Smart Grid Principal Characteristics

ENABLES ACTIVE PARTICIPATION BY CONSUMERS

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EXECUTIVE SUMMARY

The systems view of the smart grid features seven principal characteristics. (See Figure 1.) One of the seven characteristics is to provide the consumer with choices that benefit both consumers and the grid itself. We describe this as "enabling active participation by consumers."

<u>*Principal Characteristics*</u>

- *Enable* active participation by consumers
- *Accommodate* all generation and storage options
- *Enable* new products, services, and markets
- *Provide* power quality for the digital economy
- *Optimize* asset utilization and operate efficiently
- *Anticipate & respond* to system disturbances (self-heal)
- *Operate* resiliently against attack and natural disaster

Figure 1: The Smart Grid Systems View provides a holistic perspective that considers all aspects and all stakeholders.

The smart grid is defined by its seven principal characteristics. How the characteristic, *enables active participation by consumers,* might be attained is the subject of this paper.

In the smart grid, consumers will be an integral part of the electric power system. They will help balance supply and demand and ensure reliability by modifying the way they use and purchase electricity. These modifications will come as a result of consumers having choices that will motivate different purchasing patterns and behavior. These choices will involve new technologies, new information about their electricity use, and new forms of electricity pricing and incentives.

From the smart grid's perspective, electric load is simply another manageable resource, similar to power generation, grid capacity, and energy storage.

From the consumer's perspective, electricity consumption in the smart grid is an economic choice that recognizes both the variable cost of electricity and its value to the consumer under a range of times, places, and circumstances.

Consumers with choices in how they purchase, use, and produce energy will be able to:

- Use price signals and other economic incentives such as demand response (DR) to decide if and when to purchase electricity and whether to produce or store it using a distributed energy resource (DER).
- Purchase "intelligent load" end-use devices that consume power wisely and that become integral parts of the grid to help optimize its operations and reliability.
- Incorporate their plug-in hybrid electric vehicles (PHEV) and electric vehicles (EV) into the home, office, parking garage, and other locations into a "personal-use-and-produce balance".

> **Permitting consumers to face the underlying variability in electricity costs can improve economic efficiency, increase reliability, and reduce the environmental impacts of electricity production. (*Hirst, E. and B. Kirby, Retail-load participation in competitive wholesale electricity markets, 2001)***

Each of these choices has already been demonstrated to provide numerous benefits to multiple parties. The technologies that enable each, such as advanced metering, smart thermostats and appliances, distributed generation, and energy storage, have been demonstrated to give utilities, system operators, retail marketers, electricity consumers, and policy makers new tools for achieving their mutual and separate objectives. Much like the earliest personal computers and cellular phones, these technologies are poised for widespread adoption and deployment as well as for continual improvement.

The benefits of enabling the consumer to take a greater role are tangible and significant. For example, clipping the spikes of peak demand with smart grid-enabled DR reduces the need to build new generation capacity, improves the utilization of existing plants, and improves the environment by allowing the retirement or reduced use of inefficient generation.

Peak management activities also support a more efficient marketplace by acting as a dampening factor on wholesale electricity prices, which all consumers ultimately pay. In doing so, peak management activities help limit the amount of market power that electricity producers and sellers can exercise.

Environmental benefits also accrue to society because emissions, which are worse during times of peak demand, are substantially avoided.

As a result of these benefits being available, and customers taking actions to obtain them, the smart grid will be a more dynamic system where customers and their actions will be an integral part.

This characteristic of the smart grid will give consumers information, control, and options to enable their participation in grid operations. Informed energy-efficiency actions, DR programs, sale of generation and storage assets into the markets, and other smart grid innovations will benefit both consumers and grid operators.

CURRENT AND FUTURE STATES

We begin by contrasting the current situation for electricity consumers with what it could be like in the future state with a smart grid.

CURRENT STATE

In today's environment, the vast majority of consumers are fully insulated from the volatility of wholesale electricity markets and the true underlying moment-to-moment cost to produce and deliver the electricity they consume. They purchase electricity under fixed, time-invariant prices that are set months or years ahead. The costs of generating that electricity, however, vary substantially from hour to hour, often by a factor of ten within a single day (*Hirst and Kirby*).

Retail consumers who modify their usage in response to price volatility help lower the size of price spikes. This demand-induced reduction in prices is a powerful way to discipline the market power that some generators would otherwise have when demand is high and supplies tight. And these price-spike reductions benefit all retail consumers, not just those who modify their consumption in response to changing prices (*Hirst, E. and B. Kirby, Retail-load participation in competitive wholesale electricity markets, 2001).*

Today there are new opportunities emerging that provide the consumer with better information on the actual cost of electricity. They also present a monetary incentive for consumers to modify their usage in response to that information.

These opportunities primarily fall under the new business and policy area known as demand response (DR). Examples of DR are time-based or dynamic pricing options where the price varies by time of day—sometimes hourly or more frequently. Other programs are offered by utilities or independent system operators (ISOs) where consumers are paid to curtail or cut back their usage when electric system conditions would benefit.

Offerings of DR have been and can be made by utilities, systems operators, or third parties such as retail marketers or companies that specialize in DR technologies and services. Offerings can be made in either restructured markets or those that are still in a traditional, vertically integrated model. Evidence shows that consumers both large and small can be counted on to participate in DR programs and market offerings.

Another area of opportunity is the use of distributed energy resources (DER). This refers to the use of generation systems that are on the consumer side of the meter and that can be operated at times of the consumer's choosing or dispatched by the utility as an alternative to taking electricity off the grid. It also refers to the emerging storage technologies. (DER is covered extensively, in the "Accommodates All Generation and Storage Options," a white paper available from the Modern Grid Strategy at www.netl.doe.gov/moderngrid.)

The demonstrations of DR and DER to date illustrate the substantial benefits to reliability and economic stability that are attainable by motivating and including the consumer. Today, a number of technologies that support DR and DER are available, and many more are under development. The relevant information technologies (IT) and digital communications have become both more powerful and less expensive; in fact, they are ripe for deployment.

FUTURE STATE

> "Customers can now see on-line what their bank account contains and make adjustments without having to wait until they get the monthly statement in the mail. Wouldn't that also make sense for your electricity account? Perhaps you could even automate your energy use preferences based on utility prices" *(Katharine Hamilton, President of the GridWise Alliance, letter to Wall Street Journal, May 4, 2009).*

The future will see a robust and widespread link between energy consumers and the smart grid's operators. Creating this linkage will allow consumers to make informed consumption and production choices, which in turn will benefit both the consumer and the grid operator. Plus, it is clear that the plug-in hybrid electric vehicles (PHEV) and electric vehicle (EVs) will change the relationship between consumers and grid operators. At its best, this "electrification of transportation" will provide additional opportunities to shave peak load, regulate the grid, and provide the consumer with a way to sell power. At its worst, it will aggravate already challenging peak loads on the grid.

As technology improves and new policies allow or even encourage increased deployment, the number of consumers actively participating in DR and DER programs, PHEVs, and market-based offerings will increase and costs will drop.

Achieving consumer participation means making participation easy and understandable. And essential to this will be providing a user interface that successfully motivates and supports consumer action. These interfaces can take a variety of forms, depending on the sophistication and desires of the consumer. They could range from a series of simple indicators or warning lights to detailed computer-generated displays of energy and pricing information. (See Figure 2.) Today's communications and electronic technologies create options that were just not viable in the past.

Figure 2. The consumer home energy display provides easy interface to several programs. Image of EMS-100 courtesy of Control 4.

One example of a future architecture is shown in Figure 3, below. In this example, which visualizes the broad implementation of real-time pricing, the mechanism to provide consumers with greater choice involves the insertion of a gateway unit between the energy company and the consumer's appliances. This gateway provides load control based on the consumer's pre-programmed price preferences. In a sense, the gateway acts here as the consumer's agent. New technologies—such as a home energy display (HED), home area network (HAN), and consumer energy portal—that support consumer decisions and communicate pricing and other information will enable more effective interaction between the energy company and the consumer.

Motivated by economic incentives, consumers will adopt newly available smart appliances. Such appliances will monitor electrical conditions such as voltage and frequency, and will automatically turn on or off to support the stability of the grid. Some will also automatically respond to price signals ("prices to devices"). Today's digital revolution will seed the needed advances in metering, communications, and decision support. Innovation will be stimulated by competition and economics of scale.

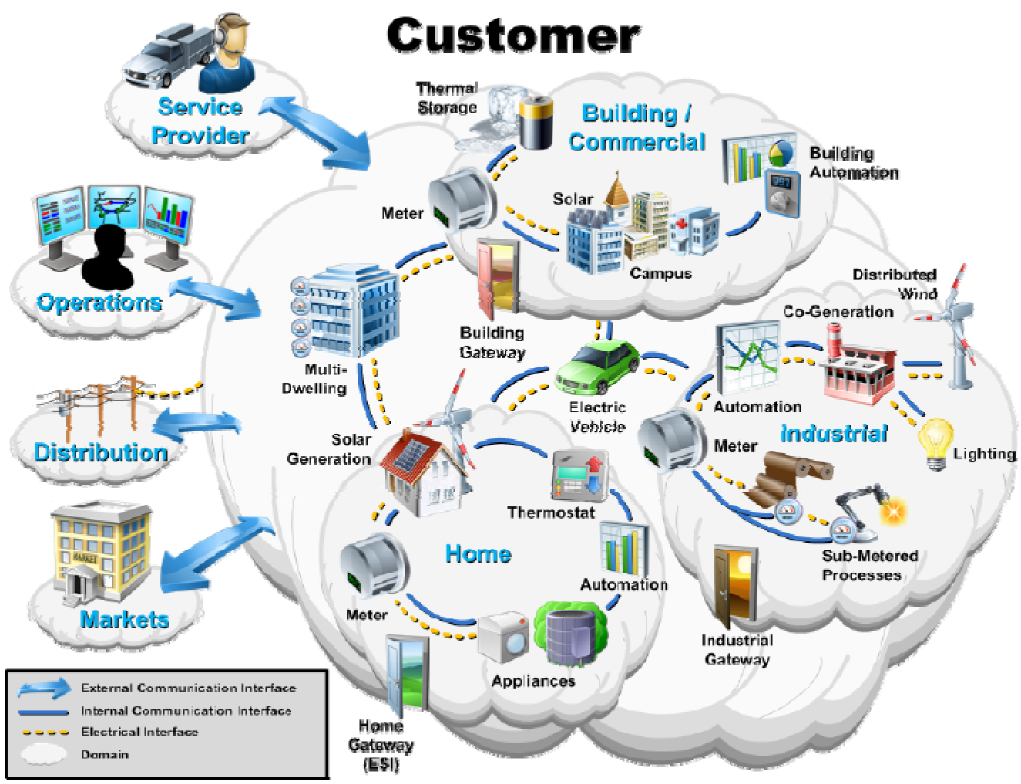

Figure 3. In this overview of the consumer domain, devices, software, third-party service providers, or other actors enable customers to manage their energy usage and generation through, for example, pre-programmed price preferences. CREDIT: *Report to NIST on the Smart Grid Interoperability Standards Roadmap* (Contract No. SB1341-09-CN-0031). Prepared by the Electric Power Research Institute, June 17, 2009.

REQUIREMENTS

Knowing the current state and envisioning the future state, what are the requirements for achieving the future?

FEATURES

Above all, the smart grid must address the consumer's primary objectives. Whether the goal is lowering the electrical bill at home; enhancing the productivity of manufacturing with cheaper, higher quality, or more reliable energy; or improving environmental stewardship, the overarching requirement is the same: choices and tools that are easy to understand and operate or automate.

Not all electricity consumers want to become buyers and sellers of electricity—their main pursuit is economical and reliable electricity that can yield for them the true values they seek. As a society, consumer trends (especially in the younger generations) are showing a strong sense of environmental and social responsibility. This is an additional factor for designing the interface between consumer and the grid operator. An energy management program that operates in the background, quietly providing the quality, reliability, and economics sought by the consumer is one example of this interface that will satisfy all customers.

The smart grid must therefore strive to include the consumer in grid operations in an automatic and cost-effective way. The system must have features that—

- Perform consistently within the rules, regulations, and agreements between the utility and the consumer.
- Provide power and/or reduce load when needed or desired.
- Deliver cost savings over time.
- Generate sufficient participation and provide incentive through cost-effective consumer programs such as DR and DER.

KEY COMPONENTS

There are a number of key components of the smart grid that must be provided to enable greater consumer participation:

- Consumer applications (such as DR systems) that are reliable, easy to use, and tamper-resistant.
- Applications for the consumer that respond to pricing signals from the utility and automatically manage the consumer's usage based on price and boundaries established by the consumer.
- Smart meters that supply consumer usage, pricing information, and grid conditions to help the consumer and utility enable services at minimum cost.

- On-premise infrastructure that supports the easy-to-use applications, such as the HAN and HED.
- The communications infrastructure and control systems to support two-way power and information flow.
- Processes, tariffs, new pricing regimes, and incentive programs that serve both the utility and consumer.
- Multiple, affordable choices for consumer-usable DER.
- Grid-friendly appliances that consumers are encouraged to deploy.

BARRIERS

In the context of active participation in our power service, we have described the current state, explored the future state, and identified the features and functions required to transport us from one to the other. However, there are some barriers.

“…, it's time to start bridging some of the gaps between what it means to utilities, technology companies, and grid wonks—and what it means to plain old energy users. Making the smart grid's most basic elements—two-way communication between utilities and energy users, advanced control systems, and smart devices—appealing to consumers could be key to its success.” *(Josie Garthwaite, GigaOm, BusinessWeek, 19 April 2009)*

The technologies that enable DR and DER are now and will be for some time in a constant state of technological evolution. For example, further development is required on:

- Cost-effective, secure, and reliable metering, communications, and supporting IT.
- Systems and processes that more fully recognize and incorporate the active consumer role in grid management.
- The design of associated tariffs.

Much non-technological work also remains to be done.

- Consumer education will be necessary to promote the broad acceptance of voluntary programs.
- New design of innovative rate structures that benefit both the consumer and the power system's managers is required.
- Many different stakeholders must agree upon a clear, auditable method to manage the various programs of rates and tariffs as consumer options multiply.
- Federal and state regulatory bodies need to set a clear direction, including agreement on promoting DR programs. For example, state regulators have the authority to provide consumers with time-based pricing options or not. In 2008, the FERC-NARUC Smart Grid Collaborative became active in coordinating policy and regulation change that supports a responsible consumer-centric approach to a smart grid.

Barriers in the way of accomplishing this work include:

- **Cultural views of electricity services**—The transition from a passive, protected user to a proactive, informed consumer should apply to electricity, just as it does to other services.
- **Long-established regulations**—Current state legislatures and regulatory commissions' efforts exist largely to protect consumers from the risks of competition.
- **Lack of consumer education on electricity services**—The consumer must come to understand that the price of electricity should reflect its current cost of production and delivery so that more economic usage decisions can be taken. Everyone benefits from optimizing electricity use.

- **Lack of consumer education on environmental impacts of electricity services**—Consumer must come to understand the relationship between production and delivery of electricity and the associated environmental impacts. This is necessary so that trade-off decisions at the policy level can be made from an informed position.
- **Slow process of technology deployment**—While the news is filled with pilot projects across the nation and advances in metering, communications, information processing, and DR, the actual deployment is gradual. Because of the complexity of the transformation required in the grid, it is important to carefully transition the industry using a deliberate approach.

BENEFITS

Once we fill the gaps and overcome the barriers, the economic ripple effect of giving consumers informed choices will benefit all sectors of society.

REDUCING CONSUMPTION

Reducing consumption comes in two forms: reducing usage of electricity services and using more energy-efficient technologies and processes for the same electricity service. A recent Brattle Group study of data from several utility pilot projects shows that when consumers are active in using energy consumption information they average about 7 percent reduction in their consumption.

DEMAND RESPONSE

DR has enjoyed considerable progress in overcoming the barriers of regulation and consumer education. Several regional transmission organizations (RTO) now embrace DR as a cost-effective ancillary service. NYISO has measured benefit ratios exceeding 5:1 with their emergency DR program. ISO New England has shown that DR programs can be very responsive, reaching committed reduction levels in less than 30 minutes.

> **"Smart grid" is a term that refers to the modernization of the electric system through the integration of new information-age technologies, new strategic public policies, and allows for new uses of the electric grid, both in operations and through new customer side applications, that extract the benefits of more efficient operation, more efficient use of grid assets, and more cost-effective expansion of the electric grid…." *(Summary of Smart Grid Benefits and Issues, Illinois Smart Grid Initiative, June 2008)***

Recently, the chair of the Federal Energy Regulatory Commission described DR as "the silver bullet of market design." The U.S. Congress has included strong DR provisions in the Energy Policy Act of 2005. This signals national recognition of DR's value in reshaping the industry. The DOE Office of Electricity Delivery and Energy Reliability views DR as an essential element of the smart grid. At the same time, the Environmental Protection Agency believes DR can lead to more investment in efficient end-use devices.

DR projects that included consumers have already produced very positive results. One program in Illinois was the first to clearly show just how effective DR can be. Independent evaluators found:

- Participants respond to peak period prices — Small changes in behavior reduced overall demand by up to 20 percent.
- Participants saved money—15 percent over the first two years.
- Participants of all incomes benefited—Low-income households especially respond proactively to high prices.
- The meters were not expensive.
- Participants had a better understanding about energy usage.

DISTRIBUTED ENERGY RESOURCES

Consumers may represent the largest market for DER well into the next decade as they use it to save money and improve reliability.

Deployment of DER will benefit the entire value chain of consumers—commercial, industrial, and residential. Simple connections to the grid will accelerate consumer usage of small generation, storage devices, and PHEVs, and pave the way for larger ones. Allowing the consumer to store and generate electricity can support the grid by—

- Lowering the risk of load imbalances.
- Providing responsive, local peak-power response.
- Providing a wide range of economic and environmental benefits.

Perhaps the largest application of DER over the next 10 to 20 years will also be mobile, namely PHEV and EV. With 12 PHEV and/or EV platforms expected to become commercial and readily available between 2010 and 2012, consumers are expected to embrace "fueling" their transportation with electricity. This new application could become a "game-changer" for the consumer and provide a very practical motivation to better understand electricity services and consumption.

RECOMMENDATIONS

With an understanding of the barriers to be overcome and the benefits that are attainable, this section summarizes the recommendations of the Modern Grid Strategy.

The transition to active participation by consumers will be gradual, with pockets of progress occurring first in those regions where regulators are most supportive. Over time, and with the emergence of increasingly effective programs and technology, consumer involvement will become the norm. Each step along the path will produce its own set of benefits.

Our recommended steps include:

- **Regulatory encouragement at federal and state levels.** Society would benefit greatly from clear directives that treat DR and DER programs as viable solutions to the fundamental power system requirement of continuously balancing generation and load. Utilities would employ these tools if it were clear that their investment would have the regulatory clarity of other resources.

- **Broader education regarding the opportunities to deploy DR and DER and the overall benefits they produce.** Education programs can reveal the many beneficiaries of well-conceived programs that motivate and involve the consumer. The value of transitioning from passive, protected users to proactive, informed consumers must be conveyed clearly. The benefits of energy with higher quality, lower cost, more reliability, and greater customer choice—and additionally with a reduced CO2 footprint and greater national security—must be shared.

- **Continued improvement in the cost and performance of supporting technologies.** Considerable work is afoot to demonstrate the most effective, secure, and reliable solutions for metering, communications, and IT. Available modern advances in digital communications can be applied to these utility applications and can support more advanced grid-control methods. In addition, new smart appliances and enhanced DER must be developed to help support the consumer's proactive interaction with the grid. Integration of such devices requires substantial engineering to ensure compatibility.

- **Recognition of the risks of a complex transformation in electricity services and the surrounding business models.** There is risk in deploying advanced metering infrastructures without providing interoperability, cyber-security standards, privacy of information, integration of DER without distribution management systems, or integration of PHEV and EVs without methods to manage the charging and discharging times and flows.

- **Development of programs, tariffs, and computer agents that satisfy both utility and consumer needs.** This includes the development of systems that enable timely and effortless interaction between the consumer and the power grid operator. Innovative rate structures that provide economic benefits to both the consumer and the utility are integral to these systems. New applications must become interoperable with the many utility legacy programs that will still be required for reliable and efficient overall operation of the grid.

SUMMARY

In the smart grid, consumers become an integral and active part of the overall electric power system. Consumers' actions taken in their own self-interest and in the interest of society will help balance electrical demand (loads) with supply.

Motivating consumers to play that part means giving them the opportunity to make informed choices, profitably. Consumers with choices in their energy usage will be able to:

- Utilize consumption information to help them understand their loads and better conserve energy.
- Rely on price signals to decide when and if to purchase, store, or generate power.
- Employ smart devices that know and respond automatically to the consumers' preferences about energy usage. Smart devices can also improve the stability of the power system.
- Relieve the grid's loads by reducing peak demand when necessary.

DR programs are examples of proven consumer receptivity to being included as a part of the power system, and it has demonstrated measurable benefits to suppliers of electrical power.

DER is poised now for the same inevitable widespread deployment seen with personal computers and cell phones. DER can also be an important component of consumer involvement, one that can complement large central generation and reduce the burden on the grid, while offering environmental, reliability, and economic improvements.

The Modern Grid Strategy team 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 (MGS) team. Documents are available for free download from the Modern Grid website.

The Modern Grid Strategy

http://www.netl.doe.gov/moderngrid/

info@TheModernGrid.org

(304) 599-4273 x101

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