EPIC Final Report

Program	Electric Program Investment Charge (EPIC)
Administrator	San Diego Gas & Electric Company
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Attribution

This comprehensive final report documents the work done in Electric Program Investment Charge (EPIC) 3, Project 7, Module 3. The project team that contributed to the project definition, execution, and reporting included the following individuals, listed alphabetically by name:

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Executive Summary

The objective of San Diego Gas & Electric's (SDG&E) EPIC-3 Project 7 is to perform a pre-commercial demonstration of mobile battery energy storage systems (MBESS) and examine the value proposition from using MBESS across multiple sites and use cases. An MBESS is a battery energy storage system on wheels that can provide multiple use cases based on a single MBESS application or a combination of several applications (stacking of applications) to provide grid support and reliability/resiliency solutions for utility projects at different sites. This third module of EPIC 3, Project 7 includes operational flexibility demonstrations using the Institute of Electrical and Electronics Engineers (IEEE) communication protocol 2030.5 to communicate with the MBESS, as well as deployment of the MBESS during planned outages, emergency events, and Public Safety Power Shutoffs (PSPS).

The project approach included the following tasks:

- Integrate the IEEE 2030.5 standard with the existing SDG&E MBESS
- Demonstrate operational flexibility use cases identified by the California Public Utilities Commission's (CPUC) Smart Inverter Operationalization Working Group (SIOWG) of the IEEE 2030.5 standard use with the MBESS
- Demonstrate the consequence of several communication loss scenarios of the IEEE 2030.5 standard use with the MBESS
- Select one site for use case demonstration by an MBESS integrated with the IEEE 2030.5 standard
- Demonstrate the use case of an electric distribution interconnection equipment trailer equipped with the MBESS
- Provide the test plan document before the demonstrations
- Relocate and connect the MBESS electrically at the chosen site and demonstrate the use cases using the test plans created
- Provide a test report after the demonstrations
- Complete the final report document after completing all the demonstrations

Key Findings

The demonstration at the Cameron Corners field site showcases the MBESS's utilization of the IEEE 2030.5 standard, highlighting successful use cases such as flexibility during grid reconfiguration, capacity increase, voltage boosting with fixed reactive power injection, and voltage reduction with Volt/Var curve mode. Additionally, various communication loss scenarios were tested at the Integrated Testing Facility (ITF), including loss between the IEEE 2030.5 server and gateway, and between the gateway and MBESS local controller, occurring at different times. The project's results suggest that integrating the MBESS with the IEEE 2030.5 standard will facilitate further developments recommended by California Rule 21 and enable effective monitoring and control of both stationary and portable DERs in the field.

This project demonstrated that the IEEE 2030.5 standard can be integrated successfully with the MBESS[1]. Through the IEEE 2030.5 standard integration, the MBESS can perform the following use cases:

- Flexibility during grid reconfiguration
- Capacity increase[2]
- Voltage boosting with fixed reactive power injection
- Voltage reduction with Volt/Var curve mode

The integration of the MBESS with the IEEE 2030.5 standard enhances scalability, visibility, operational flexibility, and power quality. The project addresses bidirectional communication, studying various communication loss scenarios and providing a successful solution even during disruptions. Future steps include incorporating Distributed Energy Resource Management System (DERMS) actions to optimize operations for the broader network.

Additional Use Case

Building on the MBESS earlier deployments, which demonstrated several use cases detailed and reported in Modules 1 and 2, this third module added an additional use case focused on pairing the battery alongside a distribution interconnection equipment trailer, commonly referred to as the MBESS “companion trailer”—to facilitate easier and faster mobilization when providing backup power to customer load pockets on the distribution system. This setup is particularly valuable during emergency events, where rapid deployment of generation is critical to temporarily restore power to customers experiencing prolonged outages, such as a Public Safety Power Shutoff (PSPS) event.

With the addition of the companion trailer use case, further details on this component of the project are provided in Appendix B.

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[1] The references to this type of communication in this document are strictly theoretical, since operational data exchange would be governed by wholesale market requirements and interconnection agreements.

[2] The references to “Capacity increase” in this document are limited to the distribution operating environment, not to permanent distribution capacity increases necessary to energize new customer loads or to mitigate other distribution needs identified in the distribution planning domain.

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List of Acronyms

Acronym	Acronym Description
ADMS	Advanced distribution management system
BESS	Battery energy storage system
BMS	Battery management system
BTM	Behind the meter
C&I	Commercial and industrial
CPUC	California Public Utilities Commission
CSIP	Common Smart Inverter Profile
DAC	Disadvantaged community
DER	Distributed energy resource
DERMS	Distributed energy resource management system
EPIC	Electric Program Investment Charge
GCM	Grid-connected mode
GHG	Greenhouse gas
HMI	Human-machine interface
IEEE	Institute of Electrical and Electronics Engineers
ITF	Integrated testing facility
LTE	Long-term evolution
MBESS	Mobile battery energy storage system
NFPA	National Fire Protection Association
PCC	Point of common coupling
PCS	Power conversion system
POI	Point of interconnection
SDG&E	San Diego Gas & Electric
SIOWG	Smart Inverter Operationalization Working Group
SLD	Single-line diagram
SOC	State of charge
USD	U.S. dollar

Acronym	Acronym Description
UV	Undervoltage
VPN	Virtual private network

1 Introduction

California Rule 21 (Rule 21) is an interconnection standard that California Investor-Owned Utilities (IOU) administer within their service territories. The standard describes the interconnection, operating, and metering requirements for generation assets to be connected to the utility's distribution system. It allows customers with generating or storage facilities to access the grid while protecting the safety and reliability of the distribution and transmission infrastructure [1].

Deploying Rule 21 consists of three chronological implementation phases:

- Phase 1: Autonomous inverter functions
- Phase 2: Communications requirements
- Phase 3: Advanced smart inverter functions

In Phase 1, smart inverters are configured with settings that conform to each utility's interconnection handbook. Once configured, they operate autonomously by adjusting their output to local conditions.

In Phase 2, Rule 21 requires establishing bidirectional communications between the utility and the smart inverter or aggregator. It has selected the IEEE 2030.5 standard (also known as Smart Energy Profile 2.0) as the default communications protocol. Although Phase 1 functions can operate autonomously, their parameters cannot be updated. Furthermore, most, if not all Phase 3 functions require communications. Hence, bidirectional communication allows functional and security updates to be issued to the smart inverters as required.

IEEE 2030.5 is a secure and scalable application-layer protocol built upon standard Internet protocols. The standard contains distributed energy resource (DER) object models based on IEC 61850, direct controls, autonomous curves, and status and meteorology information. Additionally, IEEE 2030.5 standard integration ensures that the utility has the necessary tools to maintain grid stability and reliability.

The Common Smart Inverter Profile (CSIP) guidelines create a common communication profile for inverter communications and together with the IEEE 2030.5 specification and interconnection handbook, provide the tools to implement Phase 2 requirements.

In Phase 3 several smart inverter functions permit the systems to play an active role in distribution system stabilization, power system reliability, and overall energy efficiency.

This project focused on demonstrating the IEEE 2030.5 operational flexibility use cases as identified by the California Public Utilities Commission's (CPUC) Smart Inverter Operationalization Working Group (SIOWG). The project successfully demonstrated the ability to monitor, control, and schedule mobile battery energy storage system (MBESS) events through the IEEE 2030.5 standard over the private LTE network.

2 Project Objectives

With the increasing penetration of DERs within SDG&E service territory, monitoring and control of DER assets becomes a critical aspect of utility operations to mitigate any adverse impact of DERs on the distribution grid and leverage their benefits. Furthermore, California Rule 21 has mandated IEEE 2030.5 as the default communications standard protocol for bidirectional communication between the utility and the DERs or aggregators. This will eventually enable the utility to monitor and control all DER assets within its territory through its distributed energy resources management system (DERMS) platform.

SDG&E originally initiated EPIC 3 Project 7 to perform a pre-commercial demonstration of an MBESS as an emerging technology for evaluating its benefits and assessing its value proposition across SDG&E territory for several use cases. Subsequently, SDG&E's EPIC-3, Project 7, Module 3 project objective was to further improve the value proposition of MBESS by remote monitoring and control of the unit through IEEE 2030.5 communication protocol. The project focused on demonstrating the operational flexibility provided to utility operators by monitoring and control of a DER asset through the IEEE 2030.5 communication protocol. MBESS, as an energy storage asset in the field, was used in conjunction with an IEEE 2030.5 master platform to perform operational flexibility use cases. The project demonstrates how the IEEE 2030.5 communication protocol can be leveraged for a mobile energy storage system or other DERs (which does not inherently support IEEE 2030.5 communication) to enhance monitoring and control of field assets, which in turn provides operational flexibility to the operators for better using the assets for grid support use cases.

3 Project Focus

This project focuses on integrating the IEEE 2030.5 standard with the MBESS and demonstrating the MBESS' capability to perform several use cases using the IEEE 2030.5 standard as the core bidirectional communication standard between the utility and the MBESS. Before performing the use cases, the suitable MBESS with the IEEE 2030.5 standard utilization use cases were identified and include:

1. Flexibility during grid reconfiguration event
2. Capacity increase
3. Voltage boosting through reactive power increase
4. Voltage reduction with local Volt/Var support

Two additional scenarios were identified and demonstrated regarding communication loss and include:

5. Loss of communication between the server and gateway
6. Loss of communication between the gateway and local MBESS controller

The communication loss use cases were evaluated during capacity increase use cases. These demonstrations were done at two different locations, the Integrated Testing Facility (ITF) and at Cameron Corners, Campo, CA.

These demonstrations were done with a single-phase 150 kVA rated MBESS integrated with IEEE 2030.5 standard. The MBESS internal datalogger captured all essential data during system operation and demonstration to support more inclusive investigation and verification.

- **Reliability:** Real-time DER dispatch helps manage distribution-level congestion and supports voltage stability.
- **Safety:** The pilot includes protocols for secure communication and interoperability standards, reducing operational risks.
- **Affordability:** Dynamic pricing and automation deliver measurable bill savings for customers and reduce grid investment needs.
- **Equity:** The framework ensures participation options for diverse customer segments, including disadvantaged communities, promoting inclusive decarbonization.
- **Sustainability:** Integrating diverse DERs like solar PV, EVs, smart devices, and storage under dynamic pricing accelerates renewable adoption and reduces carbon emissions.

1.1General Description of the MBESS

The selected MBESS for this demonstration is designed for frequent relocation and fast interconnection at a new site, using a standard generator terminal box with Cam-Lok plugs.

The MBESS is a clean alternative for emergency diesel generators. Using a fully mobile platform enhances the value proposition as it increases the usability of the energy storage system by introducing flexibility in capturing the locational benefits of grid support or customer-specific applications.

The MBESS unit selected `for the EPIC project is a single-phase system. It includes an onboard 150 kVA isolation transformer to provide a customer-specific connection for 120/240 V split-phase (3 wires). Figure 2-1 illustrates a simplified schematic of the MBESS for this project. In this project, the existing SDG&E MBESS was upgraded to enable the IEEE 2030.5 communication with the unit by adding a protocol converter/gateway (IEEE 2030.5 to Modbus), as shown in Figure 2-1.

Figure 2-2 presents a picture of the MBESS trailer used for this demonstration. This MBESS is integrated with the IEEE 2030.5 standard (Figure 2-1). Specifically, the IEEE 2030.5 server at the ITF sends the commands/schedules to the IEEE 2030.5 gateway located within the MBESS container. This IEEE 2030.5 gateway stores the commands/schedules and sends these commands/schedules to the MBESS local controller at the time of each event. In addition, the MBESS local controller shares the information from sensors/measurements with the IEEE 2030.5 server by using the IEEE 2030.5 gateway as a medium. This is a simplified description of IEEE 2030.5 standard integration with the MBESS.

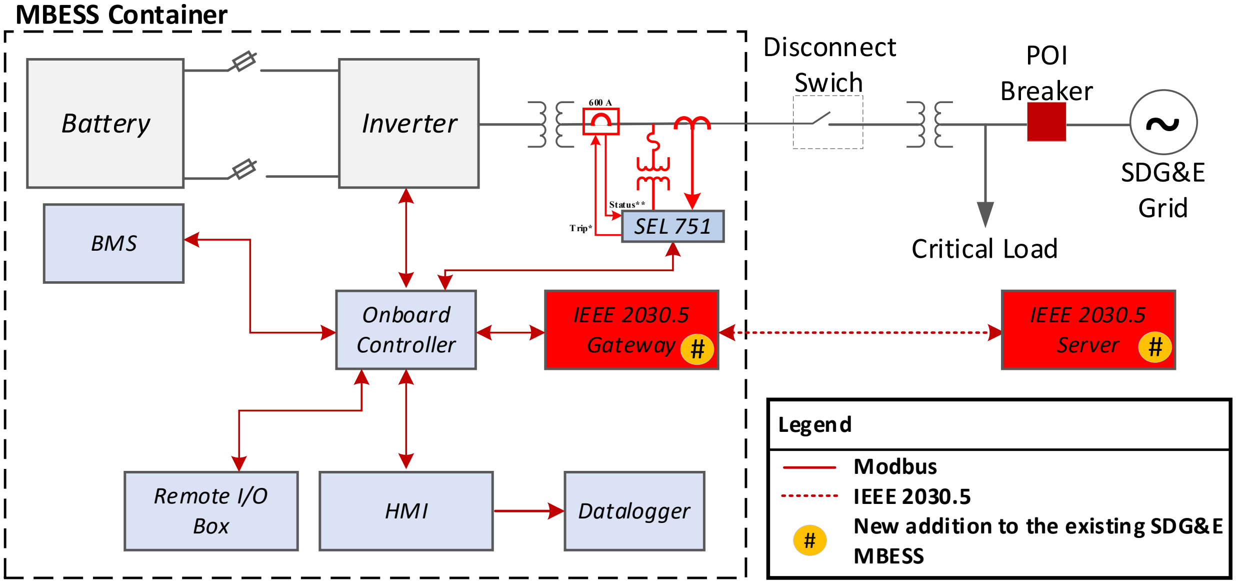
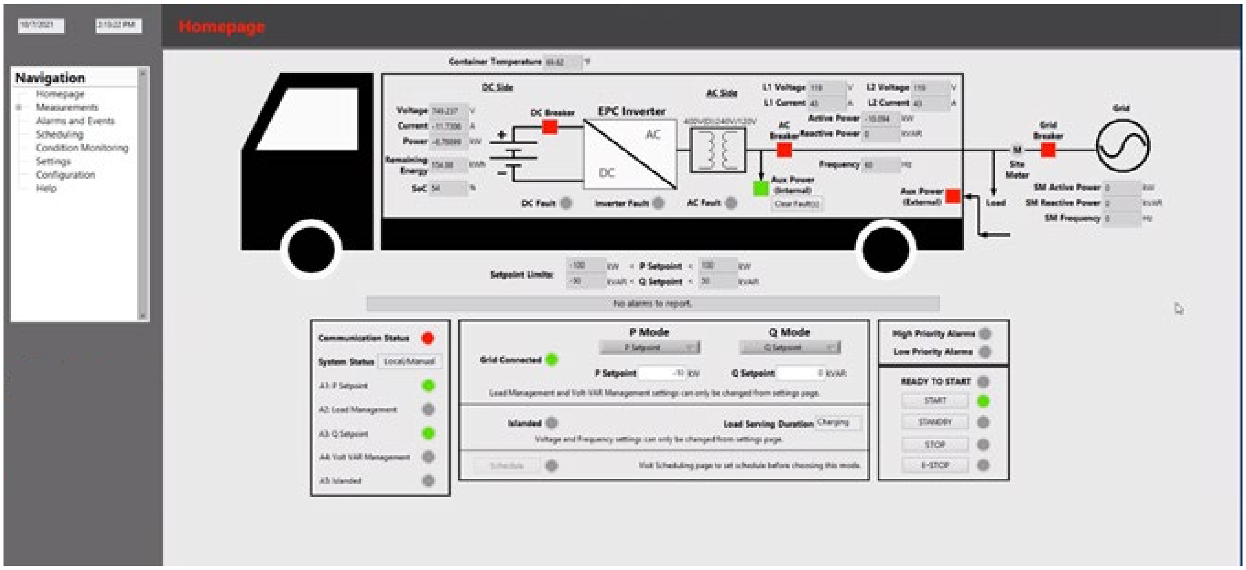


Figure 2-1. Simplified Schematic of MBESS

Figure 2-2. MBESS Container Used in the Project (Pictured)

1.2 Control and Monitoring

A robust onboard monitoring and control platform is implemented in the MBESS, which has all the required software associated with the operation and monitoring of the unit. The MBESS general controls are described in the previous EPIC-3, Project 7, Module 2 Final Report [1]. Figure 2-3 presents a sample picture of the home page of the human-machine interface (HMI) of the MBESS. MBESS has two control modes: local and remote. To enable the control of the MBESS through IEEE 2030.5, MBESS was set to remote control. More information regarding the remote-control mode and other features of the SDG&E MBESS can be found in the EPIC-3, Project 7, Module 2 Final Report. [1].



System Status: Local/Manual

No alarms to report.

Load Management and Volt-VAR Management settings can only be changed from settings page.

Voltage and Frequency settings can only be changed from settings page.

Visit Scheduling page to set schedule before choosing this mode.

Figure 2-3. MBESS HMI Homepage

The MBESS is integrated into the IEEE 2030.5 server through a CSIP-compliant IEEE 2030.5 gateway. The gateway is responsible for the IEEE 2030.5 communications (server and resource discovery, security, acting on DER controls, and reporting DER data) and for converting IEEE 2030.5 communications to and from the Sunspec Modbus for communication with the MBESS local controller.

A CSIP-compliant IEEE 2030.5 server is used to send and schedule DER controls and monitor the relevant DER data from the MBESS. The server is configured by registering the DER end devices, setting up default DER controls and curve-based DER controls, and sending relevant DER controls as required for each use case.

4 Project Scope Summary

The scope of work was to perform the first phase of the CPUC's IEEE 2030.5 operational flexibility pilot using the MBESS from EPIC 3, Project 7, Module 2 with the following goals:

- Demonstrate IEEE 2030.5 operational flexibility for DER within SDG&E territory, including:
  - Flexibility during grid reconfiguration
  - Capacity increase
  - Voltage boosting
  - Voltage reduction
- Demonstrate the consequences of communication loss between the IEEE 2030.5 server, gateway, and MBESS local controller.
- Demonstrate additional use cases for EPIC 3's mobile battery energy storage project.

Additionally, throughout this project, all these types of DER control management, as defined by "IEEE 2030.5 Implementation Guide for Smart Inverters"[2], were tested, including the following:

- **Immediate controls:** IEEE 2030.5 DER event to change a specific setpoint at a scheduled time for a specific duration. Examples of immediate controls used in this project include DERControl with OpModMaxLimitW, OpModFixedW, and OpModFixedVAR.
- **Default controls:** the controls that cannot be scheduled and have indefinite duration. These settings are not expected to change often. Examples of default-only controls used in this project include DefaultDERControl with OpModMaxLimitW, OpModFixedW, and OpModFixedVAR.
- **Curve control:** This is an IEEE 2030.5 DER event that can be scheduled, which uses a series of (x,y) points to define the behavior of a dependent variable (y) based on the value of an independent variable (x). A default curve may be used in the absence of other active events. This project demonstrated the OpModVoltVar curve control.

Table 3-1 lists the DER controls and modes used in this project with their descriptions.

Table 3-1. IEEE 2030.5 Standard Controls Used in the MBESS

Control/Mode	Abbreviation	Description
Limit Maximum Active Power Injection Control	OpModMaxLimitW	This command makes the MBESS have a specific active power limit.
Active Power Injection Setpoint Control	OpModFixedW	This command sets a specific value for the active power injection from the MBESS.
Reactive Power Injection Setpoint Control	OpModFixedVar	This command sets a specific value for the reactive power injection from the MBESS.
Operation in Volt/Var Mode	OpModVoltVar	This command makes the MBESS set its reactive power based on a defined Volt/Var curve.

Control/Mode	Abbreviation	Description
Default Controls Mode	DefaultDERControl	The operator sets this mode. This mode cannot be scheduled and has an indefinite duration.
Immediate Controls Mode	DERControl	The operator can schedule this mode for a specific time and duration.

1.3 High-level Overview

The project scope includes the major tasks listed in the following subsections.

4.1.1 Task 1: Define Use Cases and Requirements for Integration of IEEE 2030.5 into the Mobile Battery System

The use cases in this task focused on operational flexibility and grid support provided by MBESS through IEEE 2030.5 communication. Clarification between the differences of real-world implementation and the project demonstration is provided to understand the impact of IEEE 2030.5 adoption by the MBESS and the required utility infrastructure.

4.1.2 Task 2: Initial Benefits Analysis

In this task, an initial benefit analysis was performed to identify the benefit areas associated with enabling IEEE 2030.5 communication to MBESS and develop an estimation of the benefits and business case for the demonstration. The benefits were aligned with the identified use cases to assess the value of IEEE 2030.5 communication capabilities for DERs within SDG&E territory.

4.1.3 Task 3: Integrate the IEEE 2030.5 Standard with the MBESS and Testing at ITF

This task was dedicated to adding IEEE 2030.5 communication capabilities to the SDG&E MBESS. To do so, a local IEEE 2030.5 gateway was installed inside the MBESS container and was integrated into the existing MBESS controller. Upon successfully integrating the IEEE 2030.5 gateway to the MBESS controller, the team demonstrated all the desired operational flexibility use cases (identified in Task 1) and tested communication failure scenarios at the ITF. This allowed the team to validate the unit's operation before taking the MBESS to the field.

4.1.4 Task 4: Relocation and Transportation Services

In this task, the project team supported the de-energization and relocation of the MBESS between different sites. This project's demonstration site was Cameron Corners, Campo, CA.

4.1.5 Task 5: Develop a Test Plan for Execution of the Field Demonstration

The team created a detailed test plan to follow for demonstration of the selected use cases at Cameron Corners. This test plan was reviewed and finalized before transporting the MBESS to the field.

4.1.6 Task 6: Perform the Demonstration

Once the unit was successfully energized at Cameron Corners (outcome of Task 4), the test plan developed in Task 5 was used to execute the use cases.

4.1.7 Task 7: Perform Data Analysis

Upon completing the demonstrations, the team focused on organizing and analyzing the data collected. The data analysis was done based on collected test results from various devices and data sources within the system.

4.1.8 Task 8: Revised Cost/Benefits Analysis Based upon Demonstration Results

Using the analyzed data from the site, the team updated the original benefit estimates and created a cost estimate for commercial use of the IEEE 2030.5 standard integrated DER within the SDG&E territory.

4.1.9 Task 9: Prepare Findings and Comprehensive Final Report

Using the results from Tasks 7 and 8, the team prepared the project findings, including conclusions, the value proposition for commercial adoption of the demonstrated solution, recommendations on whether to pursue commercial adoption and requirements for pursuing commercial adoption. These findings and more are documented in the comprehensive EPIC 3, Project 7, Module 3 Final Report.

4.1.10 Task 10: Project Management

Throughout the project, a dedicated technical project manager oversaw the project’s execution.

5 Project Approach

Various benefits are associated with using the MBESS integrated with the IEEE 2030.5 standard. This section will demonstrate how the IEEE 2030.5 standard was integrated with the existing SDG&E MBESS, the use cases that were demonstrated and their benefits, and the loss of communication scenarios that were investigated while using the IEEE 2030.5 standard.

Figure 4-1 provides a conceptual depiction of IEEE 2030.5 standard integration with the MBESS. A CSIP-compliant IEEE 2030.5 gateway was installed inside the MBESS container to accommodate remote control and monitoring of the MBESS from the IEEE 2030.5 server. The IEEE 2030.5 gateway maintains IEEE 2030.5 communications, including security, server and resource discovery, registration, DER controls, and DER data reporting. For monitoring and control, the IEEE 2030.5 data model is converted to Sunspec Modbus for communication with the MBESS local controller. During this project, the IEEE 2030.5 server was located at the ITF and communicated to the IEEE 2030.5 gateway through SDG&E's private LTE network for site testing and the field demonstration at Cameron Corners.

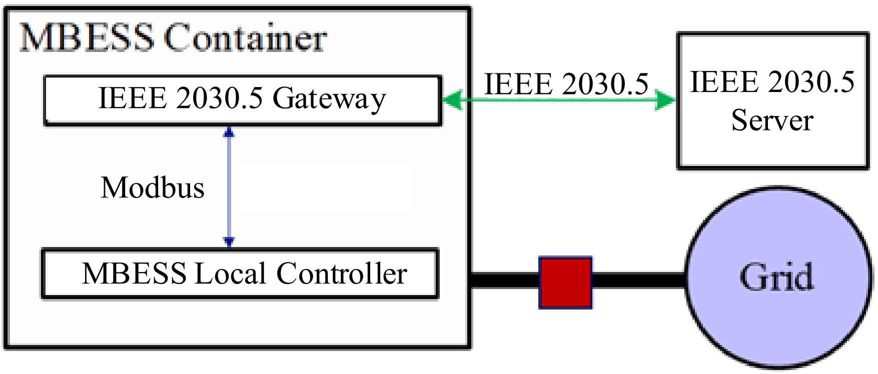


Figure 4-1. IEEE 2030.5 Standard Integration with MBESS

All DER controls are entered by the operator on the IEEE 2030.5 server and communicated to the IEEE 2030.5 gateway. The IEEE 2030.5 gateway receives the DER controls, maintains the schedule of active DER controls, and responds to the IEEE 2030.5 server as required by CSIP (e.g., event received, event superseded, etc.). At the time of an event onset, the gateway will set the corresponding command for reverting the unit to the default setting on Sunspec Modbus and send it to the MBESS local controller. Alternatively, the MBESS local controller is responsible for communicating the relevant settings, ratings, and measurements to the gateway using Sunspec Modbus. The gateway sends the relevant alarms, Mirror Meter Readings (MMR), device capability, DER status, and DER settings to the IEEE 2030.5 server.

Figure 4-2 depicts the installation of the gateway box with the SDG&E modem on the MBESS interior container wall. An eight-pin RJ45 cable is connecting the gateway and the MBESS controller (see Figure

4-2). In addition, Figure 4-3 (a) shows a picture of the IEEE 2030.5 server located at ITF, and Figure 4-3 (b) shows the Modbus gateway connection to the MBESS local controller.

Figure 4-2. Gateway Installation for MBESS Integration with IEEE 2030.5 Standard

(a)

(b)

Figure 4-3. IEEE 2030.5 Standard Integration with the MBESS: (a) IEEE 2030.5 Standard Server, and (b) Modbus Gateway Connection to MBESS Local Controller

1.4 Use Cases

This project focused on demonstrating the control and monitoring of the equipment at the grid edge using IEEE 2030.5 standard as the main bidirectional communication. The IEEE 2030.5 server used in this project will execute each command specified by the operator but does not host any additional logic. As a result, the implementation of some of the use cases in this project was different from the implementation where a DERMS is present and hosts the required logic. In commercial operation, the DERMS or similar platforms will be integrated into the IEEE 2030.5 server through API and execute various optimization functions.

This following section describes each use case and its implementation.

5.1.1 Use Case 1: Flexibility During Grid Reconfiguration

Definition

A customer can agree to reduce or curtail power during system maintenance or grid outages involving system reconfiguration following any additional operational flexibility constraint requirements. As a result, the connected DER may need to curtail its active power output for the duration of this reconfiguration event, which is the focus of this use case. The range of adjustability and limits on the number of events is determined by mutual consent and included in the interconnection agreement.

Implementation

During a scheduled event in response to a maintenance or planned outage, the DERs will connect to another feeder. In such a case, the IEEE 2030.5 server will create a scheduled event to adjust the maximum DER outputs based on the new feeder's capacity, as needed. Notably, in implementations where the server is integrated into DERMS, the operator will not need to re-enter the schedule on the server. The DERs will receive this event through the IEEE 2030.5 gateway and will curtail its active power output at the time of the event.

To demonstrate this use case, the IEEE 2030.5 server, IEEE 2030.5 gateway, and MBESS local controller each need to play a key role, as outlined below:

- IEEE 2030.5 server:
  - Provide the ability for the operator to create a new event to limit the power output of the unit (OpModMaxLimitW)
  - Successfully connect and disconnect the MBESS (opModConnect)
  - Send the scheduled event to MBESS
  - Monitor the MBESS
- IEEE 2030.5 gateway:
  - Receive the DefaultDERControl and DERControl Event from the IEEE 2030.5 server and stores the relevant data to send to the MBESS local controller at the time of the event.
  - Respond to the IEEE 2030.5 server for DERControls (e.g., acknowledgment of event received).
  - Resolve DERControl conflicts through prioritization.
  - Share the relevant scheduled system limits (at the time of the event) with the MBESS local controller.
  - Re-sets the default setpoints to MBESS upon completion of the event.
  - Sends monitoring data from MBESS to the IEEE 2030.5 server.
- MBESS local controller
  - Curtail the active power of the MBESS based on the setpoint received from the gateway, as needed

5.1.2 Use Case 2: Capacity Increase

Definition

A customer agrees to modify their active power injection in response to a communication-based request received through the IEEE 2030.5 standard. These requests can be active power injection increases for the DER to a certain level or by allowing their DER to follow a specific predefined pattern provided by a dispatch signal.

Implementation

Upon identifying the need for a capacity increase on the feeder, the IEEE 2030.5 server will send the information regarding the capacity increase event to the MBESS. In this project, the IEEE 2030.5 server was only communicating with one DER. As a result, there was no need to identify capacity increase allocation per DER. In an application where the server is communicating with more than one DER, it can accept group controls from the operator or through DERMS and send them to individual end devices. The server does not host any logic to calculate the required capacity increase per device to achieve a required total increased capacity.

To demonstrate this use case, the IEEE 2030.5 server, IEEE 2030.5 gateway, and MBESS local controller each played a key role, as outlined below:

- IEEE 2030.5 server
  - Provided the ability for the operator to create multiple new events to increase the power output of the unit (opModFixedW)
  - Successfully connected and disconnected the MBESS (opModConnect)
  - Sent the scheduled events to MBESS
  - Monitored the MBESS.
- IEEE 2030.5 gateway:
  - Receive the DefaultDERControl and DERControl Event from the IEEE 2030.5 server and stored the relevant data to send to the MBESS local controller at the time of the event
  - Respond to the IEEE 2030.5 server for DERControls (e.g., acknowledgment of event received)
  - Resolve DERControl conflicts through prioritization
  - Share the new active power setpoint (at the time of the event) with the MBESS local controller
  - Re-sets the default setpoints to MBESS upon completion of the event
  - Send monitoring data from MBESS to the IEEE 2030.5 server
- MBESS local controller
  - Adjust the active power of the output of MBESS based on the setpoint received from the gateway.

5.1.3 Use Case 3: Voltage Boosting

Definition

This use case focuses on increasing the voltage along a feeder to address undervoltage issues by injecting reactive power.

Implementation

During an undervoltage (UV) event, the measured voltage at pre-specified metering points is sent to DERMS. DERMS hosts the logic to calculate the reactive power injection required from each DER to address this UV event and send the required setpoints to the IEEE 2030.5 server. The server then shares the setpoint with each DER under its control.

In this project, however, due to the lack of availability of DERMS, instead of calculating the required reactive power based on the measured voltage, the team validated the functionality of the IEEE 2030.5 server, IEEE 2030.5 gateway, and MBESS local controller by manually creating control events to inject a specific reactive power at the output of the MBESS. These events were sent to the IEEE 2030.5 gateway and, in turn, shared with the MBESS local controller at the time of the event to increase the reactive power generation based on the requested setpoint by the IEEE 2030.5 server.

To demonstrate this use case, the IEEE 2030.5 server, gateway, and MBESS local controller each played a key role, as outlined below:

- IEEE 2030.5 server
    - Provide the ability for the operator to create multiple new events to adjust the injected reactive power at the output of the unit (opModFixedVAR)
    - Successfully connect and disconnect the MBESS (opModConnect)
    - Send the scheduled events to MBESS
    - Monitor the MBESS
- IEEE 2030.5 gateway:
    - Receive the DefaultDERControl and DERControl Event from the IEEE 2030.5 server and stores the relevant data to send to the MBESS local controller at the time of the event
    - Respond to the IEEE 2030.5 server for DERControls (e.g., acknowledgment of event received)
    - Resolve DERControl conflicts through prioritization
    - Share the new reactive power setpoint (at the time of the event) with the MBESS local controller
    - Re-sets the default setpoints to MBESS upon completion of the event
    - Send monitoring data from MBESS to the IEEE 2030.5 server
- MBESS local controller
    - Adjust the reactive power of the output of MBESS based on the setpoint received from the IEEE 2030.5 gateway

5.1.4 Use Case 4: Voltage Reduction (Volt/Var)

Definition

This use case focused on using Volt/Var and Volt/Watt curve controls to address the overvoltage issues along the feeder. Note that the MBESS unit under test in this project does not support the Volt/Watt function, and as a result, only Volt/Var was tested in the field.

Implementation

Volt/Watt and/or Volt/Var curve characteristics for each resource are set through the 2030.5 server. The overall control can be implemented as default or scheduled for a specific duration. Upon enabling the curve control, DERs are responsible for following the curve based on the measured voltage.

To demonstrate this use case, the IEEE 2030.5 server, IEEE 2030.5 gateway, and MBESS local controller each played a key role, as outlined below:

- IEEE 2030.5 server:
  - Provide the ability for the operator to define the curve criteria and schedule events for curve control.
  - Successfully connect and disconnect the MBESS (opModConnect).
  - Send the scheduled events to MBESS.
  - Monitor the MBESS.
- IEEE 2030.5 gateway:
  - Receive the DefaultDERControl and DERControl Event from the IEEE 2030.5 server and stores the relevant data to send to the MBESS local controller at the time of the event
  - Respond to the IEEE 2030.5 server for DERControls (e.g., acknowledgment of event received)
  - Resolve DERControl conflicts through prioritization
  - Share the new reactive power setpoint (at the time of the event) with the MBESS local controller
  - Re-sets the default setpoints to MBESS upon completion of the event
  - Send monitoring data from MBESS to the IEEE 2030.5 server
- MBESS local controller
  - Implement the curve characteristics based on the setpoints from the IEEE 2030.5 gateway.
  - During the volt/var event, adjust the reactive power at the output of MBESS following the voltage measurements

1.5 Communication Loss Scenarios

Communication loss between the IEEE 2030.5 server, IEEE 2030.5 gateway, and MBESS local controller is a risk during field deployment. As a result, it is crucial to understand the possible scenarios for the loss of communication and what to expect during each scenario. To this end, the project demonstrated the communication loss between the IEEE 2030.5 server and gateway and between the IEEE 2030.5 gateway and MBESS local controller while the MBESS was energized. Table 4-1 provides an overview of the possible instances when the communication loss event may happen. These instances were demonstrated during this project to understand the potential consequences and how to address them.

Table 4-1. Communication Loss Scenarios

#	Communication Loss Scenario	Sub #	Different Instances of Communication Loss
1.		**1.1.**	After the scheduled control starts

#	Communication Loss Scenario	Sub #	Different Instances of Communication Loss
	Communication Loss between the Server and Gateway	1.2.	After the gateway receives the scheduled control but before the start time
		1.3.	After the gateway receives the scheduled control but before the start time, and communications return before the event duration elapses
2.	Communication Loss between the Gateway and Local MBESS Controller	2.1.	After the scheduled control starts
		2.2.	After the gateway receives the scheduled control but before the start time
		2.3.	After the gateway receives the scheduled control but before the start time, and communications return before the event duration elapses

1.6 Baseline Analysis of the Benefit Areas

As previously detailed in Module 2, the MBESS, with its mobility feature (i.e., being a non-stationary DER), further provides the benefits of deploying a battery storage system in different locations for maximizing the benefits throughout the year. In Module 2, the highlighted benefit areas were improved safety, improved reliability, improved power quality, lower greenhouse gas emissions, lower operating costs, better economic developments, and the capability to deploy rapidly in disadvantaged communities. In Module 3, the identified benefit areas in Module 2 are extended, as depicted in Figure 4-4, including the IEEE 2030.5 standard as the main means of bidirectional communication.

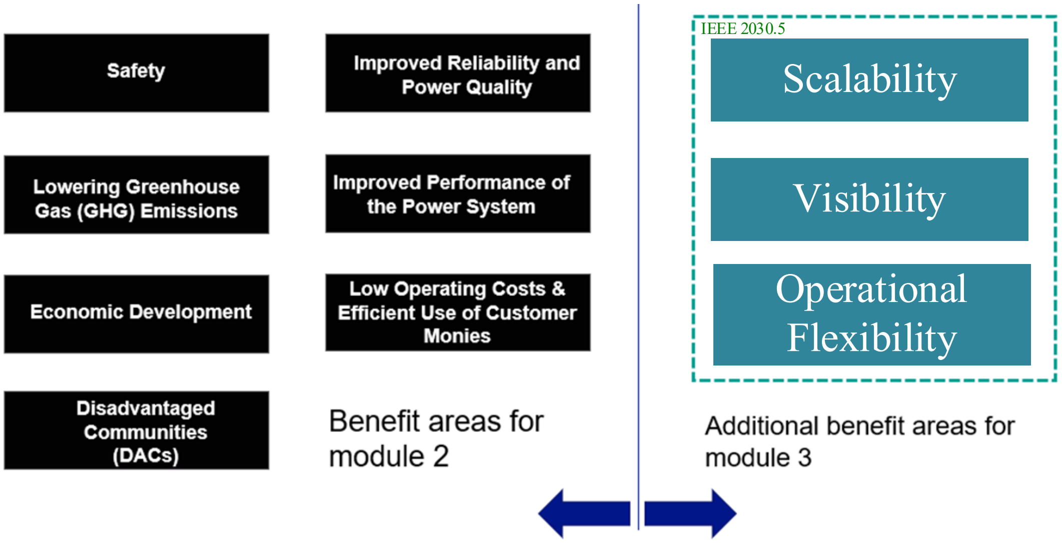


Figure 4-4. Benefit Areas in Module 2 Extended in Module 3

Three main benefit areas from an IEEE 2030.5 communications-enabled MBESS are improved scalability, visibility, and operational flexibility. These benefits arise from enabling bi-directional communication between MBESS and the utility system, which allows for monitoring (hence improved visibility), controls (hence improved operational flexibility), and scalability for future technology adoption. Moreover, the benefits associated with the MBESS integrated with IEEE 2030.5 are as follows:

- Scalability:
    - *Interoperability:* IEEE 2030.5 provides a standardized communication framework, ensuring interoperability among different vendors' equipment. This interoperability supports the scalability of MBESS integration, allowing utilities to connect and manage a diverse set of devices seamlessly.
    - *Plug-and-play integration*: With standardized communication protocols, new DERs can be easily integrated into the existing infrastructure, promoting a plug-and-play approach. This simplifies the process of adding more resources, enhancing scalability.
- Visibility:
    - *Real-time data exchange:* The standard facilitates real-time data exchange between utilities and the MBESS. This improves visibility into the grid's status, enabling utilities to monitor and manage distributed resources more effectively.
    - *Remote monitoring and control:* Utilities can remotely monitor and control the MBESS, enhancing visibility into their performance. This allows for proactive decision-making and quicker response to grid conditions.
- Operational flexibility:
    - *Demand response integration:* IEEE 2030.5 supports demand response functionalities, enabling utilities to manage load variations dynamically. This flexibility is crucial for optimizing grid operations and responding to changing energy demand patterns.
    - *Grid stability:* By providing real-time information on the MBESS, SDG&E can make more informed decisions to enhance grid stability. This includes adjusting power flow, managing voltage levels, and ensuring optimal use of resources.

Table 4-2 below associates the selected use cases with the benefit areas.

Table 4-2. MBESS Integrated with IEEE 2030.5 Standard Use Cases Linked to the Benefit Areas

#	Use Case	Description	Benefit Areas[3]
1	Flexibility during Grid Reconfiguration	In a location that is constrained by operational flexibility, a customer can agree to reduce or curtail power during system maintenance or grid outages that involve the system reconfiguration that caused the operational flexibility constraint. The range of adjustability and limits on the number of events will be determined by mutual consent and included in the interconnection agreement.	▪ Operational flexibility ▪ Operational reliability ▪ Operational capacity ▪ Operational safety
2	Capacity Increase	Coordinated dispatchable or scheduled electricity production in accordance with utility operating needs . This will mostly be the discharge of stored energy. Communications must be enabled, which may be less than real-time if the discharge is scheduled ahead of time.	▪ Operational flexibility ▪ Operational capacity ▪

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[3] As specified by Smart Inverter Operation Working Group (SIOWG).

#	Use Case	Description	Benefit Areas[3]
3	Voltage Boosting	Increase voltage that has become lower along a feeder due to distance from a substation and the existence of machine loads. This is achieved with constant or periodic production of reactive power.	▪ Operational flexibility ▪ Operational capacity ▪
4	Voltage Reduction	Reduce voltage in locations that have regular occurrences of high voltage due to reasons beyond the specific customer site.	▪ Operational flexibility ▪ Operational capacity ▪

Additionally, Table 4-3 provides a summary of all MBESS benefit areas, metrics, and outcomes identified and discussed in Modules 1 and 2 of this project. The table was created and populated as part of the Module 1 Final Report. [2]. For the sake of consistency, the previous table is preserved in its original format, and additional areas related to Module 3 results have been added.

Table 4-3. MBESS Metrics and Benefits

Benefit	Description	Criteria and Metrics	Desired Target	Outcome
Safety	The use of an MBESS instead of traditional mobile diesel generators can improve job site safety by reducing the risk, however unlikely, of a fuel spill and by decreasing ambient noise, allowing for clearer job site communication. [4]	▪ Decrease the potential for a diesel fuel spill through use of an MBESS rather than traditional diesel generators. [2] ▪ Calculate the reduction in job site noise pollution by using an MBESS instead of diesel generators. [2]	▪ Demonstrate that an MBESS can perform the function of a diesel generator so on-site fuel storage can be reduced. [2] ▪ Calculate a meaningful decrease in job site noise pollution. [2]	▪ Based on the results from Modules 1 and 2, it was demonstrated that the use of MBESS prevents any fuel spillage while performing similar functions and even beyond compared to a diesel generator. ▪ For more information, refer to [1] and [2].
Improved Operational Flexibility	Using a remotely controllable MBESS (through IEEE 2030.5 in this project) provides operational flexibility to system operators to: 1) Increase the capacity of a circuit for seasonal or locational demands (and hence defer certain upgrades). 2) Manage circuit reconfiguration constraints. 3) Coordinated dispatchable or scheduled electricity production in accordance with solicitation requirements or grid service tariff rules.	▪ Remote adjustment of active power based on a control signal form the utility operator. ▪ Distribution system upgrade deferral based on capacity requirements on a circuit for seasonal or locational demands. ▪ The revenue stream from participation in demand response programs and energy markets and providing active power as needed for energy and capacity requirements.	▪ Demonstrate that an MBESS can be controlled for direct active power controls or demand response use cases. ▪ Demonstrate that an MBESS can be controlled remotely by a utility operator to curtail and adjust its active power during a circuit reconfiguration and based on the constraints of a new circuit.	▪ Based on the results from module 3, it was demonstrated that MBESS can be controlled remotely to adjust its active power either for direct setpoints or demand response use cases. ▪ MBESS can be used to defer distribution upgrades associated with the rated power it provides. For example, an MBESS of 500 kW can defer investments needed on a circuit requiring up to 500 kW additional capacity (including cable and

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[4] From the final report related to Module 1.

Benefit	Description	Criteria and Metrics	Desired Target	Outcome
				switchgear replacement, transformer replacement, etc.).
Improved Visibility and Scalability	Using a remote communication enabled MBESS (through IEEE 2030.5 in this project) provides enhanced visibility for the operators over the field assets. Additionally, it facilitates interconnecting and integrating new assets in a more convenient and scalable fashion.	▪ The ability of MBESS to establish bi-directional communication with the IEEE 2030.5 master platform through the gateway. ▪ The ability of MBESS to send monitoring data on key system status, measurements, and alarms. ▪ The ability of MBESS to receive control signals for intended use cases and perform accordingly.	▪ Demonstrate that an MBESS can communicate with the IEEE 2030.5 master platform provide monitoring information and be controlled remotely based on the control functions specified in Table 3.1.	▪ Based on the results from Module 3, it was demonstrated that MBESS can be monitored and controlled remotely for various control functions based on the defined use cases.
Improved Reliability and Power Quality	Currently, diesel generators provide an adequate solution for SDG&E when providing grid support during emergencies. However, because of their emissions, they are limited to emergency functions only. An MBESS can provide emergency backup, supporting reliability. However, it also can support broader grid reliability through peak shaving, load smoothing, voltage and frequency regulation, and prolonging the life of grid equipment.[5]	▪ Ensure that MBESS can act as a backup power source, capable of black starting downstream loads like a diesel generator.[3] ▪ Demonstrate peak shaving and load smoothing abilities.[3] ▪ Calculate the increase in grid infrastructure lifespan based on circuit amperage reductions and corresponding equipment temperature reductions.[3] ▪ Calculate the dollar value of grid equipment lifespan increases.[3] ▪ Calculate the dollar value of grid/circuit upgrade deferrals.[3] ▪ Using the MBESS provides an opportunity for preventing planned and unplanned outages and increasing localized reliability and power quality. ▪ From Module 2, several metrics were defined, including: 1) Avoided the number	▪ Successfully blackstart and power downstream customer loads, demonstrating PSPS outage mitigation. [3] ▪ Show peak load shaving capabilities and load smoothing thresholds[3] ▪ Grid equipment lifespan extensions are real and meaningful[3] ▪ Value calculations for lifespan increases and grid infrastructure upgrade deferrals demonstrate value to SDG&E[3] ▪ For more information on the targets set for the demonstration of Module 2, refer to [3].	▪ Based on the results from Modules 1 and 2, it was demonstrated that MBESS can successfully perform outage management and other grid support functions to improve reliability and power quality. ▪ For more detailed information on the outcome, please refer to the final reports of Modules 1 and 2. [2],[3]

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[5] From the final report related to Module 1.

Benefit	Description	Criteria and Metrics	Desired Target	Outcome
		and duration of PSPS outages. 2) Average load served during the outages. 3) Total supported energy during the outage. 4) Saving on avoided cost of the outage.		
Improved Performance of the Power System	Improved system operations and performance (i.e., system electrical efficiency) will help reduce electrical losses in the system, such as reductions in resistive losses associated with current flow through the conductors and reductions in transformer electrical losses.[6]	▪ Calculate the peak current reduction for the MBESS deployment.[4] ▪ Determine the percentage of reduction the MBESS is of a full circuit loading.[4]	▪ Visible reduction in circuit loading and current when using MBESS.[4]	▪ For information on the outcome, please refer to the final report of Module 1. [2]
Lower Greenhouse Gas (GHG) Emissions	Using an MBESS instead of diesel generators will provide reductions in localized emissions at sites needing grid resiliency.[4]	▪ Calculate the diesel fuel savings (gallons and cost) associated with a switch to MBESS.[4] ▪ Convert diesel savings to yearly metric tons of CO_2e.[4] ▪ Calculate the CO_2e reduction value on California's Cap and Trade market.[4] ▪ From Module 2, the metrics defined included the annual reduction of CO_2 based on the number/duration of served outages (and hence kWh served) and the difference between diesel-supplied vs. MBESS-supplied outages.	▪ Show a reduction in diesel fuel consumption for grid resiliency support.[4] ▪ Determine the value of emissions reductions on California's Cap and Trade market.[4] ▪ From Module 2, the desired target was to demonstrate a reduction of CO_2 based on the projected number of outages supplied by MBESS.	▪ Based on the results from Modules 1 and 2, it was demonstrated that MBESS can successfully reduce the emission for outage management use cases where MBESS is used as a replacement for diesel generators. Further reduction can be achieved by charging MBESS from a 100% clean resource such as solar or wind. ▪ For more detailed information on the outcome, please refer to the final reports of Modules 1 and 2. [2],[3]
Lower Operating Costs and More Efficient Use of Customer Monies	Using an MBESS to support grid upgrade deferrals provides real value to SDG&E, money that would otherwise be spent on infrastructure upgrades. Because of the mobile nature of an MBESS, strategic deployment based on SDG&E's grid needs assessment can push out capital upgrades, which would save or defer use	▪ Calculate the 10-year lifecycle cost of an MBESS purchase vs. a diesel generator rental model currently employed by SDG&E. Include upfront costs of the MBESS purchase, ongoing and yearly costs, and potential	▪ Demonstrate a greater ROI for an MBESS vs. a diesel generator.[4] ▪ Demonstrate positive value from partial participation in CAISO market functions.[5]	▪ Based on the results from Modules 1 and 2, it was demonstrated that MBESS provides a financially advantageous investment provided that the unit is used properly and based on stacked use cases to generate

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[6] From the final report related to Module 1.

Benefit	Description	Criteria and Metrics	Desired Target	Outcome
	of ratepayer dollars. This value can be calculated and can be factored into the lifecycle cost of an MBESS for SDG&E. Ideally. It could make MBESS a more financially advantageous investment for SDG&E to meet its grid resiliency needs than the more traditional diesel generators.[7]	revenue streams from other MBESS functions such as grid upgrade deferrals and CAISO market functions. [5]		revenue (e.g., from Module 2, an IRR of 33% and Benefit to Cost Ratio of 2.03 is calculated). ▪ For more detailed information on the outcome, please refer to the final reports of Modules 1 and 2. [2],[3]
Economic Development	Should SDG&E choose to procure additional MBESS to support grid resiliency and grid infrastructure upgrade deferrals, this will generate a local market for these units. Not only will it draw awareness to such a product and its flexibility, but it will also attract jobs associated with the supply, setup, operation, and maintenance of the MBESS. [5]	▪ Calculate the number of MBESS needed to fully defer SDG&E's planned grid upgrades between 2022 and 2030. [5] ▪ Calculate the value of local market investment required to procure MBESS for grid upgrade deferrals. [5] ▪ Based on Module 2, the following metrics were defined: 1) Affected businesses/communities to assess the project's impact on affected communities and their local businesses 2) Determined the population within a 1-mile radius of the CRC to evaluate the expected number of people that would have access to the CRC during an outage 3) Determined the number and type of businesses within one block around the CRC that would be visited.	▪ Generate a significant local market investment in MBESS technology. [5] ▪ Provide financial and business gains associated with serving the population during the outage.	▪ Based on the results from Modules 1 and 2, it was demonstrated that MBESS provides additional economic development opportunities. ▪ For more detailed information on the outcome, please refer to the final reports of Modules 1 and 2. [2],[3]
Disadvantaged Communities (DACs)	The CPUC has encouraged EPIC program administrators to seek projects that benefit disadvantaged communities, including rethinking the location of clean energy	▪ An MBESS can operate in a disadvantaged community and show investment in these communities. The project may achieve GHG benefits that support state	▪ Demonstrate SDG&E's increased ability to support GHG reductions in DACs through the deployment of an MBESS in their operations and	▪ Based on the results from modules 1 and 2, it was demonstrated that MBESS provides additional benefits for DACs, including:

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[7] From the final report related to Module 1.

Benefit	Description	Criteria and Metrics	Desired Target	Outcome
	technologies to benefit burdened communities. Furthermore, specific project benefits may have a direct benefit to the local community (i.e., reduced source emissions when the source is physically located in the disadvantaged community, such as using a mobile battery instead of a diesel generator. GHG emission reductions due to electrical savings are attributed to the generation source, which may not be in the disadvantaged community).[8]	goals and may reduce emissions from sources located within the disadvantaged community. [6]	reduction in generator runtime hours when MBESS is deployed for resiliency purposes. [6]	1) Outage duration reduced in DACs. 2) Avoided cost of using diesel genset in DACs. 3) avoided GHG emissions by not using diesel gensets at DACs. ▪ For more detailed information on the outcome, please refer to the final reports of Modules 1 and 2. [2],[3]
Incremental Benefits of a Mobile Solution	When compared to the traditional resiliency solution (a diesel generator), an MBESS solution will accrue incremental and stacked benefits by being relocated to a variety of sites and performing a variety of functions, minimizing MBESS idle time and providing a variety of benefits to SDG&E. ROI and long-term benefits have been quantified in the other benefit areas above. [6]	▪ Demonstrate increased flexibility in MBESS deployment vs. traditional diesel generators.[6] ▪ Evaluate additional potential value generation opportunities for MBESS vs. traditional diesel generators.[6] ▪ Identify any additional benefits associated with using an MBESS over generators.[6] ▪ Based on module 2, the following metrics were identified: 1) The incremental benefits achieved with the mobile battery over the appropriate diesel generator alternative. 2) The costs associated with a mobile battery and the appropriate diesel generator alternative. 3) Incremental return on investment (ROI) by considering incremental benefits and incremental costs.	▪ Increased flexibility of deployment.[6] ▪ Additional functionality successfully demonstrated by an MBESS.[6] ▪ Quantify any additional benefits.[6]	▪ Based on the results from Modules 1 and 2, it was demonstrated that MBESS provides additional benefits compared to a diesel generator, such as grid support applications (peak shaving, market participation, power quality improvement, etc.), which leads to additional benefits to the utility and customers. ▪ For more detailed information on the outcome, please refer to the final reports of modules 1 and 2. [2],[3]

1.7 Description of Pre-Commercial Demonstration

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[8] From the final report related to Module 1.

5.4.1 Location/Transportation

The field test demonstration for this project was performed at Cameron Corners.. The aerial view of the location is depicted in Figure 4-5.

Figure 4-5. Aerial View of the Field Test Location at Cameron Corners, Campo, CA, 91906 (Coordinates: 32.631240, -116.472847)

The transportation route of the MBESS from SDG&E's ITF, to the demonstration site at Cameron Corners is shown in Figure 4-6. The distance traveled from the ITF to the demonstration site is around 80 miles. Figure 4-7 shows pictures of the MBESS during the use case demonstration at the field test location.

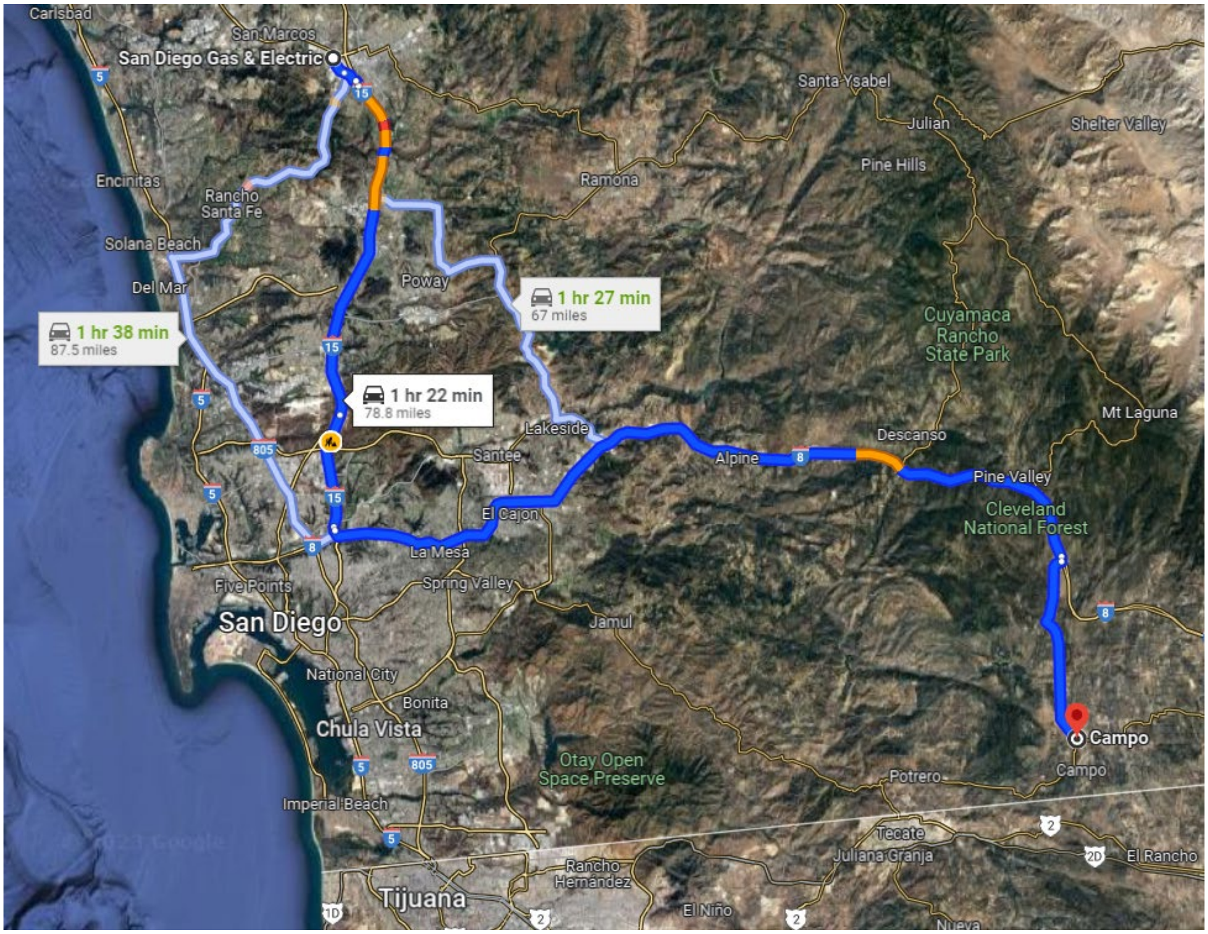


Figure 4-6. Path for Transporting the MBESS from the ITF to the Demonstration Site at Cameron Corners

Figure 4-7. Pictures of the MBESS at Cameron Corners during the Use Case Demonstrations

5.4.2 Use Case Demonstration Approach

Before transporting the MBESS to Cameron Corners for field demonstration, all the use cases and loss of communication scenarios were tested at the ITF to validate the operation of the MBESS, the successful integration of the IEEE 2030.5 gateway to the MBESS local controller, and the successful communication between the IEEE 2030.5 server and gateway over a private LTE network. Upon completion of site testing, the MBESS was transported from the ITF to Cameron Corners for the field demonstration of the use cases.

5.4.3 Equipment Requirements

The following equipment was used during the demonstration:

- **MBESS:** 100 kW/250 kWh MBESS with an integrated IEEE 2030.5 gateway to enable remote monitoring and control of the unit through the IEEE 2030.5 server.
- **Permanent connection box:** This is required on the utility/customer side to establish an interconnection point to the MBESS at the demonstration site.
- **Cam-Lok cables:** A set of 400 A Cam-Lok cables was needed to connect MBESS with the permanent connection box. Proper Cam-Lok cables are located inside MBESS to accelerate the interconnection process.
- **Auxiliary cables:** A set of auxiliary cables to connect to the 120/240 V auxiliary input. These cables are located inside the MBESS terminal box.
- **IEEE 2030.5 server:** The IEEE 2030.5 standard server is located at the ITF to send commands for monitoring and controlling the MBESS in the field.

Notably, there were minimal equipment requirements for interconnecting the MBESS to utility/customer facilities, considering the fully integrated design of MBESS.

5.1.1 Software Requirements

A CSIP-compliant IEEE 2030.5 server is required from the utility to send and schedule DER controls and monitor the relevant DER data from the MBESS.

5.1.2 Supporting SDG&E Infrastructure and Data Requirements

Based on the defined use cases for the MBESS and the required remote control of the unit for the demonstration, a private LTE connection from the IEEE 2030.5 server at the ITF to the MBESS in the field was established.

5.1.3 Site Testing at the ITF

The site testing performed at the ITF included a demonstration of operational flexibility use cases and loss of communication scenario testing of the MBESS while operating in remote control mode. The second part was to perform the use case identified in the ITF with the MBESS integrated with the IEEE 2030.5 standard.

Table 4-3 depicts the details of the use case demonstrations at the ITF. Specifically, Table 4-3 provides the details related to the DERControl mode, objective, duration, and date of the tests.

Table 4-4. MBESS Integrated with IEEE 2030.5 Standard Use Cases Demonstrated at the ITF

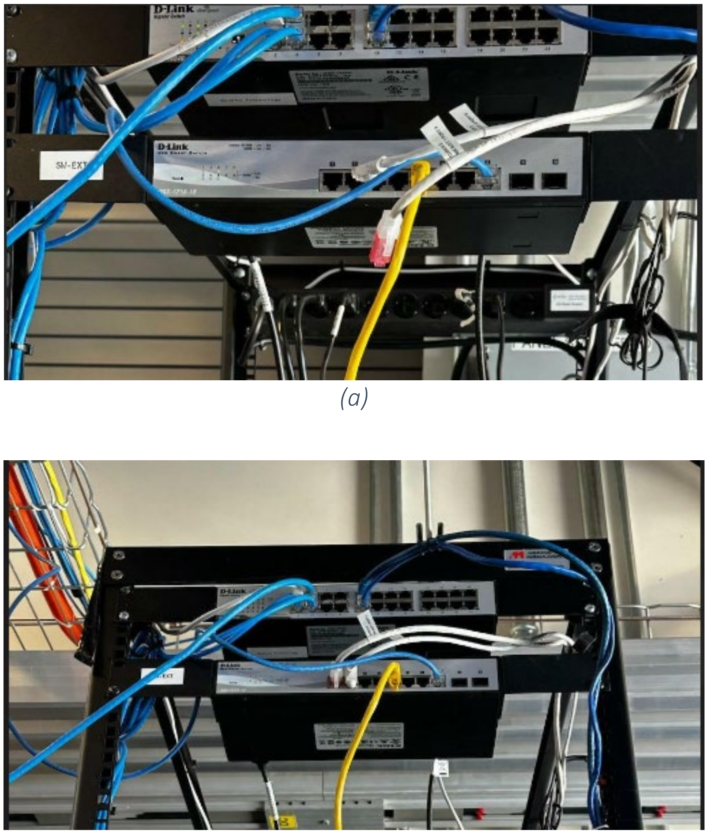
#	Use Case	Objective	Duration	Pass/Fail	Date
1	Flexibility during Grid Reconfiguration	Confirm the flexibility of the MBESS during grid reconfiguration through the IEEE 2030.5 server (DERControl: OpModMaxLimitW). Note that events are scheduled one at a time.	55 min	☒/☐	07/06/2023
2	Capacity Increase	Confirm the flexibility of the MBESS during grid reconfiguration through the IEEE 2030.5 server (DERControl: OpModMaxLimitW). Note that events are scheduled one at a time.	45 min	☒/☐	07/06/2023
3	Voltage Boosting	Confirm voltage boosting by the MBESS through the IEEE 2030.5 server (DERControl: OpModMaxFixedVAR).	45 min	☒/☐	07/06/2023
4	Voltage Reduction	Confirm voltage reduction with Volt/Var curve by the MBESS through the IEEE 2030.5 server (DERControl: OpModVoltVar).	30 min	☒/☐	07/06/2023

The communication loss between the server and gateway is emulated in Figure 4-8 (a) and (b), an ethernet cable disconnection and reconnection. Also, the communication loss between the gateway and MBESS local control is emulated in Figure 4-9 through disconnection from the MBESS Modbus.

Table 4-5. MBESS Integrated with IEEE 2030.5 Standard Communication Loss Scenarios Effects Demonstrated at the ITF

#	Use Case	Objective	Duration	Pass/Fail	Date
1	Communication Loss between Server and Gateway	Test the effect of communication loss between the server and gateway during a use case demonstration with an MBESS integrated with the IEEE 2030.5 standard. The use case selected here is the capacity increase use case. Moreover, three different times are tested in this communication loss scenario: communication loss between the server and gateway (1) after the scheduled control starts, (2) after the gateway receives the scheduled control but before the start time, and (3) after the gateway receives the scheduled control but before the start time, but then communications return before the event duration elapsing.	55 min	☒/☐	07/06/2023
2	Communication Loss between Gateway and MBESS Local Controller	The objective is to test the effect of communication loss between the gateway and MBESS local controller during a use case demonstration with an MBESS integrated with the IEEE 2030.5 standard. The use case selected here is the capacity increase use case. Moreover, three different times are tested in this communication loss scenario: communication loss between the server and gateway (1)	45 min	☒/☐	07/06/2023

#	Use Case	Objective	Duration	Pass/Fail	Date
		after the scheduled control starts, (2) after the gateway receives the scheduled control but before the start time, and (3) after the gateway receives the scheduled control but before the start time, but then communications return before the event duration elapsing.			



(a)

(b)

Figure 4-8. (a) Communication Loss Between Server and Gateway Emulation by Disconnecting the Ethernet Cable, (b) Reconnection of the Ethernet Cable to Emulate Communication Restoration

Figure 4-9. Modbus Gateway Disconnection from MBESS Local Controller to Emulate the Communication Loss Scenario

5.4.7 Field Demonstration

Figure 4-10 presents a simplified schematic of the setup used during the field demonstration at Cameron Corners. The MBESS connects to a tap box (including a disconnect switch) at the SDG&E site, which is then connected to the 12 kV distribution system through a step-up transformer.

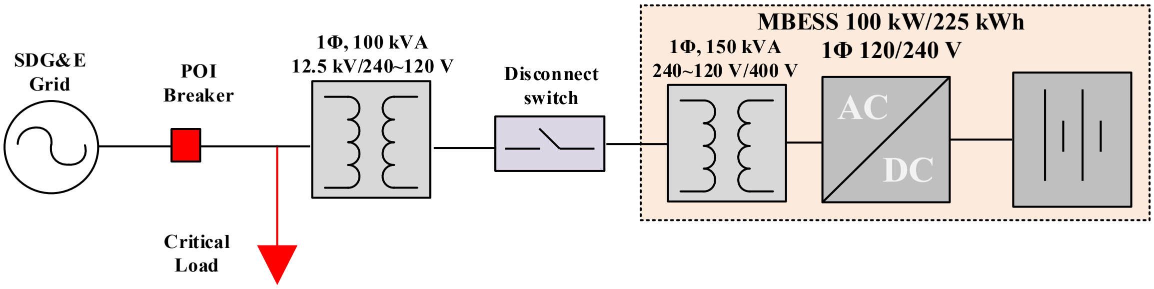


Figure 4-10. Setup of Cameron Corners Site Use Cases Demonstration

Figure 4-11 depicts the network diagram of the MBESS integrated with the IEEE 2030.5 standard. As seen in this figure, the communication between the IEEE 2030.5 server and MBESS was through a private LTE network. This communication was used to control and monitor the unit.

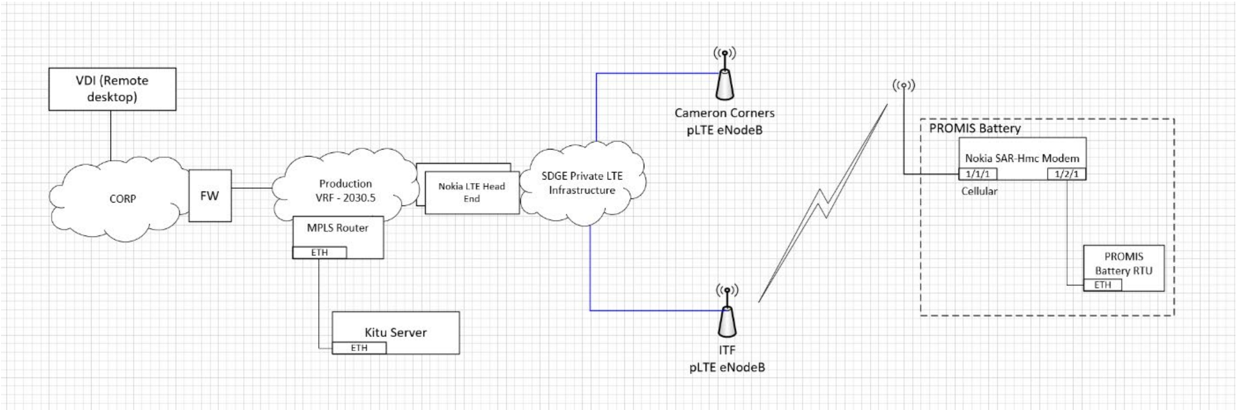


Figure 4-11. Network Block Diagram for the Field of the MBESS Using IEEE 2030.5 at Cameron Corners (PROMIS is Another Name for the MBESS)

Before initializing the demonstration, the team followed the subsequent steps to energize the MBESS and prepare the setup:

1. Connect the Cam-Lok cables from the MBESS output terminal box to the disconnect switch, as shown in Figure 4-10 above (see Figure 4-12 from the site), and ensure the disconnect switch is open initially.
2. Follow the MBESS step-by-step procedures in [3] for post-transportation inspection and confirm that the unit is ready to be energized.
3. Energize the MBESS unit and check the system status/measurements from the HMI.
4. Confirm that the communications between the server located at the ITF and the gateway are established.
5. Verify that the system data are being logged correctly by the MBESS and the IEEE 2030.5 server.

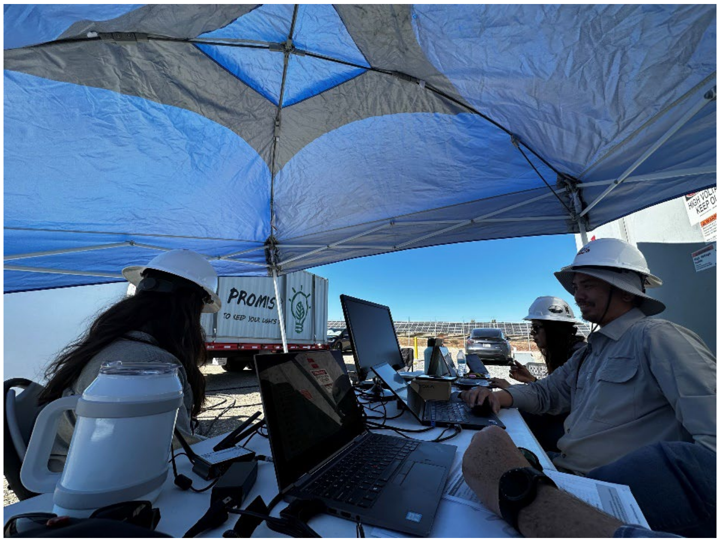


Figure 4-12. Picture Taken during the Field Test Demonstration at Cameron Corners

Table 4-4 depicts the details of the use case demonstrations in the field. The team successfully demonstrated all the use cases at Cameron Corners.

Table 4-6. MBESS Integrated with IEEE 2030.5 Standard Use Cases Demonstrated in the Field

#	Use Case	Objective	Duration	Pass/Fail	Date
1	Flexibility during Grid Reconfiguration	Confirm the flexibility of the MBESS during grid reconfiguration through the IEEE 2030.5 server (DERControl: OpModMaxLimitW). Note that events are scheduled one at a time.	32 min	☒/☐	09/19/2023
2	Capacity Increase	Confirm the flexibility of the MBESS during grid reconfiguration through the IEEE 2030.5 server (DERControl: OpModMaxLimitW). Note that events are scheduled one at a time.	16 min	☒/☐	09/19/2023
3	Voltage Boosting	Confirm voltage boosting by the MBESS through the IEEE 2030.5 server (DERControl: OpModMaxFixedVAR).	23 min	☒/☐	09/19/2023
4	Voltage Reduction	Confirm voltage reduction with Volt/Var curve by the MBESS through the IEEE 2030.5 server (DERControl: OpModVoltVar).	20 min	☒/☐	09/19/2023

6 Project Results

The following section provides the results associated with integrating the MBESS with the IEEE 2030.5 standard.

1.8 Results Discussion

6.1.1 Results Construction Sample from Data Collected from a Use Case Demonstration

The data collected from the test, either in the field or the ITF, are plotted against the recorded duration of the specific use case. For instance, Table 5-1 shows data collected from Use Case 3, “Voltage Boosting,” demonstration at the field on 09/19/2023 from 3:07:00 PM–3:30:00 PM. Table 5-1 depicts the MBESS active power, MBESS reactive power, and MBESS terminal voltage. This use case aims to demonstrate the capability of using the MBESS with the IEEE 2030.5 standard integration to boost the voltage with reactive power injection. Plotting the time vector versus the three quantities of the MBESS (i.e., active power, reactive power, and terminal voltage vs. time in Figure 5-1) will validate that the MBESS capability in boosting voltage will be a schedulable DER. The same process is repeated to plot the results related to all use cases and communication loss scenarios.

Table 5-1. Sample Date Collected from Use Case 3 “Voltage Boosting” from the Field Test Demonstration

Time	Q (kVar)	P (kW)	V [%]
3:07:00 PM	-2	0	103.450
3:08:00 PM	-2	0	103.625
3:09:00 PM	25	25	107.050
3:10:00 PM	25	25	106.950
↓	↓	↓	↓
3:24:00	60	25	109.325
↓	↓	↓	↓
3:27:00 PM	25	25	106.850
3:28:00 PM	25	25	106.700
3:29:00 PM	25	25	106.650
3:30:00 PM	25	25	106.550

Figure 5-1. Results of Sample Use Case 3, "Voltage Boosting," at the Field Demonstration: (a) Reactive Power Profile, (b) Terminal Voltage Profile, and (c) Active Power Profile

6.1.2 Use Case 1: "Flexibility during Grid Reconfiguration" Results

Figure 5-2 depicts the active power profile of the MBESS during the whole demonstration of Use Case 1 at Cameron Corners. At 1:49:00 PM, the MBESS is set to default mode with an active power injection of 75 kW. Note that the base 100% active power is selected to be 100 kW. Then, at the time instant 1:53:00

PM, an event scheduled for 3 minutes ahead was sent to the MBESS to limit the active power to 50 kW for a 2-minute duration. This event should occur between 1:56:00 PM and 1:58:00 PM in Figure 5-2.

However, at the site, upon opening the POI breaker at the time instant 1:54:00 PM, the upstream breaker tripped. This caused the MBESS to miss the time window for the pre-set event (as seen in Figure 5-2 between 1:54:00 PM–2:06:00 PM). Therefore, it was decided to avoid opening the POI breaker in the next steps. The operator continued the use case testing to validate the successful MBESS response to the opModMaxLimW command. After the re-energization of MBESS with the default 75 kW active power injection at 2:06:00 PM, the MBESS receives two scheduled events of limiting the active power to 50 kW at 2:12:00 PM–2:14:00 PM and 25 kW at 2:18:00 PM–2:19:00 PM (Figure 5-2). Note that the limiting event at the 50 kW event was sent to the MBESS at 2:09:00 PM, and the limiting event at the 25 kW event was sent at 2:16:00 PM. Finally, it seems that the default setting of the MBESS was changed from 75 kW to 100 kW because, after completing the last limiting event, the MBESS active power goes to 100 kW.

Use case 1 demonstrates that the MBESS with integrated IEEE 2030.5 standard can provide grid flexibility during a reconfiguration of events using the opModMaxLimW command. Additionally, the MBESS properly responds to a single scheduled control event, and after completion of the schedule, the smart inverter returns to the DefaultDERControl.

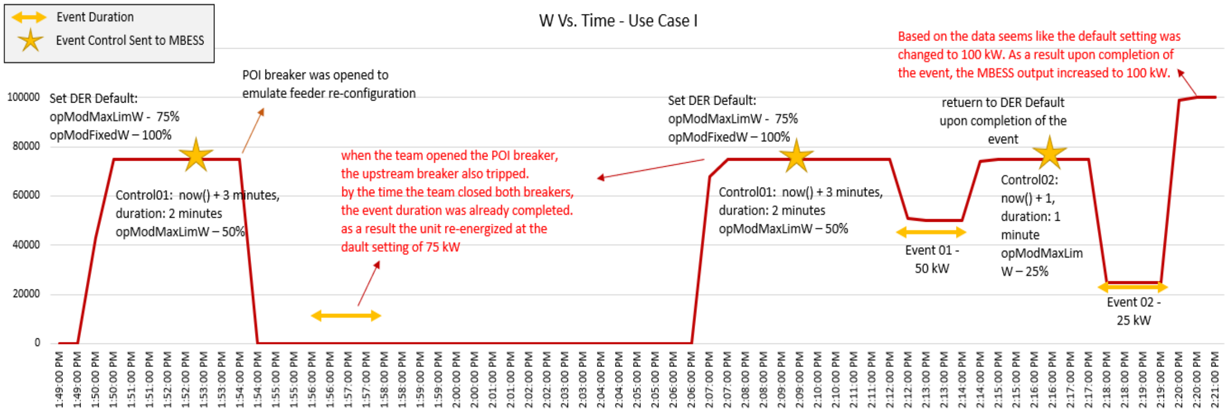


Figure 5-2. Use Case 1 “Flexibility During Grid Reconfiguration” Active Power Profile

6.1.1 Use Case 2: “Capacity Increase” Results

Figure 5-3 depicts the active power profile of the MBESS during the use case 2, “Capacity Increase,” demonstration at Cameron Corners. Initially, at 2:26:00 PM, the MBESS operates at default mode with 25 kW active power injection, as Figure 5-3 shows. After that, at 2:28:00 PM, a request to increase the active power to 50 kW using opModFixedW for two minutes is sent to the MBESS. Therefore, Figure 5-3 shows that the active power is 50 kW from 2:30:00 PM–2:32:00 PM. At 2:30:00 PM, a request to increase the active power to 75 kW (i.e., Event 2) for three minutes ahead with a duration of two minutes was sent. Then, at 2:31:00 PM, Event 3, which increased the active power to 100 kW for five minutes ahead with a duration of two minutes, was sent. Please note that both Events 2 and 3 were sent to MBESS during Event 1, and the output of the unit was increased to 50 kW.

Afterward, at time instant 2:32:00 PM, Event 1 completes, and the MBESS goes back to the default 25 kW injection mode. As can be seen from Figure 5-3, at the time instants 2:33:00 PM and 3:36:00 PM, Events 2 and 3 start as expected, respectively. Note that, due to power limitations in the site, the active power was set to a maximum of 85 kW instead of 100 kW in Event 3.

This field test confirms the MBESS capability in performing capacity increase use case through the opModFixedW command from IEEE 2030.5. Additionally, the MBESS properly responds to multiple scheduled control events, and after completion of each event, the smart inverter returns to the DefaultDERControl.

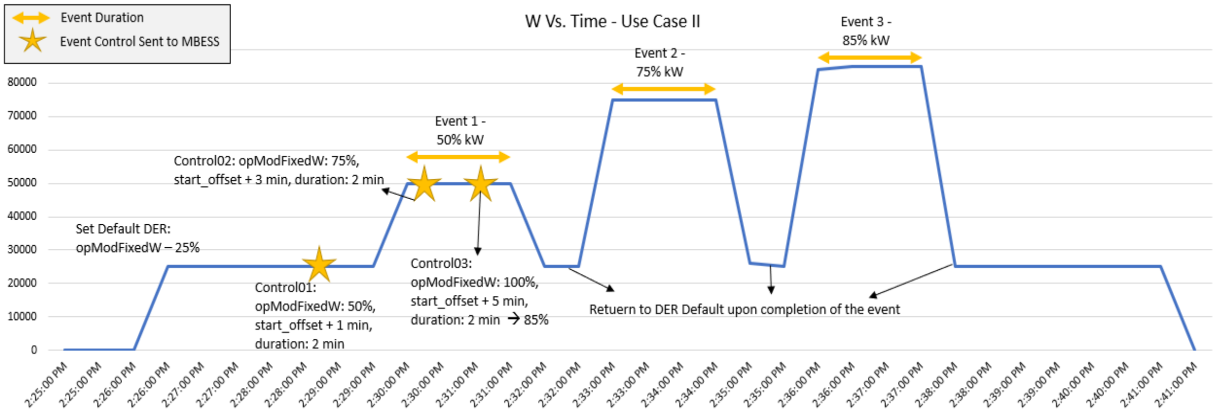


Figure 5-3. Use Case 2 "Capacity Increase" Active Power Profile

6.1.2 Use Case 3: "Voltage Boosting" Results

Notably, in real-world implementation, the voltage measurements received by the IEEE 2030.5 server and gateway will be shared with the DERMS. The DERMS will host the logic to calculate the reactive power required based on the voltage drop and will share the Q setpoint with the IEEE 2030.5 server, which, in turn, will send the setpoint to the DERs. However, since this project's scope did not cover the upstream integration of the DERMS and the IEEE 2030.5 server, the team only sent the opModMaxFixedVar command to the MBESS through the server located at the ITF.

Figure 5-4 shows Use Case 3's reactive power, voltage, and active power profiles during the field test demonstration at Cameron Corners. At the time instant 3:08:00 PM, the MBESS is enabled by setting the opModConnect and opModEnergize to "True" for a 10-minute duration by the IEEE 2030.5 server located at the ITF. The opModMaxFixedVar and opModFixedW of the unit are set to 25% (inject) and 25% active power delivery, respectively. Figure 5-4 (a) and (b) show that the unit was successfully energized and operated at the default values.

Furthermore, using the IEEE 2030.5 server, at 3:13:00 PM, an event is scheduled for one minute ahead to increase the reactive power to 50 kVar for two minutes. As a result, the reactive power is increased in

Figure 5-4 (a) at the time instant 3:14:00 PM to 50 kVar. Another schedule was sent at 3:16:00 PM for one minute ahead to increase the reactive power to 65 kVar. However, before initiating this event, the MBESS was disabled at 3:17:00 PM. At 3:20:00 PM, the opModConnect and opModEnergize were set to "True" again by the IEEE 2030.5 server. As a result, the MBESS was enabled again and followed the pre-set default settings for active and reactive power, as Figure 5-4 (a) and (b) show. At 3:22:00 PM, an alternative schedule was sent one minute ahead to increase the reactive power of the MBESS to 60 kVar. As Figure 5-4 (a) shows, following the scheduled event at 3:23:00 PM, MBESS reactive power increased to 60 kVar and lasted for two minutes. Upon the event's completion, the unit returned to the default kVar setpoint of 25% (25 kVar). Figure 5-4 (c) illustrates the voltage at the inverter terminal (internal to the MBESS unit) during the duration of the test. This figure shows that voltage closely follows the reactive power injection.

In conclusion, this use case demonstrates that the MBESS, with IEEE 2030.5 capabilities, can use the opModMaxFixedVar command to increase its reactive power injection to address voltage drops along the feeder.

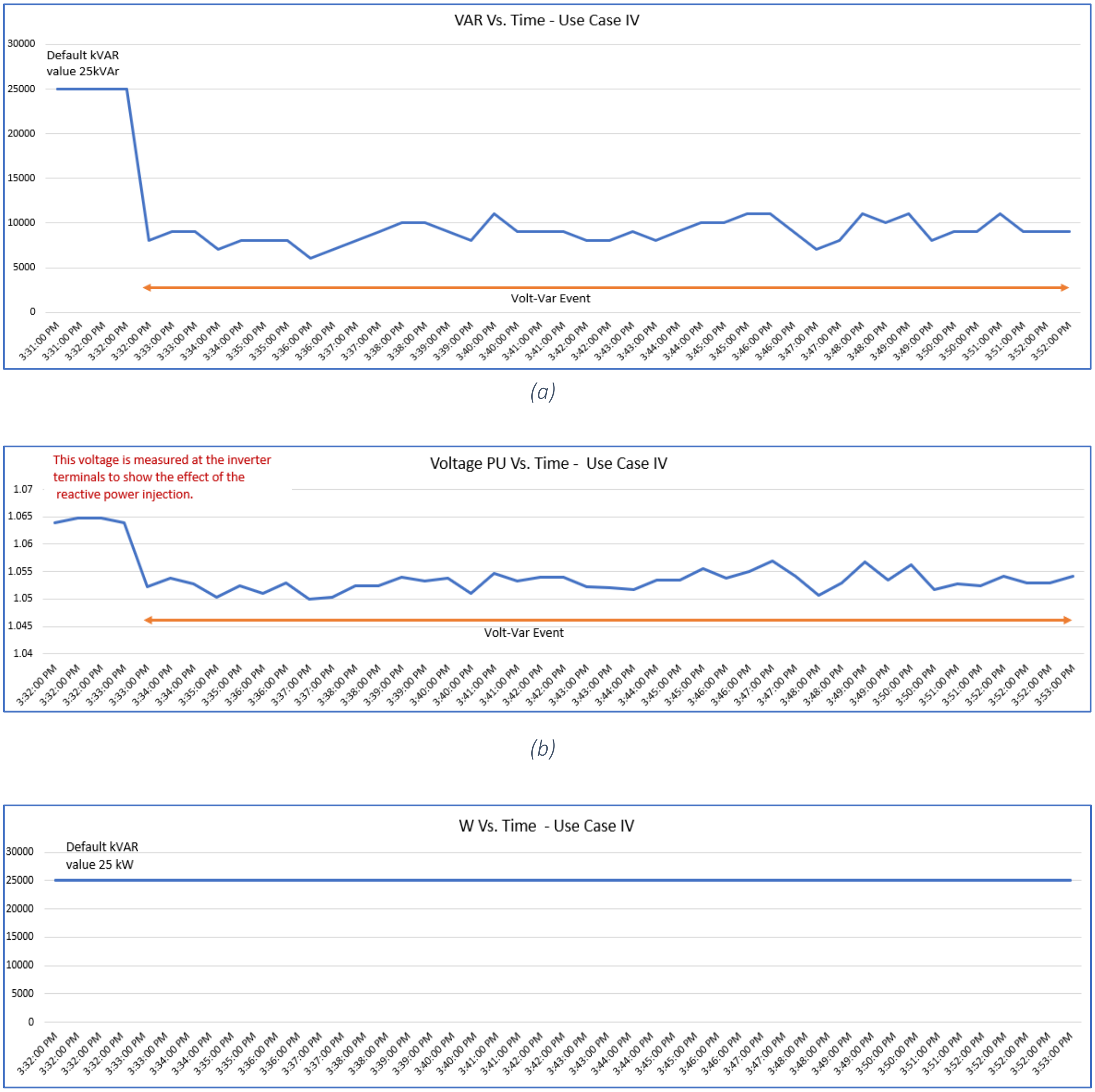
Figure 5-4. Use Case 3 "Voltage Boosting": (a) Reactive Power Profile, (b) Terminal Voltage Profile, and (c) Active Power Profile

6.1.3 Use Case 4: "Voltage Reduction (Volt/Var)" Results

Figure 5-5 shows the use of the Volt/Var curve of the MBESS with an integrated IEEE 2030.5 standard. Specifically, Figure 5-5 (a) depicts how the reactive power changes at 3:32:00 PM from the default 25 kVar to supplying reactive power in a method that decreases the terminal voltage in Figure 5-5 (b). Notably, the reference point for the MBESS to perform Volt/Var is at its inverter terminal, and Figure 5-5 (b) shows the voltage measured at the AC side of the inverter.

Also, the active power for this use case's duration was set at 25 kW (Figure 5-5 (c)). This use case concludes that the reactive power of the MBESS can be set to follow a specific Vol/Var curve to reduce the terminal voltage through IEEE 2030.5 standard use.

This use case confirmed that the MBESS can accept the volt-var curve settings from the IEEE 2030.5 server and adjust its reactive power based on the voltage measurements to follow the curves and maintain the voltage.



(a)

(b)

(c)

Figure 5-5. Use Case 4 "Voltage Reduction (Volt/Var)": (a) Reactive Power Profile, (b) Terminal Voltage Profile, and (c) Active Power Profile

6.1.4 Communication Loss Scenario 1: "Communication Loss between Server and Gateway" Results

The observed behavior of the Modbus gateway, server, and MBESS performed as expected in Figure 5-6. The Modbus gateway did not perform a watchdog reboot with a loss of network connection in less than two minutes. However, extended loss of communication (> 2 minutes) triggered the watchdog to reboot the gateway, which in turn caused the MBESS controller to go to local mode. Below are key observations from this test, all of which were expected system behaviors:

- The Modbus gateway handled a temporary loss of network communication lasting less than two minutes without restarting itself.
- The Modbus gateway handled a loss of network communication lasting longer than two minutes by performing its programmed recovery mechanism of rebooting (restarting) itself.
- All DER controls were processed (received, started, completed) by the Modbus gateway at the expected times before the gateway reset, regardless of the communication status with the server.
- The MBESS reverted to local mode after restarting the Modbus gateway.
- The server will be inoperable and will not receive any data from the Modbus gateway due to the loss of network communication.
- The loss of communication event resulted in the loss of meter data for that given time frame.

Figure 5-6 shows the active power measured at the output of the MBESS during the loss of communication between the gateway and server.

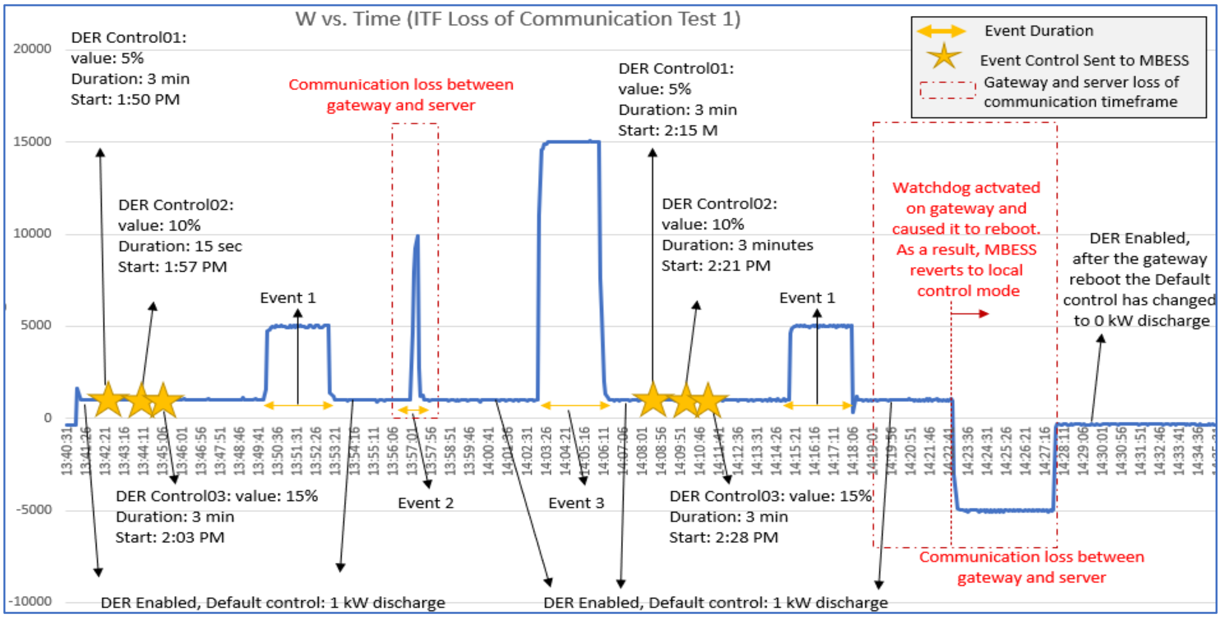


Figure 5-6. Communication Loss Scenario 1: Active Power Profile at MBESS Output during Server and Gateway Connection Loss at the ITF

6.1.5 Communication Loss Scenario 2: "Communication Loss Between Gateway and MBESS Local Controller" Results

The observed behavior of the Modbus gateway, server, and MBESS performed as expected in Figure 5-7. The MBESS local controller returned to local mode after losing network communication. Once set to remote mode, the MBESS could accept and process DER controls.

- The MBESS reverted to local mode upon losing connection to the Modbus gateway. This behavior is expected.
- To restore the MBESS's operation, an enable command must be sent and processed by the MBESS local controller.
- The enabling of remote mode from local mode is currently handled remotely through the vendor's technology. To accept and conform with DER controls, the MBESS must operate under remote mode.
- The loss of communication event resulted in the loss of meter data for that given time frame.

Figure 5-7 shows the power output of the MBESS during the gateway and local controller communication loss test at the ITF.

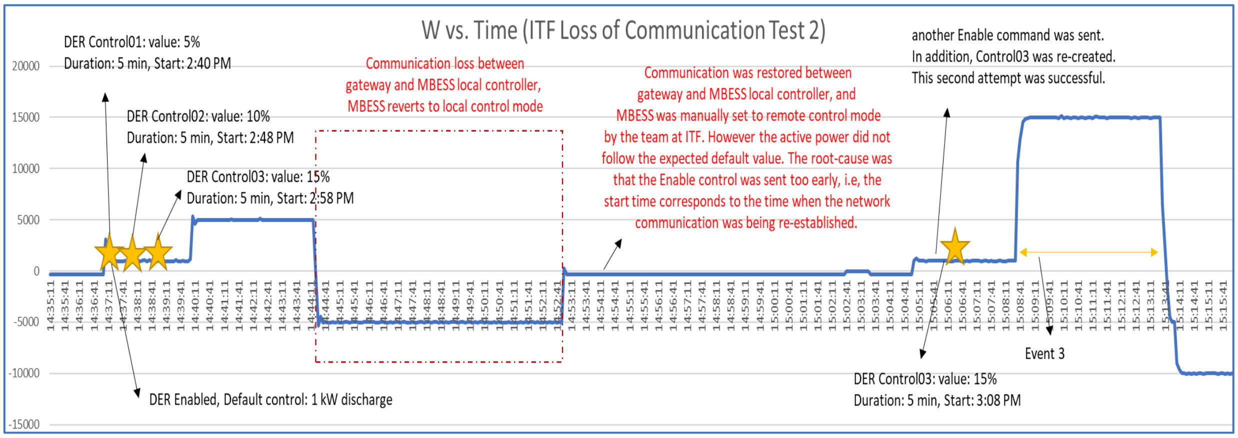


Figure 5-7. Communication Loss Scenario 2: Active Power Profile at MBESS Output during Gateway and MBESS Local Controller Connection Loss at ITF

1.9Commercialization Cost Estimates

The following is an outline of costs associated with the commercialization of IEEE 2030.5:

- Development and integration of an IEEE 2030.5 server platform
    - This includes the IEEE 2030.5 software application, database server, and associated server infrastructure to integrate into existing infrastructure

- Integration of an IEEE 2030.5 Gateway with a DER
    - If not using a native IEEE 2030.5 client, the integration of IEEE 2030.5 Gateway will incur costs. This includes the development and integration of the 2030.5 Gateway to communicate with and translate IEEE 2030.5 data through the DER's communications protocol.

- Network infrastructure and data usage for IEEE 2030.5 Gateway and IEEE 2030.5 server platform communication
    - If using cellular communication, costs include the cellular modem, but ultimately, the data usage for each DER as it transmits IEEE 2030.5 data. Otherwise, hardware equipment that is associated with integration into an Ethernet network is required.

7 Findings

The demonstration of these cases at the Cameron Corners field site shows the MBESS' capability to use the IEEE 2030.5 standard. Specifically, the successful use cases demonstrated (1) flexibility during grid reconfiguration, (2) capacity increase, (3) voltage boosting with fixed reactive power injection, and (4) voltage reduction with Volt/Var curve mode. In addition, various communication loss scenarios were demonstrated at the ITF. These communication loss scenarios included (1) communication loss between the IEEE 2030.5 server and IEEE 2030.5 gateway and (2) communication loss between the IEEE 2030.5 gateway and MBESS local controller. These communication losses were demonstrated at different times. For instance, communication loss was initiated before the scheduled event started, after the scheduled event started before the event started, and returning before the planned event time elapsed. The results of this project indicate that the MBESS with the IEEE 2030.5 integrated standard will pave the way to include further developments recommended by California Rule 21 and facilitate the monitoring and control of stationary as well as portable DERs in the field.

1.10 Findings Discussion

This project demonstrated that the IEEE 2030.5 standard can be integrated successfully with the MBESS. Also, through this IEEE 2030.5 standard integration, the MBESS can perform the following use cases: flexibility during grid reconfiguration, capacity increase, voltage boosting with fixed reactive power injection, and voltage reduction with Volt/Var curve mode. This integration enhances the scalability, visibility, operational flexibility, and power quality that the MBESS provides. In addition, since this project focuses on bidirectional communication implementation on the MBESS (i.e., the IEEE 2030.5 standard server and gateway), several realistic communication loss scenarios were studied. These communication loss scenarios include communication loss between the server and gateway and communication loss between the gateway and MBESS local controller. The solution provided (i.e., the MBESS integrated with the IEEE 2030.5 standard) showed successful use case deployment even during communication loss occurrences. Furthermore, as potential next step of this project is including a DERMS action to deliver optimized operation from the perspective of the upper network.

1.11 Updated Value Proposition

The updated value proposition achieved with the MBESS integrated with IEEE 2030.5 standard can be described as follows:

7.1.1 Improved Scalability

For flexible resources such as MBESS, the addition of IEEE 2030.5 communication capability supports future scalability for adding other mobile energy storage systems to SDG&E's service territory. For instance, as the utility integrates more MBESS units into its asset portfolio and moves toward owning, operating, and maintaining a fleet of MBESS, it becomes more important to minimize the efforts associated with the integration of a new unit to the 2030.5 control platform (such as DERMS). The IEEE 2030.5 communication enables higher scalability and as a result, faster adoption of new MBESS.

DERMS will be an essential utility platform for monitoring and control of DERs, mitigating DER-related operational issues, optimizing grid performance, and capturing new benefits. The increasing scale of DER assets (especially BTM DERs) to be integrated over time highlights the importance of platform scalability. Using a standard framework for communication within all DERs improves the overall interoperability and plug-and-play integration of the assets, which in turn leads to improved scalability for the platform.

The scalability of MBESS will be improved by increased interoperability and enhanced plug-and-play integration, as described below.

Improved Interoperability

IEEE 2030.5 provides a standardized communication framework, ensuring interoperability among different vendors' equipment. This interoperability supports the scalability of resource integration, allowing utilities to connect and manage MBESS devices seamlessly.

Enhanced Plug-and-Play Integration

With standardized communication protocols, new MBESS can be easily integrated into the existing infrastructure, promoting a plug-and-play approach. This simplifies the process of adding more resources, enhancing scalability.

7.1.2 Improved Visibility

It enables a standard communication framework, and requiring the DER assets to adhere to that are the key steps to establish the communication between the utility and DER assets, initially for monitoring purposes and enhanced visibility.

Monitoring MBESS as a non-stationary utility asset is even more critical than stationary assets from a security and operational perspective. Since the schedule of operation, field staff, physical location and interconnection point might change, the importance of having remote monitoring and visibility is even more highlighted. The operator's visibility toward MBESS in the field (status, availability, measurements, KPIs) leads to operational awareness in the first step. It is eventually the base for decision-making and asset control in the field.

Improved Real-time Data Exchange

The standard facilitates real-time data exchange between utilities and MBESSs. This improves visibility into the grid's status, enabling utilities to monitor and manage distributed resources more effectively.

Improved Remote Monitoring and Control

Utilities can remotely monitor and control the MBESS, enhancing visibility into their performance. This allows for proactive decision-making and a quicker response to grid conditions.

7.1.3 Enhanced Operational Flexibility

The ultimate goal for utilities in regard to MBESS is to leverage their benefits for enhanced grid operations through aggregating and controlling them for different use cases. This is essential while the utility intends to maximize the benefits from MBESS by stacking its use cases and applications and covering different use cases on a seasonal and locational basis. A standard communication framework that allows for MBESS integration into utility platforms provides aggregation and control capability over MBESS assets in the field. This leads to enhanced operational flexibility by managing MBESS connect/disconnect, controlling their active/reactive power output, and aggregating them for an optimum operation for specific use cases. The operator can use this flexibility to mitigate grid constraints and/or optimize grid operation.

Demand Response Integration

IEEE 2030.5 supports demand response functionalities, enabling utilities to manage load variations dynamically. This flexibility is crucial for optimizing grid operations and responding to changing energy demand patterns.

Improved Grid Stability

By providing real-time information on MBESS, utilities can make more informed decisions to enhance grid stability. This includes adjusting power flow, managing voltage levels, and ensuring optimal use of resources.

8 Conclusion

This EPIC project successfully demonstrated the MBESS's capability to integrate with the IEEE 2030.5 standard. In addition, the MBESS's capability to perform several operational flexibility use cases was successfully demonstrated. These use cases were recommended by the state of California and involved using the IEEE 2030.5 standard as the main bidirectional communication. The successful use cases demonstrated through the IEEE 2030.5 standard use were (1) flexibility during grid reconfiguration, (2) capacity increase, (3) voltage boosting with fixed reactive power injection, and (4) voltage reduction with Volt/Var curve mode. Furthermore, the robustness of the MBESS integrated with the IEEE 2030.5 standard was tested with two communication loss scenarios. These scenarios included (1) communication loss between the server and gateway and (2) communication loss between the gateway and MBESS local controller. Additionally, it was demonstrated that for DERs without inherent 2030.5 communication capability, a protocol converter/gateway can be added locally to enhance the capabilities of the DER and accommodate the IEEE 2030.5 communication.

9 Tech Transfer Plan

1.12 Project Result Dissemination

This report is the main record of what was demonstrated and learned in EPIC-3, Project 7, Module 3, and is the primary technology transfer tool. The project's results and findings may also be submitted for consideration by the public and industry conference organizers.

Several meetings were held throughout the project design and testing stages involving the stakeholders and subject matter experts from various SDG&E departments. The focus of the meetings was to describe the project's progress and obtain feedback or suggestions on aspects of the use cases and test system development. A short list of key meetings is provided below:

- A meeting involved reviewing the use case definitions and requirements for integrating the IEEE 2030.5 standard with the MBESS. The recommendations from various teams were gathered and synthesized to help select the use cases for the demonstration.
- A meeting involved reviewing the soft qualitative benefits of the use cases selected to demonstrate the IEEE 2030.5 standard integrated with the MBESS. This meeting resulted in identifying the qualitative benefits from these use cases.
- Meetings were held to identify possible communication loss effects when using the IEEE 2030.5 standard with the MBESS. These meetings resulted in setting a plan for demonstrating the effects of communication loss.
- Meetings were held to ensure the proposed test setups for the ITF and field test setup development were comprehensive. This is to facilitate various test cases and operating scenarios that would help evaluate the MBESS with the IEEE 2030.5 standard features and performance.
- Remote witnessing meeting for the ITF and field testing.
- An in-person meeting was held at the ITF during testing, and another in-person meeting was held at the field site to perform the tests and discuss the results.

The engagement of these key SDG&E stakeholder groups in these activities supports their ability to engage in commercial adoption processes after the EPIC project ends. The key internal stakeholders to engage in post-EPIC activities include the following:

- Advanced technology
- Distribution operations
- Protection and automation (SPACE)
- Customer programs

1.13 Transition for Commercial Use

The energy industry has been moving toward increased reliability and resiliency while decarbonizing the energy supply. To achieve these targets, mobile energy storage systems offer flexibility of operation and clean energy supply for a wide spectrum of operational use cases, including emergency response and outage management, as well as grid support functions (peak shaving, voltage support, etc.). While these units can operate locally, it is critical from several aspects of safety, security, and operation to integrate them into the utility infrastructure for monitoring and control purposes.

Ideally, the utility will have a dedicated DERMS (either as an integral part of their advanced distribution management system (ADMS) or as a standalone platform communicating with ADMS for monitoring and control of key DER assets and demand response programs/aggregators in the field. With IEEE 2030.5-enabled DERs, the integration with a future utility DERMS platform will be a more seamless procedure.

The following considerations for transition to commercial use should be considered:

- Mobile energy storage solutions can be deployed in the field to supplement existing grid assets and improve power system stability and reliability, as this EPIC project illustrates. To use the full potential of these solutions, it is important to integrate them into the utility's existing control and monitoring infrastructure.
- All control and monitoring in this project was done manually on the IEEE 2030.5 server. However, it would be beneficial to integrate the IEEE 2030.5 server communication into the existing DERMS and/or ADMS to optimize and potentially automate some aspects of DER management and minimize the amount of manual control required.
- Aspects related to managing the IEEE 2030.5 server must be formalized and documented to facilitate the commercial operation of multiple DERs. These could include, but are not limited to, registration and identification of DERs, group management policies (topology-based and/or non-topology-based groups) and control prioritization, default DER controls, default polling, posting rates, etc. In particular, mobile assets should be given careful consideration as to how they may need to be moved between various groups when they are deployed to different areas.
- For DER solutions that do not support IEEE 2030.5 clients natively, adding an IEEE 2030.5 gateway is an effective alternative. The gateway supports the IEEE 2030.5 protocol, including server and resource discovery, security, acting on DER controls, and reporting DER data. The gateway can also convert the IEEE 2030.5 protocol to protocols such as Modbus, DNP3, openADR, etc. In this project, Modbus was chosen as the target protocol, and Sunspec Alliance's DER models (Sunspec Modbus) were used because the mapping between the models is well-defined in IEEE 1547.1.

10 Recommendations

The objective of SDG&E EPIC-3, Project 7, Module 3 was to demonstrate operational flexibility use cases using the IEEE 2030.5 standard with an MBESS in the field. Four use cases focused on CA Rule 21 Phase 3 advanced functions, while two use cases tested the system behavior during communication loss.

Based on the successful demonstration of these use cases, it is recommended that SDG&E continue with integrating DERs into their control and monitoring infrastructure using the IEEE 2030.5 protocol and that the IEEE 2030.5 server should be integrated into existing systems such as DERMS and/or ADMS to optimize DERs further.

In terms of management of the IEEE 2030.5 server, it is recommended that the requirements and policies for DER interconnection are formalized. Some issues for consideration include:

- Registration and identification of DERs (e.g., in-band, out-of-band methods)
- Group management policies and prioritization
  - Topology-based groups (e.g., substation, feeder, service point, etc.)
  - Non-topology-based groups (e.g., tariff-based, area-based, etc.)
- Consideration of Default DER controls (when no scheduled control is active)
- Default polling and posting rates, etc.

For DERs that do not support the IEEE 2030.5 protocol, it is recommended to consider adding IEEE 2030.5 gateways that can provide the conversion to a protocol that the DER supports.

11 References

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[4]. https://sunspec.org/wp-content/uploads/2019/08/CSIPImplementationGuidev2.103-15-2018.pdf

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Appendix A: Standards and Guidelines

#	Name	Definition
1	ANSI	American National Standards Institute
2	ANSI C37/IEEE	Surges withstand capabilities, whenever applicable
3	ANSI C57/IEEE	Transformer Standards, whenever applicable
4	ANSI Z535	Product Safety Signs and Labels
5	ANSI/IEEE C2	National Electric Safety Code
6	Cal/OSHA	California Occupational Safety and Health Administration
7	CFC	California Fire Code
8	Electric Tariff Rule 21	Generating Facility Interconnections
9	IEEE 1547	IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems
10	IEEE 1881	Standard Glossary of Stationary Battery Terminology
11	IEEE 2030.5	California default communications protocol for residential distributed energy resource (DER) integration applications
12	IEEE 519	IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems
13	NEC	National Electric Code
14	NEMA	National Electrical Manufacturers Association
15	NESC	National Electric Safety Code
16	NFPA 704	Standard System for the Identification of the Hazards of Materials for Emergency Response
17	NFPA 855	Standard for the Installation of Stationary Energy Storage Systems *Applicable in the event of adoption by contract execution
18	UL 1642/IEC 62133	Applicable sections related to battery cell safety, where applicable
19	UL 1741	Standard for Inverters, Converters, Controllers, and Interconnection System Equipment for Use with Distributed Energy Resources
20	UL 1778	Underwriters Laboratory's Standard for Uninterruptible Power Systems (UPS) for up to 600V AC

#	Name	Definition
21	UL 9540/9540A	Standard for Energy Storage Systems and Equipment
22	42 United States Code (U.S.C.)	Noise Control Act of 1972

Appendix B: Additional Use Case – MBESS Companion Trailer

12 Introduction

Expanding on the previous MBESS deployments described in Modules 1 and 2, this third module introduced an additional use case that integrates the mobile battery with a distribution interconnection equipment trailer, known as the "MBESS companion trailer." This integration enables quicker and more efficient mobilization to supply backup power. The configuration is particularly valuable during emergency events, when rapid deployment of generation resources is essential to temporarily restore power for customers impacted by prolonged outages, such as during Public Safety Power Shutoff (PSPS) events. The demonstration showcased how operating the battery in parallel with generators can extend power availability.

13 Objective

The demonstration objective was to use the MBESS with 3Phase power capabilities to connect the battery to SDGE's electric distribution system showcasing how a pre-assembled electric distribution interconnection equipment trailer, equipped with a mobile energy storage system, can provide extended backup power through parallel operation with generators.

14 Project Approach

1.14 Additional Use Case

The additional use case demonstration highlighted the MBESS's ability to support both planned and unplanned outages, particularly during prolonged events such as Public Safety Power Shutoffs. To streamline and accelerate deployment, a companion trailer was acquired to connect the MBESS to the distribution system. This trailer includes a step-up transformer, grounding bank, and a four-position switch equipped with a protection relay. Traditionally, these components are transported and connected individually at the site, which can be time-consuming and costly. By integrating all necessary equipment into a single trailer, setup time and labor costs are significantly reduced, allowing for quicker delivery of temporary power to affected customers.

1.15 Description of the Demonstration

3.2.1 Description of the Companion Trailer

The design of the companion trailer was driven by the interconnection requirements of the MBESS inverter. When connecting an inverter to a high-voltage system via a step-up transformer, the type of inverter determines whether it must connect to a "delta" or grounded "wye" transformer secondary. The MBESS inverter specifically requires a solidly grounded circuit, so it was connected to a grounded "wye" secondary. The transformer's primary side is configured as "delta", which necessitates a grounding bank on the grid side to provide a ground and neutral source for line-to-neutral loads—this is only required when the battery is used for grid-forming purposes. To facilitate interconnection between the two transformers, a four-position switch was installed, with two positions reserved for future load connections.

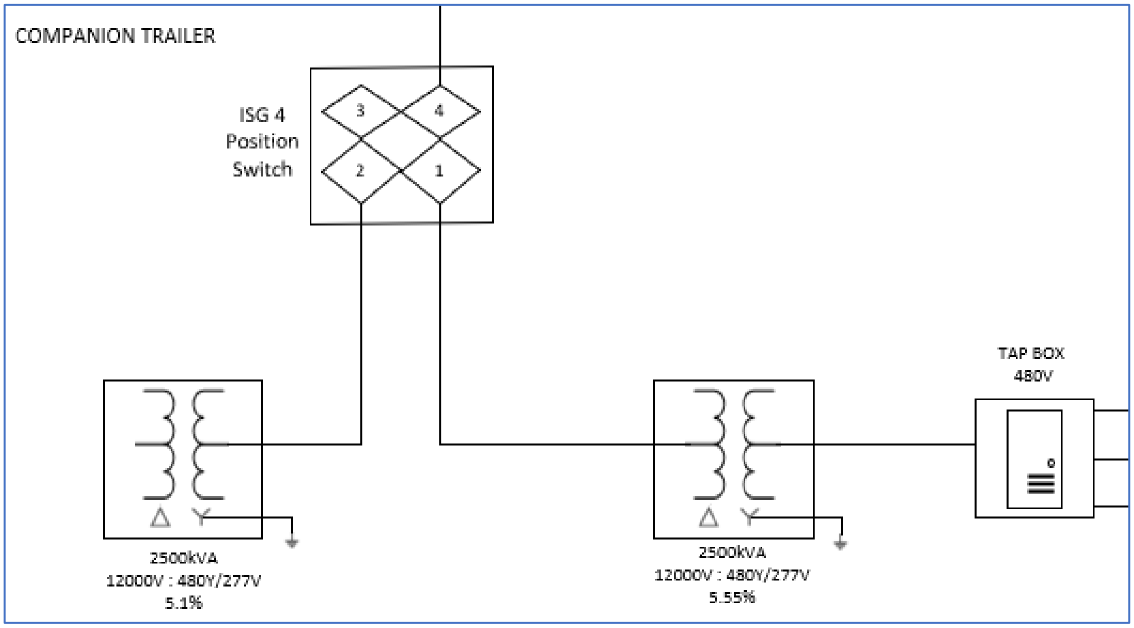

Figure 1. Companion Trailer Single Line Diagram

Figure 2 is a photo of the companion trailer, which has been strategically engineered to optimize weight distribution of all the equipment for safety over the road transport. All equipment is securely mounted, electrically connected and grounded, and has ample workspace for technicians to do necessary work.

Figure 2. Photo Demonstrating Companion Trailer Configuration

Figure 3 shows the 480V tap box equipped with Camlok connectors, allowing for quick and easy connection of generation resources. For this design, eight Camloks per phase and neutral were selected to fully utilize the rated capacity of the step-up transformer. Given the typical size of generators and MBESS units used, 4/0 cable is selected for its capacity to handle up to 400A per conductor.

Figure 3. 480V Tap Box

The equipment and cable selected for the trailer are standard to SDG&E, ensuring consistency with existing field practices. This equipment was sent to the vendor for mounting. Standardization was a key consideration so that any qualified electrical worker operating the trailer is already familiar with the operating procedures and can easily replace any components as needed. Another key consideration was whether to place the equipment on one trailer or split it across two. Opting for a single trailer offered lower costs and simplified logistics, requiring only one truck for towing. However, this approach limits available space at the deployment site. Using two trailers would provide greater flexibility for maneuvering in tight areas, but it would come at a higher cost.

1.16 Description of the Test Set up

3.3.1 Location

Testing took place at SDG&E’s Skills Training Center, which includes a dedicated underground system test yard that accommodated all required equipment. The MBESS unit made a 56-mile trip from its base location to the site, arriving with approximately 65% state of charge (SOC).

3.3.2 Description of Equipment Used

The following was used for this demonstration:

- MBESS – 362kW/1400kWh mobile battery, 480V 3 Phase
- MBESS SEL RTAC (Real-Time Automation Controller) – Used to control the MBESS and Generators
- Companion Trailer
- Rental Transformer and Load Bank
- Two rental 275kW Generators
- 4/0 Cables for MBESS and Generator Connection
- Dranetz Meter – Used for monitoring voltage, current, power, frequency

Figure 4 shows the single line diagram of how the equipment was electrically connected.

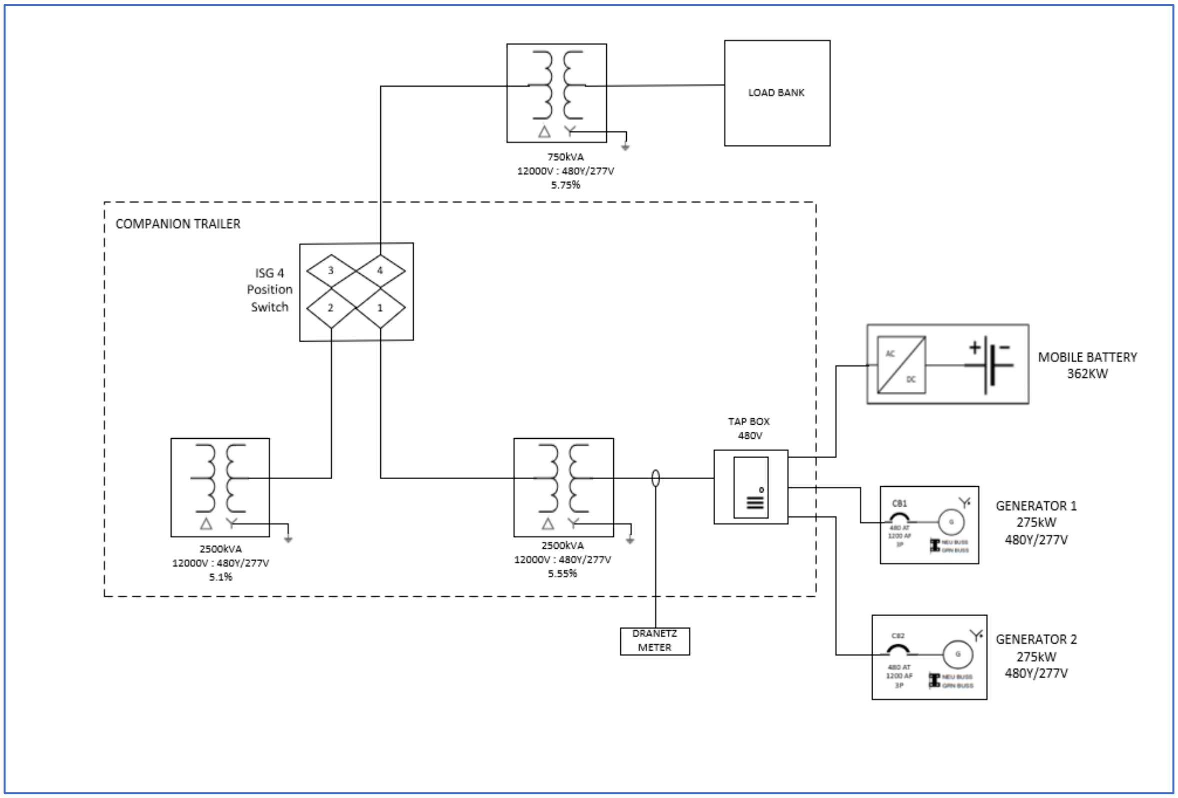

Figure 4. Single Line Diagram of Electric Connections

3.3.3 Description of Test Cases

The companion trailer was assembled out of state and had not been energized prior to its arrival in San Diego. Therefore, the initial phase of commissioning involved energizing each piece of equipment individually to verify correct wiring and confirm that voltage readings were within expected parameters. This step was critical to ensure the safe operation of the equipment and the reliable delivery of power to the connected load. Additionally, calibration and functional testing were performed on the protection relay associated with the four-position switch.

The next phase of testing demonstrated the system's ability to operate with both the MBESS, and generators connected in parallel, simulating a prolonged backup power scenario. The MBESS RTAC was programmed to monitor the battery's state of charge (SOC). When the SOC reached a predefined minimum threshold, the RTAC sent a hardwired signal to start the generators and supply a predetermined base load. Once the SOC returned to the maximum threshold, the RTAC signaled the generators to shut down. A successful test was defined by a seamless transition from the MBESS supplying the full load to the generators taking over and recharging the battery, confirming readiness for an extended outage event.

Due to budgetary constraints and limited deployment opportunities, the mobile battery and companion trailer have not yet been used in a live outage scenario. However, the plan moving forward is to prioritize the use of the mobile battery system when feasible, especially in situations where extended backup power is required. This approach aligns with SDG&E’s commitment to leveraging innovative solutions for grid reliability and operational efficiency.

15 Results

4.1 Test Results

The data collected was from two different sources. Figure 5 shows the data collected from the Dranetz meter which was hooked up on the secondary side of the step-up transformer on the companion trailer. It shows how much power was flowing through the equipment on the trailer to the load bank. Since the battery is rated at 362kW, we did not set the load bank any higher than a set point of 300kW. The base load setting of the generators was set to output 180kW each to total 360kW of power output when turned on.

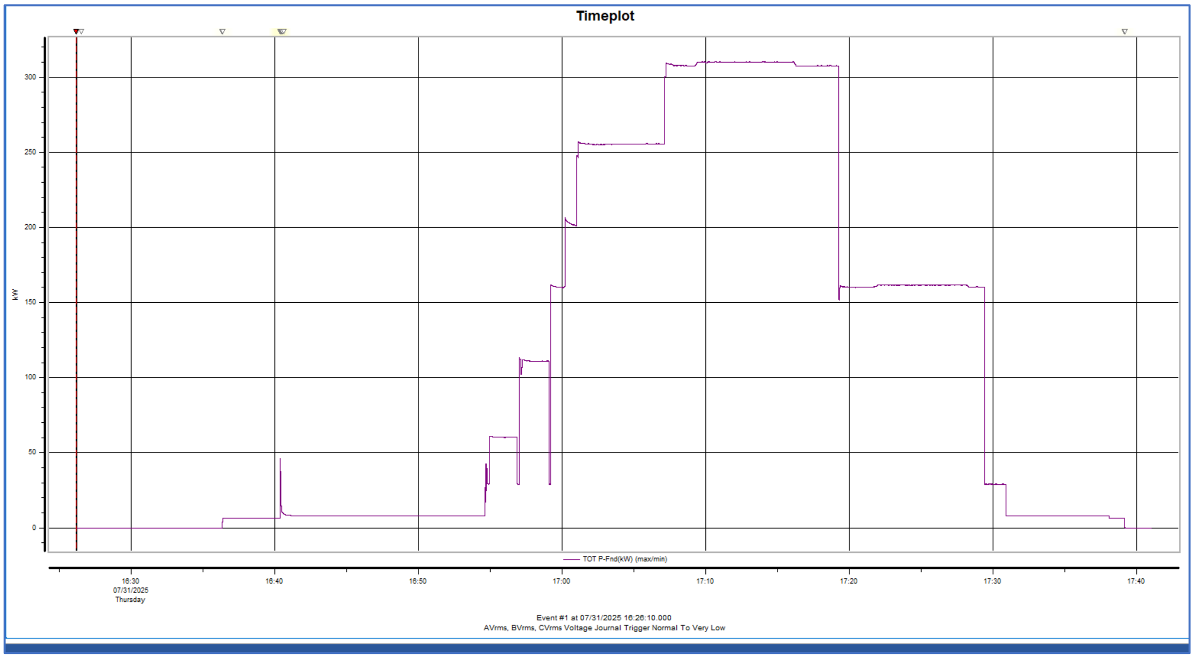

Figure 5. Power to Load Bank Meter Data

The load was brought up to 300kW by load steps of 50kW. Once 300kW was reached, the battery SOC in the controller was forced to 10%, which is under the lower threshold of the minimum SOC the battery should be during an operation, and a signal was sent to the generators to turn on. The generators ramp up to the full output of 360kW over a minute. As shown in Figure 6 below, the battery real power output went from 300kW to -53kW at around 17:10. If the load were to stay at this 300kW level, it would take about 20 hours to get the battery up to 80% and the generators would then turn off.

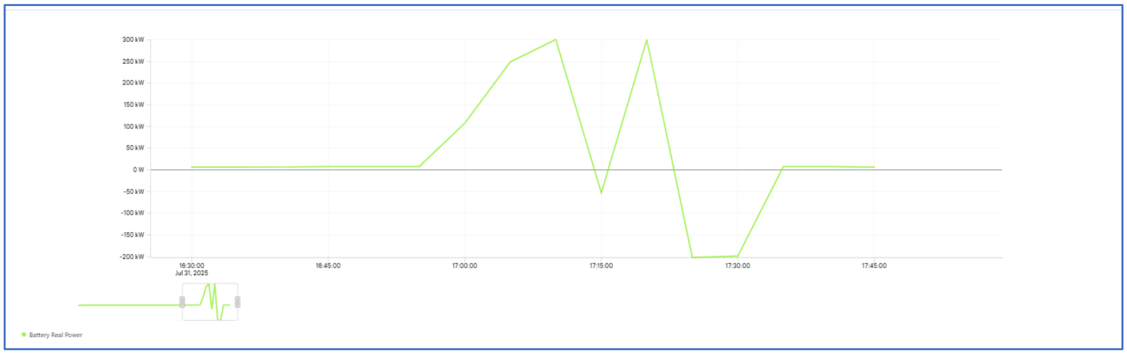

Figure 6. Power to Load Bank Meter Data

We removed the forced value of 10% SOC in the controller, and the generators then turned off. We lowered the setpoint on the load bank to 150kW. We forced the SOC to be a value of 10% and turned on the generators again. The battery started charging at 200kW. At this rate, it would take about five hours to charge back up. It is preferable to optimize how much power the generators should output based on the size of the battery and the typical load the battery will be expected to serve.

4.2 Set up Time

In previous generator deployments where we connected to the primary distribution system, all equipment was transported and assembled separately. Based on those experiences, the time required to set up equipment equivalent to what is now integrated on the trailer would typically range from 2.5 to 5 hours. This estimate includes staging and setup, laying down nine runs of cable, securing and dressing the cable, and performing inspection and testing.

However, this does not account for cable termination work. If terminations or connections are not pre-installed, each could add an additional 1 to 2 hours per termination.

With the trailer configuration, all major equipment is already connected and pre-mounted, significantly reducing labor time. The remaining tasks are limited to connecting the generation resources to the tap box on the trailer and making the final cable connection to the distribution system—whether overhead or underground—resulting in a much more efficient deployment process.

16 Conclusion

The MBESS companion trailer demonstration successfully validated the concept of a fully integrated, mobile battery and interconnection system capable of providing extended backup power during planned or unplanned outage events. By combining the MBESS with a pre-assembled trailer containing a step-up transformer, grounding bank, and protective switchgear, the use case demonstrated significant improvements in setup efficiency, operational flexibility, and system reliability.

Testing confirmed the system’s ability to operate the MBESS in parallel with generators, automatically transitioning between power sources based on the battery’s state of charge. This functionality enables seamless, prolonged backup operations without manual intervention. Additionally, the standardized equipment design aligns with SDG&E’s existing field practices, ensuring ease of deployment, familiar operation, and maintainability.

Compared with traditional configurations that require individual transport and assembly of components, the integrated trailer reduced setup time from several hours to a fraction of that, providing a faster and more cost-effective solution for emergency power restoration. Although the system has not yet been deployed in a live outage event, its proven performance in controlled testing demonstrates its readiness to support SDG&E’s resilience objectives, particularly during Public Safety Power Shutoffs (PSPS) and other extended outage scenarios.

Overall, this demonstration highlights how modular, pre-engineered mobile energy systems like the MBESS companion trailer can enhance grid resilience, streamline deployment logistics, and serve as a scalable model for future emergency response applications.