Today's Power Engineering Shortage – An Alarming Problem With a Powerful Upside

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***Abstract*—This paper examines an alarming problem: there is a potential shortage of electrical power engineering expertise that, if not addressed, could have catastrophic effects on the industry and society. This problem results from a decrease in engineering graduates specializing in power engineering, questionable preparedness of engineering graduates, and an aging experienced workforce. This paper presents data, considerations, examples, and opportunities concerning this problem.**

Topics covered in this paper include the state of the power industry's workforce, how to plan for and meet future labor requirements, and recommendations for acting now to understand and prepare for long-term workforce needs.

I. Today's Power Industry Workforce

Electric utilities depend on the knowledge and expertise of the power industry workforce to support the nation's electric power system. Two disciplines discussed in this paper include power engineers and electrical line workers.

Studies show that the number of engineering graduates and skilled workers entering the workforce may not meet the imminent number of retirements. The soon-to-retire Baby Boomer generation holds a wealth of knowledge and experience necessary to support today's electric power systems. This presents a challenge to find replacements and transfer knowledge accordingly. Furthermore, a perception exists among some students that careers in energy-related fields are obsolete and old-fashioned, making it difficult to build interest and attract for careers in this industry.

A. Power Engineering

Power engineering is one of the oldest branches in engineering. A power engineer's responsibilities span generation, transmission, and distribution of electricity and include the design and support of devices and apparatus for the conversion, delivery, and use of electrical energy. The fundamental principles of power engineering, for the most part, remain unchanged. However, new advances in control and communications technology are continually introduced to improve the overall capability of the power system. Consequently, expertise is needed to support both traditional and new technology.

The aging workforce, combined with the decline in engineering graduates, has become a source of concern for the industry. In 2004, there were 10,280 electrical engineers working in the electric power generation, transmission, and distribution industry in the United States. The Bureau of Labor Statistics predicts that demand will grow to 11,113 by 2014. The average annual demand for electrical engineers, resulting from employment growth or the need to replace workers that leave the electric utility industry, is 749 per year for the ten-year period from 2004 to 2014 [1]. Currently, the number of career opportunities is expected to be in rough balance with the supply of graduates. However, this situation may not be sustainable over time. Statistics indicate that the primary producer of power engineering graduates, i.e., university programs, may be in jeopardy.

Fig. 1. Utilities need a skilled workforce to support the power system

1) Power Engineering Programs Decline

In 2006, the U.S. Department of Energy reported to the United States Congress on workforce trends in the electric utility industry. There has been a decline in power engineering programs at universities over the past two decades; the current estimate is less than 30 programs in the United States and about 75 programs worldwide. Some top research schools have eliminated the power engineering focus from their electrical engineering programs. To make matters worse, many retired power engineering faculty have not been replaced. The state of university-based power engineering programs will erode without qualified replacements for retiring faculty [1].

2) Power Engineering Graduates Decline

For nearly three decades, the United States has experienced a steady decline of engineering students with a power emphasis (Fig. 2). The IEEE reports 360,000 electrical and 23,000 registered professional engineers. However, today there are only about 500 undergraduate degrees awarded annually in power engineering compared to nearly 2,000 in the late 1970s. Fewer than 200 master's degrees and approximately 20 PhDs are awarded annually in the United States [2].

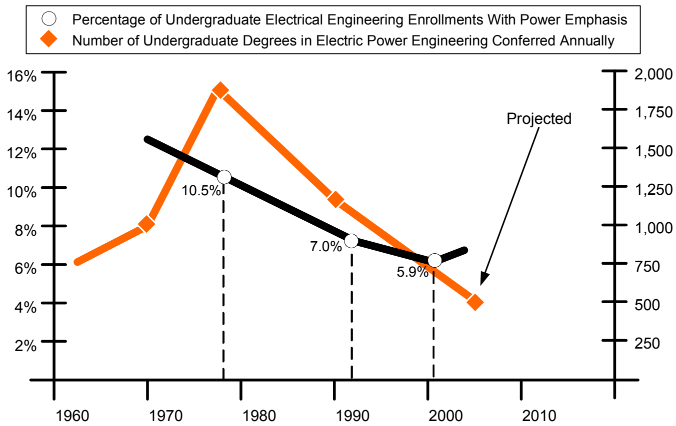

Fig. 2. United States electrical engineering students with a power emphasis contrast with degrees conferred annually

While the number of career opportunities is expected to be in balance with the supply of graduates, this implies that all power engineering graduates will work for a utility upon graduation. This would leave a shortage of power engineers to work for consulting firms, industrial plants, product manufacturers, etc. Likely, some graduates will choose to work for a utility, while others will work for a consultant or manufacturer, thus leaving a shortage in all types of organizations that need power engineers.

3) Salaries Lag Behind Other Engineering Fields

Engineering salaries vary dramatically by specialty and industry. For example, a survey by IEEE-USA shows that salaries for engineers in the power and energy markets are behind other fields that employ electrical engineers, as indicated in Table I [1].

TABLE I
MEDIAN SALARIES FOR UNITED STATES ELECTRICAL ENGINEERS

Engineering Discipline	Salary ($)
Solid-state circuits	93,500
Communications	92,900
Laser and electro-optics	91,000
Software, aerospace, and electronics	89,000
Components and manufacturing	88,850
Signals and application	87,000
Antennas and propagation	86,000
Medicine and biology signal processing	85,000
Electron devices	84,750
Network administration	81,000
Power electronics	80,050
Circuits and systems	80,000
Instrumentation and measurement	76,000
Energy and power engineering	**73,625**

B. Electrical Line Workers

Electrical line workers represent the physical labor required to operate and maintain the electric grid. They erect poles and transmission towers, and install or repair cabling to carry electricity from the power plant to the customer. This is a physically demanding and dangerous career in which workers often respond in bad weather or during natural disasters to repair power system damage (Fig. 3). Risks include electrocution, injury due to falls, and flash burns.

Fig. 3. Electrical line workers respond in harsh conditions

The U.S. Department of Energy predicts the demand for line workers is expected to outpace supply over the next decade [1]. Overall employment is projected to increase more slowly than average, although a growing number of retirements should create very good career opportunities [3].

Line workers are in one of the highest paid professions that do not require a postsecondary education. However, as first responders, they have unpredictable work schedules, which result from being on call virtually 24 hours a day, 7 days a week. This can lead to quality of life concerns [1].

1) Line Worker Programs

There are over 30 line worker training schools in the United States today, double from ten years ago. Utilities offer these programs for employees training to be journeyman line workers. It typically takes four or more years of training for an apprentice to become a journeyman. Mentoring and training from experienced journeymen is key to the training process and is relied on by utilities. Some organizations expect up to 50 percent of line workers to retire in the next 5 to 10 years [1]. Even with the increase of training programs, a significant forecasted shortage of line workers is feared.

Employment of utility line workers in the United States reached a low of 44,660 in 2000 and steadily increased to 53,780 in 2005 (Fig. 4).

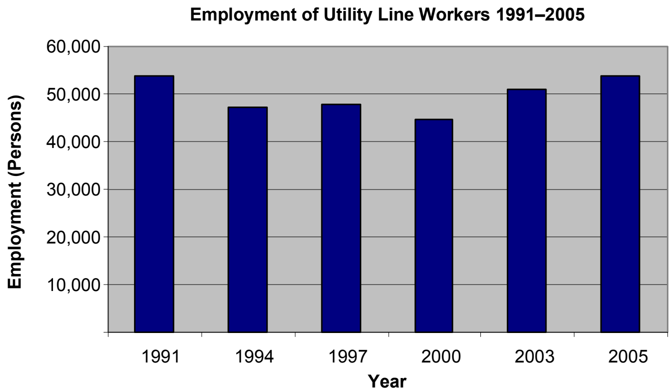

Fig. 4. Employment of utility line workers continues to improve

C. *Pending Retirements Could Put the Electric Grid at Risk*

More than 25 percent of the United States population is classified as part of the aging Baby Boomer generation that is now nearing retirement. The 80 million Baby Boomers represent about 44 percent of the American workforce that has accumulated decades of experience and knowledge.

Nearly 50 percent of the utility workforce is 45 years or older (Fig. 5). Many positions within the utility industry are highly specialized, require years of training, and have accumulated historical knowledge of in-service power system assets. The loss of critical knowledge and the ability to maintain a reliable electric grid is at risk. Considering the recent Northeast blackout and the increasing attention to homeland security, this potential loss of knowledge is a great concern [1] [2].

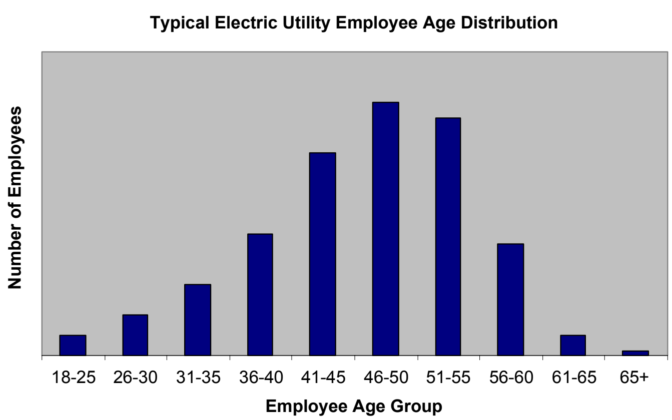

Fig. 5. Fifty percent of the utility workforce is 45 years or older

According to a study by Senator Maria Cantwell, "Meeting the National Demand for a Skilled Energy Force," more than half the nation's science and engineering workforce will reach retirement age in the next 20 years. "The nation faces a critical shortage of power engineers in the years ahead. Workers with science and technology degrees will soon retire, creating a dramatic vacuum of employees available to satisfy a growing industry [4]."

II. Understanding the Generations

The power industry workforce demographics continue to change. Baby Boomers are beginning to retire, creating new openings for Generation X and Generation Y workers. Each generation possesses different characteristics, expectations, and approaches to work and have different technological upbringings, as described in Table II.

The Baby Boomer generation, born between 1946 and 1964, represents the largest generation in the United States at around 80 million. Generation X includes those born between 1965 and 1980. Generation Y, sometimes called the "Echo Boomers" or "Millennials," was born between 1981 and 1993 [1] [2]. Consider the differences of these generations to plan for future labor requirements and to attract and retain new employees.

TABLE II
UNDERSTANDING GENERATION DIFFERENCES

Baby Boomer	Generation X	Generation Y
Born 1946–1964	Born 1965–1980	Born 1981–1993
TV	PC	Internet
Have technology	Use technology	Raised on technology
Comfortable with print	Computer savvy; expect up-to-date technology	All information is a click away
Value ongoing training to keep skills up to date	Value skill-development training and accumulating transferable job skills	Thrive on flexibility and space to explore
Want to feel needed; want to be recognized for personal contributions	Like immediate tangible rewards	Seek to make a difference; desire to be a hero
Willing to mentor younger workers, but expect younger people to "pay their dues"	Enjoy freedom to get the job done in their own way	Partner well with mentors
Process oriented	Desire flexibility	Value guidance

III. Planning for Future Labor Requirements

In order to meet future labor requirements, organizations need to understand the state of today's workforce and plan accordingly to meet future needs. This section provides short- and long-term recommendations to build interest in engineering and develop and retain qualified personnel.

A. *Build Interest in Energy-Related Fields*

Considering the perception among some students that careers in energy-related fields are obsolete and old-fashioned, it is vital to build interest in careers in this industry.

1) *Become a Mentor*

Formal and informal mentor programs allow mentors to share knowledge, experience, and advice with less experienced mentees. Likewise, emerging professionals gain access to information and guidance regarding their chosen career path. The alliance between the mentor and mentee often reduces knowledge gaps.

2) Expose Students to Math and Science Early

Most agree that it is important to build interest in math, science, and engineering at an early age. A high-tech manufacturer in Eastern Washington has hired an instructor to teach elective electronic courses to the local high school students. The goal of this program is to expose students to the fundamentals of electronics and create interest for those who had not had that opportunity. At the start of the program, students were bused from the high school to the manufacturer's facility. Today, the instructor has a convenient lab and classroom at the high school.

In 7 years, approximately 240 students have been through this electronics course. Twenty students have gone on to college with an engineering major. Another dozen or so have gone on to pursue careers in high-tech or other skilled fields. About half of the students that said they were going to pursue an engineering career said they never considered doing so before taking the course at school. The number of future engineers is expected to increase because about 25 percent of these students have not yet graduated, and 20 percent say they intend to study engineering.

3) Participate in Internship Programs

Internship programs benefit employers and students. Students get invaluable hands-on experience working side-by-side with professionals in the industry. Employers benefit from the added help to complete necessary work and have the opportunity to evaluate the intern's performance for potential full-time employment.

a) Western United States Utility Implements Intern Program

A Western United States utility has a managed, organized internship program for upper-level students and college graduates who desire to enter the power industry. When the program began in 2003, the utility expected that an effective recruiting program would take years to show positive, long-term benefits. The goals of the program are to identify and hire the best candidates from diverse backgrounds and provide an invaluable experience of utility life. Selected schools all have strong power programs and are active members of PSERC (Power Systems Engineering Research Center).

Interns work on real projects in a specialty area, such as protection and control, substations, or project management, as opposed to working a rotation schedule. Interns participate in weekly group outings to learn about all areas of the utility, regardless of group assignments. These outings include visiting generation facilities, touring substations, or observing line crews connecting a new service or pulling wire. Since 2003, this utility has hired 20 percent of their interns as full-time employees.

b) Manufacturer Implements Intern Program

A large manufacturer in the power industry that has run a successful internship program for college students since 2001 has employed over 200 interns, converting over 40 to full-time positions. Interns are assigned projects that put their skills and knowledge to the test and give them an opportunity to gain invaluable real-life experience. They work alongside full-time employees and are given real problems to solve that have measurable effects on the company. This program provides students an opportunity to develop job-related skills and provides an environment that encourages personal and professional growth.

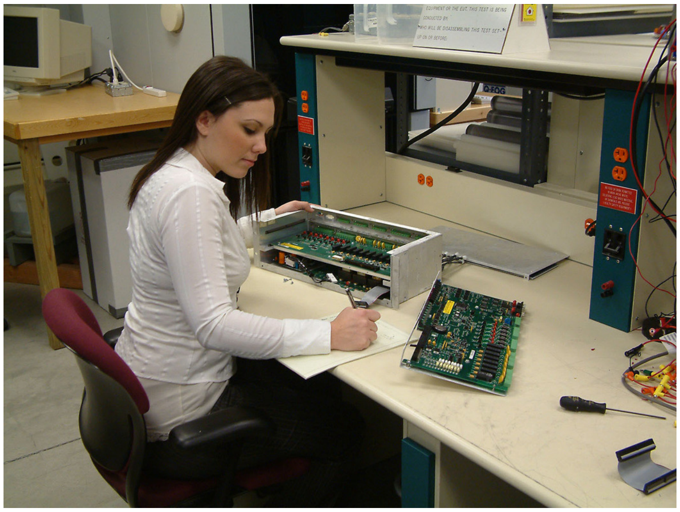

Fig. 6. Interns gain invaluable experience

4) Sponsor Senior Design Projects at Universities

Colleges are continually looking for companies to sponsor senior design projects and to mentor design teams. Sponsorships vary but may include financial, equipment, software, or tool donations. Additionally, technical experts may provide consultations. Through sponsorships, students get exposure to solving real-world problems, following engineering procedures, and working as a team to complete their assignments.

a) Relay Replacement Study for University Distribution System

A design project for Washington State University (WSU) included developing settings for digital relays to retrofit electromechanical relays on nearly 50 distribution feeders in the campus steam plant (Fig. 7). The project spanned several years, allowing multiple design teams to work on the upgrade.

Fig. 7. WSU steam plant

The feeders supplied power to approximately a quarter of the buildings on the WSU campus. Each feeder had three single-phase overcurrent relays that were replaced by a single digital overcurrent relay. The upgrade project also replaced older meters with new technology to enable energy studies and usage measurements for campus buildings.

The relay settings from the existing protection could not be reused because the university had substantial growth over the 30-plus years since the relays were installed. Some of the protective relays were more than 44 years old. Settings changes were not made unless there was a specific problem on a feeder.

Typical project teams consisted of three electrical engineering students, all in their final year of undergraduate power engineering. Teams reviewed the paper one-line diagrams of the university distribution system and then developed models using commercial software. To build accurate models, the team evaluated the age and type of conductor for each feeder, the fuse type and location for coordination in a fuse-saving design, the motor contribution to fault current, and the load conditions. All the information was used to calculate fault current levels and coordinate the relays with fuses. It was also necessary to develop a plan for load shedding based on the importance of the loads fed by each feeder. Medical and lab facilities were given the highest priority and would be shed last, while classrooms and offices would be shed first. At the end of the project, the teams provided the electronic one-line diagrams, coordination study, load-shedding logic, and relay settings for each feeder.

Fig. 8. Students created settings for digital relays to replace electromechanical relays on feeders in WSU steam plant

This project represents actual work that electrical engineers perform to support today's electric power system. The experience gained from this design project resulted in several students going on to work as full-time employees of the manufacturer who supplied the newer digital equipment, while others went on to work for electric utilities.

5) Volunteer as a Guest Speaker

Volunteer to speak at a university career day or as a supplement to ongoing curriculum. Students learn from professionals who share real-world problems solved by engineering.

Fig. 9. Guest speaker lectures to engineering students

6) Participate on Industry Advisory Councils

Companies should participate on industry advisory councils at universities and colleges. This involvement provides an opportunity to work with engineering departments, faculty, and professors to offer advise for planning curriculum, staffing, and laboratory needs and to work on issues such as building interest to attract and retain students. This is also an opportunity for industry employers to share hiring plans and expectations for new graduates entering the workforce. Contact electrical engineering department chairs at universities and colleges to participate on their advisory councils.

7) Donate Equipment

Equipment donations are key to the success of most engineering programs. Equipping laboratories with up-to-date, high-tech equipment provides students with invaluable hands-on experience using tools and equipment commonly used in the industry. Putting state-of-the-art equipment in the hands of engineering students is an opportunity to rid them of perceptions that careers in energy-related fields are obsolete and old-fashioned.

8) Sponsor Visiting Professorships

Sponsor visiting professorship programs with universities to incorporate industry experts in the teaching and learning process. Students benefit from professional knowledge and experience through lecture and classroom interaction. Successful programs have ranged from one week to a year or more.

9) Attend Recruiting and Career Fairs

Employers should consider attendance at career fairs to be more than just handing out gadgets but, rather, an opportunity to attract and hire qualified candidates. One manufacturer regularly attends engineering career fairs where practicing engineers participate as guest lecturers in the classroom and discuss a variety of topics. Two lecture examples are provided.

The first lecture, on protective relay design, was given to a power systems analysis course. The lecturer described the electronics, signal processing, and protection logic necessary to implement a simple inverse-time overcurrent element in a protective relay. The lecture covered signal scaling, sampled data system theory, electronics design, digital filtering, magnitude and angle calculations, programmable logic, latching trip and close logic, and contact I/O operation.

The second lecture was given to a power electronics class on metallic contact switching capacity. The class learned why metallic contacts have trouble interrupting dc current and how to improve their ability to do so.

Following both lectures, students remained after class to ask questions and talk more with the guest lecturer. This contact resulted in interviews with five highly qualified students that had not before considered electric power systems as an area of interest.

B. Develop a Plan for Future Labor Requirements

Organizations need to plan for their future labor requirements in today's increasingly competitive job market. In a study conducted in 2005 by the American Public Power Association (APPA), "Work Force Planning for Public Power Utilities: Ensuring Resources to Meet Projected Needs," 77 percent of the organizations polled did not have a formal plan for meeting projected workforce needs. The report outlines a seven-step workforce planning model that can be used to address workforce issues arising from anticipated retirements [5].

1. Link workforce needs to the strategic plan.
2. Conduct workforce analysis.
3. Identify future workforce needs.
4. Perform a gap analysis.
5. Develop a strategy.
6. Implement the strategy.
7. Monitor, evaluate, and revise.

IV. Training the Next Generation of Power System Engineers

Considering the projected number of new hires combined with the retiring experienced workforce, meeting the demand for a knowledgeable workforce is a concern for many organizations. Organizations short on experienced staff or that do not have formal training programs in place should leverage established training programs to improve the technical competencies of their workforce.

Fig. 10. Training the next generation of power systems engineers

One manufacturer offers a training program with courses for engineers, technicians, power system specialists, and managers concerned with protection, monitoring, control, automation, metering, and management of utility and industrial electric power systems. To date, this program has trained about 5,000 students in the power industry.

V. Conclusion

If not addressed, a shortage of expertise in the power industry as a result of imminent retirements in the aging workforce could have catastrophic effects on the nation's electric power system and society.

A powerful upside to the problem is that utility line worker programs are steadily increasing and providing a promising outlook for career opportunities to replace retiring personnel. Likewise, engineering positions in the power industry are in high demand, and employment opportunities are great for college students in this competitive market.

As an industry, we must communicate the opportunities to these potential engineers and emphasize the important role they will play in the delivery of safe and reliable electric power. Make it clear that the fundamentals of engineering learned in school will be applicable in their careers, and they will be continually challenged to learn, innovate, and support state-of-the-art technology to advance the capability of today's power systems to meet the needs of tomorrow.

Work with your company's human resources department to see what is being done to analyze the workforce, plan for pending retirements and new hires, and fill knowledge gaps. When recruiting employees, go through benchmarking activities to ensure salaries are competitive and attractive to new hires. Learn more by contacting companies that have already implemented mentor and intern programs. Contact colleges and universities to get involved with industry advisory councils, to participate in career fairs, or to be a guest lecturer.

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VII. Biographies

Amy Grice received a BS in electrical engineering from WSU in December 2002. She joined Tacoma Power in January 2003 as an engineer in the SCADA department. Currently, Amy is a protection engineer in the Protection and Control department and manages Tacoma Power's engineering intern program, where she recruits and trains interns. Amy is also completing an MS degree in engineering and technology management from WSU.

Greg Morris has an MBA from the University of Phoenix and a BS in mathematics from Ottawa University. He joined SEL in December 2001 as business manager for SEL University. He is now the regional sales and service director for the SEL West Region. Prior to joining SEL, Greg worked for Honeywell, Inc. for twenty-five years in the Automation and Control Solutions group where his last assignment was director of Training and Information Services. Greg is a member of the Manufacturers' Agents National Association.

Jackie Peer has a B.S. in electrical engineering from WSU. In 1996, she joined SEL as an application engineer. She managed Distribution Engineering in R&D and, presently, is the marketing manager at SEL. Prior to joining SEL, she worked for the U.S. Army Corp of Engineers at a hydroelectric facility. She is a member of the American Marketing Association, IEEE, and WIE and is a senior member of the Society of Women Engineers. She also serves on the WSU Electrical Engineering and Computer Science Industry Advisory Board.

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