Smart Grid Principal Characteristics

ACCOMMODATES ALL GENERATION AND STORAGE OPTIONS

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EXECUTIVE SUMMARY

The smart grid is defined by its seven principal characteristics. One of those characteristics is "accommodates all generation and storage options." How this characteristic might be attained is the subject of this paper.

One enabler of economic growth is the quality of a nation's power generation and delivery system. Today, our electricity grid is powered primarily by large, centralized generation facilities with only a minor contribution from small distributed energy resources (DER) which include both distributed generation and storage. In the future, the contribution of DER must grow so our nation can realize the benefits that decentralized resources and two-way power flow on the distribution system can provide.

A smarter grid will be needed to accommodate not only large, centralized power plants, but also a much wider range and greater number of DER. These distributed resources include renewables, distributed generation, energy storage and plug-in electric vehicles. And their deployment will increase rapidly all along the value chain, from suppliers to marketers to consumers.

This characteristic of the smart grid will enable the generation portfolio to move toward a more decentralized model that will include a balance of large, centralized generating plants as well as DER.

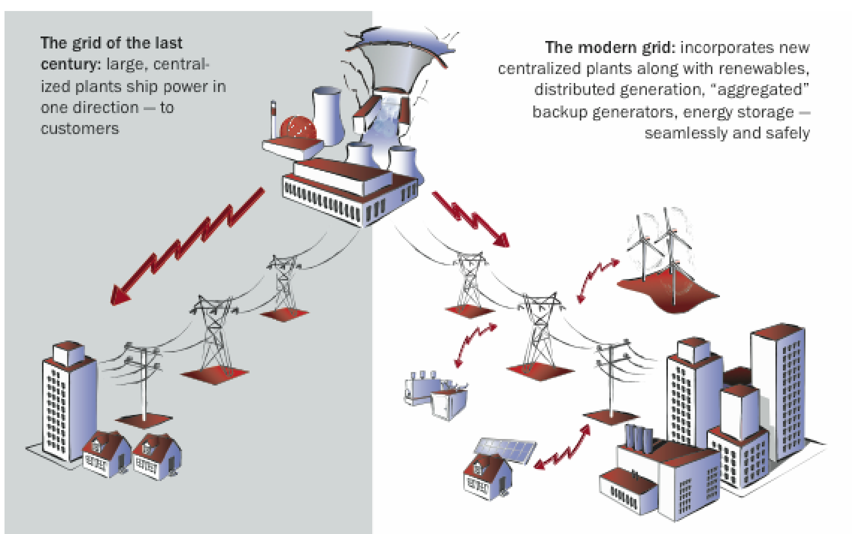

Figure 1: The Smart Grid accommodates all generation and storage options

Current and Future States

Before we discuss *how* to support a wide variety of generation options, we need to understand where we are today and what kinds of options will be accessible tomorrow. This section explores the current state and the probable future state of distributed generation and storage.

Current State

A substantial gap exists between the desirable amounts of DER and what we have today, particularly in the renewables category. The U.S. is dominated by big, centralized generating facilities. Large generators (coal, nuclear, and hydro) made up nearly 74% of net generation in 2007. Only 2% of the energy generated was from renewables. Of the DER that currently exists, most are from internal combustion engines and are not connected to the grid.

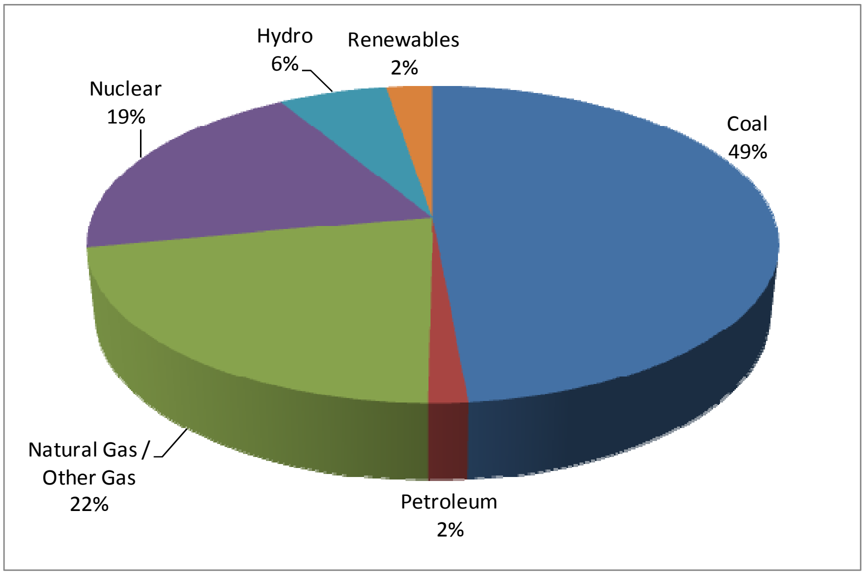

Figure 2: The U.S. Net Generation by Energy Source

Distributed generation (DG) contributes only a small amount to our nation's electricity supply. As of 2005, approximately 12.3 million DG units were installed in the United States. Collectively these units represented approximately 234 gigawatts of capacity; however, less than 1 percent of them are connected to the grid. The majority of these units are small reciprocating engines used to supply emergency or standby power. The remainder is made up of combined heat and power units (CHP) and combustion turbines.

FUTURE STATE

The future offers several growth pathways for DER, depending on how technologies and markets evolve. The Smart Grid will experience a significant growth of DER:

Figure 3: Renewable generation sources are an important option: the smart grid must enable the integration of intermittent resources such as wind turbines.

1. DER numbers will increase dramatically. The Smart Grid must expect and enable a substantial increase in the number of new energy sources. Renewable portfolio standard (RPS) programs require investor-owned utilities to provide a more significant portion of their electricity from renewable sources many of which will be distributed. DER is also likely to grow rapidly among consumers as the total cost of ownership is reduced, more favorable regulations are created, profit incentives are made increasingly available and the desire to reduce the impact on the environment increases.

2. DER will be everywhere. Deployment will occur throughout the distribution system. Utilities will install it. Power marketers will embrace it. And all types of consumers—commercial, industrial, residential—will adopt it. DER will be located close to the consumers as well as aggregated into centralized energy farms where appropriate. The grid will be expected to enable the same widespread deployment of DER that occurred with personal computers, cell phones, and the Internet. The plug-in hybrid electric vehicle (PHEV) connected in the "vehicle to grid" mode is positioned to be a game changing technology providing new options for generation and storage "everywhere."

3. DER will be grid-connected. Stand-alone generation will continue to be common. But in the future, more DER will be connected to the grid at many different points—at transmission voltages, at distribution voltages, and in AC and DC networks and micro-grids. Solutions will be found to make existing back-up generators (BUGs) attractive for interconnection, including methods to significantly reduce their environmental impact.

4. DER will be aggregated. For instance, wind and solar units may be aggregated into energy "farms" and scattered backup generators utilized as "peaking plants." In addition, virtual plants, in which many geographically diverse generators are coordinated to act as a single large unit, will be created through the utilization of advanced computer and communications technologies.

5. DER will be diverse. DER will not be dominated by any one size or type of generation or storage. Instead, it will include a wider variety, ranging from those already available to those not yet invented. In particular, the Smart Grid will greatly facilitate the interconnection of renewable DER and will also enable a deeper penetration of intermittent sources than could otherwise be reliably accommodated.

The diversity of DER will include many individual sources that have relatively small capacities such as photovoltaic (PV) arrays, wind turbines, fuel cells, plug-in hybrid vehicles, and advanced energy storage. These devices will typically be connected to medium- and low-voltage distribution lines or will become part of a micro-grid. Their benefits and affordability will lead to a significant increase in the deployment of DER by consumers. In fact, consumers may represent the largest market well into the next decade as they use distributed generation to save money and improve reliability.

But diversity will include larger plants, too. Large power customers and marketers will invest in CHP units and non-utility generation facilities. Combustion turbines will be built at a rate consistent with fuel costs and will be located closer to load centers than conventional, centralized power stations.

As we now turn our attention to what is required to reach our DER goals, it is important to remember that the Smart Grid must also accommodate new centralized plants. We will continue to need conventional, large, centralized power stations to help meet the expected future increase in demand. A smarter grid and a bigger grid are complementary.

REQUIREMENTS

Accommodating all generation and storage options will impose a number of new requirements on the Smart Grid.

Time of Use and Real-Time pricing is needed to encourage consumers to invest in DER. Price signals based on the dynamic wholesale price of electricity are needed to provide that incentive. Advanced metering infrastructure systems can provide the metering and communication infrastructure to support the effective integration of such price signals.

Applications and standards that provide "plug and play" functionality are needed to support DER implementation. Interconnection standards that are simple and safe are needed to promote interconnection (the "plug"). Applications that recognize devices when they are connected and can act upon the status of the DER and the permission settings pre-programmed by the owner will enable simple and immediate interaction between DER and grid operators (the "play"). The development of these standards and applications will enable DER to be easily and economically integrated with the Smart Grid—similar to the "plug and play" convenience we enjoy today with many of our computing and communication devices.

Operational and planning tools are needed to incorporate large numbers of generation sources that are smaller, decentralized, and often intermittent. Some of these tools include:

- New operating models and algorithms that address the transient and steady-state behavior of a grid that employs a deep penetration of DER.
- Improved operator visualization techniques and new training methodologies to enable system operators (both of distribution and transmission) to work together to manage decentralized systems in both routine and emergency operations.
- Advanced simulation tools that can provide a more complete understanding of grid behavior where a large number of diverse DER units are deployed.
- Methods for resolving the unique maintenance and operational challenges created by the interaction among DER, demand response, other new generation sources, and advanced storage.
- Advanced system-planning tools that assess the benefits and challenges (and consider the uniqueness) of DER for locating optimal sites for new power stations.

- Improved short-term forecasting algorithms that allow confident prediction of the availability of intermittent sources.

Smart sensors and controls are needed for integrating DER into the grid. Lower cost sensors, protective devices, and controls will reduce DER installation costs, ensure stable operation of interconnected DER units, and safeguard line crews and the public during maintenance and restoration. On the customer side of the meter, home energy-management systems are needed to monitor and control DER operations and demand-response requests from the utility.

BARRIERS

Although some DER adoption is occurring today, significant barriers remain to meeting the requirements of the future that will enable full-scale deployment.

- **Total cost of ownership is high.** Although improving, the lifetime cost (investment, operation, maintenance, fuel, etc.) is generally too high for DER devices to compete with traditional alternatives. Advances in research, development and commercialization are needed to make these costs more competitive with conventional power generation. Because of environmental and cost considerations, very little of the U.S. distributed generation capacity (234 gigawatts) is connected to the grid and dispatched by system operators. Perhaps this existing fleet where the capital investment has already occurred— and PHEV's—are good places to pursue a broader deployment of integrated DER at the consumer level.
- **Consumers are not motivated to invest**. The value proposition for the consumer is not yet compelling. Favorable price signals coupled with a reduction in the cost of DER for consumer applications is needed to improve the "consumer's business case" for investing in and operating DER.
- **Power system behavior with deep DER penetration is not well understood.** We need to further study how various distribution systems interact when DER of many types and designs are broadly deployed, particularly their behavior during upset conditions.

BENEFITS

The seamless integration of DER will deliver substantial benefits.

Figure 4: Reliability - With the Smart Grid, operators will aggregate and dispatch a network of backup generators for better peak management.

Improved reliability—Integration of DER can reduce the grid's dependency on the transmission system; increase operational flexibility during routine, emergency, and restoration activities; improve power quality; and reduce transmission losses and congestion due to DER being located closer to the loads. These benefits put us "on the road" to a self healing grid.

Improved security—DER decentralizes and diversifies generation and storage resources, reduces the grid's vulnerability to a single attack, and gives operators more options in response to a security emergency.

Improved economics—DER deployment adds to the Smart Grid's economic advantages by allowing the deferral of capital investments in generation, substations and lines; giving consumers additional options for participating in the electricity market; and reducing peak demand, transmission congestion, and peak prices. In addition, smaller DER units can be placed in service relatively quickly, while large central plants pose more risk and require long approval, financing, and construction periods. Collectively these benefits of DER can help put downward pressure on electric rates for consumers.

Improved efficiency—DER gives system operators new options to improve the utilization of grid assets, gives system planners additional options to address future demand issues, and reduces losses by locating sources closer to the load centers. Significant gains in efficiency can be realized when DER provides both power and heat.

Less environmental impact—The Smart Grid will encourage the deployment of renewables and CHP installations. It will enable a greater level of penetration of intermittent renewables than could otherwise be accommodated with today's grid. The Smart Grid will also reduce system losses, thereby reducing the overall amount of generation needed.

RECOMMENDATIONS

Considering the barriers to meeting the requirements of the Smart Grid and the benefits to be attained in overcoming these barriers, what are some of the steps we can take right now?

Table 1– Recommended Steps
Establish and communicate a clear vision
Increase R&D
Create financial incentives
State regulators take leadership role
RTO consider DER as a congestion solution
Continue DER demonstration programs

Specific actions are needed to accelerate the deployment of generation and storage options, including—

- **Establish and communicate a clear vision**—Stakeholders need to be given a clear, consistent Smart Grid vision that identifies the role of centralized generation, DER, and Demand Response. The vision needs to explain why the new model is beneficial to all stakeholders and particularly to society.
- **Increase R&D**—Additional research and development is needed to accomplish the items cited in the "Requirements" section above.
- **Create financial incentives**—Until the value proposition becomes compelling, financial incentives are needed to stimulate DER deployment. As overall demand for DER increases, production will increase, thereby allowing prices for DER to be reduced due to economies of scale.
- **States should take a leadership role**— State regulators need to take the lead in creating incentives that encourage utilities to invest in technologies that enable DER deployment. Also, disincentives that inhibit deployment should be identified and eliminated. Perhaps a new regulatory model is needed to achieve these outcomes.
- **Explore DER as a congestion solution**—Regional transmission organizations (RTO's) should consider the use of DER as a partial solution to transmission line congestion.
- **Continue DER demonstration programs**—Regional demonstrations are needed to learn more about the integration of distributed systems and to better understand their capabilities and value. The Energy Independence and Security Act of 2007and the American Recovery and Reinvestment Act of 2009 have provided opportunities in this area.

SUMMARY

The ability to accommodate a wide variety of generation and storage options is essential to realizing the full promise of the Smart Grid. Generation will increasingly include renewables and distributed generation alongside energy storage and other non-traditional sources.

Coping with this diversity will require a wide range of new and improved functions, including real-time pricing, smart sensors, integrated communications, advanced decision-support tools and more.

If we can successfully integrate large and small generation and storage, we will gain a grid that is more reliable, secure, safe, efficient, and environmentally friendly. At the same time, it will cost less to build, operate, and maintain than continuing "business as usual."

Barriers exist that may slow our progress. Our understanding of DER and its interactions is still limited, and prices remain high.

But despite the challenges, there is now a path forward.

The Modern Grid Strategy (MGS) is working with a wide range of stakeholders. The MGS will continue its outreach efforts to communicate and educate stakeholders on various Smart Grid concepts and to assist in better defining the Smart Grid value proposition.

For more information

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

The Modern Grid Strategy

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