Power Grid Modernization

Introduction Guide for Educators

FESTO

The power grid is constantly evolving: are your training programs keeping pace?

This introduction guide is primarily intended for teachers and instructors in the field of electrical engineering. It provides basic information about the modernization of electric power grids and the consequent impact on training and skills requirements for current and future workers. The document also provides guidance for bridging the gap between school curriculum and industry requirements.

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Power Grid Modernization: Benefits and Challenges

Harnessing electric power has been one of the greatest technological advances of humankind. Embedded into virtually all aspects of our lives, it is also a vital prerequisite for our interconnected, digitized world.

To produce and deliver electricity to domestic, commercial, and industrial consumers, we have developed complex infrastructures – power plants, transmission lines, substations, etc. – all part of a larger construct: the power grid. Since the end of the 19th century, the power grid has been characterized by a top-to-bottom model: centralized energy production at large power plants connected to unidirectional distribution networks that passively service customers. Unfortunately, this model comes with risks, such as lack of monitoring and control, energy losses, failures, and blackouts.

Increasing worldwide demand for electricity, rising energy costs, and pressing environmental challenges, are forcing a power grid evolution – first, to replace aging equipment, but more importantly, to rethink the actual way that energy is generated, transmitted, distributed, stored, traded, and used. Today, power grids are being modernized; they are getting smarter.

The smart grid can be defined as an electric power grid that has been digitized to enable bidirectional communication between the electricity producers and the electricity consumers. This is largely achieved by the integration of advanced communication, control, and sensor technology to establish two-way, producer-consumer communication

Increased reliability, efficiency, and resilience, as well as improved security and sustainability: these are among the benefits of smarter grids. Innovating and driving changes that efficiently modernize power grids requires qualified people and greatly impacts training and skills requirements, putting digitalization and information technology at the forefront. As a result, the field of electric power technology offers diverse, stimulating career opportunities.

Technical education teachers and instructors are at the vanguard, developing a workforce that can successfully design, deploy, and operate the smart grid. Success requires that courses and training programs in electric power technology be developed or updated. At the same time, there is a modernization of education consumption patterns and student expectations – including eLearning and lifelong learning, among other profound trends.

These are challenging – yet exciting – times for electrical engineering educators!

Educator Challenges

- Attract and retain new students in training programs related to a field often perceived as outdated
- Train a wide range of workers, with varied educational backgrounds, experiences, and career objectives
- Provide training opportunities to update and upskill current workers so that they can embrace new challenges
- Update school curricula that often fail to keep pace with technological developments and emerging topics

Qualified Workers Required, All Across the World

Because electricity is a vector of economic and social development, many governments and power corporations are accelerating their investments in power grid modernization. So, the underlying objectives of different programs – public, private, or a mix of both – converge: better energy management, increased efficiency, resilience, and reliability of infrastructures, as well as positive environmental impacts.

A Sample of Smart Grid Investments

USA: $110 billion by 2024
Canada: $99 billion by 2030
South America: $18.1 billion by 2030
Germany: $23.6 billion by 2026
China: $77.6 billion by 2026
Australia/New Zealand: $6.1 billion by 2027
Middle East North Africa: $17.6 billion by 2027
Sub-Saharan Africa: $141 billion by 2030
(in US dollars)

Examples of Initiatives and Projects

- Recovery Act Smart Grid Program (USA)
- Smart Grid Program (Canada)
- Smart Grid Vision and Routemap (United Kingdom)
- The Energy Transition (Germany)
- 5G Smart Grid Project (China)
- Smart Cities and Suburbs Program (Australia)
- National Smart Grid Mission (India)
- Smart Grid Programme (South Africa)
- PRODESEN 2019-2033 (Mexico)

Top Changes that Shape Power Grid Infrastructures

Global investments in smart grids have ranged between $250 and $300 billion annually over the last five years, according to the International Energy Agency. Expansion of grid infrastructures to increase electrification is important in many regions of the world, but there are several other types of investments toward modernizing grids.

General Improvements

- Increasing grid redundancy, or doubling of critical equipment
- Interoperability standards and cybersecurity for multidirectional communications, while improving data and infrastructure privacy and protection
- Implementation of micro grids, small-scale power networks that cater to energy needs of a specific area

Distribution

- Installation of substation automation systems (SAS) to allow for remote control of operations
- Upgrade of substation switching schemes

Control and Communication

- Installation of phasor measurement units (PMU) and supervisory control and data acquisition (SCADA) systems
- Use of unified power flow controllers (UPFC) for dynamic control of power flow
- Integration of digital protective relays with communication capability, key enablers of self-healing grids

Generation

- Greater integration of renewable energy sources (sun, wind, water, etc.) for energy production
- Increased grid-tied home energy production for small-scale electricity production

Transmission

- Integration of static var compensators (SVC) and static synchronous compensators (STATCOM) to prevent energy losses and minimize voltage fluctuations
- Fixed series compensation (FSC) to increase the maximal amount power lines can transfer
- Thyristor-controlled series compensation (TCSC) for dynamic, remote adjustments of the power transferred by lines
- Implementation of high-voltage direct-current (HVDC) transmission systems to minimize power losses

Storage and Usage

- Development and incorporation of demand response and demand side resources
- Mass installation of smart meters
- Advanced energy storage and peak-shaving technologies, including plug-in electric and hybrid electric vehicles, as well as thermal storage air conditioning

For optimal returns on investments, a qualified workforce is necessary to implement changes and make full use of the technologies.

Evolving Job Profiles and Education Prerequisites

Power grids are more than just technical infrastructures: they are also a complex ecosystem of interdependent professionals. Power grid modernization creates new and transforms existing job roles related to engineering; installation, maintenance and repair; production; data management; computer science and cloud computing; management, and more.

Occupations That Require General Knowledge

- Architects, building designers, urban planners
- Managers and supervisors (general, operations, sales, IT, finances, engineering, etc.)
- Business and data analysts
- Legal and regulatory specialists
- Communications and public relations workers
- Customer service and sales representatives

Occupations That Require a Technical Background

- Engineers (electrical, electronics, computer systems, civil and mechanical engineers)
- Field employees (electricians, line installers, equipment repair and maintenance staff, assemblers, operators, etc.)
- IT, telecommunications, cybersecurity, and interoperability specialists
- Software developers and programmers

Various study paths can lead to a career related to smart grid. Traditional training programs that cover smart grid topics are mostly in the engineering and technology departments of colleges and universities, such as power engineering, electrical engineering, and computer science.

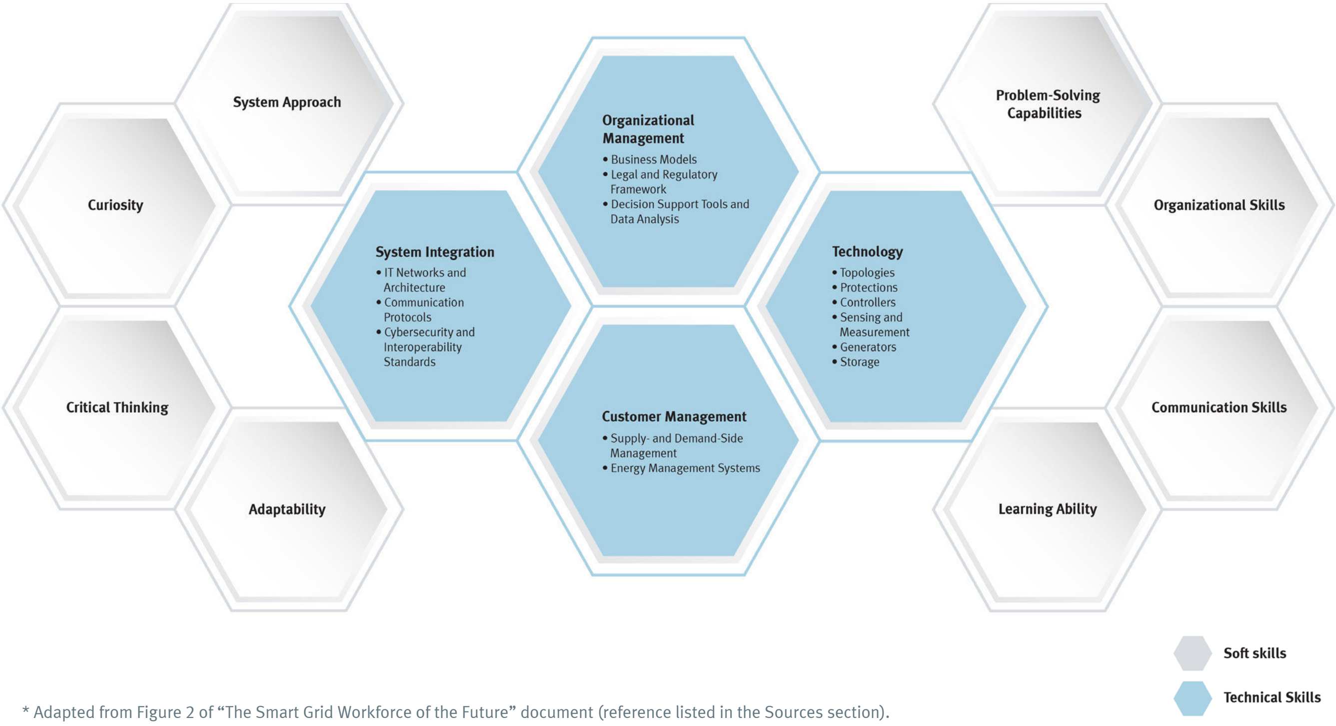
However, given the rising importance of smart grids and clean energy, more smart grid training programs – short or long – and other derivatives, such as renewable energy programs or eMobility programs, are being created to train a new generation of workers or upskill power grid specialists, with courses specifically tackling the new technologies.

Many training programs are being created to answer industry needs. By more closely aligning the course content to on-the-ground realities and job market requirements, smart grid curricula ensure that the new generation of workers are qualified and have a sound understanding of industry realities and challenges. These programs cover a variety of smart grid-related topics, including smart meters, renewable energy integration, electric car charging stations, energy storage, and many more. Training may occur in schools, but is also effective using external training providers, as well as in-house, industrial training done directly in power plants.

Additional courses and short certifications are also being developed to answer the specialized needs of non-technical workers; communicating what they need to know and developing a complete overall comprehension. For instance, some basic courses can last for a couple of days, weeks, or even months, depending on the curriculum objectives. This is followed by more in-depth learning paths at different education levels to train the workers for the job profile they aspire to within the real needs and conditions of their local grids. Very often, these programs are developed or restructured in collaboration with local power utilities to align with their market requirements and future expectations.

New Skill Sets Required for Technical Workers

Energy challenges are so large and complex that any potential solutions require a multidisciplinary, multi-specialist, collaborative effort. Workers must develop T-shaped profiles – a wide general knowledge and skills in several topics, with deep expertise in a specific field.



* Adapted from Figure 2 of "The Smart Grid Workforce of the Future" document (reference listed in the Sources section).

Technical Skills

Smart grid skills require new understanding and technological expertise encompassing relevant technologies, business models, management systems, etc. Every job profile in this field will require a diverse fusion of these skills, and the most effective way to develop enduring technical skills is through study and hands-on training together.

Soft Skills

Quick-changing environments and complex challenges require cross-functional and interdisciplinary collaboration, which requires sound, non-technical – or "soft" – skills to ensure success.

Soft skills can be fostered in several ways, for example, through teamwork, project-based learning approaches, supervised apprenticeships, or mentoring.

5 Keys to Successful Power Grid Education

To actively take part in the electric grid modernization, power grid workers – especially technicians and engineers – require wide-ranging skill sets and new expertise, acquired and developed through education programs correlated with industry needs. Many factors contribute to successful power grid education:

1 Multidisciplinary Training

The integrative nature of the smart grid construct requires a multidisciplinary, collaborative effort by multiple specialists. Training should encompass traditional courses from the electrical engineering discipline, as well as from relevant computer science, communications, and information and security systems disciplines. Additionally, to better understand their own roles and the impact of their actions, power grid workers must develop a wider, "aerial view" of the overall energy landscape, to include regulations and policies, business models, etc.

2 Practical Experimentation

Hands-on training turns learning into doing. Experimenting and putting one's skills to the test on real-world-like equipment enables tangible learning, which deepens student understanding. When schools invest in modern, power-grid-laboratory infrastructure – whether in training hardware that emulates electric systems, simulation and modeling tools, virtual or augmented reality applications, testbeds for research, or other tools – they help equip workers with the capabilities to quickly apply their new skills and knowledge to the workplace and out into the world.

Examples:
- → Smart Electric Power System Laboratory, The College of New Jersey (TCNJ), USA.
- → Clean Technology Facility, Centennial College, Canada.

3 Apprenticeships

Learn, practice, work. Apprenticeships teach smart grid workers the theories and principles of relevant technical topics, like electrical engineering, and how to translate academic knowledge into on-the-job training at authentic work environments. Smart grid work requires specialized and challenging hard and soft skills. The mix of classroom instruction with training, under the guidance of both an experienced educator and an experienced working specialist, make apprenticeships an effective way to prepare students for the workplace.

4 Lifelong Learning

The evolving nature of smart grid necessitates that workers cultivate inquisitiveness and abilities for continuous learning. Companies must provide workers with ongoing training opportunities, keeping track of each worker's trajectory with personalized support that enables career growth. But workers must also be accountable for an objective self-assessment that allows them to determine what skills they must learn to fill any knowledge gaps and maintain peak job competence, or what they must do and learn to continue on a forward career path, rather than simply rely on their managers or human resources. Partnerships between local educational institutions and energy sector companies (i.e., utilities) can also provide lifelong learning opportunities.

And the final, and perhaps most important, key to relevant, modern power grid training: partnerships.

5 Partnerships

The sheer speed of technological changes makes smart grid a fast-evolving sector. So, it becomes challenging for educators to keep pace with electrical grid technology changes and align their course content and training infrastructures accordingly. Educators are pedagogical experts who know the best ways to teach and train students; external partners are experts in their fields and can support teachers in building industry knowledge and expertise, as well as provide access to equipment that accelerates and enhances education programs.

Examples:

→ The Workforce Training for the Electric Power Sector at the University of Tennessee, Chattanooga, USA

→ IGEE program of the Institute of Electrical Power Engineering, Canada.

Educators and key industry professionals can leverage synergies and expertise to create an optimal resource of qualified workers.

Potential Partners:

Power Utilities

Power utilities are at the heart of grid modernization. To successfully implement changes related to smart grid, they invest in upskilling current workers and integrating newcomers into the industry. They also invest in education through research institutes.

Research Institutes

Energy-related research institutes play a key role in advancing knowledge and stimulating innovation, as quickly-evolving technologies drive continuous research.

Academic Organizations

Through meetings, seminars, and publishing of journals and magazines, academic organizations help expand specialized knowledge by providing dialog and communication opportunities.

Labor Unions and Professional Associations

These groups can upskill their working members with training in key topics and hot issues relevant to specific occupations.

Governments

Energy, particularly smart grid education, is a critical topic that requires both a better-informed general public and continued support to school systems. Governments must also invest in key energy infrastructures, develop policies that frame the changes, and clearly explain plans for catalyzing actions and mobilization throughout the energy ecosystem.

Other entities, such as learning solutions providers and international organizations dedicated to education, are also valuable sources of guidance and advice.

Main Takeaways

Grid modernization is happening now, and success relies on a skilled workforce.

Technological and structural changes in the grids impact training and skills requirements.

Industry partners can help align school curricula with industrial realities.

Ready to discover technical topics to include in modern power engineering training?

Smart grid, power electronics, rotating machines, renewable energies, and more: See a range of training systems and turnkey courses that support electric power technology teaching and learning.

Download an overview of a course program with a complete topic coverage (PDF):

bitly.com/ElectricPower-Courses-EN

Sources

Canadian Electricity Association. “The Smart Grid: A Pragmatic Approach” (PDF file). 2017. → Link
Festo Didactic Ltd. “Smart Grid”. Instructor Guide. Ed. 2019.
Informa Markets. “Energy & Utilities Market Outlook Report 2020”. 2020. → Link
International Energy Agency (IEA). “Tracking Energy Integration 2020”. 2020. → Link
Mead, D. & Folsom, A., Exemplary Performance. “Smart Grids Start with Smarter Employees”. Powergrid International. 2012. → Link
Middleton, A. Energy Skills Queensland. “A changing industry, a changing workforce” (PDF file). 2020. → Link
Reed, G.F. & Stanchina, W.. “Smart grid education models for modern electric power system engineering curriculum”. Conference Power and Energy Society General Meeting. 2010 IEEE. → Link
Smart Energy International. “Africa’s power industry – insights in 2020”. April 3, 2020. → Link
Smart Energy International. “China to invest $77.6 bn in smart grid infrastructure”. August 4, 2016. → Link
Smart Energy International. “Germany to invest $23.6 bn in smart grid by 2026”. September 28, 2016. → Link
Smart Energy International. “Smart grid infrastructure investments in South America to hit $18.1 billion”. May 29, 2020. → Link
Smart Energy International. “Smart grid investments in Australia and New Zealand to reach $6.1bn”. May 24, 2017. → Link
Smart Energy International. “US smart grid market, twists and turns, analysis”. February 6, 2018. → Link
U.S. Bureau of Labor Statistics. “Powering the nation: Smart Grid careers” (PDF file). 2013. → Link
U.S. Department of Energy. “Power Jobs: The Smart Grid Workforce”. September 20, 2011. → Link
West Monroe Partners, LLC and Illinois Institute of Technology. “The Smart Grid Workforce of the Future”. 2011. → Link

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 For more information about Festo Didactic → www.festo-didactic.com.

Festo Didactic Inc.

607 Industrial Way West
Eatontown, NJ 07724
USA
Phone +1 732 938-2000
services.didactic@festo.com

Festo Didactic Ltd.

675, rue du Carbone
Quebec City (QC) G1K 8W1
Canada
Phone +1 418 849-1000
services.didactic@festo.com

Festo Didactic SE

Rechbergstrasse 3
73770 Denkendorf
Germany
Phone: +49 711 3467-0
did@festo.com

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