ELECTRIC POWER RESEARCH INSTITUTE

DER Enterprise Integration: Interoperability Workshop Results

December 2014

Abstract

In a multi-year effort, the Electric Power Research Institute (EPRI) has facilitated advances in the development of standard functions for enterprise integration of distributed energy resources (DER), bringing inverter-connected distributed energy storage and generation into use as a grid resource. Recent industry efforts have defined a wide range of standard grid-supportive functions that inverters may provide and standard communication protocols that allow these functions to be remotely monitored and managed. These "smart inverter" functions have been codified in the International Electrotechnical Commission (IEC) standard 61850-90-7. After the functions were codified, the next focus was on the ability to aggregate messages to these smart inverters in an enterprise context, so that an edge server termed a *DER Management System* (DERMS) would manage communication to the devices and provide aggregated information to the other utility systems that need it. This effort focused on developing these enterprise messages (using the Common Information Model and MultiSpeak™) and then creating a test plan that would provide clarity on the expectations of how these messages would be used.

This whitepaper summarizes the findings of a DER Enterprise Integration Testing workshop facilitated by EPRI and held at the National Renewable Energy Laboratory (NREL) Research Support Facility in Golden, Colorado, on October 28, 2014. This paper describes the journey and major milestones leading up to DER integration testing, including the creation of common functions for smart inverters. The whitepaper describes the findings of the workshop and the next steps associated with this initiative.

The objective of this publication is to recap the background to these efforts, summarize the findings of the DER enterprise integration testing, and outline future research.

Table of Contents

This white paper was prepared by John Simmins of EPRI

Figure 1 – Activities Leading Up to the Testing Workshop for Enterprise Integration Functions

Background

In terms of direct utility benefits, this collaborative activity has taken place at an ideal time, because breakthroughs in both photovoltaics (PV) and battery storage have heightened the potential for their deployment in large scales and high penetration levels. In addition, the period has been marked by a focus on standards and protocols for integration, as exemplified by the work of the National Institute of Standards and Technology (NIST) in the United States and activities in the Institute of Electrical and Electronics Engineers (IEEE) and the IEC.As a result, this work has been a useful and significant contribution to several standards groups and activities. The common functions support use cases collected by the NIST Priority Action Plan (PAP) 07, have provided technical input into work in the IEC TC57 WG17 and IEEE 1547.8, and have been or are being mapped into the DNP3, SEP2.0, and ModBus communication protocols.

Utilities may use these functional descriptions to aid in the development of requirements for smart distributed resources. Wherever common approaches such as these can be referenced, rather than individually documenting similar functions, opportunity for interoperability is enhanced, and the ability to provide standards-based communication support is more likely.[1]

The Creation of "Common Functions for Smart Inverters"

In 2009, EPRI's Integration of Distributed Renewables Program (P174) began a series of studies related to the high penetration of DER. One research area in this program specifically focuses on the communication aspects of DER integration, and in mid-2009, this research led to the launch of a broad industry collaboration to identify a common means by which smart, communicating inverters may be integrated into utility systems. The Department of Energy, Sandia National Laboratories, and the Solar Electric Power Association—all agencies that have historically been involved in this area of study—partnered with EPRI to drive this work forward.[2]

Formally launched at a mid-2009 workshop held in Albuquerque, New Mexico, during the DOE's SEGIS-ES conference, the project initially compiled a master list of potential uses for communication-connected PV and storage systems. The large range of use cases was then down-selected into seven core functions deemed by project stakeholders to be of highest priority (shown in Figure 2[3]). These selected functions have since been the focus of the collaboration's work.[4]

Volunteers were solicited to form a technical focus group with the charter to develop detailed descriptions for how each

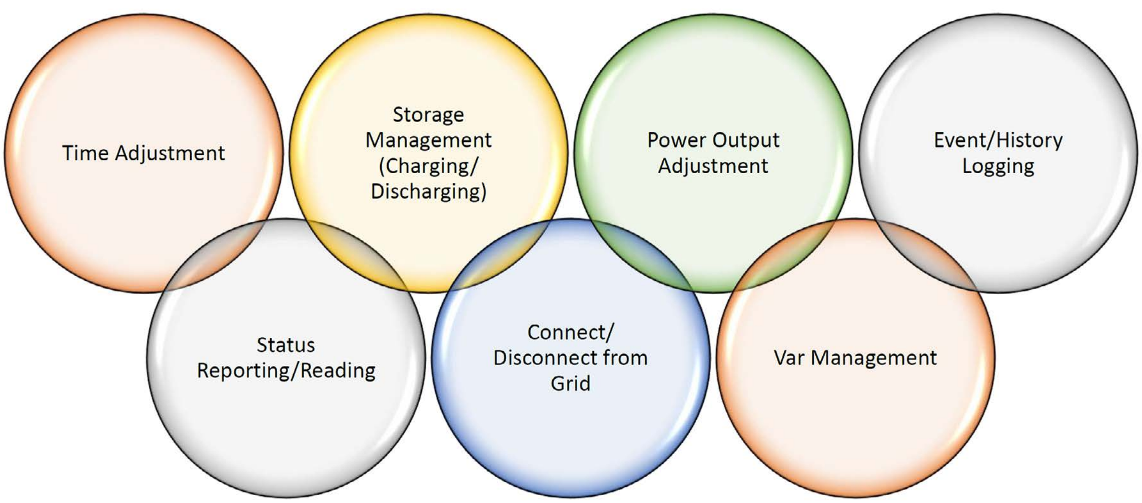

Figure 2 – Common Functions

[1] *Common Functions for Smart Inverters. Version 3*. EPRI, Palo Alto, CA: 2013. 3002002233.
[2] *Standard Language Protocols for Photovoltaic and Storage Grid Integration*. EPRI: Palo Alto, CA. 2010. 1020906.
[3] *Common Functions for Smart Inverters. Version 3*. EPRI, Palo Alto, CA: 2013. 3002002233.
[4] *Development of a Standard Language for Photovoltaic and Storage Integration*. EPRI, Palo Alto, CA: 2009. 1020435.

function should be implemented. Further, the focus group was to identify the information to be exchanged by each function and to represent this information in terms of the IEC 61850-7-420 object model for DER.[5]

This initiative has supported common functions in standard communication protocols. For example, "common communication methods such as the DNP3 AN2013-001 make it possible for many different types, brands, and sizes of DER to be integrated and utilized in a uniform, consistent way. Such cooperative integration could enable higher levels of DER usage in utility distribution systems, and create higher value for the distributed resources."[6]

DNP3 also implements the full slate of common smart inverter functions identified in IEC 61850-90-7.

The DNP3 User Group released a new application note in 2013, "AN2013-001 DNP3 Advanced Photovoltaic Profile," which describes a standard data point configuration (a set of protocol services and settings—also known as a *profile*) for communicating with PV generation and storage systems using the DNP3 standard (IEEE Std 1815-2012). The application note provides inverter manufacturers, utilities, and system integrators with standard-based methods for integration of inverter-based photovoltaic and battery-storage systems with utility communication and control systems. It enables the use of DNP3 to apply the full slate of the common functions of smart inverters identified by the IEC in IEC/TR 61850-90-7.[7]

Once a set of common functions were identified and defined, the focus shifted to implementation of these functions and protocols by manufacturers and field demonstrations (Figure 3). The Smart Grid Ready PV Inverters with Utility Communication project (DOE FOA-479) is one example of these field demonstrations.

The objectives of this project included the following:

- Develop, implement, and demonstrate smart-grid-ready inverters with grid-support functionality and communication links required to capture the full value of distributed PV:
  - Implement advanced standard grid-supportive functions into inverters.
  - Establish remote management and configurability of functions from a distribution operation center.
  - Enable utility companies to better use these grid assets.[8]

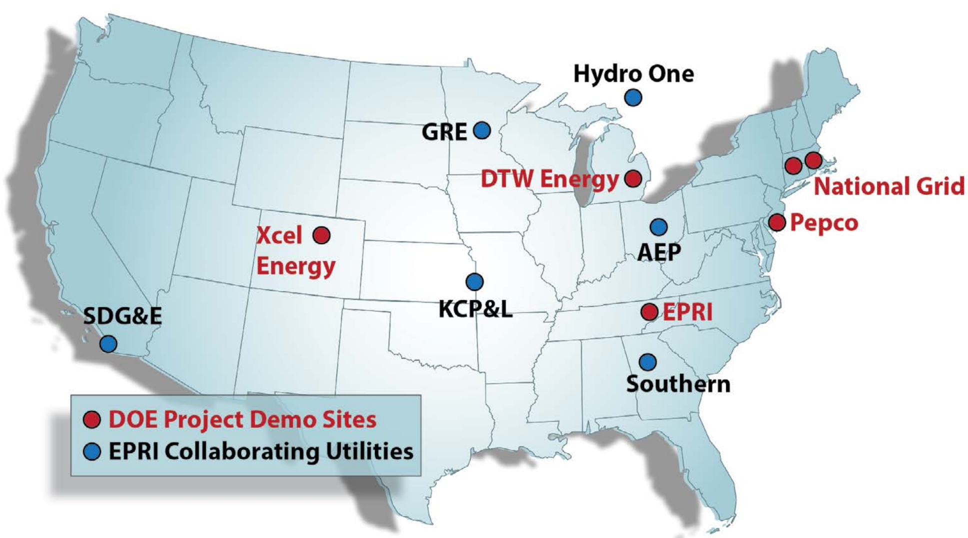

Figure 3 – Demonstration Sites and Collaborating Utilities

5 *Specification for PV & Storage Inverter Interactions Using IEC 61850 Object Models and Capabilities. v. 14*. EPRI. 2010.
6 DNP3.org. "Advanced Photovoltaic Profile." Press Release. https://www.dnp.org/Lists/Announcements/DispForm.aspx?ID=21 [Accessed 25 November 2014]
7 DNP3.org. "Advanced Photovoltaic Profile." Press Release. https://www.dnp.org/Lists/Announcements/DispForm.aspx?ID=21 [Accessed 25 November 2014]
8 Electric Power Research Institute, et al. *Smart Grid Ready PV Inverters with Utility Communication*. (February 27, 2014). DOE-FOA-479 Quarterly Report.

Recognizing the Need for Enterprise Integration Functions

In the field-demonstration process, the need for enterprise-integration functions and support (such as how DMD systems and DERMS interact in a central office) was recognized. This was due to the understanding that as DER increases its penetration in the distribution system, there would be a profound effect on the designs and operating practices that have existed for a century or more. On feeders with very high penetrations of customer-owned generating resources, the potential exists for having more power supply than demand on a given feeder, resulting in reverse power flow that can cause unacceptable voltage profiles and possible overloads along the distribution feeder. In addition, some renewable DER (such as solar PV and wind power) have highly variable power output, which can produce voltage fluctuations that reduce the overall quality of voltage on the feeder and, therefore, must be mitigated.

For these reasons, the distribution system operator and the distribution monitoring and control systems used by the operators must be aware of the current operating status of the DER at all times and must be able to manage the output of these units. This is necessary to enable the operators to maintain quality of power on the circuits at all times, to guarantee the safety of the workforce and general public, and to protect existing utility-owned electrical assets. DER that are equipped with smart inverters and other intelligent controllers may be able to provide additional functionality, such as volt-Var support, to meet the changing feeder requirements on demand.

The conceptual purpose of a DERMS is to manage many diverse DER, to understand the unique status and capabilities of each, and to present these capabilities to DMS and other applications in a more useful and manageable way. This could mean aggregating the capabilities of individual devices and transforming their settings and effects so that they become attributes at the circuit, feeder, or segment level. Interoperability of systems requires open standards. Those standards include both functional behaviors (standardizing the DER-related use cases and services on the enterprise) and the communication standards (information models) needed to support these functions.

Communication standards in the enterprise-integration environment include the IEC 61968/61970 CIM and MultiSpeak and are different from standards that cover field network protocols (such as IEC 681850 and DNP3) both in terms of design and purpose. As research continues in the DER/DMS area, EPRI intends to contribute and coordinate it with the CIM and MultiSpeak standards-development groups—and with the NIST groups that are helping to coordinate overall activities—with the vision of making standards-based end-to-end DER integration possible.[9]

Initiative Launched to Address Challenges

In response to the gaps identified above, an initiative was launched to address these issues. The initiative began with a face-to-face workshop held in Washington, D.C., in September 2012. Following the initiation of this project, a yearlong focus-group activity was facilitated to take the priorities identified in the workshop and expand them into specific CIM and MultiSpeak model changes and messages.

To identify a starting list (core set) of practical, enterprise -level interactions for DER, these meetings brought together a group of experts in the field of utility distribution management, software for distribution management, distributed energy storage, and generation.[10] The use cases developed during the meetings included:

- Creation and maintenance of DER groups (a method to aggregate individual DER)
- Status monitoring
- Forecasting
- Dispatch

The ongoing activity of the focus group is being coordinated with DOE through its SunShot Solar Energy Grid Integration Systems—Advanced Concepts (SEGIS-AC) program, as well as with NIST through its Smart Grid Interoperability Panel's Distributed Renewables, Generators, and Storage Domain Expert Working Group.[11]

CIM- and MultiSpeak-based messages were created to support each of these use cases. In 2014, a test plan was created to provide a means to determine whether a given vendor complied with the messages that were defined and to provide clarity of intent of how the messages were to be used.[12]

The following section provides a summary of this initiative's latest effort.

---

9 *Integrating Smart Distributed Energy Resources with Distribution Management Systems*. EPRI: Palo, Alto, CA. 2012. 1024360.
10 *Collaborative Initiative to Advance Enterprise Integration of DER: Workshop Results*. EPRI, Palo Alto, CA: 2012. 1026789.
11 *Enterprise Integration Functions for Distributed Energy Resources: Phase 1*. EPRI, Palo Alto, CA: 2013. 3002001249.
12 *Enterprise Integration Functions Test Plan for Distributed Energy Resources, Phase I*. EPRI: Palo, Alto, CA. 2014. 3002004681.

Figure 4 – Workshop Attendees Preparing for the Day's Testing

Proceedings of the Interoperability Workshop

On October 28, 2014, EPRI facilitated a workshop at NREL's research support facility in Golden, Colorado. The workshop allowed for interoperability testing for DER enterprise integration by several vendors. The objective of the workshop was to get the vendor systems to support the various message types. Three vendors tested their systems with the Common Information Model (CIM) and MultiSpeak data model.

This workshop leveraged a semantic standard test harness that was originally developed in 2011 and updated with these new message types.

The end vision is to have a testing platform that is available 24/7 and will facilitate standards-based testing of various enterprise systems such as CIS, MDMS, AMI, and DER.

With the CIM and MultiSpeak efforts, it is important to document what is going to be accomplished and illustrate how the standards are utilized, where the information is in the model, and how to use it.

Enterprise-Level Functions Tested

The functions tested at the workshop are identified and summarized below. Testing was conducted by Schneider Electric using CIM-based messages, while Boreas Group, Nebland Software, and Smarter Grid Solutions tested both CIM and MultiSpeak messages. (While Spirae sent several test observers and provided feedback in the conversations on the goals and objectives of the workshop, they did not test any interfaces). These functions were innovative in that:

- They represent a significant step forward in enabling distributed energy resources to be supported on distribution systems.
- The messages provides a means for existing distribution controls and new smart inverter capabilities to work cohesively together.
- They facilitate the development and demonstrate the first standards-based monitoring and management of aggregated groups of DER.
- They set the stage for utility-to-aggregator integration as well as internal DERMS.
- The messages represent enterprise-level integration that is harmonized with the smart inverter functions specified in IEC 61850.

The functions tested are shown in Table 1 on the following page.

Table 1 – Summary of Functions Test at Workshop

Test	CIM	MultiSpeak	Observations
Test 1: Create DERGroup	Successful	Successful	• A method to support group versioning is required. • Issues were identified in CIM headers.
Test 2: Querying DERGroup	Successful	Successful	• Use a GUID (in Java this is a UUID). • Limitation of test harness is the "canned" response. This could be changed to be more dynamic, such as a DERMS reference implementation. • Business logic is difficult to enforce (for example, what you would allow to happen versus not allow to happen) and is not enforced at the message level; it must occur within a given application.
Test 3: Adding DER to group	Successful	Successful	• Suggestion to add details to error reporting to be "human readable"? And something an operator could handle. • Identified feature missing: logging headers in both directions. • Notification that a group membership has changed; do you have pending forecasting that is impacted by that change? Business logic would need to be in place to check for an impacted forecast. • Idea of forecast: There should be a level of confidence (such as 95% confidence); over time, you will know how system is supposed to work.
Test 4: Removing DER from group	Test not performed	Successful	
Test 5: Deleting DERGroup from group	Successful	Successful	
Test 6: Notifying DERGroup	Test not performed	Test not performed	
Test 7: Monitoring the status of DERGroup	Successful	Successful	• Status is what it is doing at this point in time versus capability, which is the nameplate information, etc. • DER group versus DER group IDs: The naming conventions need to match.
Test 8: Discovering capabilities	Successful	Test not performed	
Test 9: Dispatching DERGroup	Test not performed	Successful	• Enumerations currently have no meaning; suggestion is to include an index field. • Scheduling of dispatch use case is not yet covered. • Even with scheduling, there is no duration in the message (for example, start now and run for 4 hours as a demand-response event). • Ongoing process to monitor the DER and enterprise group management of how you achieve that is limited. • A mechanism is needed to change set points (i.e. adjust the event or adjust the group). • There is only one message for controlling dispatch. Suggestion is to include a stop, interrupt, and cancel dispatch request.
Test 10: Forecasting DERGroup	Successful	Successful	

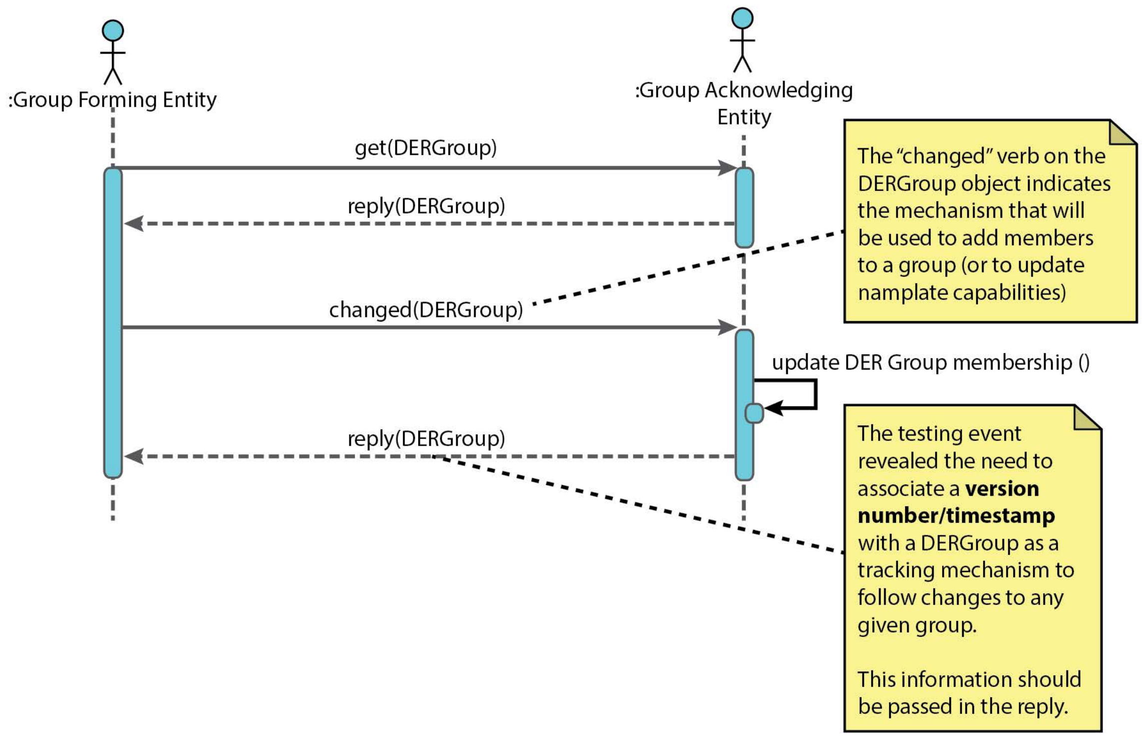

Figure 5 – Addition of Version Number/Timestamp Associated with Updates to DERGroups

Test Findings

After testing, an observation was made that although this workshop was successful, there were numerous opportunities for improvement. For example, if there are multiple entities managing groups dealing with publication and notification types of service requests, then the message would be much more complicated. A potential solution proposed to deal with this complexity is to keep track of group versioning. Figure 5 provides an illustration of how this versioning process would work.

Going forward, the response should indicate that the group version is now x, and the timestamp is included. For example, the DERMS as the system of record has the group version (x), and time-stamp information (in addition the personnel making the changes or receiving messages) has this version information.

The framework for a new use case was also identified. The scenario was presented where there is 90% confidence in a forecast, but something happens after messages have already been established, and so there is a need to send an update to the forecast. The use case would investigate what happens if a forecast changes.

Workshop Wrap-up

The workshop concluded with a discussion of what the attendees would like to see in the semantic standard test harness. From the EPRI perspective, the test harness would ideally be a reusable and repeatable set of data and may even include a reference implementation, which was available 24/7. Workshop participants also suggested that there needs to be a GitHub community created to create reference implementation, perhaps one specific to Java, one specific to Microsoft.Net, or one using other platforms. Providing a place such as GitHub to share files and to share suggestions for improving semantic standards could expedite the number of agreed-upon messages. GitHub is an online, collaborative code sharing program that allows for code management and revision.[13]

[13] GitHub. *About Us*. https://github.com/about

Workshop Summary

The goal of this workshop was to validate DERMS-related messages that were based on both CIM and MultiSpeak standards and to update the EPRI test harness to support these new messages. The idea going in was not that the messages would be perfect, but rather assumptions would be clarified on the expectations for the messages. In fact, it was presumed that if there were errors in the message design (there were), the group could work together and quickly address any errors of definition or assumption. From the notes captured for each test, one can see how these issues and clarifications played out. One example in particular was the use of the CIM master resource ID (mRID), which is the equivalent to objectID in MultiSpeak. The expectation was that this attribute should be a globally unique ID (GUID). However, in the MultiSpeak XSD (XML schema definition), this attribute was restricted to enforce using a GUID, while in the CIM XSD, a less restrictive "string" data type was used. While the assumption of global uniqueness did not change (mRID and objectID both must be a GUID), this rule was not enforced in one XSD, allowing the introduction of errors if a string was used that was not in fact a GUID.

The value behind the workshop is in accelerating the "contact" (having vendors test the messages derived from the use cases) and catch issues before they become codified in a standard. This both accelerates the standards process and makes the resulting standard more reliable.

The workshop validated that while there were a few issues with the message design, there were no issues with the underlying use cases and how they were addressed by these messages. As this work progresses into a second phase, the issues and clarifications will be reflected in updated version of the messages, and additional use cases will be added to this body of work.

Next Steps

In 2015, the Phase II portion of this project will begin to verify that current issues identified in Phase I were addressed and to test new functions as they are developed. The overall vision for this work is a shared tool that will allow utilities to set up testing within their respective firewalls. In the long term, workshops such as the one held in 2014 in Colorado will allow for the collection of additional test scripts for DER, metering, or other standards-based enterprise messages.

The workshop was a productive session that "moved the ball forward" in the understanding of how enterprise integration and aggregation of DER capabilities should be accomplished. The workshop also identified additional issues that need to be addressed as this initiative moves forward. This will include reconvening of the interest group in order to identify the next top-priority functions and addressing the improvements captured in Table 1. Additionally, the use cases, findings, and suggested updates need to be shared with the CIM and MultiSpeak communities for consideration for inclusion in the next version of the respective standards.

Finally, the test harness will be put online and kept available and up to date with new additions and new features making it easier to use. The intention is to develop this enterprise interface on the EPRI Open DERMS tool and place the interface on a site such as Sourceforge,[14] a resource for open source developers to share code and entire applications. The use of GitHub as another place to foster a user community will also be explored (per workshop participant feedback).

[14] Sourceforge. http://sourceforge.net/

The Electric Power Research Institute, Inc. (EPRI, www.epri.com) conducts research and development relating to the generation, delivery and use of electricity for the benefit of the public. An independent, nonprofit organization, EPRI brings together its scientists and engineers as well as experts from academia and industry to help address challenges in electricity, including reliability, efficiency, health, safety and the environment. EPRI also provides technology, policy and economic analyses to drive long-range research and development planning, and supports research in emerging technologies. EPRI's members represent approximately 90 percent of the electricity generated and delivered in the United States, and international participation extends to more than 30 countries. EPRI's principal offices and laboratories are located in Palo Alto, Calif.; Charlotte, N.C.; Knoxville, Tenn.; and Lenox, Mass.

Together . . . Shaping the Future of Electricity

EPRI Resources

John Simmins
Technical Executive, Information & Communications Program, EPRI, 865.218-8110, jsimmins@epri.com

Gerald Gray
Technical Executive, Information & Communications Program, EPRI, 865.218-8113, ggray@epri.com

Brian Seal
Technical Executive, Information & Communications Program, EPRI, 865.218-8181, bseal@epri.com

3002003035

December 2014

Electric Power Research Institute
3420 Hillview Avenue, Palo Alto, California 94304-1338 • PO Box 10412, Palo Alto, California 94303-0813 USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com