Demand Response And Standards

New Role for Buildings in the Smart Grid

By David Holmberg, Ph.D., Member ASHRAE

For the past century, buildings have been simply "load" or "demand" from the perspective of utilities. The role of buildings in the electric grid is steadily being transformed to that of active participant in managing the grid, serving as a key player in maintaining grid reliability. The necessity for this transformation results from three factors:

- Grid use is not constant, but rather characterized by night troughs, and strong summer afternoon and winter morning peaks. And it is getting more "peaky."
- Power produced to meet peak demand is expensive and dirty (pollution and CO_2).
- Political and environmental pressures are pushing toward intermittent renewable power generation, which is not dispatchable; it generates when the resource (solar, wind) is available.

These factors are driving the U.S. and the world to greatly expand the scope and use of demand response (DR), and to tackle the standards, regulatory, and technology issues that hinder that expansion. Demand response is the "demand" side (the customer) responding to the needs of the grid. While DR has traditionally been associated with temporary load reductions during system peaks, the goal of the Smart Grid is an "all the time" paradigm. It is about facilities (homes, commercial and institutional buildings, and industrial facilities) supporting grid reliability with shared benefits. It is not only peak event communication, but also real-time electricity price communication, and facility participation in energy market interactions.

This rapid growth of demand response has revealed the need for a clearer understanding of how buildings should interface with the grid, and the need to develop standards to enable buildings to actively participate in the Smart Grid. This article describes the changing nature of DR, the architecture of the customer interface to the Smart Grid, and then focuses in on the key standard for DR: OASIS Energy Interoperation produced by the Organization for the Advancement of Structured Information Standards (OASIS).

Demand Response Advancements

As of 2010, the Federal Energy Regulatory Commission (FERC) estimated

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there were 58 GW of demand response resources enrolled in DR programs, representing 7.6% of peak demand.[1] As an indication of the growth of DR, results of the recent PJM (an eastern U.S. Independent System Operator [ISO]) capacity auction for resources serving the 2014–15 delivery year show that while 6.9 GW of coal-fired power fell out of the market, DR saw significant growth, adding 4.8 GW—a 52% increase over current PJM DR levels.[2]

In addition to this growth in capacity, DR has an increasing number of variations in response to different energy market products (capacity, energy, and ancillary services) and regulatory variation state to state. The development of automated demand response communications combined with facility automation has enabled faster response times and better reliability. This, in turn, allows demand response to be bid into day-ahead energy markets, and more recently has enabled "fast DR" resources that can respond in minutes and meet the requirements for ancillary services including voltage and frequency regulation.[3]

These expanded DR program options are accompanied by changes in the customer domain. DR is now more than load shedding and shifting; it also includes the integration of facility-owned storage (to aid load shifting) and generation resources (both renewables and fossil fuel generators). As an example of the changing technology options in the customer domain, a recent Electric Power Research Institute report detailing the state of storage technology says that the availability of storage solutions is expected to increase markedly in 2012, when a host of new options begins to emerge.[4] These include new battery chemistries, supercapacitors, and flywheels, integrated into storage systems to meet different application needs from customer power quality and support for load shifting up to grid-scale renewable energy support. Regarding renewable energy integration, customer facility-sited photovoltaics (PV) are growing rapidly. The Solar Electric Power Association reports that the top 10 utilities integrated 561 MW of PV in 2009, representing a 100% increase over the previous year, and 60% of this was customer-sited PV.[5]

DR programs exist at the wholesale and retail levels. Retail DR programs serve smaller customers (residential and small commercial) and are operated by the distribution utility (or energy service provider). Wholesale energy markets, run by Independent System Operators and Regional Transmission Operators (RTOs), have minimum power requirements that limit participation to larger generators, aggregators, and large facilities. Many types of DR programs are offered at the wholesale and retail levels, with differences in terms of: product, notification times, response times, length of response, baseline calculation methods, payment terms, etc. The availability of DR opportunities depends on the local utility, state policy, and regional energy markets.

These DR advancements highlight some specific needs. The rapid growth in number of DR resources and changing dynamics of customer response (from "shed this load" to "shed, shift, store, bring on backup generation") highlight the priority of understanding how the facility should interact with the grid—that is, the architecture of the facility-to-grid interface. The wide variety of DR programs at retail and wholesale levels (with variation from region to region), each with similar but different product classifications and other program requirements, highlights the need for clear standards for communication of DR program and market information.

Taking Advantage of the Smart Grid

What should the facility owner or manager be doing now to take advantage of the Smart Grid wave? Here are some action items:

- Look at any utility (or ISO wholesale-level) DR programs or real-time dynamic tariffs that may be available. These are the tools for providing economic justification for investing in more advanced energy management software, hardware, and renewable technology such as solar PV or storage.
- Ask about utility rebates for installation of renewable energy technologies, including solar PV and automated DR controls. Your local utility may soon support OpenADR and provide financial incentives for installing energy management and auto-DR controls.
- Consider demand response strategies. First look at energy efficiency strategies—what can you do to reduce energy consumption all the time. Then consider what loads can be shed or shifted during peak times to minimize demand peaks or energy consumption during high-price windows.
- Make plans for additional control systems and renewable technology to enable DR strategies when electricity rates go up, dynamic rates are in place, grid reliability event response is mandated, or new DR programs are offered.

Architecture of the Facility-to-Grid Interface

As part of the federal government's efforts to advance Smart Grid, Congress assigned to the National Institute of Standards and Technology (NIST) the task of coordinating standards development for the Smart Grid. NIST has tackled that assignment in two ways: by developing a roadmap/framework to guide standards development, and by establishing the Smart Grid Interoperability Panel (SGIP) that serves as a public/private partnership for addressing interoperability issues and accelerating solutions.[6]

NIST has just published the "NIST Framework and Roadmap for Smart Grid Interoperability Standards v2.0."[7] This "NIST Framework" provides an architectural framework for the Smart Grid, identifies standards gaps, and introduces priority action plans to address these gaps. Chapter 3 of that document specifically addresses the architecture of the customer interface and the concept of the "energy services interface" (ESI).

The conceptual reference model (*Figure 1*) from the NIST

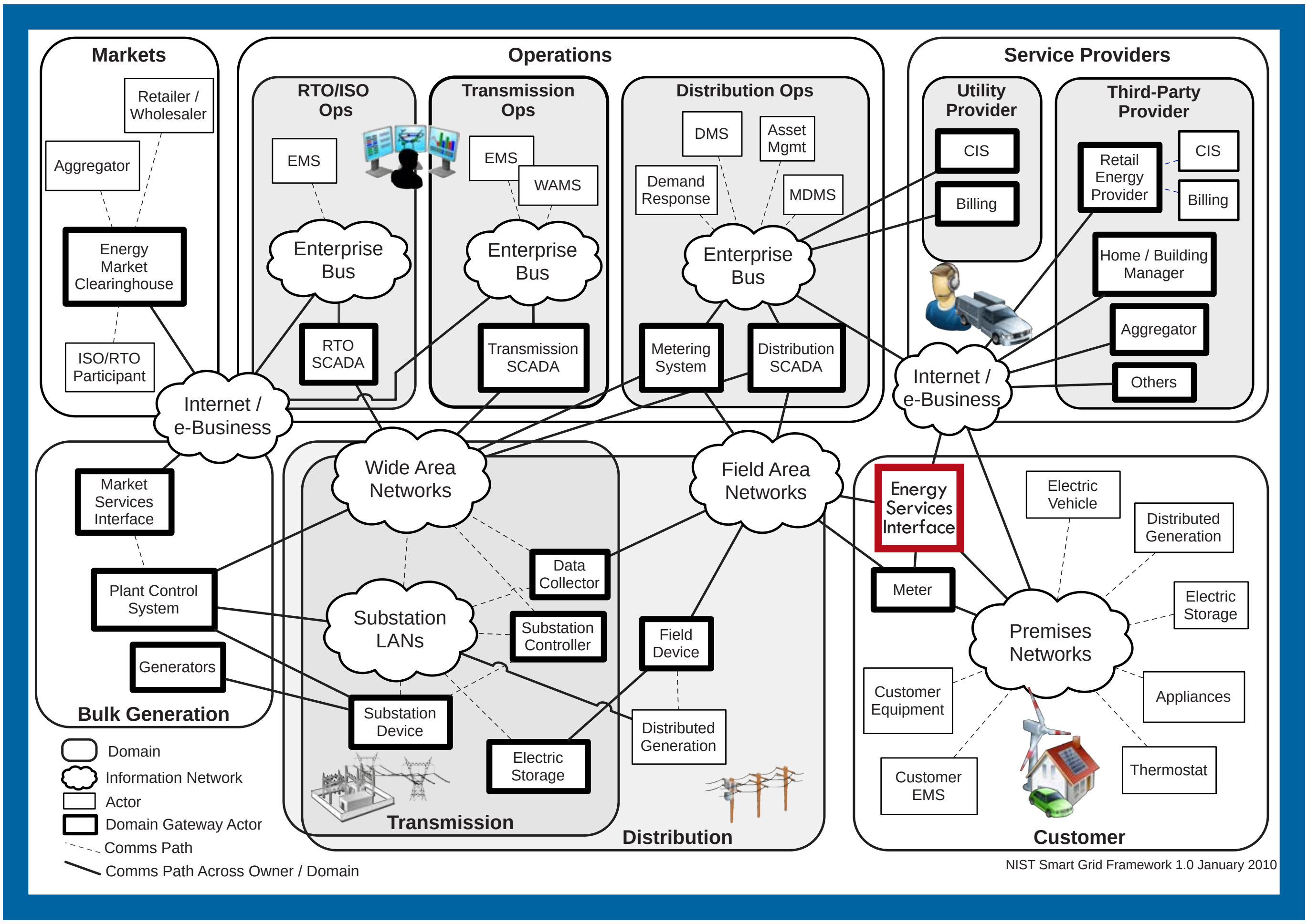

Figure 1: NIST conceptual reference model for the Smart Grid[7] and the energy services interface (outlined in red) as the information interface to the customer domain.

Framework shows the ESI as the communications interface to the Customer domain.* In commercial buildings it might be integrated into an energy management system (EMS), or into a sub-system or device. In reality, there may be multiple ESIs in a facility, and they may even be organized in a hierarchy. The ESI provides access to information to support business processes involving interactions between energy service providers and energy service consumers. ESI information services include: DR signals (event signals from a utility, as well as availability schedules and event feedback from facility to utility), price communications, weather data provisions, and market communications (bids, offers, transactions).

Figure 1 shows that the Customer domain interacts with multiple other Smart Grid domains via the ESI and the "Internet e-Business" cloud. Specifically, the ESI is the interface to the Markets, Operations, and Service Providers domains. The traditional narrow scope of DR has been limited to peak event signals originating in the Distribution Operations sub-domain of the Operations domain and ending at the Customer domain.

The more expansive Smart Grid view of DR includes the aggregator in the Service Provider domain, the RTO/ISO Operations sub-domain of Operations, and the Markets domain.

The lower half of *Figure 1* (Bulk Generation, Transmission and Distribution, Customer domains) represents the traditional power system, with bulk generators producing power delivered through the transmission and distribution domains to the customer. As we move forward, we will see more generation and storage resources distributed throughout the transmission and distribution system, including on the customer site as already noted. In fact, a customer facility may be a self-contained microgrid that includes aspects of all the domains in *Figure 1*, including a local market. And we may see the development of retail energy markets serving multiple customers.

The potential for more market interactions at the customer level, and the reality of a broader DR scope that includes price communication, pointed to a need for standards to address price and product definition as well as DR and market communications. The SGIP serves as a consensus-building organiza-

*The meter also serves as a communication interface. While the meter and ESI are logically separate, the ESI function may be implemented in the meter. This is common for residential "smart meters."

OpenADR Specification

Some readers may be familiar with Open Automated Demand Response (OpenADR). OpenADR was developed by Lawrence Berkeley National Laboratory in trials with California utilities over the last decade. The OpenADR 1.1 specification served as input to the development of Energy Interoperation. OpenADR 2.0 is a subset (a profile) of the larger EI standard. OpenADR 2.0 is intended to benefit utilities and aggregators by enabling DR communications. The focus of OpenADR is on the traditional event-based model, although it allows for communicating real-time price as part of an event signal.

This past year has seen the establishment and growth of the OpenADR Alliance (www.openadr.org), an industry alliance that will provide the education, training, testing and certification needed to bring OpenADR to a wider market. The Alliance will advance demand response and increase the options (products as well as utility programs) available to facility managers.

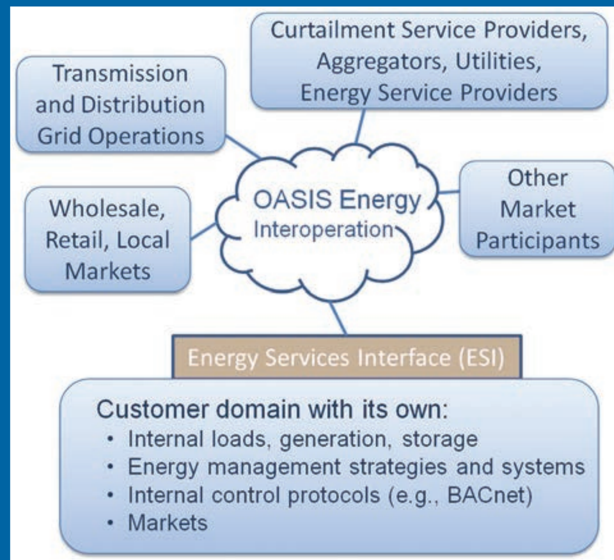

Figure 2: OASIS energy interoperation serves as the direct response and market communication protocol for cross-domain interactions.

tion for identifying standards gaps and coordinating the effort to develop standards to fill those gaps. In this case, a series of workshops in 2009 highlighted these standards gaps and led to the development of a priority action plan (PAP) to address a price and product information model,[8] and another action plan to address DR and Distributed Energy Resources (DER) communications.[9] The Organization for the Advancement of Structured Information Standards was chosen to develop a new standard (Energy Market Information Exchange, EMIX) as part of the first action plan, and another new standard (Energy Interoperation) as part of the second action plan.

OASIS EMIX[10] provides the information model for representing a price as part of a schedule, and also for representing the details of the product that is being bought or sold. If one is bidding a DR resource into a market, what is the size of the resource, notification requirements, time response and duration capabilities, ramp up and down details, etc.? EMIX can represent this information, as well as market requirements for capacity, energy, ancillary services, and any other type of energy product.

OASIS Energy Interoperation (EI)[11] includes an information model for DR events, and also provides the messages for communicating DR events and market transactions. When communicating price and product information, it encapsulates EMIX payloads. At the time of publication of this article, EI should be in process for SGIP recognition as the standard for DR in its broadest sense—serving the cross-domain interactions discussed earlier in reference to *Figure 1*. A simplified picture is shown in *Figure 2* where EI serves as a web services-based protocol for communications between the customer ESI and other domains in the Smart Grid. In fact, EI may be used in other domains beyond the customer domain (e.g., for market interactions for bulk generators) as well as within the customer domain. This is discussed more in the following section.

OASIS Energy Interoperation

OASIS EI specifies an information model and messages to enable standard communication of: DR events, real-time price, market participation bids and offers (tenders), and load and generation predictions. The standard includes (1) the specification document with scope, architecture, and service descriptions including Unified Modeling Language (UML) diagrams, along with (2) service descriptions in XML schema (web services messages must conform to the schema). The specification and schema are all freely available from OASIS.[11] The standard version 1.0 is slated to be completed around the time of publication of this article.

EI has two main components: demand response communications, and market interactions. A common framework was developed for these two parts, with DR events fitting inside the larger context of market interactions. In the semantics of EI, a market interaction process is shown in *Figure 3*.

The figure shows where a DR event fits within the context of the transaction process—in this case, the facility owner has a pre-executed options contract that says the owner agrees to take some action when an event is called (exercising the option). The contract was signed earlier at DR program enrollment. Delivery happens when the facility sheds load as verified by the meter.

Most of today's U.S. energy market interactions take place in the ISO/RTO wholesale markets. The ISO/RTO Council (IRC) worked to build a common perspective among its members on the information exchanges needed to support the business processes of the different ISOs and RTOs along with wholesale DR program and market interaction requirements. This was provided as input to the OASIS EI Technical Committee. In addition to this, the OpenADR specification (see sidebar, "OpenADR Specification") represented a solid foundation for retail (that is, utility to customer) demand response programs, serving as a second important input to the EI Technical Committee.

The EI architecture is very simple, reduced to service interactions between two parties. A party can be a facility EMS or device, demand response provider, market operator, distribution system operator, microgrid, or any other participant in a DR event or market transactions of energy. Parties may participate in many interactions concurrently as well as over time. In theory, any party can transact with any other party subject to applicable regulatory restrictions. In practice, markets will establish interactions between parties based on regulations, economics, credit, locations, and other factors.

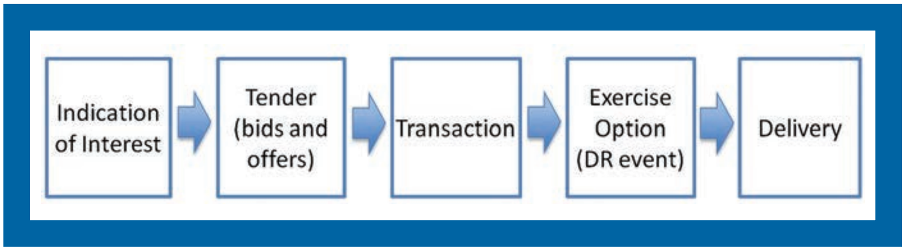

Figure 3: Transaction process in energy interoperation.

Figure 4 presents this architecture from the EI Event interaction perspective. This figure introduces the notation of Virtual Top Node (VTN) and Virtual End Node (VEN), the two abstract parties in the DR event interaction. The VTN is the node coordinating a response, and the VEN is the responding node. In *Figure 4*, certain parties (B, E, and G) act as both VTN and VEN. This directed graph with arrows from VTN to its VENs could model a reliability DR event initiated by an ISO (at A) who would invoke an operation on its second level VENs B and E, which could be aggregators. The second level VTN B in turn invokes the same service on its VENs F, G, and H, who might represent industrial parks with multiple facilities or a company headquarters with facilities in many different geographical areas, who then invoke the same operation on their VENs. Each interaction can have its own security and reliability composed as needed—the requirements vary for specific interactions. *Figure 4* does not mean to imply a hierarchy, since a customer EMS could be the VEN for a DR event message, and at the same time be the VTN for a DR resource bid to market.

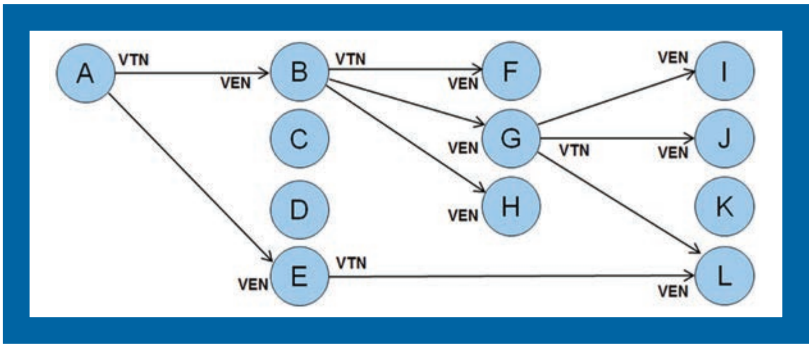

Figure 4: Directed graph of example demand response interactions.

Different EI services provide for the communication of DR event details, including both simple and more complex schedules. In addition to the EI Event service (EiEvent), there are supporting services for DR program enrollment (EiEnroll), communication of schedule constraints (EiAvail) and opting out of events (EiOpt). There are two other DR services: the Feedback service (EiFeedback), which communicates information about the state of the resources, and the Status service (EiStatus), which communicates information about the state of an Event. Apart from DR event interactions, there is a separate set of transactive services for party registration, quotes, tenders (bids and offers), transactions, and delivery.

EI was developed on the principles of loosely coupled interactions at a clearly defined interface (the ESI), and composition of standards, as reflected in the Service Oriented Architecture[12] approach. Different interactions require different choices for security, privacy, and reliability. EI defines only the core information exchanges and services; there is no optionality related to security or reliability in EI.

Energy Interoperation is the NIST/SGIP-recommended and supported national standard for demand response. This standard for DR signaling and market interactions enables:

- Effective response to price signals and DR events;
- Trading of load curtailment and distributed generation; and
- An EMS vendor to sell EI-“speaking” products that allow facility systems to interact with any utility (or other service provider) implementing EI without custom programming of the interface.

ASHRAE’s Role in Smart Grid

OASIS Energy Interoperation is the key cross-domain DR and market transaction standard. ASHRAE members have been actively participating in the SGIP process: discussing the nature of the ESI and developing the standards framework at the customer interface to the grid. ASHRAE is developing two key standards for Smart Grid: ASHRAE Standard 201, Facility Smart Grid Information Model (discussed in an accompanying article in this issue), and ASHRAE Standard 135, BACnet. In essence, the Standard 201 information model incorporates the Energy Interoperation DR event and EMIX pricing models to address energy interactions within the customer domain as well as across the ESI. BACnet then uses that same information model and provides tools for enabling facility energy management for demand response. A future article will address recent advances within BACnet for Smart Grid.

Conclusion

Options for facility interaction with the power grid are increasing daily as standards, technology, regulations and markets advance, and as DR programs expand in scope and number. The concept of demand response has expanded from a traditional view of utility peak shaving via central dispatch to that of facility interaction with markets, grid operations, and service providers, enabled by a common protocol and standard information models. OASIS Energy Interoperation now makes consistent communications possible in demand response programs nationwide, and if adopted by utilities and service providers, the ability of energy management systems to participate in any DR program without custom programming.

The grid is steadily getting smarter, with technology, regulations and legislative changes pushing it forward. In fact, the U.S. must move toward a system where buildings and other consumer facilities act as "demand response" resources to help maintain grid reliability. We will be integrating more intermittent renewables and depending on buildings to become more intelligent, shifting and balancing load and demand peaks in response to price and grid reliability signals. You, too, will be carried along by this wave, so make plans to surf the rising water!

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