Smart Grid

An Online Continuing Education Course for Engineers

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Introduction

Throughout the 20th century, the U.S. electric power industry has served our nation well, providing adequate, affordable energy to homes, businesses, and factories. This state-of-the-art system has brought a level of prosperity to the United States unmatched by any other nation in the world. But a 21st-century U.S. economy cannot be built on a 20th-century electric grid.

Many agree there is a need for major improvements in the nation's power delivery system and that advances in key technology areas can make these improvements possible.

This course is based on a DOE report, which essentially describes a roadmap for the transformation of the current grid structure to meet future needs. The original document was written in 2009 and is somewhat dated, but the fundamentals presented in this document are still valid. Some concepts presented by the DOE have occurred, and many are slowly beginning to take hold in the utility industry. Other concepts are years away. And there have been new concepts introduced since this report was issued, such as microgrids and the proliferation of shale oil, which has fundamentally changed the generation markets and resulted in greatly reduced emissions resulting from the production of electricity.

The Modern Grid, as defined by the DOE, sets the foundation for a transition that will focus on meeting the six key goals discussed below:

1. The grid must be more reliable

- A reliable grid provides power dependably, when and where its users need it and of the quality they value. It provides ample warning of growing problems and withstands most disturbances without failing. It takes corrective action before most users are affected.

2. The Grid must be more secure

- A secure grid withstands physical and cyber attacks without suffering massive blackouts or exorbitant recovery costs. It is also less vulnerable to natural disasters and recovers more quickly.

3. The grid must be more economic

- An economic grid operates under the basic laws of supply and demand, resulting in fair prices and adequate supplies.

4. The grid must be more efficient

- An efficient grid takes advantage of investments that lead to cost control, reduced transmission and distribution electrical losses, more efficient power production and improved asset utilization. Methods to control the flow of power to reduce transmission congestion and allow access to low cost generating sources including renewables will be available.

5. The grid must be more environmentally friendly

- An environmentally friendly grid reduces environmental impacts through initiatives in generation, transmission, distribution, storage and consumption. Access to sources of renewable energy will be expanded.

6. The grid must be safer

- A safe grid does no harm to the public or to grid workers and is sensitive to users who depend on it as a medical necessity.

It is believed that achieving these goals will result in a “Smart Grid” that will exhibit the following seven characteristics.

1. Self-Healing

First, the grid will heal itself. The modernized grid will perform continuous self-assessments to detect, analyze, respond to, and as needed, restore grid components or network sections. It will handle problems too large or too fast-moving for human intervention. Acting as the grid’s “immune system,” self-healing will help maintain grid reliability, security, affordability, power quality, and efficiency.

2. Engage Consumers

Second, it will motivate consumers to be active grid participants and will include them in grid operations. The active participation of consumers in electricity markets brings tangible benefits to both the grid and the environment while reducing the cost of delivered electricity.

In the modernized grid, well-informed consumers will modify consumption based on the balancing of their demands and the electric system’s capability to meet those demands. Demand for new cost-saving and energy-saving products will benefit both the consumer and the power system.

3. Resist to Attack

Third, the modern grid will resist attack. Security requires a system-wide solution that will reduce physical and cyber vulnerabilities and recovers rapidly from disruptions. Both its design and its operation will discourage attacks, minimize their consequences, and speed service restoration.

It will also withstand simultaneous attacks against several parts of the electric system and the possibility of multiple, coordinated attacks over a span of time. Modern grid security protocols impact the grid and the economy. A less susceptible and more resilient grid will make it a less desirable target of terrorists.

4. Enhanced Power Quality

Fourth, the modern grid will provide the level of power quality desired by 21st-century users. New power quality standards will balance load sensitivity with delivered power quality at a reasonable price. The modernized grid will supply varying grades of power quality at different pricing levels.

5. Readily Accommodate All Generation Options

Fifth, the modern grid will accommodate all generation and storage options. It will seamlessly integrate many types of electrical generation and storage systems with a simplified interconnection process analogous to the “plug-and-play” technology of the retail computer industry.

Improved interconnection standards will enable a wide variety of generation and storage options. Various capacities from small to large will be interconnected at essentially all voltage levels and will include distributed energy resources such as photovoltaic, wind, advanced batteries, plug-in hybrid vehicles, and fuel cells. It will be easier and more profitable for commercial users to install their own generation and electric storage facilities.

6. Enable Competitive Markets

Sixth, the modern grid will enable markets to flourish. Open-access markets expose and shed inefficiencies. The modern grid will enable more market participation through increased transmission paths, aggregated demand response initiatives, and the placement of energy resources, including storage within a more reliable distribution system that is closer to the consumer.

7. Optimize Asset Use

Finally, the modern grid will optimize its assets and operate more efficiently. Asset management and operation of the grid will be fine-tuned to deliver the desired functionality at a minimum cost. This does not imply that assets will be driven to their limits continuously but rather that they will be managed to efficiently deliver what is needed when it is needed.

Improved load factors and lower system losses are the cornerstone aspects of optimizing assets. Additionally, advanced information technologies will provide a vast amount of data and information that will be integrated with existing enterprise-wide systems, significantly enhancing their ability to optimize operations and maintenance processes.

These seven characteristics describe a grid that is generally more resilient and distributed, more intelligent, more controllable, and better protected than today’s grid.

Advancements in large, centralized generating stations and higher capacity, more controllable transmission lines will continue to be needed and will complement the benefits of shifting to a more distributed grid model. This vision will enable the modern grid to benefit from better utilization of the transmission and distribution systems and active involvement by end-users to meet the 21st century needs of consumers and society. Significant opportunities exist to apply modern communications, computing technologies, and advancements in materials to achieve this modern grid vision.

Chapter 1: Self-Healing Grid

The first characteristic of a smart grid is known as self-healing. The premise of a seal-healing grid is stated as follows,

> **A self-healing grid is an engineering design that enables the problem elements of a system to be isolated and, ideally, restored to normal operation with little or no human intervention. These self-healing actions will result in minimal or no interruption of service to consumers.**

The modern, self-healing grid will perform continuous, online self-assessments to predict potential problems, detect existing or emerging problems, and initiate immediate corrective responses. The self-healing concept is a natural extension of power system protective relaying, which forms the core of this technology.

A self-healing grid will frequently utilize a netw... ...ultiple energy sources.
Advanced sensors on netw... ...and communicate to
nearby devices when a... ...etect patterns that are
precursors to faults, pr... ...e event occurs.

The self-healing objecti... ...sible. This approach
can also mitigate power ... ...nditions, and
corrective steps can be ta... ..."clean" power quality
or source.

Another element of self-h... ...en impending
weather extremes, solar m... ...alyses are
incorporated into a probab... ...nderstand the risks
of each decision they may ... ...uch applications,
the expected volume of rea... ...rate those data up
to the control area, regiona... ...level, or the entire
national grid, including its ... ...and Mexico.