Distributed Energy Resources (DER) Protocol Reference Guidebook—5th Edition: Public Version

SUMMARY

- The Electric Power Research Institute's (EPRI's) *DER Protocol Reference Guidebook* takes the pulse of an ever-changing set of distributed energy resources (DER) standards.
- The 2021 edition of the guidebook includes briefs on 11 DER standards, focusing on the nuances in adoption across electric vehicles (EVs), solar, storage, group/aggregation management, and demand management.
- This free version includes an overview of the guidebook and an example brief on the EcoPort/CTA-2045 demand response standard mandated in Washington, Oregon, and California.

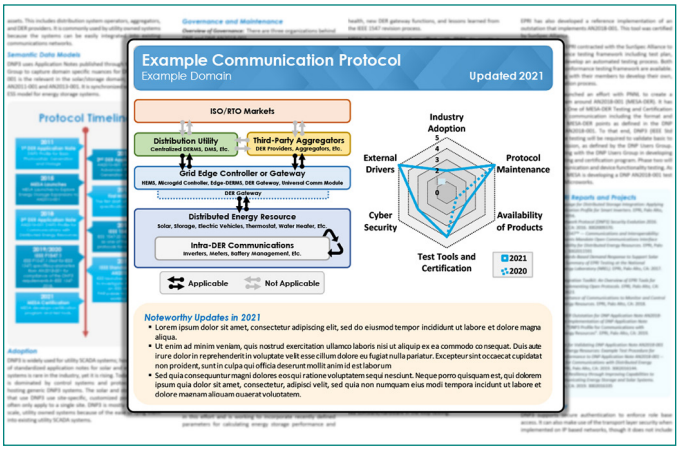
RESEARCH DRIVERS

- Regulators are seeing the need for interoperability, as evidenced by an increasing number of requirements in grid codes and state laws mandating their adoption of these requirements.
- DER information and protocols are changing quickly. In 2021, for the first time since the tracking effort began five years ago, EPRI saw maturity increase for almost every protocol tracked.
- Grid codes (e.g., CA Rule 21) and interconnection standards (IEEE 1547-2018) are driving an increase in maturity of generation-focused standards and protocols.
- Adoption of EV protocols and storage technologies is increasing, but adoption of information and protocol standards is low.
- Federal Energy Regulatory Commission (FERC) O2222 creates new opportunity and new integration challenges for DERs. Information and protocols will be critical to facilitate required coordination between distribution utility, market operator, aggregator, and DER technology.

DER interoperability is a hot topic. There are multiple categories of DERs. Each has its own set of manufacturers and providers, and each manufacturer offers multiple models. Given this variety and rapid adoption to meet clean energy targets, most systems today are not interoperable. However, customization of these interfaces would drain utility resources due to the large number of permutations. The right time to address this is now.

The key to interoperability is standardization. Today there are around 15 standards for communication interfaces with DERs and the data exchanged with them. Many of these standards are fairly new to the industry in comparison to legacy supervisory control and data acquisition (SCADA) protocols, and they are constantly evolving as DER capabilities, applications, and business models evolve. Tracking the standards' capabilities and progress in the industry can be overwhelming. Adding to the complexity, much of the information on these standards is not available on the internet but is instead gathered from participation in industry discussions.

To help you stay on top of this evolving landscape, EPRI's Information and Communication Technology for Distributed Energy Resources and Demand Response program (PS161D) developed the *DER Protocol Reference Guidebook*. The guidebook helps you achieve interoperability with DERs by describing DER information and protocol standards. Whether you are learning about them for the first time or want the latest updates, it has content tailored for you. It is designed to be your finger on the pulse of the ever-changing set of DER standards.



This free, public version of the *DER Protocol Reference Guidebook* does four things.

- Lists the standards included in the fifth edition
- Outlines the purpose and history of the guidebook
- Describes what the guidebook assesses and why
- Provides a peek at a protocol brief (historically only available to members)

The *fifth edition (2021) of EPRI's DER Protocol Reference Guidebook* includes the following information and protocol standards:

Application Focus	Standard Name	Technical Name
Demand Response	Modular Communications Interface for Energy Management	EcoPort (ANSI/ CTA-2045:2018)
	Open Automated Demand Response	OpenADR / IEC 62746-10-1:2018
DER Group Management	Standards for Information Exchanges Between Electrical Distribution Systems	IEC 61968-5:2020
	Standard for Smart Energy Profile Protocol	IEEE 2030.5-2018
Electric Vehicle	Open Charge Point Protocol	OCPP
	Road Vehicles – Vehicle to Grid Communication Interface	ISO/IEC-15118:2019
	Standard for Smart Energy Profile Protocol	IEEE 2030.5-2018
Energy Storage and Smart Inverters	Communication Protocols for Intelligent Electronic Devices at Electrical Substations	IEC 61850 Series and IEC 61850-7-420:2021
	DNP3 Profile for Communications with Distributed Energy Resources	IEEE P1815.2 (DNP3) and DNP AN2018-001
	SunSpec Modbus	SunSpec Modbus
	Standard for Smart Energy Profile Protocol	IEEE 2030.5-2018
	MESA-DER	MESA-DER
	MESA-Device	MESA-Device

Purpose of the Guidebook

EPRI initially developed the *DER Protocol Reference Guidebook* as a compilation of frequently asked questions (FAQ) about DER information and protocol standards to help inform member utilities about the protocols for managing DER and demand response technologies. It has expanded since then into a maturity assessment tool, guidebook, and planning tool that members and individual readers can apply based on their needs.

In 2019 EPRI published an EPRI Success Story that summarized how Kyle Cormier at Salt River Project (SRP) has used the guidebook to quickly convey information to different stakeholders within SRP. This has made conversations between the teams more productive because each team can come to the table more educated on the options for managing DER in its territory.

> "EPRI's Protocol Reference Guidebook is helpful in communicating and educating the various departments within SRP on the many different attributes of DER protocols. This information helps all stakeholders get on the same page to better define requirements and next steps for DER integration."
>
> **Kyle Cormier,** *Manager Engineering – Control Engineering*
> Salt River Project

Other members have used the guidebook to come up to speed on the current state of protocols, to keep tabs on recent developments in the DER standards domain, or to determine if there are any questions they may not have thought to ask. The guidebook is designed for information technology (IT) and operational technology (OT) audiences. It supports network and IT professionals with information about the protocols that may be used on their networks in the future. It supports OT professionals with overviews of the types of functionalities supported by these protocols, which are key to DER and demand response programs.

Coverage of the Guidebook

The methodology was created with the help of American Electric Power (AEP), Duke Energy, and SRP. EPRI, AEP, Duke, and SRP developed a list of common questions that industry stakeholders have about communications protocols and a framework to answer them. The guidebook is designed to be updated regularly to cover new protocols and capture any changes to protocols already evaluated. It answers questions including:

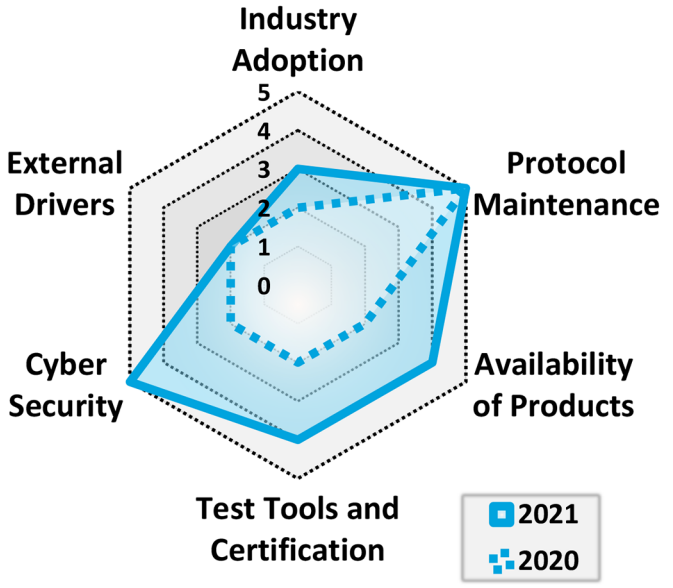
- What types of industry drivers are causing DER protocols to be adopted?
- What data models are used that could be leveraged in an abstraction layer?
- What certifications are available for different protocols to ensure conformity?
- What are the strengths of and opportunities for each protocol in the DER domain?
- What projects is EPRI working on in relation to each DER protocol?

To answer these questions, each brief covers five key areas: maturity models, architecture applicability, key recent developments, key event timelines, and supporting information.

Maturity Scores

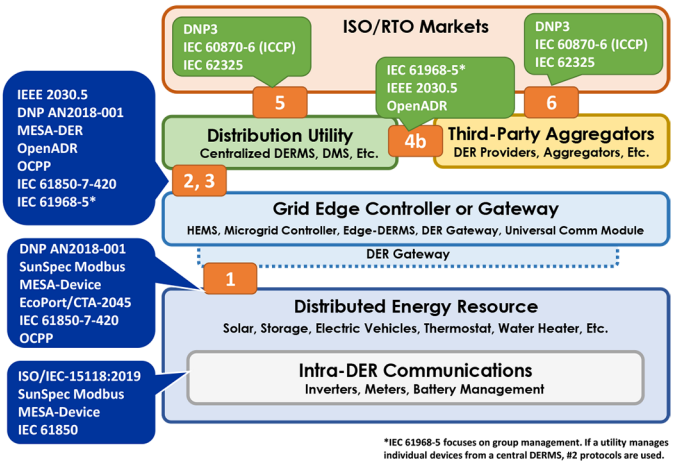
Adoption of information and protocol standards requires a robust support system. It requires organization support to maintain momentum and relevancy, tools to evaluate conformance, availability of products and technologies, and general industry interest in adopting and rallying behind the standards. Without these, the cost and risk of adoption increase. A key gap in the industry is a metric that provides a wholistic view of this ecosystem. To address this, EPRI developed an innovative maturity scoring process that evaluates six key metrics of a given standard

protocol and captures nuances in how scoring can vary by the type of DER. The metrics are industry adoption, protocol maintenance and support from industry organizations, availability of products on the market today, availability of test tools and certification processes, cyber security capabilities, and external drivers like grid codes or other mandates that can streamline adoption.



Architecture Applicability

Every protocol has a place within the greater control architecture. The architecture overview identifies where a protocol fits into the grid architecture. Protocols can be implemented at any level; however, various traits of the protocols make some better suited than others in given areas. These traits may include functionality captured in the associated data models, common use by the industry, grid code requirements and other industry mandates, and other factors. EPRI captures the applicability of each protocol on a generic model of a DER-centric grid architecture.

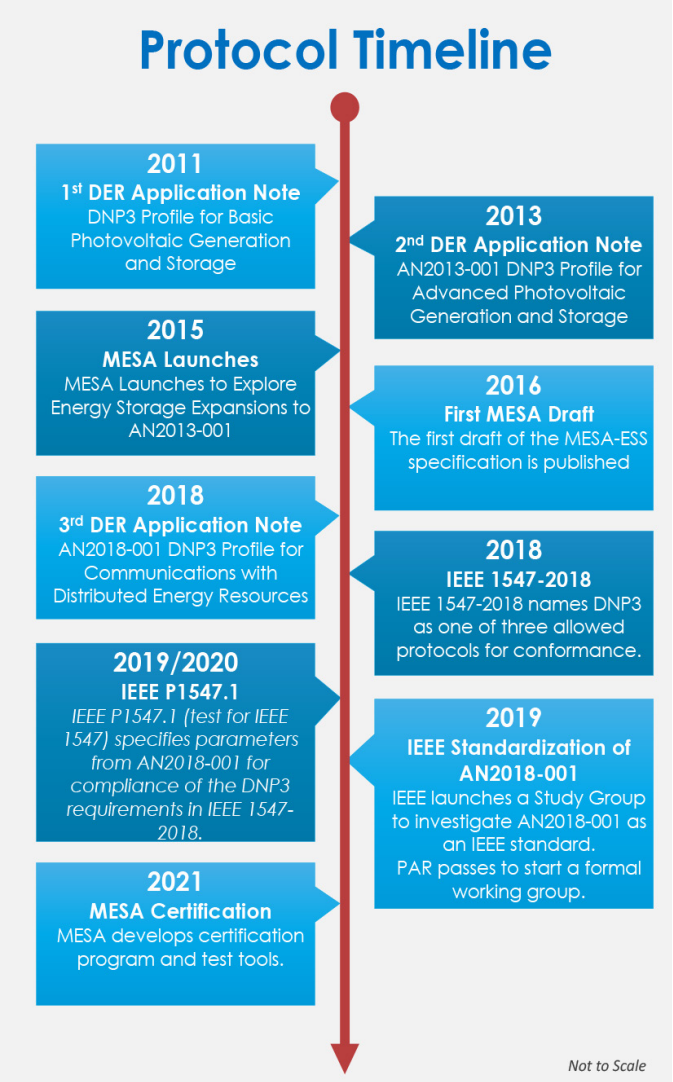


Key Recent Developments

The protocol landscape has been changing rapidly. In 2021 EPRI found that most of the protocols tracked had significant changes impacting their maturity scores. This is the first time this has happened in the five years EPRI has been publishing this guidebook. To help members keep up, a new section highlights notable changes since the previous revision.

Key Event Timelines

Information and protocol standards may not be widely adopted until years after they are conceived. To help capture this journey, EPRI includes a protocol timeline that highlights key milestones.



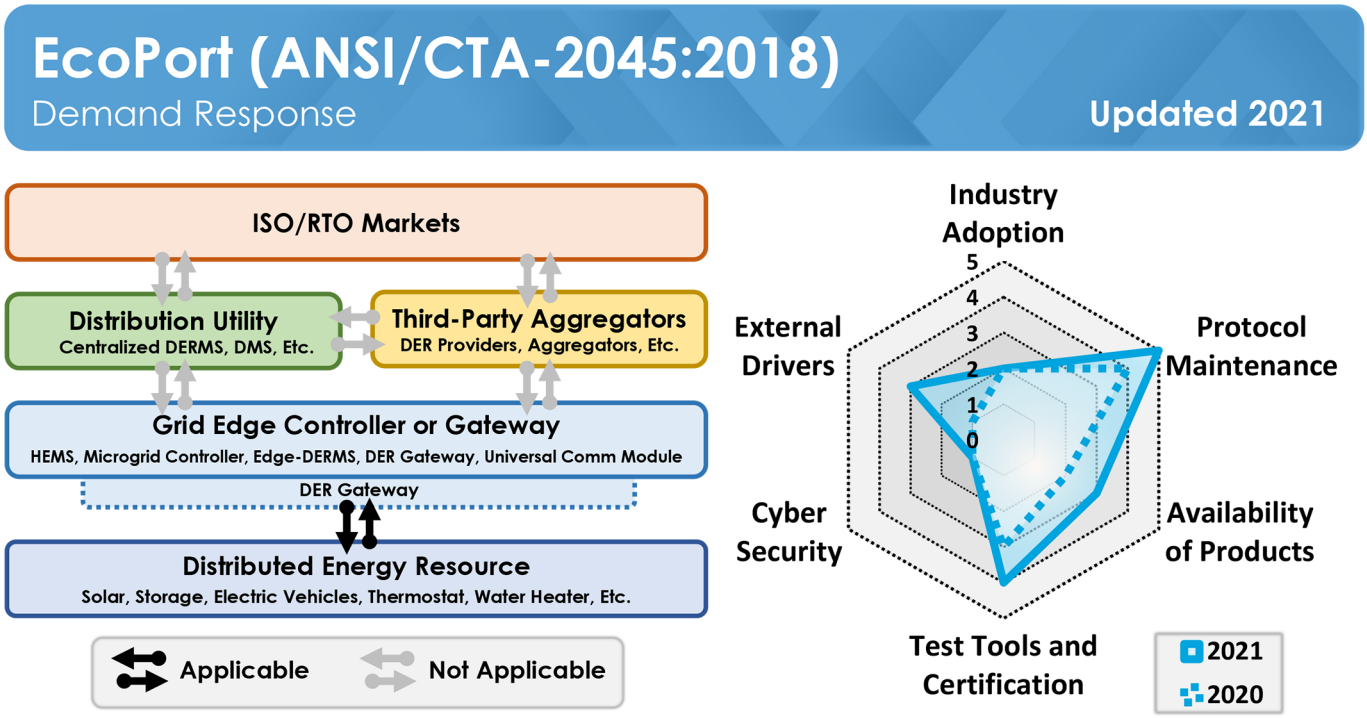
In-Depth Description

Scores and graphics are great for quickly absorbing information, however the details behind them are equally important. To address this, each brief includes two to three pages that explain maturity scores, architectural applicability, and other information in more detail. In addition to the components of the maturity score, this section covers relevant data and information standards, devices and technologies supported, implementation examples, relevant EPRI reports and tools, and other information.

Example Brief – EcoPort (ANSI/CTA-2045:2018)

Starting in 2009, EPRI and its member utilities sought to standardize information exchange at the device to reduce the implementation and operational costs associated with systems that use behind-the-meter resources to provide grid services. Research generated in earlier phases was donated to the Consumer Technology Association (CTA) and published in 2013 as ANSI/CTA-2045. Since then, the standard has been revised, utilities have demonstrated the technology in the field, and states are mandating its use in specific customer technologies.

The following brief covers the latest state of this rapidly expanding protocol.



NOTEWORTHY UPDATES IN 2021

- A new version of ANSI/CTA-2045 was released: ANSI/CTA-2045-B. This revision adds additional basic and intermediate commands to support ENERGY STAR® Program Requirements Product Specification for Residential Water Heaters and California Energy Commission Title 24 – 2019 Appendix JA-13.
- The number of products supporting EcoPort is rising due to external drivers, largely due to the requirements in Washington Law.
- Certification and test tools also increased. In 2021 the first independent ANSI/CTA-2045 certification was available to the industry through the OpenADR Alliance. Also, a third party, SkyCentrics, developed the first certification test tools under contract with the OpenADR Alliance. This first phase of certification focuses mostly on water heaters.

Overview of the Protocol

ANSI/CTA-2045 is a "modular communications port" standard that defines interface requirements for (1) the DER (typically load) and (2) a communication module to plug into and communicate with the resource.

Compared to other protocols designed to transport and exchange data between machines connected to a shared network, the ANSI/CTA-2045 focuses on information exchange between the module and the DER. The intent of the standard was to provide a means by which DER manufacturers could reduce the risk of embedding a network technology into their products that may change over the life of the product.

The module, referred to as a "Universal Communication Module" or UCM provides the means for networks to be bridged to the resources. It's important to note that the CTA-2045 standard does not specify or presume anything about this network. In practice, communication modules have been built to have bridged CTA-2045 resources to networks such as Wi-Fi, Cellular and AMI that transport application-layer protocols including OpenADR, DNP3, or a third-party specific protocol.

Officially called the "Modular Communications Interface for Energy Management", the CTA-2045 standard was first released in February 2013 by the Consumer Electronics Association (which has since become the "Consumer Technology Association"). It was created by a consortium of

stakeholders to provide a single, standardized interface for smart grid-enabled devices. Since connectivity for shared networks are implemented in the UCM, the device manufacturers need only design, manufacture, and distribute equipment with one standard communications capability, regardless of the network with which it will eventually be integrated. This is intended to protect buyers (and manufacturers) from obsolescence as new networks and protocols emerge and allows equipment to be switched between different programs and geographies merely by replacing the UCM. CTA-2045 defines two form factors to accommodate a large variety of communication protocols. For example, the AC form factor can support power line carrier and higher power communication technologies. A more compact socket and plug combination is used for lower-power RF networks.

Architecture Applicability

CTA-2045's physical connection to the DER allows it to the be a mechanism for entities upstream of a DER to communicate with the DER. The information models include detailed device information (load information, power levels, etc.) but also include higher-level grid controls to allow a site management system, owner, or utility to manage the system via abstract signals, including grid status and prices. The information models apply to the connection between the CTA-2045 UCM and the DER. Other protocols can be used between the UCM and the upstream entity.

CTA-2045 is not a networking protocol like IP, it is a machine-to-machine protocol. CTA-2045 only defines requirements of the form factor and communications between the module and the DER which are physically connected to each other.

RELEVANT EPRI REPORTS AND PROJECTS

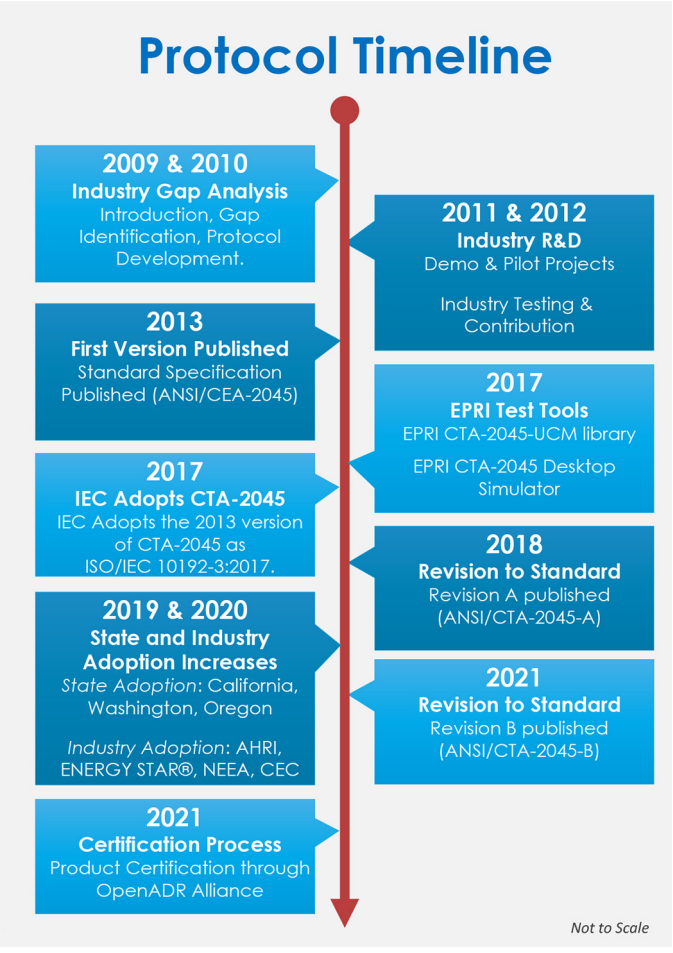
1. *Consumer Devices Functional Specification for Photovoltaic Support.* EPRI, Palo Alto, CA: 2018. 3002013875.
2. *Performance Test Results: CTA-2045 Water Heater: Testing Conducted at the National Renewable Energy Laboratory.* EPRI, Palo Alto, CA: 2017. 3002011760.
3. *Performance Test Results: CTA-2045 Solar Inverter: Testing Conducted at the National Renewable Energy Laboratory.* EPRI, Palo Alto, CA: 2017. 3002011748.
4. *CTA-2045 UCM C++ Library (LIBCEA2045 – OPEN), version 1.0.* EPRI, Palo Alto, CA: 2017. 3002009782.
5. *CTA-2045 Desktop Simulator User's Manual: Version 19.08.22.* EPRI, Palo Alto, CA: 2017. 3002009750.
6. *2016 CTA-2045 Summit Overview and Presentations.* EPRI, Palo Alto, CA: 2016. 3002008853.
7. *Overview of EPRI's Simulation Tool for Emulating Smart Water Heaters on Communication Networks: An Introduction to EPRI's Smart Water Heater Simulator.* EPRI, Palo Alto, CA: 2017. 3002009852.
8. *Mounting Importance of Communications to Monitor and Control Distributed Energy Resources.* EPRI, Palo Alto, CA: 2018. 3002013480.
9. *EPRI's Distributed Energy Resources Integration Testbed and Toolkit: An Overview of EPRI Test Tools for DER Integration.* EPRI, Palo Alto, CA: 2019. 3002016138.

Semantics and Data Models

The CTA-2045 standard defines message types and commands. This includes commands like shed, critical peak, grid emergency, end shed, relative price, time remaining in price period, customer override, sleep/wake, and operational state. The functional response for a device when it receives these commands is not strictly defined in the standard. For example, critical peak events are defined as events that are intended to only be used a few times per year, on a system peak day, for a maximum duration as determined by a program. Specifications like EPRI's device specifications like the ones created in EPRI's CTA-2045 demonstration projects and connected criteria like AHRI, EnergyStar, and CA Title 24 pair these message types and commands with predictable functional responses.

Adoption

Starting in 2019, the adoption of the ANSI/CTA-2045 standard has seen exponential growth across the industry. There has come new interest in increasing the visibility of the standard, and the OpenADR Alliance is taking the lead for promoting CTA-2045-related solutions. The industry is introducing to a new name for certified ANSI/CTA-2045-enabled devices – EcoPort.[1]



1 EcoPort. OpenADR Alliance. http://ecoport.openadr.org/

Governance and Maintenance

Overview of Governance: The standard is governed by Communications Technology Association (CTA), an ANSI-accredited standards development organization and the sponsors of the annual Consumer Electronics Show in Las Vegas. The standard is under the jurisdiction of Consumer Electronics Networking Committee for Energy Management Working Group 1 - Modular Communication Interface.

State of the Protocol: The most recent release of the core standard, ANSI/CTA-2045-B, published in February 2021, includes messages to comply with ENERGY STAR® and JA-13 (CEC); the new update offers an advanced Load Up and an intermediate price scheduling command. In addition, the new standard includes normative requirements for certification of CTA-2045 devices (Appendix F). Related protocols include ANSI/CTA-2045.2 ("Modular Communications Interface for Firmware Transfer Message Set") and ANSI/CTA-2045.3 ("Modular Communications Interface for Thermostat Message Set"). The emerging ANSI/CTA-2045.4 is expected to define how compliant modules will communicate with the outside world via TCP/IP, either locally through a HEMS or a third-party cloud. All the standards are available from CTA.[2]

Additionally, the Air Conditioning, Heating, & Refrigeration Institute is working on a new standard, AHRI 1430, intended to not only harmonize the connectivity and functionality of water heaters in demand response programs but also address the existing gaps. EPRI was initially involved in the development work but withdrew from the technical working group due to a request for a Non-Disclosure Agreement. EPRI, however, still holds a vote in the approval committee for AHRI 1430.

The IEC has also adopted CTA-2045 as ISO/IEC 10192-3:2017. The version of the standard is verbatim the 2013 version of the ANSI/CTA-2045 standard. The ISO/IEC 10192-3:2017 standard is maintained under the Joint Technical Committee ISO/IEC JTC1 of the International Organization of Standardization (ISO) and the International Electrotechnical Commission (IEC) in the Home Electronic Systems working group (WG 1). Similar to other ISO/IEC communication standards, updating 10192-3 would go their internal submission, review, vetting, and approval processes, and interoperating with 10192 would rely on subsequent IEC and/or ISO standards. There has been some conversation around updating the ISO/IEC 10192-3 to reflect the changes included in the new ANSI/CTA-2045-B standard. However, it is not yet clear whether the IEC would keep their copy of the standard or collaborate closely with the Consumer Technology Association, CTA, to address future changes and updates to 10192-3. EPRI research has identified the ISO/IEC 10192-3:2017 has been adopted internationally as it is one of the standards listed in the grid code of Vietnam.

Devices and Technologies

Applicable Device Types: The target for CTA-2045 is residential and light-commercial smart-grid resources. It supports a mixture of generic and device commands. Smart inverters are also supported by the standard through pass-through of the SunSpec Modbus protocol.

Availability of Products: The modular approach of CTA-2045 requires two components for the system to work; a UCM and the DER. These two may be supplied from the same vendor/manufacturer or supplied separately.

DER: Products started to become available in 2016. Some CTA-2045-equipped products are available in the market through big box stores. Others are available by request from manufacturers. Products including pool pumps, thermostats, electric vehicle supply equipment (EVSE), packaged terminal air conditioner (PTAC), water heaters (HPWH and resistive), and load switches are UL certified and available today. There are six manufacturers – some with significant market share in their industry – who support CTA-2045 in at least one of their models.

UCM: Communications models available today are supplied by three manufacturers. The communications technologies supported are Wi-Fi and FM RDS. Some vendors are looking to support cellular. Since the communication technologies are dependent on program requirements it is expected that more modules will be available in the market as more utility programs adopt CTA-2045.

Implementation

The standard defines the application-layer, link-layer, physical-layers (RS-485 or Serial Peripheral Interface SPI), electro-mechanical specifications of the connectors and the dimensions for developing and accommodating two different types of communication modules. A CTA-2045 implementation includes the physical/media access layers (the AC or DC form-factor interfaces), a data link layer that provides: link handling; ACK/NAK; error codes negotiation of speed, message length, and power; bit-error detection; and retires; and basic DR messages at the network and application layers. It also has the capability of passing unmodified messages from other network protocols (such as IEEE 2030.5, OpenADR, or IP) through to the device.

Example Application: A customer purchases a CTA-2045 enabled water heater. They contact their local utility to request being added to the utility's demand response program. The utility sends a UCM configured for their program to the customer. The customer plugs it into the water heater and configures it for their wireless network.

The utility communicates with the customer's water heater through an existing OpenADR server. Later the utility chooses to switch to a new server that uses different protocols (e.g. their AMI network). The utility procures new modules from a vendor and ships these to their customers. The customer changes out the existing OpenADR/Wi-Fi module on their water heater for the module supporting the AMI communications.

2 Consumer Technology Association. http://www.cta.tech

Test Tools and Certification

The first independent ANSI/CTA-2045 certification is available to the industry through the OpenADR Alliance. The certification of ANSI/CTA-2045 products will validate the implementation of both the UCM and SGD conform to either Level 1 or Level 2 as described in appendix F of the CTA-2045 technical standard. Two laboratories have already expressed interest in becoming test houses for this certification: Intertek and Underwriters Laboratories.

To brand a CTA-2045 product as EcoPort, the vendor must submit a declaration of conformity, a protocol implementation statement, and additional marketing-related information, then go through and pass the certification. All certified CTA-2045 devices will carry the "EcoPort" logo and be on the certified products web-listing page.

A third party, SkyCentrics, developed the first certification test tools under contract with the OpenADR Alliance, and the first phase of certification focuses mostly on water heaters.

EPRI has produced a general CTA-2045 software simulator, a water heater simulator, test cables, open-source implementations containing schematics and source code, and tools to aid in the development and test of ANSI/CTA-2045 products.

Cyber Security

CTA-2045 is not a network protocol like IP, it is a machine-to-machine protocol. CTA-2045 only defines requirements of the form factor and communications between the module and the DER which are physically connected to each other. Hence, there is no need for cyber security requirements.

External Drivers in Adoption

CTA-2045 is referenced in Northwest Energy Efficiency Alliance (NEEA) heat pump water heater specifications, the Consortium for Energy Efficiency (CEE) pool pump and water heater initiatives, and the Air-Conditioning, Heating, and Refrigeration Institute: AHRI-1380 standard, among other entities.

The following table includes links to state laws, standards, building codes and specifications that depend on this standard.

Protocol Maturity

Industry adoption is low for device-level open protocols in the DR space, so this is typical. CTA-2045 is supported by a few products. There are CTA-2045 adapters to allow the protocol to be used with smart-grid devices. The inclusion of CTA-2045 in AHRI-1380 (variable-capacity heat pumps), AHRI-1430 (electric water heaters), NEEA specifications (heat pump water heaters), CEE initiatives (water heaters, pool pumps), Washington HB 1444 - 2019-20 (water heaters), Oregon HB 2062 (electric storage and heat pump water heaters) and Energy Star (water heaters), as well as the requirements for certification of CTA-2045 devices, will more likely industry adoption in the upcoming years.

Entity/Source	Title
Northwest Energy Efficiency Alliance	Advanced Water Heater Specification
Consortium of Energy Efficiency	CEE Residential Water Heating Specification
Air-Conditioning, Heating, and Refrigeration Institute	AHRI 1380 (I-P) Demand Response through Variable Capacity HVAC Systems in Residential and Small Commercial Applications AHRI 1430 Standard for Demand Response for Electric Water Heaters
Environmental Protection Agency's ENERGY STAR® Program	ENERGY STAR® Program Requirements Product Specification for Residential Water Heaters Eligibility Criteria Version 3.3 Draft 2
Oregon State	House Bill 2062 – 2021 Appliance Energy Efficiency Stds
Washington State	House Bill 2062 – 2021 Appliance Energy Efficiency Stds
California Energy Commission	Appendix JA13 Qualification Requirements for Heat Pump Water Heater Demand Management Systems Express Terms, 2022 Energy Code, Title 24 Parts 1 and 6

Free Vs. Member-Only Version

Information and communications technologies will be critical for the success of utility grid modernization efforts and clean energy targets due to the degree of coordination required between distribution utility, market operator, aggregator, and DER technology. As the industry orients to support utility clean energy targets, information about relevant standards and their maturity is important to inform decision making by utilities, manufacturers, solution providers, and regulators. To help inform the industry about these key metrics, EPRI is publishing a free, public summary of relevant research results. This version includes an overview of EPRI's assessment framework and an example brief. The full version of the EPRI Protocol Reference Guidebook will continue to be available only to members of EPRI's Information and Communication Technology for Distributed Energy Resources and Demand Response program (PS161D).

Did you find this version of the *DER Protocol Reference Guidebook* helpful? If so, there are a few ways you can get more engaged:

- Join EPRI's PS161D program to get access to the full version.
- Sign up for training through EPRI|U.
- Host EPRI for an on-site or virtual workshop for you and your team.

A PART OF A PAIR: THE *DER INTEROPERABILITY GUIDEBOOK*

EPRI's Information and Communication Technology for DER program publishes two guidebooks. The *DER Protocol Reference Guidebook* provides a high-level summary of information and protocol standards. The second, the *Distributed Energy Resources Interoperability Guidebook*, goes deeper and provides information about achieving interoperability and cost-effectiveness in DER and demand response programs. The guidebook leverages 10-plus years of work in developing and applying standards. Sections include:

- The Four Key Attributes of DER Interoperability
- Streamlining Interoperability Requirements Using Profiles and Grid Connected Criteria
- Validating Conformance: Test Tools and Certification Programs
- Other DER Standards (e.g., Orange Button)
- Example Communication Architectures
- Cloud-Based Architecture to Support Demand Response Programs
- Integrating with Third-Party Aggregators
- Common Interoperability Failures
- Network Connectivity for DERs

About EPRI

Founded in 1972, EPRI is the world's preeminent independent, non-profit energy research and development organization, with offices around the world. EPRI's trusted experts collaborate with more than 450 companies in 45 countries, driving innovation to ensure the public has clean, safe, reliable, affordable, and equitable access to electricity across the globe. Together, we are shaping the future of energy.

Contact

Did you find the *DER Protocol Reference Guidebook* helpful?

Ben Ealey, *Manager, Info and Comm Tech for DER Integration*
bealey@epri.com

3002023419 March 2022

EPRI
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