Demand Response & Advanced Metering Coalition (DRAM)

Overview of Advanced Metering Technologies and Costs

April 2004

Introduction

As policy makers at both the federal and state levels look at what options they have to address today's energy challenges, they continue to focus on demand response as one of the key options at their disposal. As such, they have begun to look at the most common enabling technology for demand response – advanced metering - and are seeking to understand, from a technology standpoint, exactly what these "smart" meters are and how much they cost. This paper is intended to provide information to address those questions. While advanced metering provides a number of benefits and capabilities outside of the area of demand response, this review focuses on the type of demand response known as dynamic pricing. Dynamic pricing refers to when customers are provided with time-differentiated rate and price signals that incent them to modify their electricity usage in ways that benefit them as well as the electricity provider and other parties. The most common types of dynamic pricing are time-of-use (TOU), real-time, and critical peak.

Metering Technology

The primary technology for enabling customers to receive the price and usage information necessary for them to be demand response participants is the electricity meter. However, not all meters are designed to measure and provide such data and allow the necessary communication to enable demand response. The following represents an overview of the different metering technologies that are currently being used and/or deployed, with particular emphasis on the ability to support demand response.

Conventional Meters

For decades after the birth of the electricity industry, the electricity meter was a simple technology with a simple purpose. Its job was to measure the amount of electricity used by a customer, primarily in terms of total consumption (kWh) but in the case of larger customers in levels of maximum demand (kW), or highest instantaneous use, as well. Such meters do not allow the recording of usage by time of day and, thus, do not enable time-based pricing.

While these conventional meters automatically *measure* and *record* usage data, the *reading*, or *collection*, of such data is not automated. Instead, meter readers go building to building visually inspecting the meter and manually recording the usage data. Such data for a mass market customer almost always consists of one data point – total cumulative kWh usage during the measurement/billing period (usually monthly).

One disadvantage of this system of conventional meters and manual meter readings has always been the difficulty, and sometimes impossibility, of having access to the meter in many buildings - particularly in urban settings. This has created problems for the utility in terms of bill estimation and dissatisfaction on the part of the customer receiving multiple estimated bills.

From a standpoint of business operations, a conventional system is reliable but yet it does not yield any added-value data that would allow a utility to know more about its customers and how, when and why they were consuming its product. It also provides the utility with no detailed information to use in designing, building and operating its system more efficiently or cost-effectively. Such information is of great value, since utility systems must be sized to serve peak demand, and conventional meters do not provide such data (except for a small number of large commercial customers, and even then it is not time stamped data).

AMR – Automatic Meter Reading

In the 1990's, general advances in technology began to be applied and commercialized to metering. The most significant and most applicable advancement came in the area of communications. Radio, power line and wireless-based communications technologies meant that it was now possible to collect and read the meter without a visual inspection of each and every meter. A meter could now be installed or fitted with technology that would allow its data to be sent to meter readers as they walked by a building or, better yet, drove down a street in a van equipped with equipment that could poll the meter and retrieve the data. The immediate advantage to the utility from these new Automatic Meter Reading (AMR) systems was the potential for cost savings due to a reduction in labor costs. Such cost savings have indeed been at the core of the business cases done by utilities which have deployed these systems in past years.

AMR systems were a major technological breakthrough in many ways and have provided benefits to utilities deploying them. Meter reading accuracy increased and costs decreased. It became easier for customers to request billing data changes and for Customer Service Representatives (CSRs) to deal with customers, particularly regarding outages. However there was no new price and usage information for customers that would prompt them to use energy any differently. The technology did not enable the utility to implement time-based dynamic pricing nor did it "enable" the customer from a demand response standpoint. Utility operating departments for the most part did not see any new data with which to improve their efficiency and effectiveness.

It is important to note that AMR systems which rely on mobile or "drive-by" technology are generally unable to be modified to provide advanced metering capabilities, since these capabilities require a fixed network. This issue is discussed further in the section on advanced metering below.

Non-communicating Time-of-Use (TOU)

Some AMR systems do have the capability to *measure* and *collect* usage data based on the time of day of that usage. Such measurement is essential to be able to bill using prices that differ based on time of day. These systems measure and assign a kWh to the time period in which it was used, but there is no daily/hourly *recording* of such usage on an interval basis. At month's end, only the gross totals for each time period, i.e. one data point for each period are produced. In addition, these systems do not have the capability for the utility, when it makes sense for it and its customers, to remotely change the time period boundaries. It means instead manually accessing the meter to make such a change.

There are meters that go beyond AMR to allow measurement in smaller intervals and allow more precise TOU pricing as well as Critical Peak Pricing (CPP), but yet which do not have communications capabilities. These meters also are likely to have other additional measurement capabilities for things such as power quality. But the absence of communications means that there is still a lack of flexibility for remote control of the metering parameters. It also means that the data collection remains a manual read by a meter reader, so customers do not receive feedback on a Critical Peak Pricing (CPP) event until the end of the month.

Advanced Metering

During the 1990's advances in communications technology (e.g. internet, power line communications [PLC] and wireless) began to be applied to metering to create "advanced metering". The meter itself also advanced technologically with the introduction of solid state metering technology with more accurate measurement capability as well as new capabilities to measure parameters other than simply usage and demand.

Advanced metering incorporates AMR ability but provides additional capabilities not only to the electricity provider but also to the customer and other parties such as regional transmission/market entities and competitive electricity providers.

It is important to note that some conventional meters can be retrofitted to provide advanced metering capabilities. However, the resulting cost may be only slightly lower than the cost of replacing the meter.

The key criteria that define advanced metering include the following:

Continuously available communications

An essential ingredient for advanced metering is the fact that communications now become continuously available, since advanced meters communicate via a fixed network, not a van driving by once a month as is typical with AMR. Not only does the meter automatically communicate with the utility to allow billing of the customer, but the utility (and in some cases the customer) can now receive data more frequently from the meter (typically daily, but in some cases on an hourly basis or less). The utility also may be able to easily change its metering measurement parameters remotely.

Interval measurement

Whereas most AMR technology is based on a cumulative total data point for what is most often a monthly period, advanced metering introduces interval measurement. Advanced meters are normally considered those capable of, at a minimum, measuring usage data on an hourly basis.

Dynamic pricing

Dynamic pricing in simple terms refers to pricing that varies according to the time at which the energy is used. It is normally tied directly or indirectly to prices in the wholesale market or to system conditions (peaks) and normally is delivered to the customer via time-based rates or tariffs. Commonly and erroneously referred to generically as Real Time Pricing (RTP), the latter is only one example of dynamic pricing, with Time-of-Use (TOU) and Critical Peak Pricing (CPP) being other forms. Each has very different attributes and characteristics but each relies on advanced metering to be enabled.

Without the utility's meters being able to measure in intervals, it cannot bill according to the time of usage and it cannot offer time-based dynamic pricing options to its customers. Without customers being able to see how and when they are using electricity, they will not accept being placed on time-based options. Advanced metering provides what each party needs.

Combine interval measurement with continuously available remote communications and a utility has an even greater ability and flexibility in the provision of dynamic pricing programs, as it can change the interval and other measurement parameters automatically and remotely at any time.

Information to the customer

The vast majority of customers, particularly in the mass market, still receive at most a daily usage total and a cumulative monthly billed amount which is determined by multiplying total usage by one fixed, non-time-sensitive price.

With advanced metering, the utility has new and different data to provide to the customer. Interval measurements allow the customer to choose to participate in demand response programs. Customers feel empowered with a new ability to change the way that they use electricity in ways that will benefit them financially. As the saying goes, "one cannot manage what one does not measure" and that is surely true in the case of advanced metering as it becomes a platform for customer efforts on energy efficiency and demand response.

Frequency of transmittal

Separate from *measurement* of the usage is the frequency at which such data is *transmitted* to the utility and the customer.

The commonly accepted parameter for advanced metering is that it should be capable of transmitting data to the utility on at least a *daily* basis. The customer may be provided with the capability to also see the metering data on a daily basis but it is not necessary for the customer to access such data daily to participate in dynamic pricing programs. The added value information can be provided to the customer via their monthly bills and also via reports by the utility (bill inserts or even e-mail).

It is also important to note that this parameter of *transmittal frequency* is different not only from *measurement frequency* but also *billing frequency*. Hourly measurement and daily transmittal frequencies are usually combined with monthly billing. The key is the type of data provided.

Information to the utility

Armed with the information that an advanced meter can provide, a utility can use aggregate information and use it to optimize the planning, design and operation of its generation, transmission and/or distribution system. For example, numerous studies, including DOE's May 2002 National Transmission Grid Study, have pointed to the potential for demand response to be used to mitigate transmission constraints and operate an electricity system more efficiently during times of peak demand. Advanced meters also provide information on power quality and outage detection and restoration that can make those aspects of a utility's operations more efficient, cost-effective and customer responsive.

In addition, a utility can use the information it obtains via advanced metering to develop new products and services for its customers, ranging from demand response programs to other added value offerings. The dynamic pricing programs themselves can become new products for a utility which introduce new and interesting choices for customers in terms of how they purchase the product.

Communications Technology

One of the major differentiating factors among metering systems, including from a cost standpoint, is the communications technology and devices that are used to enable advanced metering. Communications is also the key factor that supports other demand response and control technologies that are required to take advantage of maximum price elasticity. The communications technologies utilized use open standards (like Internet protocols) and (where possible) the public infrastructure for interface between the meter and other demand response technologies and the existing utility IT infrastructure.

Most advanced metering and demand response communications systems use a multi-layer communications architecture, typically defined as a Wide Area Network (WAN), and a

Local Area Network (LAN). WANs are often some form of generally available public network, such as telephone, wireless phone, wireless data, and Internet. LANs extend from the gateway, router, or bridge between the WAN and the LAN to the end device (meter or control device). LANs are typically wireless or power line carrier. The WAN/LAN interface device is typically called a gateway.

Each layer of the communications system must support the necessary data throughput for the maximum expected number of devices. Devices can be connected directly to a WAN, such as for large commercial customer metering. However, in most cases, devices communicate through a LAN and gateway. The reason is that the cost of a LAN communications module in a device is typically significantly lower than a WAN module.

The following considerations enter into selection of WAN and LAN technology:

- Minimum throughput required to support primary metering or control applications
- Maximum latency required to support metering or control applications
- Minimum availability (percent of uptime vs. downtime) of communication to each device
- Interface standards between the LAN and WAN
- Interface standards to metering and control devices
- Interface standards between the WAN and the utility's information technology infrastructure

WANS

Most publicly available WANs are reasonable for use in advanced metering and demand response communications. Public networks are characterized by open access, transparent pricing (generally), and high reliability and availability. But these networks are evolving.

LANS

LANs are typically either wireless or power line carrier. Standards are evolving for both. Some wireless LANs are proprietary. Some large-scale deployments of advanced metering network LANs use proprietary wireless LANs. Other wireless LANs are standards-based, such as IEEE's 802.11b (a.k.a., Wi-Fi or Wireless Fidelity) for wireless networks. While popular, Wi-Fi has cost and coverage issues that must be considered in its potential use. At this time, no significant installations of advanced metering or control technologies utilize Wi-Fi, so it has yet to be proven as a viable technology for advanced metering or control. Other standards are under development for wireless LANs (an example is 802.15). As with Wi-Fi, none of these standards-based wireless LANs has been used for advanced metering or load control in any significant way.

As with wireless LANs, both proprietary and standards-based power line LANs are available. Current large-scale deployments include examples of both.

Device Density

A major consideration in communications network design and deployment is device density. The cost of a gateway must be amortized over the number of devices connected to the gateway. As the number of nodes serviced by each gateway decreases, the cost per device increases. Thus, the gateway cost per device is not a specific number, but a curve that decreases with increasing density.

Metering and Communications Technology - Options and Costs

Table A presents DRAM's view of the different metering and communication technology options, ranging from conventional metering to advanced metering. It also includes cost ranges for these technology options.

Table A lays out four different *technology options*. In addition to a conventional meter and an AMR option, it differentiates between a non-communicating TOU meter with some advanced functionality and a communicating advanced meter.

It is evident by the categories that communications technology is key to the capabilities of a metering system and the delineation among system options. Among the communication factors that need to be considered are the *media*, which can range from a human meter reader to a private radio system (as in a drive-by AMR situation) to the various options that fall under the heading of "fixed network". Table A lists the various types of fixed networks and indicates that only with such networks does one have the ability to also introduce remote and price-sensitive control of equipment and appliances.

The second major segmenting factor is *functional capability*. It focuses in particular on interval measurement and non-billing-related capabilities of the different meters. It does indicate that some AMR systems are capable of supporting time-based pricing. Absent hourly interval measurements, however, the TOU basis would come from pre-set intervals that would provide one monthly number for each interval, as opposed to hourly and daily based information. Pre-set means that the time-differentiated measurement periods are set inside the meter and cannot be changed without manually accessing the meter.

The third factor is the frequency of data measurement, which is discussed in a previous section of this document.

The fourth factor is frequency of data transmittal, and Table A subdivides among three subcategories: transmittal to the utility, transmittal of billing data to the customer, and transmittal of usage data to the customer (the last being for purposes of managing or shifting energy or usage during the day in close proximity to when the information is received).

The fifth factor breaks out information to customers in terms of what type of information they would get and how they would get it.

The final three factors all deal with costs: Meters vs. Installation vs. the Communications Network.

Metering Costs are shown for the type of meters most applicable to the mass market and large customers, respectively. It also differentiates between those meters with built-in communications capabilities and those that would be retrofitted with such.

Meter installation costs are broken down between mass market and large customer segments but more importantly are separated between ad hoc, scattered deployments and large-scale contiguous deployments. The cost range between the two deployment scenarios depicted here may be conservative. Estimates have been made that it can be up to 5 to 7 times more costly to buy and install meters on an ad hoc basis as opposed to via a mass deployment.

Communications network costs indicate show the cost of the one-way communications network for AMR and the fixed network costs for advanced systems. The range within the advanced category is wide, owing to the fact that such costs depend on the specific meters being utilized. As previously noted, some meters have more communications capability embedded in them than others, and thus require less in the way of a fixed network. A trade-off on location of the communications capability between meter and network means a trade-off in location of the costs for such.

Total costs, largely because of the communications cost issue just discussed, show a wide range but also indicate a marginal cost of approximately $20 to 25 dollars between AMR and advanced meters.

Summary

Fueled by demand response and the large benefits it provides, but also by the general expectations today by customers for informational and pricing options, advanced metering is increasingly being viewed as a basic building block of a "smart" electricity system. Costs for advanced metering technology and products have dropped and are lower than commonly assumed. There are many advanced metering options, particularly when it comes to communications technology, that all focus on common performance and functional parameters that include frequency of measurement, frequency of retrieval by the utility, and frequency of information and price signals to customers.