METERING, COMMUNICATIONS AND COMPUTING FOR PRICE-RESPONSIVE DEMAND PROGRAMS

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1. INTRODUCTION

Competitive wholesale markets today resemble the sound of one hand clapping. They are often inefficient and not fully competitive, in part because retail-customer loads do not participate in these markets. Although electricity costs vary substantially from hour to hour, often by a factor of ten within a single day, most customers continue to buy electricity under time-invariant prices that are set months or years ahead of actual use. Thus, consumers are fully insulated from the volatility of wholesale electricity markets.

Customers should have the *opportunity* to see electricity prices that vary from hour to hour, reflecting wholesale-market price variations. Permitting customers to face the underlying variability in electricity costs can improve economic efficiency, increase reliability, and reduce the environmental impacts of electricity production (Hirst and Kirby 2001).

Metering, communications, and computing technologies are needed to support these dynamic pricing and voluntary-load-reduction programs (Fig. 1). To begin, customers must have meters that record, store, and communicate data on their electricity use at the hourly or subhourly level. Second, the load-serving entity (LSE) must be able to provide price and interruption-request information to the customer in a timely, usually automated, fashion. Similarly, the customer's interval kWh-consumption data must be transmitted periodically to the LSE. The LSE may provide additional data and analysis on the customer's electricity use and bill-saving options to the customer. Finally, based on these data and analysis, the customer may take action, either automatically or manually, to manage electricity use and costs.

The type of program determines how quickly information must be transmitted from the LSE to the customer and from the customer to the LSE. For example, if the customer is participating in a day-ahead dynamic-pricing program, the LSE needs to communicate with the customer only once a day. The LSE can post the next day's 24 hourly prices on its web site; customers can then access these data at their convenience. On the other hand, if the customer is providing nonspinning reserve, the system operator may issue customer-specific control signals on a minute-by-minute basis (e.g., reduce your load by 2 MW within 10 minutes). (Nonspinning reserve refers to a resource, either generation or load, that can increase or decrease output by a stated amount within 10 minutes.)

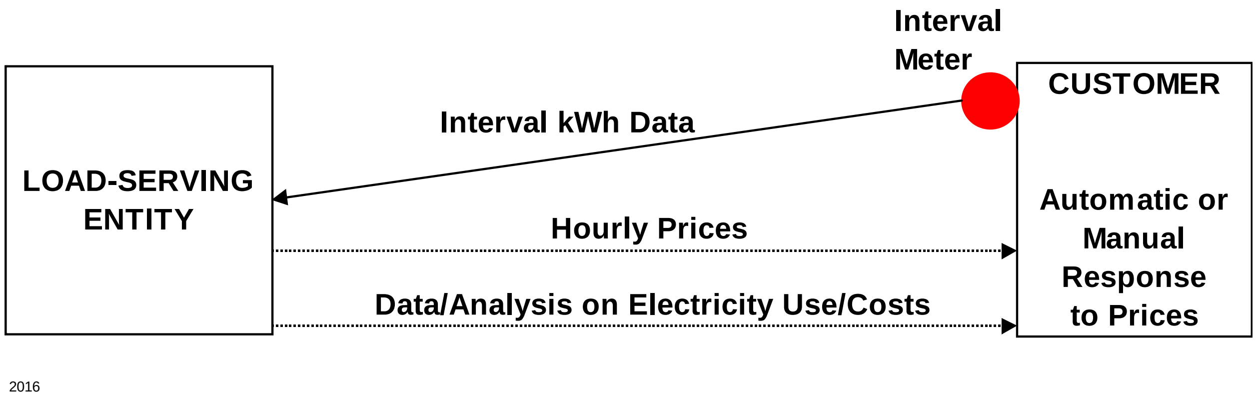

Figure 1 Dynamic-pricing and load-reduction programs require interval meters, communication systems to move data and instructions between the customer and its LSE, and perhaps automatic-control systems that respond to time-varying prices.

The frequency with which the customer's electricity-use data must be transmitted to the LSE also varies. Although all these programs require that the customer's load data be measured and stored hourly or subhourly, these data need not be reported to the LSE more often than once a month. However, if the customer is participating in a load-reduction program, the LSE might want to know the load reduction as it occurs, in which case the communication from the customer's meter to the LSE needs to be either much more frequent.

If the customer participates in a program that provides it with current information on its electricity use, ways to reduce that use, and current prices, the LSE will need frequent access to the meter data so that it can analyze these data and provide the customer with the results of its analysis. Alternatively, the customer's electric meter could communicate directly with its computer or energy-management system.

Because of the factors discussed above, it is difficult to estimate the costs of these enabling technologies. Table 1 offers a broad range, suggesting an annual cost of $30 to $250 per residential or small commercial customer. For large commercial and industrial customers (which use about 100 times more electricity than residential and small commercial customers), the range in annual cost is roughly $100 to $800.

Table 1. Approximate costs for metering, communication, and decision-support technologies

	Residential and small commercial	Large commercial and industrial
Interval meter	\$50 (retrofit) to \$200 (new meter)	\$250 to \$1,000 (new meter)
Communication systems (from LSE to customer and from meter to LSE) plus analysis software	\$2 to \$20/meter-month	\$5 to \$50/meter-month

2. METERS

Meters differ in what they measure and how frequently they do so (Otero-Goodwin 1999). Meters for residential and small commercial customers usually measure single-phase real energy use only. Meters for large commercial and industrial customers measure three-phase demand and energy and may also measure reactive-power consumption and power-quality characteristics. The traditional residential meter records cumulative electricity use, typically read once a month by a meter reader who walks from house to house. Advanced meters record and store (within the meter) electricity consumption at intervals of 5, 10, 15, 30, or 60 clock-synchronized minutes.

For residential and small commercial customers, it may be cost-effective to retrofit existing meters. These retrofits include a pulse initiator that generates an electrical pulse for every revolution of the meter disc, a data recorder that records the number of pulses, and a communication interface. These packages permit the capture of electricity-use data at 15-minute intervals with communication of that data to the LSE on a daily or weekly basis. The cost of such upgrade packages is \$50 to \$200.

For new installations, larger customers, or more sophisticated applications, a new electronic solid-state meter may be installed. Such meters range in cost from \$200 to more than \$3,000. The range is so large because these meters differ in the number of channels of data they record, the amount of data that can be stored within the meter, the number of communication ports, and the communication medium.

Expanding meter functionality can spread these costs over more purposes. Some advanced meters can accept data from gas and water meters and can transmit that data to the appropriate utility. Some meters can accept inputs from customer alarms, such as those that provide notification of flooding, freezing, or meter tampering.

3. COMMUNICATION SYSTEMS

As with all products, customers must know the price before they can make consumption decisions. Historically, fixed prices were communicated through published tariffs. This type of communication is adequate for prices that do not change or for prices that change with a fixed pattern, such as time-of-use rates.

Automatic price communication is required to communicate time-varying prices. Because customers are generally price takers, price signals can be *broadcast* to all the applicable loads simultaneously. Therefore, the LSE need not send a unique message to each consumer.

The frequency with which prices need to be communicated depends on the market. It may be acceptable to take several hours to deliver day-ahead energy prices. Real-time prices (e.g., those that are produced by the system operator's 5- or 10-minute markets) must be delivered within minutes. The communication system for transmitting such real-time prices must be automated and integrated with the system operator that runs the real-time market.

Several technologies are used to communicate real-time price information, including fax, telephone, e-mail, pagers, PC-to-PC communication, and the Internet. E-mail is currently the most popular choice because it is cheap and easy to automate. In some cases, the customer determines when it wants to obtain current price data, possibly downloading from a web site. In other cases, the supplier initiates the communication either when prices change or on a scheduled basis, usually by e-mail or by telephone. In either case, the communication is with the customer's staff, computer or end-use equipment (e.g., thermostat), not with the electricity meter.

Communicating price signals over the Internet (i.e., posting prices on a web site) is cheap, easy to use, and provides broad access to customers. It is much simpler for an LSE to host a web site than to establish telephone communications with each customer in a large group.

The kilowatt-hour consumption data recorded by revenue meters must be transmitted to the LSE and to the customer to guide load-control actions. For the vast majority of electricity consumers, meters are read manually once a month by meter readers. Automated-meter reading, now in use for 5 to 10% of the nation's electricity meters, is required to record and communicate electricity-use data at the hourly or subhourly level (Nesbit 2000). Two technologies dominate the AMR field, telephone and fixed radio networks.

Telephone lines are often used to communicate with meters, usually through a modem. The data transmission can either be initiated by the LSE (called outbound communication) or by the meter (inbound communication). In both cases, the communication can be conducted with the same phone line the customer uses; in some cases, a separate phone line is installed, which increases the cost of this option.

For inbound communication, the meter is programmed to call a phone number at certain times (e.g., at 2:30 am every night). The meter modems recognize when the phone is in use and will then place their phone call later. These modems can also recognize when the telephone is picked up while they are transmitting data to the LSE; they immediately terminate their use of the phone to permit the customer to use the phone and then resume data transmission later.

Outbound communication provides more flexibility for the LSE, permitting it to poll the meters whenever it wants to. On the other hand, the LSE now has to manage all these phone numbers and needs a ringless technology (so the customer does not hear the phone ring when the LSE calls the meter).

Phone systems can be used for customers who are geographically dispersed. Where the loads are densely packed, fixed radio systems may be preferred. In such systems, each meter has a transmitter/receiver attached to it. Radio transmitters/receivers are mounted on utility poles or outside walls of buildings, situated so they can "see" the meter-mounted radio systems. The pole- or wall-mounted systems then communicate with central transmitters/receivers, which in turn send the electricity-consumption data to the LSE's central computer.

Because radio systems do not rely on phone lines, they can communicate with the meters at any time. Communications are faster with fixed radio networks than with telephone systems. For low volumes, readings can take less than 10 seconds per meter. Such systems are used today to serve commercial and industrial customers. For high volumes, up to 100,000 meters can be read per hour, but this increases the processing time greatly. In most high-volume applications, the systems collect and deliver a daily read file for a million or more end points by 8 am next business day.

The costs of fixed radio systems depend on the number of customers connected to the system, the geographic density of the customers, the topology of the area (which affects the propagation of the radio waves), and the location of meters (indoors vs outdoors). Fixed-radio networks are lowest in cost when all (or almost all) the customers in a particular area are served by the same communication system. These radio systems are typically owned and operated by third-party vendors, which sell the service to utilities on a dollar-per-meter-month basis. The costs vary from about $1 to $5/meter-month, depending on the frequency of meter reading and the amount of data transferred.

4. ANALYSIS, DECISION, AND RESPONSE SYSTEMS

Communicating price signals from the LSE to the customer and consumption data from the customer to the LSE is, technically speaking, all that is required for customer participation in dynamic-pricing programs. But the benefits of such participation are much greater if the customer responds intelligently to these price and consumption data. Customers, based on this information might decide to:

- Do nothing and continue to consume electricity as before,
- Respond to price changes by manually or automatically adjusting consumption, or
- Invest in new equipment and controls to expand the range of possible responses.

In some cases, consumers might like to see data and analyses of their energy bills on a monthly basis. They may use this after-the-fact data to decide on operations and maintenance changes or capital investments that, on a long-term basis, will cost-effectively reduce their electricity bills. In such cases, the meter resolution is hourly but the communications can occur infrequently.

Other customers will choose to respond closer to real time. For these customers, LSEs may provide data and analysis tools that help customers decide what to do when. Such systems can be especially helpful to customers who decide to take manual-control actions only during the few hundred highest-priced hours during the year. Systems such as Silicon Energy’s Enerscape software (and similar packages from iTron and Active Energy Management) can facilitate such decision making.

If the customer plans to respond routinely to price changes, automatic response is more practical. Johnson Controls and Honeywell market systems that integrate electricity-price data with their automated building-management systems. In general, these systems use the Internet to communicate with customers, although pagers are also used. The Honeywell system was tested at a few large facilities and demonstrated savings of 10 to 20% through automated response to dynamic prices (Kiernan 1999).

Carrier Electronics developed a thermostat for residential application that, upon receipt of a control or price signal from the LSE, can adjust air-conditioning or space-heating temperature settings up or down. Puget Sound Energy conducted a small Home Comfort Control pilot program during the 1999/2000 winter season. The program featured a two-way radio-communication system from Schlumberger, programmable thermostats from Carrier Electronics, and energy management and Internet services from Silicon Energy. The program tested customer comfort and acceptance of 2^o and 4^o F decreases in temperature setting for two hours at a time, periodically invoked by the utility. The pilot program demonstrated the reliable operations and integration of the technologies and very high customer satisfaction.

Apogee Interactive operates an Internet-based demand exchange that permits customers to bid load reductions to their LSE. Several utilities, including Portland General Electric, GPU Energy, and the Bonneville Power Administration use the Apogee system (Gilbert 2000). Apogee has about 2,800 MW of load reduction under contract, involving more than 500 customers of all types.

5. CONCLUSIONS

The Federal Energy Regulatory Commission (2000) recently noted that “lack of price responsive demand is a major impediment to the competitiveness of electricity markets.” Clearly, we must have customer participation in bulk-power markets; otherwise these markets will not and cannot be truly competitive, and the expected benefits of competition will not be realized.

Although the potential benefits of dynamic pricing are large, so too are the barriers to widespread adoption. One important barrier is the limited use to date of the metering, communication, computing, and control technologies needed to realize these benefits. These technology barriers will likely fall as more dynamic-pricing programs are offered throughout the country and as these functions are standardized, allowing equipment and software manufacturers to harness the benefits of mass-produced electronic systems.

Standardization can help lower the costs of advanced meters and communication systems. The tasks required of these systems are no more complicated than those performed by devices like cell phones, pagers, and calculators. To realize cost reductions requires mass production, which should not be a problem, given the existence of 125 million electric meters in the United States. Such mass production, however, requires standardization of the functions, communication protocols, and markets so that inexpensive devices can be designed and manufactured.

Ultimately, the convergence of retail competition, wholesale competition, and improved technologies should greatly expand the type and magnitude of price-responsive demand. Permitting and encouraging retail customers to respond to dynamic prices will improve economic efficiency, discipline market power, improve reliability, and reduce the need to build new generation and transmission facilities.

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