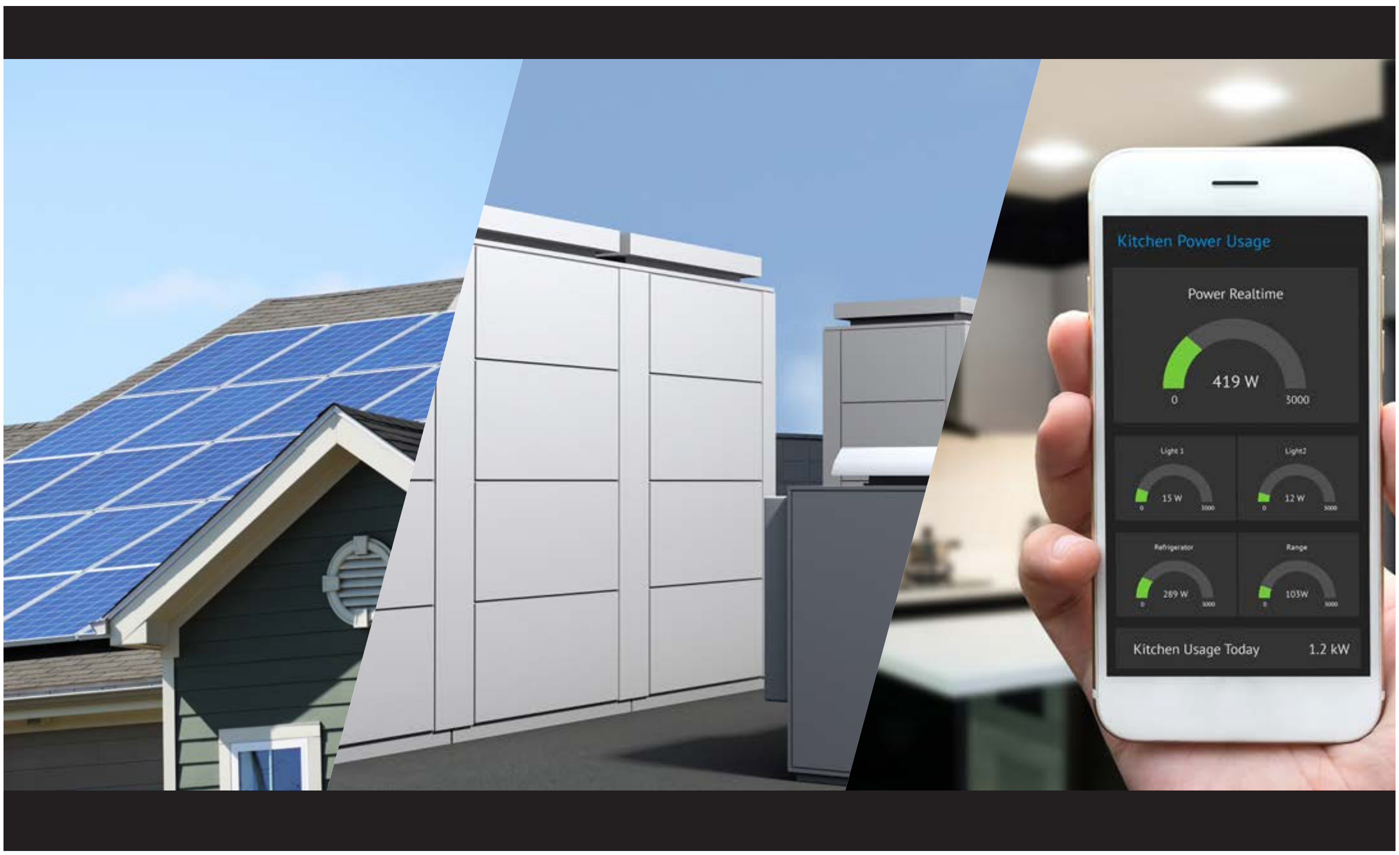
ELECTRIC POWER RESEARCH INSTITUTE

MOUNTING IMPORTANCE OF COMMUNICATIONS TO MONITOR AND CONTROL DISTRIBUTED ENERGY RESOURCES



December 2018

Introduction

Utilities worldwide are challenged by the technical and business decisions to embrace distributed energy resources (DER) as a key component to maintain a flexible, reliable, and renewable integrated grid. The DER technologies in reference include demand response (DR), distributed generation (DG), energy storage, and electric vehicles (EV). The design and implementation of capabilities for robust and interoperable communications between DER technologies and other grid systems are at the heart of addressing many of these challenges. Communications can enable advanced capabilities needed to maintain a reliable and secure grid including dynamic control of DER[1,2,3]; system analytics to improve efficiency and effectiveness; and optimized dispatch of DER to improve utilization.[4,5]

Electric utilities across the world are looking at methods to more effectively operate the distribution system in alignment with the increase of distributed energy resource technologies such as solar, energy storage, and controllable loads for DR. This includes direct[6,7] non-proprietary access across a variety of vendor makes and models of DER; optimization of the dispatch of DER through advanced distribution grid control systems including Distributed Energy Resourced Management Systems (DERMS) and Advanced Distribution Management Systems (ADMS); and data analytics for grid modeling and to unlock new undiscovered use cases. Though these future states appear to be long-term goals, there are utility projects and vendors across the world looking to make these systems a reality through pilots and demonstrations.[8,9,10,11] Under this not-so-distant future state underlies a communications backbone that supports standard and open access to DER devices and grid systems and allows access to the DER over the life of the system.[7] In response to these challenges faced, utilities, regulators, industry, and trade organizations are planning to add communications requirements in their specifications, mandates, and proposal selection criteria that support their short-term and long-term grid planning and operation, policy, and business needs.[12,13]

To address these challenges, this paper explores at a high-level the emergence of requirements for open protocols in DER communications. The objectives of the paper are to review documents setting requirements for DER – interconnection standards, industry specifications, and building codes to provide background on the documents, identify what DER types and protocols are in-scope, and assess the impact the requirements for open protocols may have on the industry.

1 *Common Functions for Smart Inverters: 4th Edition*. EPRI, Palo Alto, CA: 2016. 3002008217.
2 *Common Demand Response Functions for Heating, Ventilating, and Air Conditioning (HVAC): A Summary of Demand Response Functionality Discussed in the Industry to Date*. EPRI, Palo Alto, CA: 2017. /ZWS
3 *Applying Standards-Based Demand Response to Support Solar Integration: A Summary of EPRI Testing at the National Renewable Energy Laboratory (NREL)*. EPRI, Palo Alto, CA: 2017. 3002009849.
4 *DER Grouping Methods and Considerations for Operations: A Study on the Different Approaches for Creating and Managing Groups of DER and the Impact on Operations*. EPRI, Palo Alto, CA: 2017. 3002009857.
5 *Common Functions for DER Group Management, Third Edition*. EPRI, Palo Alto, CA: 2016. 3002008215.
6 “Direct Access” relates to where in the communication pathway an open, standard interface exists at the device.
7 *The Value of Direct Access to Connected Devices*. EPRI, Palo Alto, CA: 2017. 3002007825.
8 Southern California Edison, “Grid Modernization Initiative: Grid Management System Architecture,” February 2016, http://www.edison.com/content/dam/eix/documents/innovation/SCE%20Grid%20Management%20System%20Architecture%202.1.16b.pdf.
9 Shuichi Ashidate. Tokyo Electric Power Co., Inc. “Opportunities and Challenges for Smart Grid in Japan”. March 8, 2016. http://www.nedo.go.jp/content/100778194.pdf.
10 *Beneficial Integration of Energy Storage and Load Management with Photovoltaics*. Office of Energy Efficiency and Renewable Energy. U.S. Department of Energy. https://www.energy.gov/eere/solar/project-profile-electric-power-research-institute-shines.
11 *Tucson Electric Power Project RAIN*. EPRI, Palo Alto, CA: 2018. 3002014812.
12 *Interoperability Strategic Vision – A GMLC White Paper*. Pacific Northwest National Laboratory. March 2018. https://gridmod.labworks.org/sites/default/files/resources/InteropStrategicVisionPaper2018-03-29.pdf.
13 *IEEE Standard 1547™ — Communications and Interoperability: New Requirements Mandate Open Communications Interface and Interoperability for Distributed Energy Resources*. EPRI, Palo Alto, CA: 2017. 3002011591.

Table of Contents

This white paper was prepared by Ben Ealey, EPRI.

Emergence of Requirements for Open Communication Protocols

The industry is recognizing the need for standardized communications. Evidence of this is an increase in the number of regulations, mandates, and requirements that specifically call out – or are considering – aspects of interoperability including standardized communications protocols, information models, and functional requirements. There has been growth in citing open communications protocols to alleviate risks by providing direct, standardized, and open access to DERs. In this context, open communication protocols are defined as protocols like OpenADR, ANSI/CTA-2045, IEEE 1815 (DNP3), SunSpec Modbus, IEC-61850, and IEEE 2030 but also includes the DER-focused information models associated with each of these protocols. These documents span all the DER domains including photovoltaic generation, energy storage systems, electric vehicles, and controllable loads. This includes California Title 24, Northwest Energy Efficiency Alliance's water heater specifications, Consortium for Energy Efficiency's (CEE) pool pump and water heater initiatives, Air-Conditioning, Heating, and Refrigeration Institute's (AHRI) variable capacity heat pump standard, Energy Star, California's Rule 21 interconnection standard, and IEEE 1547-2018 – *IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces*.

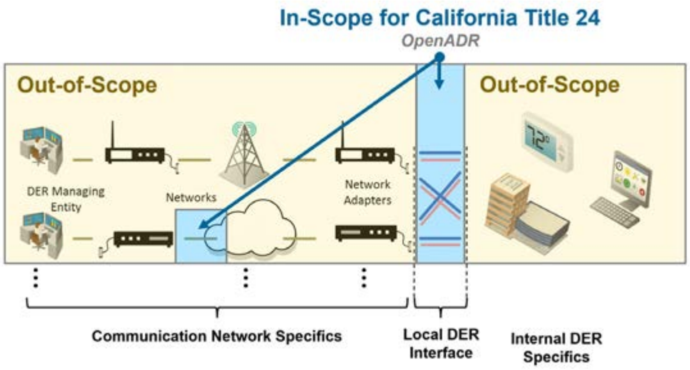
Documents Driving the DER Requirements[14]

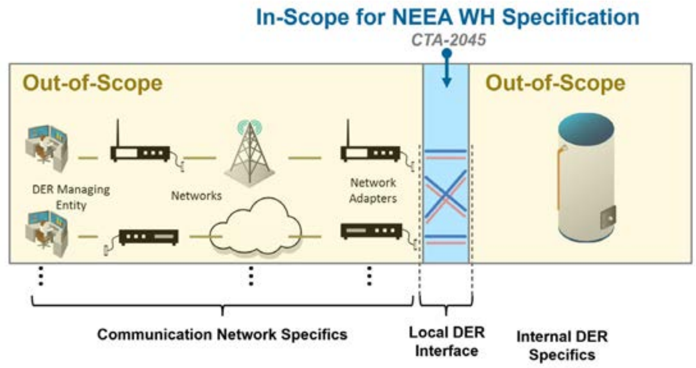
Stakeholders at varying levels of the industry are creating documents that drive the requirements of DER. There are regulatory documents like California Rule 21 and California Title 24 which mandate certain DER specifications to ensure safe, secure, and economically feasible operation. There are standards like IEEE 1547-2018 and AHRI-1380 that utilities or other stakeholders can reference to develop regulatory documents or otherwise define standardized sets of functionalities. There are also groups like the Consortium for Energy Efficiency (CEE) Initiatives and Northwest Energy Efficiency Alliance (NEEA) Specifications which create specifications and other tools to help utilities create and enforce requirements for programs in their territory. Though each of these documents are applied differently in the industry, they are all ultimately drivers for the requirements of DER on the electric grid.

14 This document is high level overview of these standards and may not capture some of the complexities and special cases of these standards. Refer to official rulemaking documents for compliance with these standards.

	DER in Scope	Optional/Mandatory	Protocols
California Title 24	EE and DR of non-residential HVAC Controls, Lighting Controls, Electronic Messaging Center Controls	Mandatory in the State of California	OpenADR
Northwest Energy Efficiency Alliance (NEEA) Specifications	Heat Pump Water Heaters	Optional until required in a utility program.	CTA-2045
Consortium for Energy Efficiency (CEE) Initiatives	Water Heaters, Pool Pumps	Optional until required in a utility program.	CTA-2045
Air-Conditioning, Heating, and Refrigeration Institute: AHRI-1380	Variable Capacity Heat Pumps	Optional until required in a utility program.	OpenADR CTA-2045
California Rule 21	Inverter-based DERs	Mandatory for DER in Service Territories of California Investor-Owned Utilities	IEEE 2030.5
IEEE 1547-2018	Smart Inverters	Optional until referenced in a grid code.	IEEE 2030.5 IEEE 1815/DNP3 SunSpec Modbus

Note: Requirements may apply to a subset of the industry whether regional, technology specific, or type of building.





California Energy Commission

Title 24 – Building Energy Efficiency Program[15]

OpenADR for HVAC Controls, Lighting Controls, and Electronic Messaging Center Demand Responsive Controls

Title 24 was created as part of the California Energy Efficiency Building Code to reduce energy consumption across the state and prevent the state from having to build new power plants.[16] It specifies requirements for manufacturing, construction, and installation of certain systems, equipment, appliances, and building components in non-residential, high-rise housing, and hotel/motel buildings.

Title 24 is currently in revision with updates estimated to be published in January 2019 and will go into effect on January 1st, 2020. The current version has requirements for communications capabilities but does not include requirements for standardized communication protocols.[17] In the 2019 revision of Title 24 this has changed. The 2019 version mandates the use of OpenADR 2.0 (a or b profile specifications) for communicating price and DR event signals for demand-responsive controls for HVAC, lighting, and electronic messaging centers. It allows either clients within the device or clients in-the-cloud. Title 24 applies to certain new construction, remodels, and retrofits in the State of California.

Northwest Energy Efficiency Alliance (NEEA)

Advanced Water Heater Specification[18]

CTA-2045 in Water Heaters

The Northwest Energy Efficiency Alliance (NEEA) is a trade alliance for utilities and energy efficiency organizations that works to transform the market through programs to accelerate adoption of efficiency devices, services, and practices. They maintain specifications, protocols, tools, and qualified product lists. NEEA has over 140 member organizations.

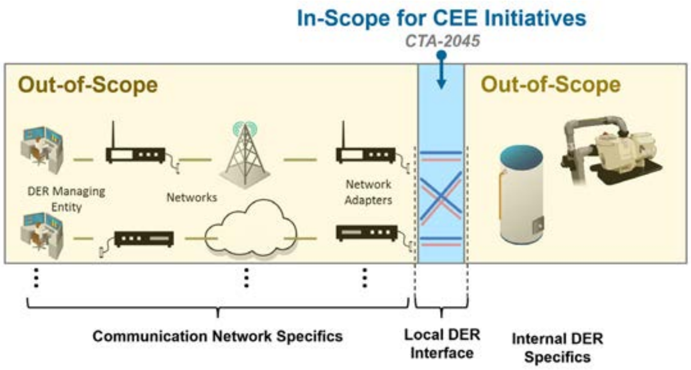
NEEA's Advanced Water Heater Specification is intended to advance higher-performing heat pump water heaters. In NEEA's Advanced Water Heater Specification (AWHS 6.0) support of DR is optional. AWHS 7.0 that takes effect in 2019 requires that for water heaters to support the Tier 3 or above requirements that they must support DR. Meeting the DR requirements requires that they a CTA-2045 interface. NEEA's advanced water heater specification is optional and has no jurisdiction until utilities or authorities choose to use it in utility incentive programs.

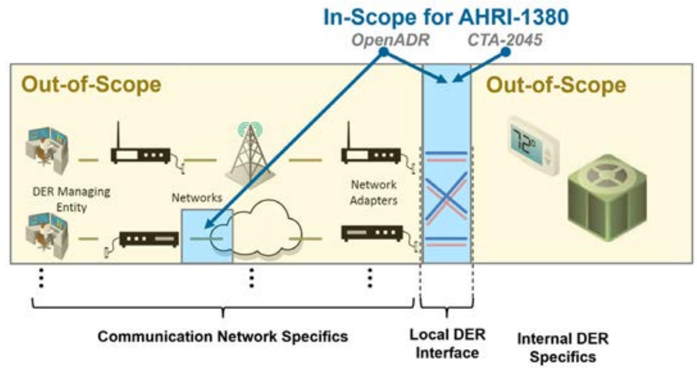
15 California Energy Commission. "Building Energy Efficiency Program." California Energy Commission. Accessed November 05, 2018. http://www.energy.ca.gov/title24/.

16 California Energy Commission. "California's Energy Efficiency Standards Have Saved Billions." California Energy Commission. Accessed November 05, 2018. https://www.energy.ca.gov/efficiency/savings.html.

17 Ghatikar G., E.H.Y Sung, and M.A. Piette, Diffusion of Automated Grid Transactions Through Energy Efficiency Codes, ECEEE Summer Study on Energy Efficiency, France, June 2015. LBNL-6995E. https://drrc.lbl.gov/publications/diffusion-automated-grid-transactions.

18 "Advanced Water Heater Specification." NEEA. August 06, 2018. https://neea.org/our-work/advanced-water-heater-specification.





Consortium for Energy Efficiency (CEE)

CEE High Efficiency Residential Swimming Pool Initiative[19]

Residential Water Heating Initiative[20]

CTA-2045 in Water Heaters and Pool Pumps

The Consortium for Energy Efficiency (CEE) is a trade organization of utilities, energy offices, government agencies, and non-utility program administrators with a focus on increasing the supply and demand for energy efficient products and services. They do this through the creation of member committees that are tasked with developing initiatives that analyze business cases, identify products and services, and engage industry stakeholders. They create specifications, product lists, and summaries from member programs.

CEE has initiatives across residential, commercial, and industrial sectors. In two of their initiatives—residential water heating and swimming pool—they are exploring including CTA-2045 as the preferred method for communicating with DER. The specifications created by CEE are optional and have no jurisdiction until utilities or authorities choose to use them in utility incentive programs. CEE lists 40 utility participants on their residential water heating initiative and 36 utilities in their residential swimming pool initiative.

19 "Residential Swimming Pools Initiative." CEE Annual Report. Accessed November 05, 2018. https://library.cee1.org/content/cee-high-efficiency-residential-swimming-pool-initiative/.

20 "Residential Water Heating Initiative." CEE Annual Report. Accessed November 05, 2018. https://library.cee1.org/system/files/library/13557/CEE_ResWaterHeating_Initiative_16Mar2018.pdf.

Air-Conditioning, Heating, and Refrigeration Institute

AHRI Standard 1380 (I-P) – Demand Response through Variable Capacity HVAC Systems Equipment in Residential and Small Commercial Applications[21]

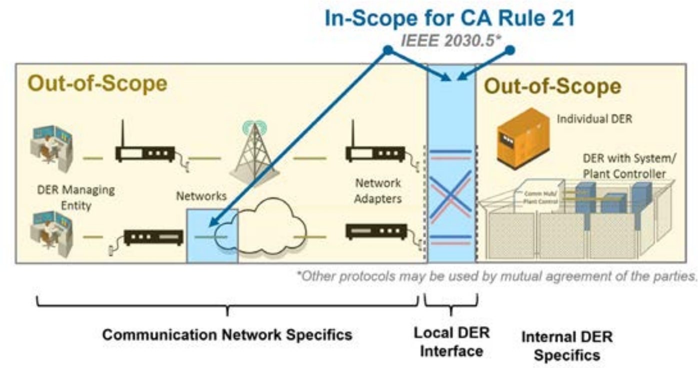
OpenADR and CTA-2045 in Variable Capacity Heat Pumps

The Air Conditioning, Heating, & Refrigeration Institute (AHRI) is a trade organization for manufacturers of HVAC and water heating equipment across the world. AHRI has 315 members and accounts for 90% of the market in North America. AHRI advocates to the government on behalf of its members, operates a certification program, and develops performance standards. AHRI standards are developed through their working groups.

The purpose of AHRI 1380 - AHRI Standard 1380 (I-P), is to establish requirements for variable capacity HVAC systems (5-ton or less) to support demand response grid services, enabling customers to leverage their equipment for financial incentives by participating in programs offered by electric utilities or third-party. The original intent of the standard was to specify functions required to support grid services that were accessible through an open communication interface at the device. To enable this functionality, the original draft required devices to include both OpenADR 2.0 and CTA-2045 interfaces at the device. As the draft moved through different AHRI committees, it was modified to allow variable capacity units with either a proprietary or CTA-2045 interface to meet the demand response requirements.

AHRI is an optional standard and has no power until utilities or authorities choose to use it in utility incentive programs.

21 "Proposed Standards and Guidelines". Air Conditioning, Heating, and Refrigeration Institute. Accessed November 05, 2018. http://www.ahrinet.org/Standards/HVACR-Industry-Standards/Proposed-Standards-and-Guidelines.



California Public Utilities Commission

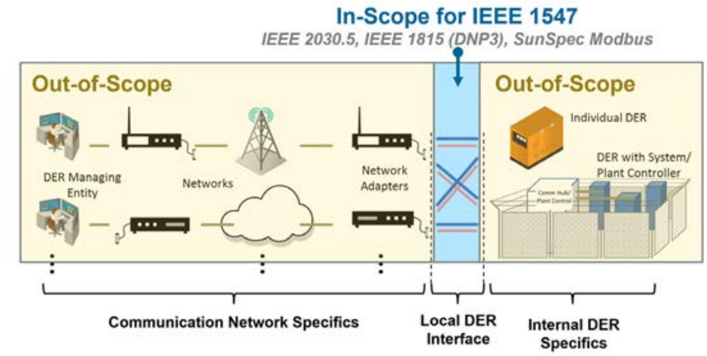
Rule 21 Interconnection Standard[22]

IEEE 2030.5 at Aggregator Interface for Smart Inverters

Large amounts of solar have been added to the California grid. As the numbers increase due to mandates within the state, there is a need for utilities to maintain voltage and frequency stability on the grid continuing to accommodate additional solar. In response to this, the California Public Utilities Commission has created Rule 21 to define requirements for smart inverters and identify specific functionalities they can provide to support grid voltage and frequency. California's Rule 21 is an interconnection standard for connecting generating or storage facilities to the electric grid. Similar to IEEE 1547-2018, the standard's goal is protecting the safety and reliability of the electric grid. The standard was developed based on recommendations for advanced inverter functionality from the Smart Inverter Working Group.

Among requirements for smart inverter functions like volt-var and power curtailment, Rule 21 requires communications to DER. Rule 21 specifies IEEE 2030.5 as the default protocol for use between utilities and aggregators and utilities and DER and defines specific smart inverter functions that must be present in the device. It allows other protocols, including IEEE 1815/DNP3 and IEC-61850, through mutual agreement between parties. The standard has three phases. Phase 1 requires specific autonomous functionalities in smart inverters. Phase 2 adds communications requirements. Phase 3 adds communicable smart inverter functions.

The Smart Inverter Working Group's (SIWG) recommendations were reviewed by the California Public Utilities Commission (CPUC) and published as Rule 21. Rule 21 is a California state-level mandate for investor-owned utilities. Each investor-owned utility (PG&E, SCE, and SDG&E) is responsible for creating their own tariffs for each territory and publishing a "Generation Interconnection Handbook".



Institute of Electrical and Electronics Engineers (IEEE)

IEEE 1547-2018 IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces[23,13]

IEEE 2030.5, DNP3, SunSpec Modbus at DER Interface

IEEE 1547 is a standard that includes the technical specification and testing requirements for interconnection and interoperability between power systems and DERs. The requirements cover performance, operation, testing, safety, and maintenance of the connection to the grid. It is maintained by IEEE Standards Association and was created and is maintained by an IEEE working group.

In the 2018 revision to IEEE 1547, there was a paradigm shift in the expectations for DER. IEEE 1547-2013 required that DER disconnect from the grid if grid conditions went outside of a tolerance band. In IEEE 1547-2018, DER are recognized as an important resource in maintaining grid stability. As part of this, communications are needed to provide dynamic control of DER. The standard defines functional and communications requirements. In communications, it requires standardization at the DER's interface. DER may support more interfaces; however, at least one of the three named protocols (IEEE 2030.5, IEEE 1815-DNP3 using Application Note 2018-001, SunSpec Modbus) must be supported. IEEE 1547 also has an associated test procedure, IEEE 1547.1, which defines the testing criteria for certifying to IEEE 1547.

22 "Rule 21 Interconnection." California Public Utilities Commission. Accessed November 05, 2018. http://www.cpuc.ca.gov/Rule21/.

23 "1547-2018 - IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces." The IEEE Standards Association. April 04, 2018. https://standards.ieee.org/standard/1547-2018.html.

Similar to California's Rule 21 interconnection standard, IEEE 1547's goal is protecting the safety and reliability of the electric grid. IEEE 1547 does not have any jurisdiction until IEEE 1547 is referenced in a public utility commission's grid code—a specification defining safe, secure, and economical operation.

Impact of Communications on Electric Utilities and Their Customers

The emergence of requirements documents that help utilities add communications requirements in their specifications, mandates, and proposal selection may impact both utilities and their customers though helping to simplifying choices, mitigating risks, and indirectly increasing the number of products supporting these protocols.

Simplify choices. Utilities and public entities looking to define requirements for communicating to DER are presented with numerous choices including network layers, functionality communicated over the communications network, and expected functional response when receiving commands. These documents can simplify this by providing a reference set of requirements that covers basic and near-term applications. Advanced users can append or amend as needed.

Regardless of whether the requirements are mandatory or optional, each of the requirement documents listed above provides a list of minimum requirements for conformance. Utilities and consumers can use these criteria to identify key communications capabilities that may help improve interoperability by looking for certification to these regulations, mandates, or requirements. In areas where no regulations, mandates, or requirements are in place, the above documents can serve as a baseline template for creating requirements in the form of new regulations, mandates, or requirements. For example, IEEE 1547 contains requirements that can be referenced by public utility commissions in grid codes. IEEE does not carry any power on their own until a grid code references the sections within the standard.

Mitigating Risk. As previously addressed in EPRI's *The Value of Direct Access to Connected Devices*[6], there are a variety of risks that may be assumed when not using open, standard, direct access to DER. Open protocols may mitigate risks by providing utilities with flexibility in control architectures, cohesive integration across varied makes and models, customer choice of DER access over the life of the product, and quantifiable services.

The primary motivation for the recent regulations, mandates, or requirements documents is preserving the longevity of the communications interfaces to distributed energy resources. As the number of DER on the grid increase, it is likely that the grid's stability will depend on reliable control of DER. These entities—or associated working groups—recognize that investments to install these resources must be protected from risks that could lead to stranded assets like companies going out of business. Many of the requirements do not limit the interfaces to only standardized ones but require a standardized interface be present, which preserves at least one communications path to the DER.

More products supporting open protocols. Adoption of new technologies can be influenced by a mix of natural consumer/industry adoption, regulations/mandates in government, or utility requirements. In the case of regulations and mandates, the manufacturers and vendors will work to comply with these requirements to ensure their products continue to be marketable in the regions where those regulations, mandates, or requirements exist. This can have secondary effects in areas where those regulations, mandates, or requirements may not exist. Consider the European Union's Restriction of Hazardous Substances Directive (RoHS) requirements launched in 2003. This directive restricts the use of ten substances in electronic and electrical equipment.[24] The USA has no such countrywide mandate; however, states like California have created their own standards similar to RoHS. Though these mandates do not apply to all states, electronics sold across the USA have been certified to these requirements. In the manufacturing industry, economies of scale keep costs low so it may be cheaper to comply with the most restrictive requirements in all areas so that the same manufacturer process can be followed.

Though communications protocols in DER are a different context, the industry may see a similar effect where protocols applied outside of a utility's service territory may impact the availability of products to that utility. These protocols and requirements may drive manufacturers and vendors to develop the necessary software to add open communications protocols to their products. Once available, they could be available to other customers in areas outside of the scope of the regulations, mandates, or requirements.

24 "The RoHS Directive." European Commission. Accessed November 05, 2018. http://ec.europa.eu/environment/waste/rohs_eee/index_en.htm.

Conclusions and Next Steps

As the industry explores how distributed energy resources can play a part in a flexible grid, organizations like utilities, regulators, and trade organizations are adding communications to their specifications, mandates, and proposal criteria. This growth in citing open communication protocols is often justified by improving reliability over the lifespan of connected distributed energy resources by defending against defunct communications interfaces. However, it also helps to simplify choices, mitigate risks, and may lead to more products supporting these protocols.

- It simplifies choices by providing industry stakeholders with referenceable specifications. The alternative is to build specifications from scratch which requires understanding the large variation of choices available.
- It mitigates risks by providing utilities with flexibility in control architectures, cohesive integration across varied makes and models, customer choice of DER, and access over the life of the product.
- It may lead to more products supporting these protocols through manufacturers and vendors building to the requirements to ensure their products continue to be marketable in the regions where those regulations, mandates, or requirements exist. As more utilities reference these protocols, it may help manufacturers justify adding the required features to their products.

Next steps for utilities and governing bodies are to decide whether, and to what extent, the different specification documents could be referenced in their territory to help them provide safe, reliable, affordable, and environmentally-responsible energy.

EPRI RESOURCES

Ben Ealey, Senior Project Manager, Information and Communication Technology
865.218.8117, bealey@epri.com

Information and Communication Technology

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, affordability, 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 members represent 90% of the electric utility revenue in the United States with international participation in 35 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

3002013480 December 2018

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