare opportunity to capture the interest and enthusiasm of the young students and faculty in the energy area. The interest of students and funding agencies in smart grid technology including the electrification of transportation and sustainable energy sources is growing daily and represents the largest shift in technology focus in recent years.

Given the current market trends, ECE is uniquely positioned to lead energy educational efforts. This represents a significant growth opportunity. Successfully assuming a leadership position will require a strong foundation in power likely realized through investment in applicable curriculum, faculty, research, industry collaboration and student outreach.

Conclusions

There exist pockets of excellence in the disciplines required for designing, developing and operating the next-generation power grid in selected North American universities. The scale and scope of this essential infrastructure demands many more strong power engineering programs, however. The dissemination of the results of this workshop among ECE department heads and faculty will alert them to the opportunity and set them on a path to close the gap between current capabilities and future needs. The workshop centered on the urgency for ECE educators to update and upgrade university-level power engineering programs to advance fundamental knowledge and prepare the next generation of engineering professionals in this critical field.

The workshop reflected the international scope of the issues to be addressed, and by the serious attention that will need to be devoted to recruiting, retaining, and mentoring undergraduate students, graduate students and young faculty, while drawing as much as possible from underrepresented groups in engineering.

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