

Research and Education Opportunities in Power Systems

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The electric power system is one of the most important engineering accomplishments of the 20th century. Initially developed in the late 1800s, the power system started as a series of relatively small regional utilities, each serving a limited population. Under this structure, each utility company had to have excess generation capacity to meet the seasonal load variations. Later, due to customer and public service commission demand for increased efficiency and reliability, these grids were connected using “tie lines” to allow electric energy transactions between the regions. Consequently, the system was never designed to take into account the high level of interconnection that characterizes it today.

Highly interconnected utilities in today's electric power system introduce a new kind of complexity for coordinating the objectives of the numerous participants. Economic forces, governmental actions and environmental policies have driven the energy sources from the fossil fuels in the past to renewable resources in the present. The intermittent and stochastic nature of renewable energy sources necessitates different strategies for optimal planning and operation of the power system. In addition, distributed generation technologies such as diesel and gas fired ICE, combined heat and power, micro turbines and fuel cells need to be accounted for in any distribution expansion planning strategy in the future. As well, technology advances in storage devices in the last decade make the energy storage system an inevitable component of today's power system.

A major obstacle for the development of renewable energy resources is the lack of transmission systems for bringing the generated power to the load center. Transmission technologies including superconducting cables, HVDC and FACTS devices require more comprehensive investigation of their potential to increase the operating efficiency and optimize asset utilization. To sustain reliable system operation, we also need new infrastructures and smarter control paradigms. In addition, the recent proliferation of renewable energy applications is only sustainable through the incorporation of advanced technologies which will increase the efficiency of systems monitoring and control.

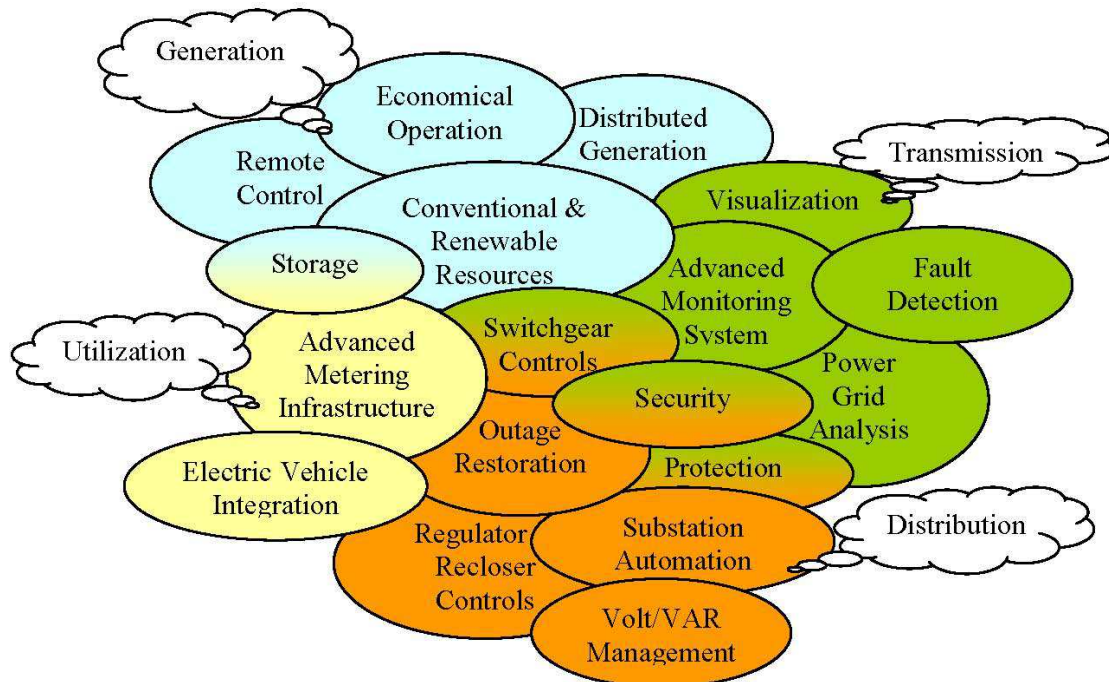


Figure 1. The essential functions of an electric power grid operation

All of these challenges can be satisfied by an intelligent electric power system called the "smart grid". The term "smart grid" evolved from the proposed Electrical Power Research Institute's "Intelligrid" of the early 2000s. The power engineering community tends to classify smart grid applications into three subtopics: transmission, distribution and electrical machines/power electronic systems. The community strives to make the operation, monitoring and control of each application "smarter" than it is now.

The power transmission system, which is the backbone of the entire electrical system, is a large-scale interconnected network spanning Mexico, the United States and Canada. This network is governed by regional transmission organizations and independent system operators and also involves electrical energy wholesale markets. Under the smart grid umbrella, advanced technologies are currently being researched and applied for faster and better monitoring and control of the large interconnections, as well as reliable integration of large-scale -- hundreds of megawatts -- renewable power generation.

Power distribution systems can be considered as pockets in the transmission system serving industrial, governmental and residential customers. These are governed by local utilities. Smart grid applications in distribution systems include smarter metering technologies for efficient integration of distributed small-scale -- tens of kilowatts to hundreds of kilowatts -- renewable power generation, fair pricing mechanisms, and remote monitoring and control of electrical power consumption.

Smart grid applications for electrical machinery consist of smarter interfacing and control schemes for electrical machines by using advanced power electronics circuits and microelectronics. The increased integration of large- and small-scale wind farms requires research on advanced energy conversion, monitoring, and control units as well as new efficient storage systems that compensate for the intermittency of photovoltaic and wind resources.

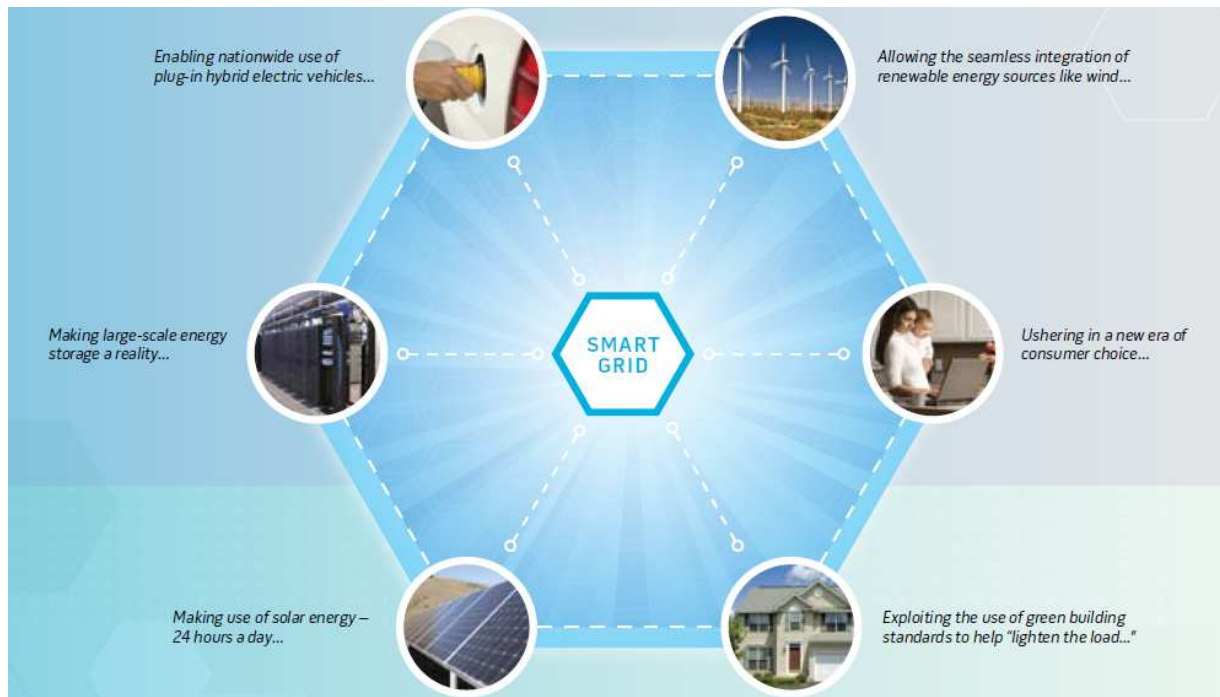


Figure 2. The components of the smart grid (Courtesy of the DOE) [1]

Comparison of today's grid and the smart grid (Courtesy of the DOE) [1]

Characteristic	Today's Grid	Smart Grid
<i>Enables active participation by consumers</i>	<i>Consumers are uninformed and non-participative with power system</i>	<i>Informed, involved, and active consumers - demand response and distributed energy resources.</i>
<i>Accommodates all generation and storage options</i>	<i>Dominated by central generation- many obstacles exist for distributed energy resources interconnection</i>	<i>Many distributed energy resources with plug-and-play convenience focus on renewables</i>
<i>Enables new products, services and markets</i>	<i>Limited wholesale markets, not well integrated - limited opportunities for consumers</i>	<i>Mature, well-integrated wholesale markets, growth of new electricity markets for consumers</i>
<i>Provides power quality for the digital economy</i>	<i>Focus on outages - slow response to power quality issues</i>	<i>Power quality is a priority with a variety of quality/price options - rapid resolution of issues</i>
<i>Optimizes assets & operates efficiently</i>	<i>Little integration of operational data with asset management - business process silos</i>	<i>Greatly expanded data acquisition of grid parameters - focus on prevention, minimizing impact to consumers</i>
<i>Anticipates and responds to system disturbances (self-heals)</i>	<i>Responds to prevent further damage- focus is on protecting assets following fault</i>	<i>Automatically detects and responds to problems - focus on prevention, minimizing impact to consumer</i>
<i>Operates resiliently against attack and natural disaster</i>	<i>Vulnerable to malicious acts of terror and natural disasters</i>	<i>Resilient to attack and natural disasters with rapid restoration capabilities</i>

The 2009 American Recovery and Reinvestment Act stimulus bill allocates \$4.4 billion toward the development of the smart grid. This provides a great opportunity in all three of the above-mentioned aspects of smart grid enhancement and renewable energy research and development. Research and education opportunities in today's intelligent electric power system, as supported by the DOE R&D division, include the following areas [2]:

- Communications and information infrastructure
- Grid control
- Asset and capital efficiency
- Renewable and distributed energy resources integration
- Customer solutions

[1] [http://energy.gov/sites/prod/files/oeprod/DocumentsandMedia/DOE_SG_Book_Single_Pages\(1\).pdf](http://energy.gov/sites/prod/files/oeprod/DocumentsandMedia/DOE_SG_Book_Single_Pages(1).pdf)

[2] <http://www.ita.ucla.edu/news/presentations/Ton-UCLA1119-rv.pdf>