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Energy Management Rediscovered

Economists in last quarter of the twentieth century predicted that in the 1990s the industrialized world would face energy shortages. The United States Congress prepared by passing the Energy Policy Act of 1992 that encouraged utilities to shift focus from expanding generation capacity to managing the demand for power.

Utilities started to develop various techniques for demand-side management (DSM) of energy. However, the 1990s brought industrial slow-downs and major shifts away from manufacturing towards information technology. As a result, by the end of the decade the energy supply remained adequate. Most of the innovative DSM programs were abandoned and utilities refocused on financial transactions such as mergers and acquisitions. Reality returned following the Enron-induced crisis in California where wholesale price manipulation widely affected consumers and resulted in a major utility bankruptcy.

The U.S. Energy Policy Act of 2005 is mandating that utilities revisit energy management with appropriate equipment and tariffs. I helped utilities explore and develop DSM programs 10 years ago and am seeing similar programs re-emerge. This article examines the goals and technologies being developed for effective management of electric energy.

The Objective of DSM

Electricity consumption patterns have peaks daily and seasonally. Figure 1 is an actual plot of hourly demand for a major Canadian utility. During weather extremes of heat and cold the demand for electricity rises sharply. In the U.S. the average rate of power generation is only about 46 per cent of the peak generation that occurs during these situations. Some utilities need to keep relatively expensive generators running to meet this peak. These peak generators are called Spinning Reserves.

Figure 1 - Ontario Daily Electricity Demand (Courtesy Independent Electricity System Operator)

Ideally, the utilities would like to maintain the supply of electricity sufficient to meet any demand. This has been achieved in some industrialized countries, primarily in North America. However, this is becoming less practical because of public resistance to new power plants and government rules controlling environmental pollution.

The expensive Spinning Reserves could be idled if customers evened out their power consumption so the peak is flattened. Utilities have developed DSM methods to influence the customer demand for power in order to align with the available supply.

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

What is DSM?

DSM programs 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 Demand Response (DR). 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.

Demand Response offers effective methods of DSM, but is currently applied only to about five per cent of all U.S. customers, according to a government survey reported in August 2006.

Demand Response via Utility Control

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.

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 remove equipment from the power grid. Utilities have instituted Direct Load Control to interrupt the operation of selected residential devices like air-conditioners and water heaters. The utility sends a signal via the power line or radio to a switch that cycles the air-conditioner off for about 15 minutes or the water heater off for about two 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. Most load control programs in the U.S. are based on direct control.

Demand Response via Electricity Pricing

An indirect method of Load Control is based on electric rates that vary over time. In the simplest scheme, the utility establishes a peak and off-peak price where the ratio of on-to-off peak pricing is 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 control with much increased flexibility. The utility has the opportunity to change prices at will by following the wholesale market price of electricity to reflect actual utility costs. Intelligent 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.

Implementing Effective Demand Response

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. This gateway interconnects a public network using telephone, cable TV, power lines, or radio 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.

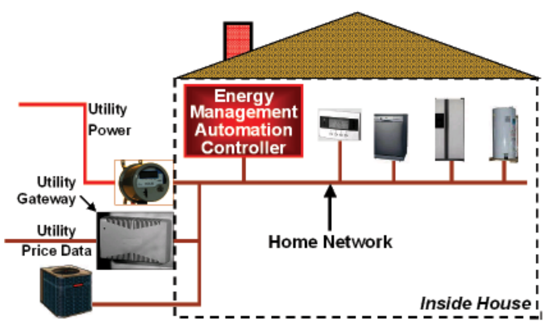

Figure 2 – Distributed Load Control Systems (Utility Gateway courtesy of Broadband Energy Networks)

Control signals are sent from the Utility Gateway to the major energy consuming appliances via the home network to control when and in what modes they operate. The element in this system responsible for regulating energy consumption is the Energy Management Automation Controller (EMAC). The EMAC 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 EMAC are illustrated in Figure 3.

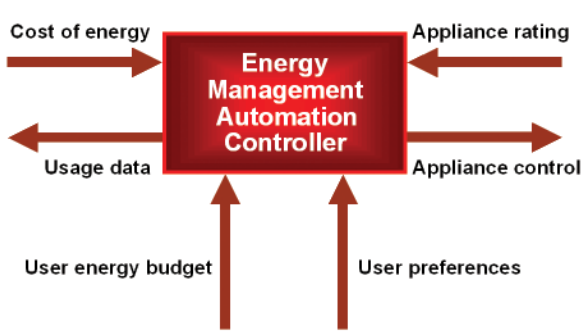

Figure 3 – Energy Management Controller

The EMAC 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 EMAC. After processing these data, the controller issues signals that are distributed over a home network to the relevant appliances. Intelligent appliances that can operate in energy conserving modes can improve the effectiveness of a Distributed Load Control system.

Leadership from the Home Systems Industry

Demand Response coupled with local intelligence and a home network increases residential customer cooperation. The decisions are simple, while consumer privacy and convenience are not compromised. Some Direct Load Control programs presume that the utility collects individual appliance usage data at hourly or more frequent intervals. The potential for misusing such data could impede customer cooperation. Local intelligence obviates the need for utilities to gather such consumer data.

I would encourage developers of home systems and consumer products to help utilities integrate with a home network via a residential gateway. Also, home system companies should work with appliance manufacturers to include access via a home network for managing appliance energy consumption in response to utility peak pricing. Utilities need the advice and leadership of the home systems industry in order to create effective, user-friendly energy management systems.

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. For further information, please contact Dr. Wacks at 781.662.6211; fax: 781.665.4311; kenn@alum.mit.edu; www.kenwacks.com.