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Teaching and Research Initiatives in Power Engineering Technology

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Abstract

The existing centralized, producer controlled generation, and uni-directional transmission and distribution network has been gradually shifting to distributed generation with significant integration of renewable energy and bi-directional power flow, leading to the so called "smart grid". The power grid evolvement is boosting related industries and provides a great opportunity for United States to secure its leadership for future economic growth. However, the education of engineers, technicians, and educators themselves has not kept pace with the rising demand for both grid modernization and workforce replacement. To address both technical and educational challenges, an NSF proposal was successfully proposed to develop a smart grid platform for multidisciplinary teaching and research activities. Obviously the revival of power engineering education cannot be the simple duplication of the previous curriculum. Traditional core courses in power engineering technology, such as power system, power electronics, electric machines, etc, need to be revamped to deliver relevant information in light of current industrial practices. Complementary knowledge and skills including control theory, embedded system, communications, digital signal processing, etc, are needed to strengthen student knowledge and skills in communication and information technologies. The project investigator team is composed of three faculties in two departments, and this presentation focuses on the teaching and research initiatives in Engineering Technology (ET).

Background

As a supreme engineering achievement of the 20th century, U.S. power grid is one of the largest and most capital-intensive sectors of the economy. Its total asset value has exceeded $800 billion, of which about 60% in power plants, 10% in high voltage transmission networks, and 30% in lower voltage distribution facilities. The annual electric bills paid by America’s 131 million electricity customers from business to household are about $247 billion[1]. With the growing need from computerized economy, it is estimated that U.S. electricity demand will grow by 39% from 2005 to 2030, reaching 5.8 billion MWh by 2030[2]. On the other hand, the existing power grid with aging infrastructure is operating in ways that are increasingly inadequate. The majority of power plants have been more than 30 years, with out-of-date technologies and low efficiency. Distribution transformers are approaching an average age of 40 years. While electricity demand increased by about 25% since 1990, construction of transmission facilities decreased by about 30%. Due to heavy utilization and frequent congestion, nation-wide power losses in transmission and distribution grew to 9.5% in 2001, whereas it was only 5% in 1970. Power outages and power quality disturbances cost the economy $25 - $180 billion per year[1]. The most serious accident of 2003 Northeast Blackout wiped out essential services for 55 million people across U.S. and Canada, leading to 11 deaths and $7 - $10 billion cost[3].

The electric power grid evolved over a century in a largely regulated context and tightly integrating network. As shown in Fig. 1, traditionally the electricity is first generated in power plant and then transmitted in high voltage over long distances to substations, where it is transformed into lowered voltage and then distributed to consumers. Currently 63% electricity in America is generated from fossil fuel like coal, gas and oil, 20% from nuclear, and 6% from hydro. For those obsolete power plants established several decades ago, they are running with a very low efficiency. After deducting the losses in generation, transmission and distribution, only 30% energy stored in coal is finally delivered to the customer as electricity[1].

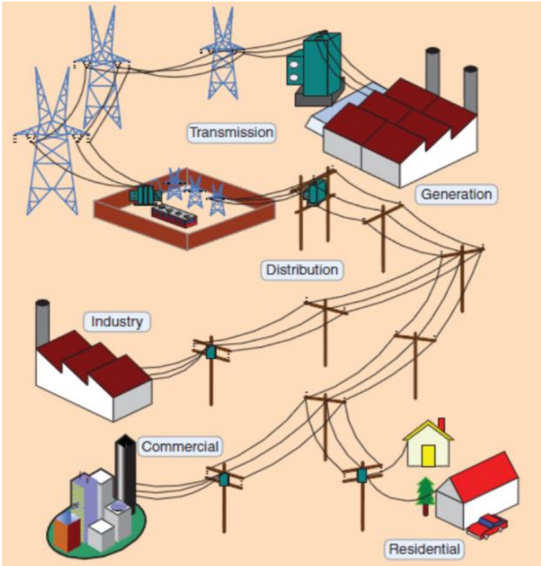

Fig. 1. Traditional Power Grid[4]

In order to build a cleaner, more efficient and more competitive economy and create new jobs, the nation needs a "Smart Grid" commensurate with its aspirations. One that is adaptable, secure, reliable, resilient, and can accommodate changing loads, generation technologies, and operating business models[3]. It means the existing centralized, producer controlled generation, and uni-directional transmission and distribution network will gradually shift to distributed generation with significant integration of renewable energy and bi-directional power flow as shown in Fig. 2. Considering the maturity of technology development as well as the slow turnover of capital assets to replace the aging facilities, the emergence of smart grid probably will follow an evolutionary trajectory[5]. Along with the trend, several particular aspects have been sketched for the future scenario.

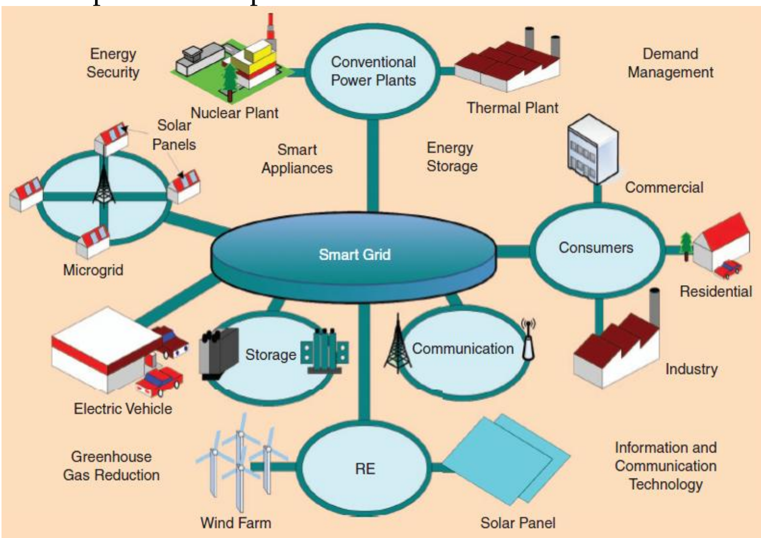

Fig. 2. Emerging Smart Grid[4]

(i) Distributed Generation: In recent years, new generation deployments have been shrinking in scale meanwhile dispersing geographically, driven by changes in policy, business models, and technologies[3]. Since planning, regulatory, and capital risks increase with scale, investors and policy makers have preferred modular deployment at the scale of a few hundred MW, instead of previously preferred GW-scale centralized big plants. These small-scale technologies also enable consumer deployment of generating technologies onsite, to provide more reliable service and lower transmission costs[6]. Distributed generators and associated loads may form intentional islands in the electrical distribution network to construct so-called microgrids, which can be switched between islanded mode and grid-connected mode with minimal disruption on the local loads[7].

(ii) Renewable Integration: Newly established Renewable Portfolio Standards (RPS) has placed an obligation on electricity supply companies to provide a minimum percentage of their electricity from approved renewable sources[8]. Therefore, a high penetration level from renewable energy will be seen in the near future. Since the availability of renewable energy sources like wind and sunshine are intermittent and uncontrollable, traditional power plants in addition with energy storages may be needed to stabilize the fluctuation of the renewable generation, constructing a diversified power portfolio.

(iii) Power Electronics Interface: With hundreds and thousands of distributed and renewable energy sources connected to the utility network, it will introduce different dynamics to the system, and power electronics interfaces are needed to enable efficient and flexible interconnections between different players in smart grid[9]. Power electronics devices can optimize power transfer, ensure active/reactive power control, maintain synchronization in distributed nodes, improve power quality, and enable bidirectional power flow, etc. With the rapid progress of semiconductor technology, switching components, embedded microprocessors, and corresponding control strategies are quickly improved. Power electronics technologies will be pervasively utilized in the future grid[6].

(iv) Communication System: The existing communication system is designed to serve the centralized hierarchical power grid, where legacy control systems or Supervisory Control and Data Acquisition (SCADA) systems were typically built with a star topology in which data are exchanged between the control center and substations. With the evolvement towards distributed generation paradigm, the communication system will also experience a fundamental change to enable horizontal data exchange between distributed nodes in addition with vertical communication[10]. Two-way communication and ubiquitous sensing with Advanced Metering Infrastructure (AMI) and Phasor Measurement Unit (PMU) will induce unprecedented software-based innovation in the system, including integrated management of both loads and generation[3].

Workforce Shortage:

Economic opportunities in the global power sector are driving deployment, innovation, and manufacturing worldwide. It provides a great opportunity for United States to secure its leadership for future economic growth. Even during the economic recession, modest increase in electricity consumption and slow replacement for aging infrastructures resulted in 14 GW new generation capacity in 2010, corresponding with tens of billions of dollars investment in domestic market[3]. Meanwhile, with the looming retirement of baby boomers, roughly half of power and energy engineers are going to retire over the next five to ten years. This could leave more than 7,000 power engineer vacancies in electric utility companies only[11].

However, the education of engineers, technicians, and educators themselves has not kept pace with the rising demand for both grid modernization and workforce replacement[12]. Along with the continuously shrinking of graduating engineers over the past 15 years, the pipeline of students into power and energy industry to support the coming need is not optimized. Every year, the whole country only has 800 to 1,000 undergraduates educated in power engineering. Even for educational institutions, without strong research support for power systems and without qualified replacement for retiring faculty for many years[13], power programs at many universities have stagnated and in need of major reform[14]. If not managed properly, the loss of experience and expertise will affect reliability, safety, productivity, and the ability to solve the pressing issue of grid modernization[11].

Undoubtedly there is an urgent need to strengthen the education for human resources to work on developing and deploying smart grid, but the revival of power engineering education cannot be the simple duplication of the previous curriculum. Most existing courses in power engineering, such as power system, power electronics, electric machines, etc, have not updated for a long while and are failing to deliver relevant information in light of current industrial practices. In addition, complementary courses including control theory, embedded system, communications, digital signal processing, etc, are needed to strengthen student knowledge and skills with communication and information technologies[15]. Graduate student research needs to be leveraged for the undergraduate curriculum development and laboratory modernization to improve student education in the area of smart grid. Through engaging students in education innovation and research, it not only helps student learning of fundamental knowledge, but also prepares them with lifelong learning skills.

Implementation:

1. Course development

As shown in the table I, all the three core courses (power grid, electric motor, power electronics) in power engineering have been developed and offered in PI's home department Engineering Technology. The complete curriculum provides a systematic training for undergraduate students to get involved in this field.

Semester	**Course**	**Level**
2013 Fall	ELET 4103 Power Electronics	Undergraduate
	ELET 4101 Power Electronics Lab	Undergraduate
	GNEG 5193 Advanced Motor Drive	Graduate
2014 Spring	ELET 4103 Motors and Drives	Undergraduate
	ELET 4101 Motors and Drives Lab	Undergraduate
2014 Fall	ELEG 4103, Power Grid	Undergraduate

Table 1. Curriculum Development

2. Faculty workshop

Every summer, the faculty workshop is offered to gather all the related faculties together to update the progress, exchange information, brain storm ideas, and discuss the future development plan.

Fig. 3A. Lab visit

Fig. 3B. Graduate student demonstrated his research on cyber security in smart grid context

Fig. 3C. FPGA controlled power electronics board

Fig. 3D. Lab visit

3. Laboratory demonstration

The laboratory is not only used for the related courses, but opened for project demonstration, summer camp, open house, etc, to disseminate the achievements in the general public.

Fig. 4A. The facilities were demonstrated for mechanical students in related robotics class

Fig. 3B. Summer camp students from neighboring high schools

4. Senior design

Every year, PI will instruct one group of students to work on the project in the context of smart group. Leveraging on the previous NSF project, one online teaching server has been established and courseware can be graduate added to enrich the contents. Based on their course works in the three core courses, each group chooses one series of topics in the areas of signal processing, power electronics, and power systems, and then post their works online for the benefit of future users.

Fig. 1A. Undergraduate senior design on signal processing

Fig. 1B. Undergraduate senior design on power electronics courseware

Conclusions and Future Work:

This paper reviewed the activities for NSF sponsored research and teaching initiatives in power engineering technology. In the next project year, the power grid simulator will be developed to integrate the individual platforms into a virtual grid with hardware-in-the-loop. The authors and colleagues in other engineering departments will collaborate to share the facilities to achieve a broader impact on multidisciplinary teaching and research.

Acknowledgment

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Bibliography

1. "*Grid 2030 - A National Vision for Electricity's Second 100 Years*", DOE Office of Electric Transmission and Distribution, Jul 2003.
2. "*20% Wind Energy by 2030*", DOE, Jul 2008.
3. "*Report on the First Quadrennial Technology Review*", DOE, Sep 2011.
4. Yu, X.; Cetati, C.; et al, "*The New Frontier of Smart Grids*", IEEE Industrial Electronics Magazine, pp. 49-63, Sep 2011.
5. Farhangi, H., "*The Path of the Smart Grid*", IEEE Power & Energy Magazine, pp.18-28, Jan/Feb 2010.
6. Guerrero, J.M.; Blaabjerg, T.; et al, "*Distributed Generation*", IEEE Industrial Electronics Magazine, pp. 52-64, Mar 2010.
7. Kroposki, B.; Lasseter, R.; et al, "*Making Microgrids Work*", IEEE Power & Energy Magazine, pp. 41-53, May/Jun 2008.
8. Ipakchi, A.; and Albuyeh, F., "*Grid of the Future*", IEEE Power & Energy Magazine, pp.52-62, Mar/Apr 2009.
9. Liserre, M.; Sauter, T.; et al, "*Future Energy Systems*", IEEE Industrial Electronics Magazine, pp. 18-37, Mar 2010.
10. Bouhafs, F.; Mackay, M.; and Merabti, M., "*Links to the Future*", pp. 24-32, Jan/Feb 2012.
11. Reder, W.; Bose, A.; et al, "*Engineering the Future*", pp. 27-35, Jul/Aug 2010.
12. Venkata, S.S.; Brahma, S.; et al, "*Continue Your Learning*", pp. 37-43, Jul/Aug 2010.
13. "*Workforce Trends in the Electric Utility Industry*", DOE Report to Congress, Aug 2006.
14. "*U.S. Power and Energy Engineering Workforce Collaborative*", IEEE Power & Energy Society, 2009.
15. Wollenberg, B.; Mohan, N. "*The Importance of Modern Teaching Labs*", IEEE Power & Energy Magazine, pp. 45-52, Jul/Aug 2010.