ELECTRIC POWER RESEARCH INSTITUTE

Residential Battery Energy Storage: Demand Response Opportunities with OpenADR 2.0b

Field Deployments and Performance Analysis

3002017985

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Final Report - January 2020

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ABSTRACT

Electric utilities are exploring opportunities to leverage the potential demand response flexibility offered by energy storage systems, and how customers may benefit from reduced energy costs as well as additional value streams from grid service offerings. In support of that emerging technology advocacy, this report details efforts to assess the feasibility of integrating the open automated demand response (DR) communications standard (OpenADR 2.0b) with residential, behind-the-meter (BTM) energy storage systems. Preliminary testing was accomplished in a laboratory environment, with additional testing accomplished at one field site to determine the feasibility of communicating standardized DR signaling via the OpenADR 2.0b protocol to manage the opportunities for demand response flexibility offered by the energy storage system under test.

The energy storage demand response use cases used with *LOAD_DISPATCH* signals were charge, discharge, and hold, as well as returning to normal operations. Each *LOAD_DISPATCH* signal included a power and time component, as well as a start time and duration. The project demonstrated successful application of the OpenADR 2.0b communication protocol standard to send and receive *LOAD_DISPATCH* signals to manage flexibility from an OpenADR certified E-Gear energy storage system.

Keywords
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PRIMARY AUDIENCE: Demand Response Teams

SECONDARY AUDIENCE: Distribution Engineering, Transmission Engineering

KEY RESEARCH QUESTION

This research was undertaken to determine the efficacy of using OpenADR 2.0b for messaging demand response signals to residential battery energy storage systems in the laboratory and in the field.

RESEARCH OVERVIEW

EPRI undertook research to determine the efficacy of using OpenADR 2.0b for messaging demand response signals to residential battery energy storage systems in the lab, and in the field. E-Gear's residential energy storage system was chosen for this research, as the system is OpenADR 2.0b certified and E-Gear was willing to work with EPRI and SCE to carry out the research. Testing was accomplished using OpenADR server infrastructure provided by Nebland's DR Engine as the Virtual Top Node (VTN) and E-Gear's residential energy storage system as the OpenADR 2.0b profile Virtual End Node (VEN). EPRI assessed interoperability among OpenADR VTN and VEN for the BESS and implemented software updates to conduct the tests to implement OpenADR 2.0b LOAD_DISPATCH control logic.

KEY FINDINGS

- The OpenADR 2.0b protocol can be used to control distributed energy storage units in the field.
- OpenADR 2.0b certification of energy storage systems allows signal reception but does not specifically provision the control logic to respond to OpenADR signals. Further software updates to the Battery Energy Storage System (BESS) control logic may be required to respond to the OpenADR 2.0b protocol message structure, as demand response use cases are developed.
- Control of BESS customer operated assets via OpenADR may align well for utilities and energy markets that already use OpenADR for remote messaging of other field assets or for enabling response to dynamic prices for customer benefit and providing flexibility for local grid reliability and wholesale market resources.

WHY THIS MATTERS

While OpenADR 2.0b is not required by the California Rule 21 condition of service for behind the meter storage, the OpenADR protocol is used by many utilities for secure communications to customers for their demand response programs. The protocol is also now included in the California Energy Commission's Title 24 new construction standards. The potential to incorporate existing or new distributed, customer-owned battery energy storage systems into existing demand response programs by using existing standards and utility procedures may benefit both utility and customer for meeting California's future energy needs.

HOW TO APPLY RESULTS

Results contained in this report can be used to judge the efficacy of using the OpenADR 2.0b protocol for demand response communications of energy storage systems, as it relates to sending and receiving charge, discharge and hold signals.

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ACRONYMS AND ABBREVIATIONS

BES	battery energy storage
BESS	battery energy storage system
BMS	battery management system
BTM	behind the meter
DERMS	distributed energy resource management system
DR	demand response
ECC	elliptic curve cryptography (an alternative to RSA public-key encryption)
EMS	energy management system
HTTP	hypertext transfer protocol
M&V	measurement and verification
OpenADR	open automated demand response
PKI	public key infrastructure
RSA	Rivest, Shamir and Adelman (public-key encryption technology developed by RSA Data Security)
SCE	Southern California Edison
SOC	state of charge
TLS	transport layer security
VEN	virtual end node
VTN	virtual top node
XML	extensible markup language
XMPP	extensible messaging and presence protocol

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INTRODUCTION

Electric utilities are exploring opportunities to leverage the potential demand response flexibility offered by energy storage systems, and how customers may benefit from reduced energy costs as well as additional value streams from grid service offerings. In support of that emerging technology advocacy, this report details efforts to assess the feasibility of integrating the open automated demand response (DR) communications standard (OpenADR 2.0b) with residential, behind-the-meter (BTM) energy storage systems. Preliminary testing was accomplished in a laboratory environment, with additional testing accomplished at one field site to determine the feasibility of communicating standardized DR signaling via the OpenADR 2.0b protocol to manage the opportunities for demand response flexibility offered by the energy storage system under test.

The energy storage demand response use cases used with *LOAD_DISPATCH* signals were <u>charge</u>, <u>discharge</u>, and <u>hold</u>, as well as returning to normal operations. Each *LOAD_DISPATCH* signal included a power and time component, as well as a start time and duration. The project demonstrated successful application of the OpenADR 2.0b communication protocol standard to send and receive *LOAD_DISPATCH* signals to manage flexibility from an OpenADR certified E-Gear energy storage system.

Goals and Objectives

Develop Product and Technology Requirements

- Validate product requirements to support OpenADR 2.0a/b
    - Research existing products to provide storage visibility and response based on an OpenADR signal
    - Determine obstacles to integration of OpenADR functionality to energy storage equipment
    - Determine security requirements for communication with equipment
- Analyze benefits/drawbacks of one vs multiple partners/technology types
- Research and report on vertically integrated vendors who can offer an end-to-end solution
- Determine what challenges exist in integrating partners' equipment, software, and IT systems
- Review current state-of-the-art in communications technologies for utilities/batteries communications

Develop Standardized Control Requirements and Deploy Control Algorithms Directly or via 3rd Party

- Charge, discharge, hold
- kW and kWh request
- Time Stamp

Develop Metering/Monitoring Framework

- Development of data requirements for monitoring, measurement and verification (SOC, kWh available, etc.)
- Measurement & Verification Plan
  - Via vendor discussions and API availability, develop M&V plan that allows for accurate reporting of results

Test Storage Assets with Focus on Service-as-a-DR-Asset Use Case

- Develop specific messaging for electric storage activities (charge, discharge, hold, etc.), related to real-world dispatches' scenarios
- Send DR signals from 3rd party VTN
- Validate signals received by assets

Analyze Results

- Analyze response of energy storage asset(s) based on request(s) (on individual basis and in aggregate)
  - Charge
  - Discharge
  - Hold
  - Power input/output over interval
  - Energy input/output over interval
- Analyze performance of storage assets based on
  - Capacity availability of assets
  - Communications/data connectivity availability of assets
  - Response of assets compared to expected results

Methodology

The study team located a vendor (E-Gear) with OpenADR 2.0b certification to be used as a Virtual End Node (VEN), and chose Nebland Software's NOVA DR Engine as its Virtual Top Node (VTN). After software development by E-Gear was completed, testing was first accomplished in a lab environment, and then carried out in a controlled field test.

Report Organization

This report is organized as follows:

- Section 2 reviews products and technologies currently available as well as the process for system registration and OpenADR certification.
- Section 3 summarizes the development of the testing and measurement and verification (M&V) plans.
- Section 4 addresses the field tests, including site selection, the testing process, and results obtained.

- Section 5 presents project conclusions and key recommendations.

2

Product and Technology Requirements

This section describes a broad-based effort to assess the functional applicability of OpenADR relevant to energy storage equipment, data communication, control, M&V, and real-world performance of storage, as a demand-responsive asset communications tool.

- An overview of standards and standards-based interoperability principles for BES demand response (DR), with an assessment of the OpenADR 2.0b standard and DR signal characterization
- A review of the current state-of-the-art in communications technologies
- A review of the status of current BES products with respect to supporting the OpenADR 2.0 standard, including:
  - Researching existing products to provide storage visibility and response based on an OpenADR signal
  - Identifying security requirements for communication with equipment
- An examination of the current challenges in implementing OpenADR for BES and DR
  - Reporting on vertically-integrated vendors who can offer an end-to-end solution
  - Identifying the technology gaps remaining as obstacles to integrating communications equipment, software, and IT systems
  - Reviewing price-signaling protocols currently available

State-of-the-Art BES Communication Technology Practices

Figures 2-1 through 2-5 give an overview of the state-of-the-art in communications for residential battery storage, as of the beginning of this project. These figures come from an informational presentation prepared by EPRI for Southern California Edison's Emerging Markets and Technology (EM&T) program. As energy storage becomes an increasingly important customer asset and potential grid resource, communications systems for DR programs become increasingly important.

Energy storage continues to emerge as a grid resource that supports increased generation from renewables, lowers the cost per kWh of delivered energy, and helps satisfy policy mandates towards increased grid stability. Effective monitoring and control capabilities assure that BES systems provide grid services to electric utilities and grid operators. Effective, standards-based communications are essential to achieving these goals, enabling BES to provide multiple benefits simultaneously and to seamlessly integrate utility and third-party systems that provide stand alone or aggregated grid resources.

At present, one can identify four distinct communication scenarios to integrate a standalone BES system:

1. Vendor-customer
2. Vendor/third-party/customer
3. Utility/systems operator/customer
4. Utility/service provider/vendor/customer

When only a vendor and customer are involved (Figure 2-1), the focus is on managing the customer's onsite resources and energy/capacity demands, such as output from a rooftop PV or a need for backup power. Here, the vendor provides storage as either a standalone or integrated service, in which case the service provider may be a separate entity. In this case, communications are not motivated by a need to provide grid services but to serve the customer.

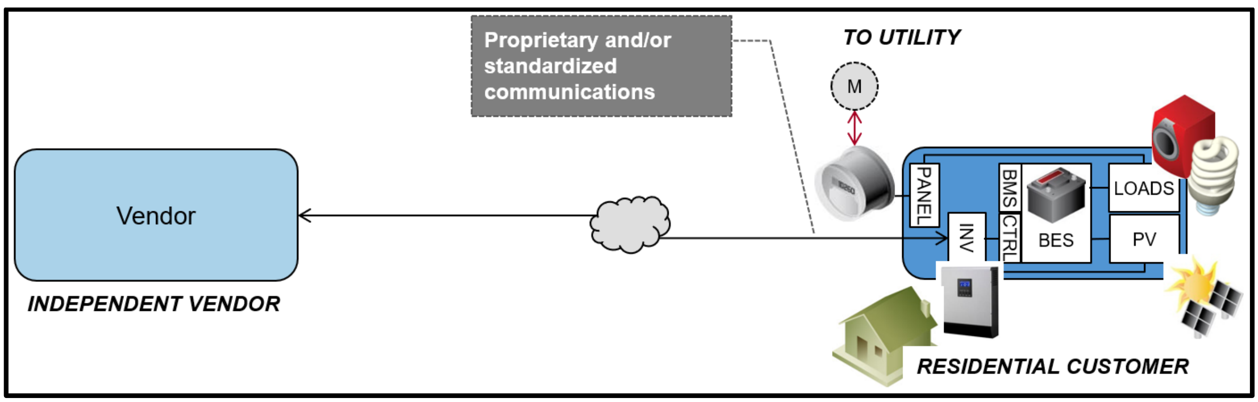

Figure 2-1
The vendor/customer scenario for BES integration

When a third-party service provider is a part of the scenario (Figure 2-2), communications help that entity to manage energy services across many customers, such as controlling daily peak loads with solar PV. Here, the customer receives integrated services under a business agreement with the vendor and service provider. A BES aggregator such as Tesla Energy may provide solar integration, microgrid services, and similar support with either single or multiple customer relationships. Again, BES communication technologies for this case are not driven by either current or future opportunieis for grid services.

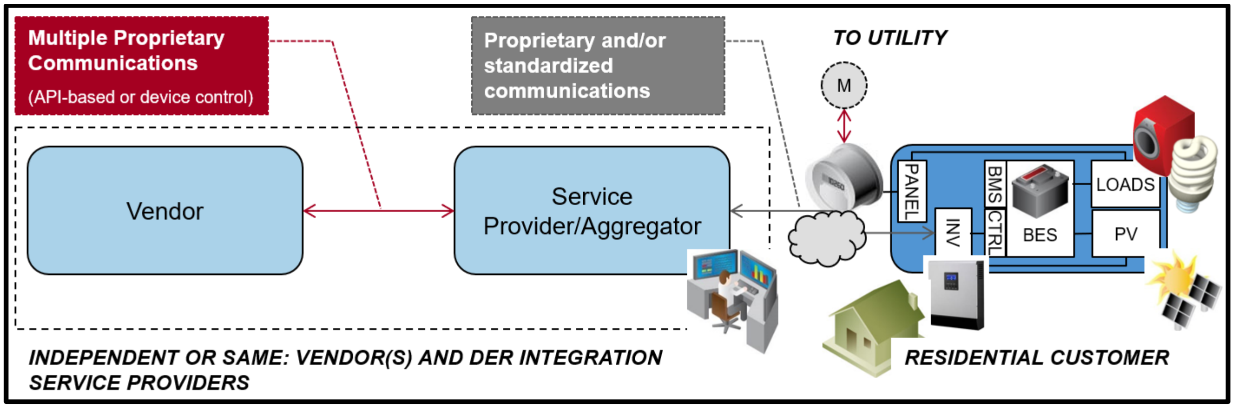

Figure 2-2
The vendor/third-party/customer scenario for BES integration

Extending communications links to the utility (Figure 2-3) allows the BES to provide grid services—day-ahead and ancillary-services or demand response. There may be a mix of proprietary communications streams, some using APIs, some accessing standardized communications and others using proprietary ones. Here, the customer may engage directly with the utility to participate in grid services, including existing demand response programs. The customer—or the aggregator—may also engage with the local utility or their ISO for retail DR programs and aggregator-supported wholesale DR market products.

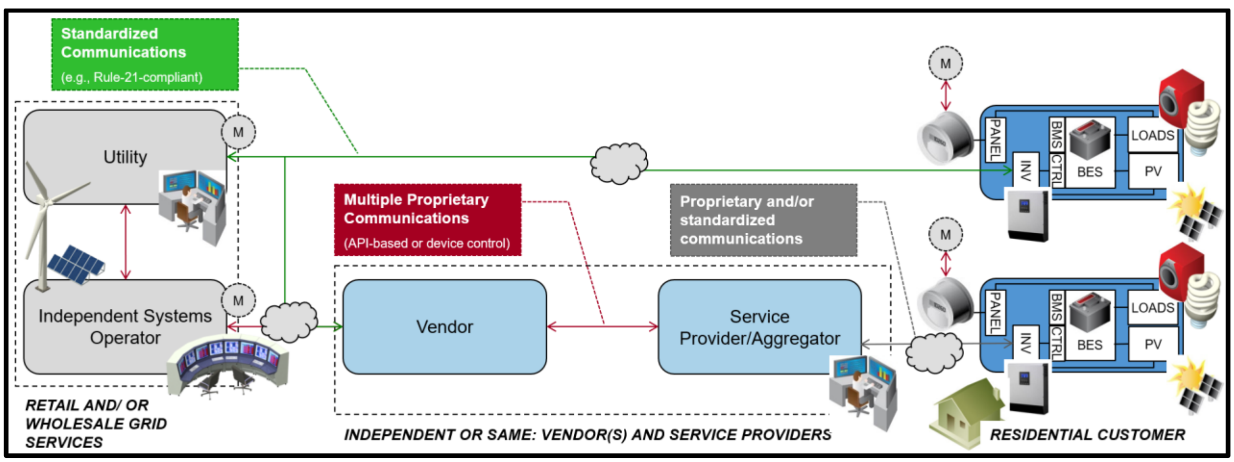

Figure 2-3
The utility/systems operator/customer scenario for BES integration

A fully-integrated communications scenario (Figure 2-4), with the utility, vendor systems, third-party providers, and customers exchanging data, forms the basis for a state-of-the-art, forward-looking implementation of grid-connected storage. The number of interconnected entities increases the need for standardized communications to ensure smooth operation. The vendor landscape for this scenario continues to evolve, with some vendors supporting certain services, others focused on different business models. Figure 2-5 provides a high-level view of the current technology market.

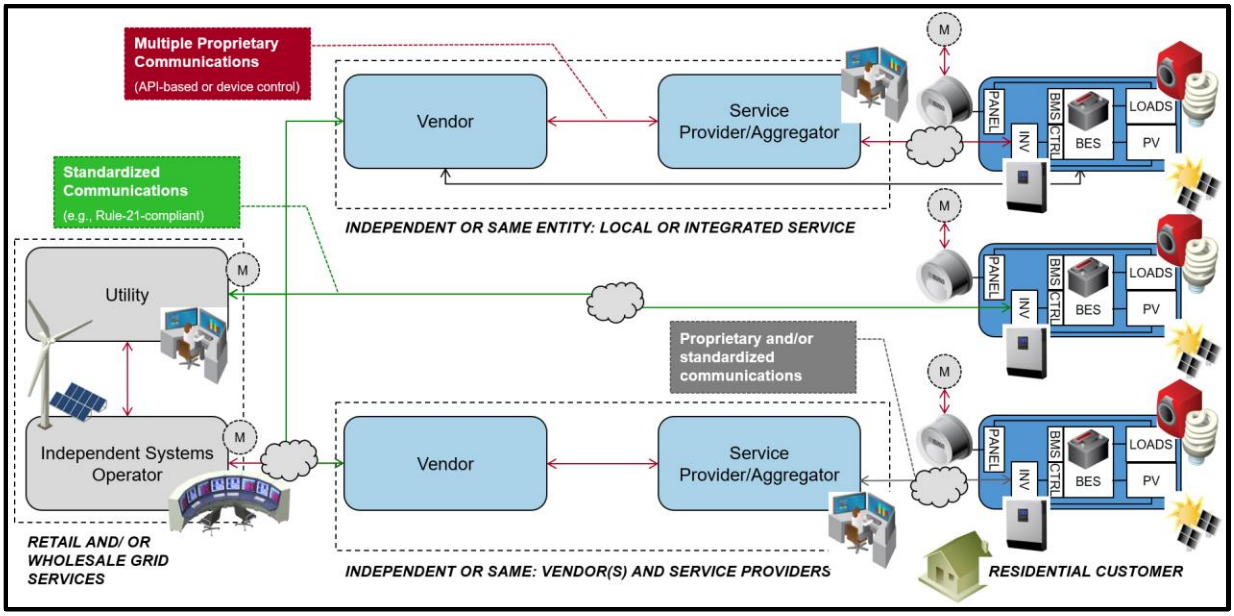

Figure 2-4
The utility/service provider/vendor/customer fully-integrated scenario

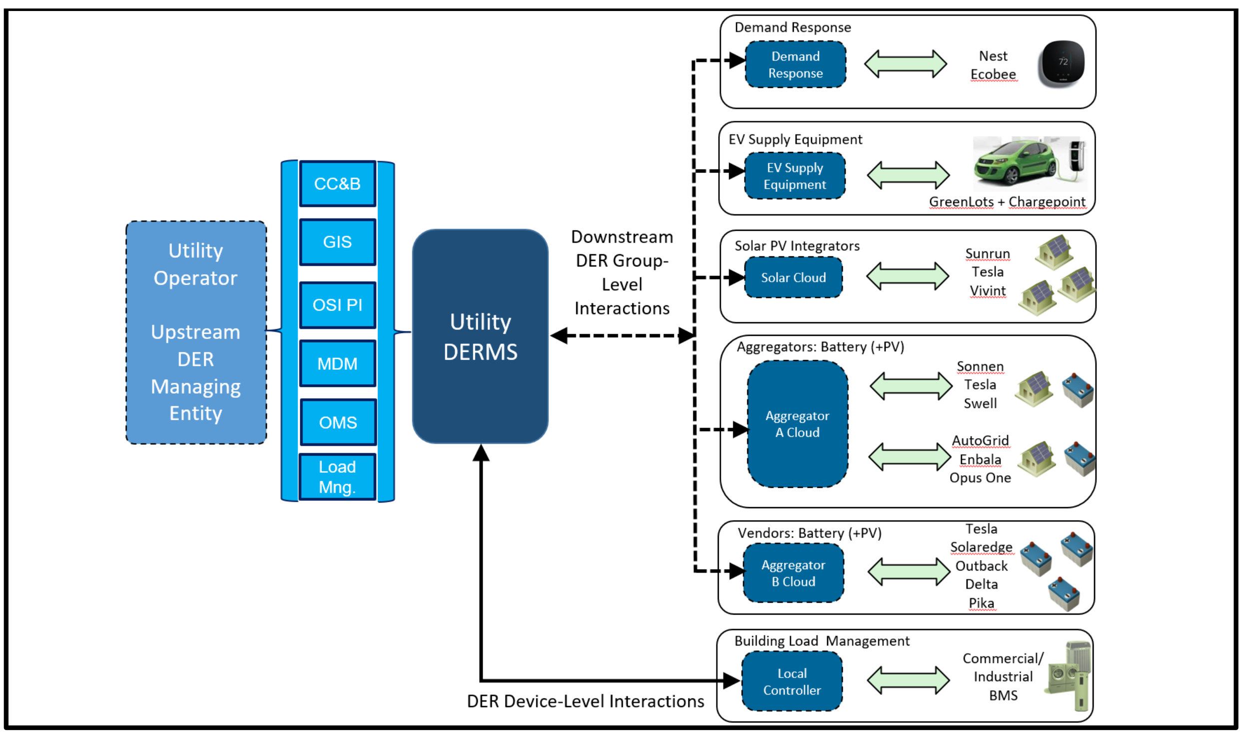

Figure 2-5
The vendor landscape in OpenADR communications for energy storage and demand response

BES Products Supporting the OpenADR 2.0 Standard

Vendor Data Communication Assessment Matrix

EPRI's Customer-Sited Energy Storage group has developed the "Customer-Sited Energy Storage Systems Technology Assessment Matrix", which includes information on sixty-six behind-the-meter energy storage technologies. This document is only available to EPRI members, and can be found via the EPRI Member Cockpit by searching for Product ID: 3002013748, or by using the link below. The "Energy Management System Specifications" on Tab 4 provides a detailed list of communications & network capabilities for these BTM energy storage devices.

Vendor Data Communication Assessment Matrix (XLS)

Cybersecurity Requirements

This sub-section focuses on the cybersecurity specified for using OpenADR 2.0 over HTTP. In addition to HTTP, XMPP is also an allowed transport for OpenADR 2.0, but because its security requirements are very different and HTTP is widely-used among the industry, the cubersecurity requirements focuses on the HTTP transport. To fulfill the cybersecurity requirements and the smart cybersecurity guidelines outlined by the National Institute of Standards and Technology (NIST),[1] the OpenADR Alliance decided to implement server and client-side certificates using the public-key infrastructure (PKI) model. This means that product manufacturers need to purchase valid OpenADR-specific certificates to authenticate communication links between a client and server. It should be noted that this section is not meant to serve a tutorial on the PKI nor on the inner workings of any software environment in which OpenADR may be operating.

Although the OpenADR Alliance provides a basic framework for testing and certification of these cybersecurity requirements, the final cybersecurity scheme used by a deployment will likely be determined by a utility's DR program specifications.

Cybersecurity Architecture and Certificate Types

As a result of architectural decisions, both virtual end nodes (VEN) or clients and virtual top nodes (VTN) or servers use active PKI certificates. Two levels of security are defined for OpenADR 2.0, called *Standard* and *High*. Standard security uses Transport Layer Security (TLS) for establishing secure communication channels between a VTN and a VEN and supports the NIST cybersecurity guidelines. The TLS is a protocol used for cryptography of data over communication networks. High security additionally uses XML signatures and encryption to provide nonrepudiation if needed. The *Standard* security is mandatory and tested during certification for VTNs and all VEN types. OpenADR 2.0b VEN currently requires TLS 1.2 and the corresponding cipher suites.

VTNs support both ECC (elliptic curve cryptography) and RSA (Rivest, Shamir and Adelman)

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[1] NIST Interagency Report (IR) 7628, Guidelines to Smart Grid Cyber Security.

certificates from vendor, Kyrio. The following requirements are met by the certificates:

- ECC – 256 bits (or longer) keys
- RSA – 2048 bits (or longer) keys
- Certificate types – X.509v3

Mandatory Interoperabiltiy Requirements

- Transport Layer Security: TLS 1.2
- Cipher Suites for ECC and RSA certificates:
  - ECC – TLS_ECDHE_ECDSA_WITH_AES_128_CBC_SHA256
  - RSA – TLS_RSA_WITH_AES_128_CBC_SHA256

Note that a VTN or VEN may be configured to support any TLS version and cipher suite combination, based on the needs of a specific deployment. The behavior of the devices under default configuration of the VTN or VEN is, as noted above.

System Registration Process

Registration is defined as the VTN becoming "aware" of the VEN via exchange of credentials (and other information) so that the VTN can properly authenticate and register a VEN.

Certificate Fingerprints

VENs facilitate registration by providing a "certificate fingerprint" that can be easily transmitted out of band to the VTN operator (typically, a utility or an aggregator). On the VTN, there is a one-to-one mapping between the venID and the certificate fingerprint. The fingerprint may then be used by the VTN to identify a VEN when it first connects to the VTN.

XML Signatures for OpenADR 2.0 Message Payloads (High Security)

The High security profile in OpenADR 2.0b uses detached XML signatures, where the signature element and the signed element do not have a parent-child relationship. The detached signatures reside in the same XML document as the content being signed, essentially living as a sibling element.

Conformance Rules for Certification

To meet the cybersecurity compliance requirements, OpenADR 2.0b VEN rules mandate the following security configuration for compliance certification:

- TLS Version 1.2 for the exchange of X.509 certificates
- VTNs with both SHA256 ECC and RSA certificates
- VENs supporting SHA256 ECC and/or RSA certificates
- Both VTNs and VENs requesting client certificates if they are going to play the role of a transport server (i.e., respond to requests from the other party)
- Both VTNs and VENs providing a client certificate when requested by the other party as part of the TLS negotiation process

Test certificates provided by vendor, Kyrio, are delivered in a ZIP file specific to the OpenADR role (VEN or VTN), release (typically release 2), and the encryption type (RSA or ECC). The following files are provided:

- Root Certificate
- Intermediate Root Certificate
- Device Certificate
- Private Key

In general, the Private Key is used to encrypt payloads sent by a VEN or VTN. The Device Certificate is a set of unique identifying information about a VEN or VTN that has been created by Kyrio and encrypted using the Private Key. The Root and Intermediate Certificates are used to decrypt the Device Certificate and validate that the Device Certificate came from a trusted authority.

A Note on OpenADR 2.0a Cybersecurity

Note that specification OpenADR 2.0a profile VENs, which many products deploy for demand response programs, allows the use of TLS 1.0[2] and the 2.0b VENs must support TLS 1.2.[3]The use of TLS 1.0 in 2.0a VENs is a result of legacy systems implementing TLS 1.0 cipher suites. The TLS 1.0 was originally released in 1999 and its use can result in use of cryptography techniques that can be outdated. The OpenADR Alliance allows the "support higher versions of TLS provided that they can still interoperate with TLS 1.0 implementations." Since 2014, all 2.0a VENs are tested and certified to meet the higher security requirements specified in TLS 1.2.

Current Challenges in Data Communication and Products

This aspect of the project had a two-fold research objective:

1. Determine which BTM residential energy storage systems are OpenADR 2.0b compliant, or progressing in that direction with certification
2. Determine what technology gaps exist for the development of an OpenADR 2.0b device which would convert existing non-compliant systems to OpenADR 2.0b

Residential Storage Systems With Prospects for OpenADR 2.0b Compliance

EPRI expanded and updated its research related to products with significant market share potential in SCE's service territory. As of December 2018, none of these standalone products offered OpenADR 2.0b functionality yet: Sunrun BrightBox (SolarEdge/LG), Tesla Powerwall, Sonnen (Outback/Sony LFP), Sunverge One, and LG Chem (Delta/LG) storage systems. Swell Energy, a Southern California integrator of energy storage products, has contracted with AutoGrid to provide aggregated management of Tesla Powerwall and Sonnen products. However, details specific to how they will use OpenADR, and the means of incorporating OpenADR functionality into the products are also unknowns at this time. From the limited

[2] OpenADR Alliance, OpenADR 2.0 Profile Specification: A Profile, Revision Number: 1.0. 2011. 20110712-1

[3] OpenADR Alliance, OpenADR 2.0 Profile Specification: B Profile, Revision Number: 1.0. 2013. 20120912-1

information available, EPRI researchers predict that local control will be dependent on proprietary protocols and third-party aggregator management. This architecture could be considered under future SCE DR program designs and grid risk mitigation strategies.

Technology Gaps/Obstacles to Integration

The key technology gaps for the development of a plug-in OpenADR 2.0b device that will be able to convert existing non-compliant systems to OpenADR 2.0b are:

- Storage industry preferences for the use of IEEE 2030.5, given the expanded inverter capabilities for meeting Rule 21
- A lack of standards for controls mapping, thereby requiring custom configuration to integrate with a variety of BESS units
- Expenses associated with the addition of virtual end nodes (VENs) to existing energy storage equipment
- Technical and contractual challenges with the addition of VENs to existing energy storage equipment

Integration of an OpenADR 2.0b compliant VEN with existing energy storage equipment, without proper planning and technical support from the energy storage vendor on how the system can respond to DR messages, can lead to several complications. These complications arise from the fact that, without EMS/BMS integration, the VEN may have to override these integrated energy storage systems in order to provide DR control. Over-riding the EMS and BMS can lead to safety and warranty compliance issues, as well as over-riding controls chosen by the customer for energy bill management and backup power, among other customer priorities.

Protocol Customization for Price Signaling

OpenADR 2.0 Pricing Structure

OpenADR 2.0 Profile Specification, an International Electrotechnical Commission (IEC) standard 62766-10-1:2018[4], supports a comprehensive electricity pricing data model that can be used to manage grid and distributed energy resources (DER). The electricity pricing model is supported by this IEC standard under OpenADR 2.0b Profile Specification Virtual End Node (VEN 2.0b). The characteristics of this pricing data model are:

VEN Type: OpenADR Profile Specification 2.0b (OpenADR VEN 2.0b)
OpenADR VEN 2.0b Service Name: eiEvent (full service)
Signal Name: ELECTRICITY_PRICE
Signal Type: Price
Price Representation: [currency] per kWh

The above prices at different timescales can be used to target across a utility service area, service delivery point, and/or a service location.

[4] IEC 62746-10-1:2018, Systems interface between customer energy management system and the power management system - Part 10-1: Open automated demand response. Available at https://webstore.iec.ch/publication/26267

While OpenADR 2.0 has a mature interoperability compliance and testing program that ensures a VEN can communicate with a Virtual Top Node (VTN) that publishes or dispatches the prices, both VTN and VEN will require customizations to support utility electricity pricing programs and structures (e.g., day-ahead hourly, 15-minute prices).

A Related Standard

Another industry-supported standard, Institute of Electrical and Electronics Engineers' (IEEE) 2030.5 standard[5], or as it is popularly known, the Smart Energy Profile (SEP) 2.0, also supports price signaling. Unlike OpenADR 2.0, SEP 2.0 does not have a mature interoperability compliance and testing program yet, thus making it difficult to scale the implementations uniformly across different DER products. More review is needed to understanding specific design and structural changes in the electricity pricing models between OpenADR 2.0 and SEP 2.0.

[5] IEEE 2030.5-2018, IEEE Standard for Smart Energy Profile Application Protocol, https://standards.ieee.org/standard/2030_5-2018.html

3
DEVELOPMENT OF TEST PLANS, CONTROLS, AND PERFORMANCE ASSESSMENT METHODS

In preparation for the testing program, the research team first developed a Test Plan and a measurement and verification (M&V) plan.

- The Test Plan included specific signals and responses including:
  - Charge, discharge, hold
  - Requests for kW and kWh
  - Time Stamp
  - State of Charge
- The M&V plan was designed to assess performance under the associated Test Plan

Measurement of state of charge (SOC) was included in planning to serve overall research goals. The SOC metric can be used to benefit rule development and also assists in determining system availability.

Test Plan

In this subsection, we present the test plan as developed for this project. Note that the plan was adjusted as needed during the course of the actual testing to accommodate the research needs.

Purpose

The purpose of this test plan is to fulfill the requirements of the SCE Sub Project A3 by demonstrating the use of OpenADR to manage distributed, residential energy storage systems on the grid. Testing will take place in 3 phases.

Scope

Application

Develop and use OpenADR LOAD_DISPATCH signals for management of residential energy storage systems via a Virtual Top Node.

Test Results

Testing will provide information for determining:

- Ability to remotely manage distributed residential BESS via OpenADR 2.0b
- Timeliness of BESS response
- Accuracy of BESS response
- Frequency of BESS response

Data Collection

Data collection will occur via two systems.

1. EPRI Virtual Top Node
    a. Load_Dispatch signal requested
        i. Includes kW, start time and duration
    b. Time and date of signal request
2. E-Gear Data Acquisition System
    a. Receipt of Load_Dispatch signal
    b. Time and date of signal received
    c. kW response, start time and duration of Load_Dispatch signal response

Responsibilities

- EPRI personnel shall:
    - Coordinate and lead testing
    - Establish cloud hosted VTN
    - Provide guidance to E-Gear regarding OpenADR 2.0b framework to be used for testing
    - Coordinate and provide for record collection
    - Provide final test report
- E-Gear personnel shall:
    - Implement appropriate code to receive and respond to Load_Dispatch signals
        - Positive dispatch signals shall result in the battery discharging to the grid, and negative dispatch signals shall result in the battery charging from the grid
        - Load dispatch signals will include a start time and duration, in addition to the load being requested
    - Implement 'Resume Local Control' Signal
    - Report testing results to EPRI, including:
        - Time signal received
        - kW response, start time and duration contained in signal
        - Battery response
        - kW
        - start time
        - duration
- Eguana personnel shall:
    - Assist EPRI with procurement of 3 E-Gear customers within SCE territory

Testing Equipment & Procedure

Phase I – Proof of Concept Testing

- Equipment
    - E-Gear Battery located at E-Gear "Batt-Lab" in Hawaii
    - EPRI Virtual Top Node (VTN)
- Procedure

Test 1

- E-Gear ensures the "Batt-Lab" battery is clear of any 4-quadrant instructions, and charged to 50% capacity *(Note: 4-quadrant instructions refers to any real power (possitive or negative) or reactive power (leading or lagging) instructions)*
- EPRI VTN sends Load_Dispatch signals and E-Gear measures response of battery
  - Send 1kW signal with 15-minute duration and await response
  - Send 0kW signal with 15-minute duration and await response
  - Send -1kW signal with 15-minute duration and await response
  - Send 0kW signal with 15-minute duration and await response
  - Send 'Resume Local Control' Signal

Expected Results: Battery shall respond to Load_Dispatch signals at the requested start time and remain at the requested charge rate until signal duration is over or further action is requested. Positive dispatch signals shall result in the battery discharging to the grid, and negative dispatch signals shall result in the battery charging from the grid.

Test 2

- E-Gear initiates 1kW signal locally (not via OpenADR)
- EPRI VTN sends Load_Dispatch signals and E-Gear measures response of battery
  - Send 1kW signal with 15 minute duration and await response
  - Send 0kW signal with 15 minute duration and await response
  - Send -1kW signal with 15 minute duration and await response
  - Send 'Resume Local Control' Signal

Expected Results: Battery shall respond to Load_Dispatch signals directly (not via an additive or delta methodology). As the E-Gear battery begins with local instructions to discharge at a rate of 1kW, the 1kW OpenADR Load_Dispatch signal of 1kW should not change the batteries operation, except if perhaps a momentary pause is initiated. Upon receipt of 'Resume Local Control' Signal, or at the end of the signal duration, battery should resume local control.

Test 3

- E-Gear initiates solar smoothing operation
- EPRI VTN sends Load_Dispatch signals and E-Gear measures response of battery
  - Send 1kW signal with 15-minute duration and await response
  - Send 0kW signal with 15-minute duration and await response
  - Send -1kW signal with 15-minute duration and await response
  - Send 'Resume Local Control' Signal

Expected Results: Battery shall respond to Load_Dispatch signals directly (not via an additive or delta methodology), by ending solar smoothing operation and charging or discharging as requested. Upon receipt of 'Resume Local Control' Signal, or at the end of the signal duration, battery should resume solar smoothing operation.

Test 4

- o E-Gear ensures the “Batt-Lab” battery is clear of any 4-quadrant instructions, and charged to 50% capacity
- o EPRI VTN sends Load_Dispatch signals and E-Gear measures response of battery
  - ▪ Send 10kW signal with 15-minute duration and await response
  - ▪ Send 0kW signal with 15-minute duration and await response
  - ▪ Send -10kW signal with 15-minute duration and await response
  - ▪ Send 0kW signal with 15-minute duration and await response

Expected Results: As the E-Gear battery is not capable of 10kW responses, it will respond by charging and discharging at its maximum rate. Upon receipt of ‘Resume Local Control’ Signal, or at the end of the signal duration, battery should resume normal operation.

Phase II – Location 0 Testing at the EPRI Pacifica Site

Test 1

- o EPRI ensures the “Pacifica” battery is clear of any 4-quadrant instructions, and charged to 50% capacity
- o EPRI VTN sends Load_Dispatch signals and measures response of battery
  - ▪ Send 1kW signal with 15-minute duration and await response
  - ▪ Send 0kW signal with 15-minute duration and await response
  - ▪ Send -1kW signal with 15-minute duration and await response
  - ▪ Send 0kW signal with 15-minute duration and await response
  - ▪ Send ‘Resume Local Control’ Signal

Expected Results: Battery shall respond to Load_Dispatch signals at the requested start time and remain at the requested charge rate until signal duration is over or further action is requested. Positive dispatch signals shall result in the battery discharging to the grid, and negative dispatch signals shall result in the battery charging from the grid.

Test 2

- o EPRI initiates 1kW signal locally (not via OpenADR)
- o EPRI VTN sends Load_Dispatch signals and measures response of battery
  - ▪ Send 1kW signal with 15 minute duration and await response
  - ▪ Send 0kW signal with 15 minute duration and await response
  - ▪ Send -1kW signal with 15 minute duration and await response
  - ▪ Send ‘Resume Local Control’ Signal

Expected Results: Battery shall respond to Load_Dispatch signals directly (not via an additive or delta methodology). As the Pacifica battery begins with local instructions to discharge at a rate of 1kW, the 1kW OpenADR Load_Dispatch signal of 1kW should not change the batteries operation, except if perhaps a momentary pause is initiated. Upon receipt of ‘Resume Local Control’ Signal, or at the end of the signal duration, battery should resume local control.

Test 3

- o EPRI initiates solar smoothing operation
- o EPRI VTN sends Load_Dispatch signals and measures response of battery
  - Send 1kW signal with 15-minute duration and await response
  - Send 0kW signal with 15-minute duration and await response
  - Send -1kW signal with 15-minute duration and await response
  - Send ‘Resume Local Control’ Signal

  Expected Results: Battery shall respond to Load_Dispatch signals directly (not via an additive or delta methodology), by ending solar smoothing operation and charging or discharging as requested. Upon receipt of ‘Resume Local Control’ Signal, or at the end of the signal duration, battery should resume solar smoothing operation.

Test 4

- o EPRI ensures the Pacifica battery is clear of any 4-quadrant instructions, and charged to 50% capacity
- o EPRI VTN sends Load_Dispatch signals and measures response of battery
  - Send 10kW signal with 15-minute duration and await response
  - Send 0kW signal with 15-minute duration and await response
  - Send -10kW signal with 15-minute duration and await response
  - Send 0kW signal with 15-minute duration and await response

Expected Results: As the battery is not capable of 10kW responses, it will respond by charging and discharging at its maximum rate. Upon receipt of ‘Resume Local Control’ Signal, or at the end of the signal duration, battery should resume normal operation.

Measurement and Verification (M&V) Plan for OpenADR Control of Residential Battery System

The M&V plan focuses on the four BESS management use cases defined for field testing:

1. **CHARGE:** Explicit DR instruction to charge a BESS, expressed in power metrics, kilowatts (kW).
2. **DISCHARGE:** Explicit DR instruction to discharge a BESS, expressed in power metrics, kilowatts (kW).
3. **HOLD:** Explicit DR instruction to hold the battery from either charging or discharging.
4. **NORMAL:** The normal operation of the energy storage system, as determined by the customer, was exercised when the other three use cases were not exercised.

While the specific type of signal from the OpenADR 2.0 VTN to a residential OpenADR 2.0a or 2.0b Profile Specification VEN is under evaluation by EPRI and E-Gear, the following M&V plan focuses on evaluating the signaling requirements and verification of the battery responses for these three use cases.

The M&V process will need metering to disaggregate the energy and power use of battery against rest of the residential energy use.

M&V for OpenADR Signals

- VTN
  - Timestamp of signal published
  - Timestamp of VEN acknowledgement
  - Event start time
  - Event duration
  - Type of signal dispatched (Charge/Discharge/Hold)
- VEN
  - Communication status
  - Polling interval and status
  - Diagnostic flags (when BESS does not meet requested values)
  - Timestamp of when the DR signal was received
  - Timestamp of when the DR signal was activated
  - Timestamp of when the DR Event was completed

M&V for BESS

- Energy (kWh) values in 1-minute meter data intervals or timestamps
- Power (kW) values in 1-minute meter data intervals or timestamps
- State of Charge (SOC) for at least 1-minute meter data intervals or timestamps
- SOC when the OpenADR event was active
- SOC when the OpenADR event ended
- Specification of the metering accuracy (e.g., 0.2%, 2.0%)

Baseline Model for M&V

Because the M&V focuses on the individual BESS performance and not the entire residential system performance compared to the typical settlement approached used in a utility demand response program, the instantaneous BESS metering data, as mentioned above, was used.

4

SITE SELECTION, FIELD TESTS, AND RESULTS

This section describes the work completed in preparing for and conducting the field tests, including:

- Procurement of Virtual Top Node (VTN)
- Development of additional control logic for the E-Gear System, consisting of charge, discharge and hold operations
- Phase I OpenADR 2.0b Testing at the E-Gear testing facility ("Batt-Cave") in Hawaii
- Transfer of control logic to Pacifica field site and further testing
- Phase II OpenADR 2.0b testing at the Pacifica field test site

Procurement of Virtual Top Node (VTN)

Nebland Software's NOVA DR Engine was chosen as the virtual top node (VTN) for OpenADR 2.0b testing. The EPRI team was familiar with the Nebland Nova DR Engine, and was confident that it would provide all of the necessary functionality. It was further noted that E-Gear used the Nebland VTN for their own testing, integration and certification of OpenADR 2.0b capability.

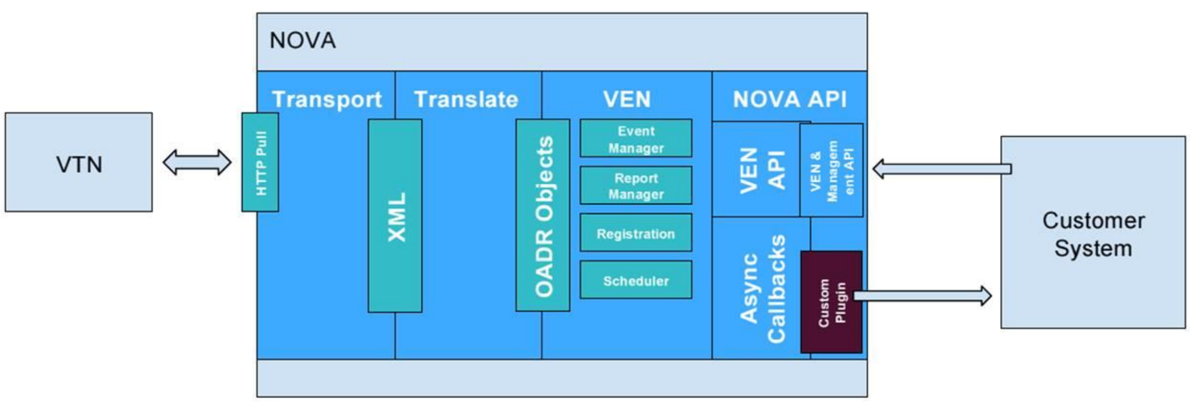

Figure 4-1
Nebland Software NOVA DR Engine selected for VTN use

Prior to purchasing Nebland VTN server access on a monthly basis, it was noted that E-Gear's systems were able to receive the Discharge, Charge and Hold signals sent via a VTN server using OpenADR 2.0b as required by the certification they received. However, OpenADR 2.0b certification does not require the energy storage system itself to be capable of interpreting individual control signals. Further effort was required to integrate control logic in the E-Gear system, so that it was able to respond to Discharge, Charge and 'Hold' signals as testing required. (Detailed control logic updates are provided in the Appendix, as Table A-1.)

Development of additional control logic for the E-Gear System

As discussed above, the OpenADR 2.0b certification for a BESS requires the energy storage system to be capable of receiving OpenADR 2.0b signals, but it does not require the BESS system to have the control logic to interpret and appropriately respond to that control logic. EPRI and E-Gear chose to use LOAD_DISPATCH Event Signals to send Charge, Discharge and Hold Signals. The LOAD_DISPATCH Event Signals allow a VTN operator to choose a power level, start time and duration for the energy storage system.

Because OpenADR certification does not require the battery to respond to signals in a specific way, EPRI, SCE and E-Gear made the determination that the signals should be followed as absolute values, rather than as additive values to the current operating mode. This means that for example, if the battery was discharging at 2kW when it received a 3kW discharge signal, the batteries expected response was to discharge at 3kW (absolute) rather than 5kW (additive). Both the absolute and additive approach to BESS response may have merits. The project team chose to use the absolute response because of its relative ease of implementation.

Field Tests and Results

Completion of field testing required use of the Nebland Virtual Top Node via the NOVA DR Engine. Charge, Discharge and Hold signals were sent by creating an even in the Standard Event Details screen, assigning the appropriate Target (i.e. battery), and finally publishing the event.

New Events are created in the following order:

1. Complete Standard Event Details by entering the following information:
    a. Preferred Time Zone
    b. Start Time
    c. Duration of Event
    d. Signal Name (LOAD_DISPATCH)
    e. Signal Type (Setpoint)
    f. Payload
2. Assigning the target (i.e. battery or batteries)
3. Publishing the event

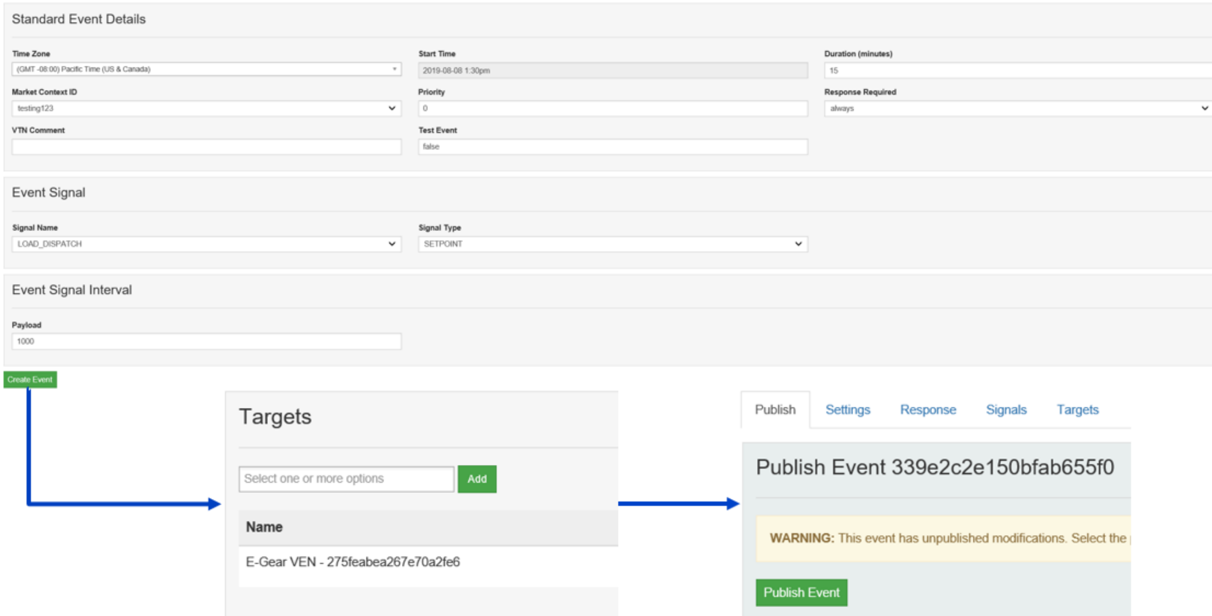

Figure 4-2
Sample of the event publishing process

All signals were sent in Watts, as opposed to the terms of KW or MW, etc. It was decided by EPRI, SCE and E-Gear, that because the test signals were being sent from the utility perspective, that a negative payload would result in the battery charging, and a positive payload would result in the battery discharging. The 'hold' signal was achieved by sending a payload signal of 0 Watts. A 'resume operation' signal was requested, but ultimately unnecessary. OpenADR signals were sent using a 'Start Time' and 'Duration (minutes).' Therefore, the battery resumed local operations or controls at the conclusion of the event duration automatically.

Phase I - OpenADR 2.0b Testing at the E-Gear testing facility ('Batt-Cave') in Hawaii

In June of 2019, integration of control logic that would appropriately respond to OpenADR LOAD_DISPATCH events was completed. Per the test plan, 4 tests were conducted. All tests resulted in the successful dispatch of OpenADR signals, as they were published.

Test 1 – Load_Dispatch without competing objectives

- E-Gear battery is clear of any 4-quadrant instructions, and charged to 50% capacity
- EPRI VTN sends Load_Dispatch signals and E-Gear measures response of battery
  - Send 1kW signal with 15-minute duration and await response
  - Send 0 kW signal with 15-minute duration and await response
  - Send -1kW signal with 15-minute duration and await response
  - Send 0 kW signal with 15-minute duration and await response
  - 'Resume Local Control'

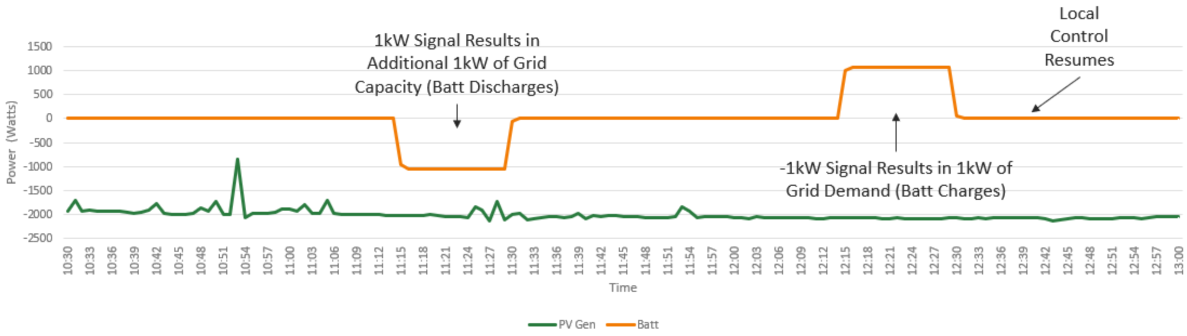

Figure 4-3
Results, Test 1

Test 2 - Load_Dispatch w/ competing objectives (1kW discharge)

- E-Gear initiates 1 kW signal locally (not via OpenADR)
- EPRI VTN sends Load_Dispatch signals and E-Gear measures response of battery
    - Send 1 kW signal with 15-minute duration and await response
    - Send 0 kW signal with 15-minute duration and await response
    - Send -1 kW signal with 15-minute duration and await response
    - 'Resume Local Control'

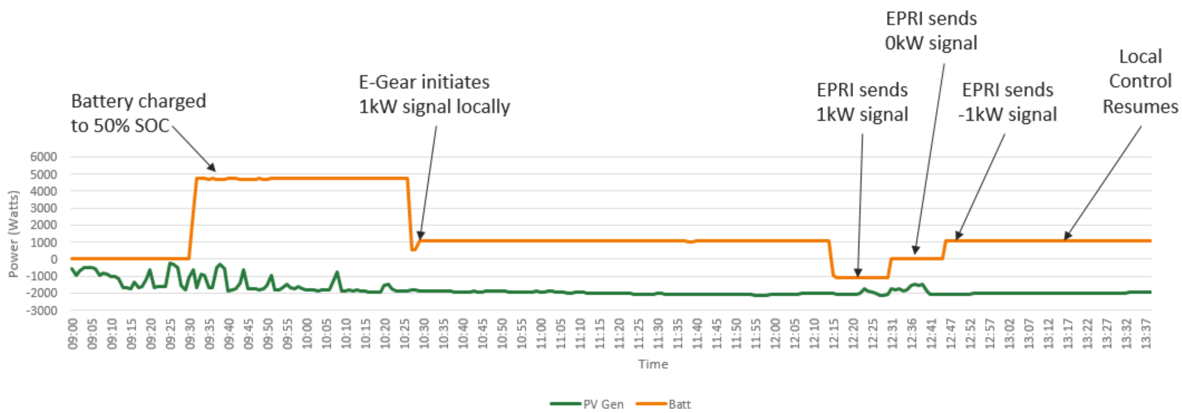

Figure 4-4
Results, Test 2

Test 3 - Load_Dispatch with competing objectives (non-export)

- E-Gear initiates non-export mode
- EPRI VTN sends Load_Dispatch signals and E-Gear measures response of battery
    - Send 1 kW signal with 15-minute duration and await response

- Send 0 kW signal with 15-minute duration and await response
- Send -1 kW signal with 15-minute duration and await response
- ‘Resume Local Control’

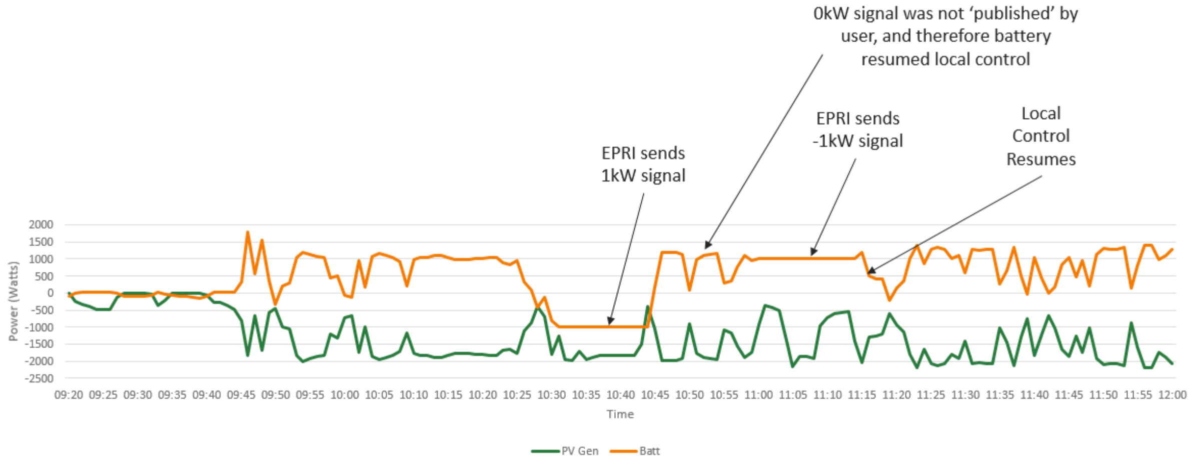

Figure 4-5
Sample results, Test 3

Test 4 – Load Dispatch Beyond BESS’ Capabilities

- E-Gear ensures the “Batt-Lab” battery is clear of any 4-quadrant instructions, and charged to 50% capacity
- EPRI VTN sends Load_Dispatch signals and E-Gear measures response of battery
  - Send 10 kW signal with 15-minute duration and await response
  - Send 0 kW signal with 15-minute duration and await response
  - Send -10 kW signal with 15-minute duration and await response
  - Send 0 kW signal with 15-minute duration and await response

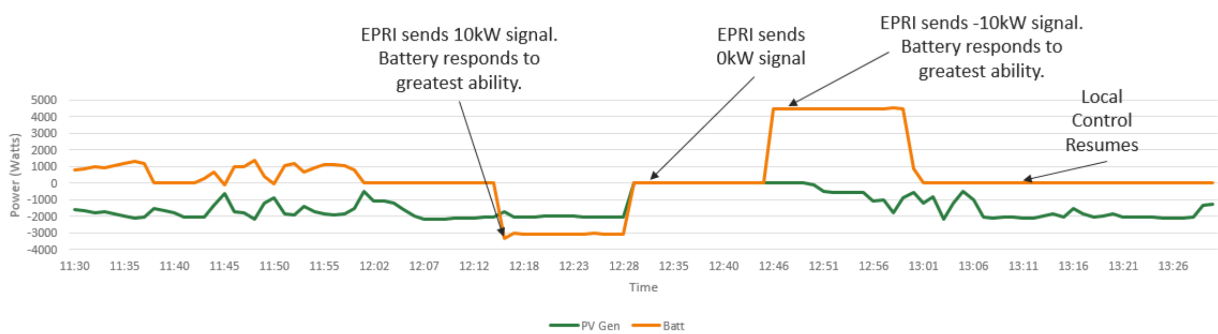

Figure 4-6
Results, Test 4

Additional testing was accomplished in July and August to ensure consistency of results. Generally speaking, when OpenADR signals were received, they were processed correctly per the algorithms developed by E-Gear. The exception to this rule occurred when E-Gear published software updates to their systems with updated code. Because the code developed for the OpenADR testing was not developed as part of the final, exemplar software code, updates to the OpenADR testing code had to be made whenever the exemplar software was updated.

A final test at the E-Gear 'Batt-Cave" test facility was conducted in early September, 2019. All OpenADR signals, as sent to the BESS were correctly interpreted and executed.

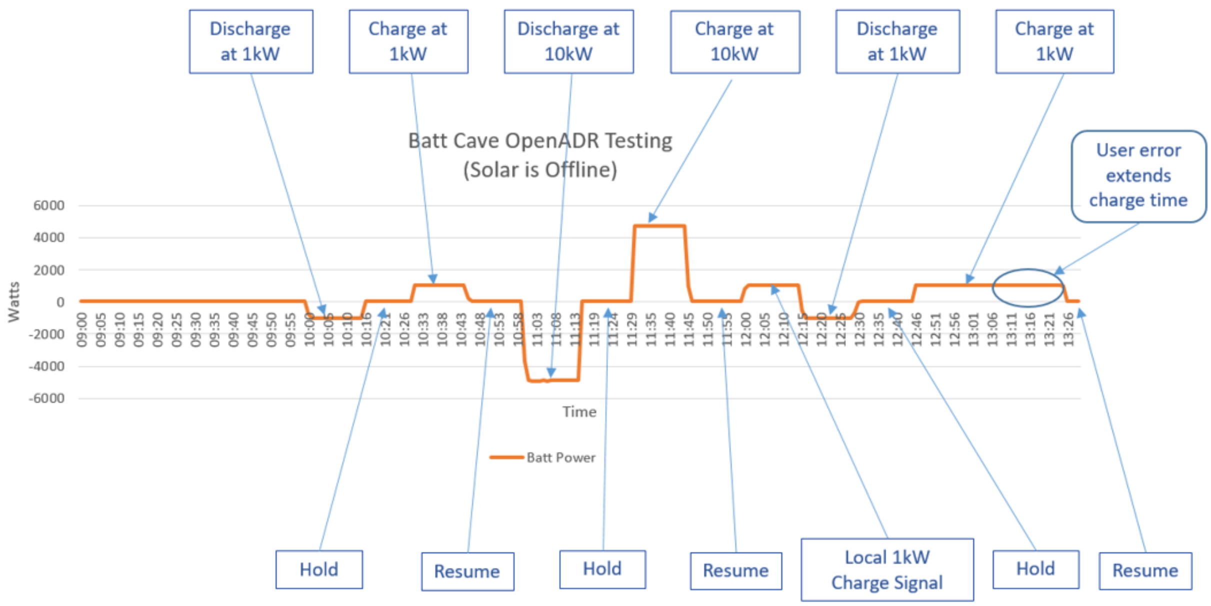

Figure 4-7
Results, Final Test

Phase II – Location 0 Testing at the EPRI Pacifica Site

Updated control logic developed and tested in the 'Batt-Cave' testing facility was remotely uploaded to the Pacifica test site in September of 2019. Testing began in September with the execution of two tests.

Test 1 (As requested)

- discharge at 1 kW: 11 pm - 11:15 am
- Hold: 11:15 pm - 11:30 pm
- Charge at 1 kW: 11:30 pm - 11:45 pm
- Resume: 11:45 pm - 12 am

Test 2 (As requested):

- Discharge at 10 kW (get response available): 12 pm - 12:15 pm

- Hold: 12:15 pm - 12:30 pm
- Charge at 10 kW (get response available): 12:30 pm - 12:45 pm
- Resume: 12:45 am - 1:00 am

Results of Test 1 and Test 2:

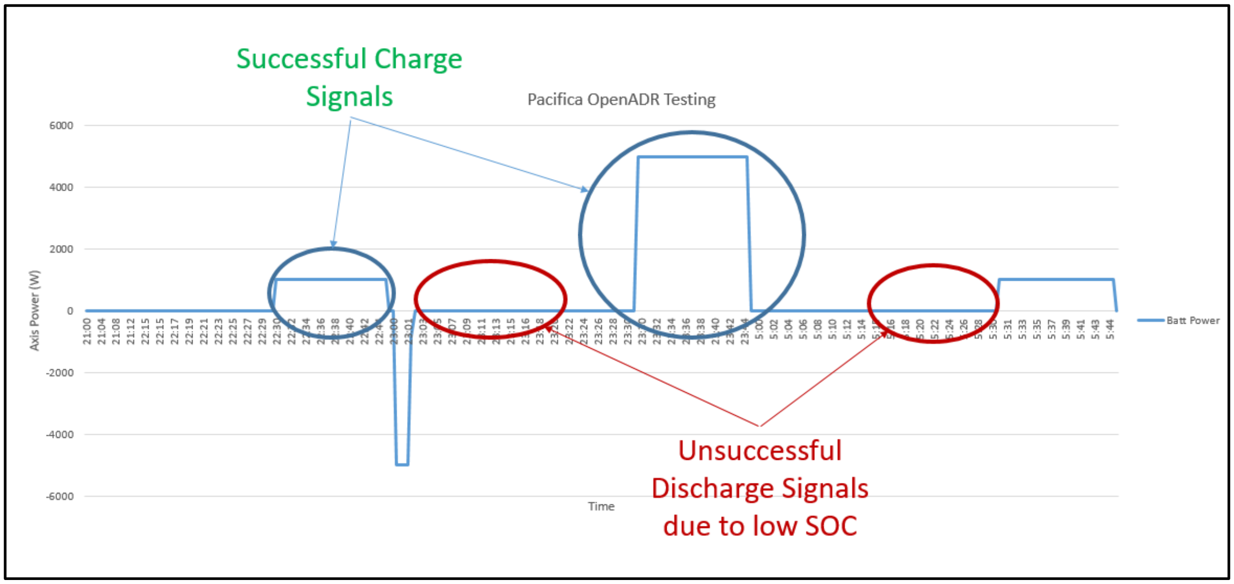

Figure 4-8
Phase II, results for location 0 tests

While the battery charged as expected, it was determined that the battery did not discharge as expected because the battery State of Charge (SOC) was below its minimum threshold of 20% at the start of testing. The battery was at 20% SOC because the homeowner previously programmed the battery to self-consume, or provide the full energy requirements of the home until the battery was discharged to 20% SOC. This test was done in the middle of the night, after the battery had been completely discharged and without and solar irradiance to recharge the battery via the home's solar PV panels.

Charge signals, on the other hand, were successfully executed because they were not SOC limited. When the battery was 'returned to normal operation,' it was quickly discharged by local controls again, which left it unavailable for further discharging by OpenADR command 15 minutes later.

In summary, the OpenADR signals were properly sent. The battery responded by charging at the times and levels requested. However, the battery did not respond to discharge signals because it was limited by the battery management system, which directed the battery not to discharge when the SOC was below 20%. This conflict has been noted earlier in the report as a need to be addressed in future DR program designs that include residential storage.

Additional Pacifica Site Testing

During a subsequent OpenADR test at the Pacifica Site, the battery messaging was as follows:

- Pre - Test
  - Battery was charged at 5kW for 1 hour to bring SOC near 60% to ensure successful discharge testing
- Test 3 (As requested):
  - Discharge at 1 kW: 6 am - 6:15 am
  - Hold: 6:15 am - 6:30 am
  - Charge at 1 kW: 6:30 am - 6:45 am
  - Resume: 6:45 am - 7 am
- Test 4 (As requested):
  - Discharge at 10 kW (get response available): 7 am - 7:15 am
  - Hold: 7:15 - 7:30 am *(Note: battery did not receive hold signal)*
  - Charge at 10 kW (get response available): 7:30 am - 7:45 am
  - Resume: 7:45 am - 8:00 am
- Test 5 was performed while the battery was in non - export mode (As requested)
  - discharge at 1 kW: 8 am - 8:15 am
  - Hold: 8:15 am - 8:30 am
  - Charge at 1 kW: 8:30 am - 8:45 am
  - Resume: 8:45 am - 9 am

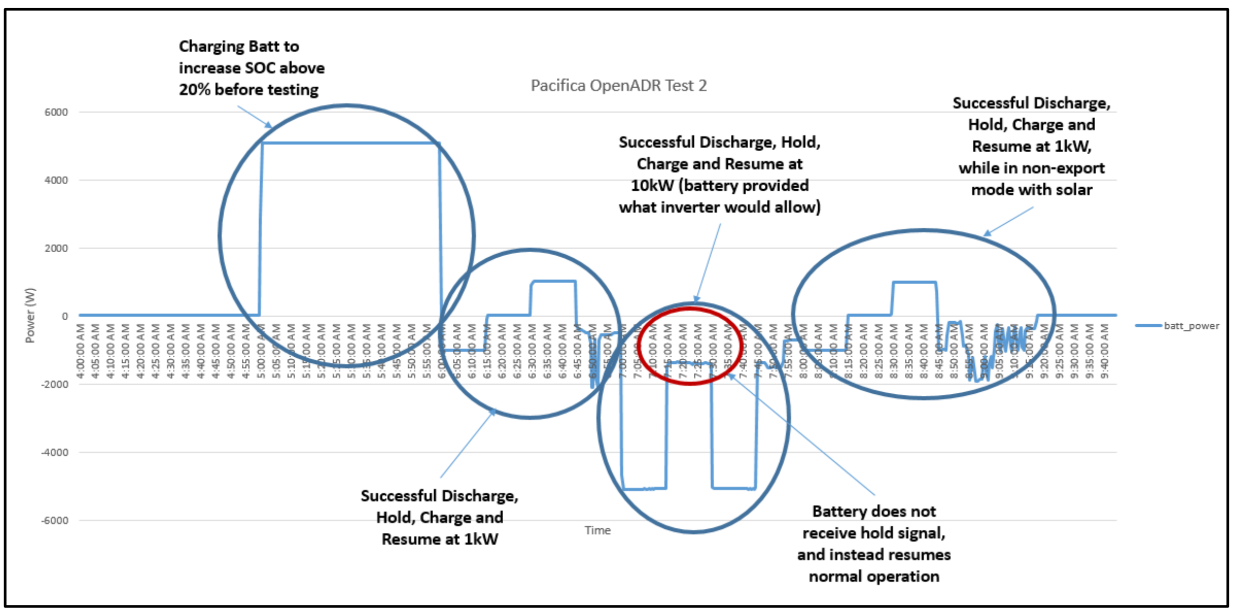

Figure 4-9
Phase II results, additional tests at Pacifica site

EPRI charged the battery at 5kW for 1 hour (via OpenADR LOAD_DISPATCH signal) prior to initiating testing. This was done to alleviate the SOC constraints we experienced during our initial testing operation. This allowed the battery to perform all but one task as expected. The only task it did not perform as expected was a 'Hold' request during test 4. The appropriate 'Hold' signal was sent by the VTN, and appeared to have been received by the VEN as well. However, this signal was somehow not operated on. All other hold events occurred as expected during all other Pacifica site tests.

5
CONCLUSIONS AND RECOMMENDATIONS

The research performed and the laboratory and field testing conducted as part of this effort all confirm that OpenADR 2.0 communication standard, in particular the OpenADR 2.0b profile VEN, can be used to manage residential battery energy storage assets in the field. The greatest limitation to providing a more comprehensive assesment of the messaging protocol was that only one field asset was used and hence the datapoint is not indicative of scaled assessment. Aggregating BESS assets in future tests may provide additional insights into the potential complications when controlling multiple assets simultaneously, which may or may not directly relate to the use of OpenADR 2.0 for communication.

Project learnings useful for understanding OpenADR 2.0b VEN for control of battery energy storage assets in the field include:

- *OpenADR 2.0b certified VEN and BESS systems may not respond to OpenADR signals, as expected, by default.*

  OpenADR 2.0b certification of a BESS only requires that the system be capable of recieving an OpenADR signal; it does not require that the BESS be capable of responding to the signaluner any specific DR use case scenario. This means that for the BESS to respond appropriately to OpenADR 2.0b DR messages, appropriate control logic must be programmed into the BESS.

  For example, the testing described above used the OpenADR 2.0b LOAD_DISPATCH signals. LOAD_DISPATCH signals allow the user to set a start time, event duration and payload (charge/discharge rate) for the target system. These signals can be sent to and received by the target BESS system, but the BESS will act on those signals only if it has been programmed with the control to respond to them properly.

- *Different BES systems may respond differently to the same LOAD_DISPATCH signal, depending on the preferences of the BESS manufacturer or aggregator.*

  As noted above, programming of the BESS asset is required to ensure the BESS responds appropriately to an OpenADR signal. When programming the E-Gear BESS used for this effort, the study team recognized that there are at least two ways that the battery may respond to a LOAD_DISPATCH signal. The payload (charge/discharge rate) could be interpreted by the BESS as either an absolute value oran additive value.

  For example, if the battery was discharging at 2kW when it received a 3kW discharge signal, the battery's expected response could be to discharge at 3kW (via the absolute methodology) or at 5kW (via an additive methodology). Either approach to BESS response may have merits from the perspective of grid operators; it is important to be aware of the potential disparity between different BESS in this regard.

- *BES systems are more likely to be IEEE 2030.5 certified than OpenADR certified.*

  This is because OpenADR is not mandated by the California Rule 21, which is becoming a defacto nationwide standard for smart-inverter control due to recommendations in the grid-codes. However, OpenADR is the default DR protocol in California and in other states, as well as in international energy markets.

- *OpenADR 2.0b does not inherently support 4-quadrant control for VAR support*.

  4-quadrant control includes charge, discharge, leading power factor support and lagging power factor support. OpenADR 2.0b does not inherently support leadig and lagging power factor control. This would impact applications that rely on VAR support.

- *Where demand response is a priority, OpenADR for BES systems may be especially beneficial.*

  Control of these distributed, customer operated assets via OpenADR may align well for utilities and energy markets that already use OpenADR for control of other field assets or for enabling response to dynamic prices for customer benefit and providing flexibility for local grid reliability and market resources.

A

APPENDIX A: E-GEAR MATERIALS

E-GEAR™
energy solutions

03/20/19

David Stevens
Electrical Power Research Institute

David,
E-Gear is please to present Electrical Power Research Institute with an estimate to add communication functionality and control under the OpenADR 2.0b protocol.

E-Gear LLC retains full ownership rights to the Software, all object code, source code, trademarks, service marks, patents, and copyrights, and Customer acknowledges that it obtains no ownership rights to the Software under the terms of this project.

Scope of Work Outline

Task	Description
Implement OpenADR load dispatch setpoint handling.	Add logic to extract event type and event data and override system operation for event duration.
Log all OpenADR events on the backend.	When the VTN triggers an OpenADR event to our VEN, it is dispatched to the application server, which distributes the event to the relevant EMC end device(s). Update the application and database to record the event parameters and results (per device success / failure) of event distribution.
Publish OpenADR event telemetry from the EMC.	When an end device is operating under an active event, collect performance metrics (e.g. ability to meet event requirements) and relevant status indications for end of project performance analysis.
Record OpenADR event telemetry on the back end.	Update the application server and database to incorporate the OpenADR event telemetry published by the end devices.
Post Pilot Data Collection and Reporting	Generate consolidated reports from data collecting during the pilot period for delivery to the customer.
OPTIONAL - Update VEN telemetry reporting.	Directly report EMC telemetry data to the VEN and publish it to the VTN as well-known OpenADR reports or as a custom telemetry report.

Figure A-1
E-Gear Statement of Work

ELECTRIC POWER RESEARCH INSTITUTE

SOURCING STATEMENT OF WORK

Contractor Name: E-Gear
EPRI Contract ID: [Type Contract ID Here]
Contract Title: "OpenADR 2.0B Load Dispatch Functionality"
EPRI Task ID: [Type Task ID Here]

Introduction and Background

E-Gear has partnered with EPRI to provide OpenADR 2.0B functionality via their energy storage systems for testing with SCE as part of SCE Sub Project A3. While E-Gear's systems are OpenADR Certified, they require additional development to become OpenADR functional.

Objectives

Implement OpenADR 2.0B LOAD_DISPATCH control functionality

Third Party Intellectual Property

N/A

Tasks

Additional requirements for tasks identified as "NQA Tasks" are in the attached Quality Assurance Requirements. *[Delete this phrasing for non-NQA contracts.]*

1. Implement OpenADR load dispatch setpoint handling.
   - ***1.1.*** Add logic to extract event type and event data and override system operation for event duration.
2. Log all OpenADR events on the backend.
   - ***2.1.*** When the VTN triggers an OpenADR event to our VEN, it is dispatched to the application server, which distributes the event to the relevant EMC end device(s).
   - ***2.2.*** Update the application and database to record the event parameters and results (per device success / failure) of event distribution.
3. Publish OpenADR event telemetry from the EMC
   - ***3.1.*** When an end device is operating under an active event, collect performance metrics (e.g. ability to meet event requirements) and relevant status indications for end of project performance analysis.
4. Record OpenADR even telemetry on the back end
   - ***4.1.*** Update the application server and database to incorporate the OpenADR event telemetry published by the end devices.
5. Post Pilot Data Collection and Reporting
   - ***5.1.*** Generate consolidated reports from data collecting during the pilot period for delivery to the customer
6. OPTIONAL – Update VEN telemetry reporting
   - ***6.1.*** Directly report EMC telemetry data to the VEN and publish it to the VTN as well-known OpenADR reports or as a customer telemetry report.

Deliverables

1. E-Gear BESS response to LOAD_DISPATCH signals

1

Figure A-2
EPRI/E-Gear SOW for implementation of LOAD_DISPATCH functionality

1.1. E-Gear batteries shall respond to LOAD_DISPATCH signals as defined by the OpenADR 2.0b Profile Specifications Framework developed and maintained by the OpenADR Alliance.

1.1.1. These Load Dispatch signals shall include the following key elements, as specified by the event notification in the OpenADR 2.0b Profile Specification.

1.1.1.1. Event Start time

1.1.1.2. Event Duration

1.1.1.3. Charge or Discharge Rate (expressed in Watts)

1.1..1.3.1. Charging shall be represented by a negative value

1.1..1.3.2. Discharging shall be represented as a positive value

1.1..1.3.3. Hold shall be represented by a rate of 0

1.1.1.4. Cancel Command

1.1..1.4.1. Response shall be to end remote operation request and resume local management of the battery.

1.2. Expected responses for various situations (*Note that these expected results can be adapted if we determine they require too great a level of effort to implement cost effectively*).

1.2.1. The receipt of signal notification is expected whenever the BESS has received an event

1.2.2. When BESS is asked to charge or discharge beyond its capability (due to inverter limitations, SOC limitations, etc.), the battery will respond by charging or discharging at its available capability at that time.

1.2.3. When the BESS is performing a task (charging, discharging, smoothing, etc.) when the OpenADR signal start time begins, the BESS should cease the previous operation and begin the new operation. In other words, the LOAD_DISPATCH request is always additive or subtractive from a charging/discharging level of 0 and the LOAD_DISPATCH signal takes precedence over any existing local optimization modes.

1.2.3.1. Notification for why the battery is unable to export, if it is due to battery non-export. Notification would come as a report (either real time or after the fact is fine)

1.2.4. Telemetry (minute aggregated) for every device will be provided

1.2.4.1. Include flags for diagnosis of why we may not be meeting values requested

Figure A-3
EPRI/E-Gear SOW for implementation of LOAD_DISPATCH functionality (cont'd)

openADR™ 2.0b CERTIFIED

Certificate of System Conformance Awarded to

E-Gear, LLC

E-Gear NOVA Server
(Firmware v. 1.0)

Certified Sep 3, 2018 to OpenADR 2.0b Test Plan 1.1.2

Rolf Bienert
Technical Director

Figure A-4
E-Gear OpenADR 2.0b certificate

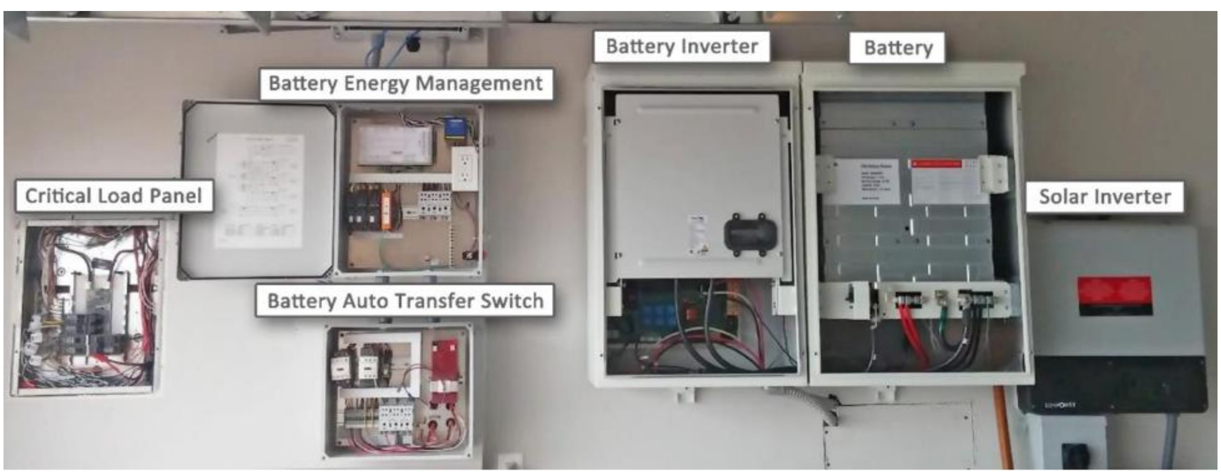

Figure A-5
Expanded view of E-Gear system

Example of XML for OpenADR Event

The following is XML for a 5 minute charge event @ 2200 Watts.


```
<?xml version="1.0" encoding="UTF-8"?>
<ns2:oadrPayload xmlns:ns2="http://openadr.org/oadr-2.0b/2012/07 [openadr.org]"
xmlns="http://www.w3.org/2000/09/xmldsig# [w3.org]"
xmlns:ns10="http://www.opengis.net/gml/3.2 [opengis.net]" xmlns:ns11="http://docs.oasis-
open.org/ns/emix/2011/06/siscale [docs.oasis-open.org]"
xmlns:ns12="http://www.w3.org/2009/xmldsig11# [w3.org]"
xmlns:ns13="http://openadr.org/oadr-2.0b/2012/07/xmldsig-properties [openadr.org]"
xmlns:ns14="urn:un:unece:uncefact:codelist:standard:5:ISO42173A:2010-04-07"
xmlns:ns3="http://docs.oasis-open.org/ns/energyinterop/201110 [docs.oasis-open.org]"
xmlns:ns4="http://docs.oasis-open.org/ns/energyinterop/201110/payloads [docs.oasis-open.org]"
xmlns:ns5="urn:ietf:params:xml:ns:icalendar-2.0" xmlns:ns6="http://docs.oasis-
open.org/ns/emix/2011/06 [docs.oasis-open.org]" xmlns:ns7="urn:ietf:params:xml:ns:icalendar-
2.0:stream" xmlns:ns8="http://www.w3.org/2005/Atom [w3.org]" xmlns:ns9="http://docs.oasis-
open.org/ns/emix/2011/06/power [docs.oasis-open.org]">
  <ns2:oadrSignedObject>
    <ns2:oadrDistributeEvent ns3:schemaVersion="2.0b">
      <ns3:eiResponse>
        <ns3:responseCode>200</ns3:responseCode>
        <ns3:responseDescription>O</ns3:responseDescription>
        <ns4:requestID>ed85b39f15ad461ff4ad</ns4:requestID>
      </ns3:eiResponse>
      <ns4:requestID>2f9f2858094bd0238b5c</ns4:requestID>
      <ns3:vtnID>NEBLAND_VTN</ns3:vtnID>
      <ns2:oadrEvent>
        <ns3:eiEvent>
          <ns3:eventDescriptor>
            <ns3:eventID>a685ceb9cef5ab312978</ns3:eventID>
            <ns3:modificationNumber>0</ns3:modificationNumber>
            <ns3:modificationReason />
            <ns3:priority>0</ns3:priority>
            <ns3:eiMarketContext>
              <ns6:marketContext>testing123</ns6:marketContext>
            </ns3:eiMarketContext>
            <ns3:createdDateTime>2019-10-23T18:43:27.000Z</ns3:createdDateTime>
            <ns3:eventStatus>far</ns3:eventStatus>
            <ns3:testEvent>false</ns3:testEvent>
            <ns3:vtnComment>Battery Charge Test</ns3:vtnComment>
          </ns3:eventDescriptor>
          <ns3:eiActivePeriod>
            <ns5:properties>
              <ns5:dtstart>
                <ns5:date-time>2019-10-23T18:45:00.000Z</ns5:date-time>
              </ns5:dtstart>
```

```
      <ns5:duration>
        <ns5:duration>PT5M</ns5:duration>
      </ns5:duration>
      <ns5:tolerance>
        <ns5:tolerate>
          <ns5:startafter>PT0M</ns5:startafter>
        </ns5:tolerate>
      </ns5:tolerance>
      <ns3:x-eiNotification>
        <ns5:duration>PT0M</ns5:duration>
      </ns3:x-eiNotification>
      <ns3:x-eiRampUp>
        <ns5:duration>PT0M</ns5:duration>
      </ns3:x-eiRampUp>
      <ns3:x-eiRecovery>
        <ns5:duration>PT0M</ns5:duration>
      </ns3:x-eiRecovery>
    </ns5:properties>
    <ns5:components xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance
[w3.org]" xsi:nil="true" />
  </ns3:eiActivePeriod>
  <ns3:eiEventSignals>
    <ns3:eiEventSignal>
      <ns7:intervals>
        <ns3:interval>
          <ns5:duration>
            <ns5:duration>PT5M</ns5:duration>
          </ns5:duration>
          <ns5:uid>
            <ns5:text>0</ns5:text>
          </ns5:uid>
          <ns3:signalPayload>
            <ns3:payloadFloat>
              <ns3:value>-2200.0</ns3:value>
            </ns3:payloadFloat>
          </ns3:signalPayload>
        </ns3:interval>
      </ns7:intervals>
      <ns3:signalName>LOAD_DISPATCH</ns3:signalName>
      <ns3:signalType>setpoint</ns3:signalType>
      <ns3:signalID>81812ec7f385a48e81d2</ns3:signalID>
      <ns3:currentValue>
        <ns3:payloadFloat>
          <ns3:value>0.0</ns3:value>
        </ns3:payloadFloat>
      </ns3:currentValue>
```

```xml
          </ns3:eiEventSignal>
        </ns3:eiEventSignals>
        <ns3:eiTarget>
          <ns3:venID>275feabea267e70a2fe6</ns3:venID>
        </ns3:eiTarget>
      </ns3:eiEvent>
      <ns2:oadrResponseRequired>always</ns2:oadrResponseRequired>
    </ns2:oadrEvent>
  </ns2:oadrDistributeEvent>
 </ns2:oadrSignedObject>
</ns2:oadrPayload>
```


Figure A-1
Example of XML for OpenADR Event

Table A-1
E-Gear Communication Functionality and Control Requirements

Task	Description
Implement OpenADR load dispatch setpoint handling.	Add logic to extract event type and event data and override system operation for event duration.
Log all OpenADR events on the backend.	When the VTN triggers an OpenADR event to our VEN, it is dispatched to the application server, which distributes the event to the relevant EMC end device(s). Update the application and database to record the event parameters and results (per device success / failure) of event distribution.
Publish OpenADR event telemetry from the EMC.	When an end device is operating under an active event, collect performance metrics (e.g. ability to meet event requirements) and relevant status indications for end of project performance analysis.
Record OpenADR event telemetry on the back end.	Update the application server and database to incorporate the OpenADR event telemetry published by the end devices.
Post Pilot Data Collection and Reporting	Generate consolidated reports from data collecting during the pilot period for delivery to the customer.
OPTIONAL - Update VEN telemetry reporting.	Directly report EMC telemetry data to the VEN and publish it to the VTN as well-known OpenADR reports or as a custom telemetry report.

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