Autumn 2017 Volume 14, Number 3

iHOMES and BUILDINGS

THE MAGAZINE OF THE CONTINENTAL AUTOMATED BUILDINGS ASSOCIATION

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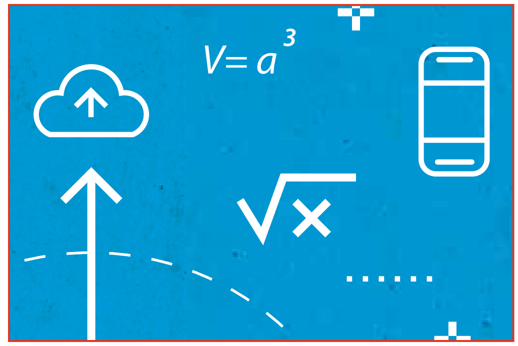

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The Evolution of Demand Response

By Ken Wacks

Thomas Edison developed the light bulb and built generators so his Wall Street investors could work after sunset to raise money for his company. To create a demand for electricity during the daytime when lights were not needed, appliances were invented. Many utilities sold these appliances to their customers. Throughout most of the twentieth century public policy, regulations, and tax laws encouraged utilities to expand the supply of power with increased generation and grids.

It was not until the late 1980s that policy makers started to worry about whether the supply of electricity could continue to increase in step with the anticipated demand, primarily from industrial growth. The utility industry developed trial programs to manage customer demand for power. Some regulators in the early 1990s mandated integrated resource planning, where utilities were ordered to consider both supply and demand when preparing budgets to justify tariffs.

The introduction of local power generation from wind and solar is adding impetus to demand management because the supply can fluctuate quickly with changing weather. Automation and artificial intelligence are becoming increasingly important tools for managing customer demand for electricity, as I explain in this article and will continue in the next issue of *iHomes and Buildings*.

Demand-Side Management (DSM)

Early demand management programs were called Demand-Side Management (DSM) on the assumption that they were established and actively managed by the utility after the customer agreed to join the program. The latest trend is to shift some responsibility to customers once they sign up for the program. Therefore, these programs are now called Demand Response (DR) to indicate that customers have some control on how their energy usage responds to supply fluctuations.

With modern DR programs, changes in customer consumption of electricity are motivated by pricing incentives or event notifications (such as an anticipated heat wave). A framework that specifies these options for DR is the basis for an international standard, ISO/IEC 15067-3. I proposed and edited this standard, which was approved by the member nations for publication in 2012.[1]

Traditional DSM

Some large industrial customers volunteer for lower electric rates in exchange for occasional service interruption. When utilities are reaching supply limitations, perhaps on a hot summer day, they order these volunteers to reduce or to curtail some energy consuming equipment. The analogous DSM program for residential customers is called Direct Load Control.

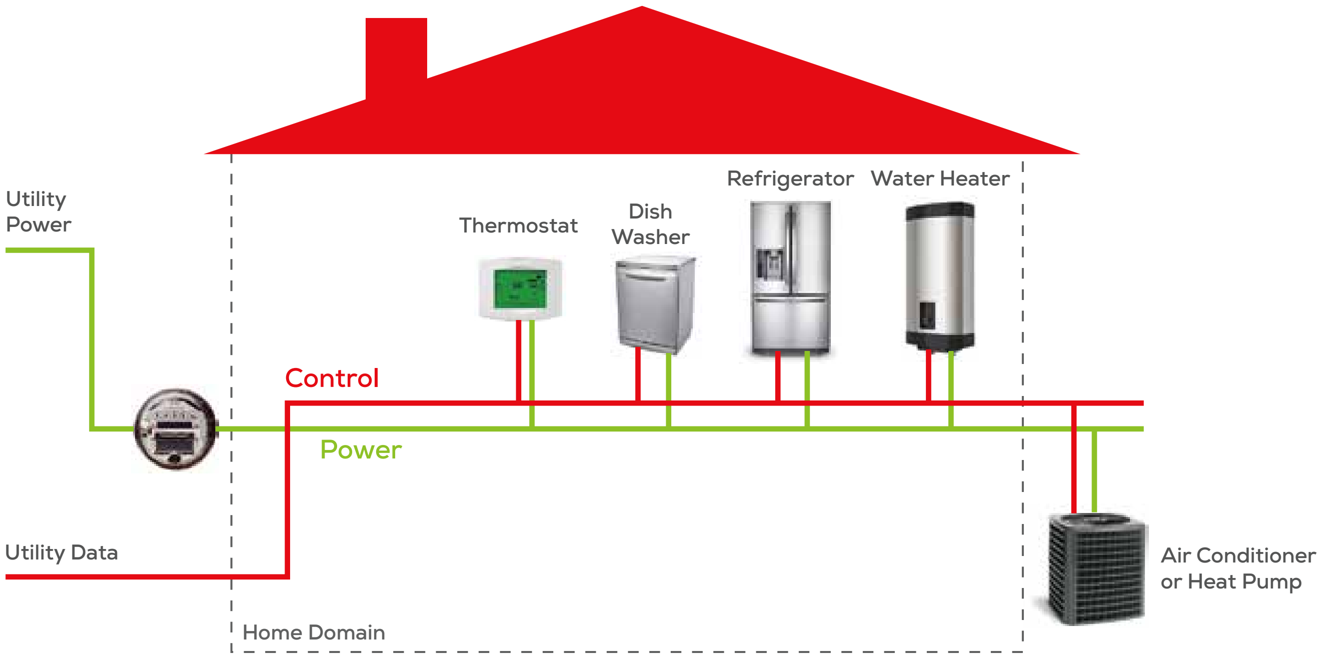
Direct Load Control was one of the earliest DSM programs and is still deployed. Participants are offered a monthly rebate up to $10 for allowing the utility to control selected appliances. These appliances are usually a water heater and an air conditioner. The water heater might be cycled off for two hours or more per day, while the air conditioner is turned off for about 15 minutes via remote signals from the utility or energy service provider. Of the 10% of US customers under demand management, most are participating in Direct Load Control.

Direct Load Control

Direct Load Control requires prior arrangements with volunteer customers and equipment installation. The service and equipment providers must select a signaling method, a communications channel, and appliance interfaces. Various communication methods were developed

1 ISO/IEC 15067-3 may be purchased in North America at:
Canada: http://shop.csa.ca/en/canada/p55/isoiec-15067-32012/invt/055596
US: http://webstore.ansi.org/RecordDetail.aspx?sku=ISO%2fIEC+15067-3%3a2012

Figure 1 – Direct Load Control



for utility control signals to actuate appliances remotely for DSM. The most widely deployed communications, used by more than 400 utilities, is a proprietary system that embeds control signals within the electric power at the distribution substation.

The system, developed by Aclara Technologies LLC in 1978, is called TWACS (Two-Way Automatic Communication System).[2] The target appliances are modified with communication interfaces to receive the TWACS signal, decode it, extract the control message, and operate a switch on the appliance to stop or start operation.

Figure 1 illustrates the architecture of a Direct Load Control system. In this case the utility is controlling the water heater and air conditioner or heat pump either directly or via the thermostat. The other appliances are not participating in load control in this example. The participating appliances must contain internal or external communication interfaces to receive electronic commands sent by the utility.

Indirect load control

The alternative to Direct Load Control is Indirect Load Control. With indirect control methods utility suppliers do not operate any customer appliances or devices remotely. Instead, the energy service provider shapes demand by offering incentives that encourage customers to make choices and receive more benefits than with direct load control. Options for implementing Indirect Load Control include:

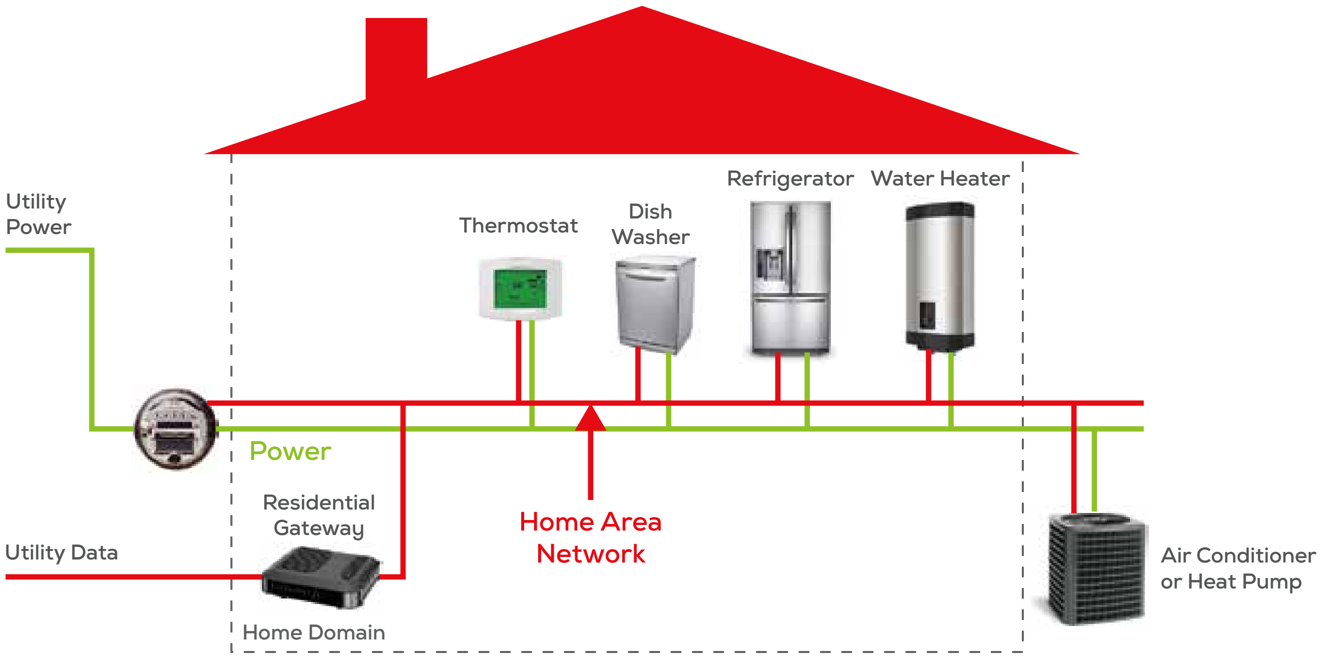
- Time-of-use pricing
- Real-time pricing
- Event notices (message about electricity supply)
- Prices-to-Devices[3]
- Energy Management Agent[4]

The objective of indirect control is to influence customer choices about when to operate appliances that consume significant amounts of electricity. These programs depend on market forces to alter customer demand for electricity rather than remote control by the utility.

The obvious method for customers to execute choices based on these prices and messages is to defer appliance usage or to change the thermostat setting. Automatic actions by smart appliances can be more effective. Even

2 TWACS was developed by Distribution Control Systems, Inc. (DCSI), which was ac-quired by Aclara.
3 The term Prices-to-Devices is a service mark of the Electric Power Research Institute (EPRI).
4 Specified in ISO/IEC 15067-3

Figure 2 – Prices-to-Devices



better are computer-based decisions by an Energy Management Agent, a computing entity that manages appliance operation using elements of artificial intelligence, as will be described.

Time-varying prices

Most electricity tariffs in the U.S. do not vary over time, although the rate might change with usage volume. New pricing schemes are adding time as a factor. Time-of-use (TOU) rates change the price according to the time of day. Typically, on-peak and off-peak rates are announced. The hours for each rate are fixed for each day, or at least for work days, similar to some mobile telephone rates. Rates that change dynamically with one-day or even no advanced notice con-stitute "real-time" pricing. Time-of-use rates are usually static compared to "real-time" pricing.

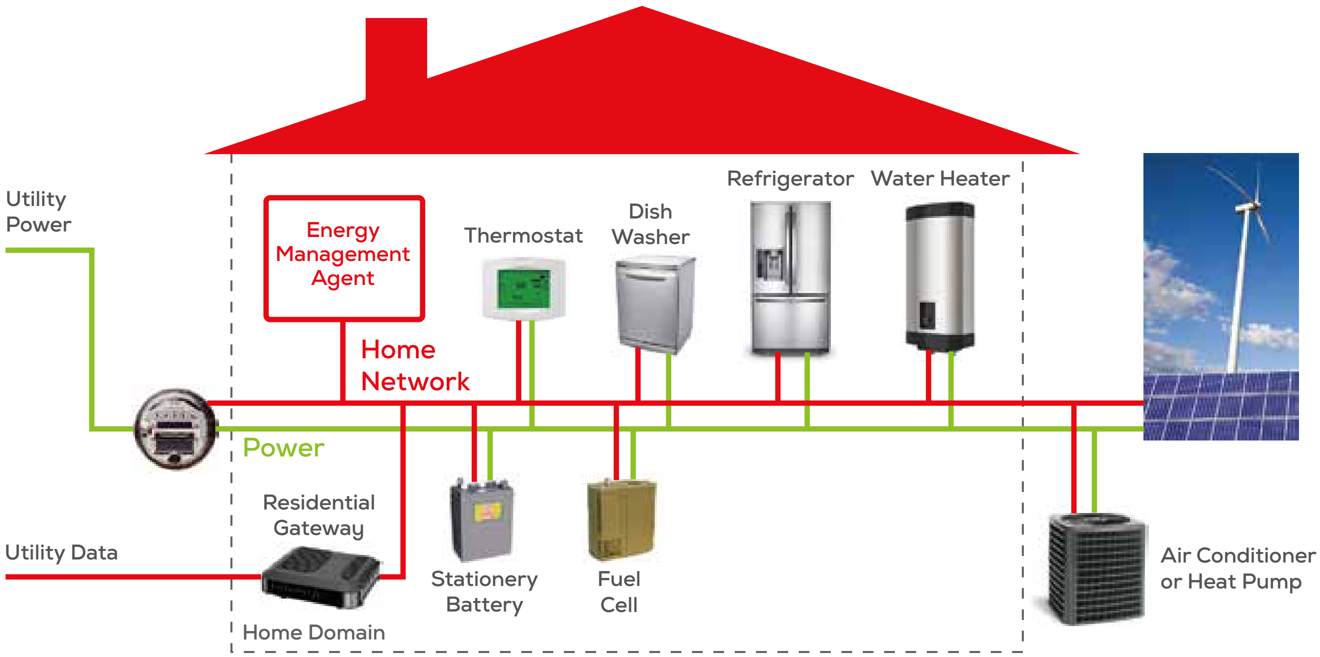
TOU pricing involves pricing electricity higher during specified hours, such as 4 to 8 PM when the wholesale cost of power is higher. Some utilities set the ratio of on-to-off peak pricing high enough to motivate customers to defer heavy power-consuming appliance usage to the off-peak times. Some utilities implement critical-peak pricing when market prices for electricity are especially high. Such situations may result from supply limitations (such as fuel shortages) or extraordinary demands due to unusual weather extremes. The proliferation of solar and wind power is starting to influence utility generation costs, especially at sunset when solar-panel outputs fall.

In some cases, TOU pricing also includes a demand charge (more common for commercial customers). The consumer pays a special charge called a demand charge if the total electricity consumed during a short interval (in the range of 15 to 30 minutes) exceeds a pre-set limit.

Utilities can better match electricity supply with customer demand by dynamically varying the retail price of electricity using real-time pricing as market conditions change. Eventually, utility policy makers want to adjust prices according to the wholesale market price of electricity to reflect actual utility costs. Thus, the utility would have the opportunity to change prices when a demand peak is expected.

Some utilities are capable of accurately forecasting the cost of energy in the near term, typically 24 hours in advance, and supplying this information to the residential consumer. The combination of predictive pricing and consumer DR may reduce peaks in demand, thereby flattening the load curve. As these innovative pricing schemes lower the peak demand, utility costs are reduced.

Figure 3 – Distributed load control



With Direct Load Control programs customers have limited choices about participating and which appliances are involved. They receive a small rebate regardless of the operating conditions or set points of the appliances-under-control. The control signals are not designed to switch operating modes of appliances even if these appliance were designed with an optional energy conservation mode.

Local load control

A manual version of Indirect Load Control is called Local Load Control, where customers are informed about electricity prices by printed or electronic mail and asked to adjust usage voluntarily. For this technique to be effective the customer would need to:

- 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.
- Know which combination of appliances may result in a demand charge if imposed by the utility.

Prices-to-Devices

It is possible to implement Indirect Load Control by sending utility prices and event notifications directly to smart appliances. EPRI calls this 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 appliances might be programmed with options that use less power by operating slower or altering a temperature set point. Ideally, customers should always have the option to override these actions and to restore full power usage, to select a different energy consumption mode, or to delay operation.

Figure 2 illustrates the connection of appliances programmed for Prices-to-Devices. A home network (also called a Home Area Network or HAN) delivers the price or event messages from the utility or service provider. A residential gateway may be interposed if the communications protocols on the utility and home networks are different. The gateway also serves as a line of demarcation between utility and homeowner equipment. As with Direct Load Control, the utility could install and maintain the home network and connect it directly to the utility network.

Distributed Load Control

Much more effective Demand Response is possible by exploiting microprocessor-based intelligence at the customer premises using Distributed Load Control. Distributed Load Control combines Local and Direct Load Control with much increased flexibility and customer control.

Distributed Load Control delivers enhanced energy management by processing a multitude of data sources about energy availability, appliance power requirements, and customer preferences using artificial intelligence (AI) features. The architecture is illustrated in Figure 3. The Energy Management Agent is the AI element. This will be the subject of my column in the next issue of *iHomes and Buildings*.

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. The United States Department of Energy appointed him to the GridWise® Architecture Council to guide the electric industry toward smart grids. For further information, please contact Ken at 781.662.6211; kenn@alum.mit.edu; www.kenwacks.com.

INDUSTRY TRENDS

Home Automation

Estimates from Transparency Market Research published last year suggest that global sales of home automation systems could exceed $21 billion within five years, yielding a healthy compound annual growth rate (CAGR) of 26.3 percent between 2013 and 2020.

Commercial Office Space

According to Building Owners and Managers Association (BOMA) International, 10.5 billion square feet of commercial office space located within the markets served by BOMA International's U.S. local associations generated $89.1 billion in operational expenditures in 2015 – $7 billion more than in 2013.

Video Streaming

The percentage of U.S. households with access to subscription video streaming services has matched DVR adoption for the first time, data from a Nielsen report indicate. DVR penetration has remained around 50 percent over the past year, while over-the-top video access has risen from about 42 percent adoption to 50 per cent in the same period.

Televisions

More than half of TVs shipped worldwide in the first quarter were connected to the Internet, IHS Markit data indicates. Four of every five TVs shipped from China were smart TVs, while 56 percent of sets shipped in North America were Internet-connected, a trend that was not seen in Japan or Europe.

Internet of Things (IoT)

IDC projects worldwide spending on the Internet of Things (IoT) to grow by 16.7 per cent year over year in 2017, reaching just over $800 billion. The research vendor projects that by 2021, global IoT spending is expected to total nearly $1.4 trillion as organizations continue to invest in the hardware, software, services, and connectivity that enable the IoT. Smart building technologies are also forecast to see significant investments this year to the tune of $40 billion.