The NETL Modern Grid Initiative

A Vision for The Modern Grid

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TABLE OF CONTENTS

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. Given that vision, we can create the alignment necessary to inspire passion, investment, and progress toward an advanced US grid for the 21st century.

A modernized grid is a necessary enabler for a successful society in the future. Modernizing today's grid will require a unified effort by all stakeholders rallying 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.

Many agree there is an urgent need for major improvements in the nation's power delivery system and that advances in key technology areas can make these improvements possible. But more is needed. The Modern Grid vision will set the foundation for a transition that will focus on meeting the six key goals discussed below:

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.

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.

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.

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.

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. Where possible, future designs for Modern Grid assets will occupy less land reducing the physical impact on the landscape.

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.

The nation's grid should be modernized not by randomly gathering a group of interesting technologies and calling it modern, but rather by first building a vision and the framework that enables that vision. The systems view taken by the NETL MGI team provides such a comprehensive perspective.

This document describes our vision for the Modern Grid. The vision discussed in this document modifies the traditional approach that was used in developing today's grid. In addition to continuing the traditional approach based on large, remote, central generating stations (coal, nuclear, hydroelectric, natural gas, renewables, etc.) providing energy to consumers through 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.

A Call to Action is included at the end of this document to solicit your input on further developing the vision and other aspects of the Modern Grid Initiative.

THE VISION

Vision statements are often used to help define the future state for government and business. A vision statement for the Modern Grid could be stated as:

"To revolutionize the electric system by integrating 21st century technology to achieve seamless generation, delivery, and end-use that benefits the nation."

But a vision statement such as the one above does not adequately convey the level of detail necessary to support a clear understanding for stakeholders.

Additional detail that supports this vision statement is needed to provide a platform for debate and an opportunity to gain consensus among all stakeholders. Beginning with the goals described in the previous section and the broad vision statement presented above, we must move to the next level of detail in defining the overall vision. This will provide the level of understanding needed to stimulate debate and ultimately enable stakeholder alignment.

But what are the defining characteristics of this vision? These characteristics should describe the features of the grid in terms of its functionality rather than in terms of specific technologies that may ultimately be needed. Reaching a vision that includes the seven characteristics described below will enable the Modern Grid to achieve its goals.

First, it 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.

The self-healing grid will minimize disruption of service, 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.

Second, it will motivate consumers to be an active grid participant 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.

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 the operation of inefficient peaking power plants. Over time, DR will also encourage consumers to replace inefficient end use devices such as incandescent lighting. In addition, emerging products like the plug-in hybrid vehicle will result in substantially improved load factors while also providing huge environmental benefits.

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. The Modern Grid will demonstrate resilience to attack, even from those who are determined and well equipped. 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 will contain elements of deterrence, prevention, detection, response, and mitigation to minimize impact on the grid and the economy. A less susceptible and more resilient grid will make it a less desirable target of terrorists.

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.

Additionally, PQ 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. The digital, high-tech economy has raised the bar for quality beyond the capabilities of today's grid.

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 "plug-and-play".

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 (including highly efficient combined heat and power installations) and electric storage facilities.

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 in the Modern Grid. Enhanced transmission systems will accommodate their typically remote location. This wide variety of generation and storage options will enable the United State's dependence on foreign energy sources to be reduced.

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.

Parameters such as energy, capacity, rate of change of capacity, congestion, and resiliency may be most efficiently managed through the supply and demand interactions of markets. By reducing congestion, the modernized grid expands markets; it brings together more buyers and sellers. Consumer response to price increases felt through real time pricing will mitigate demand, driving lower-cost solutions and spurring new technology development. New, clean energy related products will also be offered as market options.

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 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. This same information will provide designers and engineers with better tools for creating optimal designs. Planners who make recommendations for capital projects to increase system capacity will have the data they need to improve their processes. As a result, O&M and capital expenses will be more effectively managed.

The seven characteristics described above represent unique yet interdependent features that refine the Vision of the Modern Grid. Table 1 below summarizes these seven points and contrasts them between today's grid and the Vision of the Modern Grid.

Today's Grid	Principal Characteristic	Modern Grid
Responds to prevent further damage. Focus is on protection of assets following system faults.	**Self-heals**	Automatically detects and responds to actual and emerging transmission and distribution problems. Focus is on prevention. Minimizes consumer impact.
Consumers are uninformed and non-participative with the power system.	**Motivates & includes the consumer**	Informed, involved and active consumers. Broad penetration of Demand Response.
Vulnerable to malicious acts of terror and natural disasters.	**Resists attack**	Resilient to attack and natural disasters with rapid restoration capabilities.
Focused on outages rather than power quality problems. Slow response in resolving PQ issues.	**Provides power quality for 21st century needs**	Quality of power meets industry standards and consumer needs. PQ issues identified and resolved prior to manifestation. Various levels of PQ at various prices.
Relatively small number of large generating plants. Numerous obstacles exist for interconnecting DER.	**Accommodates all generation and storage options**	Very large numbers of diverse distributed generation and storage devices deployed to complement the large generating plants. "Plug-and-play" convenience. Significantly more focus on and access to renewables.
Limited wholesale markets still working to find the best operating models. Not well integrated with each other. Transmission congestion separates buyers and sellers.	**Enables markets**	Mature wholesale market operations in place; well integrated nationwide and integrated with reliability coordinators. Retail markets flourishing where appropriate. Minimal transmission congestion and constraints.
Minimal integration of limited operational data with Asset Management processes and technologies. Siloed business processes. Time based maintenance.	**Optimizes assets and operates efficiently**	Greatly expanded sensing and measurement of grid conditions. Grid technologies deeply integrated with asset management processes to most effectively manage assets and costs. Condition based maintenance.

Table 1: Comparison between Today's Grid and the Modern Grid

The Modern Grid is expected to perform consistent with this vision in all of its various operating modes. These performance modes include:

- **Emergency response** – A modernized grid provides advanced analysis to predict problems before they occur and to assess problems as they develop. This allows steps to be taken to minimize impacts and to respond more effectively.
- **Restoration** – It can take days or weeks to return today's grid to full operation after an emergency. A modernized grid can be restored faster and at lower cost as better information, control and communications tools become available to assist operators and field personnel.
- **Routine operations** – With a modernized grid, operators can 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** –A modernized grid provides 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 are 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. Modern Grid data mining and modeling will provide much more accurate information to answer those questions.

The details described above expand on the vision statement presented earlier and establish a foundation from which debate among all stakeholders can begin. The ultimate objective is to reach a national consensus for the vision of the Modern Grid.

SUMMARY

These seven characteristics describe a vision for the Modern 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 a unique and more synergistic 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.

Much work remains to be done to achieve this vision. The integration of existing technologies, the development of new ones and integrated testing to show their benefits are all needed. Regulatory and legislative reform to modify regulations and statutes that are inconsistent with this vision is also needed. New standards must be developed and some existing standards will require changes. Various process issues must be resolved. We also need metrics to provide the milestones for measuring our progress towards this vision. And perhaps, most important of all, the totality of societal benefits must be included in the calculus of Modern Grid investments to provide the financial incentive needed to move us forward.

A clear understanding and consensus for this vision among all stakeholders will generate a huge force for change. Only through their aligned efforts can this vision for the Modern Grid become a reality. It is a big job, but we can do it by working together. The work is already underway at MGI and its partner organizations. But we need your active support in making grid modernization an essential part of our national energy policy. 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.

CALL TO ACTION

Creating the Modern Grid will require a monumental effort by all stakeholders. With a clear vision, we can generate the alignment needed to inspire passion, investment, and movement toward that vision. Your input is needed, along with your acceptance, which will ultimately lead to a national consensus for the Modern Grid vision.

We want your thoughts. Visit our website at www.TheModernGrid.org to find out how you can become involved or to speak directly with a team member.

For more information

This document is part of a collection of documents prepared by The NETL Modern Grid Initiative team. All are available for free download from the Modern Grid Web site.

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