CALIFORNIA
ENERGY COMMISSION

Energy Research and Development Division

FINAL PROJECT REPORT

Enhancing Grid Resiliency through Improving Capabilities to Manage Communicating Energy Storage and Solar Systems

Expanding Standards and Developing Tools to Enable DNP3 Support of Storage Use Cases

Gavin Newsom, Governor
June 2020 | CEC-500-2020-037

PREPARED BY:

Primary Authors:
Ben Ealey (Electric Power Research Institute)
Girish Ghatikar (Electric Power Research Institute)
Frances Cleveland (Xanthus Consulting)
Bob Fox (SunSpec Alliance)
Tom Tansy (SunSpec Alliance)

Electric Power Research Institute (EPRI)
3420 Hillview Avenue
Palo Alto, CA 94304
www.epri.com

Contract Number: EPC-15-089

PREPARED FOR:
California Energy Commission

Bryan Lee
Project Manager

Fernando Piña
Office Manager
ENERGY SYSTEMS RESEARCH OFFICE

Laurie ten Hope
Deputy Director
ENERGY RESEARCH AND DEVELOPMENT DIVISION

Drew Bohan
Executive Director

ACKNOWLEDGEMENTS

Project Team

- Electric Power Research Institute
    - Ben Ealey
    - Jithendar Anandan
    - Girish Ghatikar
    - Ben Kaun
    - Andres Cortes
    - Peggy Ip
- Enernex
    - Kay Stefferud
    - Grant Gilchrist
- MESA Standards Alliance
    - Darcy Wheeles
    - Margot Molloy
- SunSpec Alliance
    - Tom Tansy
    - Bob Fox
- Xanthus Consulting International
    - Frances Cleveland

Technical Advisory Committee (TAC)

- Andrew Miller – Doosan GridTech
- David Kaplan – Doosan GridTech
- Deepak Aswani – SMUD, Sacramento Municipal Utility District
- Eric Anderson – PG&E, Pacific Gas and Electric
- Glenn Skutt – PowerHub
- Jeff Kwan – CPUC, California Public Utilities Commission
- John Holmes – University of California San Diego
- Jorge Araiza – SCE, Southern California Edison
- Md Arifujjaman – SCE, Southern California Edison

Technical Contributions to the Distributed Network Protocol (DNP3) Application Note

- Doosan GridTech, SunSpec Alliance Members, MESA Standards Alliance Members, DNP Users Group, EPRI Members, and Members of the Open Collaborative Working Group

PREFACE

The California Energy Commission's (CEC) Energy Research and Development Division supports energy research and development programs to spur innovation in energy efficiency, renewable energy and advanced clean generation, energy-related environmental protection, energy transmission and distribution and transportation.

In 2012, the Electric Program Investment Charge (EPIC) was established by the California Public Utilities Commission to fund public investments in research to create and advance new energy solutions, foster regional innovation and bring ideas from the lab to the marketplace. The CEC and the state's three largest investor-owned utilities—Pacific Gas and Electric Company, San Diego Gas & Electric Company and Southern California Edison Company—were selected to administer the EPIC funds and advance novel technologies, tools, and strategies that provide benefits to their electric ratepayers.

The CEC is committed to ensuring public participation in its research and development programs that promote greater reliability, lower costs, and increase safety for the California electric ratepayer and include:

- Providing societal benefits.
- Reducing greenhouse gas emission in the electricity sector at the lowest possible cost.
- Supporting California's loading order to meet energy needs first with energy efficiency and demand response, next with renewable energy (distributed generation and utility scale), and finally with clean, conventional electricity supply.
- Supporting low-emission vehicles and transportation.
- Providing economic development.
- Using ratepayer funds efficiently.

Enhancing Grid Resiliency through Improving Capabilities to Manage Communicating Energy Storage and Solar Systems is the final report for the Expanding Standards and Developing Tools to Enable DNP3 Support of Storage Use Cases project (Contract Number EPC-15-089) conducted by the Electric Power Research Institute. The information from this project contributes to the Energy Research and Development Division's EPIC Program.

For more information about the Energy Research and Development Division, please visit the CEC's research website (www.energy.ca.gov/research/) or contact the CEC at 916-327-1551.

ABSTRACT

Design and implementation of interoperable communications between distributed energy resources and other grid systems support flexible, integrated, reliable, and renewable grid operations. This project updated current communications standards to meet distributed energy resource monitoring and control requirements in California Rule 21 and Institute of Electrical and Electronics Engineers' 1547-2018 and other industry needs, and developed tools to accelerate adoption of distributed energy resources.

As the grid integrates more distributed energy resources, communications standards become essential to ensure that utilities and the public can maximize the operational functionality and financial value of distributed and traditional grid assets. Significant work to date has addressed communication standards for inverter-based distributed energy resource systems in general, but interoperable communication standards to support large-scale energy storage is still in development. When this project started, communication standards were based on earlier global efforts to define standard functionality for smart inverters. However, the primary focus of early-stage communication standards by manufacturers and in evaluations of field demonstrations were on solar systems with limited storage system use. These solar profiles include energy storage device- and system-level functionality needing further expansion and refinement to support energy storage.

This project improves the ability of grid operators to communicate with distributed energy resources and enhances the use and value of energy storage and solar generation. The results of this project provide four key benefits:

1. Maximize the use of solar and energy storage to benefit ratepayers and the grid.
2. Update existing industry documents to incorporate these new opportunities and meet requirements defined in grid specifications including California Rule 21 and IEEE Standard 1547-2018™
3. Create open source tools to support manufacturers and industry stakeholders to implement the updated industry documents quickly and correctly.
4. Develop a framework for conformance testing to confirm that devices meet standards and requirements through testing and validation.

Keywords: grid interoperability, grid resiliency, energy storage systems, solar photovoltaic, California Rule 21, open source software, conformance testing

Please use the following citation for this report:

Ealey, Ben, Girish Ghatikar, Frances Cleveland, Bob Fox, and Tom Tansy. 2019. *Enhancing Grid Resiliency through Improving Capabilities to Manage Communicating Energy Storage and Solar Systems*. California Energy Commission. Publication Number: CEC-500-2020-037.

TABLE OF CONTENTS

Page

LIST OF FIGURES

Page

LIST OF TABLES

EXECUTIVE SUMMARY

Introduction

Utilities worldwide are challenged by the technical and business decisions to embrace distributed energy resources (DER) as a key part to support a flexible, reliable, integrated, and renewable electricity grid. DER technologies include demand response of controllable loads, distributed generation, energy storage, and electric vehicles. Design and implementation of 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 required to support a reliable and secure grid including dynamic monitoring and control of diverse DER system analytics to improve efficiency and effectiveness; and optimized dispatch of DER to improve use. Therefore, utilities, regulators, industry, and trade organizations are planning to add communications requirements in their specifications, mandates, and proposal criteria that support their short-term and long-term grid planning and operation, policy, and business needs. However, for this to be effective the standards must support the capabilities of those systems so their benefit can be fully realized.

The California's Electric Rule 21 tariff (Rule 21) mandates that electricity generating DER technologies (such as solar photovoltaic [PV] and energy storage systems) follow interconnection, operating, and metering requirements for safe and reliable operation of a distribution grid. Significant work to date has addressed communication standards for "smart inverter" based DER systems in general, but communication standards to support large-scale energy storage systems are still in their infancy. Current standards and protocols are based on earlier global efforts to define standard functionality for smart inverters. This includes standards and protocols like Institute of Electronic and Electrical Engineers (IEEE) 2030.5, IEEE 1815, SunSpec Modbus, and various International Electrical Commission (IEC)-61850 standards. However, the primary focus of early-stage implementation of communication standards and protocols by manufacturers and in evaluations of field demonstrations have, so far, been on solar PV systems. While these solar PV profiles include energy storage interconnection and communication functionality, there is a need to expand and refine how capabilities for energy storage is captured in these standards.

Project Purpose

This project improves the ability of grid operators to communicate with DER and enhance use and value of energy storage and solar PV generation connected to smart inverters. The research team addressed the critical gap in Supervisory Control and Data Acquisition systems used by utilities and other facilities to control and monitor power system equipment communications by enhancing the existing standards and protocols and developing the infrastructure to accelerate product development, certification and testing, compliance and interoperability, and field use. The team built on industry and research efforts and accelerated the dialogue and support for open communication with energy storage systems. This project focused on Distributed Network Protocol 3 for smart inverters; a standard used to communicate with large, distribution-system connected energy storage systems and other distribution assets. The project focused on the Distributed Network Protocol 3 standard protocol since it is well integrated into utility grid management systems and supported by the industry. The Distributed Network Protocol 3 standard is applicable for grid-assets such as distribution feeders and for complex utility-managed grid systems such as sub-station and supervisory control and data acquisition. The California Independent System Operators uses Distributed Network Protocol 3 for telemetry of the bulk electricity generators. Other communication standards are relevant for DER integration and the choice or co-existence can be implementation-specific.

Project Approach

The project followed a four-step process carried out by the appropriate project team members as described in Table ES-1.

Table ES-1: Project Team Members Technical Tasks

Team Member	Task
EPRI, MESA, SunSpec, Xanthus	Develop open advisory group, manage recurring stakeholder meetings. Develop a comprehensive set of use cases for energy storage, identify and address gaps in the standard functions and associated protocols.
EPRI, MESA, SunSpec, Xanthus, Enernex	Expand the Distributed Network Protocol 3 DER specifications to fill these gaps. Publish and support a single Distributed Network Protocol 3 application note that addresses these gaps.
EPRI and Enernex	Implement all aspects of the energy-storage methods and protocols in an open Distributed Network Protocol 3 client software, including cyber security requirements. Demonstrate end-to-end functionality in a lab setting.
SunSpec and EPRI	Develop Distributed Network Protocol 3 process logic needed to drive client testing. Develop Protocol Information Conformance Statement and perform conformance testing of the open Distributed Network Protocol 3 DER specifications client.

Source: EPRI

1. Identify and Develop Requirements: The team created an open, collaborative working group (110 expert volunteers from 83 companies) to perform a gap analysis between the capabilities of solar PV and energy storage and functionality supported in current communications standards. The purpose was to find opportunities that can help the industry realize the full set of benefits from solar and storage systems.
2. Transfer and Apply the Results: The team worked with the DNP Users Group to apply the lessons learned and publish an update to the existing application note defining how to use Distributed Network Protocol 3 with energy storage and solar PV systems. The purpose was to add support for the most advanced energy storage use cases. The team also shared the lessons learned with other communication standards so that they could benefit from the findings.
3. Develop Open Source Tools: The team developed open-source Distributed Network Protocol 3 software to simplify product development for manufacturers or other industry stakeholders and accelerate adoption of the updated standard.

4. Develop and Transfer Conformance Framework: The team developed a framework for conformance testing to validate interoperability. It includes (1) the Distributed Network Protocol 3 process logic which defines the test procedure and pass/fail criteria, (2) the protocol information conformance statement which lists which parameters are supported or unsupported by the product under test to inform which tests need be performed on the distributed energy resource, and (3) programming existing test software to automate testing and validation of pass/fail criteria.

The project team was selected because of each of the member's key position in the industry and the large variety of industry stakeholders they represent. Each team member also had a vested interest in the successful application of results in the project due to the parallel nature of the project results to their DER deployment plans.

In addition, a technical advisory committee was formed to guide the effort. The group consisted of utilities, manufacturers, and industry leaders who met throughout the project to increase the value and usability of the outputs. The Open Collaborative Working Group was also created to contribute to the work products throughout the project so that the results represented the various stakeholder groups in the industry. Some members of the technical advisory committee were also in the working group.

Project Findings

The core project findings, which are linked to the goals, are in three areas.

The gap analysis identified six key capabilities in smart inverters for DER that were lacking in current industry standards. This includes frequency/watt, watt/volt-ampere reactive (VAR), connect/disconnect + cease to energize, peak power limiting/load following/generation following, constant VAR mode, and scheduling capabilities. The analysis also highlighted issues in harmonization of terminology and functional descriptions across the solar and energy storage domains. The team addressed these issues by adding more robust state of charge language; supporting for referencing meters in the field; harmonizing between previously confusing overlaps in different state, status, and monitoring data points; and harmonizing functional descriptions across different industry stakeholders and grid codes.

The project filled the key gaps in the existing standards for control of solar and storage systems The updates include expanding the functionality needed for maximizing the value of storage systems, bringing the standard up to date with smart inverter functionality, and conforming with requirements in grid codes including all phases of California Rule 21 and the 2018 update to IEEE 1547. It built on earlier versions of smart inverter-based Distributed Network Protocol 3 profiles including DNP Application Note AN2011-001, DNP Application Note AN2013-001, and the MESA Standards Alliance's November 2016 MESA-ESS specification. The team supported industry acceptance of the new standard informed IEEE working groups of its capabilities. This led to it referenced in IEEE 1547-2018 (standard referenced in U.S. grid codes) as the requirement for using Distributed Network Protocol 3 in DERs. It is listed alongside SunSpec Modbus and IEEE 2030.5, as one of the three communication protocols per IEEE 1547-2018.

The team supported the accelerated adoption of the new standard through the open source Distributed Network Protocol 3 outstation and framework for conformance testing. The outstation is published open source (BSD-3 Clause) and is available from the Electric Power Research Institute's GitHub page. It is designed to absorb the complexities of the new standard, simplifies software development, and accelerates adoption of the new standard by providing example code for implementing smart inverter functionality following DNP Application Note AN2018-001. The Framework for Conformance Testing is a written document that provides the steps needed to validate interoperability with the new standard. The framework includes thirty-one test cases, associated pass/fail criteria, and software to automate and hasten testing.

Technology and Knowledge Transfer for Market Adoption (Advancing the Research to Market)

Technology transfer played a significant role in this project. The goals of this project require outreach to the industry ranging from collecting information when identifying gaps, discussing with manufacturers to understand characteristics of open source software that helps them apply it, and sharing what has been accomplished so it can be applied. The essential point is that the work in this project must be applied to be useful and without strong technology and knowledge transfer efforts, this is unlikely to occur.

- Conferences and Meetings: The project team presented at conferences and meetings to collect information to inform next steps in the project while sharing accomplishments. This ranged from workshop presentations, poster sessions, and face-to-face discussions. Examples include the Electric Power Research Institute's Member Advisory Meetings (2017-2019 – North American, Asia, Europe), Electric Power Research Institute Energy Storage Integration Council Meetings (2017-2019), Energy Storage Association STUDIO Conference (2017), an Energy Storage Association Workshop (2016), and Gridvolution Event Platform, and the DER Communication Protocols and California Rule 21 Executive Training. These meetings were an opportunity to make stakeholders aware of the work and collect feedback on the work completed.
- Webinars: Throughout the project, webinars provided the project team with a way of sharing information with interested parties. Webinars are often ideal because they provide information to the industry without requiring travel. Webinars included member webcasts with the Electric Power Research Institute, SunSpec, and MESA members.
- Press Releases/Social Media: The Electric Power Research Institute and the project team issued press releases and social media posts on key milestones to alert the industry and media outlets. A press release was issued when the new standard was published. LinkedIn posts were used throughout the project to alert the team's network about milestones in the project. Greentech Media also wrote an article on the work on the new standard.
- Working Groups/User Groups: Working groups and user groups are a common mechanism for tackling industry-wide problems. This project engaged working groups including IEEE 1547-2018, IEC-61850, the Electric Power Research Institute's Energy Storage Integration Council, Distributed Network Protocol Users Group, and working groups behind trade organizations like SunSpec Alliance and MESA Standards Alliance. These working groups develop industry standards that are referenced in today's grid codes and laws.

Benefits to California

This project updated current communications protocols to meet the DER interconnection requirements and other needs of the industry. The project benefits to California is greater use and integration of energy storage systems that will increase grid flexibility, better integration of renewable generation, and improve electricity reliability. Improved flexibility will benefit the utility's infrastructure, operations, and energy security, which ultimately can benefit ratepayers as lower costs.

Quantifying benefits to California ratepayers is difficult because of the many use-cases for integrated energy storage. However, estimates show a benefit-heavy cost-to-benefit ratio. Benefits are estimated at $5.8 million: $1 million for using standardized communications standards reducing the cost of designing new interfaces typical when using proprietary communications, $3 million from certification decreasing the investor-owned utilities cost to integrate new energy storage products, and $1.18 million from manufacturers leveraging the open-client in their products. This project had a total budget of $1,234,344 or $873,516 of Electric Program Investment Charge (EPIC) funds. This project produced benefits totaling over five times the total cost of the project (EPIC funds plus cost share).

Standardized Communications

The advanced features needed for some of the energy storage use cases may only be realized today by using proprietary systems. This requires expensive, one-off software development costs, on-going maintenance problems as systems are upgraded, and a potential for vendor lock-in. Further expanding the Distributed Network Protocol 3 to support the most advanced inverter functions will allow the investor-owned utilities to use their existing Distributed Network Protocol 3 systems to manage energy storage systems directly, and if Distributed Network Protocol 3's cyber security is implemented, to ensure secure interactions. This has the potential to save millions in integration costs and avoids possible costly attacks. To simplify the cost benefit calculation a conservative estimate of $1,000,000 in benefits is used.

Certification

The second benefit is from the certification tool for the Distributed Network Protocol 3 specifications. The development of the certification tool will help reduce the number of products that reach the market and do not comply with the current specifications. Often standards can be implemented differently depending on whether the developer misreads the standard or a portion of the standard was vague. The certification tool will reduce the risk of these mistakes making it to production by providing manufacturers a tool to validate their work. It will also provide the investor-owned utilities a tool to test new products to ensure compliance and, therefore, work on their system. This increased certainty has direct financial benefit. Considering the investor owned utilities are targeting 1.325 gigawatts (GW) of energy storage procurement by 2020 and assuming an average cost of procured energy storage projects is $2,000 per kilowatt then the 1.325 GW of additional energy storage will cost California $2.65 billion. Often administrative costs of these programs can be as high as 20 percent, or $530 million in this example. These costs can include conformance testing and measurement and verification to ensure the product will provide the benefits expected. Assuming that certification is able to shave one percent from the administrative costs, a conservative estimate, the savings is $3 million. This savings is more than five times the cost of this project. Utilities will be able to include certification as one of their requirements for participation in the procurement programs.

Leverage of Open Source Tools

A third benefit is the decreased cost to include the open, Distributed Network Protocol 3 specifications in products including solar, energy storage, and electric transportation by offering an open-source client. The initial benefit will be realized by manufacturers. The team is proposing more than $118,000 in work to develop an open-source Distributed Network Protocol 3 client to support the advanced inverter specifications. This will produce a block of software that companies can directly integrate into their existing software to create a pre-certified, Distributed Network Protocol 3 enabled product. The secondary impact of this will be an increase in the number of products available that support the Distributed Network Protocol 3 client because the hard work of developing the client has been completed. This will reduce the time spent testing and troubleshooting communication issues by essentially making the devices "plug-and-play". Assuming 25 manufacturers use this tool, the $118,000 spent to develop this tool will have been leveraged 25 times. It can be assumed that manufacturers will spend at least this much per project developing their own code. At 25 manufacturers this is a benefit of $1.18 million. In addition to this, the Electric Power Research Institute and SunSpec have spent hundreds of thousands of dollars developing the expertise to make certification and open-clients a success. This project will leverage their investment.

Specific benefits of this project include:

- The potential to lower overall installation and integration costs of energy storage systems to ratepayers and aid the efficiency, safety, security and resiliency of the grid by using standardized communications and efficient validation of DER interconnections.
- Energy storage, as a flexible resource to support grid reliability by adding or consuming energy on the electric grid on demand. This project expands the capability of utilities to control energy storage systems, which provides opportunities to maximize flexibility and benefits. Examples of increased flexibility include participation of energy storage systems in frequency support, peak load reduction, frequency and voltage anomaly ride-through, conservation voltage reduction, and alleviating distribution feeder overloads.
- Safety benefits from energy storage systems by validating standardized cyber-security features for communications. This can build confidence among the consumers to use DER assets for grid stability and to increase resource flexibility.
- Open-source tools are often associated with economic development because they provide collaboration in innovation. This will save companies money and make it easier for new companies to compete in this field. This can increase the number of products on the market and lead to cheaper products through an increase in innovation and competition in the market.
- Environmental benefits from the advanced use cases for energy storage that help reduce peaks and minimize the need for traditional generators to provide support at peak times.

Recommendations and Next Steps

- This project updated interoperability standards and created tools to help industry adopt it. It is now up to the industry to adopt these standards. Utilities should also consider them when designing new DER to take advantage of the benefits. Public utility commissions must decide whether they want to mandate these standards and if they want to create their own requirements or reference existing language in interconnection documents like California's Rule 21 or IEEE 1547-2018.
- Standards must be updated and revised periodically to the changing technology landscape and the needs of the industry. The industry must continue evaluating smart inverter capabilities, smart inverter applications, and field experiences to inform the next round of standards.
- As standards continue to be improved, working groups should be mindful and work to minimize changes that may prevent backwards compatibility. If not considered it can cause fragmentation in standards requiring that utilities and manufacturers support legacy versions of protocols to avoid losing resources already installed in the field, a costly effort. Updates to the standards must keep the backward compatibility requirement in mind and make technical and economic assessments before determining any alternate case.
- Companies must take on operating certification businesses in this domain and continue the work of projects like this one that are designed to give those processes a forward pathway. The industry must find applications for certifications to encourage manufacturers to complete certification. The certification programs must be maintained and improved over time by member-facing organizations such as SunSpec Alliance and Institute of Electrical and Electronics Engineers.
- Conformance testing has mostly focused on the ability of information exchange among systems. While there are conformance tests available to test device behavior, there are no conformance programs that define testing from origination of the signal to the resulting electrical response from the device. This will be a key for achieving grid interoperability. The new tests in IEEE P1547.1 start to address this but more work will be needed to apply this new testing paradigm and refine it over time.

CHAPTER 1: Introduction

Utilities worldwide are challenged by the technical and business decisions to embrace distributed energy resources (DER), as a key part to support a flexible, reliable, integrated, and renewable grid. The DER technologies in reference include demand response of controllable loads, distributed generation, energy storage, and electric vehicles. 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 support a reliable and secure grid including dynamic monitoring and control of diverse DER,[1,2,3] system analytics to improve efficiency and effectiveness; and optimized dispatch of DER to improve use.[4,5]

Electric utilities worldwide are looking at methods to operate the distribution system more effectively in alignment with the increase of DER technologies such as distributed solar photovoltaic (PV), energy storage, and controllable loads for demand response. These methods include embracing direct, non-proprietary access across a variety of vendor makes and models of DER; optimizing the dispatch of DER through advanced distribution grid management systems including distributed energy resourced management systems (DERMS) and advanced distribution management systems (ADMS); and enabling data analytics for grid modeling to unlock new undiscovered use cases. Though these future states are long-term goals, there are utility projects and vendors across the world looking to make these systems a reality through pilots and demonstrations. Under this not-so-distant future state is a communications backbone that supports standardized and direct access to DER devices and grid systems and allows access to the DER over the long-term use of the system. In response to these challenges; utilities, regulators, industry, and trade organizations are adding communications requirements in their specifications, mandates, and proposal criteria that support their short-term and long-term grid planning and operation, policy, and business

---

[1] "Direct Access" relates to where in the communication pathway an open, standard interface exists at the device.

[2] The Value of Direct Access to Connected Devices. EPRI, Palo Alto, CA: 2017. 3002007825.

[3] *What the Duck Curve Tells Us About Managing a Green Grid*. California Independent System Operator.https://www.caiso.com/Documents/FlexibleResourcesHelpRenewables_FastFacts.pdf. Accessed March 2019.

[4] Advanced Inverter Functions to Support High Levels of Distributed Solar. National Renewable Energy Laboratory, November 2014. https://www.nrel.gov/docs/fy15osti/62612.pdf. Accessed March 2019.

[5] VDE, Power Generating Plants in the Low Voltage Grid will Remain On-Grid Even in a Fault Scenario (E VDE-AR-N 4105), https://www.vde.com/en/fnn/topics/technical-connection-rules/power-generating-plants. Accessed March 2019

needs. However, for this to be effective the standards must support the capabilities of those systems so their benefit can be fully realized.

As the grid integrates more DER, communications standards become essential for ensuring that utilities and the public can maximize the operational functionality and financial value of distributed and traditional grid assets. Traditional approaches have been to set operating parameters of these systems and leave them in that mode. In the rare case the parameters need to be changed, utilities or site owners can revisit the site. However, there are cases for example in Germany and California[6] where the high penetration of solar PV has led to issues on the grid.[7] There are options to prevent these issues in a cost-effective manner. One such method is to develop communications capabilities in DER to allow for them to be monitored and their operating modes to be dynamically changed to meet the changing grid conditions. This has been the premise behind the recent standardization efforts across the world including California Energy Commission Rule 21, IEEE™ 1547-2018, European Commission Mandates and EN-50549, and Germany's VDE-AR-N 4105.[8]

Significant work to date has addressed communication standards for "smart inverter" based distributed energy resource (DER) systems in general, but communication standards to support large-scale energy storage systems are still in their infancy. The California's Electric Rule 21 tariff (Rule 21) mandates that electricity generating DER technologies (such as solar PV, energy storage systems) to follow interconnection, operating, and metering requirements for safe and reliable operation of a distribution grid.

Current standards and protocols are based on earlier global efforts to define standard functionality for smart inverters. This includes standards and protocols like IEEE's 2030.5, IEEE 1815 (Distributed Network Protocol 3 or DNP3), SunSpec Modbus, and various IEC-61850 standards. However, the primary focus of early-stage implementation of communication standards and protocols by manufacturers and in evaluations of field demonstrations have, so far, been on solar photovoltaic (PV) systems. While these solar PV profiles include energy storage interconnection and communication functionality, there is a need to expand and refine the function set with energy storage in mind.

Distributed energy resources (DERs) are expected to provide a significant portion of the 60 percent renewables by 2030, as outlined in the Senate Bill 100 (De Leon, Chapter 312, Statutes of 2018) in California.[9] Most of these energy services require communications

---

6 *What the Duck Curve Tells Us About Managing a Green Grid*. California Independent System Operator.https://www.caiso.com/Documents/FlexibleResourcesHelpRenewables_FastFacts.pdf. Accessed March 2019.

7 Advanced Inverter Functions to Support High Levels of Distributed Solar. National Renewable Energy Laboratory, November 2014. https://www.nrel.gov/docs/fy15osti/62612.pdf. Accessed March 2019.

8 VDE, Power Generating Plants in the Low Voltage Grid will Remain On-Grid Even in a Fault Scenario (E VDE-AR-N 4105), https://www.vde.com/en/fnn/topics/technical-connection-rules/power-generating-plants. Accessed March 2019

9 California Legislative Information, "Senate Bill No. 100," September 2018, http://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201720180SB100. Accessed March 2019

between the utility and the DER systems. In California, those communications capabilities are expected to be mandatory thorough the Rule 21 tariff.

Communications between utilities and DER systems can either be direct or go through third-party services such as aggregators, and facility energy management systems. For direct DER communications, California utilities, like most utilities in North America, expect to use the IEEE 1815 (DNP3) SCADA standard. Although DNP3 is a well-respected and deployed protocol, it does not include its own information model. Therefore, for advanced “smart inverter” functionality, standardized mappings (profiles) are needed to define the meaning on individual points within DNP3 that fit the smart inverter context. Although work has (and is continuing to) take place in developing these standardized DNP3 profiles for DER, those DNP3 profiles need to be expanded, validated, secured, certified through testing, and successfully deployed for California DER to meet not only the Rule 21 requirements but the probable future utility needs for meeting their distribution resource plans and device/systems interoperability goals.

This project improves the ability of grid operators to communicate with distributed energy resources (DER) and enhance use and value of energy storage and solar generation connected to smart inverters. This project’s goal is to address the critical gap in utility SCADA communications by enhancing the existing standards and protocols (IEEE 1815 standard and indirectly IEC 61850-7-420) and developing the infrastructure to accelerate the process of product development, certification and testing, compliance and interoperability, and field deployment. At the end of this project, utilities and manufacturers will have open-communications DNP3 support with tailored functions for smart inverters and the software tools to integrate and test standardized DNP3 profiles in products.

CHAPTER 2: Project Approach

A four-step approach was used to meet the project goal to update communications protocols for DER to meet requirements in California Rule 21, IEEE 1547-2018, and other needs of the industry and to develop open source tools to accelerate the adoption. The following sub-sections describe the approach.

- Identify and Develop Requirements: The team created an open, collaborative working group to perform a gap analysis between the capabilities of solar PV / energy storage and functionality supported in current communications standards. The purpose is to find opportunities that can help the industry realize the full set of benefits from solar and storage systems.

  Technical Leads: EPRI, Enernex, MESA Standards Alliance, SunSpec Alliance, Xanthus Consulting International

- Transfer and Apply the Results: The team worked with the DNP Users Group to apply the lessons learned and publish an update to the existing application note defining how to use DNP3 with energy storage and solar PV systems. The purpose is to add support for the most advanced energy storage use cases. The team also shared the lessons learned with other communication standards so that they could benefit from the findings.

  Technical Leads: EPRI, Enernex, MESA Standards Alliance, SunSpec Alliance, Xanthus Consulting International

- Develop Open Source Tools: The team developed open-source DNP3 software to simplify product development for manufacturers or other industry stakeholders and accelerate adoption of the updated standard.

  Technical Lead: EPRI

- Develop and Transfer Conformance Framework: The team developed a framework for conformance testing to ensure interoperability. It includes (1) the DNP3 Process Logic which defines the test procedure and pass/fail criteria, (2) the Protocol Information Conformance Statement (PICS) which lists which parameters are supported or unsupported by the product under test to inform which tests need be performed on the distributed energy resource, and (3) programming existing test software to automate and expedite testing and validation of pass/fail criteria.

  Technical Lead: SunSpec Alliance

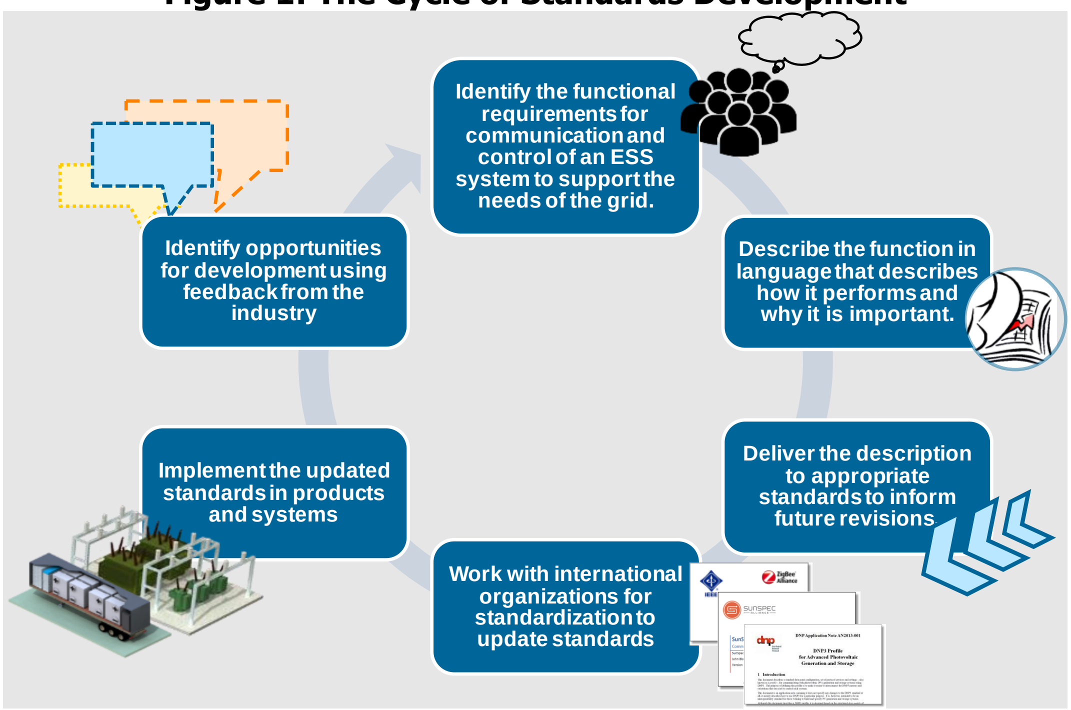
Although California will benefit significantly from the project outcomes, these efforts rely on coordination with North American and international standards. This includes communication requirements being addressed in the IEEE 1547 revision process and the updates to the IEC 61850 DER information model, which are of global significance. Therefore, the project supplemented and coordinated with efforts inside and outside of California. One example of this was the convening of a collaborative working group with the SunSpec Alliance and MESA Standards Alliance who represent solar and energy storage stakeholders respectively.

These SunSpec and MESA efforts were aligned within the complimenting goals of the project. In October 2015, MESA and EPRI launched a collaborative effort to leverage the complimentary work and progress a shared goal to accelerate the development of open communications standards for energy storage systems. The result is a public working group in EPRI's Energy Storage Integration Council (ESIC)[10] focused on communications and controls that helped inform this project.

Identify and Develop Requirements

The process to update standards is inherently iterative (Figure 1). Field experiences, product deployment, and research projects inform the next iteration of standards development. This includes clarifying ambiguous language, adding new functionality, or updating to accommodate new applications and capabilities. The intention of this task was to collect that information.

Figure 1: The Cycle of Standards Development



Source: EPRI

The project built on existing efforts to define smart inverter functional definitions. Industry working groups have defined standardized definitions of smart inverter capabilities. This work represents a decade of work by utility and technology stakeholders worldwide to define a foundation for the integration of distributed energy resources such as solar photovoltaics and energy storage. Since 2009, an industry collaborative initiative has been working to define common functions and communication protocols for integration of smart distributed resources

---

10 EPRI's Energy Storage Integration Council (ESIC) is an open, technical collaboration group focused on advancing the deployment and integration of storage. https://www.epri.com/esic

with the grid. The groups have disbanded and reconvened multiple times as new ideas and gaps have been identified through field evaluations and grid code developments such as IEEE 1547 and CA Rule 21. Most recently, working groups in EPRI's Energy Storage Integration Council (ESIC), SunSpec Alliance, MESA Standards Alliance, IEC 61850, and other groups have suggested additional and updated content to the previously completed work. The focus of these efforts included energy storage capabilities.

In this project, the team convened a public Open Collaborative Working Group to review the existing work and identify capabilities of the energy storage systems not yet captured by industry efforts. The group was diverse and consisted of utilities, public utility commissions, inverter manufacturers, system designers, and researchers. This group walked through each of the benefits and applications for energy storage systems to improve the efficiency, safety, security, and resiliency of the grid and then compared this to the capabilities defined in modern standards and guidance documents. This produced a list of functional gaps that would be discussed and addressed in the project.

In addition to this Open Collaborative Working Group, the team reviewed the discussions occurring in other key groups. This included updates to grid codes (IEEE 1547-2018,[11] California Rule 21[12]), international standardization efforts (IEC-61850-420), discussions in industry trade organizations (such as MESA, SunSpec), and experiences from the field deployments. Collectively, the findings from these groups were used to develop the gap analysis.

Transfer and Apply the Results

Communications between utilities and DER systems can either be direct or through third-party aggregators. For direct communications, California utilities, like most utilities in North America, expect to use the IEEE 1815 (DNP3) SCADA-based standard. Although DNP3 is a well-respected protocol, it does not include its own information model. Therefore, for advanced smart inverter functions, standardized mappings (or profiles) are needed. Although work has (and is continuing to) take place in developing these standardized DNP3 profiles for inverter-based DERs, those DNP3 profiles need to be expanded, validated, secured, certified through testing, and successfully deployed for DERs to meet not only California's Rule 21 requirements, but the probable future utility needs for meeting California's renewable resource goals.[13]

Once the functional gaps were identified, the project team convened a smaller group that focused on filling each of these gaps. This group consisted of representatives from SunSpec,

---

11 "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. Accessed March 2019

12 "Rule 21 Interconnection." California Public Utilities Commission. Accessed November 05, 2018. http://www.cpuc.ca.gov/Rule21/. Accessed March 2019

13 Energy Commission Adopts Standards Requiring Solar Systems for New Homes, First in Nation. California Energy Commission. https://www.energy.ca.gov/releases /2018_releases/2018-05-09_building_standards_adopted_nr.html. Accessed March 2019.

MESA, EPRI, Xanthus Consulting, Doosan GridTech, Enernex, and TESCO Automation. The group developed solutions after many discussions resulting in a draft update to the DNP Application Note. This draft application note built on existing efforts to define standardized DNP3 profiles for DER.

When the project began, smart inverter functional definitions had been mapped into IEEE 1815 / DNP3, IEEE 2030.5, and Modbus protocols to allow for these functions to be configured, controlled, and monitored over communication networks. In the DNP3 domain, the effort to standardize dates back to efforts to create the first application note, DNP Application Note AN2011-001 DNP3 Profile for Basic Photovoltaic Generation and Storage.[14] Application notes contain standardized functional definitions, a standardized list of DNP3 inputs/outputs, mapping of information communicated within each point, and information to use the points correctly. Examples of functions included in AN2011-001 included connect/disconnect, max generation limiting, power factor management, PV/storage setting management, event/history logging, status reporting, monitoring data, time synchronization, and volt/VAR functionality.

The next application note was published in January 2013 – DNP Application Note AN2013-001 DNP3 Profile for Advanced Photovoltaic Generation and Storage.[15] It superseded AN2011-001 and added new functionalities including frequency-watt, dynamic reactive current, thresholds for must disconnect and must remain connected, watt-power factor, volt-watt, temperature curves, pricing signal curves, real power smoothing, dynamic volt-watt, peak power limiting, load and generation following, curve management, scheduling, additional monitoring points, and other changes.

In 2015 the MESA Standards Alliance built on these existing efforts to focus on expanding storage functionality for Modbus and DNP3 and developed the MESA-ESS specification focused on communication between utility control centers and energy storage systems (ESS). Through their technical working group, they expanded storage functionality captured in DNP profiles by adding functions like price and time-based charge/discharge management modes, load following and generation following modes, and improving other modes and functions to include storage and represent the most recent discussions in the industry. The first draft of the MESA-ESS specification was released for public review November 15, 2016.[16]

This project started with the latest draft of the MESA Standards Alliance's MESA-ESS specification, added new capabilities based on the gap analysis, and created a draft to propose to the DNP Users Group as a replacement for the existing application note, AN2013-001. Appendix C provides more information on parallel efforts.

---

14 DNP Application Note AN2011-001 - DNP3 Profile for Basic Photovoltaic Generation and Storage. DNP Users Group. March 2011, https://www.dnp.org/LinkClick.aspx?fileticket=6p1-UT6LgCY%3d&portalid=0&timestamp=1553608633672. Accessed March 2019.

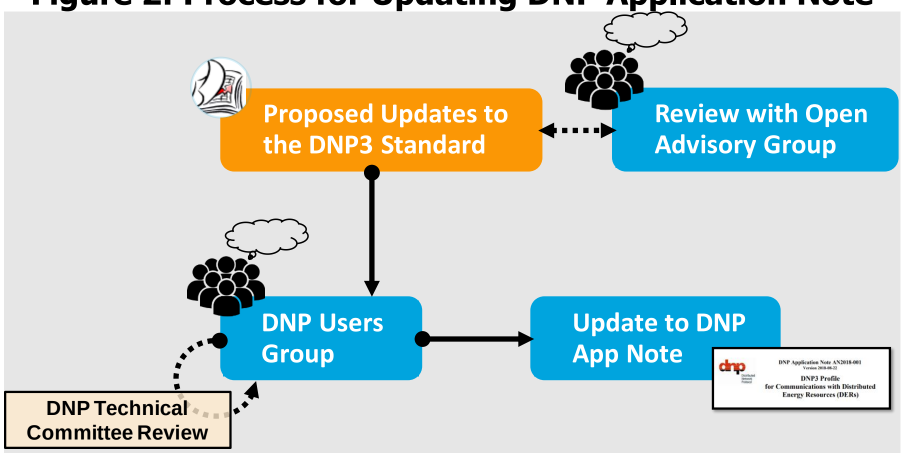
15 DNP Application Note AN2013-001 DNP3 Profile for Advanced Photovoltaic Generation and Storage. DNP Users Group. January 2013. https://www.dnp.org/LinkClick.aspx?fileticket=umDiP5_lYg0%3d&portalid=0&timestamp=1553608816304. Accessed March 2019.

16 MESA-ESS. MESA Standards Alliance. http://mesastandards.org/mesa-ess-2016/. Accessed March 2019.

Many standards organizations, such as IEEE or IEC, have defined processes for updating a standard. This includes formal processes for convening a group, defining a scope for the effort, proposing changes, and ratifying the changes as an update to the standard. DNP Application Notes are different. DNP3 is an IEEE standard so any updates to it must follow IEEE processes. However, application notes are maintained by the DNP Users Group. This group is a non-profit that supports the user community and the industry by enhancing and promoting the Distributed Network Protocol (DNP3).

The DNP Users Group's process for updating application notes is for a draft update to be proposed to the users group. Members of a technical advisory committee review the application note to ensure it was developed to their quality standards. A vote is then held to make it official. In this project the team created a draft update and proposed it to the DNP Users Group for approval. This process is shown in Figure 2. The team developed proposed updates, reviewed these with the Open Collaborative Working Group, and then presented it to the DNP Users Group. This document was reviewed by the DNP Users Group, changes were made, and it was voted for acceptance.

Figure 2: Process for Updating DNP Application Note



Source: EPRI

Develop Open Source Tools

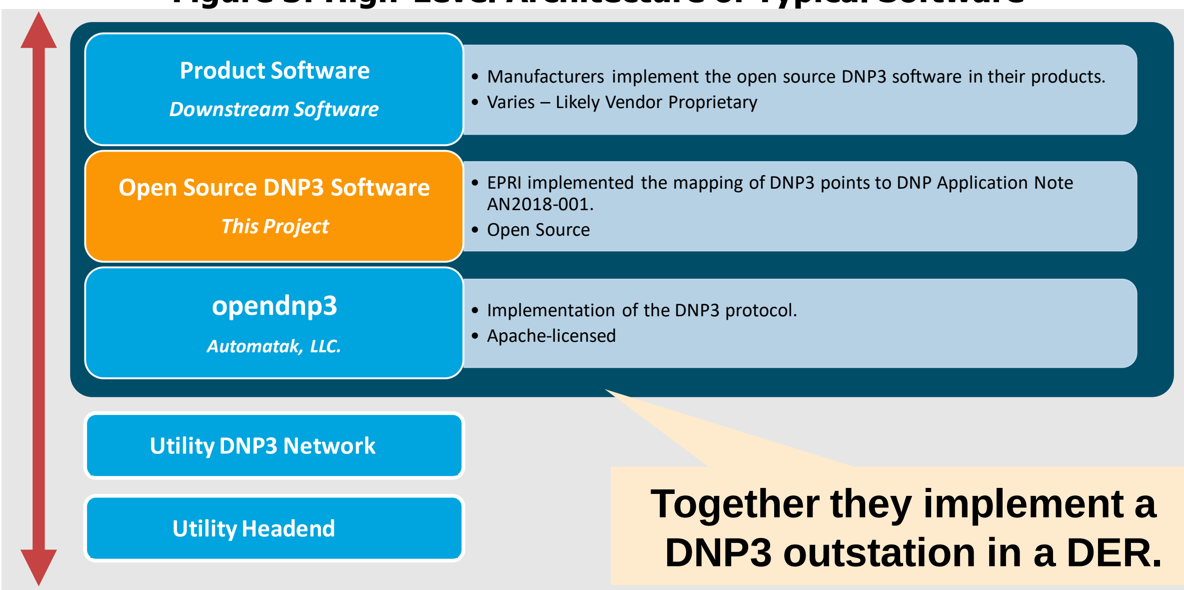
The goal of this activity was to advance communication capabilities of energy storage by providing the necessary tools to implement the protocol with minimal understanding of the technical details of the protocol. Once the new standards or profiles are published for implementation, manufacturers must develop capabilities to support the requirements in their products or systems. The project team built an open-source client to reduce the time and effort required for vendors and other stakeholders to integrate DNP3 into energy storage devices. A manufacturer could use the open source DNP3 client in their product to ensure that their product will be interoperable with other DNP3 devices that also follow the application note. This strategy also accelerates the industry adoption by reducing software development time.

The open client was tested using the Framework for Conformance Testing that was being developed in parallel to verify its conformance to the application note. This framework implements all the energy-storage methods and protocols in open DNP3 client software, including cyber security.

In addition to open source software, two other components are needed for the system to connect to a DNP3 network and exchange data and control parameters (Figure 3).

- Manufacturer software and associated hardware. This must be integrated with a manufacturer's system to implement the protocol. The manufacturer code collects data from the open source code as new control parameters are sent to the DER. It will also update the open source code with the latest monitoring and state data.
- Leveraging opendnp3 codebase. The project leveraged existing open source software to help keep the project economical. The opendnp3[17] codebase was used to implement the underlying, generic DNP3 functionality.

Figure 3: High-Level Architecture of Typical Software



Source: EPRI

Develop and Transfer Conformance Framework

Smart inverter communication standards are relatively new to the industry but are rapidly gaining popularity because utilities see benefits in providing visibility in generation of DER and controllability of these resources. Many of the inverter standards used today have been around for a long time. Modbus has been used since 1979 in building systems, and DNP3 and IEC-61850 are used globally to manage distribution system equipment. However, their application to smart inverters is new. This means that the industry is learning how to apply these technologies in the smart inverter domain.

17 opendnp3. Automatak LLC. https://www.automatak.com/opendnp3/. Accessed March 2019

Standards can help enable "plug-and-play"[18] DER, but experience says that even with robust standards, unforeseen implementation barriers can arise.[19,20,21] Implementers of standards may misunderstand requirements, vagueness in language can create confusion, and mistakes can be made. Inverter conformance pre-testing validates that standards and implementers meet the requirements. A testing and certification process reduces the cost to fix these issues after they are deployed in the field by identifying non-conformance upfront, so it can be fixed.

To address the comprehensive testing requirements an *Infrastructure for Product Certification Testing* was created as a framework to support certification efforts related to DNP3 for distributed energy resources. The infrastructure for product certification and testing comprised of three components (Figure 4).

- DNP3 Process Logic: Defines the test procedure and pass/fail criteria for the requirements defined in DNP Application Note AN2018-001 – DNP3 Profile for Communications with Distributed Energy Resources.
- Protocol Information Conformance Statement (PICS): A list defining which parameters in the DNP Application Note are supported or unsupported by the product under test. Supported and unsupported points must follow different pass/fail criteria. This document informs the testers which tests need be performed on the distributed energy resource.
- SunSpec Test Software: Testers send and receive messages from the distributed energy resource to determine if it supports DNP3 correctly. SunSpec used their existing SunSpec System Validation Platform (SVP)22 to create scripts to automate testing and validation of pass/fail criteria.

---

18 "Plug-and-play" is a phrase describing the capability of devices to work together as soon as they are connected.

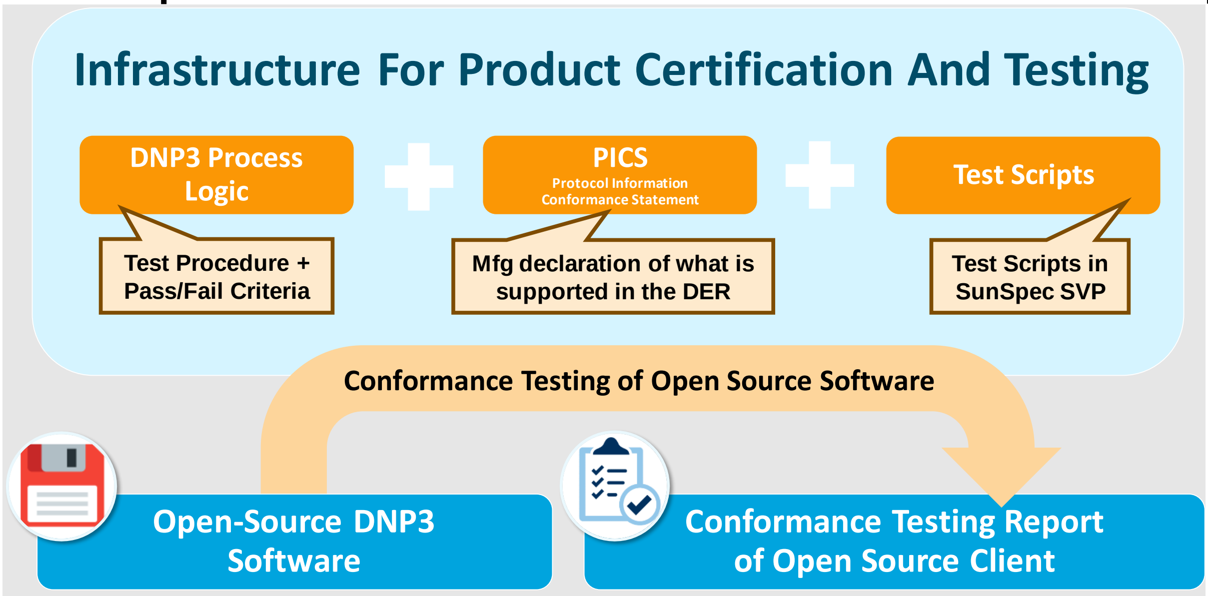
19 Evaluation of SunSpec Modbus for Distributed Energy Resources: Results from EPRI Interoperability Testing and Market Research. EPRI, Palo Alto, CA: 2017. 3002009854.

20 Assessment of Interoperability Achieved through IEEE Std 1547-2018 and IEEE P1547.1: Results from EPRI Interoperability Testing and Market Research. EPRI, Palo Alto, CA: 2018. 3002013473.

21 "Standard Communication Interface and Certification Test Program for Smart Inverters". Electric Power Research Institute. California Public Utilities Commission – California Solar Initiative. http://www.calsolarresearch.ca.gov/images/stories/documents/Sol4_funded_ proj_docs/EPRI4_Seal/2_CSI-RDD_Sol4_EPRI-Seal_StdCommInt_CertTestProg_FinalRpt_2016-08.pdf. Accessed March 2019.

22 SunSpec System Validation Platform (SVP). SunSpec Alliance. https://sunspec.org/sunspec-system-validation-platform-2/. Accessed March 2019

Figure 4: Components of the Infrastructure for Product Certification and Testing



Source: EPRI

Summary

This chapter provided an overview of the four-step process followed in this project and the various stakeholder groups and working groups that were engaged in the effort. The four-step approach was designed to find the gaps that needed to be filled in relevant communication standards, fill them, and build software and conformance tools to evaluate their implementations in products. In addition, engaging with the right stakeholder groups during this effort was key. In particular, aligning the effort with MESA, SunSpec, and ESIC was important for proper engagement with the industry. The next chapter gives an overview of the results of each of these four steps.

CHAPTER 3: Project Results

This section highlights the results and findings from (1) the gap analysis, (2) development of application note for DNP3, (3) development of DNP3 outstation code, and (4) framework for DNP3 conformance testing.

Gap Analysis

This section gives examples of findings from the project's gap analysis. A full list of gaps can is in Appendix B: Extended Summary of Gap Analysis.

Functional Definitions

The gap analysis conducted through the working group and internal team discussions found that most of the functional definitions for smart inverters were defined through the work from EPRI's ESIC, International Electrotechnical Commission (IEC) Technical Committee 57 Working Group 17,[23] MESA Standards Alliance, California Rule 21's Smart Inverter Working Group, and IEEE 1547 working groups. Though the definitions in some cases had existed for years, they had not yet been mapped to communication standards and were missing parameters related to energy storage specific functionality.

The project's collective gap analysis identified the following functions that must be added or modified significantly:

- Frequency/Watt
- Watt-VAR Function
- Connect / Disconnect and Cease to Energize
- Peak Power Limiting, Load Following, and Generation Following
- Constant VARs
- Scheduling

Parameter Definitions

Much of the project's findings relate to individual parameters within a communication protocol. Some gaps were identified in higher level smart inverter functionalities but as previously mentioned, the higher level smart inverter functionalities were largely uncovered previously.

There is a large list of parameters, monitoring points, and function settings required for smart inverter operations. It is common for a function to have 5 to 10 parameters. For reference, the updated application note defines around 970 readable parameters and 390 writable parameters. One simplifying factor is that there is a lot of similarity across functions and many parameters are used in across distinct functions. Table 1 shows an overview of these general

23 IEC TC57 WG17 was updating the IEC-61850-7-420 information models in parallel with this project. These information models relate to distributed energy resources. https://www.iec.ch/dyn/www/f?p=103:14:0::::FSP_ORG_ID,FSP_LANG_ID:2386,25. Accessed March 2019.

parameters – not specific to an individual function. This is noted here because a change to a parameter that is used across multiple functions applies to all the functions. For example, if the team added a new ramp rate or ramp time then the change applied to all functions that had ramp rates or ramp times.

Table 1: Overview of Parameter Types

PARAMETER TYPE	REFERENCE EXAMPLE(S)	WHERE DOES IT APPLY?
GENERAL FUNCTION CONTROL	Ramp rates/times, timeout windows, and enable flags	Most functions.
CURVE DEFINITIONS	X/Y arrays to define curve shape, units for X and Y axis.	All curve functions. Some curves are parameterized and captured in function specific parameters. A parameterized curve follows a standard shape and is defined using a non-curve set of parameters.
FUNCTION SPECIFIC	Output power limit, requested power factor, voltage or frequency threshold on the grid to enable a function	These parameters only apply to a single function.
MONITORING AND STATES	Current output power, error states, operating modes	These parameters are more monitoring points than parameters, as they are not settable. They are not mapped to specific functions but describe the DER or DER behavior in general. This data may be used by one or more active functions to determine the inverter’s reaction.

Source: EPRI

The project team found gaps in all four of these categories. Some of the gaps were missing parameters while others were parameters captured by one group of stakeholders but omitted by others. The follow sections give details on the parameter analysis.

Referenced Data Points

The concept of referenced data points was a new and popular topic. The general idea is that many functions use a data stream from a location – often assumed to be the device’s electrical connection point (ECP) – to inform the behavior of active functions. For example, if an inverter performing the volt-var function will produce a predefined number of VARs at a given voltage then the voltage measurement is collected from the referenced data point.

This feature is important for storage systems because their ability to charge or discharge on command makes them candidates for helping to react to changing conditions nearby (electrically) on the distribution system to help mitigate its effects where local data may not be enough. Referenced data points allow DERs to have more flexibility in the reference point. The reference data could be the measurement at the inverter or a remote meter at the facility hosting DER(s). This concept is particularly valuable for functions designed to follow or limit the behavior of nearby loads or generators because it allows the function to react to a meter at a nearby load or DER.

Bidirectional Power Flow

Current standard and smart inverter functionalities are based on a decade of industry conversations. As previously mentioned, energy storage was a secondary consideration because the group's focus was on solar PV. Energy storage functionality was considered but since the focus was on solar technologies, the full potential of energy storage systems was not fully captured. A key difference between solar PV and energy storage functionality is the storage system's ability to charge / absorb energy. Therefore, one of the gaps was bi-directional power flow across all functions. Often functions were defined but required another set of parameters to allow an operator independent control of the storage system when absorbing energy (charging) or ejecting energy (discharging/generating). The list below gives examples of additions related to bi-directional power flow:

- Addition of maximum charging rate to compliment the maximum output power (generating for solar, discharging for storage).
- Addition of independent control of power factor for input power (charging) and output power (discharging/generating).
- Addition of new ramp rates to capture charging and discharging systems. Ramp rates for increasing and decreasing were also added.
- Addition of parameters to support a DER charging to follow or limit a nearby generating DER. An example is co-located storage/solar system.

Terminologies

This is a broad topic that affected every smart inverter function. The terminology between standards organizations, communications protocols, and manufacturer's product descriptions used a mix of terminology to describe similar and identical parameters. There were also cases where the different stakeholder groups described different parameters but used the same terminology. Both are important because, the owners and dispatchers of DER need to know with certainty that when they ask a DER to perform an action it performed the same action they expected it to and that data they received from a DER matches the intended measurement, state, or flag.

The list gives examples of terminology discrepancies addressed in this project:

Disconnect, Trip, and Cease to Energize

This is an example of similarly termed functions with different actions. These terms were used interchangeably when the project began but are now defined in IEEE 1547.

- Cease to Energize: "Cessation of active power delivery under steady-state and transient conditions and limitation of reactive power exchange."[11] In cease to energize storage systems may continue to charge; limited reactive power exchange can continue; and it does not necessarily imply that the inverter will disconnect, isolate, or trip. The expectation is that the system immediate restores output when the cease to energize is lifted.

- Trip: "Inhibition of immediate return to service, which may involve disconnection." [11] In this case the system does not immediate restore output when the trip is lifted but instead must follow appropriate procedures as defined by the grid code.

Set and Limit

Another example is the term Set Maximum Output Power on the Limit DER Power Output Function. In Rule 21 this is named as Real power limit value while in IEEE 1547 it is named as Maximum Active Power. These terms reference the same parameter. Alternatively, the nameplate rating of the inverter or WMax is Active Power Charge Maximum Rating in IEEE 1547-2018.

An example of the confusion this created is that lab studies found that some manufacturers of control systems incorrectly used the *nameplate rating* value to set a *max output*. Though it performed a similar electrical response, it was not correct. In this case, it was especially dire because the manufacturer of some inverters use flash memory for ratings which have a limited number of reads and writes. If used for a period, it would cause the inverter to fail prematurely due to memory failure. This highlights the importance of understanding the parameter and variation in terms. Often it appears easy to find when two similar parameters are the same. However, users should be careful to know the definition of the term to prevent unexpected results in practice.

State and Status

The terms, state, status, and monitoring data were especially prone to terminology issues, so it is called out specifically. This section covers two examples, states and state of charge.

Four different state/status definitions exist. They appear to be identical parameters with different states however while attempting to harmonize the team found different individual states with different meaning.

- Access Status: This status provides users with information about whether the system can is available to be controlled. Different states include "normal operating state", "lockout", and "maintenance/testing".
- Connect / Disconnect Status: This status provides users with information about whether the DER is connected to the grid and if it was active. Example states included Disconnected / Unavailable, Disconnected / Available, Connected / Unavailable, Connected / Available, and Connected / On.
- Present Operating Mode: This parameter was a placeholder for the original equipment manufacturers (OEM) proprietary states.
- DER Status: This status provided users with information about the action of the DER. Example states include throttled, standby, off, starting, stopping, fault.
- Operational State – This state shows whether the DER is in normal state or is in some other state, such as Lockout, Maintenance, or Test.

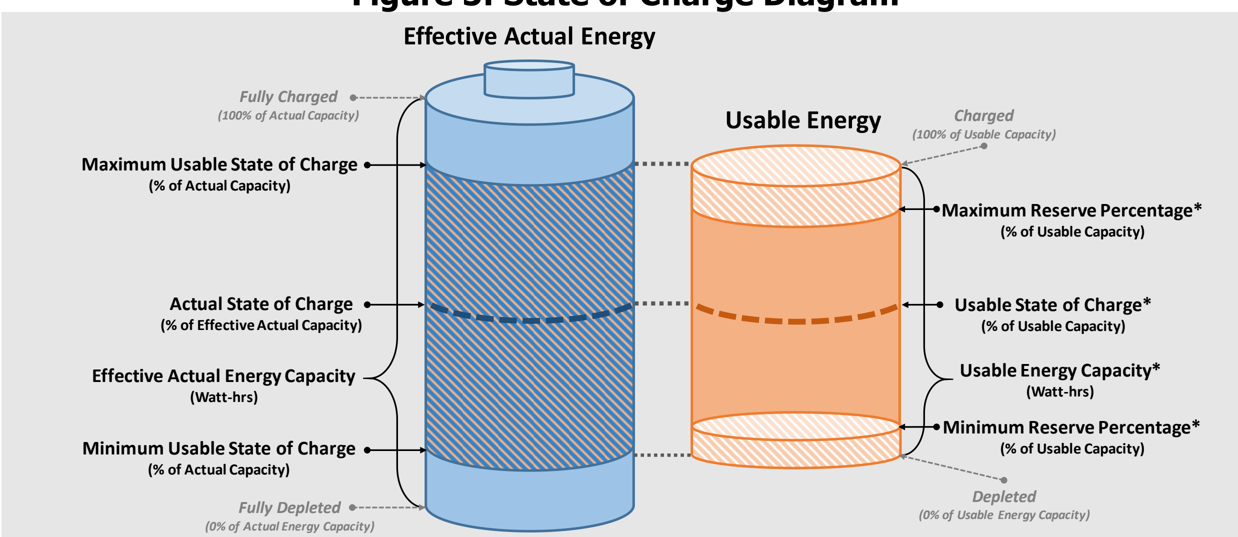
The exact list of statuses and their associated states are still being discussed by the industry.

State of Charge

Energy storage systems are unique because their primary purpose is to give electrical flexibility to the users (charge and discharge as and when needed). Operators manage this flexibility by raising and lowering the state of charge of the system by manipulating the power input/output of the system. At the beginning of this study communications protocols supported a single state of charge parameter. This is confusing because different stakeholders directly involved in the storage system define state of charge differently. Harmonization of these terminologies was critical.

A battery manufacturer reads state of charge as the current state as defined between completely charged and completely discharged. However, when a storage system is configured there is an artificial minimum and maximum state of charge assigned to provide the contracted life of the system. Over charging or discharging the battery past these setpoints impact the health and performance of the cells. An owner or operator of a storage system would consider these the minimum and maximum limits of the system because it is the full usable range to them for that contracted lifespan. Therefore, it was decided that there needs to be two sets of state of charge parameters (Figure 5). Some are useful to communicate to dispatchers of the system (right) and others are applicable within the energy storage system itself (left).

Figure 5: State of Charge Diagram



Source: EPRI

Summary

The primary conclusion from the gap analysis is there are no glaring gaps in smart inverter functionalities. Most of the functions discussed in stakeholder groups have existed for many years. Though the high-level functions were complete, the project identified important gaps in the semantics and terminology. Often function names or parameters differed slightly between stakeholder groups. The reason this is notable is that consensus across the terminologies and their definitions is needed for interoperability to occur. Slight differences in naming conventions can be overcome through education and logical mapping however differences in implementation is an obstacle because it can cause misinterpretations of what a function will give and therefore the behavior of the inverter when operating in that mode. Grid operators, manufacturers, users, standards organizations, and service providers must use the same semantics and terminologies in their documentation to ensure DER interoperability.

Application Note Development

The DNP Users Group published DNP Application Note AN2018-001: DNP3 Profile for Communications with Distributed Energy Resources in August 2018 based on the draft provided through this project. The application note contains a standardized list of DNP3 inputs/outputs, specific mapping of information communicated within each point, and information to use the points correctly. It also includes functional definitions and mapping between the internationally recognized information models, IEC-61850-7-420, which promotes harmonization between DNP3 and the globally recognized IEC standards.

The DNP AN2013-001 was used as a starting point. DNP AN2018-001 makes the following improvements to DNP AN2013-001:

1. Expands the functionality needed for maximizing the value of storage systems.
2. Brings the application note up to date with smart inverter functionality.
3. Conforms with grid codes including all phases of California Rule 21 and the 2018 update to IEEE 1547.

The AN2018-001 update added the following functions and parameters:

Functions

- Support Flag for Modes and Functions
- Limiting Response: Ramp Rates, Ramp Times and Time Constants
- Alarm Grouping and Reporting
- Cease to Energize and Return to Service Functions
- Low/High Frequency Ride-Through Mode
- Frequency-Watt Mode
- Coordinated Charge/Discharge Management Mode
- Automatic Generation Control Mode
- Constant VAR Mode
- Watt-VAR Power Mode
- Power Factor Correction Mode

Parameters

- Support for bi-directional power flow across all modes/functions
- Harmonization of terminology and concepts across stakeholder groups

In addition to the application note, a Microsoft Excel document of the point list was published to help developers implement them in software used to develop products or deploy systems. Both documents are available through the DNP Users Group page to members of the DNP Users Group – https://www.dnp.org/. The application note is provided at no fee to MESA and SunSpec Alliance members under an agreement with the DNP Users Group.

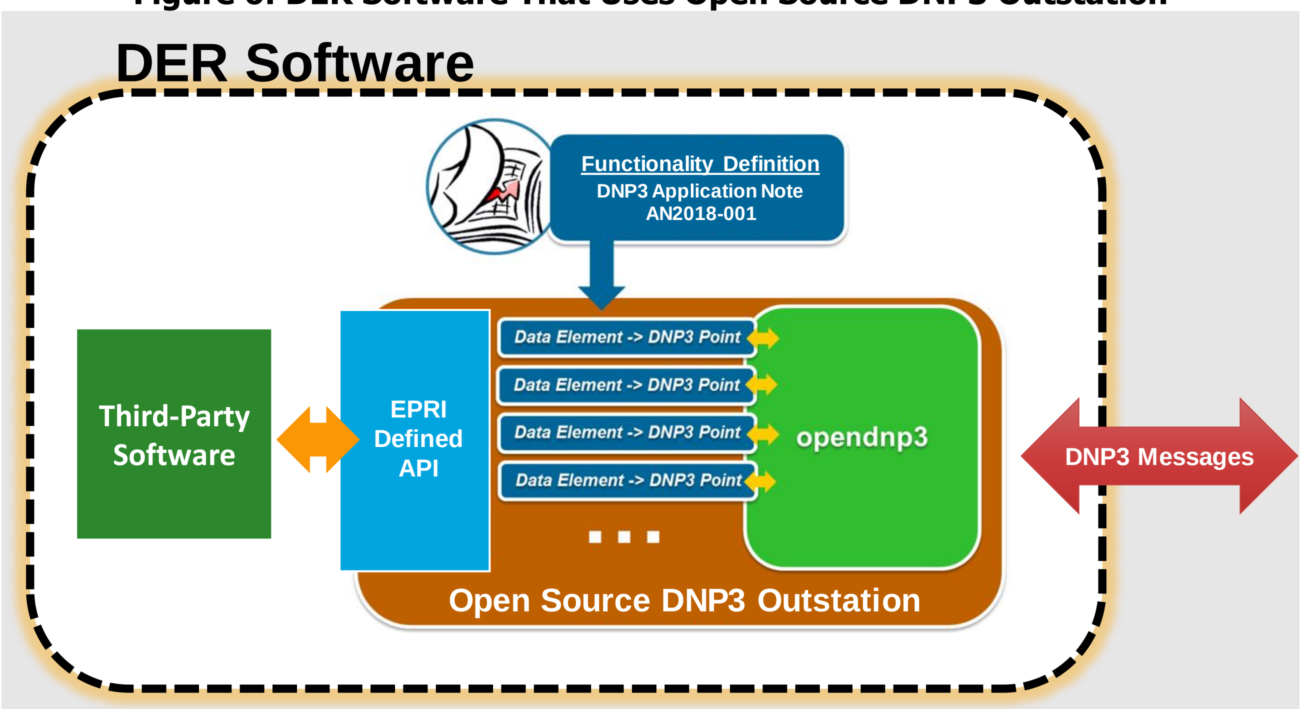
DNP AN2018-001 defines DER specific communications requirements for achieving interoperability over a DNP3 network. It integrates information from the latest field tests as well as smart inverter functionality to provide a standard information model for communicating with DER using Institute of Electrical and Electronics Engineers Standard (IEEE Std.) 1815™ (DNP3) that complies with functional requirements in California Rule 21 and IEEE 1547-2018. It is referenced in IEEE 1547-2018 as the requirement for using DNP3 in DERs. It is listed alongside SunSpec Modbus and IEEE 2030.5. At least one of the three must be implemented per IEEE 1547-2018.

Open Source DNP3 Outstation

The DNP3 Outstation implements DNP Application Note AN2018-001: DNP3 Profile for Communications with Distributed Energy Resources. The outstation is open source (BSD-3 Clause). It simplifies the process of adding the standard to devices by providing developers with a simple interface that they can connect to their software. The open source software absorbs the complexities of the standard by performing internal processes that are invisible to the user so that the DER follows the application note without having to actively implement those requirements in the product. Developers can then use the code directly in their products or use it to help guide their own development.

The Open Source DNP3 Outstation uses opendnp3 to implement the underlying DNP3 requirements as shown in Figure 6. The team's contribution includes adding the DER specific aspects defined in AN2018-001. The third-party software integrates with the DNP3 Outstation to support field implementations.

Figure 6: DER Software That Uses Open Source DNP3 Outstation

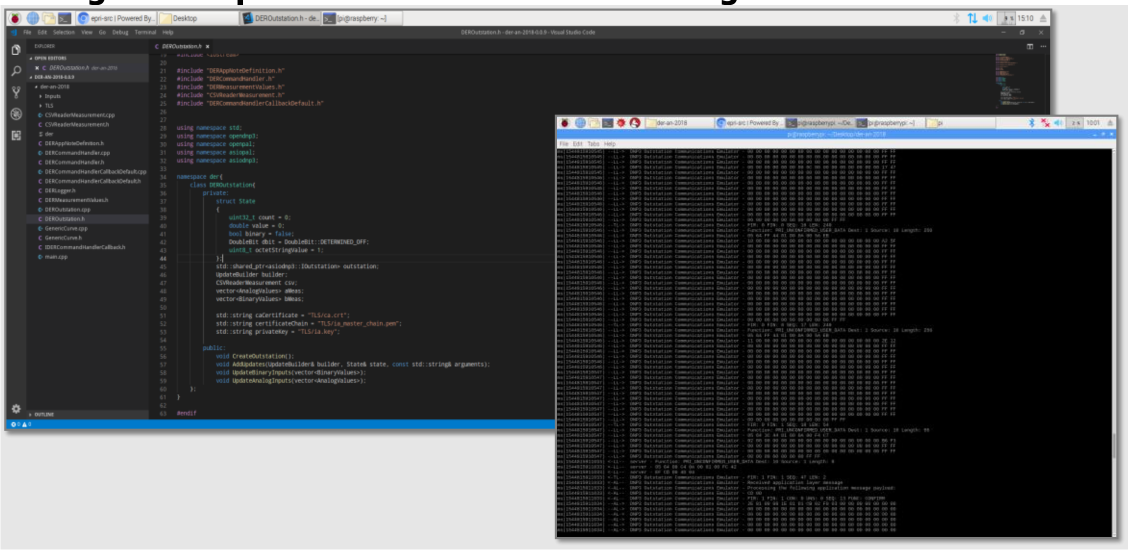


Source: EPRI

Error! Reference source not found. Figure 7 shows the terminal window running the open source outstation software in widely-used C++ coding language and a Linux based operating system. A Raspberry Pi 3[24] was used for testing. The code uses Automatak's opendnp3 library to implement the underlying DNP3 requirements. The team's contribution included adding the DER specific aspects defined in AN2018-001. It uses OpenSSL to implement Transport Layer Security (TLS) for cyber-secure communications.

The outstation is available from EPRI's GitHub repository.[25]

Figure 7: Open Source Outstation Running in Terminal Window



Source: EPRI

Smart Inverter Functions

The open source outstation software supports the following smart inverter functions. The software does not include all of the functions and parameters defined in Application Note AN2018-001. However, examples are provided for each type of function and command, so developers can easily copy the format to add new functions. This is explained further in the *Open Source DNP3 Outstation Software Developer Notes* available on EPRI's GitHub repository.[25]

- Enter Service
- Active Power Limit Mode
- Constant Power Factor Mode
- Volt-VAR Mode
- Watt-VAR Mode
- Constant VAR Mode
- Volt-Watt Mode

---

24 Raspberry Pi 3 Model B. Raspberry Pi Foundation. https://www.raspberrypi.org/products/raspberry-pi-3-model-b/. Accessed March 2019.

25 DER Outstation AN2018. Electric Power Research Institute. https://github.com/epri-dev/der-dnp3-an2018. Accessed March 2019.

- Voltage Trip
- Momentary Cessation
- Frequency Trip
- Frequency Droop (Frequency-Watt)
- Monitoring Points
- Scheduling is implemented for all functions above.

Framework for Conformance Testing

Lab testing has shown that communications with DER do not always invoke the correct response and monitoring data may not be communicated correctly.21, 26, 27, 28 For this reason, a framework for conformance process was needed to verify requirements defined in Application Node AN2018-001. The framework developed in this project includes validating that the outstation can"

- Obtain all required input points associated with tested functionality.
- Update all required output points associated with tested functionality.
- Validate that input points track output points correctly.
- Validate generic curve management functionality.
- Validate points are implemented or marked as unimplemented consistent with the logical point groups in which they reside.

The framework does not validate that the outstation can:

- Follow underlying DNP3 requirements. Existing processes address this. [29]
- Respond with the correct electric response or that monitoring points are accurate. Functional test standard like UL-1741SA and IEEE 1547-2018 address this.

The conformance-testing framework is scalable. It supports all the requirements in Application Node AN2018-001. It can therefore support testing of any requirement that specifies conformance to this application node including the IEEE 1547-2018 standard and California Rule 21 interconnection requirements. It is likely that the industry could develop profiles in the future to sub-divide the test procedure to test explicitly for the requirements in these requirements. For example, a subset of the tests could be used to confirm a DER's ability to

---

26 Assessment of Interoperability Achieved through IEEE Std 1547-2018 and IEEE P1547.1: Results from EPRI Interoperability Testing and Market Research. EPRI, Palo Alto, CA: 2018. 3002013473.

27 Results from Inverter Interoperability Assessment Using the SunSpec Specification: Summary of EPRI's Testing of Communications in Residential Solar Inverters. EPRI, Palo Alto, CA: 2016. 3002009462.

28 Evaluation of SunSpec Modbus for Distributed Energy Resources: Results from EPRI Interoperability Testing and Market Research. EPRI, Palo Alto, CA: 2017. 3002009854

29 Conformance Testing Policy. DNP Users Group. https://www.dnp.org/Products/Testing-Policy. Accessed March 2019.

meet California Rule 21 communication requirements over a DNP3 network. This scalability is a strength of the approach taken in this framework because of the flexibility it provides.

It is important to note that in the California context, Rule 21 states, "the default application-level protocol shall be IEEE 2030.5 (i.e., Smart Energy Profile 2.0 [SEP 2.0]), as defined in the California IEEE 2030.5 Implementation Guide. However, other application-level protocols may be used by mutual agreement of the parties including IEEE 1815/DNP3 for SCADA real-time monitoring and control and IEC 61850."[30] This means that other protocols, including DNP3, are allowed upon mutual agreement. However, California Rule 21 does not define standard test procedures to test other protocols like DNP3, as it does with IEEE 2030.5. This is where the conformance framework for DNP3 is critical to accelerate the adoption.

This conformance framework was tested in this project by connecting it to the open source software that was being developed in parallel. The framework confirms that the open source software meets the requirements in the DNP Application Note.

Conformance Testing of Open Source DNP3 Outstation

To ensure efficient use by third-party service providers, the project's Framework for Conformance Testing was applied to the Open Source DNP3 Outstation. **Error! Reference source not found.**Figure 8 shows the snapshot of certification details for AN2018-001, which is offered by the SunSpec Alliance.

Figure 8: Certification Details for Open Source DNP3 Outstation

SUNSPEC CERTIFIED

Certification Details for DNP3-AN2018

Key	Value
Certificate Type	IEEE 1815/AN2018
Certificate Number	REF000000001
Company Name	Electric Power Research Institute
Company Address	3420 Hillview Ave
Company City	Palo Alto
Company State/Province	CA
Company Country	USA
Company Postal Code	94304
Date Issued	01/15/2019
Test Laboratory	Not Applicable
Supervising Test Engineer	Bob Fox
Certificate Signer Name	Tom Tansy
Software Name 1	der-an-2018-0.1.5
Software Version 1	0.1.5
Software Checksum 1	e3c794330a011441331078a1b59f9b34
Operating System 1	Raspbian
Operating System Version 1	8 (Jessie)
Software Operating Environment	Device
Protocol Implementation Conformance Statement	DNP3-AN2018-PICS-EPRI.xlsx
Cloud Provider	Not Applicable
Cloud Provider Version	Not Applicable
Hardware Manufacturer	Raspberry Pi
Hardware Model 1	Raspberry Pi 3
Test Completion Date	01/15/2019
Test Description	Test performed in compliance with DNP Application Note AN2018-001 using test procedures specified in DNP DER Application Note Test Procedures.
Additional Test Comments	This evaluation report is of a reference implementation that was modified in order to verify the functionality of the protocol stack. The evaluation was not performed in a SunSpec Authorized Testing Laboratory and therefore no official certification can be provided.
Test MON-001	PASS

SUNSPEC CERTIFIED

Test ALARM-001	PASS
Test CONN-001	NOT SUPPORTED
Test SERV-001	PASS
Test OP-001	PASS
Test CURVE-001	PASS
Test CURVE-002	PASS
Test CURVE-003	PASS
Test VRT-001	PASS
Test FRT-001	PASS
Test FW-001	PASS
Test DRCS-001	NOT SUPPORTED
Test DVW-001	NOT SUPPORTED
Test APL-001	PASS
Test CHG-001	NOT SUPPORTED
Test CCM-001	NOT SUPPORTED
Test APR1-001	NOT SUPPORTED
Test APR2-001	NOT SUPPORTED
Test APR3-001	NOT SUPPORTED
Test AGC-001	NOT SUPPORTED
Test APS-001	NOT SUPPORTED
Test VW-001	PASS
Test FWC-001	NOT SUPPORTED
Test CVAR-001	PASS
Test FPF-001	PASS
Test VV-001	PASS
Test WV-001	PASS
Test PFC-001	NOT SUPPORTED
Test PSIG-001	NOT SUPPORTED
Test SCHED-001	PASS

Source: SunSpec Alliance

30 ELECTRIC RULE NO. 21: GENERATING FACILITY INTERCONNECTIONS. Pacific Gas and Electric Company. https://www.pge.com/tariffs/tm2/pdf/ELEC_RULES_21.pdf. Accessed March 2019

The testing of the outstation software verified that the outstation was implemented correctly but also verified that the framework was implemented correctly. If any discrepancies were found, the team discussed them to identify the correct implementation of the standard.

DNP3 Process Logic for Test Procedures

The *DNP3 Process Logic*[31] developed in this project specifies test procedures for the DNP AN 2018-001. This document contains sample test procedures and pass/fail criteria to test the implementation of DNP Application Note AN2018-001. An organization interested in performing conformance testing of this application note could use this as a template. The framework for conformance testing supports the following test cases:

- Monitoring
- Alarm Grouping and Reporting
- Connect and Disconnect
- Cease to Energize and Return to Service
- Operation States
- Time Synchronization
- Event/History Logging
- Generic Curve Management Tests
- Reference Indication Test
- Curve Locking Test
- Mode Type Mismatch Test
- Low/High Voltage Ride-Through Mode
- Low/High Frequency Ride-Through Mode
- Frequency-Watt Mode
- Dynamic Reactive Current Support Mode
- Dynamic Volt-Watt Mode
- Active Power Limit Mode
- Charge/Discharge Storage Mode
- Coordinated Charge/Discharge Management Mode
- Active Power Response
- Automatic Generation Control Mode
- Active Power Smoothing Mode
- Volt-Watt Mode
- Frequency-Watt Curve Mode

31 Test Procedure for Validating DNP3 AN2018-001 in Distributed Energy Resources: Example Test Procedure for Evaluating Conformance to DNP Application Note AN2018-001 – "DNP3 Profile for Communications with Distributed Energy Resources". EPRI, Palo Alto, CA: 2019. 3002016144.

- Constant Vars Mode
- Fixed Power Factor Mode
- Volt-Var Control Mode
- Watt-Var Power Mode
- Power Factor Correction Mode
- Pricing Signal Mode
- Scheduling Tests

Protocol Implementation Conformance Statement

The Protocol Implementation Conformance Statement (PICS) is a list provided by a manufacturer to define a device's support of the various mandatory and optional parameters from the DNP Application Note AN2018-001. Supported and unsupported points must follow different pass/fail criteria. This document informs the testers which tests are required, is completed by the entity submitting their product for testing and is a key for determining systems interoperability. Figure 9 shows example entries in the PICS for each parameter.

Figure 9: Example Entries in a Protocol Information Conformance Statement (PICS)

Point	Name	Supported	Present	Group	Variation	Mapping	Quality	Value	Multiplier	Status	Note
BO16	Enable Frequency-Watt Mode	TRUE	TRUE	10	2	BI68	129	TRUE			
BO17	Enable Active Power Limit Mode	TRUE	TRUE	10	2	BI69	1	FALSE			
BO18	Enable Charge/Discharge Mode	FALSE	TRUE	10	2	BI70	2	FALSE			
BO19	Enable Coordinated Charge/Discharge Mode	FALSE	TRUE	10	2	BI71	2	FALSE			
BO20	Enable Active Power Response Mode #1	FALSE	TRUE	10	2	BI72	2	FALSE			
BO21	Enable Active Power Response Mode #2	FALSE	TRUE	10	2	BI73	2	FALSE			
BO22	Enable Active Power Response Mode #3	FALSE	TRUE	10	2	BI74	2	FALSE			
BO23	Enable Automatic Generation Control Mode	FALSE	TRUE	10	2	BI75	2	FALSE			
BO24	Enable Active Power Smoothing Mode	FALSE	TRUE	10	2	BI76	2	FALSE			
BO25	Enable Volt-Watt Mode	TRUE	TRUE	10	2	BI77	129	TRUE			
BO26	Enable Frequency-Watt Curve Mode	FALSE	TRUE	10	2	BI78	2	FALSE			
BO27	Enable Constant VArs Mode	TRUE	TRUE	10	2	BI79	129	TRUE			
BO28	Enable Fixed Power Factor Mode	TRUE	TRUE	10	2	BI80	1	FALSE			
BO29	Enable Volt-VAR Control Mode	TRUE	TRUE	10	2	BI81	129	TRUE			
BO30	Enable Watt-VAr Mode	TRUE	TRUE	10	2	BI82	1	FALSE			

Source: EPRI

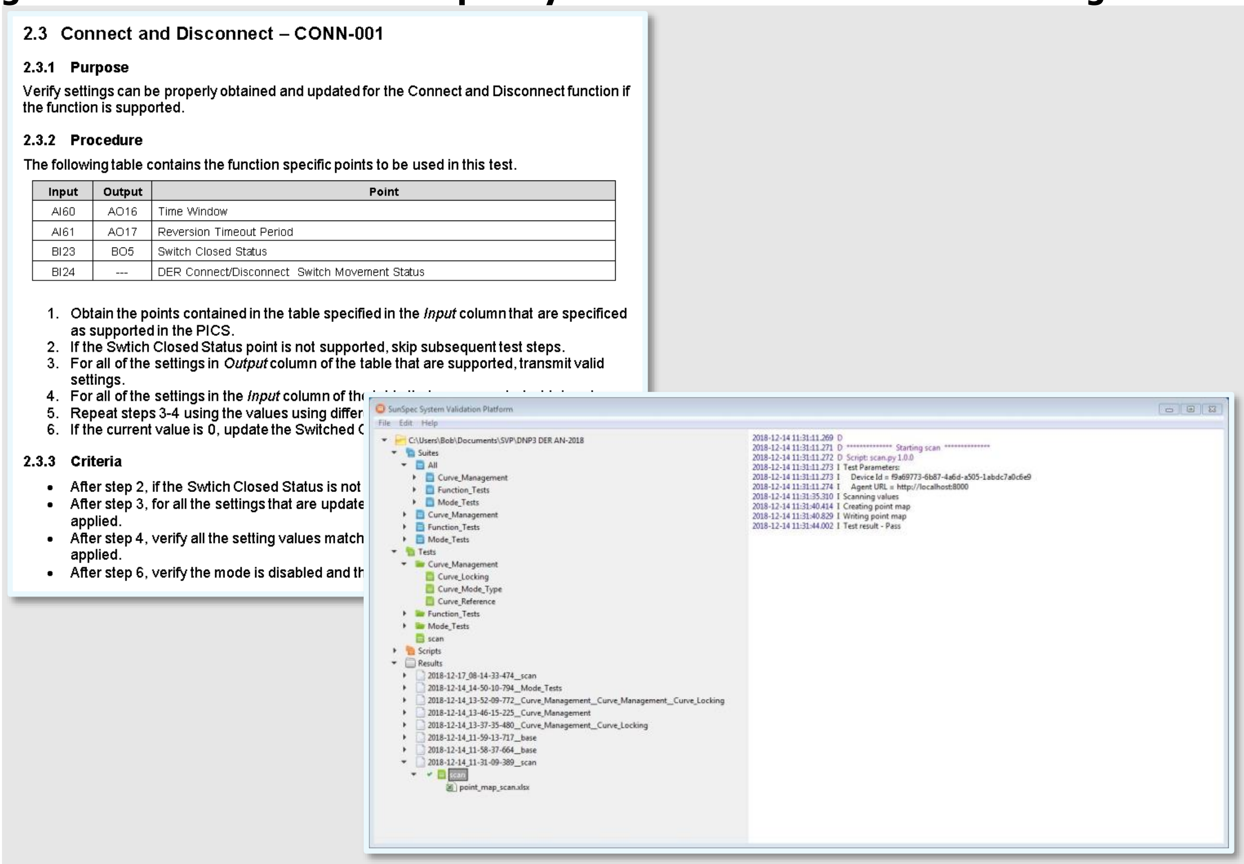
Application Note AN2018-001 contains ~1,300 possible parameters. This includes about 340 Binary Inputs, 50 binary outputs, 630 analog inputs, and 340 analog outputs. Manually completing the PICS is laborious due to the considerable number of parameters. This may lead to errors in completing the PICS. Therefore, SunSpec developed an automated approach to use the SunSpec System Validation Platform (SVP) to automatically populate the PICS with supported and unsupported values based on the standard definitions for supported and unsupported values as defined in the application note. An entity sending their product for testing would then review the automatically created PICS for errors. Any errors are signs of implementation issues in the product under testing.

SunSpec Test Software

Testers must be to send and receive messages from the DER device being tested to figure out if it supports DNP3 correctly. SunSpec leveraged their existing SunSpec SVP to create scripts to automate testing and validation of pass/fail criteria using the DNP3 Process Logic. The scripting ability of SunSpec SVP simplifies this process by allowing testers to create scripts to administer each test and verify the response. This streamlines testing, increases testing efficiency, and reduces human error.

The SunSpec SVP, as shown in **Error! Reference source not found.**Figure 10, is offered by the SunSpec Alliance.[22]

Figure 10: Screenshot of SunSpec System Validation Platform Running DNP Tests



Source: EPRI

Summary

The project closed gaps in older communication models, which did not support full capabilities of smart inverters and energy storage. These modifications add new capabilities for utility grid operators to use and unlock emerging capabilities of DER. It complies with functional requirements in California Rule 21 and IEEE 1547-2018. The project also created open source software and a conformance framework. The open source code supports implementation of the updated communications models and give examples of how the protocol can be implemented in smart inverters. The conformance framework gives example test procedures and pass/fail criteria to help reduce the risk of interoperability issues through issues related to conformance to the standard.

The next chapter summarizes the mechanisms the project team used to disseminate the knowledge gained and technology developed in the project.

CHAPTER 4: Technology and Knowledge Transfer, and Market Facilitation

Technology and knowledge transfer played a significant role in this project to ensure that the industry can use the project outcomes. The project team held discussions to identify gaps in existing capabilities in systems, recommended updates to existing standards to fill these gaps, developed open source software to help manufacturers and others implement the updated DNP3 standards, and developed a conformance testing framework and processes to ensure that implementations comply with the requirements in the updated standards. All these activities needed significant outreach to the industry in the form of collecting information to identify gaps, discussing with manufacturers to understand characteristics of open source software that helps them apply it, and sharing what has been accomplished so it can be applied. The essential point is that the work in this project must be applied to be useful and without strong knowledge and technology transfer efforts, this is unlikely to happen.

Technology and Knowledge Transfer Mechanisms

The project knowledge was made available to the public and industry (inverter and DER manufacturers, end users, utilities, regulatory agencies, and others) using methods and distribution channels that promote the adoption of the resulting communication technology into products and services for the grid. The knowledge transfer was delivered through five key mechanisms. Each mechanism was tailored to target key audiences. A summary of the mechanism and number events is shown in **Error! Reference source not found.**Figure 11.

Figure 11: Summary of Technology and Knowledge Transfer Mechanisms

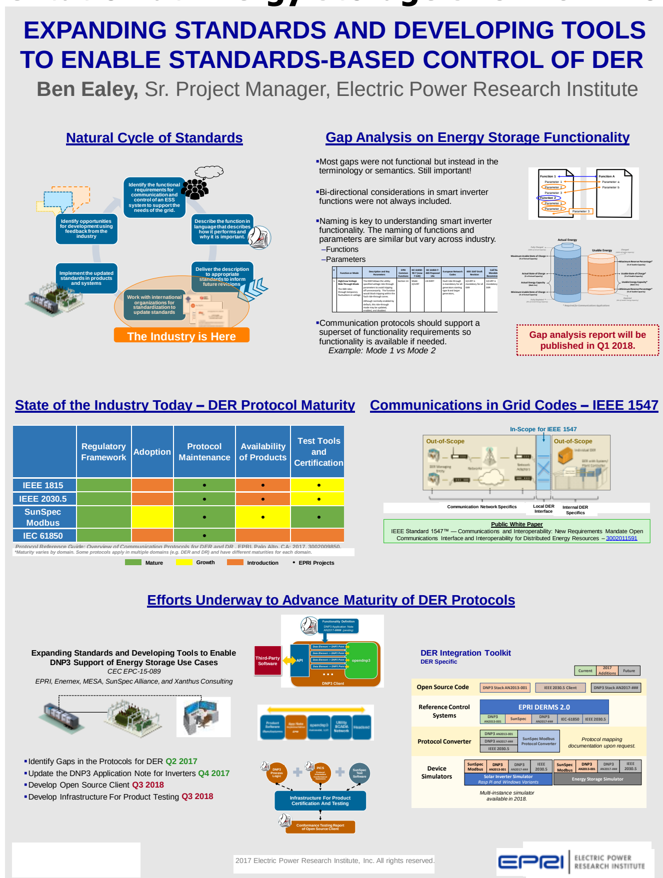
Source: EPRI

The following sections give overviews of these transfer mechanisms and examples.

Conferences and Meetings

Presentations at conferences and meetings collected information and informed next steps in the project while sharing accomplishments so far. These transfer activities ranged from workshop presentations, poster sessions, and face-to-face discussions. Figure 12 shows an example of a poster presentation at the Energy Storage Alliance's (ESA) studio conference.

Figure 12: Poster Presentation at Energy Storage STUDIO – November 14-15, 2017



Source: EPRI

Webinars

For the duration of the project, webinars (or webcasts) served as a way of sharing information with interested parties. Often, webinars are ideal since they disseminate information without requiring travel from the project members or the interested parties.

Electronic Mails and Technical Reports

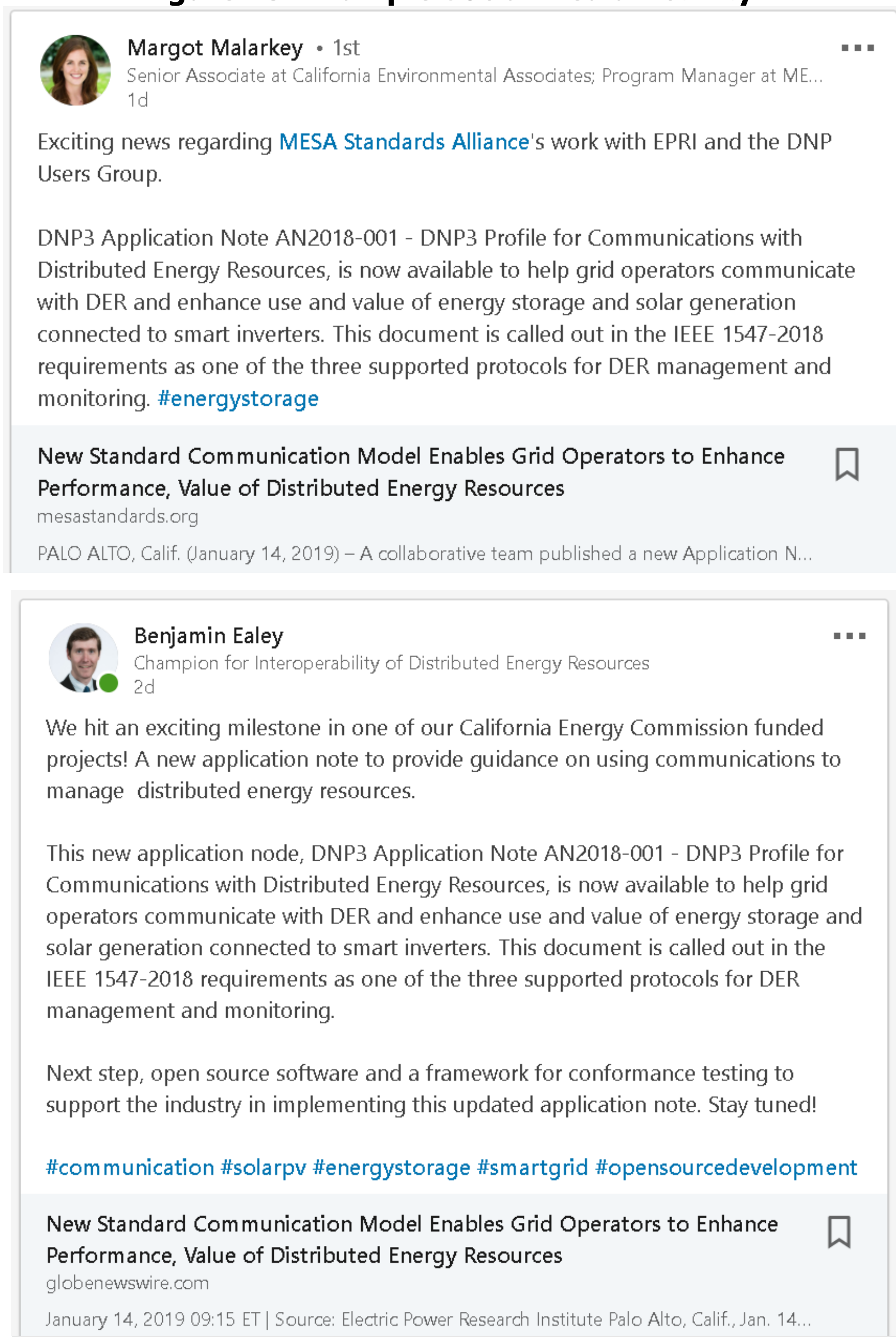
Electronic mail (email) was used to deliver updates on milestones to interested parties. The team also published reports to share the project and results.

Press Releases and Social Media

EPRI and the project team issued press releases and social media posts on key milestones to alert the industry and media outlets. In addition, the project's technical advisory committee proposed the creation of a project website to summarize the different resources created in this project and where to access them. EPRI is currently exploring options.

Figure 13 shows an example social media activity using LinkedIn.

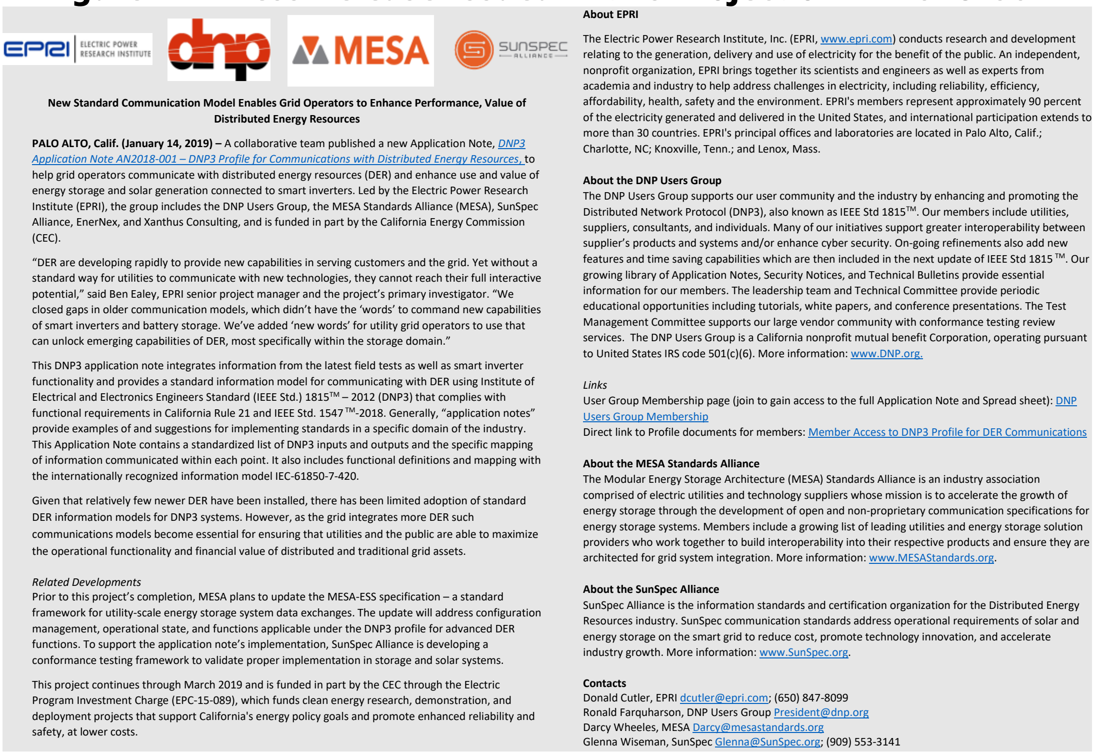
Figure 13: Example Social Media Activity



Source: EPRI

Figure 14 shows the knowledge transfer conducted through press releases.[32]

Figure 14: Press Release Issued in this Project on AN2018-001



New Standard Communication Model Enables Grid Operators to Enhance Performance, Value of Distributed Energy Resources

PALO ALTO, Calif. (January 14, 2019) – A collaborative team published a new Application Note, *DNP3 Application Note AN2018-001 – DNP3 Profile for Communications with Distributed Energy Resources,* to help grid operators communicate with distributed energy resources (DER) and enhance use and value of energy storage and solar generation connected to smart inverters. Led by the Electric Power Research Institute (EPRI), the group includes the DNP Users Group, the MESA Standards Alliance (MESA), SunSpec Alliance, EnerNex, and Xanthus Consulting, and is funded in part by the California Energy Commission (CEC).

"DER are developing rapidly to provide new capabilities in serving customers and the grid. Yet without a standard way for utilities to communicate with new technologies, they cannot reach their full interactive potential," said Ben Ealey, EPRI senior project manager and the project's primary investigator. "We closed gaps in older communication models, which didn't have the 'words' to command new capabilities of smart inverters and battery storage. We've added 'new words' for utility grid operators to use that can unlock emerging capabilities of DER, most specifically within the storage domain."

This DNP3 application note integrates information from the latest field tests as well as smart inverter functionality and provides a standard information model for communicating with DER using Institute of Electrical and Electronics Engineers Standard (IEEE Std.) 1815™ – 2012 (DNP3) that complies with functional requirements in California Rule 21 and IEEE Std. 1547™-2018. Generally, "application notes" provide examples of and suggestions for implementing standards in a specific domain of the industry. This Application Note contains a standardized list of DNP3 inputs and outputs and the specific mapping of information communicated within each point. It also includes functional definitions and mapping with the internationally recognized information model IEC-61850-7-420.

Given that relatively few newer DER have been installed, there has been limited adoption of standard DER information models for DNP3 systems. However, as the grid integrates more DER such communications models become essential for ensuring that utilities and the public are able to maximize the operational functionality and financial value of distributed and traditional grid assets.

Related Developments
Prior to this project's completion, MESA plans to update the MESA-ESS specification – a standard framework for utility-scale energy storage system data exchanges. The update will address configuration management, operational state, and functions applicable under the DNP3 profile for advanced DER functions. To support the application note's implementation, SunSpec Alliance is developing a conformance testing framework to validate proper implementation in storage and solar systems.

This project continues through March 2019 and is funded in part by the CEC through the Electric Program Investment Charge (EPC-15-089), which funds clean energy research, demonstration, and deployment projects that support California's energy policy goals and promote enhanced reliability and safety, at lower costs.

About EPRI

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'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, NC; Knoxville, Tenn.; and Lenox, Mass.

About the DNP Users Group
The DNP Users Group supports our user community and the industry by enhancing and promoting the Distributed Network Protocol (DNP3), also known as IEEE Std 1815™. Our members include utilities, suppliers, consultants, and individuals. Many of our initiatives support greater interoperability between supplier's products and systems and/or enhance cyber security. On-going refinements also add new features and time saving capabilities which are then included in the next update of IEEE Std 1815™. Our growing library of Application Notes, Security Notices, and Technical Bulletins provide essential information for our members. The leadership team and Technical Committee provide periodic educational opportunities including tutorials, white papers, and conference presentations. The Test Management Committee supports our large vendor community with conformance testing review services. The DNP Users Group is a California nonprofit mutual benefit Corporation, operating pursuant to United States IRS code 501(c)(6). More information: www.DNP.org.

Links
User Group Membership page (join to gain access to the full Application Note and Spread sheet): DNP Users Group Membership
Direct link to Profile documents for members: Member Access to DNP3 Profile for DER Communications

About the MESA Standards Alliance
The Modular Energy Storage Architecture (MESA) Standards Alliance is an industry association comprised of electric utilities and technology suppliers whose mission is to accelerate the growth of energy storage through the development of open and non-proprietary communication specifications for energy storage systems. Members include a growing list of leading utilities and energy storage solution providers who work together to build interoperability into their respective products and ensure they are architected for grid system integration. More information: www.MESAStandards.org.

About the SunSpec Alliance
SunSpec Alliance is the information standards and certification organization for the Distributed Energy Resources industry. SunSpec communication standards address operational requirements of solar and energy storage on the smart grid to reduce cost, promote technology innovation, and accelerate industry growth. More information: www.SunSpec.org.

Contacts
Donald Cutler, EPRI dcutler@epri.com; (650) 847-8099
Ronald Farquharson, DNP Users Group President@dnp.org
Darcy Wheeles, MESA Darcy@mesastandards.org
Glenna Wiseman, SunSpec Glenna@SunSpec.org; (909) 553-3141

Source: EPRI

Working Groups

Working groups are mechanism to collectively address industry-wide problems. In this project, the working groups engaged included members from standards efforts like IEEE 1547-2018, EPRI's Energy Storage Integration Council, DNP Users Groups, and working groups behind standards and industry organizations like SunSpec and MESA.

Project Audiences for Technology Transfer

The target audience for the technology transfer mechanisms varies by the project activity. The follow section highlights key audiences that aided with the project outcomes.

Open Collaborative Working Group

The team convened a public Open Collaborative Working Group to review the capabilities of energy storage systems. The group was diverse and consisted of utilities, public utility commissions, manufacturers, system designers, and researchers. This group walked through each of the benefits and applications for energy storage systems to improve the efficiency,

32 Press Release: New Standard Communication Model Enables Grid Operators to Enhance Performance, Value of Distributed Energy Resources. Electric Power Research Institute, DNP Users Group, MESA Standards Alliance, SunSpec Alliance. https://www.dnp.org/Portals/0/Public%20Documents/PR%201112%20App%20Note%20Press%20Release_2019-01-14_FINAL.pdf. Accessed March 2019

safety, security, and resiliency of the grid and then compared this to the capabilities defined in modern standards and guidance documents.

The Open Collaborative Working Group consisted of 110 expert volunteers at 83 companies. These 83 companies are listed in Appendix A.

Other Standards Groups

There are four key protocols for communicating with DER: IEC-61850, IEEE 2030.5, SunSpec Modbus, and IEEE 1815 (DNP3). This project focused on IEEE 1815 however the other standards were all in revision and working groups were meeting in parallel with this project's efforts. Ideas were shared between these groups so that the industry could tackle these issues together and solve them across all communications protocols. One of the key benefits this effort provided to other standards groups was information about expanding storage functionality.

Trade Organizations

The project team consisted of two member-based industry trade organizations: MESA Standards Alliance and SunSpec Alliance.

- MESA Standards Alliance: The Modular Energy Storage Architecture (MESA) Standards Alliance is an industry association comprised of electric utilities and technology suppliers whose mission is to accelerate the growth of energy storage through the development of open and non-proprietary communication specifications for energy storage systems. Members include a list of utilities and energy storage solution providers who work together to build interoperability into their respective products and ensure they are architected for grid system integration.
- SunSpec Alliance: SunSpec Alliance is an information standards and certification organization for the Distributed Energy Resources industry. SunSpec communication standards address operational requirements of solar and energy storage on the smart grid to reduce cost, promote technology innovation, and accelerate industry growth.

The respective alliance members filled a key role in technology transfer. They represented members of the manufacturer and utility communities that are interested in communications capabilities in solar and storage systems. These groups brought key information to help inform the direction of the project but also serve as the key benefactors of the results.

EPRI Program Members

Program members from Electric Power Research Institute (EPRI) – which conducts research and development relating to the generation, delivery and use of electricity for the benefit of the public – were engaged in the project. As 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 program members were informed on project details from start to end with the goal of keeping them engaged with key milestones, collect information to help guide the project, and give training on ways that the project could be useful to them. These meetings ranged from

30 attendees at in-person meetings to email and webcasts including over 260 individuals across 66 companies.

DNP Users Group

The DNP Users Group, a California nonprofit mutual benefit corporation, supports the DNP3 user community and the industry by enhancing and promoting the Distributed Network Protocol (DNP3). The members include utilities, suppliers, consultants, and individuals. Many of DNP User Group initiatives support interoperability between supplier's products and systems and/or enhance cyber security. On-going refinements also add new features and time saving capabilities, which are then included in the next update of IEEE 1815. The DNP User Group leadership team and Technical Committee give periodic educational opportunities including tutorials, white papers, and conference presentations. The Test Management Committee supports the large vendor community with conformance testing review services.

The DNP Users Group is the home of application notes and guidance on applying DNP3. Their collaboration in this project was important for both completing the work but also for ensuring it continues beyond this project. As the organization tasked with keeping and supporting the application note, they will be key in the continued application and relevancy of the work in this project.

Product Manufacturers

Manufacturers of DER products and developers of software platforms to manage these resources are a key group in application of the project results. Outreach was partially achieved through organizations such as MESA and SunSpec. However, additional outreach was performed through press releases, social media, conferences, workshops, and working groups. The goal was to make sure these organizations were aware of the available resources (software and conformance testing) and any changes that may have occurred in the application note.

IEEE 1547 Working Group Members

This DNP3 application note integrates information from the latest field tests as well as smart inverter functionality and provides a standard information model for communicating with DER using IEEE 1815. DNP3 complies with functional requirements in California Rule 21 and IEEE 1547-2018. It was strategic to engage with this group to make sure the requirements matched the most recent version of the application note. This was achieved through participating in the IEEE 1547 working group and aiding with the development of pass/fail criteria for the associated conformance testing (IEEE 1547.1).

CHAPTER 5: Conclusions and Recommendations

The project closed gaps in older communication protocols which did not support full capabilities of smart inverters and energy storage. These modifications add new capabilities for utility grid operators to use that can unlock emerging capabilities of DER. It complies with functional requirements in California Rule 21 and IEEE 1547-2018. The project also created open source software and a conformance framework. The open source code supports implementation of the updated communications models and give examples of how the protocol can be implemented in smart inverters. The conformance framework provides example test procedures and pass/fail criteria to help reduce the risk of interoperability issues through issues related to conformance to the standard. Overall, this project has improved the ability of grid operators to communicate with distributed energy resources (DER), created tools to help accelerate adoption of new standards, and enhanced the use and value of energy storage and solar generation connected to smart inverters.

Project Findings

The core project findings, which are linked to the goals, are in four areas.

The Gap Analysis

- Compares the capabilities of solar PV and energy storage to the functionalities supported in the current smart inverter communication standards – IEEE 2030.5, IEEE 1815/DNP3, IEC-61850-7-420, and SunSpec Modbus. This includes feedback from the project’s open, collaborative working group (110 expert volunteers from 83 companies).
- Leverages existing work including global, industry-wide efforts over the past decade to define smart inverter functionality. Examples include working groups in efforts such as IEC 61850-7-420, IEEE 2030.5, SunSpec Modbus, IEEE 1547-2018, and California’s Smart Inverter Working Group.
- Identified six key capabilities in smart inverters for DER that must be added or changed significantly in industry documents. This includes frequency/watt, watt/volt-ampere reactive (VAR), connect/disconnect + cease to energize, peak power limiting / load following / generation following, constant VAR mode, and scheduling capabilities.
- Highlighted harmonization issues in terminology and functional descriptions. The team addressed these issues by adding more robust state of charge language; support for referencing meters in the field; harmonizing between previously confusing overlaps in different state, status, and monitoring data points; and harmonizing functional descriptions across different industry stakeholders and grid codes.

The Application Note Development

- Filled the key gaps in the existing standard for using DNP3 in DER applications (DNP AN2013-001). The updates include expanding the functionality needed for maximizing the value of storage systems, bringing the application note up to date with smart inverter functionality, and conforming with requirements in grid codes including all phases of California Rule 21 and the 2018 update to IEEE 1547.

- Led to the DNP Users Group publishing DNP Application Note AN2018-001: DNP3 Profile for Communications with Distributed Energy Resources in August 2018. AN2018-001 is based on the draft provided through this project. AN2018-001 is available on the DNP Users Group webpage to members of the DNP Users Group. It is also provided at no fee to MESA Standards Alliance and SunSpec Alliance members under an agreement with the DNP Users Group.
- Builds on earlier versions of smart inverter-based DNP3 profiles including DNP Application Note AN2011-001, DNP Application Note AN2013-001, and the MESA Standards Alliance's November 2016 MESA-ESS specification.
- Supported industry acceptance of the new standard. The updated application note (DNP AN2018-001) is referenced in IEEE 1547-2018 as the requirement for using DNP3 in DERs. It is listed alongside SunSpec Modbus and IEEE 2030.5. At least one of the three must be implemented per IEEE 1547-2018.

The Open Source DNP3 Outstation

- Absorbs the complexities of the new standard, simplifies software development, and accelerates adoption of the new standard by providing example code for implementing smart inverter functionality following DNP Application Note AN2018-001. The outstation is open source (BSD-3 Clause) and is available from EPRI's GitHub page.

The Framework for Conformance Testing

- Validates interoperability with the new standard application note. The framework includes thirty-one test cases, associated pass/fail criteria, and software to automate and hasten testing.
- Fills a critical industry gap for validating California Rule 21 conformance when using DNP3. CA Rule 21 allows protocols other than the default, IEEE 2030.5, but does not define standard test procedures as it does with IEEE 2030.5. The conformance framework developed in this project fills this gap.

Recommendations and Next Steps

Industry Application of Communication Standards

Interoperability standards and conformance testing can ease integration of DER by defining and evaluating interoperability requirements upfront. This can expedite integration, reduce costs, and support long-time use of the asset. This project updated one such interoperability standard and created tools to help the industry adopt it. It is now up to the industry to adopt these standards. Utilities will need to consider them when designing new DER to take advantage of the benefits. Public utility commissions will need to decide whether they want to mandate these standards and if they want to create their own requirements or reference existing language in interconnection documents like California's Rule 21 or IEEE 1547-2018 standards.

Cyclical Nature of Standards

Intelligent and flexible grids are a popular topic in the industry. At the heart of these discussions are communications capabilities in devices of all types and their continued use in the fast-changing technology landscape. Therefore, the process for updating standards is inherently iterative. Each project, product, and study inform the next iteration of standards development. New unforeseen issues may appear that can be addressed by distributed energy resources. Manufacturers and research labs may create new capabilities, features, and functionalities for DER. The industry may identify issues in existing standards like ambiguous language. In general, standards work is never truly complete. Standards must be revised periodically to the changing technology landscape and the needs of the industry.

Backwards Compatibility

The rapid increase in the interest in communications in DER is increasing the number of pilots and demonstrations. This will result in an increase in the rate of feedback to the industry on standards to control and monitor DER. As working groups update standards to address these new use cases, backwards compatibility is important for existing systems to seamlessly integrate without expensive upgrades to DER and/or control systems like DERMS. If not considered, a lack of backwards compatibility can cause fragmentation in standards requiring that utilities and manufacturers support legacy versions of these standards to avoid losing resources already installed in the field, a costly endeavor. In addition, manufacturers will have to "rebuild" their code resulting in additional expenses. It will be premature to say how far back the backward compatibility must go since it depends on various factors such as standards design, technology proliferation, update cycle, etc. However, any update to the standards must consider backward compatibility requirements and make technical and economic assessments before determining any alternate case.

It is inevitable changes will eventually break backwards compatibility but working groups should be mindful and work to minimize changes that may prevent backwards compatibility.

On-going Conformance Testing and Management

Standards for smart inverter communications are relatively new to the industry but are rapidly gaining popularity as utilities are seeing benefits in controlling smart inverters to provide visibility in generation of DER and providing controllability of these resources. Many of the DER-supported standards have been around for a long time (e.g., Modbus, DNP3, and IEC-61850) and are used across the world for managing distribution system equipment. However, the application of advanced smart inverter functions are new additions. This means that the industry is learning how to apply these standards in the smart inverter domain.

Conformance frameworks are appearing for many of the communications standards, but more development is needed to create a sustainable model that encourages certification testing. Some of the development activities are listed below.

1. The industry needs companies to take on certification and continue the work of projects that are designed to give those processes a forward pathway. Organizations like the SunSpec Alliance perform certification testing for many communication protocols for smart inverters. IEEE and the DNP Users Group are also scaling up operations to certify these standards.

2. The industry needs to find applications for these certifications to encourage manufacturers to complete certification. Key benefits include awareness that products support these communications capabilities. However, some groups are also looking at mandating conformance testing. Standards like IEEE 1547-2018 require communication certification, but it is up to utilities and public utility commissions to weigh whether they want to enforce those requirements in their territories. In California Rule 21 there are no requirements for certification, so utilities or system integrators must decide whether this is important to them.
3. The certification programs must be maintained and improved over time by member-facing organizations such as SunSpec Alliance and IEEE. The framework developed in this project serves as a starting point, but organizations interested in performing testing will need to develop their own business practices and processes and refine the technical and business aspects of testing and certification program over time.

End-to-End Interoperability Conformance

Interoperability is the ability of two or more systems to exchange information and to use the information that has been exchanged. The benefits of interoperability can include reducing the cost and effort of system integration, improving grid performance and efficiency, facilitating more comprehensive grid security and cybersecurity practices, increasing customer choice and participation, establishing industry-wide best practices, and provides a catalyst of innovation.[33] There are two main components to interoperability in DERs.

1. The ability to exchange information. This ability defines the capability of two systems to connect with each other and exchange information.
2. The ability to use the information being exchanged correctly. This refers to understanding the meaning (or semantics) of the data exchanged over the protocol and acting on it appropriately.

Conformance testing is needed to validate that DER technologies receive communication signals and can provide the expected electrical response, known as end-to-end testing.

Conformance testing has mostly focused on the ability of information exchange among systems. While there are conformance tests available to test a device behavior, there are no conformance programs that define testing from origination of the signal to the resulting electrical response from the device. The recent *IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces* is the first to attempt to address this through requirements for communications and end-to-end testing required through IEEE 1547.1. IEEE 1547.1 defines the testing criteria for certifying to IEEE 1547 and is one of the first end-to-end interoperability test procedures. Hence, the IEEE 1547 working group was careful not to take on too much at once because the industry is still learning about the use of communications to control smart inverters. More work will be needed to apply this new testing paradigm and refine it over time.

33 Interoperability Strategic Vision. A GMLC White Paper. Grid Modernization Laboratory Consortium. U.S. Department of Energy. March 2018. https://gridmod.labworks.org/sites/default/files/resources/InteropStrategicVisionPaper2018-03-29.pdf. Accessed March 2019.

CHAPTER 6: Benefits to Ratepayers

The goal of this project is to update the incumbent communications protocols in support of requirements in California Rule 21, IEEE 1547-2018 standards, industry needs, and develop tools and facilitate industry engagement to accelerate adoption. The project provides benefits to California through greater utilization of energy storage systems that will increase grid flexibility. Improved flexibility will benefit the utility's infrastructure, operations, and energy security, and enable the state to meet the high renewable energy deployment mandates, which can benefit ratepayers in the form of lower costs and improved air-quality. Specific ratepayer benefits of this project include:

Lower System Deployment Costs

This project may lower costs to ratepayers by improving:

- Efficiency, safety, and security of the grid.
- Upfront conformance through conformance testing.
- Grid and customer-system interoperability.

Grid Reliability

- Energy storage technology is a grid flexibility resource that can help utilities maintain grid reliability by allowing them to generate or consume energy on the grid. This project will expand the capability of utilities to control energy storage systems, which provides them with opportunities to maximize flexibility that considers customer benefits.

Safety Through Grid Stability

- Ratepayers may realize safety benefits from energy storage systems improving the stability of the grid by offering increased flexibility in the use of energy. Examples of increased flexibility include energy storage participation in frequency support, peak load reduction, frequency and voltage anomaly ride-through, conservation voltage reduction, and alleviating distribution feeder overloads.

Ease of Adoption

- Open-source tools are often associated with economic development because they provide collaboration in innovation. This will save companies money and make it easier for new companies to compete in this field, which can increase the number of products on the market. This results in cheaper products and an increase in innovation and competition in the market.

Improving Renewable Integration

- Environmental benefits of this project would stem from realizing the advanced use cases for energy storage that help reduce peaks and minimize the need for generators to provide support at peak times.

Benefits of Individual Tasks

The first benefit will come from advancing the DNP3 specifications to include an expanded set of smart inverter functions and actions, which will help utilities and their ratepayers realize the benefits from use cases not currently available from DER systems. This particularly applies to storage systems because when the project began there was a lack of support from standards-based communications. It is difficult to calculate the quantitative benefit of this because of the large variety of use cases, but a few examples of use cases include participation in frequency support, peak load reduction, frequency and voltage anomaly ride-through, conservation voltage reduction, and alleviating distribution feeder overloads. Each of these use-cases has a direct financial benefit to the ratepayers by improving the efficiency, safety, and security of the grid. In addition, by providing utilities with control over DER systems, far more DER systems can be accommodated safely and efficiently on the power system, thus permitting California to meet its 50% renewable goal.

The advanced features needed for some of the energy storage use cases may only be realized today by using proprietary systems. This requires expensive, one-off software development costs, on-going maintenance problems as systems are upgraded, and a potential for vendor lock-in. Further expanding DNP3 to support the most advanced inverter functions will allow the IOUs to use their existing DNP3 systems to manage storage systems directly, and if DNP3's cyber security is implemented, to ensure secure interactions. This has the potential to save millions in integration costs and avoids possible costly attacks. To simplify the cost benefit calculation below a conservative estimate of $1 million in benefits is used.

The second benefit is from the certification tool for the DNP3 specifications. The development of the certification tool will help reduce the number of products that reach the market and do not comply with the current specifications. Often standards can be implemented differently depending on whether the developer misreads the standard or a portion of the standard was vague. The certification tool will reduce the risk of these mistakes making it to production by providing manufacturers a tool to validate their work. It will also provide the IOUs a tool to test new products to ensure they comply and, therefore, work on their system. This increased certainty has direct financial benefit. Consider this example. The CPUC targets 1.325GW of energy storage procurement by 2020. Assuming an average cost of procured energy, storage projects is $2,000 per kW then the 1.325 GW of addition energy storage will cost California $2.65 billion. Often administrative costs of these programs can be as high as 20 percent, or $530 million in this example. These costs can include conformance testing and M&V to ensure the product will provide the benefits expected. If certification can shave 1 percent off of the administrative costs, a conservative estimate, the savings is $5.3 million. This savings is over 5x the cost of this project. Utilities will be able to include certification as one of their requirements for participation in programs.

A third benefit is the decreased cost to include the open, DNP3 specifications in products including solar, energy storage, and electric transportation by offering open-source software. Manufacturers will realize initial benefits. The team's proposal included $118,000 in work to develop an open-source DNP3 client to support advanced inverter specifications. This produced software that companies can directly integrate into their existing software to create a pre-tested, DNP3 enabled product. The secondary impact of this will be an increase in the number of products available that support the DNP3 client because the hard work of developing the client has been completed. This will reduce the time spent testing and troubleshooting communication issues by essentially making the devices “plug-and-play”. Assuming 25 manufacturers use this tool, the $118,000 spent to develop this tool will have been leveraged 25 times. It can be assumed that manufacturers will spend at least this much per project developing their own code. With 25 manufacturers this is a benefit of $2.95 million. In addition to this, EPRI and SunSpec have spent hundreds of thousands of dollars developing the expertise to make certification and open-clients a success. This project leverages their investment.

GLOSSARY AND LIST OF ACRONYMS

Term	Definition
Distributed Energy Resource (DER)	Generation, storage, and controllable load interconnected to the distribution electric power system
DER System	One or more DER units that have a common DER controller (e.g. PV unit plus energy storage unit with a single controller, multiple energy storage units with a single controller)
DNP3	Distributed Network Protocol (DNP) standardized in IEEE 1815 and used by most utility SCADA systems (see below for definition) in the United States to monitor and control substation equipment
Electrical Connection Point (ECP)	The point of electrical connection between a DER system and any electric power system or EPS (see below for definition)
Electric Power System (EPS)	The facilities that deliver electric power to a load or from generation
EPS, Area	The electric power system (EPS) that serves Local EPSs
EPS, Local	An EPS contained entirely within a single premises or group of premises
Energy Storage System (ESS)	A system that can store energy and release that energy as electricity
Independent System Operator (ISO)	Utility managing the balancing of generation and load within a control area by reflecting the bulk power market while still meeting the power system reliability requirements
Inverter	Converts from direct current (DC) to alternating current (AC).
Referenced ECP	The ECP that a DER's function references as the source of power system measurements. Usually this is either the ESS's ECP or the PCC, but other ECPs may be referenced.
Supervisory Control and Data Acquisition (SCADA)	System used by utilities and other facilities for controlling and monitoring power system equipment

REFERENCES

Common Functions for Smart Inverters: 4th Edition. EPRI, Palo Alto, CA: 2016. 3002008217.

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. 3002011045.

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.

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.

Common Functions for DER Group Management, Third Edition. EPRI, Palo Alto, CA: 2016. 3002008215.

The Value of Direct Access to Connected Devices. EPRI, Palo Alto, CA: 2017. 3002007825

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. Accessed March 2019

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. Accessed March 2019

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. Accessed March 2019

Tucson Electric Power Project RAIN. EPRI, Palo Alto, CA: 2018. 3002014812

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. Accessed March 2019

IEEE Standard 1547™ — Communications and Interoperability: New Requirements Mandate Open Communications Interface and Interoperability for Distributed Energy Resources. EPRI, Palo Alto, CA: 2017. 3002011591

California Public Utilities Commission (CPUC), "Rule 21 Interconnection," Accessed February 2019, http://www.cpuc.ca.gov/Rule21/. Accessed March 2019

Institute of Electrical and Electronics Engineers (IEEE) Standards Association, "IEEE 2030.5-2013: IEEE Adoption of Smart Energy Profile 2.0 Application Protocol Standard," https://standards.ieee.org/standard/2030_5-2013.html. Accessed March 2019

Institute of Electrical and Electronics Engineers (IEEE) Standards Association, "IEEE 1815-2012: IEEE Standard for Electric Power Systems Communications—Distributed Network Protocol (DNP3), https://standards.ieee.org/standard/1815-2012.html. Accessed March 2019

DNP Users Group, DNP3 Application Note AN2018-001 - DNP3 Profile for Communications with Distributed Energy Resources. January 2019, https://www.dnp.org/LinkClick.aspx?fileticket=BiDPDkwxy70%3d&portalid=0&timestamp=1553622205077. Accessed March 2019.

SunSpec Alliance, SunSpec Specifications & Information Models, https://sunspec.org/download/. Accessed March 2019

California Independent Systems Operator (CAISO), "New Resource Implementation Guide, v29," April 2018, http://www.caiso.com/Documents/NewResourceImplementationGuide.doc. Accessed March 2019

APPENDIX A:
Open Collaborative Working Group

The team convened a public Open Collaborative Working Group to review the capabilities of energy storage systems. The group was diverse and consisted of utilities, public utility commissions, manufacturers, system designers, and researchers. This group walked through each of the benefits and applications for energy storage systems to improve the efficiency, safety, security, and resiliency of the grid and then compared this to the capabilities defined in modern standards and guidance documents. The Open Collaborative Working Group consisted of 110 expert volunteers across 83 companies. These 83 companies are listed below in alphabetical order.

8minutenergy

ABB Group

ALVEO Energy

Amber Kinetics

Ameren Services

Austin Energy

Austin Energy

Baltimore Gas and Electric Company

Cadmus Group

California Energy Commission

California ISO

Case Western Reserve University

CleanTech Energy, Inc

CSA

DNP Users Group

DNVGL

Doosan Gridtech

Duke Energy

DVN GL

Eaton

El Paso Electric

Electric Power Research Institute (EPRI)

Enernex

Esstalion Technologies Inc.

Exelon Corporation

FirstEnergy Corp

Greenlots

Hawaiian Electric Company, Inc.

Highview Power

Hoffman Power Consulting

JSR Micro, Inc.

Korea Electric Power Corporation

Lawrence Berkeley National Lab

Leidos

Lockheed Martin Corporation

MESA Standards Alliance

Mike Barker and Associates CC

Mitsubishi Electric Power Products, Inc.

National Electrical Manufacturing Association

NEC ENERGY SOLUTIONS

Net Contents

Next Era Energy

Nuvation

NV5

Oncor Electric Delivery Company LLC.

Open Access Technology International, Inc

Open ADR

OpenADR Alliance

Pacific Gas and Electric Company

Pacific North West Laboratory

PacificCorp (Pacific Power)

PARKER HANNIFIN CORP

PowerHub Systems

PSE

QuantumScape Corporation

Renewable Energy Systems Ltd

Retriev Technologies

S&C Electric Company

Sacramento Municipal Utility District

Sacramento Municipal Utility District

Saft owned by Total

Sandia National Laboratories

Snohomish Public Utility District

SOCORE ENERGY

Southern California Edison

Stanford University

Stem

Strateture Solutions

SunSpec Alliance

SunSpec Alliance

Sunverge Energy Inc

Technische Universität München

Toshiba International Corporation

Tri-State Generation & Transmission

UniEnergy Technologies

University of California SanDiego

Verday LLC

Vestas

VIONX Energy Corporation

vZ Energy Inc

Xanthus Consulting International

Xcel Energy

Younicos

APPENDIX B: Extended Summary of Gap Analysis

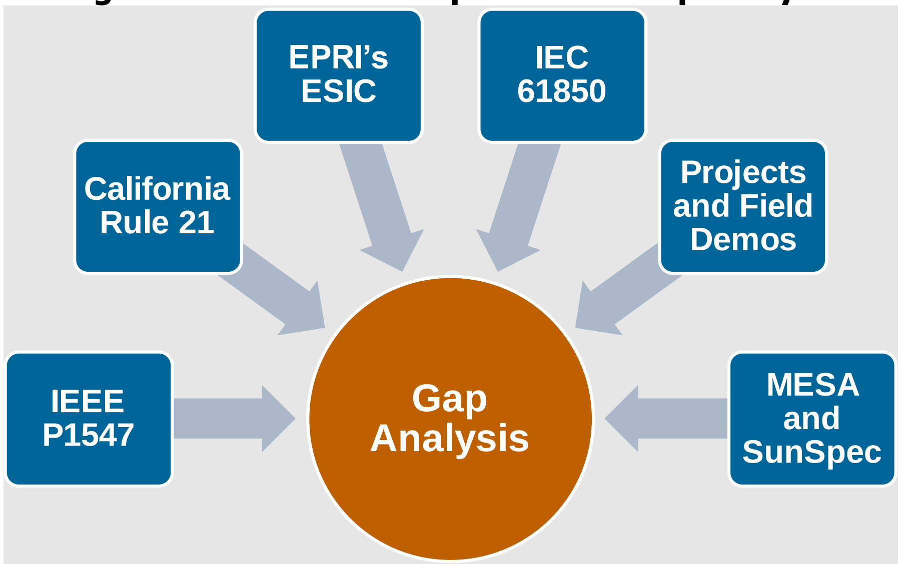
Note: The extended summary is from the project deliverable *Documentation of Functional Gaps*. It was completed June 2017. Industry discussions have advanced since completion, so discussions captured below may not reflect the most recent industry findings.

Now that storage is being called out in many utility roadmaps and energy commission goals, it is important that standards support their full set of capabilities. The project team reviewed the currently available smart inverter functions to identify gaps and harmonize industry activities across stakeholder groups. The functions include the actions and information and smart inverter can provide to an upstream control system or any type or size. The purpose of this activity was to 1) create a list of functionally and parameters to be addressed in following task to update the DNP3 application note for smart inverters and 2) share findings with the industry to help inform other stakeholder groups including standards groups, manufacturers of DER, DER control system vendors, aggregators, and utilities. Functionality in all communication protocols for smart inverters are based on information models from IEC 61850-7-420 and the functionality descriptions in the Common Functions for Smart Inverters [EPRI]. Therefore, gaps identified in DNP3 are likely to be gaps in protocols including SEP2, SunSpec, and IEC 61850.

Performing a gap analysis requires a baseline so the team used the Common Functions for Smart Inverters – 4th Edition. This document was selected because it was higher level than the DNP3 application note (no point maps) but detailed enough to give a thorough overview of functionality and parameters identified to date. It was last updated in December 2016. The team compared this reference document to discussions in stakeholder groups including EPRI's Energy Storage Integration Council (ESIC), results from field demonstrations, decisions in grid codes (IEEE 1547, California Rule 21, IEC 61850), other standards and specifications groups (MESA, SunSpec, IEEE, IEC).

The team's focus was on harmonization with other activities, identifying gaps in energy storage functionality, and identifying new functionality required by grid codes (Figure B-1). The gap analysis was the mechanism to harmonize these activities to identify gaps and inform the next step of this project where the team will update the DNP3 application note for smart inverters. In addition to harmonization the team focused on identifying functionality required for energy storage systems by comparing the use cases energy storage systems can provide with the currently available functionality. Gaps were identified. At the beginning of this effort a lot of work had been completed for storage functionality in the MESA Specification and EPRI's Energy Storage Integration Council. These bodies of work were leveraged appropriately.

Figure B-1: Source of Inputs to the Gap Analysis



Source: EPRI

It is important to note that the creation and maintenance of functional definitions for DER is an on-going process. The current function definitions have been created over the past decade and will continue for the next decade as new, innovative use cases arise. Therefore, the project team created tiers of functions to guide the gap analysis to help bound the effort. The first tier was the most important and the last tier, the least.

(1) Functionality required for grid codes including Rule 21 and IEEE 1547. It was important for grid codes to be supported to meet present day requirements for DER in California.

(2) Non-grid code functionality required to realize the full benefits of energy storage systems. Energy storage systems were a focus of this effort.

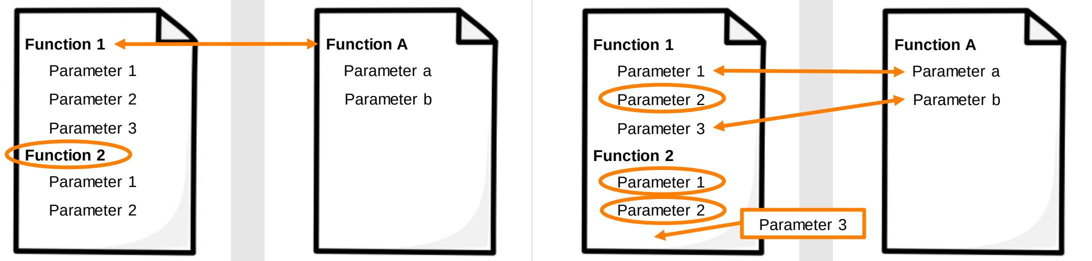
(3) All additional, already defined non-grid code functions. These functions were low hanging fruit because the discussions had occurred in other stakeholder's groups making it simpler to include them in an update to the DNP3 application note.

(4) New, theoretical non-grid code functions that have not been thoroughly defined and use cases unclear. New functions require thorough vetting with industry stakeholders before adding them to standards. Most functions in this category were concepts and did not have supporting documentation or clearly defined, near-term use cases and therefore are unlikely to be seen in products in the near future.

The goal was to bound the effort based on the project. The team decided that when all functions were finished in 1, 2, and 3 then functions in 4 would be handled 1 by 1 as time allowed. The team was successful in addressing 1-3 within the gap analysis but did not tackle the fourth in the gap analysis. The functions in the first three tiers addressed all current and near-term use cases. The new, theoretical functionality in the fourth tier did not have clear use cases so these were tabled for discussion in future efforts because there were not expected to be applied in the near-term and would therefore not be likely to be needed in communications protocols.

The team took a two-fold approach at identifying gaps. The first was on a functional level. In this activity, the team looked at the name and basic description of smart inverter functions and compared them across the various activities. The goal of this stage was to identify any large functional differences and create a single master list of smart inverter functionality. The second was on a parameter level. The parameter level is a lower level analysis compared to the functional level. In this activity, the team looked at the specific parameters that support the function. These parameters include how fast a function reacts to changes in settings (ramp rates and ramp times), how long until a function returns to default settings (timeout windows), and function specific parameters (output power setpoints, points for curves like volt/var and volt/watt, or thresholds to turn on and off functions). These parameters define the degree of control the user has over an individual smart inverter function. These two approaches are shown in Figure B-2.

Figure B-2: Function based analysis (left) and parameter based analysis (right)



Source: EPRI

Functional Findings

The results of the first stage identified that most of the functional definitions for smart inverters have already been defined and their definitions have existed for years. The recent work from MESA, ESIC, IEC 61850, and IEEE 1547 had uncovered most the gaps. The remaining gaps were mostly related to recent activities in the IEEE 1547 and IEC 61850 working groups.

Freq/Watt

A new approach to frequency/watt was introduced in the discussion of the IEEE 1547 and IEC 61850 working groups. Even though this new function provides a similar service on the grid the function behaved differently and is therefore notable. Much of products on the market today support the original version. The difference between the existing frequency/watt function and the new one is that the original one was a limiting function and the new one is a go-to function. A limiting function puts a cap on the watts the inverter is permitted to produce at a given grid frequency. The go-to function defines the output power at a given frequency once frequency has passed a threshold. The industry has decided that this new function will be required in grid codes however its information model for communications protocols has not been finalized but is expected to be completed as part of IEC-61850 and IEEE 1547.1 – test procedures for IEEE 1547.

Watt-Var Function

Watt-Var was introduced in the draft IEEE P1547 standard as a mechanism for the DER to actively control the reactive power output as a function of the real power output following a target real power – reactive power (Watt-Var or P-Q) curve. The basic concept of this function existed prior to the IEEE 1547 working group however the IEEE 1547 working group completed the definition and included it in the requirements for IEEE 1547 complaint DER.

This function does not exist in communications protocols yet but is expected to be completed as part of IEC-61850 and IEEE 1547.1 – test procedures for IEEE 1547.

Connect / Disconnect versus Cease to Energize

Until recently the connect/disconnect function was dedicated to operation of a physical switch at the inverter however not all DER have physical disconnect switches that can be operated remotely. An example is residential inverters often have manual disconnect switches that cannot be remotely operated. Additionally, this function was used for safety and the industry has voiced that this is no longer needed because safety related operation will always be initiated in-person to ensure the system operates correctly.

The need for a disconnect still exists. The discussions in 1547 diverged from this definition and instead looked at the concept of "cease to energize". The difference between cease to energize and disconnect is a physical switch and reconnection time. A cease to energize action stops the inverter from providing both active power and reactive power (less than 3% of nameplate) to the grid but energy storage systems are allowed to continue charging. There is still discussion on whether the device is allowed to power loads behind the PCC/meter (e.g. loads within the facility). An inverter can also return to service much faster than a true disconnect. A disconnect requires the inverter perform a grid synchronization activity which can take a few minutes depending on local grid codes and the settings on the inverter. These functions have been discussed together and are often confused. The team decided that because the behavior is distinctly different than the original definition and is therefore best handled independently to highlight the difference to users instead of rebranding or expanding connect/disconnect which may create confusion.

These terms are now defined in IEEE 1547.

Cease to Energize: "Cessation of active power delivery under steady-state and transient conditions and limitation of reactive power exchange."[11] In cease to energize storage systems may continue to charge; limited reactive power exchange can continue; and it does not necessarily imply that the inverter will disconnect, isolate, or trip. The expectation is that the system immediate restores output when the cease to energize is lifted.

Trip: "Inhibition of immediate return to service, which may involve disconnection." [11] In this case the system does not immediate restore output when the trip is lifted but instead must follow appropriate procedures as defined by the grid code.

Peak Power Limiting, Load Following, and Generation Following

This topic is still in discussion with stakeholder groups. The Peak Power Limiting, Load Following, and Generation Following functions have been represented as two or three distinct functions even though the functional models are similar, because they could be used in combination with each other. The Peak Power Limiting function receives data from a meter and charges or discharges to keep the circuit from exceeding a setpoint. The storage system is behind this meter so any activity at the DER is measured by the meter. The Load and Generation Following functions receive data from a nearby load, generator, or circuit and charges or discharges to compensate for anything over a setpoint. Recent discussions recognize that the key difference between a limiting and following function is the positioning of the meter. They are both designed to minimize the impact of other devices on the grid once the meter exceeds a value. There have been discussions about merging these functions because of their similarities and just using parameters to identify whether the DER under control is behind the meter it is monitoring, but ultimately the decision was to keep the functions separate to allow them to be used in combination. The benefit of this change is to simplify the information model and make the difference of the functions clear.

Constant VARs

A constant power factor function existed but did not support a parameter for a VAR parameter. IEEE P1547 requires this ability so it will be added.

Scheduling

Scheduling is key to managing energy storage systems. This function is a mechanism to allow functions to be scheduled with DER. The concept is that a user can communicate a schedule to inform the DER when it should perform functions. This is important for bidding resources on the market.

Parameter Findings

Much of the team's findings were in the parameter study. There is a substantial list of parameters, monitoring points, and functions settings. It isn't uncommon for a function to have 5-10 parameters. One simplifying factor is that there is a lot of similarity across functions and many parameters are used in many different functions. An overview of the types of parameters and where they apply is shown in Table B-1.

Table B-1: Overview of Parameter Types

PARAMETER TYPE	EXAMPLE(S)	WHERE DOES IT APPLY?
GENERAL FUNCTION CONTROL	Ramp rates/times, timeout windows, and enable flags	Most functions.
CURVE DEFINITIONS	X/Y arrays to define curve shape, units for X and Y axis.	All curve functions. Some curves are parameterized and are captured in function specific parameters. A parameterized curve follows a standard shape and can be defined using a non-curve set of parameters.
FUNCTION SPECIFIC	Output power limit, requested power factor, voltage or frequency threshold on the grid to enable a function	These parameters only apply to a single function.
MONITORING AND STATES	Current output power, error states, operating modes	These parameters are more monitoring points than parameters as they are not settable. They are not mapped to specific functions but describe the DER in general. This data may be used by one or more active functions to determine the inverter's reaction.

Source: EPRI

This is noted here because a change to a parameter that is used across multiple functions likely apples to all the functions it is found within. If a new ramp rate or ramp time was included, then it would likely need to be applied to all functions.

The team identified gaps in all four of these categories. Some of the gaps were missing parameters while others were parameters captured by one group of stakeholders and not by others. These will all be reviewed in the following section.

Referenced Data Points

The concept of referenced data points is a popular topic. The general idea is that many functions use a data stream from a location – often assumed to be the device electrical connection point (ECP) – to inform the behavior of active functions. An example is that an inverter performing the volt-var function will produce a predefined number of VARs at a given voltage. The voltage measurement is collected from the referenced data point.

This concept was created to allow DER to have additional flexibility in the reference point. It could be the measurement at the inverter or a remote meter at the entrance to the DER facility. This concept is particularly valuable for functions designed to follow or limit the behavior of nearby loads or generators because it allows the function to be assigned to a meter at a nearby load or DER.

Bidirectional Power Flow

Current standard and smart inverter functionality is based on a decade of industry conversations. Energy storage was considered however the focus was on solar. One of the gaps was considering bi-directional power flow in all functions. Often functions were clearly defined but needed another set of parameters to allow an operator independent control of the inverter when absorbing energy (charging) or ejecting energy (discharging/generating). The following opportunities were identified:

- Addition of max charging rate to compliment the max output power (generating for solar, discharging for storage).
- Addition of independent control of power factor for input power (charging) and output power (discharging/generating).
- Addition of new ramp rates to capture charging and discharging systems. Ramp rates for increasing and decreasing were also added.
- Addition of parameters to support a DER charging to follow or limit a nearby generating DER. An example is co-located storage/solar system.

Terminology

This is a broad topic that impacted every function. The group found that the terminology between standards organization, communications protocols, and manufacturer's product descriptions used a mix of terminology to describe similar and identical parameters. There were also cases where the same terminology was used to describe different parameters. These are both important because the owners and dispatchers of DER need to know with certainty that when a DER is asked to perform an action it performed the same action they expected it to.

Disconnect and Cease to Energize

An example of two similarly named functions with different actions is connect/disconnect + cease to energize and the two variants of frequency/watt. These two cases are described in the functional analysis above.

Set and Limit

Another example is the term Set Maximum Output Power on the Limit DER Power Output Function. In Rule 21 this is named as Real power limit value while in IEEE 1547 it is named as Maximum Active Power. These terms reference the same parameter. Alternatively, the nameplate rating of the inverter or WMax is Active Power Charge Maximum Rating in IEEE 1547-2018.

An example of the confusion this created is that lab studies found that some manufacturers of control systems incorrectly used the nameplate rating value to set a max output. Though it performed a similar electrical response it was not correct. In this case, it was especially dire because the rating was written to flash memory and has a limited number of reads and writes. If used for a period, it would cause the inverter to fail prematurely due to memory failure. This highlights the important of understanding the parameter and variation in terms. Often it is easy to find when two similar parameters are the same. However, users should be careful to know the definition of the term to prevent unexpected results in practice.

State and Status

The team found that state, status, and monitoring data was especially prone to terminology issues, so it is called out specifically. Two examples are given, states and state of charge.

The team found four different state/status definitions. At first glance they appeared to be identical parameters with different states however while attempting to harmonize the different individual states they found them to be quite different.

- Access Status – This status provides users with information about whether the system can be controller. States include "normal operating state", "lockout", and "maintenance/testing".
- Connect / Disconnect Status – This status provides users with information about whether the DER is connected to the grid and if it was active. Example states included Disconnected / Unavailable, Disconnected / Available, Connected / Unavailable, Connected / Available, and Connected / On.
- Present Operating Mode – This parameter was a placeholder for manufacturer proprietary states.
- DER Status – This status provided users with information about the action of the DER. Example include throttled, standby, off, starting, stopping, fault.
- Operational State – This state indicates whether the DER is in normal state or is in some other state, such as Lockout state, Maintenance state, or Test state.

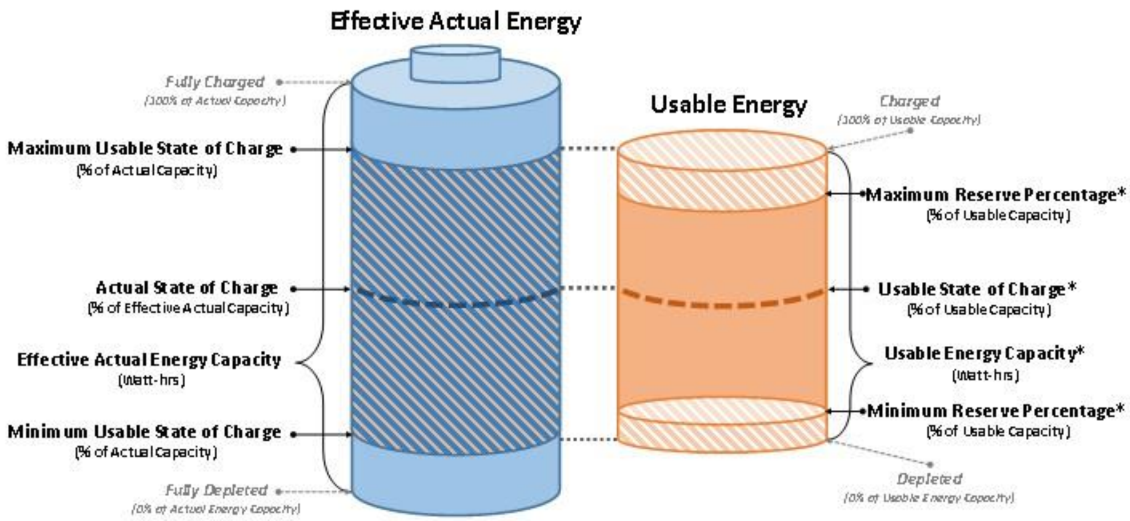
The exact statuses and their associated states are still being discussed by the industry.

State of Charge

Energy storage systems are unique because their primary purpose is to give electrical flexibility to the users (i.e., charge and discharge as and when needed). Operators manage this flexibility by raising and lowering the state of charge of the system by manipulating the power and rate of change of the system. At the beginning of this study communications protocols supported a single state of charge parameter. This is confusing because different stakeholders directly involved in the storage system define state of charge differently. Harmonization of these terminologies was critical.

A battery manufacturer reads state of charge as the current state as defined between completely charged and completely discharged. However, when a storage system is configured there is an artificial minimum and maximum state of charge assigned to provide the contracted life of the system. Over charging or discharging the battery past these setpoints impact the health and performance of the cell. An owner or operator of a storage system would consider these the minimum and maximum limits of the system because it is the full usable range to them for that contracted lifespan. Therefore, it was decided that needs to be two sets of state of charge parameters (Figure B-3). Some are useful to communicate to dispatchers of the system (right) and others are applicable within the energy storage system itself (left).

Figure B-3: State of Charge Diagram



Source: EPRI

Summary

The primary conclusion from the gap analysis is there are no glaring gaps in functionality on a high level. Most of the functions discussed in stakeholder groups have existed for many years and most of the gaps identified occurred in the semantics and terminology. Often function names or parameters differed slightly between stakeholder groups. The reason this is notable is that consensus across the industry is required for interoperability to occur. Slight differences in naming conventions can be overcome through education and logical mapping however differences in implementation of the same function is an obstacle because it can cause misinterpretations of what a function will provide and therefore the behavior of the inverter when operating in that mode

APPENDIX C: Summary of Industry Activities

There are number of different stakeholder activities across the industry. This section acknowledges the many activities and provides a short summary of their activities.

Rule 21

Rule 21 establishes the DER interconnection requirements for the three Investor Owned Utilities in California, namely Pacific Gas & Electric, Southern California Edison, and San Diego Gas & Electric. It is based on IEEE 1547 but has recently added many new functional and communication requirements, as noted in the table of functions. The discussion in the Smart Inverter Working Group (SIWG) resulted in these updates to Rule 21 and set the stage for similar updates to IEEE 1547. The SIWG Phase 1 (autonomous functions) requirements are mandatory starting September 8, 2017, while Phase 2 (protocols for communications) and Phase 3 (advanced inverter functionality) requirements are expected to become mandatory within a couple of years.

IEEE 1547

IEEE Standard 1547 is the de-facto basis for interconnection standards for DER in the United States. The standard was first published in 2003 as a voluntary industry standard for interconnecting distributed energy resources (DERs) with electric power systems (EPSs). It was developed with a focus on distribution system safety and power quality, assuming low penetration levels and treating all DER technologies in the same way (technology-neutrality). The standard was amended in 2014 to eliminate prohibitions of advanced DER grid support such as steady-state voltage control and disturbance ride-through. The full revision of 1547 started in 2014. It specifies new DER functional and communication requirements and is aimed at supporting grid codes that mandate interoperability.

MESA Specification

MESA is an industry trade association of utilities and vendors whose mission is to accelerate the growth of the energy storage industry through the development of open, non-proprietary communication specifications for energy storage systems. Through standardization, MESA accelerates interoperability, scalability, safety, quality, and affordability in energy storage components and systems. Their working group has identified several key gaps in energy storage functionality required for today's storage use cases.

IEC 61850

IEC 61850 is an international standard for the power industry. IEC 61850 consists of several standard documents. The one that applies to this body of work is IEC 61850-7-420. IEC 61850-7-420 provides the information model for the DER functions identified in Appendix C. As a result of the new requirements from Rule 21, IEEE 1547, and European grid code mandates, it is being updated to reflect those functions. After these updates are reviewed by countries across the world, the 7-420 information model will be available from the IEC as electronic "code components" which can readily be imported into DER products.

SunSpec

The SunSpec Alliance is a trade alliance of more than 100 solar and storage distributed energy industry participants, together pursuing information standards to enable “plug & play” system interoperability. SunSpec standards address operational aspects of solar PV power and energy storage plants on the smart grid—including residential, commercial, and utility-scale systems—thus reducing cost, promoting technology innovation, and accelerating industry growth.

EPRI’s Energy Storage Integration Council (ESIC)

In 2013 the Energy Storage Program at EPRI, in collaboration with utilities, vendors, National labs, and industry experts created the Energy Storage Integration Council (ESIC). ESIC is an open and active venue, executed via a combination of in-person meetings, webcasts, and teleconferences, for identifying key gaps and common approaches for the integration of energy storage across key technical topic areas. ESIC hosted a working group in 2016-2017 to define functionality gaps in energy storage systems by studying current functionality and mapping them to grid services. Gaps were identified and filled appropriately.

Common Functions for Smart Inverter – 4th Edition

EPRI maintains a plain-English overview of all known inverter functions. The purpose of this document is to be a reference document to help stakeholders understand how each function behaves and the different parameters identified for each function. It contains both current functionality and documents functionality in discussion.

IEEE 2030.5 specification

IEEE 2030.5 was initially developed for Home Automation Systems but included an information model for DER based-on IEC 61850-7-420. As will all the protocols, IEEE 2030.5 is getting updated by the working group to reflect the new requirements. The Project Authorization Request (PAR) was made in early 2014 based on request from several stakeholders. Under this PAR, the protocol is also getting revised to capture all the requirements from the updated grid codes, Rule-21 and IEEE 1547, reflecting also the changes in IEC 61850-7-420. IEEE 2030.5 has been called out as the default protocol for application level by CA’s Rule-21. The updated version of IEEE 1547 requires the communication interface to the DER support IEEE 2030.5 among other standards.

DNP3 App Note

The current application note for DER was published in 2013 with feedback from the industry including. This project is currently leading an activity to update the application note to add requirements from grid codes (Rule 21 and IEEE 1547) and add new functionality to improve handling of energy storage systems, based on the IEC 61850-7-420 information model. DNP3 is one of the protocols listed in the most recent draft of IEEE 1547.

APPENDIX D: Comparison Table of Functions

A list of the most common DER functions and modes is shown in Table D-1table. The table also indicates where the functions and modes are described in the EPRI Common Functions for Smart Inverters: 4th Edition[34] the IEC 61850-90-7 Technical Report (now included in the IEC 61850-7-520 guidelines), and the proposed updates to IEC 61850-7-420. In addition, it indicates which functions and modes are considered Grid Codes and are mandatory in different jurisdictions: European network codes (drafted by ENTSO-e), German MV & LV codes, IEEE 1547 for North America (IEEE 1547 is still being revised), and Rule 21 in California.

These Grid Code functions include:

1. Disconnect / Connect Function
2. Cease to Energize / Return to Service Function
3. High/Low Voltage Ride-Through (Fault Ride-Through) Mode
4. High/Low Frequency Ride-Through Mode
5. Dynamic Reactive Current Support Mode
6. Frequency Watt Mode (Frequency Sensitivity Mode)
7. Volt-Watt Mode
8. Fixed (Constant) Power Factor Mode
9. Fixed (Constant) Reactive Power Mode
10. Volt-Var Mode
11. Watt-Var Mode
12. Watt-PF Mode
13. Active Power Limiting Mode
14. Active Power Setting Mode
15. Monitoring key status, alarm, and measurement values35
16. Scheduling of Power Settings and Modes
17. Low Frequency-Watt Emergency Mode for Demand Side Management (fast load shedding)
18. Low Voltage-Watt Emergency Mode for Demand Side Management

[34] Common Functions for Smart Inverters: 4th Edition. EPRI, Palo Alto, CA: 2016. 3002008217.

[35] Although these functions have been identified in the past as important, they are now officially in California's Rule 21 as mandatory

Additional functions and modes are also listed. Most of these additional functions have been described in EPRI's Common Functions for Smart Inverters (now updated to version 4) and are modeled or being updated in IEC 61850-7-420 (Edition 2 to be released in mid-2017 as a Committee Draft).

The table was updated on June 29, 2017.

Table D-1: DER Functions and Modes

#	Function or Mode	Description and Key Parameters	EPRI Common Functions	IEC 61850-90-7 (now 7-520)	IEC 61850-7-420 *Proposed* LNs	European Network Codes	IEEE 1547 Draft Revision	Calif Rule 21 Mandates and Recommendations
Grid Code Modes								
1.	**Disconnect/Connect Function** Disconnect or connect the DER from the grid at its ECP	The disconnect command initiates the galvanic separation (usually via switches or breakers) of the DER at its ECP or at the PCC. There may be a time delay between receiving the command and the actual disconnect The connect command initiates or allows the reconnection of the DER at its ECP or at the PCC. A permission to reconnect may also be issued.	Section 5	Function INV1	LN DCND and/or LN CSWI LN XCBR/XSWI	All Types of DER For type A, only an interface is requested for disconnection	Either galvanic disconnect or cease to energize	Either galvanic disconnect or cease to energize

2.	**Cease to Energize and Return to Service** The DER ceases all active power output Allow active power output at the PCC	"Cease to energize" is a different function from disconnect/connect. The (draft) definition is "the DER shall not export active power during steady-state or transient conditions. Reactive power exchange (absorb or supply) shall be less than x% (maybe 10%?) of nameplate DER rating and shall exclusively result from passive devices.". There may be a time delay between receiving the command and the actual cease to energize. "Return to service" allows current flow at the PCC. A permission to return to service may also be issued.	Section 5	Function INV1	LN DCTE	Type A and B only of DER – cease active power output within 5 seconds, following an instruction being received at the input port Type A may disconnect randomly	Either galvanic disconnect or cease to energize at the PCC	Either galvanic disconnect or cease to energize at the PCC

#	Function or Mode	Description and Key Parameters	EPRI Common Functions	IEC 61850-90-7 (now 7-520)	IEC 61850-7-420 *Proposed* LNs	European Network Codes	IEEE 1547 Draft Revision	Calif Rule 21 Mandates and Recommendations
3.	**High/Low Voltage Ride-Through Mode** The DER rides through temporary fluctuations in voltage	The DER follows the utility-specified voltage ride-through parameters to avoid tripping off unnecessarily. The function would block tripping within the fault ride-through zones. Although normally enabled by default, this ride-through mode may be updated, enabled, and disabled.	Section 16	Mode H/LVRT	LN DVRT	Fault ride-through is mandatory for all generators starting type B and larger generators,	H/LVRT is mandatory for all DER	H/LVRT is mandatory for all DER

#	Function or Mode	Description and Key Parameters	EPRI Common Functions	IEC 61850-90-7 (now 7-520)	IEC 61850-7-420 *Proposed* LNs	European Network Codes	IEEE 1547 Draft Revision	Calif Rule 21 Mandates and Recommendations
4.	**High/Low Frequency Ride-Through Mode** The DER rides through temporary fluctuations in frequency	The DER follows the utility-specified frequency ride-through parameters to avoid tripping off unnecessarily. The function would block tripping within the fault ride-through zones. Although normally enabled by default, this ride-through mode may be update, enabled, and disabled.	Section 17	Mode H/LFRT	LN DFRT	no mention, except the fact that facilities must remain operational within an “extended” frequency range from 47 to 52Hz (exact range may depend on European synchronous zone)	H/LFRT is mandatory for all DER	H/LFRT is mandatory for all DER

#	Function or Mode	Description and Key Parameters	EPRI Common Functions	IEC 61850-90-7 (now 7-520)	IEC 61850-7-420 *Proposed* LNs	European Network Codes	IEEE 1547 Draft Revision	Calif Rule 21 Mandates and Recommendations
5.	**Dynamic Reactive Current Support Mode** The DER reacts against rapid voltage changes (spikes and sags) to provide dynamic system stabilization	The DER provides dynamic reactive current support in response to voltage spikes and sags, similar to acting as inertia against rapid changes. This mode may be focused on emergency situations or may be used during normal operations. When the dynamic reactive current support mode is enabled, the DER monitors the voltage at the Referenced ECP and responds based on the parameters.	Section 18	Mode TV	LN RDGS	No direct mention Synthetic inertia is requested starting Class C. Reactive power injection in case of grid fault is requested starting class B, upon TSO request. Also requested for transmission connected facilities	Is included as optional but may become mandatory	optional

#	Function or Mode	Description and Key Parameters	EPRI Common Functions	IEC 61850-90-7 (now 7-520)	IEC 61850-7-420 *Proposed* LNs	European Network Codes	IEEE 1547 Draft Revision	Calif Rule 21 Mandates and Recommendations
6.	**Frequency-Watt Mode** The DER responds to large frequency excursions during abnormal events at a Referenced ECP by changing its production or consumption rate	The DER is provided with frequency-watt curves that define the changes in its watt output based on frequencies around the nominal frequency during abnormal events. When the emergency frequency-watt mode is enabled, the DER monitors the frequency and adjusts its production or consumption rate to follow the specified emergency frequency-watt curve parameters.	Section 13	Mode FW	LN DFWC LN DFWP	Over frequency "Frequency Sensitive Mode (FSM)" is mandatory for all DER types. Under-frequency is requested starting class C Maximum power decrease in case of frequency decrease is specified and should be respected by all DER	Frequency Droop	Included under H/LFRT

#	Function or Mode	Description and Key Parameters	EPRI Common Functions	IEC 61850-90-7 (now 7-520)	IEC 61850-7-420 *Proposed* LNs	European Network Codes	IEEE 1547 Draft Revision	Calif Rule 21 Mandates and Recommendations
7.	**Volt-Watt Mode** The DER responds to changes in the voltage at the Referenced ECP by changing its production or consumption rate	The DER is provided with voltage-watt curves that define the changes in its watt output based on voltage deviations from nominal, as a means for countering those voltage deviations. When the volt-watt mode is enabled, the DER receives the voltage measurement from a meter (or other source) at the Referenced ECP. The DER adjusts its production or consumption rate to follow the specified volt-watt curve parameters.	Section 12	Mode VW	LN DVWG		Included	included

#	Function or Mode	Description and Key Parameters	EPRI Common Functions	IEC 61850-90-7 (now 7-520)	IEC 61850-7-420 *Proposed* LNs	European Network Codes	IEEE 1547 Draft Revision	Calif Rule 21 Mandates and Recommendations
8.	**Fixed (Constant) Power Factor Mode** The DER power factor is set to a fixed value.	The DER power factor is set to the specified power factor. A leading power factor is positive and a lagging power factor is negative, as defined by the IEEE or IEC sign conventions.	Section 10	Function INV3	LN DFPF	For Type C & D DER, the ability to adjust reactive power, automatically by either voltage control mode, reactive power control mode or power factor	Mandatory for all DER	Mandatory for all DER
9.	**Fixed (Constant) Reactive Power Mode** The DER is requested to provide a fixed amount of reactive power	The DER is requested to provide a fixed amount of reactive power			LN DVAR		Mandatory for all DER	

#	Function or Mode	Description and Key Parameters	EPRI Common Functions	IEC 61850-90-7 (now 7-520)	IEC 61850-7-420 *Proposed* LNs	European Network Codes	IEEE 1547 Draft Revision	Calif Rule 21 Mandates and Recommendations
10	**Volt-Var Control Mode** The DER responds to changes in voltage at the Referenced ECP by supplying or absorbing vars in order to maintain the desired voltage level	The DER is provided with voltage-var curves that define the vars for voltage levels. When the volt-var mode is enabled, the DER receives the voltage measurements from a meter (or other source) at the Referenced ECP. The DER responds by supplying or absorbing vars according to the specified volt-var curve in order to maintain the desired voltage level.	Section 11	Mode VV11 and VV12	LN DVVC	For Type C & D DER, the ability to adjust reactive power, automatically by either voltage control mode, reactive power control mode or power factor	Mandatory for all DER	Mandatory for all DER

#	Function or Mode	Description and Key Parameters	EPRI Common Functions	IEC 61850-90-7 (now 7-520)	IEC 61850-7-420 *Proposed* LNs	European Network Codes	IEEE 1547 Draft Revision	Calif Rule 21 Mandates and Recommendations
11	**Watt-Var Mode** The DER responds to changes in power at the Referenced ECP by changing its VARs	The DER is provided with watt-var curves that define the changes in its vars based changes of power. When the watt-var mode is enabled, the DER modifies its vars setting in response to the power level at the Referenced ECP.	Section 14	Mode WP	LN DWVR	German LV Grid Codes VDE-AR-N4105	Included	Included
12	**Watt-PF Mode** The DER responds to changes in power at the Referenced ECP by changing its power factor	The DER is provided with watt-PF curves that define the changes in its power factor based changes of power. When the watt-PF mode is enabled, the DER modifies its PF setting in response to the power level at the Referenced ECP.	Section 14	Mode WPF	LN DWPF			

#	Function or Mode	Description and Key Parameters	EPRI Common Functions	IEC 61850-90-7 (now 7-520)	IEC 61850-7-420 *Proposed* LNs	European Network Codes	IEEE 1547 Draft Revision	Calif Rule 21 Mandates and Recommendations
13	**Set Active Power Mode** Set the DER to generate or consume energy as a percentage of maximum capability	The DER is set to a percentage of maximum generation or consumption rate. A positive value indicates generation, negative means consumption.	Section 7	Function INV4	LN DCHD			Recommended as optional
14	**Limit Active Power Production or Consumption Mode** Limits the production and/or consumption level of the DER based on the Referenced ECP	The production and/or consumption of the DER is limited at the Referenced ECP, indicated as absolute watts values. Separate parameters are provided for production or consumption limits to permit these to be different.	Section 6	Function INV2	LN DWLM		Included	Included

#	Function or Mode	Description and Key Parameters	EPRI Common Functions	IEC 61850-90-7 (now 7-520)	IEC 61850-7-420 *Proposed* LNs	European Network Codes	IEEE 1547 Draft Revision	Calif Rule 21 Mandates and Recommendations
15	**Monitoring Function** The DER provides nameplate, configuration, status, measurements, and other requested data	The DER provides status, measurements, alarms, logs, and other data as authorized and requested by users. Examples include connect status, updated capacities, real and reactive power output/consumption, state of charge, voltage, and other measurements. Also of interest are forecast status and expected measurements.	Section 26	Function DS plus Diesel, PV, Wind, CHP, Fuel Cell, & Battery device-specific info	LN DRAT LN DRCT LN MMXU (DER-specific LNs)	Real-time monitoring of key power system values for Types C and D DERs for FSM Compliance monitoring for Types B, C, & D and optionally for type A (TSO decision). Also requested for any units which provide Demand Service response (DSR) within a demand facility	Communications capability mandated for all DER (not necessarily implemented in all DER) Monitoring where needed is mandatory	Communications capability mandated for all DER (not necessarily implemented in all DER) Monitoring where needed is mandatory

#	Function or Mode	Description and Key Parameters	EPRI Common Functions	IEC 61850-90-7 (now 7-520)	IEC 61850-7-420 *Proposed* LNs	European Network Codes	IEEE 1547 Draft Revision	Calif Rule 21 Mandates and Recommendations
16	**Scheduling of Power System Settings and Modes** The DER follows schedules according to their time and priority	The DER follows the highest priority schedule which consists of a time offset (specified as a number of seconds) from the start of the schedule and is associated with: • a power system setting • the enabling/disabling of a function • a price signal	Covered in different sections	IEC 61850-90-10	LN FSCH LN FSCC		Expected for larger DER but not mandatory	Included
17	**Low Frequency-Watt Emergency Mode** for demand side management (fast load shedding)	Enable automatic « low frequency » disconnection of a specified proportion of their demand (in stages) in a given time frame.				for all transmission-connected facilities	Not mentioned explicitly in 1547 which does not cover loads, but expected to be available	

#	Function or Mode	Description and Key Parameters	EPRI Common Functions	IEC 61850-90-7 (now 7-520)	IEC 61850-7-420 *Proposed* LNs	European Network Codes	IEEE 1547 Draft Revision	Calif Rule 21 Mandates and Recommendations
18	**Low Voltage-Watt Emergency Mode** for demand side management	Provide capabilities to … enable automatic or manual load tap changer blocking and automatic « low voltage » disconnection.				optionally for all transmission connected facility	Not mentioned explicitly in 1547 which does not cover loads, but expected to be available	
Non-Grid Code Modes								
19	**Peak Power Limiting Mode** The DER limits the load at the Referenced ECP after it exceeds a threshold target power level	The active power output of the DER limits the load at the Referenced ECP if it starts to exceed a target power level, thus limiting import power. The production output is a percentage of the excess load over the target power level. The target power level is specified in absolute watts.	Section 21	-	LN DPKP			

#	Function or Mode	Description and Key Parameters	EPRI Common Functions	IEC 61850-90-7 (now 7-520)	IEC 61850-7-420 *Proposed* LNs	European Network Codes	IEEE 1547 Draft Revision	Calif Rule 21 Mandates and Recommendations
20	**Load Following Mode** The DER counteracts the load by a percentage at the Referenced ECP, after it starts to exceed a threshold target power level	The active power output of the DER follows and counteracts the load at the Referenced ECP if it starts to exceed a target power level, thus resulting in a flat power profile. The production output is a percentage of the excess load over the target power level. The target power level is specified in absolute watts.	Section 22		LN DLFL			

#	Function or Mode	Description and Key Parameters	EPRI Common Functions	IEC 61850-90-7 (now 7-520)	IEC 61850-7-420 *Proposed* LNs	European Network Codes	IEEE 1547 Draft Revision	Calif Rule 21 Mandates and Recommendations
21	**Generation Following Mode** The consumption and/or production of the DER counteracts generation power at the Referenced ECP.	The consumption and/or production of the DER follows and counteracts the generation measured at the Referenced ECP if it starts to exceed a target power level. The consumption and/or production output is a percentage of the excess generation watts over the target power level. The target power level is specified in absolute watts.	Section 22	-	LN DGFL			

#	Function or Mode	Description and Key Parameters	EPRI Common Functions	IEC 61850-90-7 (now 7-520)	IEC 61850-7-420 *Proposed* LNs	European Network Codes	IEEE 1547 Draft Revision	Calif Rule 21 Mandates and Recommendations
22	**Active Power Smoothing Mode** The DER produces or absorbs active power in order to smooth the changes in the power level at the Referenced ECP. Rate of change of power	The DER follows the specified smoothing gradient which is a signed quantity that establishes the ratio of smoothing active power to the real-time delta-watts of the load or generation at the Referenced ECP. When the power smoothing mode is enabled, the DER receives the watt measurements from a meter (or other source) at the Referenced ECP. New data points are provided multiple times per second.	Section 19	-	LN DWSM			
23	**Frequency-Watt Primary Control mode**	The DER provides primary frequency control	Not explicitly defined		LN FWHZ		Not explicitly mentioned but expected of larger DERs	Allowed since there is explicit permission to use other F-W values

#	Function or Mode	Description and Key Parameters	EPRI Common Functions	IEC 61850-90-7 (now 7-520)	IEC 61850-7-420 *Proposed* LNs	European Network Codes	IEEE 1547 Draft Revision	Calif Rule 21 Mandates and Recommendations
24	**Automatic Generation Control (AGC) Mode** The DER responds to raise and lower power level requests to provide frequency regulation support	When AGC mode is enabled, the DER responds to signals to increase or decrease the rate of consumption or production every 4 to 10 seconds, with the purpose of managing frequency.	Defined by the Utility Control Area	Function INV4 (requires additional parameters)	LN DAGC			

#	Function or Mode	Description and Key Parameters	EPRI Common Functions	IEC 61850-90-7 (now 7-520)	IEC 61850-7-420 *Proposed* LNs	European Network Codes	IEEE 1547 Draft Revision	Calif Rule 21 Mandates and Recommendations
25	**Coordinated Charge/Discharge Management Mode** The DER determines when and how fast to charge or discharge so long as it meets its target state of charge level obligation by the specified time *(focus is on Electric Vehicle consumption)*	The DER is provided with a target state of charge and a time by which that SOC is to be reached. This allows the DER to determine when to charge or discharge based on price. The DER takes into account not only the duration at maximum consumption / production rate, but also other factors, such as that at high SOC the maximum consumption rate may not be able to be sustained, and vice versa, at low SOC, the maximum discharge rate may not be able to be sustained	Section 9 (modified)	-	LN DTCD			

#	Function or Mode	Description and Key Parameters	EPRI Common Functions	IEC 61850-90-7 (now 7-520)	IEC 61850-7-420 *Proposed* LNs	European Network Codes	IEEE 1547 Draft Revision	Calif Rule 21 Mandates and Recommendations
26	**Frequency-Watt Smoothing Mode** The DER responds to changes in frequency at the Referenced ECP by changing its consumption or production rate based on frequency deviations from nominal, as a means for countering those frequency deviations	The DER is provided with frequency-watt curves that define the changes in its watt output based on frequency deviations from nominal, as a means for countering those frequency deviations and smoothing the frequency. When the frequency-watt mode is enabled, the DER monitors the frequency and adjusts its production or consumption rate to follow the specified frequency-watt curve parameters. New data points are provided multiple times per second.	Section 13	Mode FW	LN DFWS		Shall remain operational during ROCOF events within limits, but no explicit mention of smoothing	

#	Function or Mode	Description and Key Parameters	EPRI Common Functions	IEC 61850-90-7 (now 7-520)	IEC 61850-7-420 *Proposed* LNs	European Network Codes	IEEE 1547 Draft Revision	Calif Rule 21 Mandates and Recommendations
27	**Power Factor Limiting (Correcting) Mode** The DER supplies or absorbs VArs to hold the power factor at the Referenced ECP within the PF limit	When the PF limiting (correcting) mode is enabled, the DER is provided with the target PF. The DER supplies or absorbs vars in order to maintain the PF at the Referenced ECP within the limits of the target PF.	-	-	LN DPFC		Being discussed	
28	**Historical Information**	Detailed measurement and performance data which may be valuable to record in an operational historian			LN MMXU plus PV, Wind, CHP, Fuel Cell, Battery detailed LNs			

#	Function or Mode	Description and Key Parameters	EPRI Common Functions	IEC 61850-90-7 (now 7-520)	IEC 61850-7-420 *Proposed* LNs	European Network Codes	IEEE 1547 Draft Revision	Calif Rule 21 Mandates and Recommendations
	Non-Functional Capabilities							
29	**Establish Ramp Rates**	In addition to the default ramp rate, the DER may support multiple ramp rates that reflect different conditions.	Covered in different sections		LN DRCT and all LNs needing ramp rates		Relevant ramp rates or ramp times are included in each mode	Ramp rates or ramp times are mandatory for all DER
30	**Soft-Start Return to Service**	Use ramp rate and/or random time within window when reconnecting			LN DCTE	"Ensuring appropriate reconnection", including random reconnect time windows	Using open loop response times rather than ramp rates	Ramp rates or ramp times are mandatory for all DER

#	Function or Mode	Description and Key Parameters	EPRI Common Functions	IEC 61850-90-7 (now 7-520)	IEC 61850-7-420 *Proposed* LNs	European Network Codes	IEEE 1547 Draft Revision	Calif Rule 21 Mandates and Recommendations
31	**Delta Power Control Function** Decrease active power output to ensure there remains spinning reserve amount that was bid into the market	Decrease active power output to ensure there remains spinning reserve amount that was bid into the market						
32	**Power Rate Control** The power is limited by the maximum ramp rate.	Another is ramp time, when the active power should be at the required power level by the end of the ramp time. It may reach the required power level earlier, but not later.						

#	Function or Mode	Description and Key Parameters	EPRI Common Functions	IEC 61850-90-7 (now 7-520)	IEC 61850-7-420 *Proposed* LNs	European Network Codes	IEEE 1547 Draft Revision	Calif Rule 21 Mandates and Recommendations
33	**Operating Reserve (Spinning Reserve)** The DER provides operating reserve	The DER can provide reserve power available within about 10 minutes						
				Capabilities Not Yet Defined				
34	**Microgrid Separation Control (Intentional Islanding)**	Process for normal separation, emergency separation, and reconnection of microgrids. These microgrids could be individual facilities or could be multiple facilities using Area EPS grid equipment between these facilities.		Identified by many parties	LN DMIC (not defined yet)	Type C & D shall be capable of taking part in island operation if required by the relevant system operator	Separation requirements are identified but not fully described for intentional (microgrid) and unintentional islanding	

#	Function or Mode	Description and Key Parameters	EPRI Common Functions	IEC 61850-90-7 (now 7-520)	IEC 61850-7-420 *Proposed* LNs	European Network Codes	IEEE 1547 Draft Revision	Calif Rule 21 Mandates and Recommendations
35	**Provide Black Start Capability**	Ability to start without grid power, and the ability to add significant load in segmented groups		Identified by many parties	LN ??	Not mandatory, but requirements are expected to be discussed		
36	**Provide Backup Power**	Ability to provide power to local loads when not connected to the grid		Identified by many parties	LN ??			

Source: EPRI

APPENDIX E:
Final Presentation to the California Energy Commission

Note: This is the final presentation for the project given Thursday, February 14, 2019 in Sacramento, California.

ELECTRIC POWER RESEARCH INSTITUTE

Expanding Standards and Developing Tools to Enable DNP3 Support of Energy Storage

Final Meeting: EPC-15-089

Ben Ealey
Sr. Project Manager
Electric Power Research Institute

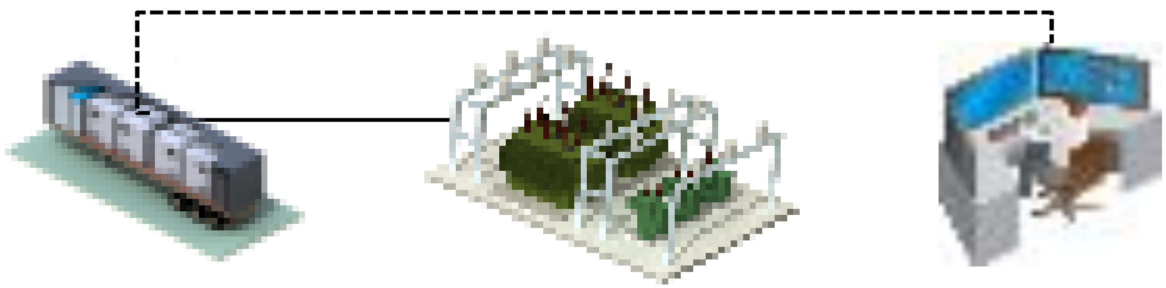
Thursday February 14th, 2019
Sacramento, California

www.epri.com


Interoperable communications between DER and other grid systems are at the heart of maintaining resiliency and stability on the grid.
Opengridscheduler – Electric Car - https://flic.kr/p/J79gTh
Allagash Brewing – Brewery Solar Array - https://flic.kr/p/JDVghU
Portland General Electric – Energy Storage System - https://flic.kr/p/eyVufF

Utilities and Energy Storage Systems in California

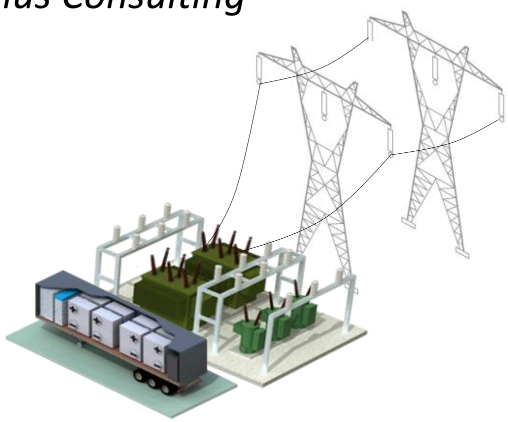
- Energy Storage Systems (ESS) can benefit utilities by providing many unique energy services to the power system.
- California utilities, like most utilities in North America, use the IEEE 1815 (DNP3) SCADA standard for large scale systems.
- Significant work to-date has addressed communication standards for “smart inverter” DER systems in general but are still in their infancy.



Expanding Standards and Developing Tools to Enable DNP3 Support of Energy Storage Use Cases *CEC EPC-15-089*

EPRI, Enernex, MESA, SunSpec Alliance, and Xanthus Consulting

- Identify Gaps in the DNP3 Standard (**Completed**)
- Update the DNP3 Standard (**Completed**)
- Develop Infrastructure for Product Testing (**Completed**)
- Develop Open Source Client (**Pending EPRI Publishing**)



$873,516 Funding + $360,828 Co-Funding

***CEC CAM:** Bryan Lee*
***EPRI Project Manager:** Ben Ealey*

This project improves the ability of grid operators to communicate with distributed energy resources (DER) and enhance use and value of energy storage and solar generation connected to smart inverters.

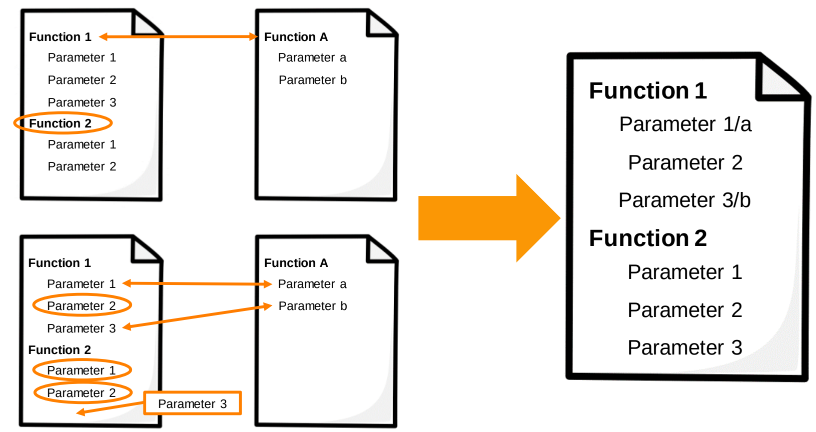
Review Gap Analysis Methodology

Objectives

- **Provide guidance to the industry on functional gaps for storage systems.**
- **Identify any key themes in gaps and highlight potential barriers.**
- **Inform the scope for the expansion of DNP3 app note.**
- **Share findings with the industry.**

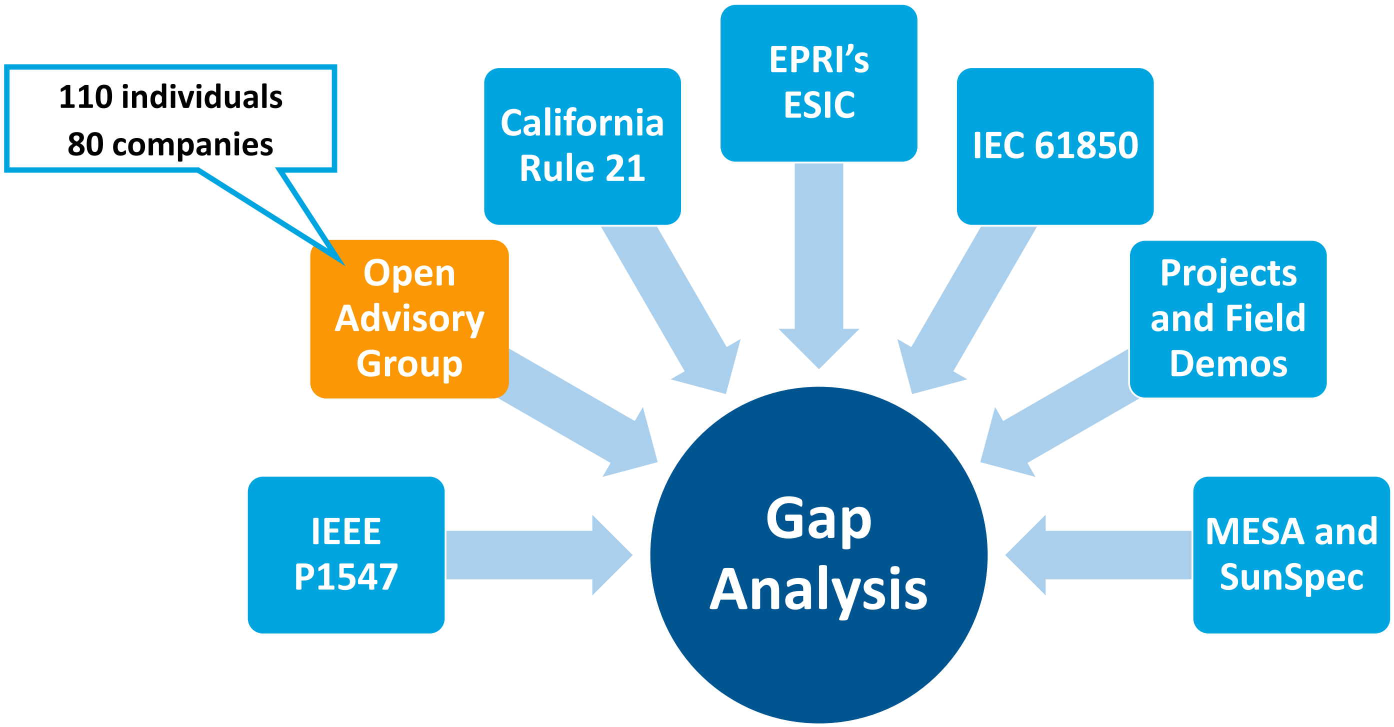
Gap Analysis

- Identify functions and parameters required for energy storage systems to provide their full list of benefits.
  - ESIC & MESA work
- Harmonize requirements in grid codes.
  - Rule 21
  - IEEE 1547-2018 + IEEE P1547.1
  - EN50549
- Understand the maturity of functional definitions to prioritize which will be implemented
  - **Example:** Function #35 Provide Black Start Capability



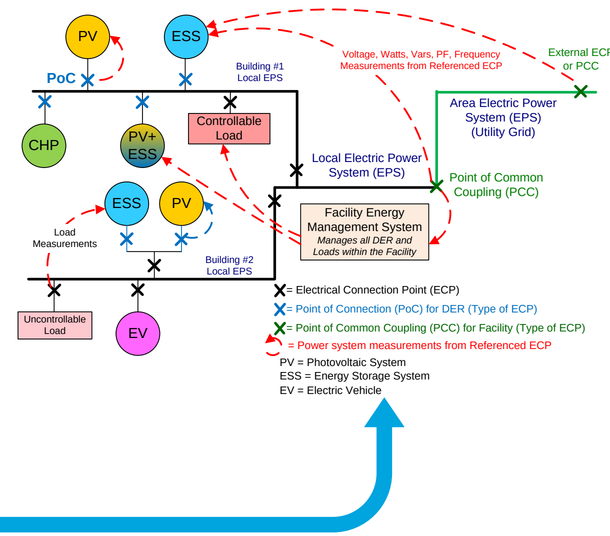
Communication protocols should support a superset of functional capabilities; prevents the protocol from limiting the value of a DER

Open Advisory Group and Gap Analysis



Gap Analysis – High Level Findings

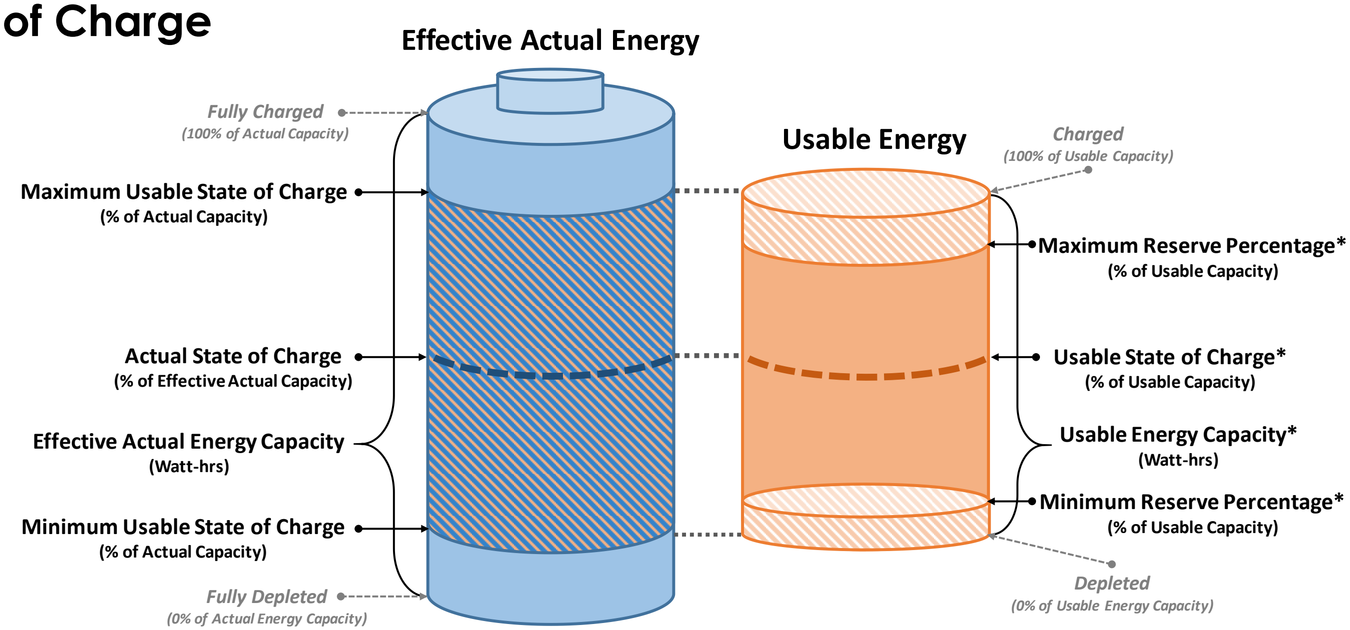
- Leveraged work from MESA, ESIC, IEC 61850, IEEE 1547
- Lack of harmonization can create confusion. Harmonization is an on-going issue and could cause implementation and interoperability issues in the field. [1,2,3]
- Example Function Modifications
  - Bi-directional power flows were not considered prior to this effort. This is important for storage systems.
  - Connect/Disconnect, Cease to Energize, and Return to Service are unique.
  - Referenced Data Points will be important for storage systems.
  - State of Charge (SoC) was expanded *(next slide)*



1 http://www.calsolarresearch.ca.gov/images/stories/documents/Sol4_funded_proj_docs/EPRI4_Seal/2_CSI-RDD_Sol4_EPRI-Seal_StdCommInt_CertTestProg_FinalRpt_2016-08.pdf
2 Results from Inverter Interoperability Assessment Using the SunSpec Specification: Summary of EPRI's Testing of Communications in Residential Solar Inverters. EPRI, Palo Alto, CA: 2016. 3002009462.
3 Evaluation of SunSpec Modbus for Distributed Energy Resources: Results from EPRI Interoperability Testing and Market Research. EPRI, Palo Alto, CA: 2017. 3002009854.

Example Gap

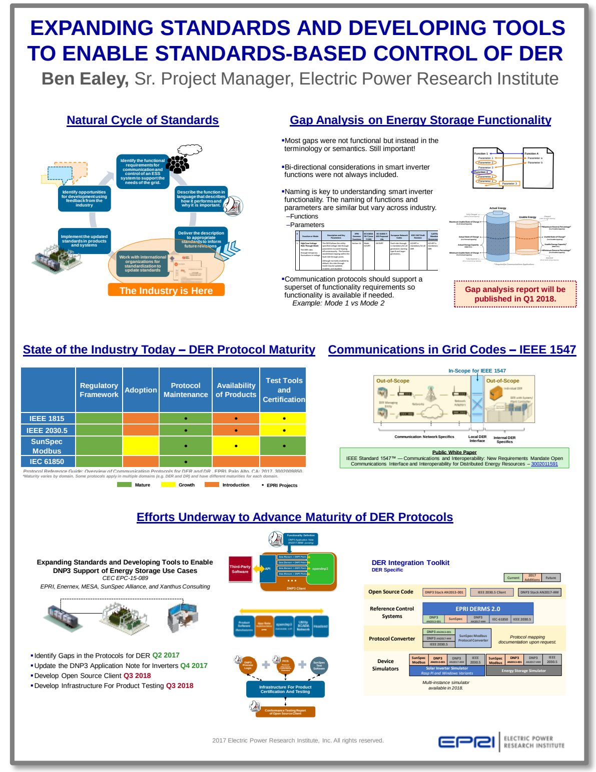
State of Charge



Terminology around state of charge of storage systems had been an issue prior to this effort. The terminology suggested in this project is now used widely.

Outreach

- **Open Advisory Group**
  - 110 individuals across 80 companies.
- **Working Groups / User Groups**
  - IEEE 2030.5 Conformity Assessment Roundtable
  - ESIC's Communication and Control Working Group
  - Other Standards Working Groups - 1547-2018, IEEE 1547.1, IEC-61850, IEEE 2030.5, SunSpec Modbus
  - MESA Technical Working Group
- **Conferences and Meetings**
  - **Four** EPRI's Energy Storage Integration Council Meetings
  - Energy Storage Association - Energy Storage STUDIO
  - Energy Storage Association Workshop



Poster Presentation at ESA's Energy Storage STUDIO – Nov. 14-15th, 2017

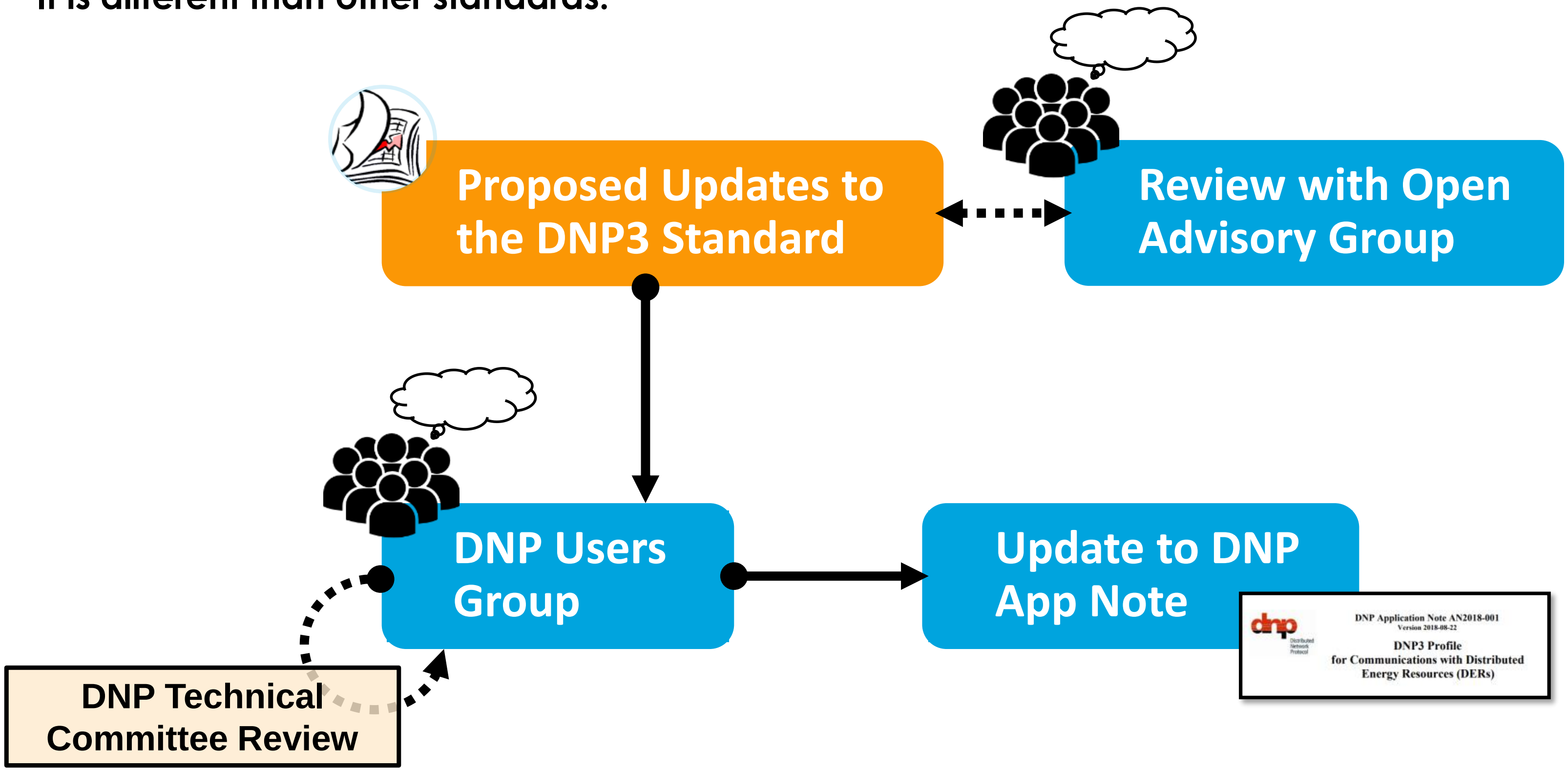
Expansion of DNP3 Application Note

Objectives

- **Update AN2013-001 to fill any gaps identified in previous phase.**
- **Work with DNP Users Group to publish an updated application note.**
- **Share new encodings and lessons learned with other standards groups.**

Process for Expanding the DNP3 App Note

It is different than other standards.



 www.epri.com EPRI ELECTRIC POWER RESEARCH INSTITUTE

Table 16 – Analog Input Points List

Point Index	Name / Description	Def Evt Cls	Transmitted Value Minimum	Transmitted Value Maximum	Scaling Multi-plier	Scaling Off-set	Units	Reso-lution				
	System Analog Inputs											
AI0	DER Profile Version Number. Always the number 0.91 for this specification.	3	91	91	0.01	0	n/a	0.01				
AI1	DER Profile Implementation Level. 1, 2 or 3 to indicate support for Level 1, Level 2 or Level 3 respectively.	3	1	3	1	0	n/a	1				
AI2	Nameplate Minimum Voltage Rating	3	0	2147483647	0.1	[illegible]	Volts	(1%)				
AI3	Nameplate Maximum Voltage Rating	3	0	2147483647	0.1	[illegible]	Volts	(1%)				
AI4	Nameplate Active Generation Power Rating at Unity Power Factor	3	0	2147483647	[illegible]	0	Watts		DSTO	WMaxRtg	ASG	2.10.4
AI5	Nameplate Active Charging Power Rating at Unity Power Factor	3	-2147483648	0	1	0	Watts		DSTO	WMaxChaRtg	ASG	2.10.4
AI6	Nameplate Active Generation Power Rating at Specified Over-Excited Power Factor	3	0	2147483647	[illegible]	0	Watts		DSTO	WOvPFRtg	ASG	2.10.4
AI7	Nameplate Active Charging Power Rating at Specified Over-Excited Power Factor	3	-2147483648	0	1	0	[illegible]		DSTO	WChaOvPFRtg	ASG	2.10.4
AI8	Specified Over-Excited Power Factor	3	-100	[illegible]	0.01	0	None	[illegible]	DSTO	OvPFRtg	ASG	2.10.4
AI9	Nameplate Active Generation Power Rating at Specified Under-Excited Power Factor	3	[illegible]	2147483647	1	[illegible]	Watts		DSTO	WUnPFRtg	ASG	2.10.4
AI10	Nameplate Active Charging Power Rating at Specified Under-Excited Power Factor	3	-2147483648	0	1	0	Watts		DSTO	WChaUnPFRtg	ASG	2.10.4
AI11	Specified Under-Excited Power Factor	3	-100	[illegible]	[illegible]	0	None	0.01	DSTO	UnPFRtg	ASG	2.10.4
AI12	Nameplate Reactive Supply (Injection) Power Rating	3	0	2147483647	1	0	VARs		DSTO	VarMaxSupRtg	ASG	2.10.4
AI13	Nameplate Reactive Absorption Power Rating	3	-2147483648	0	1	0	VARs		DSTO	VarMaxAbsbRtg	ASG	2.10.4
AI14	Nameplate Apparent Generation Power Rating	3	0	2147483647	1	0	VAs		DSTO	VAMaxRtg	ASG	2.10.4
AI15	Nameplate Apparent Charging Power Rating	3	-2147483648	0	1	0	VAs		DSTO	VAMaxChaRtg	ASG	2.10.4
AI16	Nameplate Storage Actual Capacity.	3	0	2147483647	1	0	Amp-hrs	1	DSTO	WhrRtg	ASG	2.6.2

DRAFT TEXT

DNP Application Note AN2018-001
Version 2018-08-22

DNP3 Profile
for Communications with Distributed Energy Resources (DERs)

Standardized Points List

A standardized Information Model for DNP3 points to simplify and expedite addition of new DER to a utility control network.

2.4.4 Connect and Disconnect Functions

The steps in Table 29 describe how to cause the DER to physically connect or disconnect fr… This function refers to the operation of the DER Connect/ Disconnect" switch identified in … disconnects the DER from both the utility and local customer loads and leaves any local loa… to the grid. This function is not the same as an activation of the "Utility Switch" at the Poi… Coupling, which would leave the DER connected to local loads.

The outstation shall start the time window and reversion timeout at the moment the master s… delivers the switch control command. Since the switch position is not an analog value, there is no ramp time parameter associated with this function.

Table 29 – Steps to perform a Connect/Disconnect of DER

Step	Description	Optionality	Function Code	Data Type	Point Number
1.	Set time window	Optional	Direct Operate / Response	AO	AO11
2.	Set reversion timeout	Optional	Direct Operate / Response	AO	AO12
3.	Retrieve status of switch	Optional	Read / Response or Unsolicited Response	BI	BI23
4.	Issue switch control command and receive response	Required	Select / Response, Operate / Response	BO	BO5
5.	Detect if switch is moving	Optional	Read / Response or Unsolicited Response	BI	BI24

This profile only specifies the ability to connect or disconnect the DER as a whole. It defines binary input points that indicate other levels of connectivity, e.g. Inverter #1 DC Disconnect Warning (. However, these conditions are not under control of the master.

DNP Application Note AN2018-001
Version 2018-08-22

DNP3 Profile for Communications with Distributed Energy Resources (DERs)

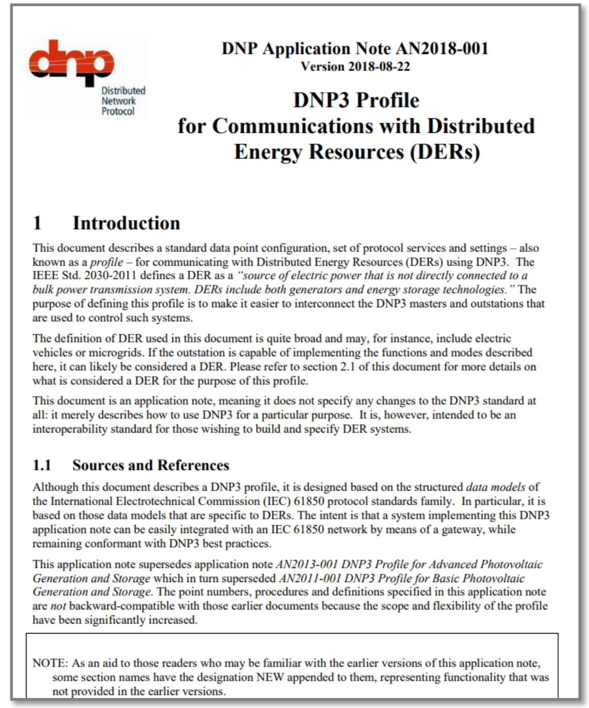
DER Specific Procedures

Written component defines procedures and guidance for applying the standardized points and achieving grid interoperability with DER.

AN2018-001 Published!

DNP3 Profile for Communications with Distributed Energy Resources (DERs)

- Application notes contain **suggestions and notes for DNP3 in specific applications**.
- AN2018-001 is **referenced in IEEE P1547.1** as the method to use for DNP3 in DERs
- IEEE is exploring make it a standard.
- What's new compared to AN2013-001?
  - Expands the storage functionality
  - Updates smart inverter functionality
  - Conforms with newest grid codes
- Available through the DNP3 Users Group website – www.dnp.org



Distributed Network Protocol

DNP Application Note AN2018-001
Version 2018-08-22

DNP3 Profile
for Communications with Distributed Energy Resources (DERs)

1 Introduction

This document describes a standard data point configuration, set of protocol services and settings – also known as a *profile* – for communicating with Distributed Energy Resources (DERs) using DNP3. The IEEE Std. 2030-2011 defines a DER as a *"source of electric power that is not directly connected to a bulk power transmission system. DERs include both generators and energy storage technologies."* The purpose of defining this profile is to make it easier to interconnect the DNP3 masters and outstations that are used to control such systems.

The definition of DER used in this document is quite broad and may, for instance, include electric vehicles or microgrids. If the outstation is capable of implementing the functions and modes described here, it can likely be considered a DER. Please refer to section 2.1 of this document for more details on what is considered a DER for the purpose of this profile.

This document is an application note, meaning it does not specify any changes to the DNP3 standard at all: it merely describes how to use DNP3 for a particular purpose. It is, however, intended to be an interoperability standard for those wishing to build and specify DER systems.

1.1 Sources and References

Although this document describes a DNP3 profile, it is designed based on the structured *data models* of the International Electrotechnical Commission (IEC) 61850 protocol standards family. In particular, it is based on those data models that are specific to DERs. The intent is that a system implementing this DNP3 application note can be easily integrated with an IEC 61850 network by means of a gateway, while remaining conformant with DNP3 best practices.

This application note supersedes application note *AN2013-001 DNP3 Profile for Advanced Photovoltaic Generation and Storage* which in turn superseded *AN2011-001 DNP3 Profile for Basic Photovoltaic Generation and Storage*. The point numbers, procedures and definitions specified in this application note are *not* backward-compatible with those earlier documents because the scope and flexibility of the profile have been significantly increased.

NOTE: As an aid to those readers who may be familiar with the earlier versions of this application note, some section names have the designation NEW appended to them, representing functionality that was not provided in the earlier versions.

Additions to DNP3 AN2018-001 since AN2013-001

Functions

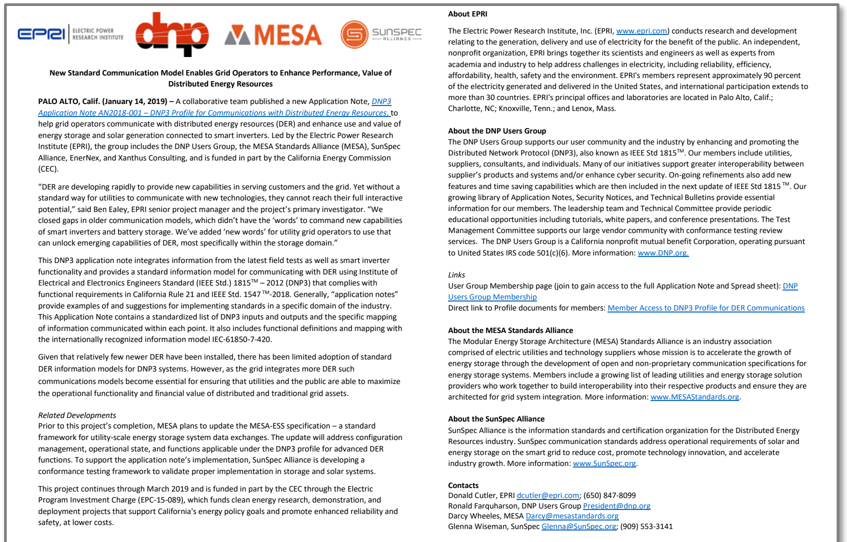
- Support Flag for Modes and Functions
- Limiting Response: Ramp Rates, Ramp Times and Time Constants
- Alarm Grouping and Reporting
- Cease to Energize and Return to Service Functions
- Low/High Frequency Ride-Through Mode
- Frequency-Watt Mode
- Coordinated Charge/Discharge Management Mode
- Automatic Generation Control Mode
- Constant VArs Mode
- Watt-VAr Power Mode
- Power Factor Correction Mode

Parameters

- Support for bi-directional power flow across all modes/functions
- Harmonization of terminology and concepts across stakeholder groups

Outreach

- **Open Advisory Group**
  - 110 individuals across 80 companies.
- **Webinars**
  - EPRI Member Research Update Webcasts
  - MESA Alliance Webcast on Application Note
- **Press Releases / Social Media**
  - Press Release for AN2018-001
  - Social Media for key milestones
  - DNP3 Podcast – SunSpec
  - DNP3 Podcast – Enernex/EPRI [pending]
  - Project Document/Website [pending]
- **Working Groups / User Groups**
  - IEEE 2030.5 Conformity Assessment Roundtable
  - ESIC's Communication and Control Working Group
  - Other Standards Working Groups – P1547.1
- **Conferences and Meetings**
  - EPRI's 2nd EPRI Smart Inverter Workshop
  - **Seven** EPRI Advisory Meetings (4 USA, 1 European, 2 Asian)
  - **Four** EPRI's Energy Storage Integration Council Meetings



New Standard Communication Model Enables Grid Operators to Enhance Performance, Value of Distributed Energy Resources

PALO ALTO, Calif. (January 14, 2019) – A collaborative team published a new Application Note, *DNP3 Application Note AN2018-001 – DNP3 Profile for Communications with Distributed Energy Resources,* to help grid operators communicate with distributed energy resources (DER) and enhance use and value of energy storage and solar generation connected to smart inverters. Led by the Electric Power Research Institute (EPRI), the group includes the DNP Users Group, the MESA Standards Alliance (MESA), SunSpec Alliance, EnerNex, and Xanthus Consulting, and is funded in part by the California Energy Commission (CEC).

"DER are developing rapidly to provide new capabilities in serving customers and the grid. Yet without a standard way for utilities to communicate with new technologies, they cannot reach their full interactive potential," said Ben Ealey, EPRI senior project manager and the project's primary investigator. "We closed gaps in older communication models, which didn't have the 'words' to command new capabilities of smart inverters and battery storage. We've added 'new words' for utility grid operators to use that can unlock emerging capabilities of DER, most specifically within the storage domain."

This DNP3 application note integrates information from the latest field tests as well as smart inverter functionality and provides a standard information model for communicating with DER using Institute of Electrical and Electronics Engineers Standard (IEEE Std.) 1815™ – 2012 (DNP3) that complies with functional requirements in California Rule 21 and IEEE Std. 1547™-2018. Generally, "application notes" provide examples of and suggestions for implementing standards in a specific domain of the industry. This Application Note contains a standardized list of DNP3 inputs and outputs and the specific mapping of information communicated within each point. It also includes functional definitions and mapping with the internationally recognized information model IEC-61850-7-420.

Given that relatively few newer DER have been installed, there has been limited adoption of standard DER information models for DNP3 systems. However, as the grid integrates more DER such communications models become essential for ensuring that utilities and the public are able to maximize the operational functionality and financial value of distributed and traditional grid assets.

Related Developments
Prior to this project's completion, MESA plans to update the MESA-ESS specification – a standard framework for utility-scale energy storage system data exchanges. The update will address configuration management, operational state, and functions applicable under the DNP3 profile for advanced DER functions. To support the application note's implementation, SunSpec Alliance is developing a conformance testing framework to validate proper implementation in storage and solar systems.

This project continues through March 2019 and is funded in part by the CEC through the Electric Program Investment Charge (EPC-15-089), which funds clean energy research, demonstration, and deployment projects that support California's energy policy goals and promote enhanced reliability and safety, at lower costs.

About EPRI

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'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, NC; Knoxville, Tenn.; and Lenox, Mass.

About the DNP Users Group
The DNP Users Group supports our user community and the industry by enhancing and promoting the Distributed Network Protocol (DNP3), also known as IEEE Std 1815™. Our members include utilities, suppliers, consultants, and individuals. Many of our initiatives support greater interoperability between supplier's products and systems and/or enhance cyber security. On-going refinements also add new features and time saving capabilities which are then included in the next update of IEEE Std 1815™. Our growing library of Application Notes, Security Notices, and Technical Bulletins provide essential information for our members. The leadership team and Technical Committee provide periodic educational opportunities including tutorials, white papers, and conference presentations. The Test Management Committee supports our large vendor community with conformance testing review services. The DNP Users Group is a California nonprofit mutual benefit Corporation, operating pursuant to United States IRS code 501(c)(6). More information: www.DNP.org.

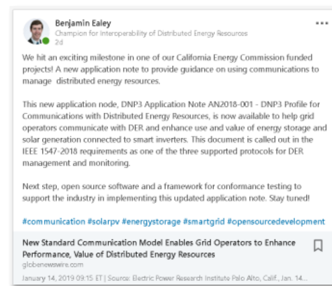
Links
User Group Membership page (join to gain access to the full Application Note and Spread sheet): DNP Users Group Membership
Direct link to Profile documents for members: Member Access to DNP3 Profile for DER Communications

About the MESA Standards Alliance
The Modular Energy Storage Architecture (MESA) Standards Alliance is an industry association comprised of electric utilities and technology suppliers whose mission is to accelerate the growth of energy storage through the development of open and non-proprietary communication specifications for energy storage systems. Members include a growing list of leading utilities and energy storage solution providers who work together to build interoperability into their respective products and ensure they are architected for grid system integration. More information: www.MESAStandards.org.

About the SunSpec Alliance
SunSpec Alliance is the information standards and certification organization for the Distributed Energy Resources industry. SunSpec communication standards address operational requirements of solar and energy storage on the smart grid to reduce cost, promote technology innovation, and accelerate industry growth. More information: www.SunSpec.org.

Contacts
Donald Cutler, EPRI dcutler@epri.com; (650) 847-8099
Ronald Farquharson, DNP Users Group President@dnp.org
Darcy Wheeles, MESA Darcy@mesastandards.org
Glenna Wiseman, SunSpec Glenna@SunSpec.org; (909) 553-3141

Press Release Announcing DNP AN2018-001

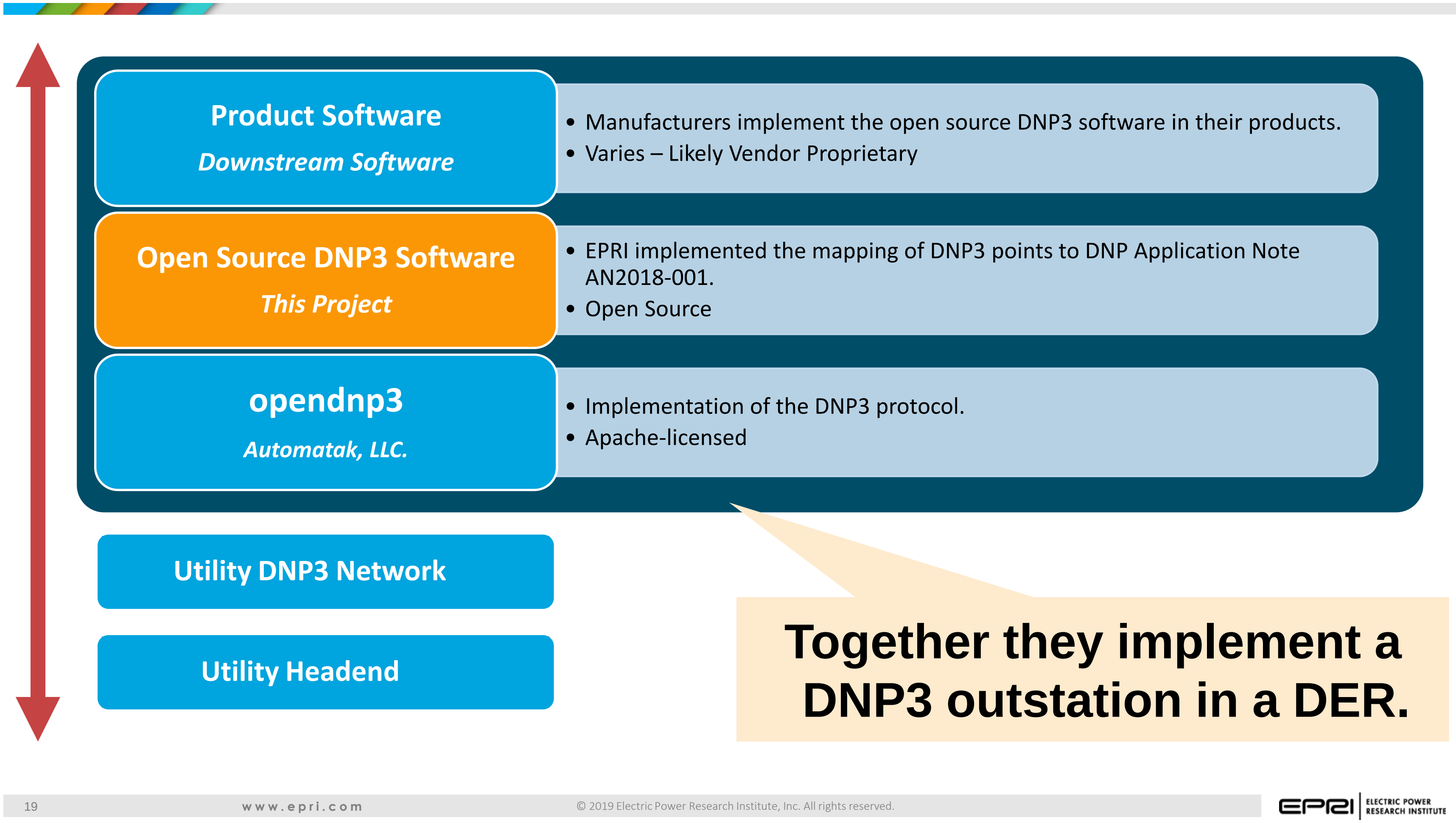


Examples of Social Media

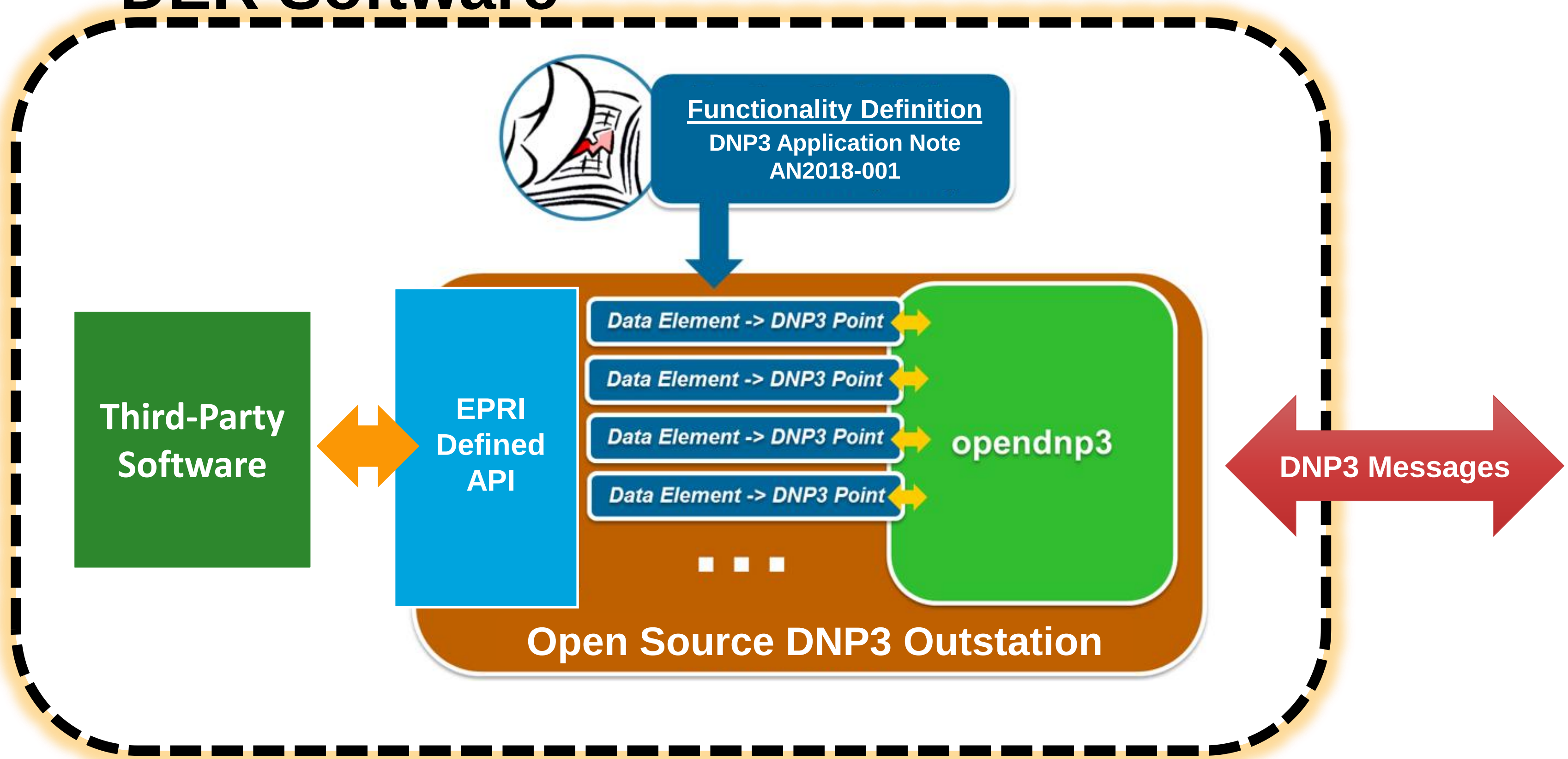
Open-Source DNP3 Software

Objectives

- **Develop open-source DNP3 software to simplify implementation of AN2018-001.**
- **Identify development environment most used by manufacturers and developers.**
- **Share progress with the industry to help pair software with potential users.**

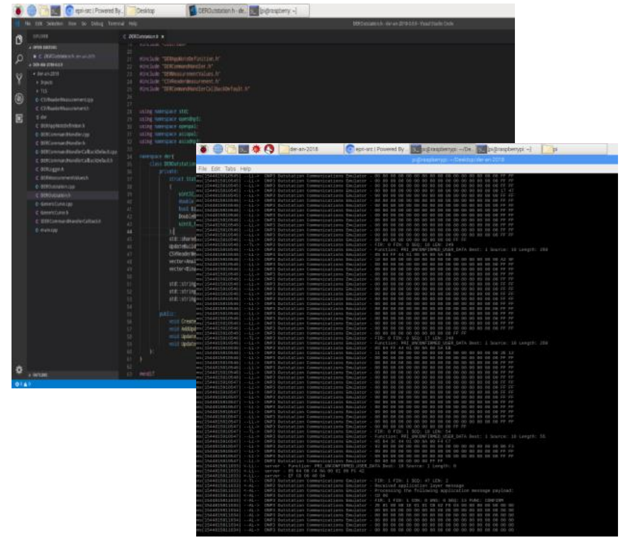

Product Software
Downstream Software
Manufacturers implement the open source DNP3 software in their products.
Varies – Likely Vendor Proprietary
Open Source DNP3 Software
This Project
EPRI implemented the mapping of DNP3 points to DNP Application Note AN2018-001.
Open Source
opendnp3
Automatak, LLC.
Implementation of the DNP3 protocol.
Apache-licensed
Utility DNP3 Network
Utility Headend
Together they implement a DNP3 outstation in a DER.
19
www.epri.com
© 2019 Electric Power Research Institute, Inc. All rights reserved.
EPRI
ELECTRIC POWER RESEARCH INSTITUTE

DER Software



Open Source Outstation – DNP AN2018

- Implements DNP AN2018-001 w/ TLS Security
- C++, Linux
- Built and tested on Raspberry Pi 3
- BSD-3 Clause



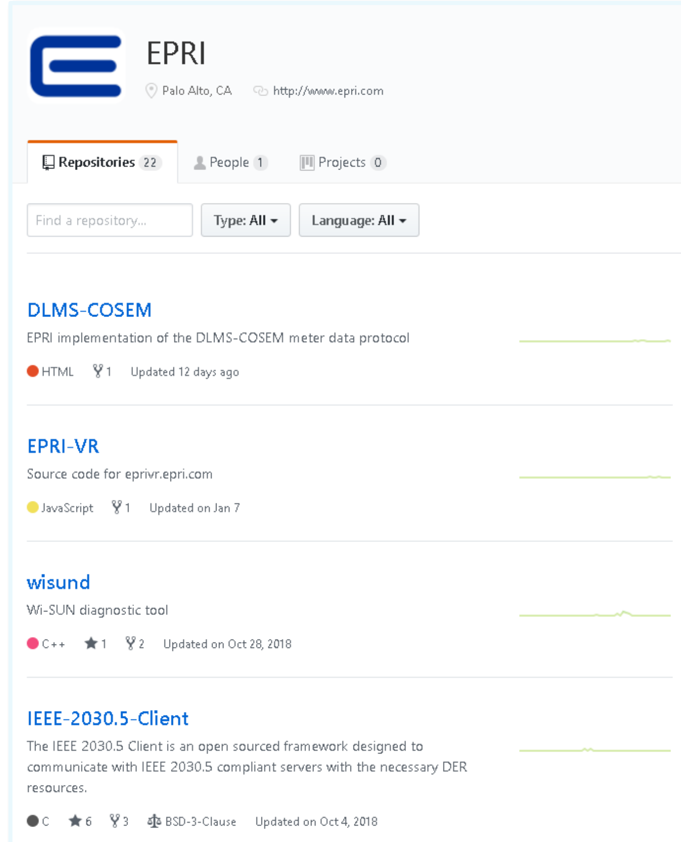
Functions Supported

- Enter Service
- Active Power Limit Mode
- Constant Power Factor Mode
- Volt-VAR Mode
- Watt-VAR Mode
- Constant VAR Mode
- Volt-Watt Mode
- Voltage Trip
- Momentary Cessation
- Frequency Trip
- Frequency Droop (Freq-Watt)
- Monitoring Points
- *Scheduling is implemented for above*

Code provides a template for others to implement these functions and others from AN2018-001

Planned Outreach

- Software will be posted on EPRI's GitHub page – https://github.com/epri-dev
- Project Document/Website [pending]
- Team will hold a webcast to demonstrate the new software
  - Invites will be shared through, email, LinkedIn, working groups, and personal invites
- Software will be included in EPRI's EPRI's Distributed Energy Resources Integration Toolkit report[1]

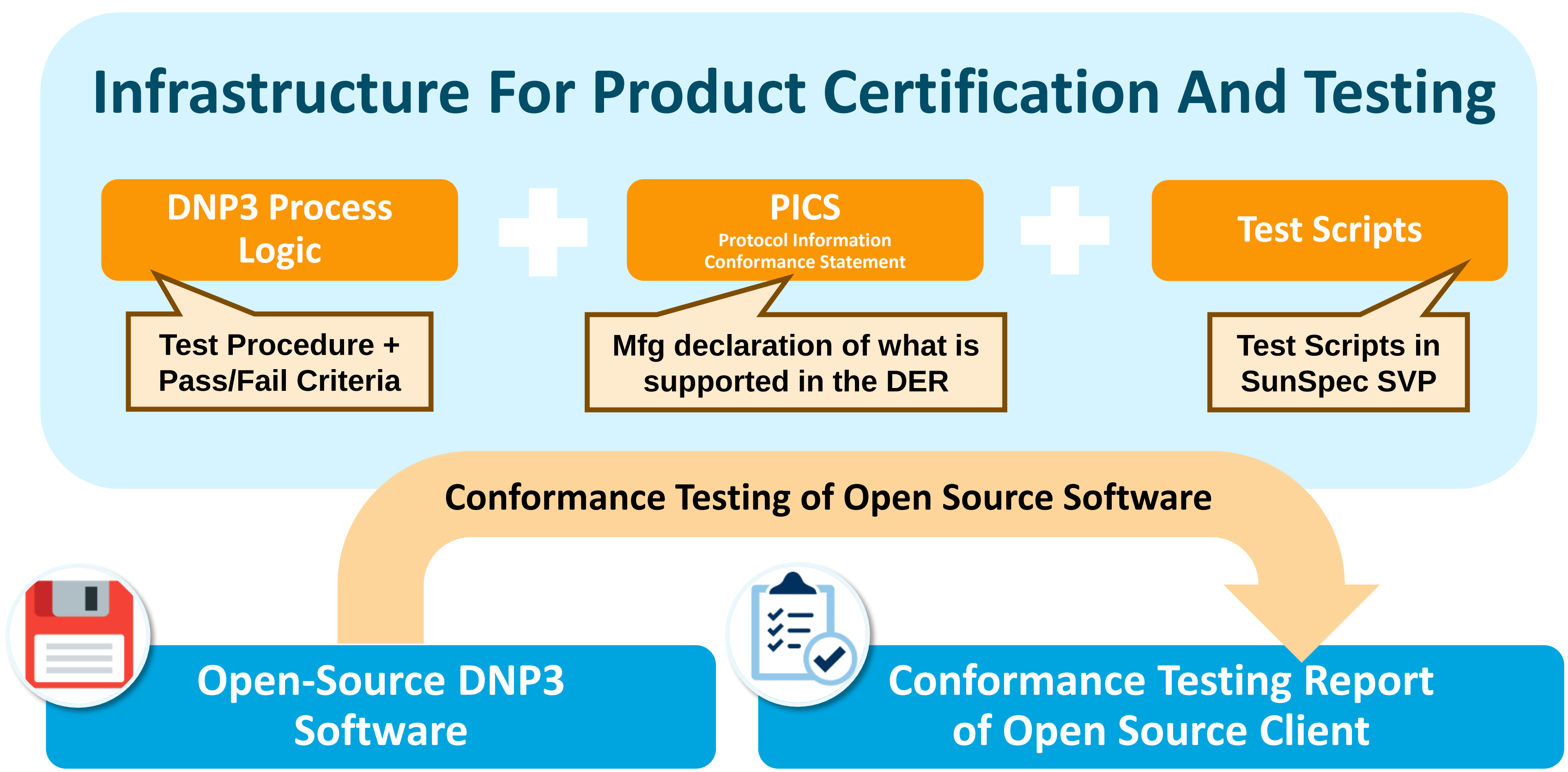


1 *EPRI's Distributed Energy Resources Integration Toolkit: An Overview of EPRI Tools for Testing and Implementing Open Protocols* EPRI, Palo Alto, CA: 2018. 3002013623

Infrastructure for Product Certification and Testing

Objectives

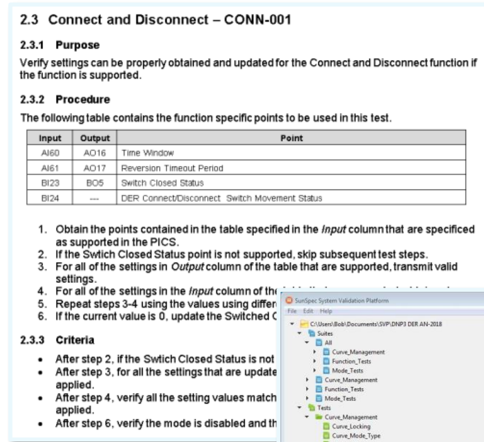
- **Develop the tools for an entity to perform conformance testing on AN2018-001**
  - **Develop test procedures and pass/fail criteria**
  - **Develop test scripts to conduct the test procedures and validate responses**
  - **Run the open source code through the test framework**



24 www.epri.com

Test Scripts

- Verifies...
  - Able to obtain all required input points associated with tested functionality
  - Able to update all required output points associated with tested functionality
  - Validate that input points which track output points perform correctly
  - Validate generic curve management functionality
  - Validate points are implemented or marked as unimplemented consistent with the logical point groups in which they reside.



2.3 Connect and Disconnect – CONN-001

2.3.1 Purpose

Verify settings can be properly obtained and updated for the Connect and Disconnect function if the function is supported.

2.3.2 Procedure

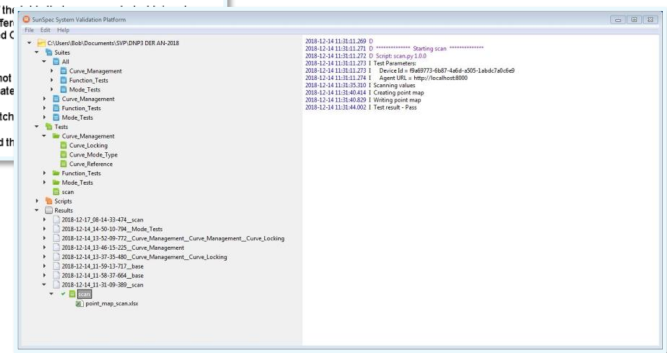
The following table contains the function specific points to be used in this test.

Input	Output	Point
AI60	AO16	Time Window
AI61	AO17	Reversion Timeout Period
BI23	BO5	Switch Closed Status
BI24	---	DER Connect/Disconnect Switch Movement Status

1. Obtain the points contained in the table specified in the *Input* column that are specificed as supported in the PICS.
2. If the Swtich Closed Status point is not supported, skip subsequent test steps.
3. For all of the settings in *Output* column of the table that are supported, transmit valid settings.
4. For all of the settings in the *Input* column of the
5. Repeat steps 3-4 using the values using differ
6. If the current value is 0, update the Switched C

2.3.3 Criteria

- After step 2, if the Swtich Closed Status is not
- After step 3, for all the settings that are update applied.
- After step 4, verify all the setting values match applied.
- After step 6, verify the mode is disabled and th

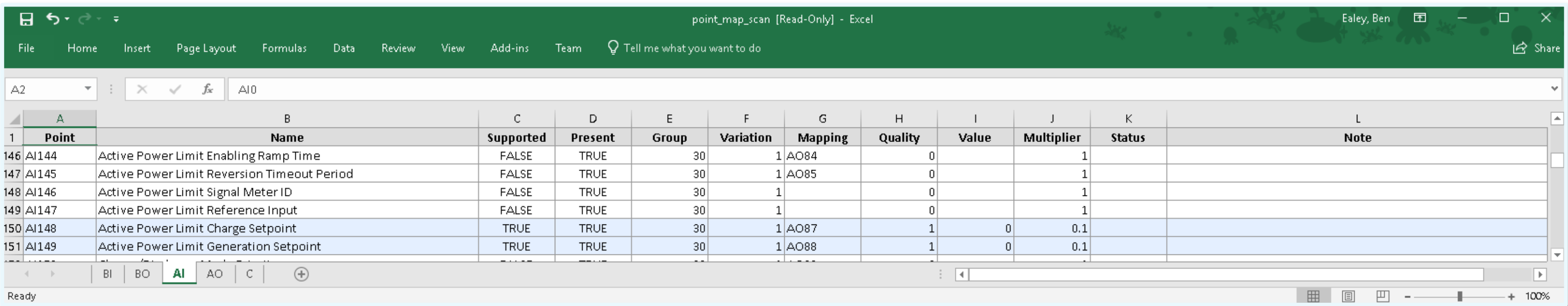


Validates **AN2018-001 implementation.**
Does not validate **DNP3 conformance.**
Does not validate issues in **electrical behavior.[1]**

1 Assessment of Interoperability Achieved through IEEE Std 1547-2018 and IEEE P1547.1: Results from EPRI Interoperability Testing and Market Research. EPRI, Palo Alto, CA: 2018. 3002013473.

Automated PICS Creation

- Team needed a method for manufacturers to create a list of points supported in their device.
- ~1,300 possible parameters.
  - ~340 Binary Inputs
  - ~50 binary outputs
  - ~630 analog inputs
  - ~340 analog outputs



	Point	Name	Supported	Present	Group	Variation	Mapping	Quality	Value	Multiplier	Status	Note
146	AI144	Active Power Limit Enabling Ramp Time	FALSE	TRUE	30	1	AO84	0		1		
147	AI145	Active Power Limit Reversion Timeout Period	FALSE	TRUE	30	1	AO85	0		1		
148	AI146	Active Power Limit Signal Meter ID	FALSE	TRUE	30	1		0		1		
149	AI147	Active Power Limit Reference Input	FALSE	TRUE	30	1		0		1		
150	AI148	Active Power Limit Charge Setpoint	TRUE	TRUE	30	1	AO87	1	0	0.1		
151	AI149	Active Power Limit Generation Setpoint	TRUE	TRUE	30	1	AO88	1	0	0.1		

Test Cases

Smart Inverter Functions

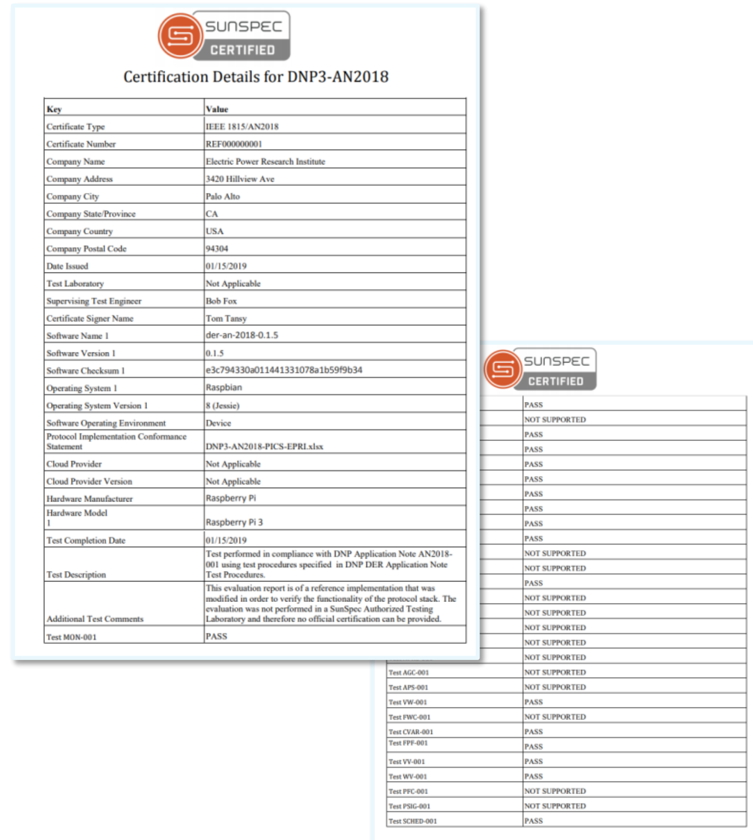
- Monitoring
- Alarm Grouping and Reporting
- Connect and Disconnect
- Cease to Energize and Return to Service
- Operation States
- Time Synchronization
- Event/History Logging
- Low/High Voltage Ride-Through Mode
- Low/High Frequency Ride-Through Mode
- Frequency-Watt Mode
- Dynamic Reactive Current Support Mode
- Dynamic Volt-Watt Mode
- Active Power Limit Mode
- Charge/Discharge Storage Mode
- Coordinated Charge/Discharge Management Mode
- Active Power Response
- Automatic Generation Control Mode
- Active Power Smoothing Mode
- Volt-Watt Mode
- Frequency-Watt Curve Mode
- Constant Vars Mode
- Fixed Power Factor Mode
- Volt-Var Control Mode
- Watt-Var Power Mode
- Power Factor Correction Mode
- Pricing Signal Mode

Generic Functionality

- Scheduling Tests
- Generic Curve Management Tests
- Reference Indication Test
- Curve Locking Test
- Mode Type Mismatch Test

Planned Outreach

- Process Logic will be published for free on EPRI.com.
- Project Document/Website [pending]
- Team will hold a webcast to demonstrate the framework
  - Invites will be shared through, email, LinkedIn, working groups, and personal invites
- SunSpec is exploring including this in their certification offerings.



Certification Details for DNP3-AN2018

Key	Value
Certificate Type	IEEE 1815/AN2018
Certificate Number	REF000000001
Company Name	Electric Power Research Institute
Company Address	3420 Hillview Ave
Company City	Palo Alto
Company State/Province	CA
Company Country	USA
Company Postal Code	94304
Date Issued	01/15/2019
Test Laboratory	Not Applicable
Supervising Test Engineer	Bob Fox
Certificate Signer Name	Tom Tansy
Software Name 1	der-an-2018-0.1.5
Software Version 1	0.1.5
Software Checksum 1	e3c794330a011441331078a1b59f9b34
Operating System 1	Raspbian
Operating System Version 1	8 (Jessie)
Software Operating Environment	Device
Protocol Implementation Conformance Statement	DNP3-AN2018-PICS-EPRI.xlsx
Cloud Provider	Not Applicable
Cloud Provider Version	Not Applicable
Hardware Manufacturer	Raspberry Pi
Hardware Model 1	Raspberry Pi 3
Test Completion Date	01/15/2019
Test Description	Test performed in compliance with DNP Application Note AN2018-001 using test procedures specified in DNP DER Application Note Test Procedures.
Additional Test Comments	This evaluation report is of a reference implementation that was modified in order to verify the functionality of the protocol stack. The evaluation was not performed in a SunSpec Authorized Testing Laboratory and therefore no official certification can be provided.
Test MON-001	PASS

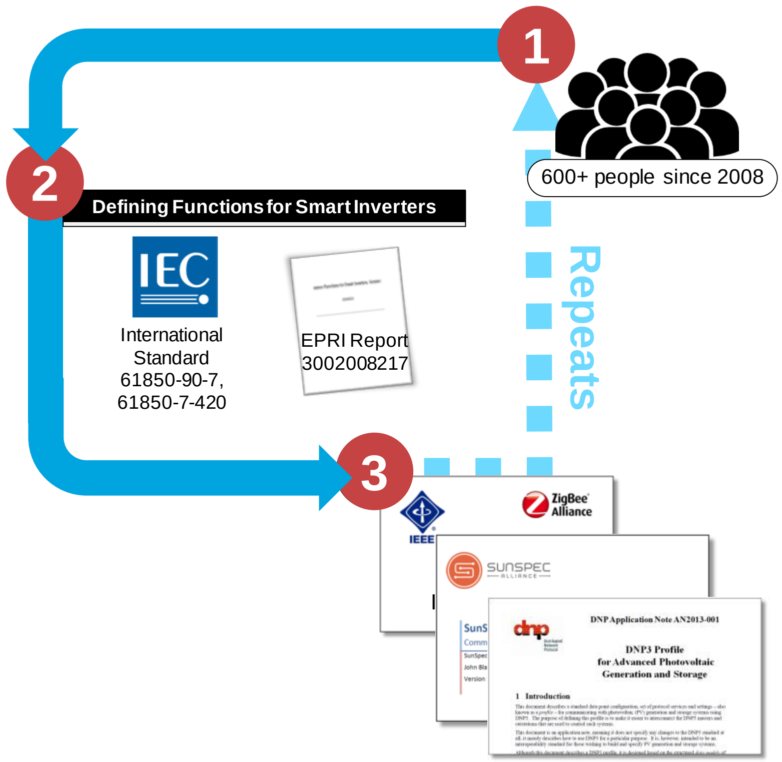
	PASS
	NOT SUPPORTED
	PASS
	PASS
	PASS
	PASS
	PASS
	PASS
	PASS
	PASS
	NOT SUPPORTED
	NOT SUPPORTED
	PASS
	NOT SUPPORTED
	NOT SUPPORTED
	NOT SUPPORTED
	NOT SUPPORTED
	NOT SUPPORTED
Test AGC-001	NOT SUPPORTED
Test APS-001	NOT SUPPORTED
Test VW-001	PASS
Test FWC-001	NOT SUPPORTED
Test CVAR-001	PASS
Test FPF-001	PASS
Test VV-001	PASS
Test WV-001	PASS
Test PFC-001	NOT SUPPORTED
Test PSIG-001	NOT SUPPORTED
Test SCHED-001	PASS

Next Steps

Next Steps

Cyclical Nature of Standards

- DER technologies will continue to adapt to grid needs.[1,2,3,4]
- Standards must adapt to these new capabilities and use cases.
- Working groups should be mindful and work to minimize changes that may prevent backwards compatibility



1 Common Functions for DER Group Management, Third Edition. EPRI, Palo Alto, CA: 2016. 3002008215.
2 Common Functions for Smart Inverters: 4th Edition. EPRI, Palo Alto, CA: 2016. 3002008217.
3 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. 3002011045.
4 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.

Next Steps

On-going Conformance Testing

- Standards for DER are relatively new to DER – the industry is learning how to apply them
- Development is needed to create a sustainable model that encourages certification testing
- This project created a framework for DNP3 – orgs must now refine the technical and business aspects of testing

  EPRI ELECTRIC POWER RESEARCH INSTITUTE

Next Steps

Conformance Testing of End-to-End Interoperability

- Exchange information + use the information being exchanged correctly
- Important given the likely breadth of makes, models, and types of DER in the future[5,6]
- PIEEE 1547.1 is the first test procedure of its kind to assess this formally in DER.
- Translation capabilities in DERMS/ADAM will be key, initial studies indicate more research needed[7]

Volatility of DER Settings

EPRI testing found some inverters revert to default settings when power to the inverters is cycled (AC or DC).

Potential Impact: If inverters lose settings where there is low DC power (night, completely overcast) this will cause inverters to forget any settings they have received each day or on overcast days. If it occurs after AC power cycling, then inverters may forget all settings after a power outage or if disconnected from the grid.

Is it Addressed by 1547? Yes, IEEE P1547.1's chapter "5.18.8 DER settings non-volatility test" addresses systems losing settings during a power down. This will test whether DER lose settings overnight.

Source: *Assessment of Interoperability Achieved through IEEE Std 1547-2018 and IEEE P1547.1: Results from EPRI Interoperability Testing and Market Research. EPRI, Palo Alto, CA: 2018. 3002013473.*

EPRI Smart Inverter Test Labs in Knoxville, Tennessee

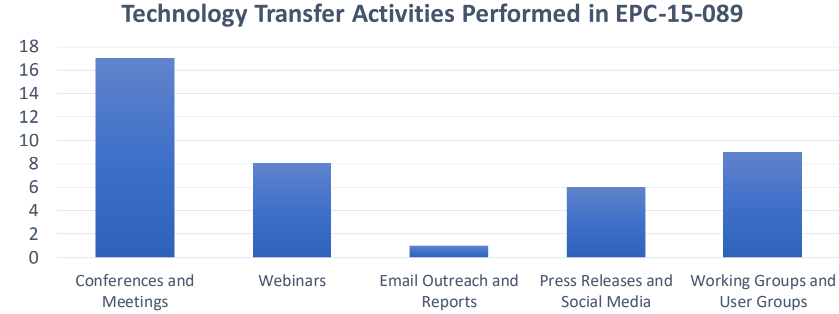
5 Title 24 and Solar Panels - http://energy.ca.gov/title24/2019standards/rulemaking/
6 Interoperability Strategic Vision. A GMLC White Paper. Grid Modernization Laboratory Consortium. U.S. Department of Energy. March 2018. https://gridmod.labworks.org/sites/default/files/resources/InteropStrategicVisionPaper2018-03-29.pdf
7 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.
8 Tucson Electric Power Project RAIN: October 2018 Update. EPRI, Palo Alto, CA: 2018. 3002014812

Together…Shaping the Future of Electricity

Technology Transfer

Summary of Tech Transfer

- **Open Advisory Group**
  - 110 individuals across 80 companies.
- **Reports**
  - EPRI's Distributed Energy Resources Integration Toolkit: EPRI Tools for Testing and Implementing Open Protocols
  - Email Outreach on Certification Framework [Pending]
  - Email Outreach on Open Source Software [Pending]
  - SunSpec Alliance Newsletters
- **Webinars**
  - **Five** EPRI Member Research Update Webcasts
  - MESA Alliance Webcast on Application Note
  - SunSpec's Cybersecurity Webinar: Securing California Rule 21 Networks
  - Release of Software and Cert [Pending]
- **Press Releases / Social Media**
  - Press Release for AN2018-001
  - Social Media for key milestones
  - DNP3 Podcast – SunSpec
  - DNP3 Podcast – Enernex/EPRI
  - Project Website



- **Working Groups / User Groups**
  - IEEE 2030.5 Conformity Assessment Roundtable
  - ESIC's Communication and Control Working Group
  - Other Standards Working Groups - 1547-2018, IEEE 1547.1, IEC-61850, IEEE 2030.5, SunSpec Modbus
  - MESA Technical Working Group
- **Conferences and Meetings**
  - EPRI's 2nd EPRI Smart Inverter Workshop
  - **Seven** EPRI Advisory Meetings (4 USA, 1 European, 2 Asian)
  - **Four** EPRI's Energy Storage Integration Council Meetings
  - Energy Storage Association - Energy Storage STUDIO
  - Energy Storage Association Workshop
  - Gridvolution Event Platform
  - DER Communication Protocols and CA Rule 21 Executive Training

EPRI and the project team will continue tech transfer after project end.

EPRI ELECTRIC POWER RESEARCH INSTITUTE