The Modern Grid Strategy

A VISION FOR THE SMART GRID

Developed for the U.S. Department of Energy
Office of Electricity Delivery and Energy Reliability
by the National Energy Technology Laboratory
June 2009

Office of Electricity
Delivery and Energy
Reliability

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WHY WE NEED A VISION

Before we can begin to modernize today's grid, we first need a clear vision of the power system required for the future. Understanding that vision, we can create the alignment necessary to inspire passion, investment, and progress toward the Smart Grid for the 21st century.

The Smart Grid is a necessary enabler for a prosperous society in the future. Modernizing today's grid will require a unified effort by all stakeholders aligned around a common vision. Throughout the 20th century, the U.S. electric power delivery infrastructure served our nation well, providing adequate, affordable energy to homes, businesses and factories. This once state-of-the-art system 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.

There is an urgent need for major improvements in the nation's power delivery system and the advances in key technology areas that will make these improvements possible. A vision for the Smart Grid is needed to set the foundation for a transition that focuses on achieving value in the following six areas:

The grid must be more reliable. A reliable grid provides power, 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.

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 quickly from disturbances.

The grid must be more economical. An economic grid operates under the basic laws of supply and demand, resulting in fair prices and adequate supplies.

The grid must be more efficient. An efficient grid employs strategies that lead to cost control, minimal transmission and distribution losses, efficient power production, and optimal asset utilization while providing consumers with options for managing their energy usage.

The grid must be more environmentally friendly. An environmentally responsible grid reduces environmental impacts thorough improvements in efficiency and by enabling the integration of a larger percentage of intermittent renewable resources than could otherwise be reliably supported.

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 for medical necessities.

Modernization of the nation's grid must start with building a vision, followed by the deployment of enabling technology platforms and the integration of smart grid applications that will support that vision. The approach taken by the NETL Modern Grid Strategy team provides such a comprehensive perspective.

This document describes our vision for the Smart Grid. In addition to continuing the traditional approach of large, remote, centralized generating stations providing energy to consumers using extensive transmission systems, this vision recognizes the major benefits the distribution system and end user involvement can provide. By blending the traditional centralized model with one that embraces distributed resources, demand response, advanced operational tools, and networked distribution systems, we can enjoy the benefits of both and minimize the negative aspects of each. The application of modern computing, communications, and materials sciences will enable this transformation.

THE VISION

Many are asking, "What is the Smart Grid?" Many more are trying to define it with short "sound bite" descriptions. These short statements cannot adequately convey the level of detail needed to provide a clear understanding of the Smart Grid.

The Smart Grid isn't a "thing" but rather a "vision". To be complete, the Smart Grid vision must be expressed from various perspectives — its values, its characteristics, and the milestones for achieving it. One aspect of the Smart Grid is its role as a transactive agent. That is, it will enable financial, informational, and electrical transactions among consumers, grid assets, and other authorized users.

What are the defining characteristics of the Smart Grid vision? The Principal Characteristics describe the features of the grid in terms of its functionality rather than in terms of specific technologies that may ultimately be needed. Achieving a vision that includes the following seven characteristics will enable the Smart Grid to generate value in the areas discussed above.

First, it will enable active participation by consumers. The active participation of consumers in electricity markets will bring tangible benefits to both the grid and the environment.

The smart grid will give consumers information, control, and options that allow them to engage in new "electricity markets." Grid operators will treat willing consumers as resources in the day-to-day operation of the grid. Well-informed consumers will have the ability to modify consumption based on balancing their demands and resources with the electric system's capability to meet those demands.

Demand-response (DR) programs will satisfy a basic consumer need — greater choice in energy purchases. The ability to reduce or shift peak demand allows utilities to minimize capital expenditures and operating expenses while also providing substantial environmental benefits by reducing line losses and minimizing the operation of inefficient peaking power plants. In addition, emerging products like the plug-in hybrid vehicle will result in substantially improved load factors while also providing significant environmental benefits.

Second, it will accommodate all generation and storage options. It will seamlessly integrate all types and sizes of electrical generation and storage systems using simplified interconnection processes and universal interoperability standards to support a "plug-and-play" level of convenience. Large central power plants including environmentally friendly sources, such as wind and solar farms and advanced nuclear plants, will continue to play a major role even as large numbers of smaller distributed resources, including plug-in electric vehicles, are deployed.

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 such as highly efficient combined heat and power installations and electric storage facilities.

Third, it will enable new products, services, and markets. The Smart Grid will link buyers and sellers together — from the consumer to the Regional Transmission Organization (RTO) — and all those in between. It will support the creation of new electricity markets ranging from the home energy management system at the consumers' premises to the technologies that allow consumers and third parties to bid their energy resources into the electricity market.

Consumer response to price increases felt through real-time pricing will mitigate demand and energy usage, driving lower-cost solutions and spurring new technology development. New, clean energy-related products will also be offered as market options.

The Smart Grid will support consistent market operation across regions. It 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 located closer to the consumer.

Fourth, the Smart Grid will provide power quality (PQ) for the digital economy. It will monitor, diagnose, and respond to power quality deficiencies, leading to a dramatic reduction in the business losses currently experienced by consumers due to insufficient power quality. New power quality standards will balance load sensitivity with delivered power quality. The Smart Grid will supply varying grades of power quality at different pricing levels.

Additionally, power quality events that originate in the transmission and distribution elements of the electrical power system will be minimized and irregularities caused by certain consumer loads will be buffered to prevent impacting the electrical system and other consumers.

Fifth, it will optimize asset utilization and operate efficiently. Operationally, the Smart Grid will improve load factors, lower system losses, and dramatically improve outage management performance. The availability of additional grid intelligence will give planners and engineers the knowledge to build what is needed when it is needed, extend the life of assets, repair equipment *before* it fails unexpectedly, and more effectively manage the work force that maintains the grid. Operational, maintenance, and capital costs will be reduced thereby keeping downward pressure on electricity prices.

Sixth, it will anticipate and respond to system disturbances (self-heal). It will heal itself by performing continuous self-assessments to detect and analyze issues, take corrective action to mitigate them and, if needed, rapidly restore grid components or network sections. It will also 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.

The self-healing grid will minimize disruption of service by employing modern technologies that can acquire data, execute decision-support algorithms, avert or limit interruptions, dynamically control the flow of power, and restore service quickly. Probabilistic risk assessments based on real-time measurements will identify the equipment, power plants, and lines most likely to fail. Real-time contingency analyses will determine overall grid health, trigger early warnings of trends that could result in grid failure, and identify the need for immediate investigation and action.

Communications with local and remote devices will help analyze faults, low voltage, poor power quality, overloads, and other undesirable system conditions. Then appropriate control actions will be taken, automatically or manually as the need determines, based on these analyses.

Seventh and finally, the Smart Grid will operate resiliently against attack and natural disaster. The Smart Grid will incorporate a system-wide solution that reduces physical and cyber vulnerabilities and enables a rapid recovery from disruptions. Its resilience will deter would-be attackers, even those who are determined and well equipped. Its decentralized operating model and self healing features will also make it less vulnerable to natural disasters than today's grid.

Security protocols will contain elements of deterrence, detection, response, and mitigation to minimize impact on the grid and the economy. A less susceptible and more resilient grid will make it a more difficult target for terrorists.

These seven characteristics represent the unique yet interdependent features that define the Smart Grid. The table below summarizes these seven points and contrasts today's grid with the vision for the Smart Grid.

Today's Grid	Principal Characteristic	Smart Grid
Consumers are uninformed and do not participate with the power system	***Enables Consumer Participation***	Full price information available, choose from many plans, prices, and options to buy and sell
Dominated by central generation, very limited distributed generation and storage	***Accommodates All Generation & Storage Options***	Many "plug and play" distributed energy resources complement central generation
Limited wholesale markets, not well integrated	***Enables New Markets***	Mature, well-integrated wholesale markets, growth of new electricity markets
Focus on outages rather than power quality	***Meets PQ Needs***	PQ a priority with a variety of quality and price options according to needs
Limited grid intelligence is integrated with asset management processes	***Optimizes Assets & Operates Efficiently***	Deep integration of grid intelligence with asset management applications
Focus on protection of assets following fault	***Self Heals***	Prevents disruptions, minimizes impact, and restores rapidly
Vulnerable to terrorists and natural disasters	***Resists Attack***	Deters, detects, mitigates, and restores rapidly and efficiently

THE MILESTONES

Smart Grid milestones represent the building blocks of the Smart Grid. Completion of each requires the deployment and integration of various technologies and applications. "One size does not fit all" — that is, the sequence for implementing these milestones and the degree of implementation will depend on the specific circumstances of those involved. The Smart Grid milestones include the following:

Consumer Enablement will empower consumers by giving them the information and education they need to effectively utilize the new options provided by the Smart Grid. This includes solutions such as advanced metering infrastructure, home area networks with in-home displays, distributed energy resources, and demand response programs as well as upgrades to utility information technology architecture and applications that will support "plug-and-play" integration with all future Smart Grid technologies.

Advanced Distribution Operations will improve reliability and enable "self-healing." It includes solutions such as smart sensors and control devices, advanced outage management, distribution management and distribution automation systems, geographical information, and other technologies to support two-way power flow and micro-grid operation.

Advanced Transmission Operations will integrate the distribution system, both the consumer enablement and advanced distribution operations milestones, with RTO applications to improve overall grid operations and reduce transmission congestion. Advanced transmission operations includes substation automation, integrated wide area measurement applications, power electronics, advanced system monitoring and protection schemes, as well as modeling, simulation, and visualization tools to increase situational awareness and provide a better understanding of real time and future operating risks.

Advanced Asset Management (AAM) will integrate the grid intelligence acquired in achieving the other milestones with new and existing asset management applications. This integration will enable utilities to reduce operations, maintenance, and capital costs and better utilize assets during day-to-day operations. Additionally, advanced asset management will significantly improve the performance of capacity planning, maintenance, engineering and facility design, customer service processes, and work and resource management.

The Smart Grid will perform in all its various operating modes:

- **Emergency response**—The Smart Grid will provide advanced analysis to predict problems before they occur and to assess problems as they develop. This allows actions such as system reconfiguration and islanding to be taken in a timely manner to minimize impacts.

- **Restoration**—It can take days or weeks to return today's grid to full operation after an emergency. The Smart Grid will be restored faster and at a lower cost as better information, control, and communications tools become available to assist operators and field personnel.
- **Routine operations**—With the Smart Grid, operators will better understand the state and trajectory of the grid, provide recommendations for secure operation, and allow appropriate controls to be initiated. They will depend on the help of advanced visualization and control tools, fast simulations, and decision-support capabilities. Some operations will be fully automated when decisions need to be made faster than is possible by operators.
- **Optimization**—The Smart Grid will provide advanced tools to understand conditions, evaluate options, and exert a wide range of control actions to optimize grid performance from reliability, environmental, efficiency, and economic perspectives. New peak-shaving and load-factor-improving strategies will be employed.
- **System planning**—Grid planners must analyze projected growth in supply and demand to guide their decisions about what to build, when to build, and where to build. Smart Grid data mining and modeling will provide more accurate information to answer those questions.

SUMMARY

The Smart Grid vision generally describes a power system that is more intelligent, more decentralized and resilient, more controllable, and better protected than today's grid.

Much work remains to be done to achieve this vision. The integration of existing technologies, the development of new ones, and the integrated testing of both to demonstrate their benefits are all needed. Regulatory and legislative reform is needed since many of today's regulations and statutes are inconsistent with this vision. New standards must be developed and some existing standards will require changes. Various process issues must be resolved. Metrics are also needed to provide a basis for measuring our progress towards this vision. And perhaps, the most important of all, the totality of societal benefits must be included in Smart Grid investment decisions.

A clear understanding and consensus for this vision among all stakeholders will generate a huge force for change. Only through their combined efforts can this vision for the Smart Grid become a reality. It is a big job, but we can do it by working together. The work is already underway by the Modern Grid Strategy team and its partner organizations. Your active participation is essential as we lay out the framework for a modernized grid that can enable our nation's future growth and preserve our global competitiveness and way of life.

For more information

This document is part of a collection of documents prepared by The Modern Grid Strategy team. All are available for free download from the Modern Grid website.

The Modern Grid Strategy

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