ELECTRIC POWER RESEARCH INSTITUTE

Energy Storage Technology Performance 2017

Lithium Ion System Installation and Test Procedures Development, Lessons Learned and Interim Report

3002010895

Energy Storage Technology Performance 2017

Lithium Ion System Installation and Test Procedures Development, Lessons Learned and Interim Report

3002010895

Technical Update, December 2017

EPRI Project Managers

P. Ip
B. Westlake

ELECTRIC POWER RESEARCH INSTITUTE
3420 Hillview Avenue, Palo Alto, California 94304-1338 ▪ PO Box 10412, Palo Alto, California 94303-0813 ▪ USA
800.313.3774 ▪ 650.855.2121 ▪ askepri@epri.com ▪ www.epri.com

DISCLAIMER OF WARRANTIES AND LIMITATION OF LIABILITIES

THE ELECTRIC POWER RESEARCH INSTITUTE (EPRI) PREPARED THIS REPORT.

This is an EPRI Technical Update report. A Technical Update report is intended as an informal report of continuing research, a meeting, or a topical study. It is not a final EPRI technical report.

NOTE

For further information about EPRI, call the EPRI Customer Assistance Center at 800.313.3774 or e-mail askepri@epri.com.

ACKNOWLEDGMENTS

The Electric Power Research Institute (EPRI) prepared this report.

Principal Investigators
P. Ip
E. Minear
B. Westlake

This report describes research sponsored by EPRI.

EPRI acknowledges the efforts and time spent on this project by the following personnel from Southern California Edison:

Gabriel Andaya
Jorge Araiza, Jr.
Loic Gaillac

EPRI also acknowledges the following personnel for providing verbal and written contributions:

Steve Willard, EPRI
Evan Giarta, EPRI

Finally, EPRI acknowledges S. Hoffman of Hoffman Power Consulting for his editorial support.

This publication is a corporate document that should be cited in the literature in the following manner:

Energy Storage Technology Performance 2017: Lithium Ion System Installation and Test Procedures Development, Lessons Learned and Interim Report. EPRI, Palo Alto, CA: 2017. 3002010895.

ABSTRACT

As more energy storage systems deploy in the field, the transition from the research and development phase into operations requires a deeper understanding of the storage systems' performance and safety characteristics. This report helps project planners and test engineers understand the nuances of setting up a test environment for a test site or commercial battery energy storage system (BESS). The report provides general considerations for procuring, installing, commissioning, testing, and analyzing energy storage systems, supplemented with specific examples from a test bed case study. Using existing publicly available test protocols, such as the Energy Storage Test Manual 2016 published by the Energy Storage Integration Council (ESIC), a utility developed a set of test plans suitable for characterizing the BESS at the test site. This report documents specific challenges, experiences, and risk mitigation strategies from the project so far at the utility's test site in the form of lessons learned. Future test objectives include long-term battery degradation tests and grid simulator tests to investigate how the BESS reacts to simulated grid events. The lessons learned, results, and findings from this demonstration project are anticipated to provide technical insight for installing and testing energy storage systems in the future. Monitoring energy storage systems from technology specifications to deployment challenges allows for a thorough evaluation of recent energy storage technology development.

Keywords

Battery energy storage system
Energy Storage Integration Council
Energy storage performance testing
Energy storage system commissioning
ESIC
Procurement

Deliverable Number: 3002010895

Product Type: Technical Update

Product Title: Energy Storage Technology Performance 2017: Lithium Ion System Installation and Test Procedures Development, Lessons Learned and Interim Report

PRIMARY AUDIENCE: Utilities, project planners, laboratory researchers, suppliers, and testing personnel seeking guidelines to set up a test environment and develop test procedures for lithium ion battery systems

SECONDARY AUDIENCE: Energy storage system site owners and suppliers seeking guidance on how to characterize technical performance of deployed lithium ion battery systems

KEY RESEARCH QUESTION

As more energy storage systems deploy in the field, the transition from the research and development phase into operations will require a deeper understanding of the storage systems' performance and safety characteristics. Utilities and other stakeholders need to better understand the nuances of setting up a test environment for existing and recently deployed lithium ion battery storage systems. The objective of this report is to provide general considerations for procuring, installing, commissioning, testing, and analyzing energy storage systems, supplemented with specific examples from a test bed case study.

RESEARCH OVERVIEW

Test engineers can test and characterize battery energy storage system (BESS) performance by planning and executing a set of comprehensive tests. This report helps project planners and test engineers understand the nuances of setting up a test environment for a test site or commercial system. Using the publicly available test protocols this report provides, test engineers can develop test plans based on existing resources. The structure of this report gives test engineers general guidelines and describes unique challenges that may arise in implementing and testing an energy storage system. This report documents these challenges and lessons learned from the project so far and indicates potential risk mitigation strategies.

KEY FINDINGS

- Test engineers can modify existing test protocols to suit specific project needs by using standardized test procedures and definitions, shortening the time needed to develop a test plan.
- Publicly available test protocols, such as the Energy Storage Integration Council (ESIC) Energy Storage Test Manual, provide guidance on testing metrics and performance characteristics of energy storage systems.
- The testing team can plan preliminary tests as an opportunity to gain operational and troubleshooting experience with the BESS and associated test equipment.
- Lessons learned with installing and testing energy storage systems can lead to a deeper technical understanding of the performance capability and deployment challenges from the site owner's perspective.

EXECUTIVE SUMMARY

WHY THIS MATTERS

This report provides guidance for project planners and test engineers to understand the nuances of setting up a test environment for a BESS. This report describes general considerations for implementing, testing, and analyzing a BESS. Project phases such as procurement, design, installation, commissioning, testing, and analysis each contain unique challenges for project planners and test engineers. Using the publicly available test protocols this report provides, test engineers can develop test plans leveraging existing resources. The report describes general considerations and includes specific references to the installation and testing of a 150-kW/600-kWh lithium ion battery system at a utility test site. This report captures the challenges and lessons learned from the project so far and indicates potential risk mitigation strategies.

HOW TO APPLY RESULTS

The general considerations for configuring a BESS test environment serve as guidance for project planners and test engineers to implement future test systems. The lessons learned from a recent BESS deployment provide insights on how to leverage existing test protocols to customize a test plan. More broadly, performance testing results of recently deployed lithium ion battery systems are crucial indicators of the general performance levels of energy storage systems. Lessons learned from installing and testing energy storage systems can deepen technical understanding of performance capability and deployment challenges from the site owner's perspective. The performance test data's availability and accessibility impact the way in which project planners and test engineers assimilate testing and deployment considerations that affect system performance.

LEARNING AND ENGAGEMENT OPPORTUNITIES

- In EPRI's Energy Storage and Distributed Generation Program (P94), an overarching goal is to develop a comprehensive technology overview that evaluates the general performance, technology readiness level, and deployment status of recent energy storage technologies.
- The Energy Storage Integration Council (ESIC) is an open, technical forum devoted to the common understanding of needs and approaches to support the safe, reliable, and cost-effective application of energy storage to the electric power system. The Testing and Characterization Working Group (WG2) facilitates industry updates and reviews of activities and products related to the performance, testing, and specification of energy storage projects. More information about ESIC and its published resources can be found at www.epri.com/esic.

EPRI CONTACT: Peggy Ip, Engineer Scientist, pip@epri.com

PROGRAM: Energy Storage and Distributed Generation, P94

Electric Power Research Institute
3420 Hillview Avenue, Palo Alto, California 94304-1338 • PO Box 10412, Palo Alto, California 94303-0813 USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com

ACRONYMS

BESS	battery energy storage system
DER	distributed energy resources
DOR	division of responsibility
EPC	engineering, procurement, and construction
EPRI	Electric Power Research Institute
ESIC	Energy Storage Integration Council
FAT	factory acceptance test
GPS	global positioning system
GT&M	Grid Technology and Modernization
GUI	graphical user interface
HMI	human machine interface
ISO	independent system operator
PCS	power conversion system
PNNL	Pacific Northwest National Laboratory
PO	purchase order
PTO	permission to operate
RFO	request for offer
RFP	request for proposal
RFQ	request for quote
RTE	roundtrip efficiency
SCE	Southern California Edison
SOC	state of charge
SOE	state of energy
THD	total harmonic distortion

CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

The steep decline in lithium ion battery system costs in recent years propelled the increase of system installations across the grid. From transmission to distribution and customer-sited projects, project planners are investigating how lithium ion battery systems help meet grid needs in a cost-effective, safe, and reliable manner. As more energy storage systems deploy in the field, the transition from the research and development phase into operations will require a deeper understanding of the storage systems' performance and safety characteristics. Battery energy storage system (BESS) performance can be tested and characterized by planning and executing a set of comprehensive tests. This report intends to help project planners and test engineers understand the nuances of setting up a test environment for a test site or commercial system. Using the publicly-available test protocols provided in this report, test engineers can develop test plans based on existing resources.

This report provides general considerations for procuring, installing, commissioning, testing, and analyzing energy storage systems, supplemented with specific examples from a test bed case study. The structure of this report is intended to give test engineers general guidelines and to describe unique challenges that may arise in implementing and testing an energy storage system. Each section includes specific references to the test bed installed at Pomona Labs by the Grid Technology and Modernization (GT&M) Distributed Energy Resources (DER) Demonstrations Team at Southern California Edison (SCE). The specific examples from SCE's Pomona Labs test site are geared towards setting up a dedicated test site, as well as challenges associated with developing customized test beds and procedures from existing protocols. Note that all projects contain unique challenges that cannot always be predicted, but preparing for anticipated issues can help project planners and test engineers implement and test BESSs more effectively.

Specifically, this report describes how the test engineers adapted existing test protocols to develop a test plan for a 150-kW/600-kWh BESS, which was installed and commissioned in 2017 at SCE's Pomona Labs test pad. Using an internal testing SCE protocol, the Energy Storage Test Manual that the Energy Storage Integration Council (ESIC) published in 2016 [1], and the Protocol for Uniformly Measuring and Expressing the Performance of Energy Storage Systems that the Pacific Northwest National Laboratory (PNNL) published in 2016 [2], SCE engineers modified parts of these test protocols to develop one test plan suitable for their specific testing needs. Suggestions and modifications to the ESIC Energy Storage Test Manual 2016 [1] from SCE engineers were incorporated into the new version of the ESIC Energy Storage Test Manual [3]. Although testing of the BESS is not yet complete, there is valuable information regarding the processes prior to testing. This report documents and captures these challenges and lessons learned from the project thus far, and indicates potential risk mitigation strategies. Future test objectives include long-term battery degradation tests and grid simulator tests to investigate how BESS reacts to simulated grid events.

2
BATTERY ENERGY STORAGE SYSTEM TEST BED DESCRIPTION

The lifecycle of an energy storage project begins with identifying a system need and evaluating possible solutions to fulfill the needs of the grid, including traditional solutions and energy storage technologies. If the energy storage solution is deemed economically feasible, the project proceeds to site selection, equipment procurement, system design, installation, commissioning, and then operation. Site location and equipment selection are a crucial part of the project and can rely on a multitude of internal and external stakeholders. The topic of siting is beyond the scope of this report, but the nature of the site can determine equipment needed for performance testing. Test engineers should consider monitoring equipment needed and connections available at the site to perform required tests. For instance, for remote locations, portable equipment may be more suitable if fewer active connections are required. Portable devices are available in various models that support a wide range of sampling rates and functionality. For long-term stationary testing sites, permanent connections may be more suitable for enhanced functionality and higher sampling rates.

In this research project, the BESS was installed at the SCE Pomona Labs in Pomona, California to investigate and analyze performance and characteristics for lithium ion battery systems. EPRI and SCE's GT&M DER Demonstration led the research. The location was selected due to proximity to the team's resources, existing equipment, data historian, and space available at SCE's laboratory to install and test the BESS. Figure 2-1 shows the 150-kW/600-kWh Tesla Powerpack™ 2 BESS.

Figure 2-1
Tesla Powerpack™ 2 Battery energy storage system at the SCE Pomona Lab

This research project intends to evaluate how a BESS can be installed at the distribution level for the following purposes:

- Increase grid reliability
- Increase renewable integration capacity
- Manage peak demand
- Defer infrastructure upgrades

The testing team identified the following tests to determine and characterize the BESS performance:

- Distributed energy storage system evaluation
- Roundtrip efficiency (RTE)
- Rated continuous active power
- Frequency regulation
- Response, rise, and settling time
- Site load limiting

This research project aims to improve the technical understanding of BESS testing, and to understand how these test procedures can be designed and adapted such that future procedures can be developed in similar fashion. Using the 2016 ESIC Energy Storage Test Manual and additional resources, SCE engineers modified the procedures according to their needs. The considerations for adapting existing test protocols are described in detail in the Performance Testing and Analysis of BESS section.

3
PROCUREMENT

In a typical BESS project, the procurement process begins when the planning process is completed, resulting in a list of minimum technical requirements that should satisfy the need for the planned energy storage project. The procurement process may include issuance of a purchase order (PO) or the development of a request for quotation (RFQ), request for proposal (RFP), or request for offer (RFO), followed by review of the energy storage system proposals received. The procurement process ends when the energy storage technology or the integrator is selected, with both buyer and supplier agreeing to the terms and conditions for the project. During this process, the scope of work is developed, with a division of responsibility matrix to illustrate each entity's responsibility within the scope of the project. The lack of standard terms and conditions relating to energy storage systems can lead to a lengthy negotiation process during procurement and may impact the project's timeline. When procuring a system through engineering, procurement, construction (EPC) firms, additional time should be scheduled for EPC-related subcontracts and equipment POs. ESIC's Energy Storage Request for Proposal Guide contains detailed information to aid this process, with considerations and recommendation specifically tailored to energy storage projects [4].

In this research project, EPRI was responsible for specifying, procuring, delivering, and installing the system, while SCE was responsible for BESS site preparation, grid integration, and testing. EPRI issued a PO to Tesla™ for the BESS, including its delivery and installation. Initially, the project negotiated to procure the first generation 200-kW/400-kWh Tesla system. However, during the negotiation of the terms and conditions, Tesla released a new product (Tesla 250-kW/500-kWh Powerpack 1) in the second quarter of 2015. Because the warranty was part of the initial contract between Tesla and EPRI, release of this new product required renegotiation of the new product warranty, terms, and conditions. In the third quarter of 2016, Tesla again released a new product, the Power Pack 2. The change in technical specification for this product required resubmittal and approval of the interconnection application to SCE. In the first quarter of 2017, all parties agreed upon use of the 150-kW/600-kWh Powerpack 2 for testing and analysis at the SCE Pomona Labs. Since the system was procured for research purposes, the project team had some flexibility to wait for renegotiations to procure the latest version of the technology. For other projects with time constraints, there may not be as much flexibility on the timing, and the planners may specify the technology that is immediately ready even though a newer generation would be released soon.

Table 3-1 shows the components of the 150-kW/600-kWh BESS.

Table 3-1
SCE BESS Equipment List

Equipment / Item Description	Quantity	Supplier
Tesla Powerpack 2	3	Tesla
Inverter	1	Tesla
Powerpack site master controller	1	Tesla
DC and communication cables	1	Tesla
Wireway kit	1	Tesla
Metering cabinet[1]	1	SCE
Acuvim II (Tesla specified meter)	1	SCE
Power quality meter	1	SCE
Data historian	1	SCE

The battery energy storage industry is continuously evolving. Although new products may offer technology improvements that can benefit the project overall, new product releases can lead to delays in negotiations. Unexpected delays due to internal and external factors may lengthen the procurement process. Project planners and test engineers need an awareness of anticipated changes in technologies, especially when procurement and negotiation coincide with potential new product releases.

Though not common, a change in product occurs when the specification changes between the procurement process and installation. The technical specifications of the new product may differ from those originally planned, and the design and engineering teams need to be aware of these changes. At the same time, product warranties associated with rapidly evolving products also change. Project planners should be aware that if the product warranty is part of the initial contract between integrator and site owner, then a contract amendment may be required with a change in product. Members of the project team need a comprehensive understanding of the warranty required for the project so the team can react quickly and new warranty terms can be negotiated.

To ensure the most time-effective negotiation period, project planners should clearly list the detailed terms and condition in the RFQ or RFP, so that vendors bidding on the BESS understand buyer expectations. Planners should also consider system sizing during the procurement phase. Projects of different system sizes may move through internal departments at various processing speeds within site owner and supplier organizations. Each organization

[1] The meter cabinet is not necessary for the listed test protocols. The SCE GT&M team intends to implement additional test systems on the test pad in the future, and the equipment is meant to accommodate additional systems in the long term. Portable power metering equipment may suffice for most applications with local data logging in the field, rather than a dedicated data historian connected to the system for BESS installations in a laboratory setting.

prioritizes projects differently. Gaining a better understanding of such priorities can help project planners manage expectations and understand how to best communicate with the other entity.

The experience of the developer as a technology supplier is also an important consideration. The suppliers' experience deploying behind-the-meter systems may differ from their experience deploying utility-scale systems, as these projects pose different implementation requirements. Suppliers with more experience deploying projects similar to projects of interest may better understand implementation challenges, and therefore working more effectively through the procurement phase.

4
PROJECT SITE AND SYSTEM DESIGN

Although the turnkey product may incorporate most of the engineering within the completed BESS components, site and system engineering design are still required for BESS implementation. The RFP should specify interconnection, electrical, and communication interface requirements between the BESS and hosting utility. The RFP should define site specifications, such as civil design and project site construction, according to local codes and standards. The team should establish communication between the vendor, procurement team, construction team, test engineers, the utility and the site owner early in the process to address and clarify the electrical and physical constraints of the location and equipment. The site owner should ensure that all applicable codes and standards are incorporated into the design to guide the permitting process. The team should involve the local utility in the project by submitting the interconnection application. After receiving the interconnection application, the utility will perform an impact study and verify if existing electrical infrastructure is sufficient.

Site Engineering

SCE engineers anticipate implementation of future energy storage test systems on the Pomona Labs Energy Storage test pad. As a result, SCE engineers pursued flexibility in the concrete pad design to accommodate future installations at the facility. The flexible pad design is a grid structure with trenches that lead to a centralized location for metering equipment. Future energy storage systems will be installed on the pad, while the trenches allow necessary cable connection from future energy storage system to metering panels without additional construction. Theoretically, no underground conduit will be needed for future projects. A simplified layout of the flexible pad design is illustrated in Figure 4-1, in which the blue borders represent the area that the Tesla BESS occupies. Figure 4-2 shows the trenches on the flexible pad, which are covered by metal plates.

Tesla provided a Site Design Manual covering electrical interconnection considerations and equipment pad design to guide the site owner and system designer. Tesla also provided a detailed installation manual that outlines the standard installation process for the Powerpack 2. SCE requested a deviation from the installation that involved modifying the way the cables enter the power conversion system (PCS). Per Tesla's feedback, the Powerpack 2 PCS enclosure is UL™ certified, with a cable entry window at the bottom of the PCS to allow the underground conduit to enter the unit. Changing the location where the wires enter the PCS would invalidate the existing UL certification and require additional engineering. This constraint was communicated between EPRI, the vendor, and SCE prior to construction of the pad, before the concrete was poured. Site engineers were able to accommodate the BESS cables by constructing a conduit from the PCS cable entry window that enters the trenches (see the gray lines in Figure 4-1). Vendors, test engineers, and site engineers should be aware of any product certification (such as UL) and determine if the product is compatible with existing site design. Modifications to the manufacturer's standard installation procedure can delay the project installation timeline, and can incur potential carrying or storage costs of the BESS equipment.

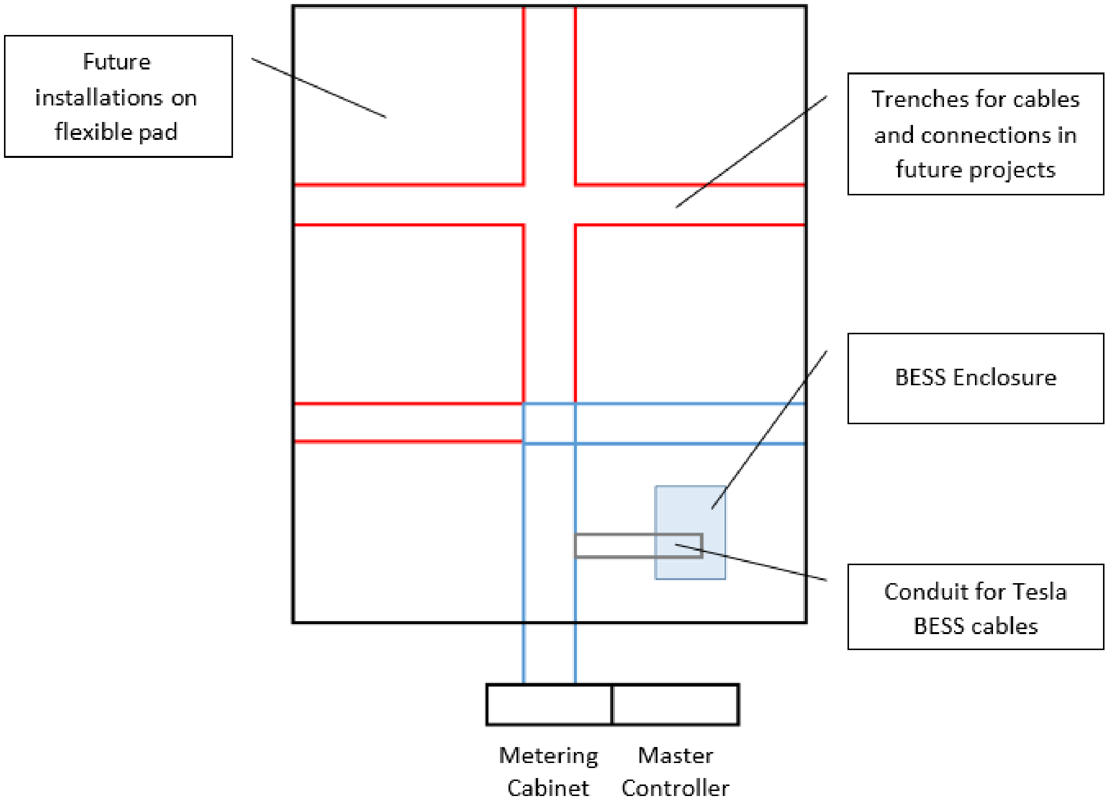

Figure 4-1
Conceptual site layout illustrating flexible pad design

Figure 4-2
Constructed metal plates covering trenches in flexible pad design

System Engineering

Figure 4-3 shows a simplified one-line diagram of the BESS. SCE engineers anticipate implementing future test systems, so the team installed a new panel board to accommodate any future loads, distributed resources, or energy storage systems.

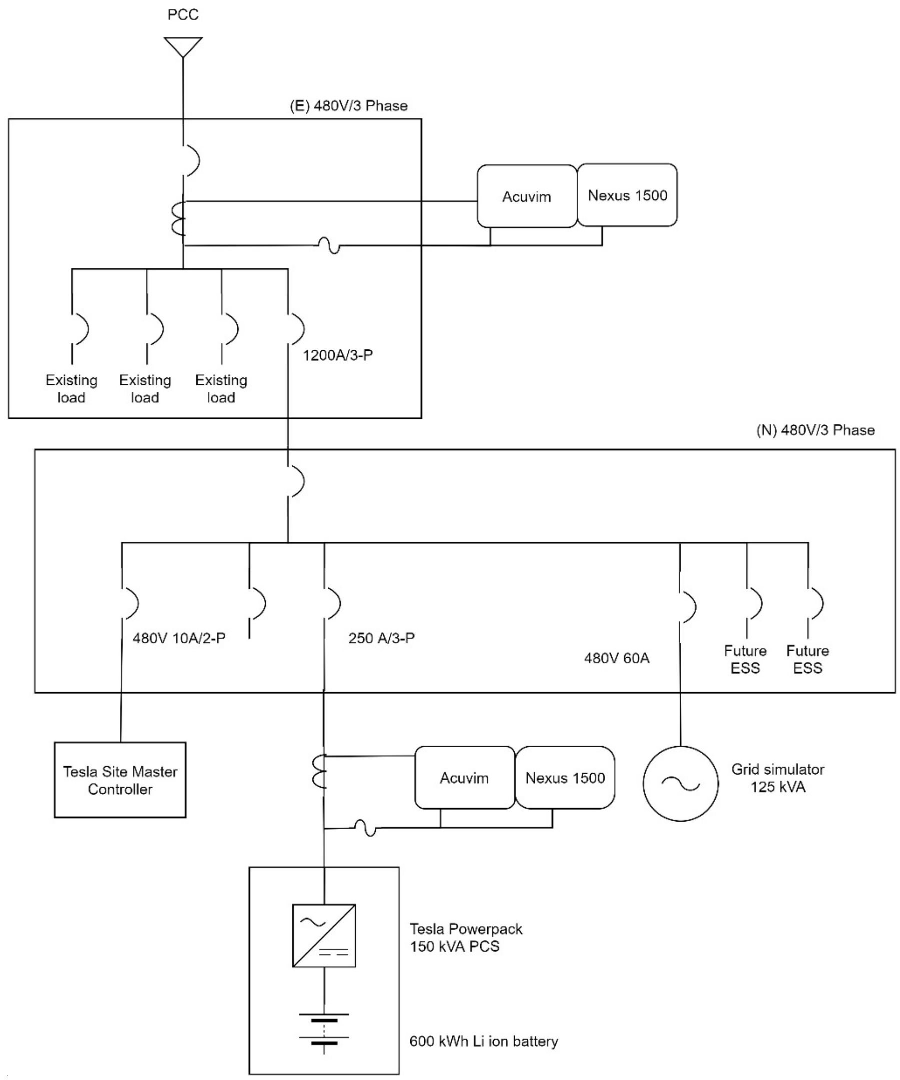

Figure 4-3
Simplified one-line diagram of BESS at SCE's Pomona Labs

As part of the electrical system design, communication design should be tailored to the BESS operations and intended performance test procedures. Test engineers should be aware of the data points that technology vendors supply, and determine the sampling rate at which data points are logged. BESS vendors may collect additional data that they do not provide to site owners, such as data on the DC bus. If the given data points and sampling rates do not match what is required for testing and analysis, the testing team should seek alternative solutions. Some solutions include installing additional meters with more capabilities to capture data points needed for the test procedure, or dictating specific requirements to vendors prior to selection. Project planners should be aware that significant modifications to the installed BESS may void the system warranty. Test engineers should initially determine if the new BESS should integrate with a specific data historian. Managing one data historian is likely to be more effective than managing multiple data historians, and therefore test engineers should consider designing and integrating the new BESS with existing data historians on site.

The testing team should also consider whether the test equipment is suitable for the location of these systems. In some instances, a portable power meter may be sufficient for field testing to accommodate remote locations. In other instances, a laboratory-grade data acquisition system may be required for long-term testing. Some portable meters may not offer the same accuracy and sampling rate as laboratory-grade equipment, but can satisfy the needs for some test manuals. A stationary data acquisition system requires additional communications design and equipment installation, potentially lengthening the project timeline.

The project team properly installed the Acuvim II meter, which the vendor’s Communication Interface Manual specified. Because SCE engineers preferred a data acquisition system that was independent of the vendor’s hardware, they installed two meters in parallel with the Acuvim II meter, the Nexus 1500 and the Dewetron. Note that other general purpose data acquisition units can serve similar purposes as the Dewetron. These two meters measure the same data points as the Acuvim II meter, but offer different functionality and are calibrated on an annual basis. SCE engineers used a Modbus map from Tesla’s Communication Interface Manual to develop an interface with the site master controller. This allowed SCE engineers to communicate with the BESS, command it to dispatch power, and poll the site master controller for data points that Acuvim II measured as reference data. The Modbus map includes the name, description, register address, units, data type, and read or write capability of each point. The Nexus 1500 is programmed to automatically record transient power quality events, such as voltage sag and surge events. With the additional meter and added capabilities, SCE engineers can collect more data points with higher sampling rates for future analysis. Figure 4-4 shows the two of the three meters installed (Acuvim II and Nexus 1500). Data points include voltage, current, total harmonic distortion (THD), power, and integrated energy values.

Because SCE engineers plan to test with higher sampling rates during future tests, the team also installed a third meter – a laboratory-grade data acquisition device from Dewetron. Compared to the Nexus 1500, the Dewetron can record at higher sampling rates, but must be manually initiated during testing to log test data. Test engineers should note that three meters are not required to complete the procedures in the ESIC Energy Storage Test Manual, but are installed to meet the SCE DER Demonstration team’s objective for long-term energy storage system testing.

Figure 4-4
Two meters measure the same data points in parallel, specified by Tesla (left) and SCE-installed Nexus 1500 meter (right)

Tesla did not provide data points on the DC bus of the BESS, as their solution is an AC-coupled listed system inclusive of the Powerpacks and inverter. To gain a deeper understanding of the system, SCE engineers plan to investigate these data points on the DC bus. DC data acquisition systems are planned for future installation. Such installations will be designed so no modifications to equipment will be required, while maintaining the product warranty. Generally, if the modifications are performed after commissioning, test engineers should verify that the warranty agreement is not violated.

The SCE Pomona Labs is equipped with a centralized data historian to support other test equipment at the facility. The Nexus 1500, and Dewetron meters are hardwire-connected to the network switch and server at Pomona Labs (see Figure 4-5). The data collected from both meters are stored in the historian, and the data can be accessed from computers or an energy storage system human machine interface (HMI) connected to the network. Historian software runs on a server-grade PC, which also contains a MySQL database. A global positioning system (GPS) clock and a weather station are connected to the main network switch to timestamp incoming data and provide environmental data such as temperature and humidity. In Figure 4-5, Acuvim II serves as the ESS Site and Battery Meters, the Nexus 1500 serves as the Testing Battery Power Quality Meter, and the Dewetron meter serves as the Testing Data Acquisition Unit.

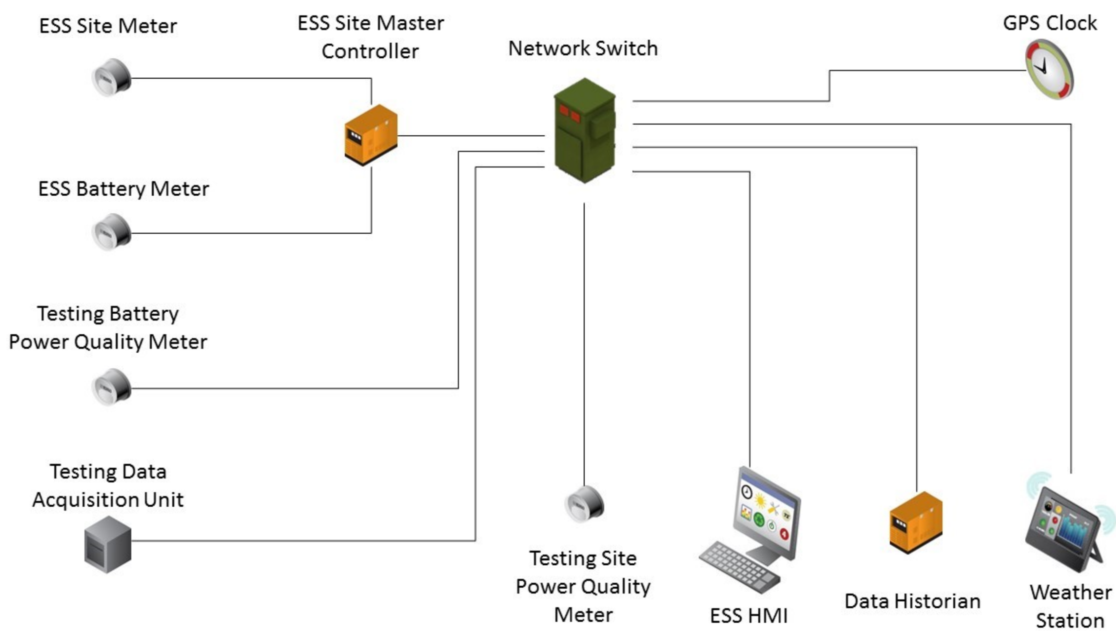

Figure 4-5
Network diagram of Tesla BESS at SCE's Pomona Labs.

5 INSTALLATION AND COMMISSIONING

Installation entails processes from preparing for product delivery to connecting the system on site. Prior to product delivery, the site owner or a third party may witness a factory acceptance test (FAT) at the vendor's manufacturing facility if the FAT is included in the scope of work. During the product shipping and receiving process, the site owner or project planners should consider equipment, safety measures, and regulations associated with shipping the energy storage system. This can be included as vendor's responsibility in the scope of work, but cooperation from the site owner is crucial to ensure smooth delivery and installation. Because scheduling may constrain completing tasks and the timeline of the scope, installation efforts require cooperation. A division of responsibility (DOR) matrix should clearly delineate the scope and responsible entities. Although coordination with a split scope can result in more efficient project installation with clear communication, it can also delay the project schedule if no communication is established beforehand. Therefore, the team should establish the point of demarcation early in the process.

Commissioning entails ensuring that the system operates as designed according to the specifications listed, and complies with appropriate interconnection requirements. The commissioning team completes the commissioning and site-acceptance tests to verify the proper installation of safety systems, the proper operation of protection equipment and switch gear, as well as the proper operation of the communication and control systems [5]. Prior to obtaining permission to operate (PTO), local interconnection requirements must be satisfied, with verification from a local utility interconnection field engineer. For systems with photovoltaic and energy storage systems, interconnection requirements may be different from those required for only energy storage systems. Adequate training and documentation from the project planners or the site owner are important to ensure vendor awareness of the interconnection test procedures that are unique to the local utility and energy storage system.

During delivery of the BESS, SCE was responsible for site preparation and installation of equipment upstream of the PCS AC terminals. The vendor was responsible for the delivery, installation, and commissioning of the BESS, including grounding and installation of communication wiring between battery packs and inverter. Tesla provided the Powerpack System 2 Transportation and Storage Guidelines to assist the product shipping and receiving process.

Figure 5-1 shows the delivery of the Tesla BESS.

Figure 5-1
Delivery of Tesla BESS at Pomona Labs in Pomona, CA

Because this BESS was installed in SCE territory, the BESS was subjected to the local interconnection standards and tests that SCE specified and verified. The Pomona Labs are subjected to the same procedures as other SCE customers in order to interconnect with the system. Commissioning consisted of utility interconnection tests and system commissioning tests. The system commissioning tests were included in the vendor's scope and include battery mechanical and electrical checks, metering, battery pack start-up, inverter commissioning, and battery performance testing. During the utility interconnection tests, Tesla field engineers were not present because interconnection was not part of the original scope, but were able to remotely provide support.

For this project, SCE engineers signed an interconnection agreement for non-compensated export operation with an addendum to allow for the system to back-feed to the grid. The system is allowed to export power to the grid, but the site owner will receive no monetary compensation. Although the building load was less than the BESS output, the interconnection requirements did not necessitate a load bank because of the non-compensated export agreement. Note that a load bank is not always required, i.e. BESSs that are connected to a building load that is greater than the system output.

The BESS commissioning involved two phases. In the first phase, SCE engineers obtained permission from SCE distribution owner for the vendor to test the system at a limited power rating and for a limited time for each power command. This process verified that the system was functional. Then, SCE engineers performed a PTO commissioning with SCE field engineers as witnesses, as stated by SCE interconnection requirements. After the system had been commissioned and received PTO, the SCE engineers began preliminary tests as planned. After conducting the preliminary testing for a few weeks, SCE engineers noticed that the Tesla BESS was self-limiting its power output. Tesla technicians diagnosed the problem remotely and determined that a broken temperature sensor in the inverter was causing the battery system to limit its power discharge. A Tesla technician then came to the facility to replace a power stage in the inverter that had a bad sensor, which caused a slight delay of one week. However, the impact of this delay could have been magnified if this system were supporting other distribution systems with reliability functions on a tight timeline.

6
PERFORMANCE TESTING AND ANALYSIS

The main objective of this research project is to a gain deeper technical understanding of various aspects of testing the performance of a lithium ion BESS. Previous sections describe general considerations and challenges specific to the Tesla BESS installation at SCE prior to testing. This section is dedicated to describing general considerations and challenges for development of the test plan, preliminary testing, and future steps.

The first step to testing and analyzing a BESS is to identify BESS objectives and develop a set of test plans that can effectively display the system's capabilities to achieve the desired objectives. The objectives could include supporting customers with backup power, improving grid reliability, increasing hosting capacity, managing peak demand, deferring infrastructure upgrades, and improving system's operations by participating with the local independent system operator (ISO).

The energy storage testing team can establish the necessary test plans by leveraging existing internally developed protocols and publicly available protocols. Within individual utilities, existing test manuals may have been developed for past BESS installations, and these manuals can be adapted for the current system. BESS testing and characterization has evolved through the efforts of many research organizations, some of which have published testing protocols. ESIC has collected industry input via the Testing and Characterization Working Group and has published a set of test protocols in the ESIC Energy Storage Test Manual 2016 [1] and ESIC Energy Storage Test Manual [3]. The 2017 version of the Test Manual includes a set of detailed test procedures for evaluating the performance of energy storage systems, including the following:

- Available energy capacity
- Charge duration
- Rated continuous power
- Auxiliary load determination
- Roundtrip efficiency
- Self-discharge rate
- Startup and shutdown time
- Response, rise, and settling Time
- Harmonic distortion
- Charge/discharge management
- Volt-var regulation
- Autonomous frequency regulation
- Peak power limiting

The HMI that the vendor provides to the site owner can limit test engineers' ability to conduct the test plan. Some vendor-provided HMIs may not allow for scheduling power dispatches as specified in protocols such as the ESIC Test Manual. The project planner can address this issue by specifying testing needs and functionality in the HMI provided by the vendor in the RFP process. Alternatively, test engineers can customize and develop the HMI so it is suitable for testing the BESS.

In this research project, SCE engineers aim to improve the technical understanding of the safety, performance, and degradation characteristics of the Tesla BESS. The team determined the following tests as points of interest:

- Distributed energy storage system evaluation tests (developed internally at SCE)
- Roundtrip efficiency (from ESIC Energy Storage Test Manual 2016)
- Rated continuous active power (from ESIC Energy Storage Test Manual 2016)
- Frequency regulation (from ESIC Energy Storage Test Manual 2016 with a duty cycle from the Protocol for Uniformly Measuring and Expressing the Performance of Energy Storage Systems)
- Response, rise, and settling time (from the ESIC Energy Storage Test Manual 2016)
- Site load limiting test (developed internally at SCE)

The team installed and commissioned the BESS in the first half of 2017, and the team focused on test bed validation, performance and safety tests in the second half of the year. Cycle life testing is scheduled to begin in 2018 and continue through 2020. Table 6-1 describes the task and duration estimated for completion.

Table 6-1
Tesla Test BESS Gantt chart for tasks in project and estimated time required for completion (from SCE DER Demonstrations Team)

Task Name	Duration
Energy storage system installation	2 days
Electrical work	122 days
Graphical user interface (GUI) configuration and validation	22 days
Instrumentation and data acquisition installation	14 days
Test bed validation	14 days
Preliminary roundtrip efficiency (RTE) testing	14 days
Preliminary reactive power testing	21 days
Data acquisition installation	100 days
Data acquisition validation	7 days
150-kW RTE test	7 days
112-kW RTE test	2 days
75-kW RTE test	3 days

Table 6-1 (continued)
Tesla Test BESS Gantt chart for tasks in project and estimated time required for completion (from SCE DER Demonstrations Team)

Task Name	Duration
38-kW RTE test	9 days
Rated continuous active power test	7 days
Frequency regulation test	7 days
Response, rise, and settling time test	7 days
Site load limiting test	7 days
Retesting buffer	14 days
Write report	14 days

It should be noted that SCE engineers only allocated 22 days for the GUI configuration and validation because the interface was developed earlier before installation. SCE engineers programmed most of the GUI prior to receiving the system, and the duration of 22 days is only to verify that the GUI worked with the BESS and to perform additional development if needed. The total duration for customizing, developing and validating a GUI is expected to be longer than 22 days.

Test engineers should consider the expected duration of each test, along with the time needed for equipment installation and electrical work. Appropriate buffering time should be included in the schedule to accommodate unexpected delays, especially if a test is run for the first time. SCE engineers scheduled 7 days for the first round of roundtrip efficiency (RTE) test, when the exact test duration could have been shorter. An individual test can contain multiple iterations, and testing RTE at lower power can take longer than other tests. For instance, the 38-kW RTE test is expected to take much longer compared to the 75-kW RTE test. Performance tests are subjected to the same schedule constraints as these test procedures. Project planners and operators should be aware of the duration of these tests, as the system will consequently be offline during performance testing.

Preliminary Tests

Since testing BESS may include new testing equipment, data acquisition systems, and communication and control infrastructure, the testing team should consider implementing a set of preliminary tests prior to testing the functions in full. Preliminary tests are opportunities for the testing team to learn how to operate and troubleshoot the technical system components. Preliminary tests also allow the testing team to investigate how the existing test protocols should be altered and adapted to suit the needs of the specific BESS project. The learnings and results of these preliminary tests, along with adapted test protocols, should be well-documented to ensure clear communication between testing team members. Preliminary tests differ from full test protocols, as preliminary tests only seek to gain operational experience of how the full test protocols should be implemented. The results of the preliminary tests may not encompass the full scope of the full test procedures, and preliminary results may or may not be included in the final results.

SCE first gathered several sets of test protocols:

- Distributed Energy Storage System Evaluation Tests developed internally at SCE
- ESIC Energy Storage Test Manual 2016[1]
- Pacific Northwest National Laboratory's (PNNL) Protocol for Uniformly Measuring and Expressing the Performance of Energy Storage Systems [2]

Prior to conducting the full set of tests, SCE engineers designed preliminary tests to validate the test bed and the data acquisition system, including a preliminary RTE test and preliminary reactive power test. During the preliminary RTE tests, SCE engineers verified that the script customized for the HMI was capable of commanding the BESS to dispatch real power, reactive power, and a combination of both. Additionally, SCE engineers were able to obtain preliminary capacity values. Through this process, the SCE engineers explored solutions to two important issues regarding test equipment validation.

First, the ESIC Energy Storage Test Manual 2016 required that certain data points be measured as part of the procedure [1]. The state of charge (SOC) is required to trigger the start and stop of tests, but the BESS HMI did not provide the SOC value. At the time of installation, the vendor provided a web interface that only states the BESS's "remaining energy available" as a percentage. SCE engineers were unsure how the remaining energy available is calculated, and therefore this parameter could not be equated to the SOC. Although an updated version of the Tesla communication manual defined state of energy (SOE) as the usable energy remaining divided by the full pack energy, the SOE remains different from the SOC. Hence, SCE engineers defined the SOC as the percentage of remaining energy divided by the energy at full charge, so that the measurements could be more consistent for the entire test procedure.

Second, the BESS offered limited control in operation besides the designated modes that were preconfigured with installation. While designated modes and minimal operational oversight provide some autonomy and may be suitable for some site owners, these modes prevented the SCE engineers from commanding charge and discharge power. This limited the team's ability to perform tests according to protocols. As documented in Tesla's Communication Interface Manual, the direct command mode can be configured to integrate into a SCADA system. To address this, the SCE engineers arranged an interface that connects the Powerpack site master controller and the HMI. The site master controller was configured to act as the Modbus Slave, and the HMI was configured to act as the Modbus Master. The site master controller requires a heartbeat signal at designated time intervals from the HMI to continue dispatching power. The testing team also designed and built a GUI in LabVIEW to control the Modbus devices (see Figure 6-1). The GUI enables SCE engineers to control BESS charging and discharging at specified power, and also displays BESS measurements. Test engineers should be aware that such customization may require additional budget and time to implement, as illustrated in the schedule in Table 6-1. In general, preliminary tests can help the testing team understand the functionalities and limitations of test equipment, allowing for modification and adjustments to equipment or the test bed prior to implementing the full test procedures.

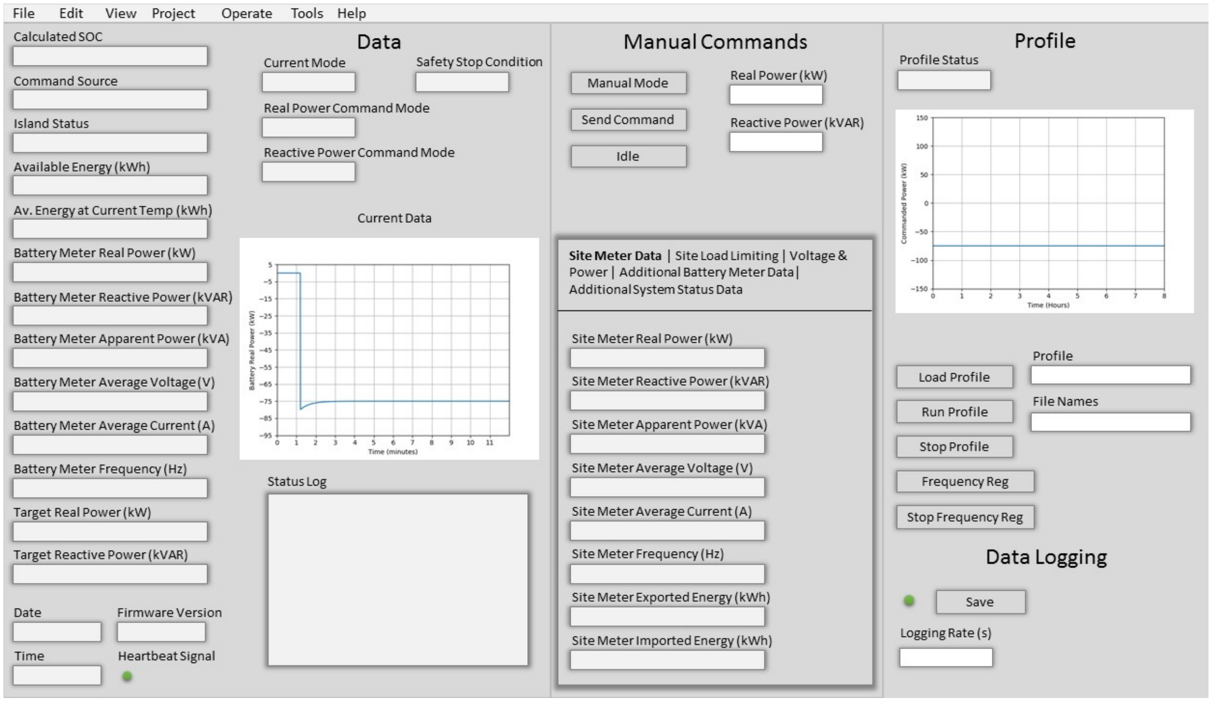

Figure 6-1
Illustration of GUI for Tesla BESS developed by SCE GT&M DER Demonstrations Team

Modification of Test Protocols

In addition to modifying test equipment, preliminary tests can help the testing team determine if alterations are needed to existing test protocols. From the list of test procedures available in the ESIC Test Manual, SCE engineers decided to adapt procedures for the RTE test, rated continuous active power test, frequency regulation test, as well as the response, rise, and settling time tests. The frequency regulation test follows the duty cycle as specified in PNNL's protocol. The distributed energy storage system evaluation tests developed by SCE include the same tests from the ESIC Energy Storage Test Manual. If a test is listed in SCE's internal procedures and ESIC's Energy Storage Test Manual, the ESIC Energy Storage Test Manual was followed.

At the start of RTE and rated continuous active power tests, the ESIC Energy Storage Test Manual 2016 requires the test system to be at 100% SOC. The manual states that the BESS should be charged at 50% rated power (in this case 75 kW) until 100% SOC is reached. Charge power is defined as the power the BESS accepts at any given time. However, during preliminary testing, when SCE engineers attempted to charge the BESS from 98% to 100% SOC to reach the starting point of the tests, they observed that the BESS would not charge at 75 kW as commanded. The level of charge power was much lower than the rated maximum power, and the BESS would not charge up to 100% SOC in a reasonable amount of time. As a result, SCE engineers added an initial operating condition to charge up or discharge down the BESS to 94%-96% SOC prior to starting the test. This creates a larger buffer between the SOC before the test and the SOC at the start of the test. Estimating battery SOC is complex. Tapering behavior differs at increasing SOC as internal resistance increases and the battery management system attempts to maintain cell voltage within limits. SCE engineers found that the buffer adequately minimizes the effects of derated power that occurs near 100% SOC.

The phenomenon above in which the BESS cannot be charged at maximum rated power at high SOC levels leads to derated power. Derated power occurs when the system operates in a power limited region in order to maintain the battery cell operating parameters and optimize system performance over the installation life. The power limited region may be defined by the charge algorithms specified by the BESS, such as a constant current, constant voltage charging algorithm. Figure 6-2 defines several energy ratings of a battery system:

- Actual energy
- Usable energy that is limited by control software
- Guaranteed energy that may be part of a contractual agreement

The BESS is able to provide full rated power for the guaranteed energy range.

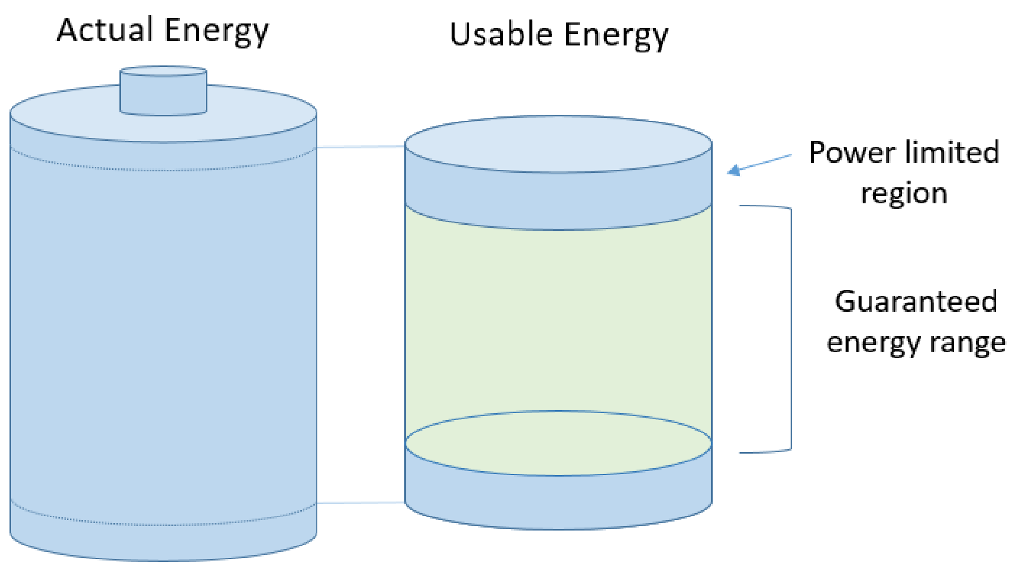

Figure 6-2
Actual energy, usable energy, power limited region and guaranteed energy range of BESS (for illustration only)

In this case, the guaranteed energy range is 600 kWh, and the system can operate at the full rated power of 150 kW for this entire range. However, for regions outside of the guaranteed energy range, the power may be limited (the “power limited region” in Figure 6-2). The ESIC Test Manual 2016 specified that the BESS test begin at 100% SOC. However, this would require operation in the power limited region. This is outside of the system’s guaranteed energy range, and hence, the charge and discharge power tapers.

Another change that SCE engineers made to the test plan is the criteria for starting the test. The ESIC Energy Storage Test Manual 2016 states that the BESS should be charged to maximum SOC prior to initiating the test. Due to the complexities described above, instead of starting the test when the BESS reaches 100% SOC, SCE engineers changed the test plan and initiated the tests when the charge power decreased below 2 kW. (Recall from above that the charge power decreases dramatically from its rated power as the SOC approaches 100%.) Changing the initiation criteria from “the BESS SOC reaches 100%” to “the charge power decreases to 2 kW” (1) ensures that the BESS is near full capacity at the start of test, and (2) maintains a consistent metric. Table 6-2 summarizes the differences early in the test procedure between the ESIC Energy Storage Test Manual 2016 and SCE’s final test plan. The test engineers made similar changes to the P/2 test (50% of rated power) and the P/4 test (25% of rated power). The ESIC Working Group captured these modifications and suggestions in the latest version of the ESIC Test Manual [3]. As shown in this project, industry input from ESIC collaborators truly drives the continuous improvements that the ESIC forum seeks. With test equipment finalized and test plans refined, SCE engineers documented a final test plan to be implemented in the following years.

Table 6-2
Comparison of ESIC Energy Storage Test Manual 2016 and SCE's Energy Storage System Evaluation Test Plan

	SCE’s Energy Storage System Evaluation Test Plan	ESIC Energy Storage Test Manual 2016
Initial Operating Conditions for SOC	94 – 96% SOC Resting requirement in manual	No conditions for SOC before test Resting requirement in manual
Beginning of Procedure	Command the BESS to charge at 75 kW (50% rated power) until its charge power decreases to below 2 kW	If the BESS is not at 100% SOC, initiate a charge cycle at 50% of the recommended charge power rate until the BESS reaches 100% SOC

7
LESSONS LEARNED

This section summarizes lessons learned thus far in this project.

Table 7-1
Lessons learned

Issue	Project Impact	Actual Resolution	Lessons Learned
The procurement process was longer than usual.	Schedule, product	The product offering changed twice, from Gen1 200 kW/400 kWh, to Powerpack 1, and (procured) Powerpack 2 at 150 kW/600 kWh	Negotiation can sometimes be a long process due to unexpected internal and external delays; Extra time should be factored in when drafting the schedule. A solicitation with more detailed terms and conditions can guide smoother negotiations
A long procurement process led to a change to the product and warranty offered.	Warranty changed, product changed	The warranty changed during the procurement process, requiring the project team to renegotiate the warranty terms	Product lines from battery manufacturers can change over the course of the procurement process. The procurement and engineering team should be aware of any changes to the warranty that deviates from the original desired project objectives.
The project was installed under a non-compensated export tariff, but the vendor was accustomed to no export.	Schedule, commissioning, testing	The utility's interconnection was able to verify only using the inverter specification sheets. However, the testing during commissioning was not allowed to be full power.	Early discussions regarding interconnection requirements are needed with the vendor and the utility to gain a better understanding before installation.
Power limiting observed	Testing	The vendor was able to remote in to help diagnose the issue and discover that a temperature sensor in the inverter malfunctioned. The vendor replaced the malfunctioning power stage.	Close monitoring of the BESS should help test engineers identify potential issues, such as self-limiting in power. Proper warranty terms should ensure the vendor's responsibility for repair in the case of a malfunctioning component.

Table 7-1 (continued)
Lessons learned

Issue	Project Impact	Actual Resolution	Lessons Learned
Not all data points were available for the tests that SCE engineers needed.	Testing, precision and consistency of test result	Although the vendor system provides access to data that is sufficient for energy, power, and RTE acceptance tests, unique tests that utilities need may require additional equipment. The utility installed a data acquisition system to collect data, with a higher sampling rate.	Vendors and manufacturers may not always provide the data necessary to achieve the utility's testing objectives. Planners should allocate additional funds and room in the schedule for implementing an additional data acquisition system.
The BESS lacked interface to command power input and output for the system.	Testing	SCE engineers were aware of this issue, and they self-built an interface in LabView, which enabled the testing team to command power, charge, and discharge as desired.	Communicate with the vendor that additional data must be acquired for testing purposes. Due to proprietary technologies from vendors, the utility or testing team may need to separately purchase a data acquisition and equipment system. If an interface is not included with the system, the test engineers must allocate resources to either develop the interface internally or for contractors to develop a suitable interface

8 CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This report describes general considerations for implementing, testing, and analyzing a BESS. Project phases such as procurement, design, installation, commissioning, testing, and analysis each contain unique challenges for project planners and test engineers. The report describes general considerations and specific references to the installation and testing of a 150-kW/600-kWh Tesla Powerpack 2 at SCE's Pomona Labs. The structure of this report is intended to provide general guidelines to describe unique challenges that may arise in implementing an energy storage system, supplemented with specific examples from this project.

The procurement schedule is sensitive to product availability and changes, as well as negotiation of product and warranty terms and conditions. Unexpected internal and external delays may extend the procurement process. Project planners should be aware of technology modifications, as new product offerings may necessitate renegotiation efforts and additional time. The procurement team and site owner should clearly state detailed terms and conditions, scope of work, and division of responsibility in an RFQ or RFP so that expectations can be communicated to bidders effectively.

The design phase requires careful consideration related to the project site and system engineering. The team should establish clear communication between the vendor, engineers, procurement team, construction team, and site owner early in the design phase so that the constraints of the site and equipment are addressed. The site owner should be aware of system data measurements and HMI that the vendor supplies, and seek alternative solutions if these measurements do not satisfy the site owner's system needs for testing or performance monitoring.

BESS installation requires collaboration between multiple project entities to ensure that no scheduling conflicts occur. Commissioning of energy storage projects may consist of both vendor commissioning tests and utility interconnection tests that are verified by utility field engineers. Although utility interconnection tests may be beyond the vendor's scope of work, the vendors may be able to support tests remotely. Utilities may require limitation of the power and duration of the BESS during interconnection tests. During early phases of operation, malfunctioning components may surface, which could expose defective components. Warranty terms should protect the site owner from incurring damaged parts.

Design of a set of test plan begins with identifying BESS objectives and researching existing test protocols that can test the system's capability to meet the intended objectives. The testing team can plan preliminary tests as an opportunity for the team to gain operational and troubleshooting experience with the BESS and associated test equipment. The team can modify existing test protocols to suit specific project needs by utilizing standardized test procedures and definitions, hence shortening the time needed to develop a test plan.

For this research project's BESS test plan, the SCE GT&M DER Demonstrations team leveraged the 2016 ESIC Energy Storage Test Manual to create a performance test plan. The team adapted RTE, rated continuous active power, frequency regulation, as well as response, rise, and settling time tests from the 2016 ESIC Energy Storage Test Manual, as well as conducted test procedures developed internally at SCE. The team made adjustments and modifications prior to finalizing a test plan. ESIC incorporated suggestions from SCE engineers into the next version of the ESIC Energy Storage Test Manual in 2017. Through use and feedback from project planners and test engineers, products from ESIC such as the Test Manual continue to improve with each iteration. These ESIC products adapt to necessary changes for effective implementation of future energy storage projects.

Future Research Objectives

The project team installed and commissioned the Tesla BESS in 2017 at the SCE's Pomona Labs, and ongoing testing and validation efforts will continue through 2020. The team will complete distributed energy storage system evaluation tests, RTE, rated continuous active power, frequency regulation, as well as response, rise, and setting time, and site load limiting tests according to modifications determined from preliminary tests. The team will analyze results from these tests to determine performance characteristics of the Tesla BESS. After validation efforts and performance characterization testing, future research efforts will investigate battery degradation behaviors under various operation conditions. A grid simulator is currently installed, but no test plan has been solidified at this point to incorporate this feature. SCE engineers intend to simulate grid events to better understand how the BESS responds to transient events and how the system can improve grid reliability. The lessons learned, results, and finding from this demonstration project are anticipated to provide technical insight for installing and testing energy storage systems in the future. Specifically, the lessons learned can be applied to current deployments and BESSs operating in the field.

More broadly, performance testing results of recently deployed lithium ion battery systems are crucial indicators of the general performance levels of energy storage systems. Lessons learned with installing and testing of energy storage systems can lead to a deeper technical understanding of the performance capability and deployment challenges from the site owner's perspective. The test data's availability and accessibility will impact how project planners and test engineers assimilate testing and deployment considerations that is affected by system performance. In EPRI's Energy Storage and Distributed Generation Program, an overarching goal is to develop a comprehensive technology overview that evaluates the general performance, technology readiness level, and deployment status of recent energy storage technologies. The quantitative ranges of technology attributes resulting from the comprehensive overview can be organized so that the data is used in storage valuation analysis, such as EPRI's Storage Value Estimation Tool (StorageVET®). Monitoring energy storage systems from technology specifications to deployment challenges allows for a thorough evaluation of recent energy storage technology development. Future objectives, such as a comprehensive technology overview, aspire to improve industry understanding of the requirements and common methods for characterizing and deploying energy storage in a safe, reliable, affordable, and environmentally responsible manner.

9 REFERENCES

1. EPRI, *Energy Storage Integration Council (ESIC) Energy Storage Test Manual 2016,* Palo Alto, CA: 2016, 3002009313, https://www.epri.com/#/pages/product/000000003002009313/.
2. Pacific Northwest National Laboratory and Sandia National Laboratories, "Protocol for Uniformly Measuring and Expressing the Performance of Energy Storage Systems," PNNL-22010 Rev 2/SAND2016-3078 R, 2016, http://energymaterials.pnnl.gov/pdf/PNNL-22010Rev2.pdf
3. EPRI, *Energy Storage Integration Council (ESIC) Energy Storage Test Manual,* Palo Alto, CA, 2017, 3002011739, https://www.epri.com/#/pages/product/000000003002011739/.
4. EPRI, *Energy Storage Integration Council (ESIC) Energy Storage Request for Proposal Guide,* Palo Alto, CA, 2017, 3002011738, https://www.epri.com/#/pages/product/000000003002011738/.
5. EPRI, *Energy Storage Integration Council (ESIC) Energy Storage Commissioning Guide 2016,* Palo Alto, CA, 2016, 3002009250, https://www.epri.com/#/pages/product/000000003002009250/.

Export Control Restrictions

Access to and use of EPRI Intellectual Property is granted with the specific understanding and requirement that responsibility for ensuring full compliance with all applicable U.S. and foreign export laws and regulations is being undertaken by you and your company. This includes an obligation to ensure that any individual receiving access hereunder who is not a U.S. citizen or permanent U.S. resident is permitted access under applicable U.S. and foreign export laws and regulations. In the event you are uncertain whether you or your company may lawfully obtain access to this EPRI Intellectual Property, you acknowledge that it is your obligation to consult with your company's legal counsel to determine whether this access is lawful. Although EPRI may make available on a case-by-case basis an informal assessment of the applicable U.S. export classification for specific EPRI Intellectual Property, you and your company acknowledge that this assessment is solely for informational purposes and not for reliance purposes. You and your company acknowledge that it is still the obligation of you and your company to make your own assessment of the applicable U.S. export classification and ensure compliance accordingly. You and your company understand and acknowledge your obligations to make a prompt report to EPRI and the appropriate authorities regarding any access to or use of EPRI Intellectual Property hereunder that may be in violation of applicable U.S. or foreign export laws or regulations.

The Electric Power Research Institute, Inc. (EPRI, www.epri.com) conducts research and development relating to the generation, delivery and use of electricity for the benefit of the public. An independent, nonprofit organization, EPRI brings together its scientists and engineers as well as experts from academia and industry to help address challenges in electricity, including reliability, efficiency, affordability, health, safety and the environment. EPRI members represent 90% of the electric utility revenue in the United States with international participation in 35 countries. EPRI's principal offices and laboratories are located in Palo Alto, Calif.; Charlotte, N.C.; Knoxville, Tenn.; and Lenox, Mass.

Together…Shaping the Future of Electricity

3002010895

Electric Power Research Institute
3420 Hillview Avenue, Palo Alto, California 94304-1338 • PO Box 10412, Palo Alto, California 94303-0813 • USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com