Standardization of Smart Grid Customer Interfaces*

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Abstract: One of the key concepts of a future "smart grid" is to combine modern communication technology with an improved electric grid to enable energy consumers to exchange information with energy suppliers in order to collaboratively manage electricity supply and demand. This information exchange can be used to reduce the stress on the grid during times of peak demand, enable the expanded use of intermittent renewable energy sources, improve resilience during weather related outages, and integrate customer-owned generation capabilities with grid supplied electricity. Standards are needed to define information exchange interfaces between energy service providers and their customers. This paper describes requirements for those interfaces and emerging standards in the United States that address these issues.

Key words: smart grid; building automation; demand response

0 Introduction-A Vision for Smart Grid

The development of national scale electric grids is considered by some to be among the supreme engineering achievements of the 20th century [1]. In spite of its success and tremendous impact, the electric grid in the United States and other countries is under strain from increasing demand and aging infrastructure. In some economically developing countries the existing grid does not have the capacity to meet needs of the population. These pressures have led to new thinking about how electric grids should be designed and operated, and the way in which they interact with end users [2-5]. The vision for a redesigned grid is still emerging, but this modernization has come to be called a "smart grid." In the United States a national policy to develop a smart grid was established by public law in 2007 [6].

The present electric grid can be characterized as a top down system with one-way flow of electricity from central generating plants through regional transmission systems to local distribution networks and end loads. Market operations centers and the generation and transmission systems take control actions to balance supply and demand with limited situational awareness or information about customer interactions. There is limited automation and, in many cases, the utility is unable to detect a service outage unless reported by a customer. Part of the idea behind a future smart grid is to improve measurement and control technology used to manage electricity generation and distribution, but the most important concept is to transform the fundamental structure of the grid by combining an information technology infrastructure with the grid that will enable two-way flow of both information and electricity(see Figure 1) [7].

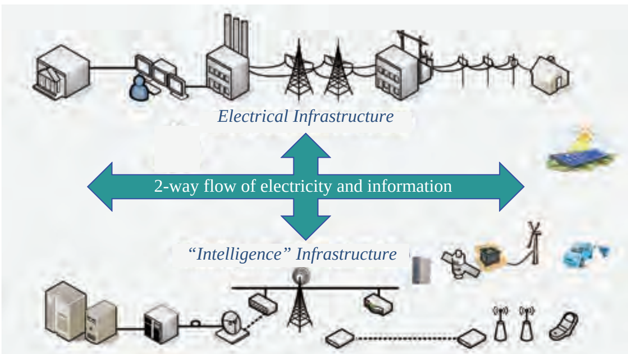

Figure 1 A smart grid will combine two-way communication infrastructure and local generation

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One of the important drivers for grid modernization is the desire to substantially increase the use of renewable generation sources，primarily wind and photovoltaic. These sources are highly variable and large-scale electricity storage to buffer this variability has not yet been shown to be economically viable. As the use of these variable energy sources grows，it is becoming difficult to match instantaneous generation with demand. Two-way communication between the grid and consumer，combined with automated control technology that can rapidly adjust loads or generation resources in home and building systems，enables homes and buildings to become a partner in managing grid reliability and stability. Taking advantage of increased ability to forecast and shift loads can also help better utilize grid resources because leveling the load means fewer resources will be needed for managing peaks.

1 Key Concepts of a Smart Grid-to-Facility Interface

An international consensus is emerging about the kinds of interactions that will be likely between energy suppliers and consumers in a smart grid environment. These interactions are documented in use cases [2,8,9]. There is also a growing consensus about the purpose and features of interfaces needed between energy suppliers and consumers to carry out these actions [2,8,9]. These features include the ability to integrate easily with the wide variety of facility management standards-based environments.

There are already mature industries supported by international standards for automation and control systems used in industrial processes and in commercial buildings. There is an emerging industry and emerging standards for automation and control systems used in residential applications. The technologies，needs，and cost constraints are different in these environments. The technologies and standards used in the customer facility domain(residential，commercial，industrial)are also different from the control technology and standards supporting grid operations.

In order for automation and control systems in the customer facility domain to interact in a collaborative way with smart grid systems，there is a need for an interface between the two domains. This is illustrated graphically in Figure 2. There are several characteristics that such an interface must have：

· It defines information that is transferred across the interface but permits flexibility in the applications that use the information，

· It enables independent evolution of the systems on both sides，

· Its features are rich enough to meet the needs of sophisticated control systems that might be found in commercial and industrial customer facilities but simple enough to be economically viable for simple systems serving residential customers，and

· It is standardized so that it becomes viable to make interoperable commercial products that can be widely used.

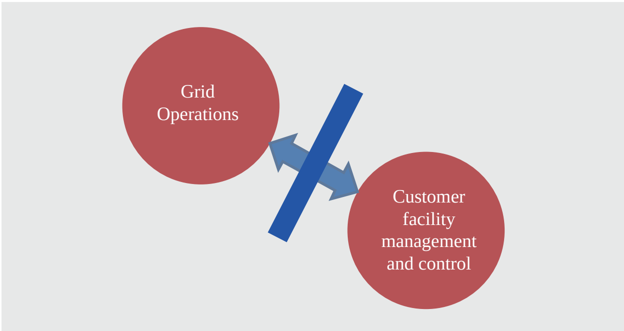

Figure 2 High-level view of the user interface(blue line)between grid and customer domains [9]

2 Emerging Standards in the United States

In the United States a public/private partnership，the Smart Grid Interoperability Panel(SGIP)，has been established to accelerate the development and implementation of interoperable smart grid devices and systems. Part of this effort is aimed at facilitating the development of needed standards in cooperation with various standards development organizations and to recognize important smart grid standards in the SGIP Catalog of Standards. The SGIP also supports the development of product testing, certification processes, and education for industry stakeholders. Some of the existing standards identified in the Catalog of Standards, or being developed with SGIP influence, are relevant to the grid-to-customer interface. These include Oasis Energy Interoperation [10], OpenADR 2.0 [11], IEEE 2030.5 Smart Energy Profile 2.0 [12], and Energy Services Provider Interface(ESPI) [13]. These standards are discussed in the following sections.

2.1 OASIS Energy Interoperation

Energy Interoperation 1.0(EI) [10] was published in December, 2011 and is maintained by a technical committee of the Organization for the Advancement of Structured Information Standards(OASIS). It specifies an information model and messages to enable standard communication of: demand response(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 freely available from OASIS.

EI serves DR and other market communications between the grid and customer domains. The EI architecture is very simple, reduced to service interactions between two parties. A party can be a facility energy management system or device, demand response provider, market operator, distribution system operator, microgrid, or anyother participant in a DR event or market transactions of energy.

The EI standard specifies three profiles that can be seen as three primary use cases described in the published standard.

1. OpenADR—this profile defines the services required for DR event and price communication. It builds on the functionality and lessons learned in field experience from the OpenADR 1.0 [14] specification.

2. Price Distribution—this profile defines the minimal set of services required to interact within a pure price distribution context, without requiring energy market transactions or event-based DR interactions.

3. TEMIX—this profile defines the services required to implement functionality for more general energy market interactions determined by negotiated price-based transactions.

2.2 Open Automated Demand Response (OpenADR)

One of the most pressing and widespread stresses on electric grids is managing short-term peak demand. In various demonstration projects it has been shown that a DR program, where customers reduce electrical consumption in response to requests from grid service providers, can be helpful in reducing peak loads. OpenADR 1.0 was developed to provide a way to automate DR signals and responses. Automation provides a way to both increase the scale of a DR program(the number of customers involved)and make the response more reliable and predictable. Lessons learned from deployment of OpenADR 1.0 have led to refinements and the development of OpenADR 2.0.

OpenADR 2.0 is a communication protocol for DR and price signals, with a defined security profile. OpenADR was designed to provide services for the communication of key information related to DR events between grid and facility domains(see Figure 2). Specific information elements related to power and energy were aligned with the IEC Common Information Model(CIM)standards [15]. OpenADR is under consideration for adoption as an IEC standard by IEC PC 118. OpenADR 2.0 is a subset of OASIS Energy Interoperation 1.0, with extensions to support some retail DR requirements, in addition to a detailed implementation specification.

OpenADR is an application-layer data model, with a simple service-oriented architecture(SOA)/web services protocol，which can use any transport mechanism. The test and certification programs support two transport mechanisms：simple RESTful web services and Extensible Messaging and Presence Protocol(XMPP) services，including security testing. The OpenADR Alliance is working on other transport bindings.

The OpenADR Alliance is an industry association that developed the detailed OpenADR implementation specifications，as well as supporting conformance，test，and certification suites. The Alliance has over 120 members and has certified over 60 OpenADR 2.0-compliant products [16]. The OpenADR Alliance has developed two profiles to meet the different product and market needs for DR. OpenADR 2.0a was designed for simple DR applications and includes comprehensive security solutions. The OpenADR 2.0b profile adds support more complex DR clients.

2.3 IEEE 2030.5 Smart Energy Profile 2.0

IEEE 2030.5 Smart Energy Profile 2.0(SEP 2)enables home energy information，control，and management applications，as well as utility communications to devices in the home，via wired and wireless connections using Internet Protocol. SEP2 was developed collaboratively by the ZigBee Alliance，HomePlug Alliance，Wi-Fi Alliance and others. SEP2 was designed to be implemented in home area control networks，spanning from the meter(or other connection to the utility such as the Internet)to devices in the home.

SEP2 provides many functions including communication of：energy usage information，price，demand response signals，and load control signals. SEP2 is designed to interact with many types of devices including：smart meters，thermostats，pool pumps，smart appliances，solar inverters，plug-in electric vehicles，in-premises displays，mobile devices，and prepayment terminals.

Testing and certification of SEP2 is supported by the Consortium for SEP2 Interoperability(CSEP). CSEP's primary mission is to aid delivery of interoperable SEP2 products by defining standard testing for SEP2 conformance and certification. In January 2015 CSEP published the first official SEP2 Test Harness for conformance testing and certification，enabling uniform certification programs for SEP2 products by multiple certification laboratories.

To support interoperability and a wide application of SEP2，requirements in the standard are not dependent on any particular physical network technology. SEP2 is built atop an Internet Protocol(IP)stack and other familiar underlying protocols.

SEP2 was designed as a profile on the IEC CIM [15]，mapping directly where possible，and using subsets and extensions where needed. It uses a RESTful architecture. The standard includes a UML model，derived schema (XSD)，and a Web Application Description Language (WADL)document. The XSD and WADL are normative documents，and these are publicly available and referenced.

2.4 Green Button

Green Button is the name given to an industry led effort to provide utility customers easy and secure access to their energy usage information [17]. The name derives from the ability of the customer to access this data from a website with a simple mouse click on a literal green button. The Green Button program is based on the Energy Services Provider Interface(ESPI)standard developed by the North American Energy Standards Board [13].

The ESPI standard consists of two parts，an XML format for energy usage information and a data exchange protocol. A customer can access and download the details of their energy usage directly or by using a Connect My Data feature they can authorize the utility to make the data available to a third party service provider of the customer's choosing.

An industry group called the Green Button Alliance has been established to support the technology and to provide testing and certification for green button implementations. As of March 2015, there are approximately 60 million utility customers in the United States and 2.5 million utility customers in Canada with access to their energy usage information through the use of Green Button. These numbers are growing rapidly and other countries are considering adopting the program as well.

2.5 Facility Smart Grid Information Model

The American Society of Heating, Refrigerating, and Air-Conditioning Engineers(ASHRAE)and the National Electrical Manufacturers Association(NEMA) have joined together to develop a Facility Smart Grid Information Model Standard(FSGIM) [7]. This draft standard defines a common information model that will enable appliances, space conditioning systems, and control systems in homes, non-residential buildings, and industrial facilities to manage electrical loads and generation resources in response to communication with a smart electrical grid. The functionality that will be enabled by this information model includes [7]:

· on-site generation management,

· demand response,

· electrical storage management,

· peak demand management,

· forward power usage estimation,

· load shedding capability estimation,

· end load monitoring(sub-metering),

· power quality of service monitoring,

· utilization of historical energy consumption data, and,

· direct load control.

A key concept in this draft standard is the idea of a "facility", which is broadly defined to be anything from a single family house, to a commercial building, an institutional building or, an industrial or manufacturing facility. By developing a common information model for all of these kinds of facilities, utility providers benefit because they may be able to interact with all of their customers in the same way. A common model also benefits consumers because the dividing lines between these different kinds of facilities are not always clear cut. Using a common model will make it easier for a product designed primarily for one of these facility types to be used in other types as well. It may also create an opportunity for manufacturers to design products or software applications with features that intentionally make them desirable in more than one facility domain [7].

The FSGIM is designed to be compatible with OASIS Energy Interoperation, OpenADR 2.0, SEP2, and Green Button. Its role is to provide a standard way for various control technology standards used in different kinds of facilities to add functionality that would make use of the information exchanged through an interface based on the standards discussed in this paper. In effect, it adds needed functionality to the customer control systems that are part of the Customer Facility Management and Control portion of Figure 2.

3 International Reaction

There is an international component to all of the standards discussed here. There are already implementations of OpenADR 2.0 and Green Button outside the United States. OASIS Energy Interoperation and OpenADR 2.0 are draft international standards being considered by IEC PC118 Smart Grid User Interface. Another standard under development within IEC PC118 is an adapter specification that would define how to connect utility control systems based on the CIM to implementations of the EI and OpenADR 2.0 standards. IEC PC118 is also considering developing an international standard based on SEP2, but that decision is not yet final. The FSGIM is a draft international standard being processed by ISO TC/205 Building Environment Design.

Figure 3 shows a more nuanced view of the interface concept depicted in Figure 2 that takes into consideration the standards discussed in this paper. It shows that there is a common logical concept of the interface itself but, in the real world, it may end up being a collection of standards that are adopted to fulfill this role.

4 Conclusion

Realizing the vision of a smart grid will require a way to link the utility grid domain to the customer domain. This needs to be done in a manner that acknowledges the significant history and infrastructure investments that have been made in both domains. An interface is needed that provides a way to exchange critical information between these domains, but still lets the technologies and practices in each domain evolve independently without breaking the connection. The basic idea is simple but the current state of industry practice and emerging standards suggests that the final result may be a small collection of related standards rather than a single, one-size-fits all standard. Activities underway in IEC and ISO involving many companies, industry trade groups, and standard development organizations, provide hope that we are on our way to an international consensus that can provide the stability needed for the new technology to flourish in the marketplace. DU

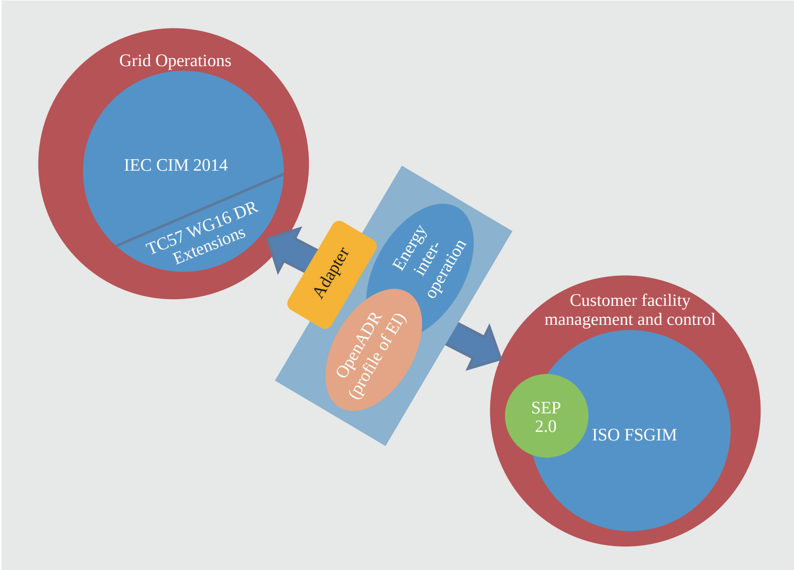

Figure 3 Detailed view of the user interface（blue line）between grid and customer domains

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