National Science Foundation Workshop on the Future Power Engineering Workforce

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Executive Summary

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North American Electric Reliability Corporation (NERC)
IEEE Power Engineering Society (PES)
Power Systems Engineering Research Center (PSERC)

Steering Committee
Mark Lauby, North American Electric Reliability Corp.
Chen-Ching Liu, Iowa State University
Dagmar Niebur, National Science Foundation
Dennis Ray, Power Systems Engineering Research Center
Wanda Reder, IEEE Power Engineering Society
Gregory Reed, KEMA and University of Pittsburgh
Frank Wayno, Cornell University

EXECUTIVE SUMMARY

Highlights

A serious need is emerging for more power and energy engineers to:

- replace retiring engineers so that critical expertise is maintained
- meet rising infrastructure construction needs
- modernize the grid as communications, computing and electric energy technologies converge
- help stem the tide of electric equipment manufacturing moving off-shore, and
- solve arising engineering challenges, such as in the development of advanced power electronics and energy conversion systems, new generation and storage technologies, and the integration of those technologies into the grid.

Analyses suggest that there are not enough students in the pipeline who are excited about and prepared for a post-high school education in power engineering. Through partnerships among industry, government and universities, new undergraduate and graduate power engineering education programs are being developed; however, at the same time, the university education and research infrastructure is being weakened by university decisions to not replace retiring power engineering faculty. Innovative university research is needed to address new engineering challenges while educating students. The university research support for doing so is increasingly difficult to find.

Attendees at the NSF Workshop and Executive Summit on the Future Power Engineering Workforce met to discuss engineering workforce issues and offered these recommendations:

1. Create a single, collaborative voice on solutions to engineering workforce challenges
2. Strengthen the case for extraordinary efforts to build, enhance and sustain university power engineering programs
3. Envision the future challenges in electric energy supply and demand, and develop an image that will increase interest in power engineering careers
4. Stimulate interest in power engineering careers and prepare students for a post-high school engineering education
5. Make the higher education experience relevant, stimulating and effective in creating high quality and professional power engineers
6. Encourage and support increased university research to find innovative solutions and to enhance student education.

In response to these recommendations, the IEEE Power Engineering Society will begin an initiative entitled the *Power and Energy Engineering Workforce Collaborative*, and will seek initiative partners from industry, government and universities. One of the next steps will be to form a collaborative executive council of key decision-makers in industry, government and universities to plan a comprehensive approach that gets wide support while taking actions that are necessary, timely, and supportable with available resources. Working groups in outreach and image, education, and research will be created to support the decision-making of the executive council, and to take actions as well. This is a transitional structure with a focus on engineers for power and electric energy careers.

Working groups will scope tasks, identify where further action is needed, do what they can themselves, plan needed changes, and negotiate with others to implement actions. Existing efforts and organizations will be used to the maximum extent possible; however, planning will include the possibility of new institutions or organizations that will sustain the initiative. Other industries will be involved, not just electric power.

Overview

A wave of retirements of experienced power engineers is imminent. A coordinated effort by industry, government and universities is needed now to prepare for this exodus. Without this effort, there will be a lag in replacing the lost expertise need to maintain economic, reliable and environmentally acceptable electric service while innovatively solving the significant technical challenges facing all industries.

Based on a survey of U.S. electric utilities, the Center for Energy Workforce Development estimates that approximately 46% of all engineering jobs could become vacant by 2012, due to retirements by the aging workforce and other forms of attrition. Although this percentage may vary across industries, it suggests that the size of the wave is so large that it must be proactively addressed through collaborative initiatives. The North American Electric Reliability Corp. (NERC), in its report entitled *2007 Long-Term Reliability Assessment*, concluded that:

> *"The loss of industry workers and their years of accumulated expertise due to retirements is a serious threat to the bulk power system reliability, exacerbated by the lack of new recruits entering the field."*

The question that all concerned parties are addressing is "are we prepared?" Unfortunately, the answer appears to be negative. In its long-term assessment, NERC states the following:

> *"Exacerbating the problem of a declining workforce is a simultaneous decline in the number of potential recruits from colleges and universities, as well as vocational schools. During the past two decades, the reduced demand for industry workers has led to a decrease in vocational training and university-sponsored electric power programs. Further to this point is the decline in the number of college professors able to teach power system engineering and related subjects."*

Aging Workforce and Engineering Faculty: Key Concerns

Not enough students in the pipeline
Retiring power engineering faculty not being replaced

Furthermore, in a 2006 report to Congress entitled *Workforce Trends in the Electric Utility Industry*, the U.S. Department of Energy declared that:

> *"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."*

A strong and concerted effort is needed by industry, government and universities to sustain university power engineering programs, attract students to the field, and increase university research support. This effort is necessary to educate for the next generation of power engineers. This is both a national crisis and a challenge that must be met to ensure that the electric energy system is able to support economic development, maintain energy security, and address major issues such as climate change.

To explore how to prepare universities for the coming large increase in demand for new power engineers, the National Science Foundation convened the *Workshop on the Future Power Engineering Workforce* on November 29-30, 2007, with approximately 75 people attending from industry, government and universities. An Executive Summit comprised of key leaders in industry, government and academia was also part of the workshop. In the discussions, workshop and summit participants identified key issues and actions on how to meet the coming increased demand for new power engineers along with possible actions to address those questions.

Key questions for preparing to meet the increasing demand for new power engineers

- How to make a strong case for action?
- How to identify ownership of the problem?
- How to build the pipeline of students into the field?
- How to communicate an exciting image of power engineers?
- How to improve teaching to motivate and prepare students?
- How to support university research for innovation and faculty hiring?

RECOMMENDATIONS

Create a single, collaborative voice on solutions to engineering workforce challenges

There was a broad consensus among industry, government and university workshop attendees that collaborative actions should be taken to prepare for the coming workforce challenges. Priority should be given to establishing a single voice that can speak to key concerns and solutions. The necessary steps are:

(1) create a national initiative to drive collaboration among industry, government and universities, and to facilitate communication of research and education priorities in electric energy systems;

(2) identify means for effective collaboration among industry, government and universities; and

(3) advocate for action when a strong voice is needed.

Strengthen the case for extraordinary efforts to build, enhance and sustain university power engineering programs

Studies indicate a looming shortage of power engineering graduates from U.S. universities to meet the need for new power engineers. An initiative is needed to build the student pipeline, and to sustain an essential number and mix of university power programs. A strong case for extraordinary efforts needs to be communicated because collective action will be motivated by a better understanding of the emerging educational challenges and what it will take to meet those challenges.

To build a stronger case, more data are needed on the future demand for power engineers; on the knowledge and skills needed by future power engineers; on trends in the number of students choosing power engineering careers; on the state of the educational infrastructure; and on metrics for describing and monitoring the state of the job market and the educational system in general. Besides making the case stronger, these studies can provide information needed to make any extraordinary efforts more efficient and effective.

Envision the future challenges in electric energy supply and demand, and develop an image that will increase interest in power engineering careers

The next generation of power engineers will face extraordinary new technical challenges. Conversations with current power engineering students suggest that they are excited about working on solutions to emerging local, regional and global challenges; however, not enough students realize that engineering offers opportunities to make a difference is solving those challenges. An image of the future power engineer should show that the future power engineer will be doing work that is exciting and important. This image needs to be communicated to prospective power engineering students in grades K-12, and in colleges. Today's engineering students are more environmentally aware, socially conscious, and globally connected. Creating a realistic image of power engineering that is appealing to this upcoming generation of engineers will be critical in the development of solutions to attract them to relevant education and research programs.

Stimulate interest in power engineering careers and prepare students for a post-high school engineering education

Concern is wide-spread regarding the decline in student interest in science, technology, engineering and math career fields. Coupled with this concern is the inadequate diversity that exists among current engineering students. Although there is a multitude of on-going industry and government initiatives to address these concerns, more participation and collaboration is needed from industry and academia to increase the effectiveness of those initiatives in obtaining larger numbers of students interested in power engineering as a career. In addition, more support is needed for teachers and school counselors who are known to be influential in stimulating interest in power engineering careers and preparing students for future education opportunities. The priorities are to increase and sustain the pipeline of power engineering students by:

(1) promoting the social importance of solving electric energy challenges and of delivering electricity economically, reliably, securely and sustainably;

(2) making education more interesting, such as by developing hands-on group projects across course levels to stimulate teamwork environments and synergy, and

(3) leveraging government programs through collaboration, such as the National Science Foundation programs titled, "Research Experience for Teachers," and "Grant Opportunities for Academic Liaison with Industry."

Make the higher education experience relevant, stimulating and effective in creating high quality and professional power engineers

To excite students about power engineering careers and to better prepare them for those careers, universities need to continually evaluate and innovate in their power engineering courses with challenges facing future power engineers in mind. For example, in recent years, student interest in new courses on renewable energy systems and sustainable engineering concepts has been high. Universities and industry also need to work together to support a range of student needs and work situations, such as through mentorship, on-line courses, matriculation agreements across campuses, industry-sponsored design projects, and various industry work experiences. These actions will be enabled in part by systematic communication with industry and students, such as through surveys, focus groups, graduation interviews, and advisory boards. Priority should be given to educating students for power engineering careers by:

(1) building strong and ongoing industry relationships with universities to enhance educational programs and to support faculty in their education activities; and

(2) increasing industry and government collaboration with universities to identify education topics and implement new delivery methods that make electric power and engineering education more exciting and relevant for a new generation of students, while making it efficient and effective to control costs and improve quality.

Encourage and support increased university research to find innovative solutions and to enhance student education

Increased support of university research can lead to innovations needed to address engineering challenges in electric energy systems. The direction of university research would benefit tremendously from higher levels of collaboration among industry, government and academia to create a strategic research and development roadmap for transforming energy systems for the 21st century. Increased support of both government and industry-based research will also help graduate students to become the researchers and educators of the future, and enrich the education of undergraduates through research experiences. Industry support is needed to help advocate for increased government support and to help fund research directly. In so doing, a balance will need to be sought between research that addresses industry's short-term objectives and research on long-term issues facing industry and society at-large. Finally, lessons from the various forms of research can be brought to the classroom to better prepare students for the challenges that they will face following graduation. Government, industry and universities should encourage and facilitate university research for innovation and education. Important actions are:

(1) supporting university researchers and students to better understand short- and long-term industry research needs (such as in power electronics and energy conversion, in planning and operating margins in real time, and in energy storage) so that they can make informed choices in their research directions;

(2) increasing industry, university and government research collaboration to support research and student education, to facilitate creation of innovative solutions to industry challenges, and to advance global competitiveness and leadership; and

(3) ensuring that sustained financial support is provided for university research and education efforts to maintain strong electric power and energy university programs.

NEXT STEPS

The NSF Workshop and Executive Summit demonstrated that there are collective concerns across industry, government and universities about power engineering workforce issues. The time the attendees spent together was sufficient to generate wide-ranging ideas about how to address the issues, but not long enough to reach a consensus on what comprehensive approach should be pursued. To make progress toward finding and implementing solutions to those concerns, the IEEE Power Engineering Society will begin an initiative entitled the *Power and Energy Engineering Workforce Collaborative.* PES will seek initiative partners from industry, government and universities. One of the next steps will be to form a collaborative executive council of key decision-makers in industry, government and universities to plan a comprehensive approach that gets wide support while initiating actions that are necessary, timely, and supportable with available resources. Working groups in outreach and image, education, and research support will be created to support the decision-making of the executive council. The next steps will be:

1. Form an executive council with three working groups providing support.
2. Formulate a comprehensive approach to addressing workforce and education challenges.
   - Define the problems and the information that exists or is needed to verify and efficiently solve
   - Devise and implement the comprehensive approach with appropriate cooperation of others.
3. Initiate actions at any time that advance solutions, and that are supportable with obtainable resources.

BACKGROUND AND DISCUSSION

1. Create a single, collaborative voice on solutions to engineering workforce concerns

The shortage of the power engineering workforce is a national security issue. A national body with representatives of the stakeholders in industry, government and academia needs to be formed to speak with one voice on concerns and solutions. Awareness and contacts at key leadership levels are needed. The national body should have a regional sub-layer. The workforce problems are multi-faceted and will not be solved by any one entity; thus, strong collaboration among all concerned entities is needed. The connection between the workforce and reliability should be identified. There needs to be collaboration across government agencies at the state and federal levels, closely involving universities in the process.

There are numerous opportunities for involvement by governmental organizations or groups trying to inform governmental policy. Leaders in the power engineering community can contribute by educating Congress. IEEE-USA is a resource for the effort. The American Society of Engineering Education provides good access to engineering deans in the U.S. There is also a significant role for the regulatory agencies. Involvement is needed by federal and state regulators. The National Governors' Association is an important forum to reach the states; their focus next year is on clean energy. Regional economies can be linked to federal partners. Added value to regional economies can be achieved by leveraging work at the Environmental Protection Agency. The National Association of Regulatory Utility Commissioners would also be a valuable resource.

Human resources are as important as electrical wires and power generators. People are a critical part of the infrastructure. There needs to be a national voice for innovative power engineering education and fundamental research. People know the importance of sustaining the educational infrastructure. Actions from the government could include tax incentives (such as credits for supporting research and education), increased funding of education and university research, and assessment of policy barriers to industry support of research and education.

Collaboration among the various entities will be challenging. A literature review is needed to better understand how to build collaboration and what collaborative models work. The steps for building a successful collaboration approach should be identified. Models for effective collaboration to sustain university power engineering programs should be assessed.

Collaboration among industry, government and universities should occur in a number of areas. Collaboration could be used in establishing centers for power education and research that meet different needs than the local universities. Collaboration could also help with leveraging resources for education and research. In this regard, examination of what the nuclear engineering industry accomplished in reviving their programs would inform the development of successful collaborative models for education and research.

2. Strengthen the case for extraordinary efforts to build, enhance and sustain university power engineering programs

There is a critical need for empirical data to make a strong case for the workforce issue and the ability of universities to contribute to the solution. Although data are available on the evolution of the university power programs, there is incomplete information about the number and scope of programs, and about the outlook for faculty hiring. There is also a lack of information on the future demand for undergraduate and graduate students. To acquire information about the future, there is a need to understand where the industry will be positioned in the next decade. It is important to forecast the future of the industry to identify what the future engineers need to know and how university programs can properly educate this

next generation of professionals. In response to a shortage of power engineers, salary offers should be trending upward, so more public information is needed about salary offers for graduating students.

3. Envision the future challenges in electric energy supply and demand, and develop an image that will increase interest in power engineering careers

Energy resource adequacy, environmental impact, regulatory effects, markets and pricing, and security are critically important to the global community. Power engineering is a core area of the broad energy problem that involves environmental issues. Economic growth leads to increased demand for energy. Regulatory coordination and markets are critical to establishing future industry strategies and direction. A reliable power infrastructure is highly important for the society. Blackouts have serious consequences. As noted above, NERC has declared that the power engineering workforce is a critical issue for the reliability of the power grid in the future. Climate change is a concern shared by countries around the world. Students are attracted to the "green energy" field; saving the planet is a great motivator for many students in today's universities. Ways should be found to capitalize on their motivation and global awareness, and provide research and educational opportunities for students to exercise their creativity.

4. Stimulate interest in power engineering careers and prepare students for a post-high school engineering education

Outreach is an important aspect of the workforce issue. Communicating the image of power engineers should start at the K-12 level. There needs to be an effective way to attract students into power engineering. Outreach efforts are important to reach the young population and understand clearly what motivates and excites them. These efforts will help to create an image that engineering is "flashy, dynamic, and cool." Nuclear engineering survived the image problems; the image of a nuclear engineer and the nature of their outreach programs should be studied.

There is a perception that children of blue collar workers tend to be more interested in engineering careers; however, tuition costs are often a barrier for them. The lack of diversity in engineering means that there are untapped opportunities for increasing student interest in engineering. Availability of scholarships may be a great boost to student interest in engineering. Internships and cooperative programs for university students can also support a student's education, and have been highly successful at many universities.

Students and their parents today are concerned about outsourcing of engineering jobs to other countries, thereby increasing job security worries about engineering careers. Whether outsourcing is a realistic option for the industry needs to be assessed and communicated.

A better job needs to be done explaining the importance of engineering to the public. Young people need opportunities to talk with young engineers. The power engineering community needs to work with high school teachers and school counselors to help them understand what power engineers do and how they can make a true difference in the world and contribute to the overall good of society based on their work. Universities could help by hosting teachers under the National Science Foundation program "Research Experience for Teachers." Companies should hire students as interns and co-ops. To help inform and excite students, national competitions could be held. For example, the FIRST Robotics Competition has the goal "to create a world where science and technology are celebrated… where young people dream of becoming science and technology heroes."

Outreach efforts need to emphasize that it is critical to maintain a strong infrastructure for power engineering education and research; increasing the number of students in power engineering classes will be helpful in sustaining and growing these programs. As part of the outreach efforts, the general public, as well as policy-makers in Congress and the regulatory agencies, needs to be informed about the negative

impact on the reliability of electric energy supply and national security posed by a diminishing power engineering workforce.

Initiatives should take advantage of the outreach and education programs available through the U.S. Department of Labor, the National Academy of Engineering and the National Science Foundation. It would be useful to take an inventory of those programs, assess their effectiveness in increasing interest in power engineers and determine how targeted industry assistance could increase effectiveness. There may also be leveraging opportunities with the U.S. Department of Energy (including the National Labs), and state programs.

5. Make the higher education experience relevant, stimulating and effective in creating high quality and professional power engineers

Universities should continue reassessing their power curricula to enhance or develop courses that deliver knowledge and values to attract top-level students. Opportunities for undergraduate and graduate students to work on industry projects should be pursued. Bringing industry speakers to the classroom as guest lecturers or as adjunct faculty would show the practicality of the education that the students are receiving. Curriculum innovations should be recognized and rewarded in the universities and by professional societies. To increase coverage of contemporary topics, course modules could be created. Universities should collaborate to share courses and resources through various forms of distance learning and web-based methodologies. Since areas of faculty expertise vary across universities, cross-university matriculation agreements could be made. On-line instruction could be achieved through maintenance and development for power courseware websites. Special funding for new courses, such as a "green energy curricula," could be sought from industry or government. College students could be involved in focus groups to better understand their motivation, topics of interest, and attraction to engineering. Industry and student participation in mentoring programs could be encouraged. Finally, research studies on how to improve engineering education should be encouraged.

Besides education for a university engineering degree, there is also a need for continuing education opportunities. Special short courses can be created either in residence, on-site or on-line. These courses can meet important short-term needs, but they do not substitute for the comprehensive education found in a university degree program, nor do they support the research missions that are critical for sustaining university programs over the long term.

6. Encourage and support increased university research to find innovative solutions and to enhance student education

A critical element in sustaining a university power program is the availability of ample research funding opportunities. In a research university, faculty members must be productive in research to become tenured. Research and educational programs without fundamental research support may be eliminated. Adding faculty is difficult to justify if the opportunities for research in power engineering are limited. Today, universities are driven by rankings of the colleges or departments that often involve their level of research funding. One of the most important criteria for faculty promotion and tenure decisions at universities is research program success. A long-term agenda for research and education is needed. Engineering deans and department chairs need to be convinced that they should replace retiring power faculty.

University research funding has predominantly come from government, such as the National Science Foundation, the U.S. Department of Energy, and the Office of Naval Research. However, government funding has been declining in general. A better job needs to be done demonstrating the value of university

research to industry. Alternative models of research collaboration among industry and universities should be explored to achieve better cooperation across universities, industry, and government. Industry can also support university programs by visiting engineering deans and department chairs at the universities, as well as helping with educating Congress and government agencies about the value of research. Complementing fundamental research with practical applications is a possible model for increased overall research program funding within the universities. This will require effective outreach activities and collaboration among academia and industry.

Collaboration between industry and academia on a strategic roadmap for university education would be helpful in stimulating ideas for innovative research by faculty and graduate students. Areas for expanded research could include:

- research on new equipment for the power industry
- identification of challenges for independent system operators and regional transmission organization
- developing new green energy generation technologies
- integration of renewable energy generation sources
- demand-side resources, energy efficiency, and distributed generation
- storage, such as battery and flywheel technologies
- power electronics and energy conversion technologies
- nanotechnology applications to energy.

Universities could provide the research and transfer the results on to hardware and software vendors for commercialization. Issues on intellectual property management need to be addressed in a collaborative manner.

In summary, sustaining university programs requires recruitment and retention of students, and solid research support. The path to achieving sustainable programs is through collaboration among industry, government and universities, and through the establishment of a single, collaborative voice regarding how to meet the coming engineering workforce challenges and the need for innovative solutions to regional, national and global energy problems.