

Toward a smarter grid ABB's Vision for the Power System of the Future

Toward a Smarter Grid

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There is a convergence occurring between the business realities of the utility industry, the energy demands of modern society, and the sustainability requirements of the environment in which we live. The combination of these factors is driving the development and implementation of a new power delivery system. This network will utilize the same basic infrastructure we know today, but will also draw on advanced monitoring, control and communications technology that is presently only beginning to be applied.

The result will be a grid that is largely automated, applying greater intelligence to operate, monitor and even heal itself. This “smart grid” will be more flexible, more reliable and better able to serve the needs of a digital economy.

What's wrong with the grid today?

Given the level of reliability we are accustomed to in North America, it's easy to overlook the unattractive truth that our investments in our power system have long been outpaced by the demands we place upon it. While transmission spending, for example, has increased in recent years, it still lags the pace of increasing energy consumption. According to a Morgan Stanley analysis, power outages cost the U.S. economy between \$25 billion and \$180 billion every year.

The grid is also not performing at the same level it was decades ago. Energy losses in the transmission and distribution system nearly doubled from 5 percent in 1970 to 9.5 percent in 2001. There is also a considerable security risk in the design of the grid with centralized generation plants serving distant loads over long transmission lines. However, adding more distributed generation, in particular variable sources like wind and solar, present new operational challenges.

Meanwhile, changes in the way electricity is bought and sold at the wholesale level have drastically increased the amount of power being traded between regions. Even the way we use electricity has changed. In our digital society, power quality is of much greater importance than it was just 15 years ago, both for end consumers and businesses like chip manufacturing, where even small disturbances in the power supply can have detrimental effects to production.

Taking all of these factors into consideration, it becomes apparent that the grid we know today is insufficient to serve us in the future.

What makes a grid “smart”?

There is a great deal of variation both within the power industry and outside it as to what exactly should be included under the idea of a smart grid. Ask a room full of utility professionals to define the term and you're likely to get a wide range of answers. Similarly, most consumers would likely associate smart meters or home automation with the concept of a smart grid, but there is much more to the picture.

ABB takes an expansive view of the smart grid, defining it by its capabilities and operational characteristics rather than by the use of any particular technology. Deployment of smart grid technologies will occur over a long period of time, adding successive layers of functionality and capability onto existing equipment and systems. Technology is the key, but it is only a means to an end—the smart grid can and should be defined by broader characteristics.

In June of 2008, the U.S. Department of Energy held a meeting of industry leaders who identified seven defining traits of what a smart grid will do:

- 1 Optimize asset utilization and operating efficiency.
- 2 Accommodate all generation and storage options.
- 3 Provide power quality for the range of needs in a digital economy.
- 4 Anticipate and respond to system disturbances in a self-healing manner.
- 5 Operate resiliently against physical and cyber attacks and natural disasters.
- 6 Enable active participation by consumers.
- 7 Enable new products, services, and markets.

What is not explicitly stated here, but is equally important, is that a fully developed smart grid concept goes far beyond smart meters. It includes technologies at both the transmission and distribution level and extends to both IT hardware and software, such as monitoring and control systems, as well as primary equipment like transformers and relays.

ABB's list of smart grid criteria covers much of the same ground as DOE's, but focuses on broad characteristics rather than specific functions. Under this model, the smart grid is:

- Adaptive, with less reliance on operators, particularly in responding rapidly to changing conditions.
- Predictive, in terms of applying operational data to equipment maintenance practices and even identifying potential outages before they occur.
- Integrated, in terms of real-time communications and control functions.
- Interactive between customers and markets.
- Optimized to maximize reliability, availability, efficiency and economic performance.
- Secure from attack and naturally occurring disruptions.

So how does the smart grid differ from the one we know today?

The table below provides a concise summary of some of the differences as they appear in various parts of

| | Current Grid | Smart Grid |
|-----------------------------------|---|--|
| Communications | None or one-way; typically not real-time | Two-way, real-time |
| Customer interaction | Limited | Extensive |
| Metering | Electromechanical | Digital (enabling real-time pricing and net metering) |
| Operation and | Manual equipment checks, maintenance | Remote monitoring, predictive, time-based maintenance |
| Generation | Centralized | Centralized and distributed |
| Power flow control | Limited | Comprehensive, automated |
| Reliability | Prone to failures and cascading outages; essentially reactive | Automated, pro-active protection; prevents outages before they start |
| Restoration following disturbance | Manual | Self-healing |
| System topology | Radial; generally one-way power flow | Network; multiple power flow pathways |

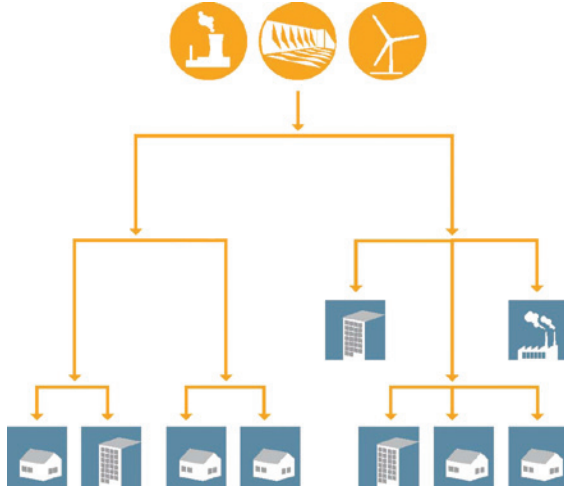
Adapted from Research Reports International

From hierarchy to network

The last item in the table, topology, hints at what is perhaps the most fundamental shift that a fully realized smart grid will require. Today's power systems are designed to support large generation plants that serve faraway consumers via a transmission and distribution system that is essentially one-way. But the grid of the future will necessarily be a two-way system where power generated by a multitude of small, distributed sources—in addition to large plants—flows across a grid based on a network rather than a hierarchical structure.

Just as the internet has driven media from a one-to-many paradigm to a many-to-many arrangement, so too will the smart grid enable a similar shift in the flow of electricity.

Today's hierarchial power system



Fully realized smart grid



The diagrams above illustrate this shift. In the first, we see today's hierarchical power system, which looks much like an organizational chart with the large generator at the top and consumers at the bottom. The second diagram shows a network structure characteristic of a fully implemented smart grid.

Standards: the key to interoperability

Interoperability—the capacity for devices from various manufacturers to work together—is vital to the realization of a network-based smart grid, and the key to interoperability is standards. Indeed, the entire smart grid proposition is predicated on open communications between the “smart” devices using common protocols. DNP3, for example, is a widely used communications protocol in substation applications and is the de facto standard in North America.

IEC 61850 is an “open source” alternative to DNP3 and other proprietary protocols that has been adopted rapidly since its introduction. However, for various reasons it has not penetrated the North American market to the same degree as in other parts of the world. Other standards will be integral to smart grid deployments of various kinds.

For example, there is broad agreement that the grid of the future will feature far more distributed generation resources than today's largely centralized system. One standard, IEEE 1547, addresses grid interconnection for distributed resources and the broader adoption of this standard will ease the development of more distributed generation resources.

The U.S. National Institute of Standards and Technology (NIST) has begun a process to identify and propagate key smart grid-related standards within the power industry. These include the standards mentioned above, as well as some that are specific to other portions of grid operations. In the near term, however, it will be especially important for equipment vendors across the electricity value chain to supply “multi-lingual” devices that can communicate using standardized protocols, preferably more than one. Proprietary systems simply do not provide the flexibility required to achieve widespread adoption.

Benefits: what good is a smart grid?

The transition to a fully implemented smart grid brings a host of benefits to a wide range of constituencies.

Grid operators will enjoy a quantum improvement in monitoring and control capabilities that will, in turn, enable them to deliver a higher level of system reliability, even in the face of ever-growing demand.

- Utilities will experience lower distribution losses, deferred capital expenditures and reduced maintenance costs.
- Consumers will gain greater control over their energy costs, including generating their own power, while realizing the benefits of a more reliable energy supply.
- The environment will benefit from reductions in peak demand, the proliferation of renewable power sources, and a corresponding reduction in emissions of CO₂, as well as pollutants such as mercury.

To put a number to these benefits, EPRI has estimated that an investment of \$165 billion in smart grid technology, integration and development will produce between \$638 billion and \$802 billion. That implies a cost-benefit ratio of between 4:1 and 5:1.

It's important to understand that, in many cases, these benefits have a symbiotic relationship to one another. Reliability and efficiency, for example, are two important objectives of any power system. With a smart grid, though, technologies applied primarily to improve one will often improve the other at the same time.

Power electronics devices known in the industry as FACTS (flexible AC transmission systems) enhance reliability by making transmission lines more resilient and less vulnerable to system disturbances. FACTS also greatly increase the capacity of transmission lines, making them far more efficient. This is just one example of how smart grid technologies can achieve multiple objectives simultaneously.

Smart grid technologies in use today

Utility companies are already implementing “smart” devices in various ways. Some examples of how smart technologies—and the practices they enable—can impact the operation and overall health of the grid include the following:

- Real-time situational awareness and analysis of the distribution system can drive improved system operational practices that will, in turn, improve reliability.
- Fault location and isolation can speed recovery when outages do occur by allowing work crews to drastically narrow the search for a downed line.
- Substation automation (SA) enables utilities to plan, monitor, and control equipment in a decentralized way, which makes better use of maintenance budgets and boosts reliability.
- Smart meters allow utility customers to participate in time-of-use pricing programs and have greater control over their energy usage and costs.
- SCADA/DMS (distribution management systems) put more analysis and control functions in the hands of grid operators.
- Voltage control, through reactive power compensation and the broader application of power electronics, increases transmission capacity of existing lines and improves the resiliency of the power system as a whole.

Of course, this is not an exhaustive list. Smart grid technologies similar to those used for voltage control, for example, are already being applied to bring power from wind farms to the local grid. In this way, the smart grid acts as an enabler for all forms of renewable generation.

Smart grid drivers

The forces driving the development of the smart grid are as varied as they are influential. Environmental concerns are increasing around the globe, and that is driving the expansion of renewable energy on a larger scale than ever before. The widespread addition of wind, solar and other renewables presents operational challenges due to those sources' intermittent nature. A grid that can handle a generation mix with a high percentage of renewables, therefore, will become a necessity for those technologies to realize their full potential.

The efficiency of the power grid itself has also come under examination, as even in the most modern systems, up to 8 percent of the electricity leaving a power plant is lost in the transmission and distribution network. Reliability, for years the chief concern of utilities and grid operators, is now only one of a wide range of considerations in power system planning, operation and management. Energy efficiency has now come to the fore as another key issue that, in many cases (notably in areas suffering from transmission congestion), is closely linked with reliability.

On the demand side, energy consumers are seeking ever greater control over their energy usage and the application of technology is already meeting this need. Residential smart meters, for example, allow utility customers to take advantage of time-of-use pricing that was formerly available only to large commercial/industrial users. Self-generation (e.g., using rooftop solar) is also on the rise and is driving a need for net metering to manage power sales from many small-scale generators.

Regulators have taken note of all these trends. There are now many examples of regulatory support for expanding renewable generation, increasing grid efficiency and enhancing system reliability. These efforts range from local government actions to ease the installation of rooftop solar panels, to state/provincial requirements for renewable generation, national reliability standards and cross-border agreements for improved interconnection between power systems.

Status of smart grid development in the U.S. and beyond

All of these elements, from the economic to the environmental, are amplifying the need for the grid to evolve. We need our power delivery infrastructure to do more, much more than it does today. To meet the many challenges facing it, the grid needs an infusion of intelligence, most of all at the distribution level.

The first steps toward a fully realized smart grid are being taken now, and the potential investment is substantial. EPRI estimates the market for smart grid-related projects in the U.S. will be around \$13 billion per year over the next 20 years. That comes in addition to an estimated \$20 billion per year spent on transmission and distribution projects generally. More recently, a Morgan Stanley report analyzing the smart grid market put current investment at \$20 billion per year, increasing to over \$100 billion per year by 2030.

Despite these remarkable forecasts, however, smart grid deployments still represent a major departure from current utility practices. For an industry with a time honored focus on reliability and certainty in the application of new technologies, the shift to smart grid presents a daunting challenge. However, some exciting projects are already underway.

ABB is working as part of a consortium in Germany to develop a "minimum emissions region." The MEREGIO project, as it is known, will integrate renewable, distributed generation and provide the grid operator with real-time information on conditions across the network. This will enable the operator to predict power flow, adapt rapidly to changing situations, send price signals to the consumer to encourage demand or restrain it if there is risk of a bottleneck, and create a regional energy market that incorporates end customers.

Consumers will be able to monitor their energy consumption and CO2 footprint, respond to price signals and adapt consumption according to price and availability. They will also be able to sell surplus power from their own generators to the grid when price conditions are most favorable. Similar demonstration projects are being undertaken around the world.

The role of government

The U.S. is home to several consortia working on smart grid issues. EPRI's IntelliGrid program and DoE's GridWise Alliance are just two examples. Likewise, the nation's utilities are actively involved with approximately 80 percent of investor-owned utilities developing some form of smart grid, for example by participating in pilot studies of wide area monitoring systems (WAMS).

However, while programs like MEREGIO and Excel Energy's Smart Grid City in Boulder, Colorado are important to advance smart grid technologies in real-world applications, the widespread adoption of these technologies will likely depend to a great extent on governmental support of various kinds.

In the U.S., the Energy Policy Act of 2005 (EPAAct) introduced mandatory reliability standards and required state regulators to investigate advanced metering, time-based pricing, and demand response programs, all of which will rely on smart grid advances. The Energy Independence and Security Act of 2007 (EISA) included an entire title devoted to smart grid that provided funding for R&D efforts, created a Smart Grid Advisory Committee, and requires state regulators to consider smart grid alternatives before approving investments in traditional technologies.

Most recently, the American Recovery and Reinvestment Act of 2009 makes provisions for \$11 billion in funding for grid improvements with a heavy emphasis on the application of smart grid technologies. Specifically, ARRA provides \$4.5 billion in grants, \$2.3 billion in tax credits and another \$6 billion in federal loan guarantees, all aimed at upgrading the nation's power systems. These funds are directed toward a number of specific activities, ranging from grants for R&D in energy storage to matching funds for new T&D construction.

Notably, one provision sets aside \$10 million for the creation of a smart grid interoperability framework. It's a comparatively tiny drop in a large bucket, but, as noted earlier, standards are vital to accelerate the adoption of smart grid technologies across the utility industry. The National Institute of Standards and Technology (NIST) is leading the standards effort and, in May 2009, published an initial list of standards that will be used in smart grid development.

The government will also play a major role in the development of the smart grid through its many regulatory agencies, both state and federal. EPAAct (2005), for example, established a mechanism for creating so called National Interest Electric Transmission Corridors to speed up the approval process for new transmission lines in heavily congested areas.

The Federal Energy Regulatory Commission (FERC) recently issued an interim rate policy, whereby smart grid investments would be included as recoverable costs in a utility's regulated rates. FERC has also joined with the National Association of Regulatory Utility Commissioners to create a Smart Grid Collaborative of regulators at the state and federal level. Among other things, the Collaborative has made recommendations to the Department of Energy on the criteria to be used in funding projects through ARRA.

These examples are only the beginning. Whether in the role of advisor, regulator, policymaker or even banker, the government holds tremendous influence over the course of smart grid development.

Conclusion

The smart grid is more than any one technology, and the benefits of making it a reality extend far beyond the power system itself. The transition from the grid we know today to the grid of tomorrow will be as profound as all of the advances in power systems over the last hundred years, but it will take place in a fraction of that time.

That said, this transition will not be easy. The integration of smart technologies of many different kinds will be essential to a functioning smart grid, and the path to integration is lined with interoperability standards. Realizing smart grids' potential will require a new level of cooperation between industry players, advocacy groups, the public and especially the regulatory bodies that have such immediate influence over the direction the process will take. In the end, though, a fully realized smart grid will benefit all stakeholders.

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