SDGE™

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April 30, 2026

ADVICE LETTER 4841-E

PUBLIC UTILITIES COMMISSION OF THE STATE OF CALIFORNIA

SUBJECT: SUBMISSION OF SAN DIEGO GAS & ELECTRIC COMPANY'S 2025 ELECTRIC PROGRAM INVESTMENT CHARGE ADMINISTRATOR ANNUAL REPORT PURSUANT TO DECISION 23-04-042

PURPOSE

San Diego Gas & Electric Company (SDG&E) hereby submits for approval to the California Public Utilities Commission (Commission) this Tier 2 Advice Letter (AL) for its 2025 Electric Program Investment Charge (EPIC) Administrator Annual Report in accordance with Ordering Paragraph (OP) 8 of Decision (D.) 23-04-042 (Decision).

BACKGROUND

D.23-04-042, OP 8, requires that the annual reports be filed as Tier 2 Advice Letters that follow the outline included in Appendix C of the Decision, and specifies that annual reports found to be deficient due to missing information or inaccurate entries in the EPIC database will require prompt resubmission within 30 days. In the Decision, the Commission agreed that annual reports should be streamlined, where possible, to support the evolving needs of the EPIC program, including leveraging the EPIC database so that the report narratives complement the database, not duplicate it.[1]

Further, the Decision requires EPIC Administrators to provide a coordinated presentation to the Commission on an annual basis, at either a Commission business meeting or the Commission's Emerging Technology Committee, at the Commission's discretion. The presentation is to be made to the Commission in a timely manner after the submission of Administrators' annual reports. Administrators shall coordinate this presentation via Energy Division Staff, who will provide guidance on timing and agenda.

As part of reporting transparency, EPIC Administrators shall post clearly and prominently in their annual reports and on all program, project, and outreach materials, websites, and any other public materials (including those of third-party EPIC contractors) the following language consistent with other utility ratepayer funding programs: "This program is funded by California utility customers under the auspices of the California Public Utilities Commission."

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[1] EPIC database: https://database.epicpartnership.org/projects.

DISCUSSION

SDG&E's 2025 EPIC Annual Report is presented in Attachment A of this Advice Letter. The 2025 EPIC Annual Report highlights progress and activities supporting EPIC-4 projects, which were launched in late 2024.[2] Additionally, pursuant to D.13-11-025, OP 14, the comprehensive final report for the EPIC-3 project, Project 7, Module 3: Demonstration of the Multi-Purpose Mobile Battery Energy Storage System (MBESS), completed in 2025, is included in the annual report in Attachment A.

SDG&E's 2025 EPIC Annual Report will be posted on SDG&E's EPIC website at: www.sdge.com/EPIC.

PROTEST

Anyone may protest this Advice Letter to the California Public Utilities Commission. The protest must state the grounds upon which it is based, including such items as financial and service impact, and should be submitted expeditiously. The protest must be submitted electronically and must be received no later than May 20, 2026, which is 20 days from the date this Advice Letter was submitted with the Commission. There is no restriction on who may submit a protest. The protest should be sent via e-mail to the attention of the Energy Division at EDTariffUnit@cpuc.ca.gov. A copy of the protest should also be sent via e-mail to the address shown below on the same date it is delivered to the Commission.

Attn: Greg Anderson
Regulatory Tariff Manager
E-mail: GAnderson@sdge.com & SDGETariffs@sdge.com

EFFECTIVE DATE

Pursuant to D.23-04-042, this submittal is subject to Energy Division disposition and should be classified as Tier 2 (effective after staff approval). SDG&E requests this Advice Letter be approved effective May 30, 2026, 30 days from its submittal.

NOTICE

A copy of this filing has been served on the utilities and interested parties shown on the attached list including interested parties in R.19-10-005, A.21-06-021, A.22-05-016, A.23-05-010, and Applicants, by either providing a copy electronically or by mailing them a copy hereof, properly stamped and addressed. Address changes should be directed to SDG&E Tariffs by e-mail at SDGETariffs@sdge.com.

/s/ Clay Faber

CLAY FABER
Director – Regulatory Affairs

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[2] SDG&E's EPIC-4 Investment Plan (Application 22-10-002) was approved by the Commission in D.23-11-086 (EPIC-4 Decision).

ATTACHMENT A

SDG&E® 2025 EPIC Annual Report

San Diego Gas & Electric Company

EPIC Administrator Annual Report

April 30, 2026

Table of Contents

1. Executive Summary

The submission of the Annual Report (Report) for the 2025 calendar year is pursuant to Decision ("D.") 23-04-042 Ordering Paragraph ("OP") 8 and California Public Utilities Commission (CPUC) Energy Division Staff guidance[1] received via email. This Report provides an overview of SDG&E's EPIC activities during the 2025 calendar year.

SDG&E proposed and received approval for five projects that demonstrate system integration solutions in its first triennial application for the years 2012-2014 (EPIC-1).[2] In addition, SDG&E proposed and received approval for six projects that demonstrate grid modernization and technology integration solutions in its second triennial application for years 2015-2017 (EPIC-2).[3] SDG&E proposed and received approval for seven projects in multiple policy areas in its third triennial application for years 2018-2020 (EPIC-3).[4] SDG&E proposed and received approval for its 2021-2025 Investment Plan (EPIC-4).[5] This report provides an update on SDG&E's 2025 progress and year-end status for the completion of EPIC-3 Project 7, Module 3 and activities related to EPIC-4 projects.

This program is funded by California utility customers under the auspices of the California Public Utilities Commission.

a. Overview of Programs/Plan Highlights

San Diego Gas and Electric Company (SDG&E) remains firmly committed to the Electric Program Investment Charge (EPIC) Program and to using it as a platform to deliver meaningful customer benefits. Through cost-effective demonstration of innovative technologies, SDG&E seeks to advance EPIC's core objectives of safety, reliability, affordability, environmental sustainability, and equity.

During the 2025 reporting period, SDG&E actively supported EPIC portfolio planning and implementation across multiple program cycles. Staff participated in EPIC 5 planning workshops, responded to data requests, and engaged in technical discussions to help shape potential initiatives and research topics aligned with Commission priorities. These efforts focused on identifying problem-driven investments, refining research gaps, and ensuring future EPIC activities are responsive to stakeholder input.

SDG&E continued coordination efforts with co-administrators to promote portfolio alignment, leverage complementary expertise, and avoid duplication of research activities. Ongoing

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[1] February 26, 2025 CPUC Staff Guidance for EPIC Annual Reports

[2] SDG&E's Application (A.12-11-002) for EPIC-1, approved in D.13-11-025, issued November 19, 2013.

[3] SDG&E's Application (A.14-05-004) for EPIC-2, approved in D.15-04-020, issued April 15, 2015.

[4] SDG&E's Application (A.17-05-009) for EPIC-3, approved in D.18-10-052, issued November 2, 2018.

[5] SDG&E's Application (A.22-10-002) for EPIC-4, approved in D.23-11-086, issued December 4, 2023.

discussions emphasized transparency and opportunities for collaboration to maximize value for customers.

Work also continued on active EPIC 4 projects, maintaining progress on planning, contracting, and demonstration activities. In addition, remaining EPIC 4 funds were strategically allocated to initiate a new project: the Integrated Testing Facility (ITF) Microgrid Testbed. This laboratory-based microgrid platform is designed to evaluate distributed energy resource (DER) integration, control strategies, and system interoperability under controlled conditions. The testbed will support DER devices to inform grid modernization and DER deployment strategies.

A milestone was achieved with the completion of EPIC 3 Project 7: Demonstration of the Multi-Purpose Mobile Battery Energy Storage System (MBESS). The project finalized demonstration of a transportable battery platform, including a self-contained companion trailer equipped with integrated switchgear and supporting electrical infrastructure. The system was successfully demonstrated as a flexible, rapidly deployable solution for grid support and resilience applications. The final technical report was completed and attached herein as Appendix C.

Together, these activities reflect continued progress in advancing innovation, strengthening inter-administrator coordination, and supporting California's clean energy and grid resilience objectives through EPIC-funded research and demonstration.

The tables below provide a high-level view of SDG&E EPIC projects' contribution to customer benefits and related progress in 2025.

Table 1. EPIC-4 (2021-2025) Portfolio Benefits

Project Name	Potential Benefits at Full Deployment	EPIC Principle Alignment
Project 1: Phaser Measurement Units (PMUs) Based Power Network Analysis for Increased Situational Awareness	Supports **reliability** through expanded observability of SDG&E local 69kV transmission system and provides a road map for optimal placement of more PMUs in the future. Provides a strategic roadmap for expanding PMU coverage across the remaining portions of SDG&E's transmission system that currently lack PMUs. This roadmap minimizes the number of PMU additions while maximizing the number of observable buses in the local area. (For example, the Eastern District has 15 69kV buses and only five buses are observable based on two buses at Alpine and Cameron substations with PMU devices). The preliminary result of the placement study indicated that	Improved Reliability Improved Affordability

Project Name	Potential Benefits at Full Deployment	EPIC Principle Alignment
	adding PMUs at six substations will make the remaining seven buses fully observable. Savings of $1,477k is expected by not installing PMU on the remaining buses, incrementally improving **affordability**. Strengthens monitoring and situational awareness in local areas with Inverter-based Resources (IBRs) by: • Enabling not only the detection of oscillations but also rapid identification of their sources through improved observability. (Identification currently does not exist or very limited but expanded observability will help expedite identification) • Allowing faster contingency analysis capable of capturing rapid battery charging or discharging behavior, offering a valuable complement to conventional contingency analysis. (Eventually the contingency analysis from the PMU-based model will become a back-up to the conventional real-time contingency analysis from the existing EMS.) This enhanced capability is particularly important in three of SDG&E service districts, where the system serves disadvantaged communities. By improving observability in these areas, the project supports more reliable service delivery and helps ensure that the benefits of increased grid visibility and resilience are equitably realized.	
Project 2: Grid Resiliency through Integrated Vehicle to Everything (V2X) and Renewable Energy at Community Resource Centers (CRCs)	Supports **reliability** by advancing deployment readiness for AC bidirectional (V2X) charging at Community Resource Centers, enabling EVs to provide resilient power and grid support during Public Safety	Improved Reliability Improved Environmental Sustainability

Project Name	Potential Benefits at Full Deployment	EPIC Principle Alignment
	Power Shutoffs (PSPS) and emergency events. Advances **environmental sustainability** by integrating renewable-powered EV charging and enabling clean V2X use cases that reduce reliance on fossil-fueled backup generation during outages. Considers **equity** by prioritizing Community Resource Centers (CRCs) in DVCs, expanding access to resilient power and charging for vulnerable populations and supporting broader replication across SDG&E's CRC portfolio (identified prospective sites also in DVCs).	Improved Equity
Project 3: Power Quality and Smoke Detection Integration	Enhances electric system **reliability** by improving early detection of line defects and abnormal conditions. In the event of a fault, the centralized monitoring system will deliver more granular, time-synchronized data, enabling faster and more accurate fault location. This improved visibility supports quicker field response, reduces outage duration, and strengthens overall grid resilience. Enhances electric system **safety** by improving early detection of minor defects and precursors, such as vegetation encroachment, before they develop into electrical faults. Earlier identification enables SDG&E to dispatch patrols more quickly and address hazards proactively, reducing the risk of wildfire ignition, equipment damage, and service interruptions. Impacts **affordability** through enhanced communication intelligence that enables faster and more accurate identification of fault locations and underlying causes, reducing undetermined outages and avoiding unnecessary or prolonged field investigations. By improving real-time	Improved Affordability Improved Reliability Improved Safety

Project Name	Potential Benefits at Full Deployment	EPIC Principle Alignment
	situational awareness and targeting patrols more effectively, the project lowers troubleshooting and restoration costs, reduces unnecessary vehicle travel, and minimizes fuel use. Additionally, the demonstrations are conducted on two circuits that include disadvantaged communities. One circuit is located entirely within a DAC, while the other is partially located within DAC areas, ensuring that the project's benefits are evaluated in communities that are often disproportionately impacted by outages and wildfire risk.	
Project 4: Zonal Electrification	The ability to quickly respond to changes in load and generation, reduces the risk of outages. Improved load management and integration of self-generation technologies enhance grid **reliability**. As more customers transition to electric service with integration of renewable energy sources, fossil fuel-based generation and resulting GHG emissions are reduced contributing to improved **sustainability**. This work directly informs future DERMS signaling, grid planning, and equitable electrification strategies by grounding decisions in real grid constraints and capabilities.	Improved Reliability Improved Environmental Sustainability
Project 5: Mobile Nanogrid	Demonstrates and supports **sustainability** through zero-emissions, mobile nanogrid that can rapidly provide temporary backup power during PSPS and emergency events. Enhanced grid **reliability** through field deployments to validate operational readiness, deployment logistics, and the potential to replace diesel generators at CRCs and other	Improved Environmental Sustainability Improved Reliability

Project Name	Potential Benefits at Full Deployment	EPIC Principle Alignment
	resilience sites, particularly in disadvantaged communities.	
Project 6: Microgrid Testbed	Supports **sustainability** through zero emissions operational testing contributing to the reduction of GHG emissions and supports the transition to renewable energy sources, reducing reliance on fossil fuels. Enhanced grid **reliability** through the creation of a testing platform that mimics the grid such that live testing can be performed without affecting production equipment. This testing and process troubleshooting will allow for faster deployments to the field, also reducing any outages to a minimum. Additionally, demonstrations are conducted in a disadvantaged community, ensuring that these communities directly benefit from innovative grid solutions, increased reliability, and exposure to clean energy technologies.	Improved Environmental Sustainability Improved Reliability

Table 2. EPIC-4 Project Highlights as of December 31, 2025

Strategic Initiative	Projects	Highlights and Key Successes
Grid Modernization	PMU-Based Power Network Analysis	The PMU Placement Tool was delivered, installed, and demonstrated, with training materials provided to support broader engineering adoption and hands-on use.
	V2X at CRCs	Completed preliminary site design and layout for the DAC-located, Pine Valley CRC, including selection and placement of AC bidirectional charging, public Level 2 chargers, and renewable-powered L2 chargers to support resilience during PSPS events. Finalized charger selection and developed a customized scope of work aligned with evolving AC bidirectional standards, site requirements, and long-term resilience objectives.

Strategic Initiative	Projects	Highlights and Key Successes
	PQ and Smoke Detection Integration	Completed 300 initial residential site assessments supporting Smart Meter 2.0 readiness, procurement and installation of substation-level power quality devices, enabling near–real-time fault analysis, and successful validation of LTE connectivity for waveform data capture. Integration efforts progressed across multiple data streams, including initial power quality data ingestion, establishment of PMU data transfer, and completion of smoke sighting integration. Together, these accomplishments positioned the project to transition into expanded field deployment and operational demonstration in 2026.
	Renewable Mobile Nanogrid	Successfully executed field demonstrations: Deployed the nanogrid for customers at SDG&E's Wildfire Safety Fair, demonstrating mobile resilience capabilities and supporting stakeholder and public engagement. Expanded stakeholder engagement and use-case evaluation: Conducted multiple project showcases and coordinated with internal teams to explore applications supporting DER deployment, wildfire mitigation, generator replacement, and potential infrastructure support. Positioned the project for future demonstrations: Initiated planning for expanded stakeholder deployments in 2026 and a long-duration hydrogen demonstration in 2027, including evaluation of export panel configurations and advanced technology integration opportunities.
DER Integration	Zonal Electrification w/Integrated DER	Advanced the zonal selection methodology, including identification of core data inputs to support equitable and targeted electrification planning. Obtained internal and external cost estimates for developing zonal electrification selection tool. After reviewing estimates, it was determined to proceed with developing the selection tool internally. Selection tool discovery discussions were initiated in Q4 2025; development of selection tool scheduled to begin in Q1 2026. Contracted with EPRI and will participate in the FLEXIT supplemental project, enabling collaboration with industry stakeholders on DER signaling and integration practices.
	ITF Microgrid Testbed	This project is still in the early stages of implementation, and therefore too early to identify key successes or potential impediments.

2. Introduction

a. EPIC Background

In Application (A.) 12-11-002, SDG&E requested Commission approval of five programs that demonstrate advanced distribution system integration solutions. In November 2013, SDG&E's Application and First Triennial EPIC Plan (EPIC-1) was approved in full, with minor modifications, by the Commission in D.13-11-025.[6]

In A.14-05-004, SDG&E requested Commission approval of its Second Triennial EPIC Plan (EPIC-2), which included five programs that have the potential to help modernize the utility power system to improve customer benefits, as well as a sixth project for SDG&E participation in industry research development & deployment (RD&D) consortia. In April 2015, SDG&E's EPIC-2 Application was approved in full, with minor modifications, by the Commission in D.15-04-020.

In A.17-05-009, SDG&E requested Commission approval of its Third Triennial EPIC Application (EPIC-3), which included seven project areas addressing topics in grid modernization, such as safety, advanced operation solutions, and resiliency. D.18-10-052 approved the project areas that were included in the application but only released 2/3 of the funds, pending approval of a Research Administration Plan (RAP), which occurred in 2020. The RAP application, A.19-04-026, was a joint filing of Investor- Owned Utilities (IOU) Administrators and was approved in D.20-02-003, releasing the remaining funds, which were applied to four project areas proposed in A.19-04-026.[7]

In A.22-10-002, SDG&E requested Commission approval of its application for the Fourth EPIC cycle (EPIC-4). Beginning with EPIC-4, the program cycle changed from a three-year basis to a five-year basis. The application consisted of two strategic objectives, each with a corresponding strategic initiative, and was filed in October of 2022. In November 2023, SDG&E's 2021-2025 EPIC-4 Investment Plan was approved by the Commission in D.23-11-086.

In April 2023, D.23-04-042[8] adopted administrative improvements for the EPIC Program including establishing measurable strategic goals and formalizing the EPIC annual report as a regular compliance process. D.23-04-042 requires the EPIC Program Administrators to file annual reports on April 30 of each year via a Tier 2 Advice Letter that follow the outline in Appendix C of the decision.

In February 2026, D.26-02-037[9] approved the EPIC-5 Strategic Objectives and authorized the IOUs continue as EPIC Program Administrators.

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[6] D.13-11-025 at 63 and 136.

[7] The IOUs' Joint Application (A.19-04-026), approved in D.20-02-003, issued February 10, 2020.

[8] Decision on Phase 2-C of Electric Program Investment Charge Rulemaking, issued April 28, 2023.

[9] Decision Adopting Electric Program Investment Charge Strategic Objectives, issued March 2, 2026

b. EPIC Program Components

The CPUC established EPIC to assist the development of non-commercialized new and emerging clean energy technologies in California while aiding commercially viable projects. EPIC consists of three program areas: (1) applied research and development; (2) technology demonstration and deployment; and (3) market facilitation, consisting of market research, regulatory permitting and streamlining, and workforce development activities. The California Energy Commission (CEC) is authorized to administer EPIC funds across all program areas, including a share of the Transmission, Distribution, and Deployment (TD&D) category. In contrast, SDG&E and the other IOU administrators are authorized to administer EPIC funds solely within the TD&D category. EPIC activities must be designed to produce electricity ratepayer benefits for SDG&E, Pacific Gas and Electric (PG&E), and Southern California Edison (SCE) customers.

EPIC funding is collected from electric utility customers, with allocation shares of approximately 50.1 percent from PG&E customers, 41.1 percent from SCE customers, and 8.8 percent from SDG&E customers. The CEC administers approximately 80 percent of the funds to support research, development, and market facilitation activities statewide, while the IOU administrators manage the remaining 20 percent to demonstrate and validate pre-commercial technologies on the electric grid. Based on its share of collections and the portion allocated to utility administrators, SDG&E administers approximately 1.76 percent of total EPIC program funding. These investments are focused on evaluating innovative technologies that can improve electric system performance and provide long-term value to customers.

During 2025, SDG&E continued to advance the strategic objectives and initiatives outlined in its EPIC-4 Investment Plan by implementing technology demonstrations and planning activities that support grid modernization and improved integration of DERs. Across the portfolio, projects advanced new tools, expanded operational capabilities, and developed testing platforms designed to improve system visibility, enhance resilience, and support the reliable integration of clean energy resources.

Under the **Grid Modernization** strategic initiative, projects strengthened situational awareness and operational flexibility through technologies that improve monitoring, fault detection, and resilient power capabilities. Progress included the delivery of a new analytical tool to support optimal placement of phasor measurement units (PMUs), advancement of integrated power quality and smoke detection monitoring capabilities, and demonstrations of innovative resilience solutions such as a mobile nanogrid and Vehicle-to-Everything (V2X) applications at Community Resource Centers.

Progress was also made under the **DER Integration** strategic initiative, where activities focused on improving the ability of DERs to provide operational flexibility and value to both customers and the grid. The Zonal Electrification with Integrated DER project advanced methodologies to better align electrification and DER deployment with grid needs, while development of the ITF Microgrid Testbed provides a controlled environment for evaluating DER interoperability and control strategies prior to field deployment.

Together, these activities demonstrate continued progress toward SDG&E's EPIC strategic objectives of creating a more nimble grid and increasing the value proposition of DERs. By validating innovative technologies, improving integration capabilities, and informing future deployment strategies, SDG&E's EPIC portfolio continues to generate insights that support California's clean energy transition while delivering long-term reliability, safety, equity and affordability benefits for customers.

c. **Coordination**

To promote effective coordination of the EPIC Program and prevent unnecessary duplication, the EPIC Administrators continued to engage in regular meetings, joint IOU workshops and webinars, and in ongoing collaboration on program-related activities.

During implementation of the EPIC-4 Investment Plan and in preparation for the EPIC-5 Investment Plan, SDG&E worked closely with co-administrators. Additionally, SDG&E has continued to coordinate with colleagues from Gas R&D, specifically SoCalGas. This collaboration included recurring conference calls, and participation/attendance in the other Administrators' public workshops. These coordinated efforts are intended to align investment plans, ensure complementary investments and avoid redundant activities.

SDG&E remains committed to supporting the Policy and Innovation Coordination Group (PICG) EPIC Project Database by submitting detailed quarterly updates on active EPIC projects. These updates provide information on project progress, key milestones, major findings, and next steps, helping ensure stakeholders have clear and timely insight into program activities. Through regular reporting to the PICG database, SDG&E enhances transparency into portfolio performance and demonstrates how EPIC investments are delivering benefits to customers.

SDG&E is tracking several CPUC proceedings that align with EPIC priorities, including microgrids, vehicle electrification, DER integration, climate adaptation, and long-term gas system planning and provides feedback on how EPIC can provide value. The following proceedings are being tracked by the EPIC Program Manager:

- Microgrid Order Instituting Rulemaking (OIR) (Rulemaking (R.) 19-09-009)
- Development of Rates and Infrastructure for Vehicle Electrification OIR (R.18-12-006)
- Higher DER OIR (R.21-06-017)
- Climate Change Adaption (R.18-04-019)
- Establish Policies, Processes, and Rules to Ensure Safe and Reliable Gas Systems in California and Perform Long-Term Gas System Planning OIR (R.24-09-012)

Equity-focused Coordination:

Equity-focused coordination is embedded throughout EPIC-4 through engagement with groups such as the Disadvantaged Community Advisory Group (DACAG), community-based organizations (CBOs), local government, and alignment with the ESJ Action Plan. EPIC-4 projects are structured to meet established equity targets, including directing at least 25% of project benefits to Disadvantaged Communities (DACs) and 10% to low-income communities.

In addition, SDG&E supports workforce development by hiring interns from DAC communities to participate in EPIC projects, including the Nanogrid and CRC V2X initiatives.[10]

Details and dates of stakeholder events held throughout 2025 are provided in the table below.

Table 3. EPIC Events

Stakeholder Event Name	Date	Details
Joint IOU Annual EPIC Workshop	July 15, 2025	Hybrid Event, SDG&E attended and presented on an EPIC-4 Project, 227 virtual, 90 in-person
CBO Mid-Year Webinar	July 22, 2025	SDG&E presented on active EPIC projects and DAC intern opportunity, 60 people in attendance
CEC EPIC Symposium	October 7, 2025	SDG&E attended
SDG&E EPIC-4 Public Workshop	November 12, 2025	Presentation of EPIC-4 Project, 34 people in attendance
eTruc DAC Workforce Development Working Group	November 4, 2025	SDG&E participates in Working Group meetings
EPIC-5 Workshops	December 3-5, 2025	SDG&E SMEs attended each workshop

d. Transparent and Public Process/CEC Solicitation Activities

In 2025, SDG&E partnered with University of California San Diego (UC San Diego) to apply to the CEC's EPIC Grant Funding Opportunity (GFO)-24-312: Advanced Grid Technology Acceleration Projects for the San Diego Supercomputer Center, and technology innovators. The project proposes launching California's first at scale demonstration of a grid interactive AI data center powered by solid state transfer (SST) technology. As of this writing, CEC provided notice of proposed award to SDG&E.

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[10] Per Advice Letter 4512-E, SDG&E is committed to equity in workforce development, internships, and education.

3. Budget

SDG&E supports the Commission's direction to promote affordability by minimizing costs where feasible. SDG&E's EPIC administrative budget is already structured with a lean staffing model designed to provide the minimum resources necessary to meet program oversight and regulatory compliance requirements. Administrative staff support essential functions such as program management, reporting, financial oversight and coordination with the CPUC and other EPIC Administrators. As of 2025, SDG&E is staffed with one full-time employee dedicated to EPIC program administration. Due to the increased complexity and volume of work required to comply with all EPIC requirements, opportunities for additional cost reductions are limited without significantly impacting SDG&E's ability to effectively implement the program. and meet regulatory obligations, which could lead to inefficiencies and potential non-compliance. In fact, SDG&E is currently evaluating staff resources needed to support EPIC in 2025 and beyond. Realistically, SDG&E may need to add resources to support the EPIC portfolio. However, SDG&E will continue to seek efficiencies where possible while maintaining the administrative capacity necessary to ensure program compliance and successful implementation of EPIC activities.

Current funding information for SDG&E's EPIC-3 and EPIC-4 Cycle is provided in Table 3.

a. Authorized Budget

Table 4 below sets forth SDG&E's Commission-authorized EPIC budget incurred costs for EPIC-3 and EPIC-4 as of December 31, 2025.

Table 4. SDG&E Budget and Incurred Costs for EPIC-3 and EPIC-4 (in $ thousands)

	EPIC 3 (2025)		EPIC 4 (2025)	
	Technology Demonstration & Deployment	Program Administrative	Technology Demonstration & Deployment	Program Administrative
SDG&E Commission-Authorized Budget[11]	8,852	916	14,571	1,628
SDG&E Incurred Costs[12] as of December 31, 2025	8,852	916	2,174	655

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[11] D.18-10-052 for EPIC-3 and D.21-11-028 Appendix B for EPIC-4

[12] Incurred costs mean actual booked expenditures.

Table 5 below sets forth SDG&E's Commission-authorized EPIC budget as of December 31, 2025, for EPIC-3 and its budget for EPIC-4 broken down by strategic objective, strategic initiative and research topic.

Table 5. SDG&E's EPIC-4 (2021 – 2025) and EPIC-3 (2018 – 2023) Budget as of December 31, 2025

Strategic Objective	**Strategic Initiative**	**Funding ($M)**	**Research Topic**	**Projects**	**Demonstrate within DAC or LI? (Y/N)**	**Budget ($M)**
Create a More Nimble Grid	Grid Modernization	$7.3	Communication & Control Infrastructure for Power System Technology Advancement	PMU Project	Yes	2.56
				PQ & Smoke Detection Integration	Yes	3.08
				V2G Project	Yes	1.6
			Mobile Microgrid	Renewable Mobile NanoGrid	TBD	1.14
				Sub Total		**8.38**[13]
Increase the Value Proposition of DERs to Customers on the Grid	DER Integration	$7.3	Integrated DER Operational Flexibility	Zonal Electrification w/ Integrated DER	TBD	4.31
				ITF Microgrid Testbed	Yes	1.89
				Sub Total:	**--**	6.19
				EPIC-4 Total:	**--**	**14.57**

NA	NA	$	NA	EPIC-3 Project 7 Mobile Battery	Yes	**$**
				EPIC-3 Total:	**0.613**	**4.67**

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[13] D.21-11-028, OP 10 allows for a transfer of 15% between Strategic Initiatives (S.I). SDG&E transferred 15% S.I. #2 into S.I. #1, rounding is presented for reader's ease

Table 6 below sets forth SDG&E's disbursements to the CEC and CPUC for EPIC-1, EPIC-2, EPIC-3, and EPIC-4 as of December 31, 2025.

Table 6. SDG&E's Disbursements to the CEC and CPUC for EPIC-1, EPIC-2, EPIC-3 and EPIC-4 as of December 31, 2025 (in $ thousands)

	EPIC Triennial 1 (2012 – 2014)		EPIC Triennial 2 (2015 – 2017)		EPIC Triennial 3 (2018-2020)		EPIC Quinquennial 4 (2021-2025)	
	RD&D	Program Administrative	RD&D	Program Administrative	RD&D	Program Administrative	RD&D	Program Administrative
SDG&E Disbursements to CEC	16,127	3,024	40,624	2,991	53,986	4,301	36,585	5,535
SDG&E Disbursements to Commission for Regulatory Oversight	N/A	273	N/A	224	N/A	384	N/A	243

b. Commitments/Encumbrances

Table 7. SDG&E's EPIC-4 (2021-2025) Portfolio as of December 31, 2025 (in $ thousands)

EPIC-4 Projects (2023 – 2025)				
EPIC-4 Projects	**Incurred[14] Costs**	**Encumbered[15] Costs**	**Commitments[16]**	**Project Status**
PMU	91	2,562	2,562	In progress
PQ and Smoke Detection Integration	1,842	3,076	3,076	In progress
V2G at CRCs	11	1,600	1,600	In progress
Mobile Nanogrid	194	1,140	1,140	In progress
Zonal Electrification w/Integrated DER	35	4,312	4,312	In progress
ITF Microgrid Testbed	0	1,881	1,881	In progress
SDG&E Program Administration	655	1,628	1,628	In progress

c. Fund Shifting Above 15% Between Strategic Initiatives

No funds were shifted in 2025.

d. Uncommitted/Unencumbered funds

Not applicable.

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[14] As used in this Report, incurred costs mean actual booked expenditures.

[15] As used in this Report, encumbered costs are funds that are specified for contracts (D.13-11-025 at 101; Ordering Paragraph 45) or for in-house work necessary in collaboration with a contractor (D.13-11-025 at 53). They differ from commitments in that commitments are the identification of blocks of funds to be assigned to projects, whereas encumbrances specify how the commitments will be used in the projects.

[16] As used in this Report, commitment means assigned for anticipated work on a project, including anticipated contractual commitments, equipment purchases, software licenses, associated technical work by the SDG&E project team, and other expenses directly associated with the project work.

4. SDG&E EPIC-3 and EPIC-4 Projects

a. High Level Summary

Project highlights comprising the Strategic Initiatives are provided in Table 2.

Table 8. SDG&E's EPIC-4 (2021-2025) Portfolio as of December 31, 2025

EPIC-4	Incurred[17] Costs ($ thousands)	Encumbered[18] Costs ($ thousands)	Commitments[19] ($ thousands)	Funding Status
Strategic Initiative: Grid Modernization	2,138	7,285	7,285	In Progress
Strategic Initiative: DER Integration	35	7,285	7,285	In Progress
SDG&E Program Administration	655	1,628	1,628	In Progress
Total[20]	**2,829**	**16,198**	**16,198**	

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[17] As used in this Report, incurred costs mean actual booked expenditures.

[18] As used in this Report, encumbered costs are funds that are specified for contracts (D.13-11-025 at 101; Ordering Paragraph 45) or for in-house work necessary in collaboration with a contractor (D.13-11-025 at 53). They differ from commitments in that commitments are the identification of blocks of funds to be assigned to projects, whereas encumbrances specify how the commitments will be used in the projects.

[19] As used in this Report, commitment means assigned for anticipated work on a project, including anticipated contractual commitments, equipment purchases, software licenses, associated technical work by the SDG&E project team, and other expenses directly associated with the project work.

[20] Total pursuant to Appendix B of D.21-11-028 but could vary due to rounding.

b. Project Status Report

The following summaries highlight SDG&E's progress on ongoing projects and work completed in 2025.

i. Strategic Initiative: Grid Modernization

In 2025, several EPIC – 4 projects supported advancement of SDG&E's grid and its operations, strengthening capabilities across monitoring, protection, maintenance and planning.

Phasor Measurement Units (PMU) Based Power Network Analysis for Increased Situational Awareness

Consistent with the EPIC objective of advancing projects that improve grid reliability, safety, and affordability in support of California's transition to 100 percent clean energy, this project advances the **Grid Modernization** initiative by enabling faster and more effective monitoring and security analysis of the local transmission system. As inverter-based resources (IBRs)—including battery energy storage systems—continue to expand across the transmission and distribution networks, grid operating conditions are becoming increasingly dynamic and complex. By enhancing real-time system visibility and analytical capabilities, this project enables quicker identification of security issues, reducing the risk of transmission or generator facility damage that could lead to extended outages. It also increases the deliverability of IBRs to the grid, supports the development of effective operational mitigation strategies, and helps defer more costly system upgrades. Collectively, these outcomes provide direct benefits to ratepayers through improved system reliability, enhanced operational efficiency, and avoided or deferred infrastructure costs, while supporting the safe and reliable integration of clean energy resources.

2025 Activities and Status:

In 2025, the project team successfully transferred contract administration for the annual support agreement with V&R Energy that covers the Physical and Operational Margin / Peak Region of Stability Existence (POM/Peak-ROSE) and Phasor Measurement Unit Region of Stability Existence (PMU ROSE) platforms. POM was provided to SDG&E through a DOE-funded project with Peak Reliability, the reliability coordinator prior to RC West. Peak-ROSE and PMU ROSE are customized versions of the POM. Additional administrative activity included the execution of a contract amendment on November 7, 2025, to incorporate development of a PMU placement program and associated input files, implement enhancements to the Linear State Estimation (LSE) and Real Time Contingency Analysis (RTCA) platforms, and provide vendor support for reviewing results generated by the placement tool, LSE and RTCA.

The PMU ROSE 2025 package, including the PMU placement tool, was delivered by the vendor, demonstrated to staff, and supported by a recorded training session.

Installation and online testing of the PMU ROSE 2025 package began with preparations for offline testing. In parallel, the project team initiated and conducted reviews of existing and proposed IBR interconnections both on the transmission and distribution network to assess potential system impacts.

Next steps focus on completing the PMU signal mapping review to incorporate updated signal names and newly added PMUs. Operating engineers will continue testing the automated PMU placement tool and building familiarity with the LSE platform. The team will also review the Purchase Request with System Protection Automation Control Engineering (SPACE) for procurement of PMU devices and associated communications equipment. Project execution will continue to account for resource constraints associated with the ongoing transition to a new EMS platform. The existing EMS platform is expected to support full node-breaker model exports, enabling more accurate topology-aware PMU signal mapping once the new EMS platform becomes available, expected in the third or fourth quarter of 2026.

Grid Resilience and Sustainability Through Integrated Vehicle to Everything (V2X) and Renewable Energy at Community Resource Centers (CRCs)

The project showcases how EVs can serve as flexible, sustainable energy assets, supporting peak shaving during high-demand periods, providing backup power during PSPS events, and enhancing overall grid resilience. By dynamically managing energy flow between EVs and other DERs such as solar PV, battery energy storage systems (BESS), and the grid, the initiative offers a scalable model for reducing energy costs, improving stability, and expanding renewable energy use, particularly in remote and disadvantaged communities at resilience support sites like Community Resource Centers (CRCs). Specifically, by leveraging AC bidirectional technology, this project aims to support future interconnection pathways for AC V2X and potentially lower cost bidirectional capabilities. The project supports the Grid Modernization Strategic Initiative by positioning EVs as DERs within a broader resilience framework. By demonstrating how EV-based technologies can be reliably integrated into grid operations at a pilot level and scaled to multiple sites, the project advances and informs long-term customer pathways and grid modernization efforts by improving reliability, accelerating clean energy adoption, and expanding customer-centric resilience solutions that can scale.

2025 Activities and Status:

During 2025, the project advanced from vendor solicitation through an RFP and concept development to deployment readiness. Early-year activities focused on evaluating competitive proposals for AC and DC Vehicle-to-Everything (V2X) resilience solutions and identifying an initial pilot CRC site within SDG&E’s service territory.

The project then completed preliminary site design and scoping for the selected CRC, including AC bidirectional charging to support resilience during Public Safety Power Shutoff events. Technical research and market assessment informed charger selection and refined the project scope to align with site-specific requirements and emerging standards.

In the second half of the year, efforts centered on finalizing a scalable contracting approach, separating software and construction services to support expedited approvals and future multi-site deployment beyond the initial CRC site. Additionally, SDG&E identified a shortlist of additional CRCs and resilience sites that could benefit from this technology as candidates for additional deployment under this pilot. SDG&E also led coordination with internal stakeholders, CRC hosts, the CEC and the Joint IOU–Working Groups to advance AC bidirectional UL certification and Rule 21 readiness for AC bidirectional charging. Collectively, these activities positioned the project for safe, compliant, and cost-effective deployment of AC V2X charging infrastructure across Community Resource Centers and other commercial and residential sites as standards mature and use case opportunities expand.

Power Quality (PQ) and Smoke Detection Integration

Power Quality (PQ), Electric Fault Data (EFD), and smoke detection will be integrated into a single platform to monitor, alarm, and quickly locate events on circuits. By using machine learning and real-time data, the system will provide actionable information to reduce response times and focus patrol efforts.

The integration of PQ, EFD, and smoke detection supports the Grid Modernization Strategic Initiative by improving public safety and reliability through advanced intelligence and accelerated detection.

2025 Activities and Status:

Early milestones centered around team and sub working group formation, vendor assessment, and procurement efforts. A formal kickoff with the vendor was completed and notification letters and door hangers for Smart Meter 2.0 pilot deployments made up much of the efforts during the first half of the year.

Accomplishments in the third quarter were related to hardware acquisition and residential site assessments. SDG&E began the acquisition process of the necessary meters and meter adapters for installation on customer sites. More than 300 preliminary residential site assessments were conducted, identifying more than 75 meters that met initial project qualifications. Additionally, waveform analytic devices were procured for installation at two substations that supply the circuits under evaluation. A presentation on this project was presented at the Joint IOU Workshop in July 2025.

During Q4, the project advanced from planning and procurement into early field deployment and data integration, making the transition toward operational capability. Key milestones included completion of the first round of extensive residential site assessments, initial installation readiness for advanced metering and access point infrastructure, and successful validation of LTE connectivity required to support waveform data capture. Progress was also made across complementary data streams, including smoke sighting analysis, PQ data integration, and PMU data transfer.

Renewable Mobile Nanogrid for Climate Resiliency

This demonstration will evaluate the nanogrid as a backup power solution for CRCs, enhancing reliability and resilience by operating independently or in coordination with stationary assets.

Featuring a built-in solar canopy, hydrogen production and storage, battery integration, and atmospheric water generation, the system can also function as a mobile command center. Beyond emergency use, it serves as an educational platform to raise public awareness about renewable technologies, including hydrogen solid-state storage. This work directly supports the Grid Modernization strategic initiative by demonstrating flexible, modular energy solutions that can be rapidly deployed. By validating mobile and island-able resources that enhance operational flexibility, the project advances the strategic objective of creating a nimbler grid capable of responding to evolving reliability and resilience needs.

2025 Activities and Status

Over the course of 2025, the project advanced the deployment, demonstration, and planning activities necessary to position the nanogrid asset for operational use and future testing. Early efforts focused on system verification and readiness, including development of installation, performance, and safety checklists in coordination with the vendor. Staff identified and prepared an optimal on-campus location for long-term deployment, balancing safety and security considerations, and completed installation of educational wraps to highlight the nanogrid's use cases and emerging technologies.

The nanogrid was successfully deployed for public and stakeholder engagement, including a demonstration at a Wildfire Safety Fair, supporting knowledge sharing and outreach. Throughout the year, the project expanded internal and external coordination to showcase the technology, explore additional use cases, and evaluate integration opportunities.

Further work included coordination with internal teams to assess applications related to DER deployment, wildfire mitigation, and replacement of traditional generators. These efforts collectively support pre-commercial validation and prepare the project for expanded stakeholder deployments in 2026 and a long-duration hydrogen demonstration planned for 2027.

ii. Strategic Initiative: DER Integration

Zonal Electrification with Integrated Distributed Energy Resources (IDER) for Operational Flexibility

The purpose of this demonstration is to explore customer decision-making by integrating DER flexibility and promoting electrification, particularly for underserved customers. The project aims to capture and understand the decision-making process of customers, ensuring the benefits of electrification and DER flexibility are accessible to all, inclusive of DACs. The project will build on previous field testing and demonstration of the Institute of Electrical and Electronics Engineers (IEEE) 2030.5 protocol where feasible, ensuring interoperability and the ability to demonstrate grid flexibility use cases. Additional communication protocols may be introduced as needed to ensure signaling of as many electrified end uses as possible. As part of a broader effort, the project will establish production Distributed Energy Resource Management System (DERMS) integration requirements. This includes ensuring the coexistence of DERMS with existing SDG&E technology components, which is crucial for optimizing the overall distribution system operator environment. By integrating these systems, SDG&E aims to enhance the efficiency and reliability of its distribution network, in support of its strategic objectives: Increase the Value Proposition of DERs to Customers on the Grid and Strategic Initiative: DER Integration.

2025 Activities and Status

Planning and research activities to support development of the Zonal Electrification Tool comprised the majority of project work during the first half of 2025. Key accomplishments during this period include building the project team, defining the tool's mapping requirements, and obtaining internal and external cost estimates for developing the tool. It was determined to proceed with an internal development of the tool led by SDG&E's IT department. Discovery discussions were initiated with internal stakeholders in Q4 2025; selection tool development is scheduled to begin in Q1 2026.

Continued stakeholder engagement and industry coordination, particularly through contracted participation in the Electric Power Research Institute's (EPRI) FLEXIT project, helped ensure the tool design reflects operational realities as well as DER signaling and integration capabilities. In parallel, research activities focused on understanding how electrification measures and customer solution packages can be aligned with grid needs to maximize overall system value.

Additionally, the project advanced the zonal selection methodology by identifying core data inputs to support equitable, targeted, and data-driven electrification planning.

ITF Microgrid Testbed

As SDG&E moves towards California's goal of renewable energy by 2045, utilizing behind the meter DER will be an integral part of reaching that goal. By developing this state-of-the-art microgrid testbed, SDG&E will collaborate with our Electric Distribution Operations Department to prepare for the leveraging of renewable energy for improved reliability, safety and environmental sustainability.

The aim of this project is to build a new and innovative microgrid testbed at SDG&E's ITF and conduct trial testing of IEEE 2030.5 gateways and DER controllers in a safe environment. The project will include collaboration with SDG&E's Electric Distribution Operations to test their IEEE 2030.5 head end controller with the project use cases.

Objectives of the ITF Microgrid Testbed include:

- Build Microgrid Testbed
    - Capable of evaluating multiple IEEE 2030.5 gateways
    - Capable of evaluating multiple grid edge system controllers
    - Integration with Distribution Operations Test Environment for full integration testing
- Improve Safety

    - Lab environment will allow renewable energy systems to be tested in a safe, controlled manner
- Testing Integrity
    - Properly planned and built testbed will allow for repeatable tests with fewer unpredictable variables such as weather, other personnel working in environment, etc.
    - Full control over all equipment: OT hardware, IT hardware, software, firmware versions, wiring, etc.
- Demonstrate Successful IEEE 2030.5 Operations
    - Demonstrate successful IEEE 2030.5 operations with production model equipment ranging from Distribution Operations head end all the way to BESS
    - Share lessons learned with the industry

2025 Activities and Status

In the early development stages of the project, key efforts focused on assembling the project team, identifying and evaluating potential vendors and initiating the procurement process. This included contract planning to secure the necessary expertise and tools for a successful project execution.

iii. Completed Projects in 2025

EPIC – 3 Project 7 – Demonstration of the Multi-Purpose Mobile Battery Energy Storage System

Module 3 Mobile Battery Energy Storage System – Additional Use Case

SDG&E completed a demonstration of an additional use case for the MBESS by integrating the mobile battery with a pre-assembled distribution interconnection equipment trailer, referred to as the MBESS companion trailer. The companion trailer incorporates key interconnection equipment, including a step-up transformer, grounding bank, protective switchgear, and connection infrastructure, into a single mobile platform designed to enable faster and more efficient deployment of temporary backup power. The demonstration evaluated the ability of the MBESS to connect to the electric distribution system and operate in parallel with diesel generators to support extended outage scenarios.

2025 Activities/Status:

In 2025, testing activities were conducted at SDG&E's Skills Training Center and included commissioning of the companion trailer, validation of electrical connections and protection systems, and operational testing of the MBESS and generators supplying load in parallel. The system successfully demonstrated automated control of generator operation based on the battery's state of charge using a real-time automation controller. When the battery reached a predefined minimum state of charge, the system-initiated generator operation to supply load and recharge the battery and automatically shut down generators once the battery reached its upper threshold. These tests confirmed the system's ability to seamlessly transition between battery and generator operation to sustain backup power during extended outages.

The demonstration also evaluated deployment efficiency. By integrating the required interconnection equipment onto a single trailer, the system significantly reduced setup time compared with traditional generator deployments that require transporting and assembling equipment individually. Previous deployments required an estimated 2.5 to 5 hours for equipment staging, cable installation, and system setup. The integrated trailer configuration substantially reduces labor requirements and deployment time, enabling faster restoration of temporary power to customers during emergency events.

This work provides important operational insights into the use of mobile energy storage systems for grid resilience and emergency response applications. By improving the speed and efficiency of deploying temporary power resources, the MBESS companion trailer concept has the potential to reduce outage durations and improve service reliability for customers during events such as PSPS or other prolonged outages.

The results and lessons learned from this demonstration were also shared with the broader industry through a presentation at DistribuTECH 2025, which was held in Dallas, Texas on March 24-27, 2025.

5. Conclusion

a. Key results for the year for SDG&E EPIC Program

SDG&E met a key milestone with the completion of the final module and use case of the EPIC - 3 Project 7, Demonstration of Mobile Battery Energy Storage System. At the same time, the company moved forward with the projects under EPIC-4 and launched the ITF Microgrid Testbed with remaining EPIC funding.

b. Next Steps for EPIC Investment Plan

Looking ahead, SDG&E EPIC Program activities will focus on the planning and coordination required to support development of the next EPIC cycle. These efforts will include the strategic planning, stakeholder engagement and analysis to inform future investment priorities and ensure alignment with the strategic objectives approved for EPIC-5 and consistent with the Commission's direction in D.26-02-037[21]. EPIC-4 Project 6 ITF Microgrid Testbed plans on releasing a Request for Proposals in 2026.

c. Issues that may have major impact on progress in projects, if any.

Tariffs affecting clean energy technologies, combined with rising costs and increased supply chain volatility, created some challenges for project development. For example, some projects had vendors reissue and increase quote costs due to increased construction materials costs.

Additionally, SDG&E continues to experience regulatory barriers to the implementation and sharing of innovations derived from EPIC projects. The three primary regulatory barriers are CPUC General Order (GO) 173, CPUC Section 851 and CPUC GO 165.

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[21] Decision Adopting Electric Program Investment Charge Strategic Objectives, issued March 2, 2026

Appendix A

CPUC Staff Guidance for EPIC Annual Report

ED Staff Guidance to EPIC Administrators on EPIC Annual Report Content

February 26, 2025

In response to Electric Program Investment Charge (EPIC) administrator requests for guidance on EPIC 2024 annual report content, CPUC Energy Division (ED) Staff provides the following guidance based on Commission EPIC decisions.

EPIC administrator annual reports should provide broad context and outcomes which demonstrate to the Commission and stakeholders the purpose, value, and impact of ratepayers' EPIC program investments.

The EPIC annual reports should serve as the narrative roadmap to complement complete EPIC database entries and tell a plain language story on outcomes at the initiative and project levels. The narrative should demonstrate alignment with the administrator's approved investment plans for efficiency of comparison and include fundamental problems to be solved, what the earlier efforts were and how they have led to current efforts, and how these efforts are anticipated to evolve through additional RD&D, such as scaling, deployment, and commercialization to create measurable impacts in terms of ratepayer benefit.

Administrators should tell a holistic story of EPIC investments over the life of the research describing the problem being addressed, proposed initiative to address, alignment with CPUC proceedings, coordination with other administrators, specific project efforts, and illustrate clear outcomes that demonstrate progress in achieving the State's climate goals.

The guidance below builds off established CPUC requirements for annual reports and highlights key points that should be addressed.[1]

Holistic Approach to Annual Reporting

- Annual reports are necessary for ongoing transparency and compliance, as well as understanding program effectiveness, and provide a basis for assessing the need for program modifications.[2]
- The annual report narratives should complement the database, not duplicate it.[3]
- Narratives should include program overviews, coordination efforts, transparency mechanisms, fund shifting, key results, and next steps.[4]
- Annual reports should summarize how past year activities have made progress in addressing investment plan Strategic Objectives and Strategic Initiatives.[5] In

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[1] Decision (D.)13-11-025 at Attachment 5 and D.23-04-042 at Appendix C.

[2] D.23-04-042 at 37.

[3] D.23-04-042 at 37.

[4] D.23-04-042 at Finding of Fact (FOF) 15.

[5] D.23-04-042 at Appendix C(1)(a).

doing so, administrators should align summaries with relevant investment plans as well as with previous reports to create continuity from year to year in demonstrating progress.

- Describe project outcomes including how results will be scaled and they be deployed, what their near-term and long-term impacts are anticipated to be, and how they support or leverage concurrent efforts – including impacts for DVCs.

Program Impact

- Address EPIC's mandatory guiding principle to provide ratepayer benefits defined as: (1) improving safety, (2) increasing reliability, (3) increasing affordability, (4) improving environmental sustainability, and (5) improving equity, all as related to California's electric system.[6]

Report Organization

- Ideally, administrators will organize reports around the Commission's adopted Strategic Goals[7] for efficiency of evaluating the progress of EPIC investments going forward to demonstrate ratepayer benefits and impacts in achieving the state's clean energy and climate goals.[8]

Database Requirements

- To be in compliance, the EPIC database must be up-to-date at the time of annual report submission and contain sufficient information details to complement the annual report narrative, as described above.[9]

Regulatory Barriers

- Include any impediments or setbacks impacting project portfolios. This includes regulatory barriers that may impede sharing information or technology among those that could benefit from such information and technology transfer.[10]

Emerging Issues

- Requirements for annual reporting are minimum requirements — EPIC administrators are free to provide additional information providing context on their activities and plans to the Commission and stakeholders in their annual reports.
- Administrators may describe opportunities to leverage EPIC innovation investments for learnings and deployments for emerging issues and events to

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[6] D.21-11-028 at OP 2 and at Appendix A.

[7] D.24-03-007 at OP 1.

[8] D.23-04-042 at 14-15.

[9] D.23-04-042 at 38.

[10] D.23-04-042 at Appendix C(1)(a) and C(4)(a).

support rebuilding of populated areas impacted by natural disaster. Articulating such opportunities and challenges that may be encountered can help provide the Commission and stakeholders with a holistic view and understanding of EPIC's value (e.g., January 2025 Southern California wildfires; January 2025 lithium-ion battery fire at Moss Landing).

Appendix B – List of Acronyms

AC	Alternating Current
AI	Artificial Intelligence
CBO	Community-Based Organization
CEC	California Energy Commission
CRC	Community Resource Center
CPUC	California Public Utilities Commission
DAC	Disadvantaged Community
DACAG	Disadvantaged Community Advisory Group
DER	Distributed Energy Resource
DERMS	Distributed Energy Resource Management System
DVC	Disadvantaged Vulnerable Community
EFD	Electric Fault Data
EMS	Energy Management System
EPIC	Electric Program Investment Charge
EPRI	Electric Power Research Institute
EV	Electric Vehicle
GFO	Grant Funding Opportunity
GHG	Greenhouse Gas
IBR	Inverter-Based Resource
IDER	Integrated Distributed Energy Resources
IEEE	Institute of Electrical and Electronics Engineers
IOU	Investor-Owned Utility
IIJA	Infrastructure Investment and Jobs Act
IRA	Inflation Reduction Act
ITF	Integrated Testing Facility
L2	Level 2 Charging
LSE	Linear State Estimation
LTE	Long-Term Evolution (wireless communication standard)
MBESS	Mobile Battery Energy Storage System
OIR	Order Instituting Rulemaking
OP	Ordering Paragraph
PG&E	Pacific Gas and Electric Company
PICG	Policy and Innovation Coordination Group
PMU	Phasor Measurement Unit
PQ	Power Quality
PSPS	Public Safety Power Shutoff
RAP	Research Administration Plan
RD&D	Research, Development, and Demonstration
RTCA	Real Time Contingency Analysis
SCE	Southern California Edison

SDG&E	San Diego Gas & Electric Company
SST	Solid-State Transformer
TD&D	Transmission, Distribution, and Deployment
V2G	Vehicle-to-Grid
V2X	Vehicle-to-Everything

Appendix C

EPIC-3 Project 7 Demonstration of the Multi-Purpose Mobile Battery Energy Storage System Final Report

EPIC Final Report

Program	Electric Program Investment Charge (EPIC)
Administrator	San Diego Gas & Electric Company
Project Number	EPIC-3, Project 7, Module 3
Project Name	Demonstration of Multi-Purpose Mobile Battery
Date	October 2025

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:

San Diego Gas and Electric (SDG&E)

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- Stephanie Lomeli
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- Mike Sanderson
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- Benedict Apilado
- George Cagle
- Chris Leclercq
- Barry Lockwood
- Cindy Phan
- David Winn
- Ming Zeng

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.

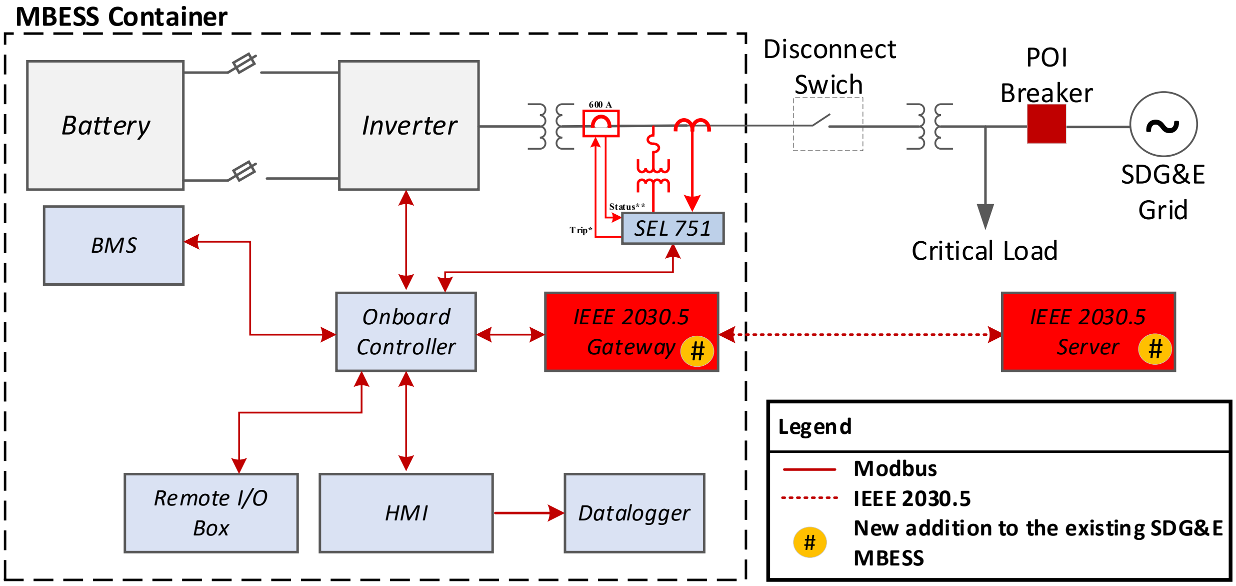
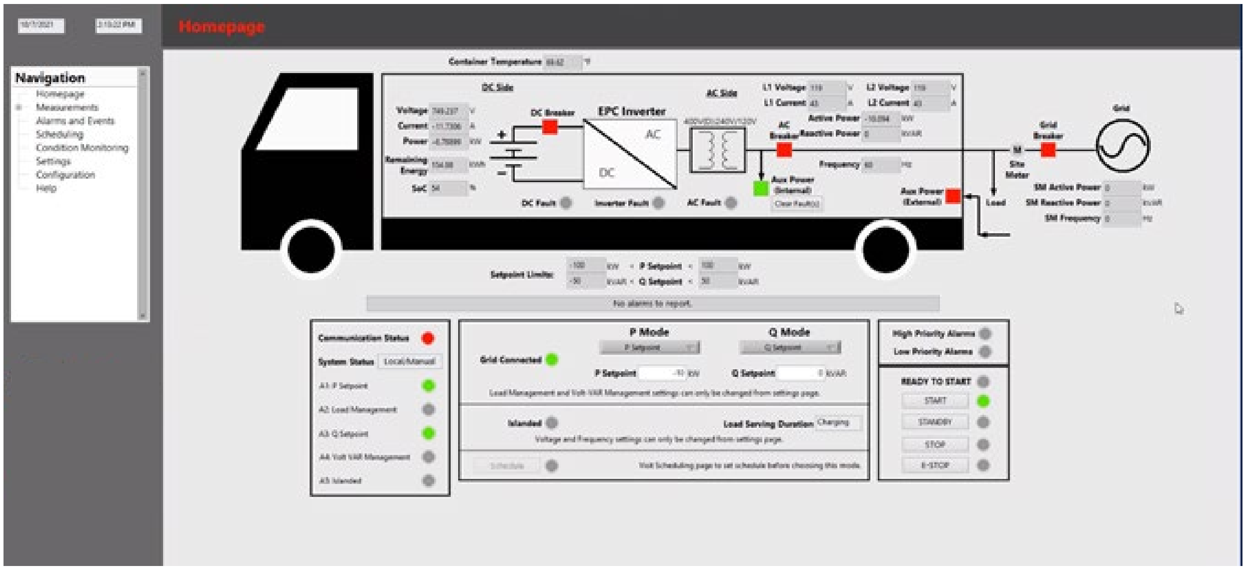


Figure 2-1. Simplified Schematic of MBESS

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

P Mode: P Setpoint

Q Mode: Q Setpoint

Load Serving Duration: Charging

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.

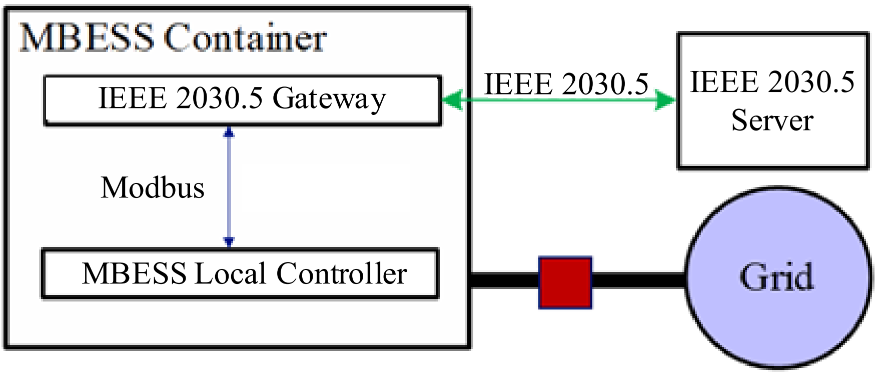


Figure 4-1. IEEE 2030.5 Standard Integration with MBESS

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.

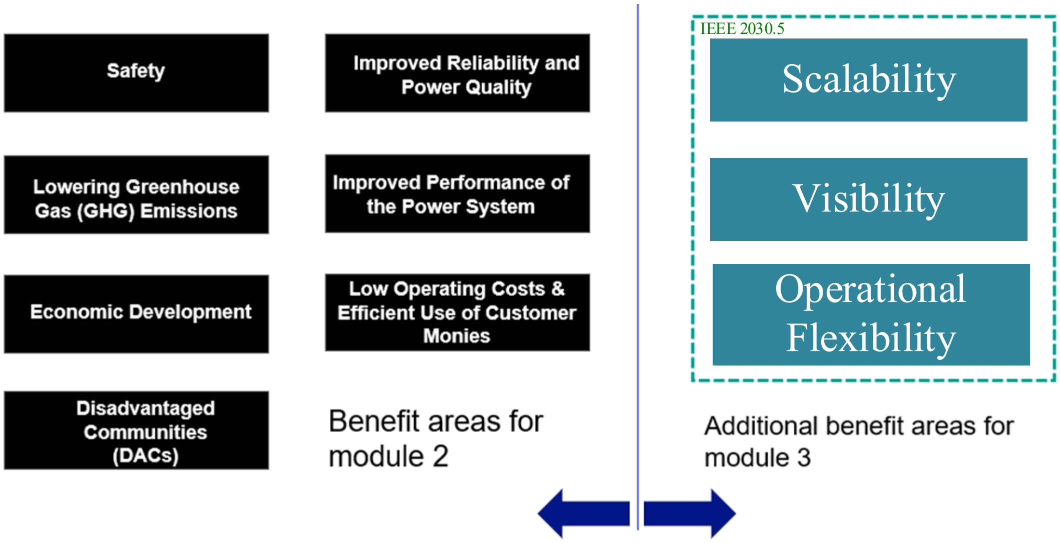


Figure 4-4. Benefit Areas in Module 2 Extended in Module 3

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.

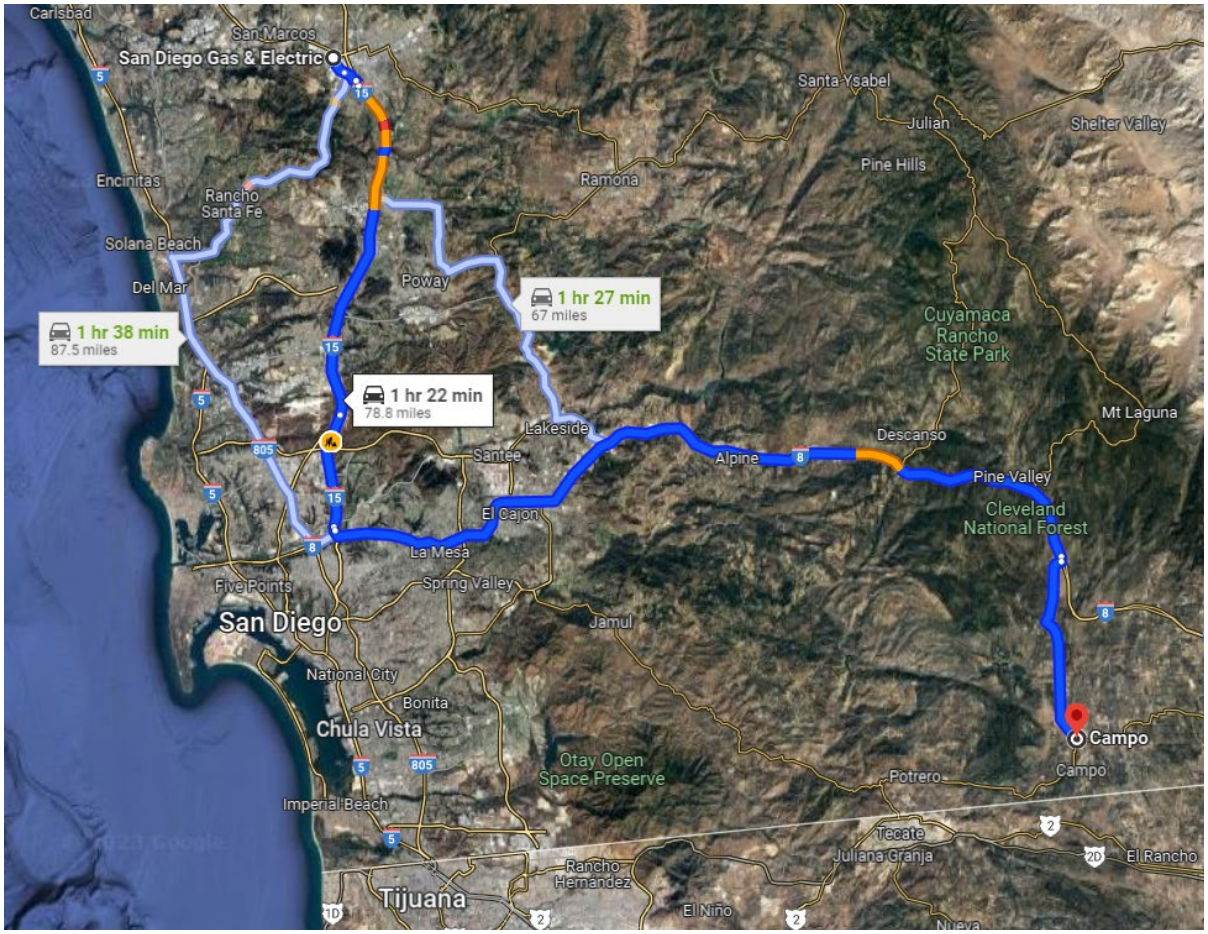


Figure 4-6. Path for Transporting the MBESS from the ITF to the Demonstration Site at Cameron Corners

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

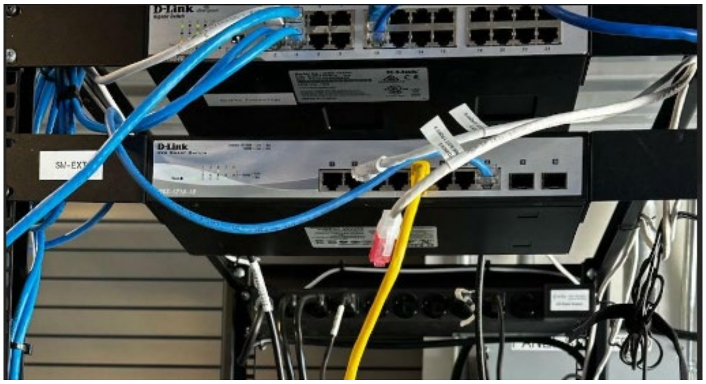
#	Use Case	Objective	Duration	Pass/Fail	Date
1	Flexibility during Grid Reconfiguration	Confirm the flexibility of the MBESS during grid reconfiguration through the IEEE 2030.5 server (DERControl: OpModMaxLimitW). Note that events are scheduled one at a time.	55 min	☒/☐	07/06/2023
2	Capacity Increase	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.

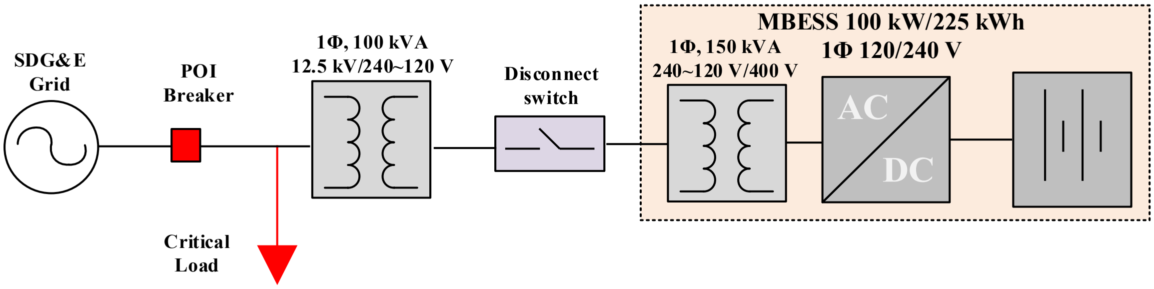


Figure 4-10. Setup of Cameron Corners Site Use Cases Demonstration

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.

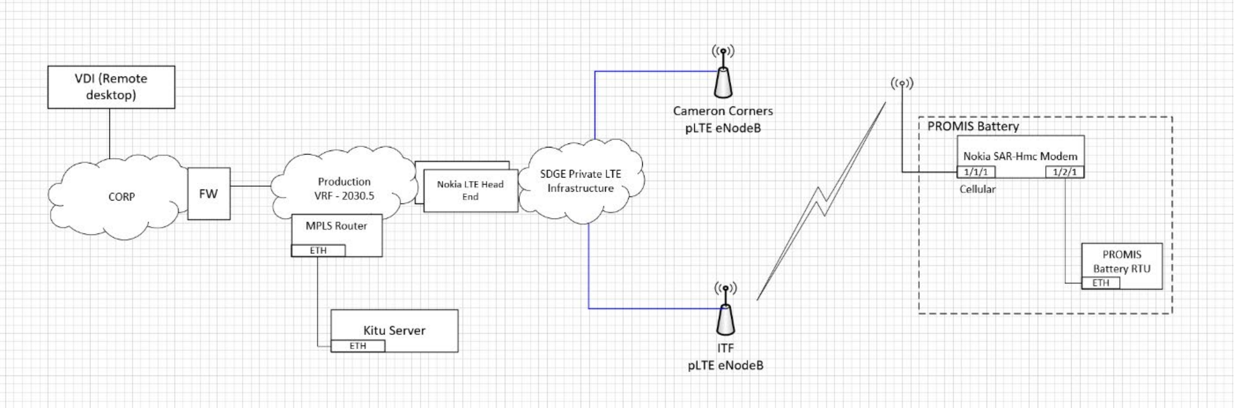


Figure 4-11. Network Block Diagram for the Field of the MBESS Using IEEE 2030.5 at Cameron Corners (PROMIS is Another Name for the MBESS)

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.

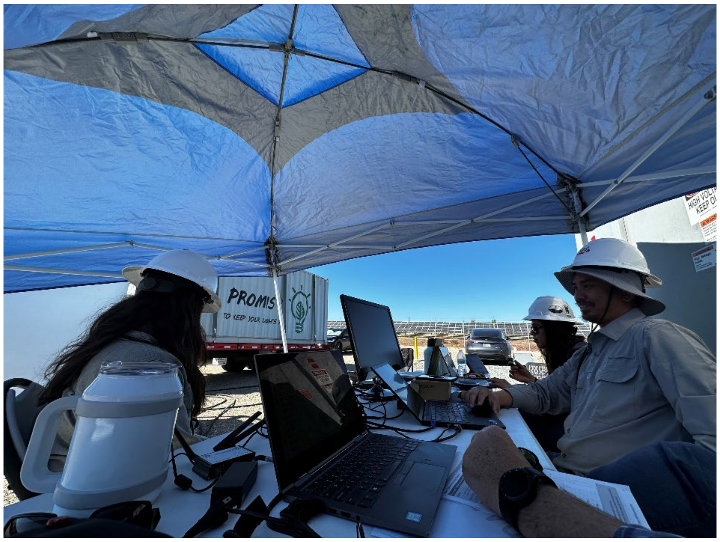


Figure 4-12. Picture Taken during the Field Test Demonstration at Cameron Corners

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.

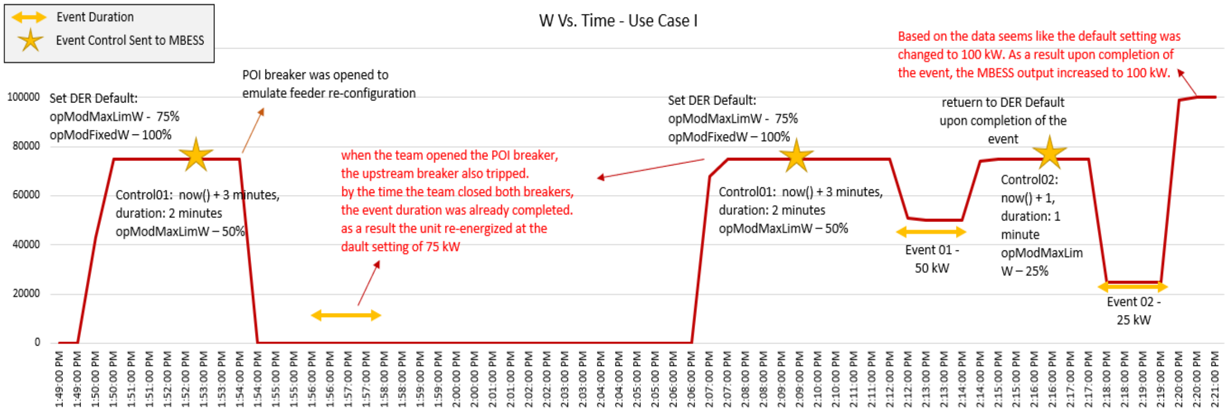


Figure 5-2. Use Case 1 "Flexibility During Grid Reconfiguration" Active Power Profile

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.

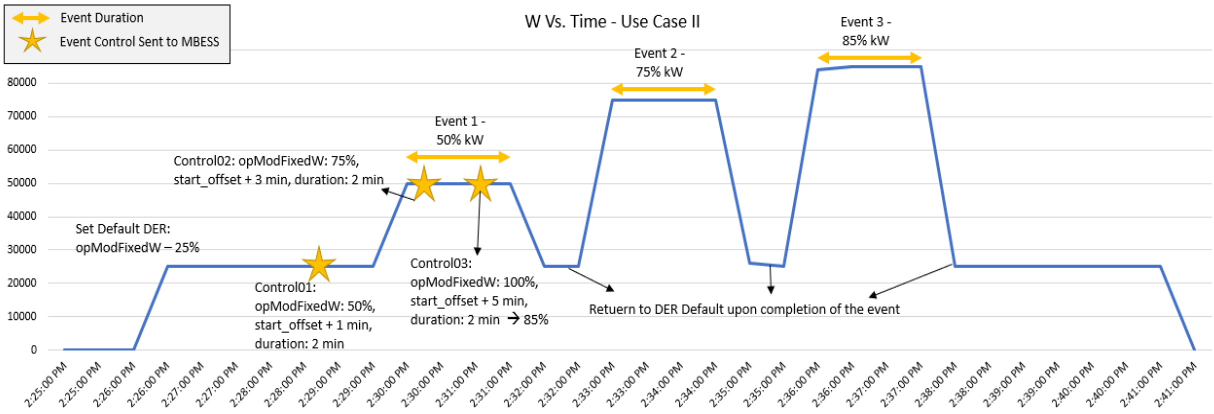


Figure 5-3. Use Case 2 "Capacity Increase" Active Power Profile

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.

(a)

(b)

(c)

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.

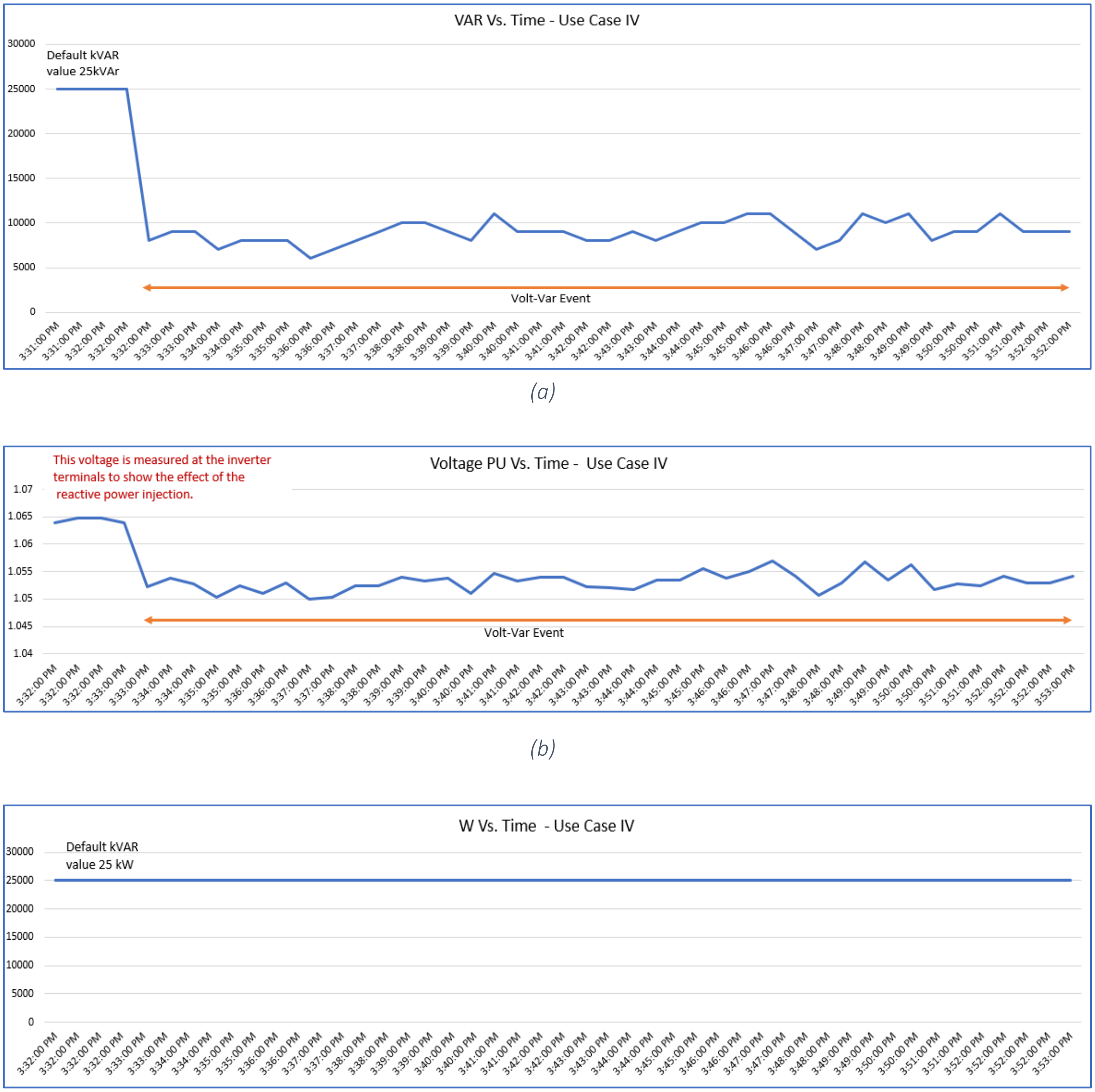


Figure 5-5. Use Case 4 "Voltage Reduction (Volt/Var)": (a) Reactive Power Profile, (b) Terminal Voltage Profile, and (c) Active Power Profile

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.

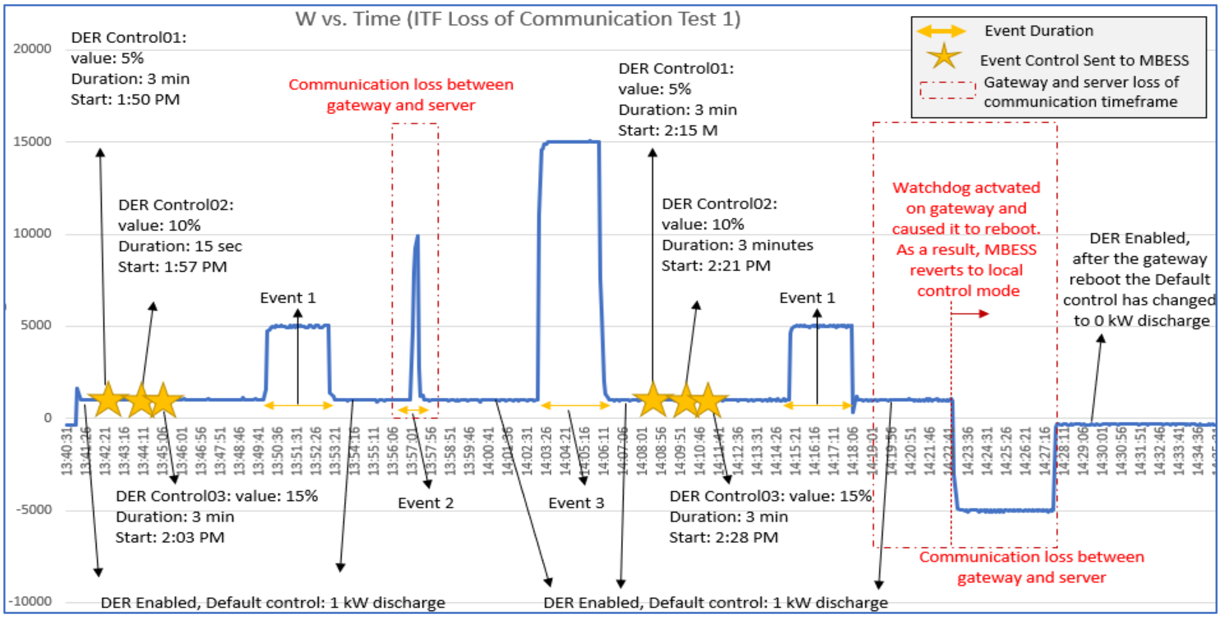


Figure 5-6. Communication Loss Scenario 1: Active Power Profile at MBESS Output during Server and Gateway Connection Loss at the ITF

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.

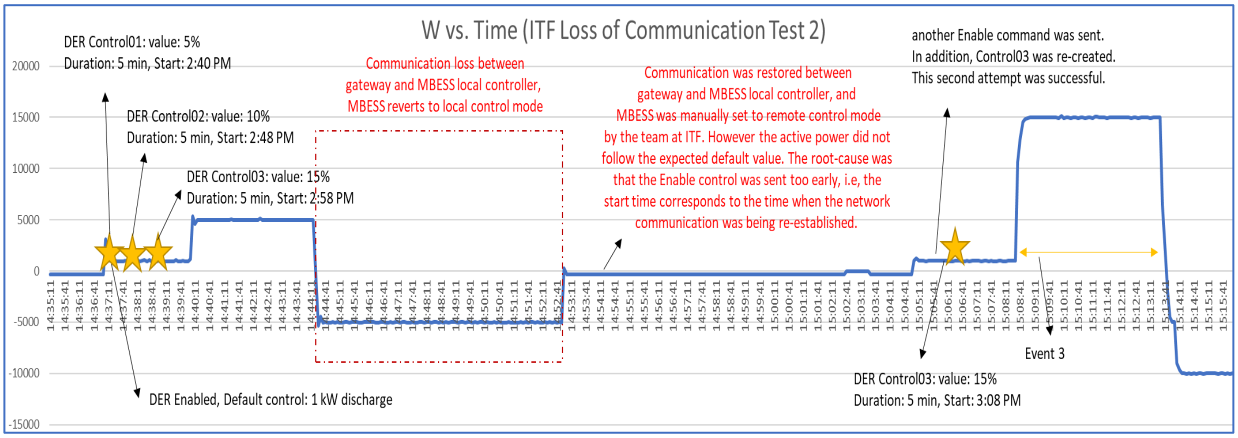


Figure 5-7. Communication Loss Scenario 2: Active Power Profile at MBESS Output during Gateway and MBESS Local Controller Connection Loss at ITF

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

[5]. “PROMIS Energization Sheet: Transportation Inspection and Checklist,” 2021

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.

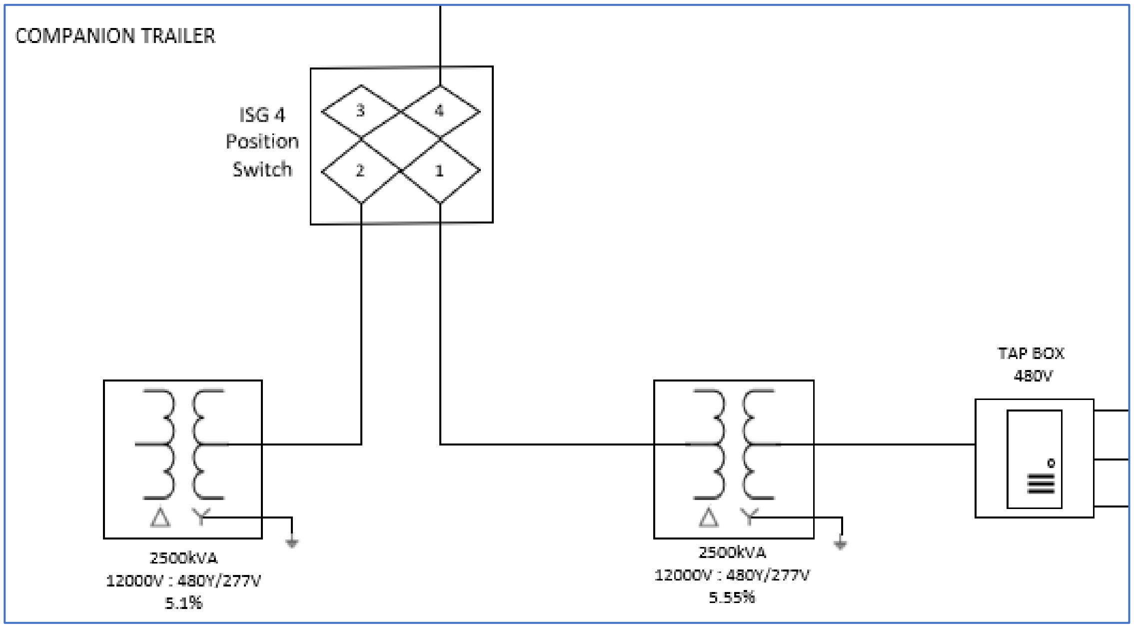

Figure 1. Companion Trailer Single Line Diagram

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.

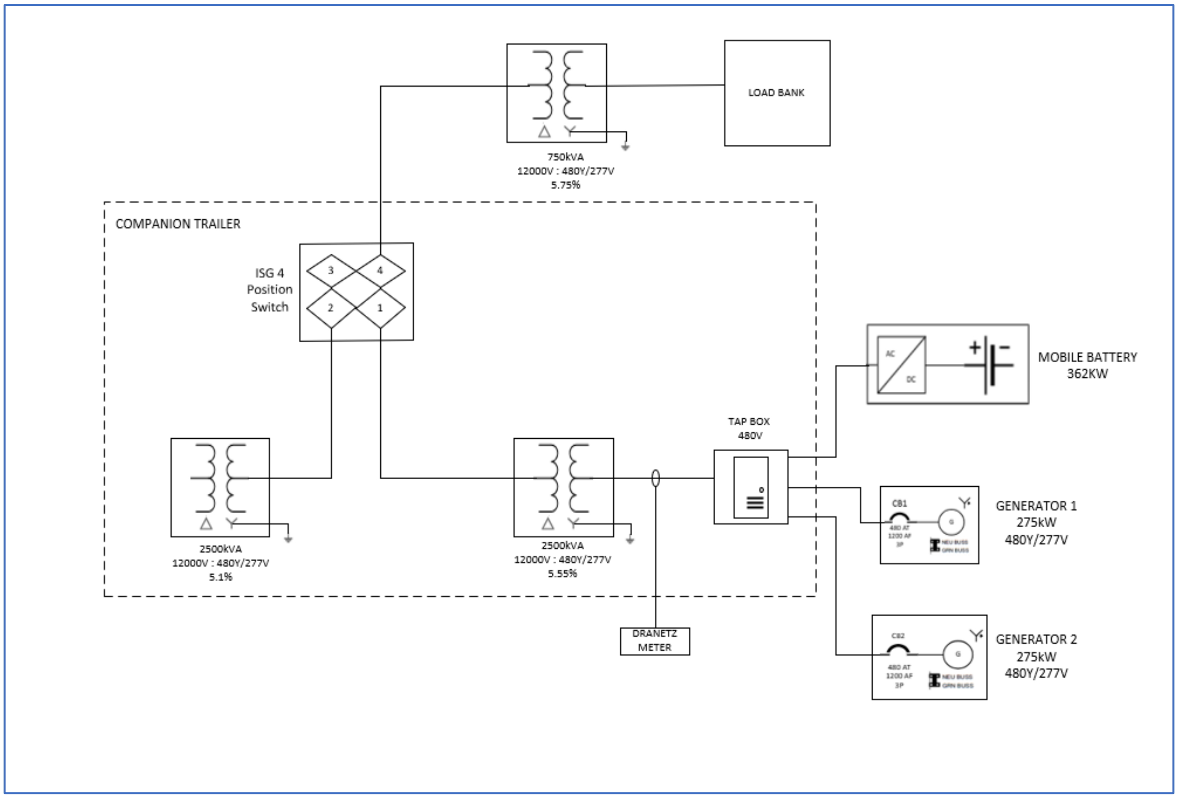

Figure 4. Single Line Diagram of Electric Connections

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.

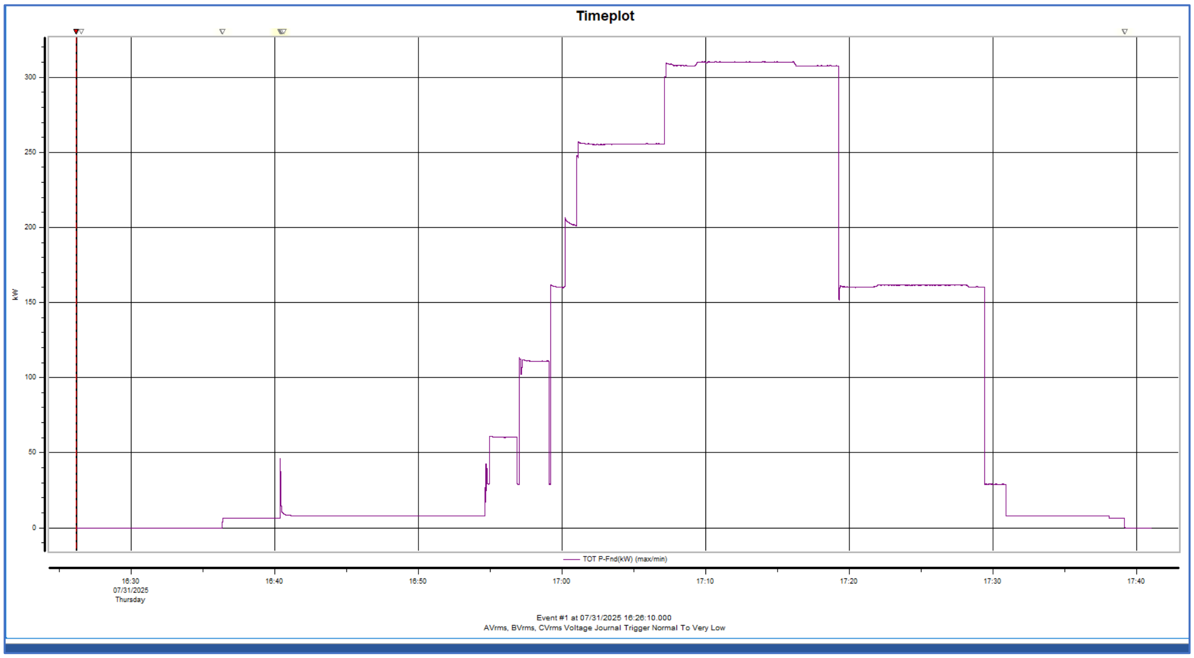

Figure 5. Power to Load Bank Meter Data

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.

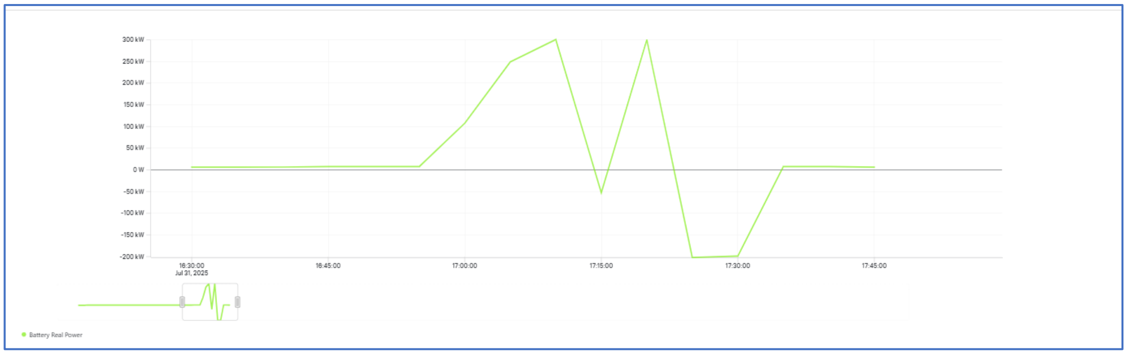

Figure 6. Power to Load Bank Meter Data

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.