The GridWise Vision for a Smart Electric Grid

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The United States Congress passed important energy policy laws mandating improvements in the distribution of electricity. To facilitate this process the Department is supporting the GridWise® Architecture Council, consisting of 13 experts from the U.S. and Europe who understand:

- Electric services
- Information technology
- Industrial controls
- Building energy management
- Consumer products
- Business and economics
- Regulatory policy

The scope of GridWise is shown in Figure 1. The work of the Council is available at www.gridwiseac.org.

Drivers of utility change

Many problems and pressures are driving utilities toward the expanded systems view of the GridWise Architecture Council. Among these are the need to:

- Integrate generation capacity from renewable sources such as wind and solar that fluctuate due to weather changes.
- Accommodate local power storage and locally generated power that is sold back to the utility.
- Ensure the reliability of electricity resources for a strong economy and for security.
- Provide a more efficient, resilient, and reliable grid.
- Enable more robust competitive markets, in part by better interaction and collaboration among power users and power suppliers.
- Adjust demand to meet supply limitations through residential, commercial, and industrial demand-response systems.

The GridWise view

The electric utility has traditionally spanned generators, transmission lines (steel towers), distribution lines (electric wires on poles to homes, buildings, and factories), and electric meters. Beyond the meter has been the domain of customers using electrical equipment for industrial, commercial, and residential applications.

The GridWise view expands the domain of the electricity system to include end-devices and incorporates information technology (IT). IT is expected to revolutionize planning and operation of the power grid just as it has changed business, education, and entertainment. GridWise is providing tools for the electric industry to create a "smart grid" by embracing high-tech in order to reap the benefits of innovative products.

The GridWise view of the new electric utility expands interactions among utility components and end-devices (such as heating and cooling equipment) by incorporating IT and e-commerce. Distributed intelligent devices are interconnected by utility, home, and building networks. This requires a fundamental shift in electric utility system engineering and management.

Report to Congress

The GridWise Architecture Council and the U.S. National Institute of Standards and Technology (NIST) are developing a report for Congress about the state of standards for electric smart grids. Among the topics requested by Congress is planning for the deployment of demand response systems. The need for demand response stems from:

- Electric supply limitations
- Public resistance to building large generating plants
- Concerns for environmental pollution including greenhouse gases
- Opposition to siting transmission lines
- The anticipated demands for electricity by electric vehicles
- The introduction of distributed generators
- The fluctuation in output with time and weather from distributed generation sources such as wind and solar panels

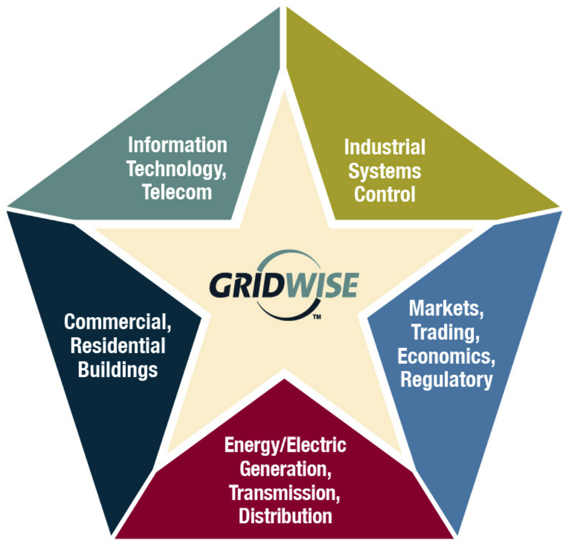

Figure 1 – The GridWise Scope
(Courtesy of the GridWise Architecture Council)

Demand Response and the Smart Grid

Dr. Wacks was asked by the GridWise Architecture Council to lead a working group at NIST to write a report about the goals and structure of a demand response system for residential customers. Since demand response systems extend beyond the meter into customer premises, those impacted by demand response technology choices include utilities, third-party suppliers of demand response services, home network developers, and appliance manufacturers. An example of a third-party demand response service provider is an aggregator serving a large building or neighborhood.

There are various methods for implementing demand response. The choices will vary by utility to achieve the load shape that aligns with supply limitations, transmission and distribution capabilities, regulatory constraints, and business considerations. Also, as the market develops for energy management products, consumer electronics companies may offer products that combine load management for demand response with energy conservation.

An important factor for the success of residential demand response is the development of appropriate gateways, controllers, and Home Area Network (HAN) devices. Utilities can specify what they would like in such products, but must also motivate manufacturers to design and market them. Utilities deal with many suppliers of industrial and business products, but most have not cultivated relationships in the consumer product industries. The annual market for consumer electronics is almost $200 billion[1] and for home appliances is about $25 billion[2]. Both markets include hundred of manufacturers that produce thousands of new products each year. Thus, there are many options for negotiating product specifications adapted for energy management provided there is motivation from public policy and from utilities.

Consumer electronics companies may offer products that combine load management for demand response with energy conservation.

Demand Response Overview

Electricity consumption patterns have peaks daily and seasonally. During weather extremes of heat and cold the demand for electricity rises sharply. To meet these occasional peak demands, some utilities need to keep relatively expensive generators running or must build new plants.

U.S. utilities are required to maintain the supply of electricity sufficient to meet any demand. However, this is becoming less practical because of the cost of new electricity plants, public resistance to new plants, and government rules controlling environmental pollution. The pressure for plants to meet peak demands could be reduced if customers evened out their power consumption so the peaks are flattened. Utilities have developed specific programs to influence the customer demand for power in order to align with the available supply. Such utility programs are called demand-side management (DSM).

The objective of DSM is to reduce peak demands for electricity by about 5% up to 100 hours per year, according to a December 2005 report of the Demand Response and Advanced Metering Coalition (DRAM - now called the Demand Response and Smart Grid Coalition)[3]. The Electric Power Research Institute estimated in 2001 that "… a 2.5% reduction in electricity demand statewide could reduce wholesale spot prices in California by as much as 24%; a 10% reduction in demand might slash wholesale price spikes by half."[4]

Demand Response and the Smart Grid

Programs for energy management initially focused on providing incentives for using less electricity with more efficient appliances. Some programs offer rebates for switching from tungsten to compact fluorescent lamps, for adding building insulation, and for purchasing energy efficient appliances.

Utilities have developed more deterministic methods for influencing the demand through DSM. Since DSM programs may not involve explicit management by the utility, the term demand response (DR) is being widely used in the industry. DR uses incentive-based and indirect methods for controlling how much electricity is consumed during a specified time interval by water heaters, air-conditioners, and industrial equipment. The more innovative methods of load control depend on market forces for exerting control by varying the price of electricity.

DR offers effective methods of DSM, but is currently applied only to about 8% of all U.S. customers, according to a FERC (Federal Energy Regulatory Commission) survey reported in December 2008[5].

Demand Response methods

Demand Response includes programs and technologies to modify customer demand for energy directly by remote control of customer appliances (called Direct Load Control) or indirectly through pricing incentives or event notifications.

Some large industrial customers volunteer for lower electric rates in exchange for deliberate service interruption. When the utilities are facing a supply limitation, perhaps on a hot summer day, they order these volunteers to reduce or to

[1] Market size per Consumer Electronics Association (www.ce.org).

[2] Market size per Hoovers, a D&B Company (www.hoovers.com).

[3] Demand Response and Advanced Metering Coalition (DRAM), comments filed in Docket AD06-2, December 19, 2005, 5. Reported in FERC, Assessment of Demand Response and Advanced Metering Staff Report, Docket AD06-2-000, August 2006.

[4] Taylor Moore, "Energizing Customer Demand Response in California," EPRI Journal, Summer 2001, p. 8.

[5] "FERC Report Marks Significant Progress in Demand Response, Advanced Metering," News Release from FERC, R-08-70, December 29, 2008.

curtail some energy consuming equipment. The analogous program for residential customers is Direct Load Control, where the operation of selected devices like air-conditioners and water heaters is interrupted. In a typical version of Direct Load Control the utility sends a signal via the power line or radio to a switch that limits the run time of air-conditioners to 0-15 minutes each half-hour for up to six hours each day. Water heaters are generally turned off entirely for 2-6 hours.

Direct Load Control requires prior arrangements with customers for permission and equipment installation. Many customers in the U.S. are offered rebates of up to $10 a month for participating in Direct Load Control. Of the 5% of U.S. customer under load control, most are participating in Direct Control.

Demand Response via electricity pricing

An indirect method of Load Control is based on electric rates that vary over time or a notice to customers of a pending event, such as a partial supply interruption, requiring consumption reductions. Time-varying pricing evolved from time-of-use (TOU) pricing where the utility establishes a peak and off-peak price. Initially the ratio of on-to-off peak pricing was chosen high enough to motivate customers to defer heavy power-consuming appliance usage to the off-peak times. For this technique, called Local Load Control, to be effective the customer must:

- Remember the time period for off-peak pricing of power.
- Know which appliances consume relatively large amounts of energy.
- Not be significantly inconvenienced by deferring appliance operation to off-peak times.

Much more effective DR is possible by exploiting microprocessor-based intelligence at the customer premises. Distributed Load Control combines local and direct load control with much increased flexibility and customer control. The utility has the opportunity to change prices when a peak demand is expected. Eventually, utility policy makers would like to adjust prices according to the wholesale market price of electricity to reflect actual utility costs. Smart appliances respond with minimal user involvement or inconvenience.

The following scenario is an example of how a user might interact with an integrated Distributed Load Control system:

It is 4 PM and the user is about to run the dishwasher. The following options appear on the appliance display panel:

1. Wash dishes now.
2. Delay wash by 3 hours and save 25¢
3. Delay wash by 6 hours and save 50¢

The user makes a simple decision based on criteria that are understandable: "Do I need the dishes cleaned in the next three hours (perhaps for a dinner party at 7 PM), or can I wait and save some money?" This makes buying energy as simple as shopping at a retail store.

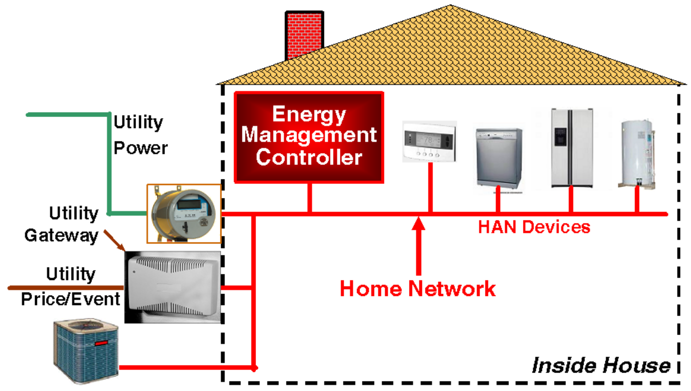

Figure 2 – Distributed Load Control System
(Utility Gateway courtesy of GridPlex, Inc.)

Implementing effective demand response

As noted, demand response systems may range from direct control of selected appliances to distributed control with pricing and event data. It is possible to implement distributed load control by sending utility prices and event notifications directly to smart appliances. This is called "prices to devices." Such appliances would need to be programmed to understand the price or event messages and to respond accordingly with reduced consumption where appropriate.

The introduction of an Energy Management Controller (EMC) adds functionality to distributed load control by enabling the allocation of limited energy (or a limited budget for energy) among appliances according to consumer preferences. Figure 2 shows a feasible Distributed Load Control residential implementation. The utility sends pricing data electronically to all houses in real-time over a network such as the Internet. This pricing signal enters the house through the Utility Gateway, a version of a residential gateway. This gateway interconnects a public network using telephone, cable TV, power lines, or radio

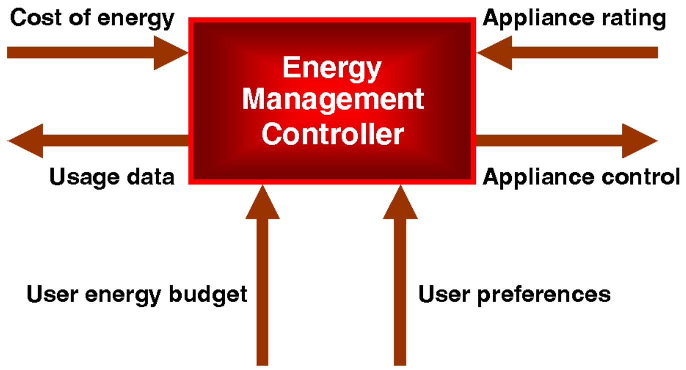

Figure 3 – Energy Management Controller

with a home network. The gateway may be a separate device, as shown in Figure 2, or could be integrated with other gateways, controllers, or even inside an electric meter.

The element in this system responsible for regulating energy consumption is the Energy Management Controller (EMC). The EMC may be a discrete physical device or the EMC functions may embedded in the gateway, in an appliance, or in a controller providing a diversity of home services.

The EMC performs specialized computing functions by receiving the electricity rate data from the residential gateway and applying sophisticated software algorithms to determine which appliances to operate and when. The functions of the EMC are illustrated in Figure 3.

The EMC is programmed to determine how and when to operate appliances based on the cost of energy, the energy requirements of the appliances, and user inputs. The user might specify a monthly energy budget (for example, $100 per month) and preferences (shower at 8 AM, air conditioning at 6 PM, pool at 8 PM, etc.). The customer should always be able to override decisions of the EMC. After processing these data, the controller issues signals that are distributed over a home network to the relevant appliances. Smart appliances that can operate in energy conserving modes can improve the effectiveness of a Distributed Load Control system. The EMC acts an intelligent agent for the customer.

Communications between the utility and the Energy Management Controller consists of the two data flows shown on the left side of Figure 3. The cost of energy data are sent by the utility or a demand response service provider using a secure link that ensures the data originated from the utility or the service provider. This level of security entails authentication to confirm that the data is from the real source and has not been altered during transmission. It is not necessary to encrypt such data since it is public. However, the customer usage data should be encrypted so that if intercepted, a potential burglar could not determine customer daily activities and occupancy. Also, the customer and the utility need to agree on how frequently usage data are collected. The more frequently the usage data are sent, the more detailed a record of household activities and preferences can be accumulated, thereby impacting customer privacy.

The GridWise framework for utilities

The GridWise Architecture Council is developing framework tools for the utility industry. The GridWise framework helps organize concepts so that interoperability issues among the electricity components can be identified and addressed. Interoperability has important economic benefits:

- Lower equipment costs.
- Lower transaction costs.
- Higher productivity through automation.
- More conversion of data and information into insight.
- Equipment substitution and upgrades.
- Increased competition among equipment suppliers.

The future electric utility

The electric utility industry is investing significant capital to improve the grid and the market for electricity. The GridWise Architecture Council intends to guide utilities toward wise investments that benefit from interoperability. The greatest impact from interoperability will occur when communications from the grid to buildings and equipment enables automatic interaction between energy users and the electric grid.

GridWise is not an engineering team developing energy products, but an experts team rethinking the system for generating, distributing, and using energy. GridWise is convinced that the creation of an interoperability platform for the grid will stimulate and enable innovations and services that enhance the electric system by adding value while driving down the cost of electricity.

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ABOUT THE AUTHOR

Dr. Kenneth Wacks has been a pioneer in establishing the home systems industry. He advises manufacturers and utilities worldwide on business opportunities, network alternatives, and product development in home and building systems. In 2008 The United States Department of Energy appointed him to the 13-member GridWise Architecture Council. The Consumer Electronics Association (CEA) chose Dr. Wacks to chair the international committee (ISO/IEC) responsible for world standards in home systems. For more information, please visit www.kenwacks.com.