Smart Grid Standards and Systems Interoperability: A Precedent with OpenADR

Girish Ghatikar

Lawrence Berkeley National Laboratory
1 Cyclotron Road, 90R3111, Berkeley, CA 94720

GGhatikar@lbl.gov

Rolf Bienert

The OpenADR Alliance
17431 Lakeview Drive, Morgan Hill, CA 95037

Rolf@openadr.org

Keywords: Demand Response, Smart Grid, OpenADR standard, interoperability, certification and testing.

Abstract

This paper describes the Smart Grid standards and systems interoperability through Open Automated Demand Response Standard (OpenADR) conformance development process. The process aligns closely with the national and GridWise® Architecture Council's recommendations for interoperability. This paper looks at the standards development, and certification and testing process through the activities of standards organizations, user-groups, industry alliances, and Smart Grid development. It references the Conformance and Interoperability Process Reference Manuals and requirements of the standards organizations for certification and interoperability of OpenADR standard to address consumers and stakeholder needs. The evaluation framework for OpenADR interoperability is characterized through the data transport mechanisms, harmonization and co-existence with other standards and systems, and Smart Grid interoperability across different markets.

The result is the interoperable information exchange among Smart Grid standards and technology implementations within the national and international standards activities; primarily the interoperability and backward compatibility needs within the California commercial deployments. This process offers significant value to consumers and builds trust in the system. The service providers and vendors can provide cost-effective solutions, which reduce the implementation costs and improve the operational efficiency of DR programs and automation.

1. INTRODUCTION AND BACKGROUND

OpenADR standard development has evolved through research, pilots, and commercialization. The OpenADR 1.0 communication specification by Lawrence Berkeley National Laboratory (LBNL) DR Research Center and the California Energy Commission (CEC) (Piette et al., 2009a) is implemented in California's commercial Automated DR (Auto-DR) programs (Wikler et al., 2008), and is soon going to be a formal standard.[1] This standard, which will be called OpenADR 2.0, is a result of contributions from many standards organizations and the OpenADR stakeholders. The OpenADR Alliance (Alliance) is the managing entity for OpenADR 2.0 and will be the provider of certification and testing programs for interoperability (Alliance, 2011).

1.1. Introduction

OpenADR provides non-proprietary, standardized interfaces to enable electricity service providers to communicate DR and Distributed Energy Resource (DER) signals to customers using a common language and existing communications such as the Internet (Piette et al., 2009b). These OpenADR data models facilitate price-responsive and reliability DR. As shown in figure 1 below, this is achieved through open Application Programming Interfaces (APIs) that provide two-way communications between the service provider (Utility/ISO) and customers (Sites) through a logical interface of an OpenADR server (called a Demand Response Automation Server).

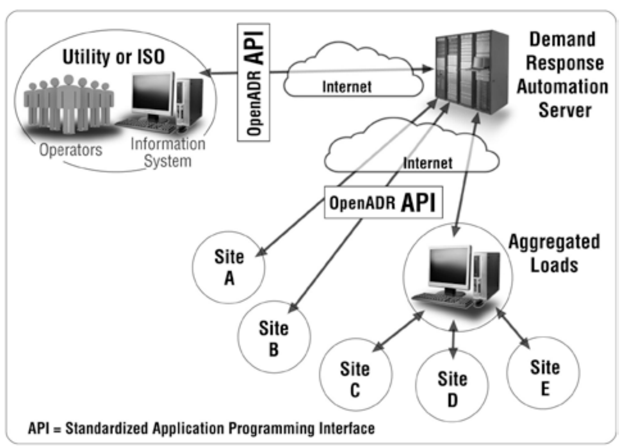

Figure 1: OpenADR Communication Architecture

The communications between the service providers and consumers in OpenADR 2.0 have evolved generically as the Virtual Top Node (VTN) and the Virtual End Node (VEN), respectively. The VTN/VEN pair structure allows a chain of

[1] When this paper was completed, OpenADR was on the verge of being published as a formal standard.

hierarchy from the parent (the one that issues primary DR signal) to the multiple parent/child relationships all the way to the end-use devices (OASIS, 2011).

1.1.1. Goals and Objectives

The goal of the OpenADR 2.0 conformance development was to enable a robust certification and testing program that can interoperate with appropriate Smart Grid systems for commercial-grade deployments. The key objectives were to:

- Utilize the final product from standards organizations and provide a conformance framework.
- Identify the key players in the certification and testing area that will provide related services.
- Evaluate relevant standards for interoperability.
- Identify market, device, and facility requirements to provide a certification and testing program.

1.2. Background

OpenADR research has led to a steady set of development and commercialization improvements since 2002. This initial research was focused on commercial and industrial facilities. As shown in figure 2, advancements have resulted from pilots, commercialization, specification development (OpenADR 1.0), standards development, and establishment of the Alliance to create a formal standard (OpenADR 2.0) and certification and testing program.

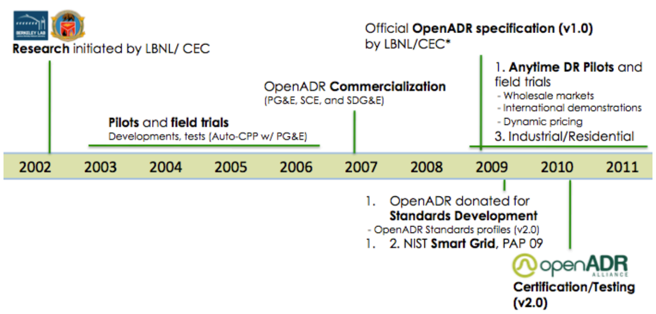

Figure 2: OpenADR Progression and Standardization

This OpenADR experience is a precedent to other standards, which are currently in the process of development.

2. LIFECYCLE PROCESS FOR STANDARDS

Over its lifecycle, OpenADR development followed a specific process leading to key milestones. **We define *lifecycle* as a complete process before a standard is ready for commercial adoption**. OpenADR progression is unique, as it was commercialized before the formal standards development. However, this makes the process more thorough for Smart Grid interoperability. Not all the standards may need to be commercialized before they are standardized. This process is critical to develop a robust, interoperable Smart Grid standard that is ready for commercialization. The process and milestones consisted of:

- Research and development
- Pilots and field trials
- Standards development
- Conformance and interoperability

This paper describes standards development and the conformance process. The research and pilots are well studied (Piette et al., 2007a) and summarized below.

Research leads to developing the concept and design of a standard. The key objective of the communication system for OpenADR was to develop a low-cost technology and increase grid and DR infrastructure reliability through automation (Piette et al., 2007b). OpenADR research was developed through pilots and field trials in collaboration with key stakeholders, i.e., service-providers, consumers, vendors, and policy makers. This provided OpenADR developers insights to the service-providers and consumer requirements and use cases for interoperability with new and legacy systems, building protocols, and integration of DR strategies within facilities (Motegi et al., 2007).

2.1. Standards Development

The requirements and use cases developed from the research and pilots led to the standards development through a consensus process with the key stakeholders. OpenADR was donated to a standards development organization (SDO), Organization for Advancement of Structured Information Standards (OASIS), and a user group: Utilities Communications Architecture (UCA). OASIS is responsible for data models and specification that are informed by UCA, which is responsible for gap analysis and providing any additional requirements from the service providers (Ghatikar et al., 2010a). This standards development is further described in Section 3.

2.2. Conformance and Interoperability

The conformance and interoperability process is the final step that leads to testing and certification framework. The conformance process is crucial to answer the key question: What is OpenADR compliance?

This process must consider how the standard operates in context of the Smart Grid. The OpenADR interaction is between the electricity service providers and consumers, and integration with facilities. OpenADR closely followed the UCA Conformance Process Reference Manual (CPRM), and is participating in the Smart Grid Interoperability Panel's (SGIP) Interoperability Process Reference Manual (IPRM) pilot, which is lead by the Smart Grid Testing and Certification Committee (SGTCC). This conformance and interoperability process is further described in Section 4.

3. STANDARDS DEVELOPMENT

The development of standards is a key step leading to a standards interoperability framework through certification and testing. OpenADR 2.0 was developed in coordination with SDOs and key stakeholders, and through a consensus process. The national Smart Grid interoperability standards coordinated by the National Institute of Standards and Technology (NIST) recommended OpenADR as a key standard for standard DR and Distributed Energy Resources (DER) signals (NIST, 2010 and NIST, 2011).

The NIST-coordinated effort selected the LBNL-identified organizations, OASIS and UCA, as key players for OpenADR standardization along with additional players, which included consumers, North American Electricity Standards Board (NAESB), Independent Systems Operator (ISO)/Regional Transmission Organization (RTO) Council (IRC), and other standards bodies, which are required for broader OpenADR interoperability.

3.1. Standards Organizations

OpenADR 2.0 is being developed through the OASIS Energy Interoperation (EI) technical committee (OASIS EI TC, 2011). The technical committee goals extend beyond the development needs of OpenADR. The EI charter also includes development of "a data model and communication model to enable collaborative and transactive use of energy." The technical committee is working toward interoperable and standard exchange of dynamic price, reliability, and emergency signals; communication of market participation information such as bids; load predictability; and generation information. Within the EI standards, OpenADR profiles were created to describe services that are applicable to OpenADR 2.0. Such profiles offer market-specific needs for standard DR and DER communications and conformance development.

The OASIS EI work was developed through contribution from different sources, primarily OpenADR 1.0. The OpenADR Task Force (TF) within UCA was a key entity that provided comprehensive requirements that included contributions from entities such as NAESB, IRC, and other standards, such as the Common Information Model (CIM). Figure 3 shows these contributions for OpenADR profiles.

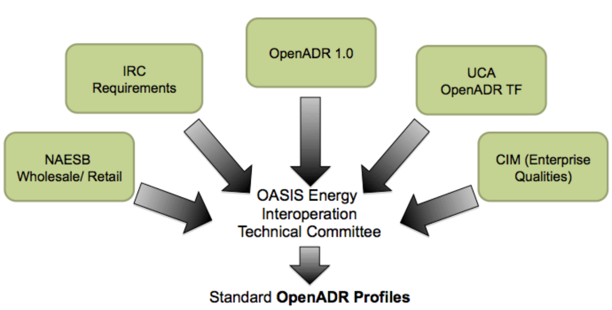

Figure 3: OpenADR 2.0 Development and Contribution

3.2. National Smart Grid Activities

Over a century, testing and compliance to standards have enabled much faster progress in the industry. Initially, steam machines were tested for safety so they would function without endangering workers and the production. Later, automobiles would be subjected to rigorous safety and functional tests and of course telecom and information technology products in the recent decades. What started as human and equipment safety assessments to protect workers and assets has quickly transformed into highly specialized testing programs to ensure basic functionality. However, only in the last 15 to 20 years have interoperability-focused standards become prevalent. First driven by telecommunication technology, these standards quickly penetrated many areas of daily life.

Several organizations have started to successfully implement guidelines for the implementation of testing and certification programs. The NIST-initiated Smart Grid Interoperability Panel (SGIP) and its subcommittee, the Smart Grid Testing and Certification Committee (SGTCC), created the Interoperability Process Reference Manual (IPRM). The IPRM provides a best-practice approach for certification schemas from actual testing to the act of certifying a product itself (NIST SGTCC, 2011). The manual considers the following aspects:

- Creating interoperable standards
- Testing of conformance and interoperability
- Certifying the products

Each individual aspect by itself cannot deliver market acceptance and interoperable products. Only in combination can a product certification scheme be successful.

The most crucial consideration during the development of the standard is the selection of optional versus mandatory features. While a lot of optional features provide great flexibility for product developers, it makes testing difficult or virtually impossible. The optional features prohibit the establishment of clear product types, and therefore prevent consistent testing. This situation ultimately leads to a lack of interoperability and a bad customer experience.

While the NIST SGIP focused on the high-level guidelines, the UCA developed the Certification Process Reference Manual (CPRM). The CPRM references the IPRM and adds specific requirements to the testing processes. The CPRM describes different layers of a protocol, from Physical connection (PHY) to the Application layers (UCA OpenSG, 2010).

Figure 4 shows an example certification scheme, as proposed for the Smart Energy Profile (SEP) 2.0 by the ZigBee Alliance (Beecher and Lin, 2010). The Test Cases have been divided in four main sets: (1) IEEE 802.15.4-

2006; (2) Stack; (3) Platform; and (4) Device type certification. Each individual technology will need to assess which layers are applicable for testing. The Alliance uses standard Web services for the data exchange, which will be independent of the transport layer. Thus, the Alliance test plan will not look at the physical connection layer, for instance, but will use relevant transport mechanisms underneath the application.

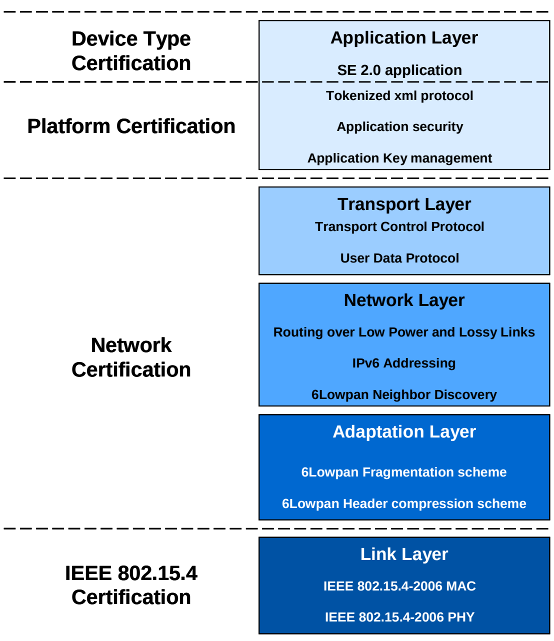

Figure 4: ZigBee Certification Scheme for SEP 2.0

4. CONFORMANCE AND INTEROPERABILITY

The Alliance manages the OpenADR 2.0 conformance and interoperability program through a well-defined third-party testing and certification process. Once the deployments scale-up, the Alliance may consider establishing additional processes to enable easier market access for new products and/or updates. For testing and certification, the members can submit their product to the designated ISO 17025 accredited test house for pretesting, troubleshooting, or final certification testing. The certification test scope is determined based on the Protocol/ Performance/ Proforma Implementation Conformance Statement (PICS) document (to be completed by the manufacturer) in conjunction with the profile outline and test case reference list. The PICS defines all the optional and mandatory features of a standard implemented in a product. Any changes to the product during certification testing will lead to a full retest of the certification test suite unless specifically stated otherwise.

After successful completion of the certification test suite, the test lab provides proof of the passing test results to the Alliance, the manufacturer, and the certification body. The manufacturer will further provide a signed version of the PICS document and a declaration that all products sold will be identical to the tested unit. Creating a framework for OpenADR compliance was a key requirement toward conformance and interoperability.

4.1. OpenADR Compliance

For compliance, the Alliance will follow the NIST SGTCC guidelines to set up the testing and certification program and to become the Interoperability Testing and Certification Authority (ITCA) for OpenADR 2.0. As the ITCA, the Alliance has to assure that the overarching interoperability and conformance requirements are being established, properly communicated, and tested and certified.

Figure 5 illustrates this compliance program for OpenADR interoperability. It also outlines basic conformance requirements. Using OpenADR profiles from EI, the Alliance created feature sets or PICS for OpenADR 2.0. These PICS were used for creating test specifications comprising of test cases and test procedures. These test specifications aid the development of test tools, which are eventually used by a test lab to conduct tests and determine OpenADR 2.0 compliance. This is an important step for Smart Grid standards interoperability. The development of test specifications, test tools, and the test labs can be one or multiple parties. For OpenADR 2.0, the Alliance selected one vendor for test tools and the other for test lab services.

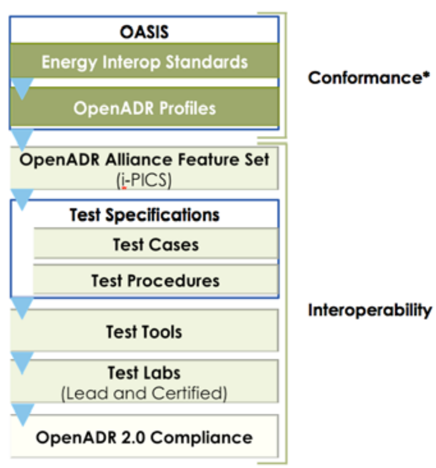

Figure 5: OpenADR 2.0 Interoperability Requirements

4.2. Testing Process

For Smart Grid standards, a well-defined test plan and validated test systems are crucial. The test cases must be unambiguous and relate to the mandatory and optional requirements of the specific feature sets. These feature sets, on the other hand, have to be well defined in the PICS. Furthermore, the IPRM describes the interaction between the different entities involved in the certification process.

4.2.1. Test Tool and Test House

During the initial setup, the Alliance selected one test house. This was a conscious decision to minimize implementation differences in the early phases of the process and to provide a viable business model for the test house vendor. Once OpenADR deployments scale up, more test facilities may be needed, at which point the Alliance will revisit the option to consider additional test house provides.

The Alliance also selected one vendor to create the test tool for certification testing. This is because the key factor to achieve interoperability is through the establishment of a single validated test system. This test system will be provided to the test house. Furthermore, vendors can opt to acquire the tool for pretesting or development support. It is envisioned that the tool will be extended to also include more development-focused functionalities.

Figure 6 shows high-level test system architecture. The SoapUI, an open source cross-platform functional testing solution, runs the simulation "engine" of an OpenADR 2.0 server and client. The test plan is implemented in a parallel container, which allows quick changes. This SoapUI framework is also connected to the Internet for easy access and to allow Web-based testing (remote testing).

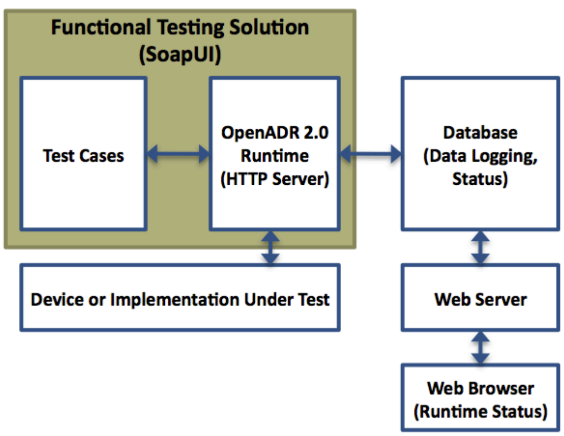

Figure 6: OpenADR 2.0 Test System Architecture

4.3. Certification Process

The IPRM, which uses the internationally accepted ISO Guide 65, was used as the basis for the OpenADR 2.0 certification processes. ISO Guide 65, which is similar to other quality system standards (e.g., ISO 9000.), describes the policies and procedures for a certification body. Training, document control, retention, and management of expired certificates are critical components of a certification program. Additionally, market controls are also needed.

The Alliance chose to outsource this certification function to an ISO Guide 65 accredited testing and certification firm. In close cooperation with the Alliance, the firm will provide the certification services to the members of the Alliance.

5. INTEROPERABILITY FRAMEWORK

The conformance process is important for the standards and systems interoperability. For OpenADR, the interoperability goes beyond these needs. The initial pilots and research has determined that OpenADR must consider coexistence among different markets, facilities, and end-uses. Figure 7 shows this interoperability framework to ascertain that OpenADR is flexible enough to be able to provide these services across different markets (Ghatikar et al., 2010a) and Smart Grid domains (Kiliccote et al., 2009). The OpenADR interoperability framework utilizes contributions from the standards organizations and solicits the stakeholder needs such as those from vendors and test agencies. This two-way process is essential for commercial deployment, continuous improvement, and enhancement of the standard.

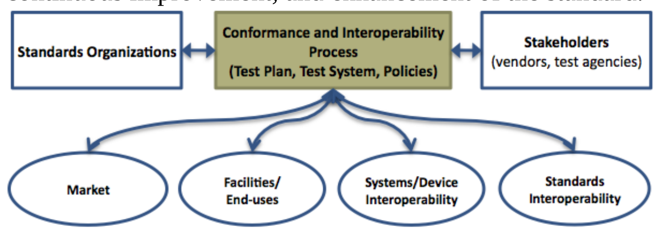

Figure 7: OpenADR Interoperability Framework

The conformance process for interoperability included the **development of PICS for interoperability (iPICS)**.[2] The iPICS were tested for real-world deployment through the plug-fest events. The results were used to provide feedback to the standards organizations and key players. The plug-fest events are essential to test the PICS and how products respond to test cases developed for a specific standard.

The conformance and interoperability process for OpenADR considered some essential elements for transport mechanisms, harmonization/co-existence with relevant standards and systems, and Smart Grid domains. OpenADR product categorizations were made accordingly and for co-existence with other standards in the Smart Grid domains.

5.1. Transport Mechanisms

OpenADR 2.0 uses Web service schemas to relay the relevant information in either a PUSH (server sending the information to client) or PULL (client polling the server) data exchange. To implement these data exchange models, a sufficiently structured transport mechanism needs to be defined. The OpenADR Alliance determined that several different transport mechanisms could be used to accomplish the data exchange. The VTN (server) will be required to accommodate all selected transport mechanisms while VEN (client) can select the most appropriate mechanism. After evaluating several available implementations such as Simple Object Access Protocol (SOAP), Representational State

[2] iPICS is a specific term we use to describe the framework that addresses both conformance and interoperability requirements.

Transfer (REST), Hyper Text Transfer Protocol (HTTP), eXtensible Messaging and Presence Protocol (XMPP) and others, the Alliance decided to initially use a REST-styled simple HTTP implementation and add others as appropriate.

5.2. Standards and Systems Harmonization

OpenADR 2.0, as described earlier, is a client-server based standard. Surrounding the client-server system, there can be a multitude of protocols from home and building automation standards, Advanced Metering Infrastructure (AMI) and systems that OpenADR may interface to. Where applicable, the Alliance will map the information elements with those used in the common standards like the Smart Energy Protocol (SEP), Building Automation and Control Network (BACnet) (ANSI/ASHRAE, 2001), and the emerging Smart Grid standards as Web Services Calendar (WS-Cal TC, 2011) and Energy Market Information Exchange (EMIX TC, 2011). OpenADR 2.0 through its predecessor, OpenADR 1.0, has already established a framework for systems interoperability and integration with the legacy systems and the BACnet standard (Piette et al., 2009a).

5.2.1. Product Categorizations

In an effort to keep the optional features within a specific product category to a minimum and allow different market and device types to use OpenADR, the Alliance opted to set up three distinct feature sets in their profile.

The basic feature set addresses simple and resource-constrained devices such as thermostats and other simple energy management systems for energy management.

The advanced feature set addresses facility management systems that can also process pricing, availability, and other information to make logical decisions about when to participate in a demand response program or not.

The last category of devices using the most advanced set of features will additionally be able to provide feedback and telemetry information in close to real-time systems.

Aligning with the interoperability framework (Ref. Section 5), the OpenADR Alliance held plug-fests for Core device testing for OpenADR 2.0. The early adopters from 10 companies gathered for a two-day plug-fest. OpenADR 2.0 implementations included six VEN clients, two Virtual VTNs, and an early (Alpha) version of the certification test suite. The plug-fest initially focused on working through the basic handshaking issues between implementations. Following that, the implementations were exchanging OpenADR messages to create, change, and cancel the DR events. This plug-fest marks a significant milestone in the development of OpenADR conformance and a pathway toward interoperability. The companies now are well on the path to developing OpenADR 2.0 compliant products.

5.2.2. Implementations Across Smart Grid Domains

The Smart Grid interoperability must follow the general notion that end-to-end interoperability needs to be achieved. Where systems with varied transport mechanisms need to interact within the Smart Grid domains and standards, the application-level messages must be processed. This enables OpenADR to be integrated with other systems and transport mechanisms. However, as the system and transport architectures vary greatly within every implementation and domain, a strict end-to-end testing may not be possible.

5.3. Links to GWAC Interoperability Framework

The GridWise™ interoperability context-setting framework facilitates systems integration and information exchange (GWAC, 2008). The standardization of OpenADR is intended to provide interoperability, backward compatibility, transport layer independence, and integration with building protocols (e.g., BACnet®, Modbus®) and end-use/device types within facilities such as data centers (Ghatikar et al., 2010b) and strategies (Motegi et al., 2007). The BACnet® protocol is interoperable with OpenADR through Web services (Ghatikar et al., 2010a). The OpenADR communications can be integrated within Smart Grid domains, as OpenADR allows the different VTN/VEN pairs within the interactions that may use different transport mechanisms. These requirements closely align with the requirements of GridWise® interoperability framework.

6. RESEARCH NEEDS

OpenADR 2.0 conformance and standards development processes provide significant insights and evidence for standards and systems interoperability within the Smart Grid and facilities. Many activities need attention for OpenADR 2.0 adoption by markets. A few key needs are:

- Backward compatibility with OpenADR 1.0 commercial implementations in California and interoperability with standards and legacy systems. This is also true of OpenADR 2.0 and other standards as they go through revisions for maturity through market adoption.
- Comprehensive analysis and adoption of security, transport mechanisms, and feedback through interoperability framework.
- Research and development of price-responsiveness, ancillary services (Fast-DR), integration with renewable and DERs, and innovative applications of OpenADR within Smart Grid domain and policy framework.

7. SUMMARY OF FINDINGS

The paper described the OpenADR 2.0 and conformance development process through real-world experience. These processes provide valuable lessons for Smart Grid standards and systems interoperability. These lessons are of significance, as many other standards will start evolving and become ready for commercialization and market adoption.

8. ACKNOWLEDGEMENT

This work was sponsored by the Lawrence Berkeley National Laboratory's Demand Response Research Center (http://drrc.lbl.gov/), which is funded by the California Energy Commission's Public Interest Energy Research Program, under Work for Others Contract No. 500-03-026, Am #1 and by the U.S. Department of Energy under Contract No. DE-AC02-05CH11231. The authors would like to thank the OpenADR Alliance Profile Working Group and standards organizations and stakeholders (OASIS, UCA, NAESB, IRC, etc.) for their contributions and review.

Reference List or References

ANSI/ASHRAE. (2001). "BACnet®: A Data Communication Protocol for Building Automation and Control Networks." ASHRAE. REPLACED by ANSI/ASHRAE 135-2004.

Beecher, P., J. Lin. (2010). "Guiding Principles Document." Utilities Communications Architecture Open Smart Grid Conformance Task Group.

Ghatikar, G., J. Mathieu, M. A. Piette, E. Koch, and D. Hennage. (2010a). "Open Automated Demand Response Dynamic Pricing Technologies and Demonstration." LBNL-3921E.

Ghatikar, G., M. A. Piette, S. Fujita, A. McKane, J. H. Dudley, A. Radspieler Jr., K. C. Mares, and D. Shroyer. (2010b). "Demand Response and Open Automated Demand Response Opportunities for Data Centers." LBNL-3047E

The Gridwise Architecture Council (GWAC). (2008). "GridWise® Interoperability Context-Setting Framework."

Kiliccote S., M. A. Piette, G. Ghatikar, E. Koch, D. Hennage, J. Hernandez, A. Chiu, O. Sezgen, and J. Goodin. (2009). "Open Automated Demand Response Communications in Demand Response for Wholesale Ancillary Services." In Proceedings of Grid-Interop Forum 2009, November 17–19, 2009. LBNL-2945E.

Motegi, N., M. A. Piette, D. Watson, S. Kiliccote, and P. Xu. (2007). "Introduction to Commercial Building Control Strategies and Techniques for Demand Response." LBNL-59975

NIST. (2010). "NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 1.0." NIST Special Publication 1108

NIST. (2011). "Draft NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 2.0."

NIST Smart Grid Testing and Certification Committee (SGTCC). (2011). "Interoperability Process Reference Manual, Version 1.0" http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/SmartGridTestingAndCertificationCommittee

OASIS Energy Market Information Exchange Technical Committee (EMIX TC). (2011). http://www.oasis-open.org/committees/emix

OASIS Energy Interoperation Technical Committee (EI TC). (2011). http://www.oasis-open.org/committees/energyinterop

OASIS Web Services Calendar Technical Committee (WS-Cal TC). (2011). http://www.oasis-open.org/committees/ws-calendar

The OpenADR Alliance (Alliance). (2011). "The OpenADR Primer: An Introduction to Automated Demand Response and the OpenADR Standard."

Piette M. A, G. Ghatikar, S. Kiliccote, E. Koch, D. Hennage, P. Palensky, and C. McParland. (2009a). "Open Automated Demand Response Communications Specification (Version 1.0)." California Energy Commission, PIER. CEC-500-2009-063.

Piette, M. A., G. Ghatikar, S. Kiliccote, D. Watson, E. Koch, and D. Hennage. (2009b). "Design and Operation of an Open, Interoperable Automated Demand Response Infrastructure for Commercial Buildings", *Journal of Computing Science and Information Engineering*, vol. 9, issue 2, no. 2.

Piette, M. A., D. Watson, N. Motegi, and S. Kiliccote (2007a). Automated Critical Peak Pricing Field Tests: 2006 Pilot Program Description and Results. LBNL-62218

Piette, M. A., S. Kiliccote, and G. Ghatikar. (2007b) "Design and Implementation of an Open, Interoperable Automated Demand Response Infrastructure." Grid Interop Forum, Albuquerque, NM. LBNL-63665

OASIS Energy Interoperation Technical Committee. (2011). "Energy Interoperation Version 1.0: Committee Specification Draft 02/ Public Review Draft 02)

Utilities Communications Architecture (UCA) Open Smart Grid (OpenSG), Edge/Enterprise Conformance Task Group. (2010). "Certification Process Reference Manual." Version 0.9.

Wikler, G, I. Bran, J. Prijyanonda, S. Yoshida, K. Smith, M.A Piette, S. Kiliccote, G. Ghatikar, D. Hennage, and C. Thomas. (2008). Pacific Gas & Electric Company 2007 Auto-DR Program: Task 13 Deliverable: Auto-DR Assessment Study.

Biography

Girish Ghatikar is the Program Manager and Smart Grid Standards and Technologies lead at LBNL, and secretary for the OASIS EI TC. Rolf Bienert is the Technical Director of the OpenADR Alliance, where he leads the profile working group and the certification efforts.