ESIC Energy Storage Commissioning Guide

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EPRI Project Managers

S. Willard
C. Cooper

EPRI
3420 Hillview Avenue, Palo Alto, California 94304-1338 USA
800.313.3774 ▪ 650.855.2121 ▪ askepri@epri.com ▪ www.epri.com

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EPRI prepared this report.

Principal Investigators
S. Willard
E. Minear
C. Cooper
B. Schenkman

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ABSTRACT

This report updates the previously published Energy Storage Integration Council (ESIC) Energy Storage Commissioning Guide 2018. In order to align with the rapidly changing energy storage technology space, these guidelines were refined to address how commissioning can be most efficiently addressed and executed in terms of project costs, safety, and schedule. Field experiences, lessons learned, and recent codes and standards updates that influence storage system commissioning were considered and adopted through a structured process involving the ESIC Working Group 3 Commissioning Task Force. Recent learnings influence the need to address commissioning intricacies from all stages of project development; commissioning needs to be assessed from the initial stages of project conception and efforts need to be identified, refined, assigned, budgeted, and scheduled appropriately in a continual effort until commissioning takes place. Failure to do so exposes the storage project to added costs and schedule delays. Decommissioning and recommissioning, which has become a focus area for many aging energy storage projects is also explored. This report presents considerations for all stages of project development, from inception to decommissioning as well as details on how numerous entities may be involved, the efforts of each, and the interdependencies between these entities.

The objectives of this Commissioning Guide Update are:

- To serve as a non-project-specific practical guide for utility users, suppliers, and other stakeholders, municipal or governmental owners, and commercial entities who are planning energy storage system projects.
- Inform the development of industry leading commissioning practices to bridge experience gaps evident with recent storage installations.
- Serve as a high-level, non-project-specific practical guide for all project stakeholders, covering all project phases that impact the commissioning activity.
- Supply real world checklists to give readers insight to specific steps of commissioning activities.
- Illuminate the impacts that new and evolving storage safety codes and standards can have on commissioning activities.
- Support the development of practical, deployment-oriented industry practices where gaps exist today.

This guide identifies commissioning-related activities that should be considered throughout the life cycle phases of an energy storage deployment project. Readers are advised that the document should be considered an informative reference guide rather than prescriptive rules.

Keywords
Commissioning
Decommissioning
DER integration
Energy storage
ESIC

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1 INTRODUCTION

Commissioning is defined by IEEE as "a process that assures that a component, subsystem, or system will meet the intent of the designer and the user."[1] Commissioning an energy storage system is a key process in the life cycle of storage deployment which evaluates if the system is capable of performing as intended. Throughout the commissioning process, functional, performance, and safety tests or checks are conducted. The completion of the commissioning process—or closeout—typically marks the point where the purchaser takes ownership responsibility of the equipment and when the warranty(ies) of the equipment begins.

After the installation and connection of an energy storage system, a commissioning process is required to ensure successful integration and downstream operation. Commissioning tests are intended to address the following list of typical concerns:

- Was the storage system installed correctly and does it meet performance and safety expectations?
- Are all required safety systems and controls properly installed and performing their intended function?
- Are the integration and protection components operating as designed?
- Are the communication and control systems fully operational?
- Is the data system fully operational on both the sending and receiving ends?
- Does the storage system perform its operational goals as intended?
- Have all the terms in the purchase agreements, including warranty conditions, been satisfied?

The complexity of commissioning can vary widely, depending on the storage system size, storage technology type, location, the configuration of the BOS (balance of system), and intended functionality. For small, simple, packaged systems, the process can be as short as a few hours—barring any unforeseen events. For large systems that are field assembled and intended for multiple functionalities, the process can easily span weeks. In any case, the commissioning process itself adds costs to the project budget and time to the project schedule. These impacts need to be understood and accounted for in the early stage of project conception and addressed through the procurement and design stages.

While the energy storage market has seen rapid and sustained growth, it is still a relatively new asset class to utility, commercial, institutional, and customer energy systems. The lack of market maturity exposes many gaps in project commissioning and closeout, where inadequately planned commissioning activities have added unforeseen costs and time to projects. To mitigate these effects and allow for more cost-effective storage solutions, it is necessary to better understand this process and learn from previous commissioning efforts, successful, or otherwise.

[1] http://dictionary.ieee.org/index/c-10.html

Objective

The objectives of this Commissioning Guide are:

- To serve as a non-project-specific practical guide for utility users, suppliers, and other stakeholders, municipal or governmental owners, and commercial entities who are participating in energy storage system projects.
- Support the development of practical, industry leading, deployment-oriented, commissioning practices to bridge experienced gaps evident with recent storage installations.
- Supply real world checklists to give readers insight to specific steps of commissioning activities.
- Illuminate the impacts that new and evolving storage safety codes and standards can have on the commissioning activities.
- Support the development of safe and practical decommissioning activities, and planning for such events early in project development.

This guide is designed to be as generic as possible for energy storage commissioning. The scope includes all the types of activities required. Some may be optional for smaller, self-contained behind-the-meter systems. For very large-scale utility or industrial systems, the time requirements may be larger. The recommended personnel may be subcontractors or employees with the required skills.

Note that while this guide is focused on commissioning of new energy storage systems and is intended to ensure their proper operation prior to system acceptance and service initiation, it can also be used as a basis for any necessary system recommissioning.

Development of this update was conducted within the wider ESIC program and involved coordination between the Testing and Characterization Working Group (working on the test protocols) and the various subgroups within the Grid Integration Working Group focused on safety, communications and controls, and those updating the ESIC Energy Storage Implementation Guide.[1]

Commissioning Process Overview

To enable an efficient commissioning process, this Guide has been developed to include leading practices from previous field experience, ESIC stakeholder input, and real-world documentation used by vendors, utilities, and other stakeholders, as well as standards, codes, and regulations for energy storage safety. General requirements for commissioning include:

- Roles and Responsibilities
  - Clear definition of roles and responsibilities for various parties, addressed at conception and reevaluated or refined at each phase of the project.
- Defined Testing
  - A clearly defined and effective set of commissioning tests, including field testing, subsystem testing, and/or Factory Acceptance Test (FAT).
  - Requirements for testing, documentation, and validation of compliance with storage system safety, building, and fire codes.

- Planned and Budgeted Commissioning Process
  - The commissioning activities need to be accounted for early in a project's planning phase, as well as executed successfully prior to system turn-over. This entails consideration of specific steps taken in a typical plan for all system components.
  - Often specific equipment and software is required to complete all aspects of commissioning. Some can be challenging to acquire and advanced planning is necessary.
- Contingencies
  - Contingency plans for special project circumstances that could affect timing associated with the conduct of any of the processes associated with system commissioning. Many impacts such as weather, shipping and installation damage, and lack of equipment could compromise the commissioning schedule and other deployment activities that depend on it.

The figure below is a graphical representation of the general commissioning process by project phase outlined throughout this document, as it fits within the overall project activity (note particularly the boxes shown under the Deployment and Integration column). There is a full-page version of this figure in Appendix B.

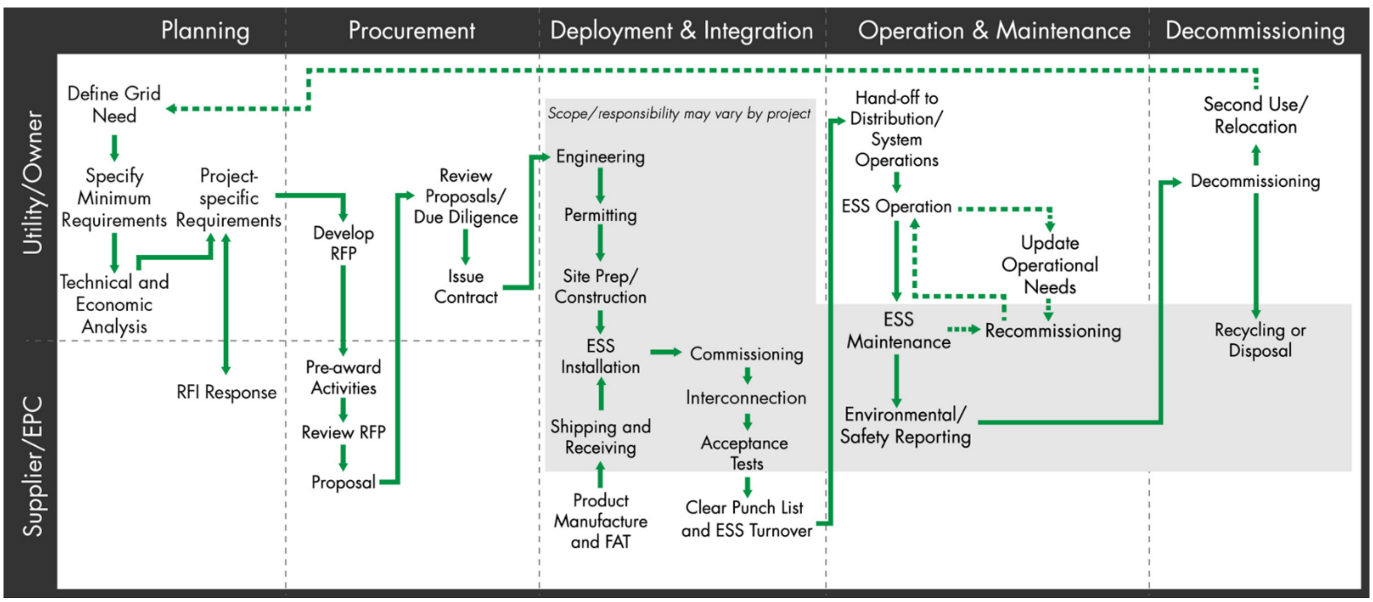

Figure 1-1
Summary of Energy Storage Project Phases

Organization of the Commissioning Guide

Chapter 2 begins with a review of the safety codes and standards that are now required for an energy storage system (ESS), and which will be reviewed prior to completing commissioning. This is placed early in the Guide because it drives not only commissioning but many design features. Following Chapter 2, the stages of the commissioning process are discussed in the typical chronological order that overall project deployment would be executed, based on the ESIC Energy Storage Implementation Guide 2018 [1] and antecessor documents.

Chapter 3 assesses commissioning considerations in the planning phase of energy storage projects. Chapter 4 discusses considerations for commissioning in the procurement phase of a project, followed by further commissioning considerations in the deployment and integration phase in Chapter 5. Chapter 6 provides guidance for recommissioning and the relevance of commissioning during the operations and maintenance phase. Finally, Chapter 7 discusses some decommissioning considerations. Chapter 8 includes References cited in the document.

Appendix A provides a list of the acronyms and abbreviations used throughout this guide. Appendix B summarizes the ESS project phase diagram. Appendix C references specific tests from The ESIC Energy Storage Test Manual, published by ESIC [2], and the Protocol for Uniformly Measuring and Expressing the Performance of Energy Storage Systems [3], which are applicable to the commissioning process.

The following checklists are also included in Appendix D:

1. Battery Commissioning Steps – Generic for Lithium Ion
2. Air Cooled Condensing Units Commissioning Steps
3. Field Evaluation Based on UL9540

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CODES AND STANDARDS REVIEW AND SAFETY CONSIDERATIONS

Safety must be considered throughout each phase of the project: planning, procurement, deployment and integration, operation, and decommissioning. Some safety considerations are detailed in the "Energy Storage Safety: 2016, Guidelines Developed by ESIC for Distribution-Connected Systems" or "ESIC Safety Guide" [4], which was used to inform past commissioning practices.

However, since the first publishing of this Commissioning Guide, there have been substantial updates and developments of safety Codes and Standards that pertain to ESS. This has been predominately driven by recognized gaps in regulation and hazardous events pertaining to, predominately, lithium ion battery ESS. Much of what has transpired since 2018 is a re-thinking of the safety and installation requirements of ESS that span from the project planning phase through the entire life of the project, with independent considerations in each phase. Three of the main Codes, Standards, and Regulations (CSR's) are discussed here. General safety considerations are also discussed below.

Codes and Standards

Three of the main Codes and Standards that apply to ESS safety and installation practices are:

- International Fire Code (IFC) Section 1207, Electrical Energy Storage Systems [5]
- ANSI/CAN/UL* 9540 Standard for Safety: Energy Storage Systems and Equipment [6]
    - ANSI/CAN/UL 9540A Standard for Safety: Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems
- NFPA**855 Standard for the Installation of Stationary Energy Storage Systems [7]

Within the context of commissioning, both NFPA 855 and the IFC (NFPA 855 6.1 & IFC 1207.2) contain requirements that the system owner or designated agent develop both a commissioning and decommissioning plan, as well as a commissioning report that describes tests, operations, and verifications conducted on safety equipment. Summarized information and content that must be included, but not inclusive of all, are:

- Commissioning plan shall include the 11 items noted in NFPA 855 6.1.5 and the 12 found in IFC 1207.2.1 with the final item on each list being a decommissioning plan. A summary of a few key items included are:
    - Roles and responsibilities shall be identified

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* ANSI = American National Standards Institute

CAN = Controller Area Network

UL = Underwriters Laboratory

** NFPA = National Fire Protection Association

- Detailed descriptions, who will perform, and schedule of each commissioning activity
- Testing of fire detection, suppression, thermal management, ventilation, or exhaust systems, and safety controls
- Training of operating and maintenance staff
- Decommissioning plan

- Commissioning report that shall include the following summary key items:
  - Summary of the commissioning process, system operation, and safety systems
  - Commissioning plan, specifications, results, issues identified, and a corrective action plan accepted by the Authority Having Jurisdiction (AHJ)

The party responsible for permitting should identify the AHJs involved and schedule regular meetings and discussions in order to inform and educate the AHJs about the project. If possible, a checklist with all of the permitting requirements should be obtained from the AHJs in advance.

The installation location of the ESS will determine the jurisdiction of the Code or Standard that applies to the project. An effort to harmonize the language between NFPA 855 and IFC Section 1207 was made in the most current IFC version. This effort serves to ensure a safe installation regardless of whether the ESS owner requires a product that is compliant with the IFC or NFPA 855 or with the applicable Code or Standard jurisdiction. As these standards develop with the industry and are codified in the IFC and International Building Code (IBC), rapid changes have led to many version-control challenges across the United States.

Lessons Learned: Identify Required Codes and Standards	
Project Context	Many vendors are not aware of the full scope of the requirements found in energy storage installation codes, standards, and regulations (CSR's – to include NFPA 855, International Fire Code) and the effects this will have on the design of their system.
Project Experience	Vendor was selected after a competitive bid process and claimed to have an ESS that was compliant with explosion mitigation requirements found in the CSR's but did not actually have a compliant system.
Root Cause	Many ESS vendors are confused about the difference between having a UL 9540 listed product and having an ESS product that is designed to meet CSR installation requirements.
Advice for Future Projects	Some things can be done in the procurement portion of the project process to improve project outcomes: Adding more descriptive language describing desired design requirements rather than simply stating that a project must meet a given CSR in the request for proposal (RFP) and adding installation requirements to the Q&A portion of vendor interviews.

The inaugural 2020 edition of NFPA 855 *Standard for the Installation of Stationary Energy Storage Systems* is a comprehensive document that combines the requirement for obtaining and using results from a UL 9540/UL 9540A certified energy storage product and incorporates those into energy storage installation requirements—many of which are incorporated in Section 1207 of the IFC. The NFPA 855 2023 edition includes many updates and additions. One of the main updates is an official Scope which covers all stationary ESS including those that are Utility owned/operated. Table 2-1 lists requirements from the NFPA 855 2023 Edition that can potentially impact commissioning.

Table 2-1
NFPA 855 (2023 Edition) main sections important to Commissioning

Requirement	Chapter
Listing	9.2.1
Hazard Mitigation Analysis (HMA)	9.2.2
Fire and Explosion Testing	9.1.5
Explosion Control	9.6.5.6
Test Reports	9.1.5.2

Product equipment listing (9.2.1) requires that the ESS be listed in accordance with UL 9540. This requirement, although found in the installation Codes/Standards, must be identified early enough in the project to be included in the Request for Proposal (RFP) and demonstrated as complete by the system vendor.

Specifically for lithium ion BESS, if it is not UL9540 listed then it shall require a hazard mitigation analysis (HMA) be performed (NFPA 855 9.2.2), with potential installation of hazard mitigation measures being required. This would trigger a re-commissioning effort for already installed BESS (See Chapter 6.2 of this Guide).

A cornerstone of NFPA 855 is the Fire and Explosion Testing (formerly Large-Scale Fire Testing – NFPA 2023 added the evaluation requirement for deflagration mitigation that are designed into the ESS). This is conducted in accordance with the UL9540A test method by an approved testing laboratory (typically a Nationally Recognized Testing Laboratory – NRTL). This test aims to reveal the behavior of an ESS in a failure state (thermal runaway) and provide insight into potential failure propagation from one ESS unit to another. Fire and explosion testing must demonstrate that a fire in one ESS will not propagate to an adjacent unit. In addition, the testing will determine if the explosion mitigation measures that may have been designed into the ESS meet the requirements found in Explosion Control (9.1.5). If explosion mitigation measures have not yet been designed into the ESS, the Fire and Explosion Testing results provide the basis of design for one of three different methods allowed by NFPA 855. The three explosion mitigation measures are explosion prevention (in accordance with NFPA 69), deflagration venting (in accordance with NFPA 68), or other methods in lieu of NFPA 68 & 69 that have been validated by Fire and Explosion Testing at the installation level and engineering evaluation compliant with NFPA 855 9.1.5 (i.e., an automatic enclosure door opening system).

Results from the Fire and Explosion Testing and an additional supplemental report prepared by a registered engineer (with expertise in fire protection) shall be provided to the AHJ per Test Reports, NFPA 855 9.1.5.2.

Fire and Explosion Testing results and the impact on the design of the BESS have the potential to impact commissioning schedules, specialty equipment, and/or personnel required to perform specific acceptance tests and should be identified early in the project process.

Depending on both large-scale fire testing and the explosion control method provided by the ESS vendor, deliverables will vary, but are required to include some combination of test data, evaluation information, and calculations (NFPA 855 4.1.2.1.3). Site field acceptance testing may also be required during commissioning.

Recommissioning may be required to verify continued safe operation, control, and shutdown of the system due to changes in operating firmware or other physical modifications made during the operational phase. A decommissioning and disposal plan may be needed to ensure materials are disposed of safely or recycled at end of life, or in the event of system damage requiring decommissioning. This plan could explain the procedure for decommissioning, including any hazards this may present.

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COMMISSIONING CONSIDERATIONS DURING PROJECT PLANNING AND DESIGN

The commissioning effort needs to be addressed and quantified from a budget and schedule perspective in the first stages of project development. This includes identifying additional equipment, instruments, and software planning and development to conduct site testing, and also describes initiation of the utility interconnection request. Once the project has been identified and energy storage parameters and requirements have been established, the following elements of the commissioning plan should be included in the initial project planning phase.

Assessment of the Intended Storage Functions and Associated Tests Required

Depending on the functionality chosen, the extent of testing needed during on site commissioning must be identified up front in order to establish adequate performance of the installed system. One approach that can define the needed tests is to establish a typical sequence of operations (SOO) for the system. In addition, it is helpful to look at whether the system is intended to provide only real power or if it is required to provide reactive power as well. Adding reactive power capabilities can substantially add to system design, integration, and commissioning activities. Table 3-1 depicts expected duration and the ability to combine tests (share duty cycle) for tests described in the ESIC Energy Storage Test Manual [2]. It also points to tests that can be conducted simultaneously through the Shared Duty Cycle column.

Table 3-1
System tests that may be required to verify specifications or functionality

Test	Purpose	Duration	Shared Duty Cycle?
Stored Energy Capacity Test or Available Energy Capacity	Performance Verification	2 days	Yes – Capacity Test
Roundtrip Energy Efficiency Test	Performance Verification	4 days	Yes – Capacity Test [2]
Charge Duration	Performance Verification	3 days	Yes – Capacity Test
Rated Continuous Power	Performance Verification	3 days	Yes – Capacity Test
Auxiliary Load Determination and Monitoring	Performance Verification	6 days (ambient temp dependent)	Yes – Capacity Test - to an extent
Self-Discharge Rate	Functional Verification	Depends – long term	
Response Time and Ramp Rate Test	Functional Verification	4 hours	Yes – Capacity Test [3]
Startup and Shutdown Time	Functional Verification	1 hour to 1 day	Yes – Capacity Test
Synchronization	Functional Verification	1 day – dependent on interconnect procedure test	Yes – Interconnect Test
DC Injection	Functional Verification	1 day – dependent on interconnect procedure test	Yes – Interconnect Test
Harmonic Distortion	Functional Verification	1 day – dependent on interconnect procedure test	Yes – Interconnect Test – Capacity Test
State-of-Charge Excursions PNNL/SNL	Functional Verification	1 day – depending	
Energy Capacity Stability PNNL/SNL	Functional Verification	3 days minimum	

[2] There may also be efficiency tests at less than full power (commonly ¼ and ½).

[3] This may not test all the response time and ramp rate conditions laid out in the ESIC test manual (full charge to full discharge and vice versa).

It should be noted that commissioning of commercial-type systems can take between one week to months based on installation size. A relatively small ESS system with one or two enclosures may be completed in one week if done efficiently. As the site grows, there is more to test—and more to fix if an issue is uncovered during commissioning.

The distinction between intended two-quadrant versus four-quadrant operation needs to be identified at this stage; if the storage system is intended to operate at unity power factor throughout its life, the controls needed and tests performed are somewhat simpler than a system performing various four quadrant functions such as frequency or voltage support. In the four-quadrant case, more complicated tests will need to be performed to establish correct functionality and allow for safe integration to the grid. The breadth and level of effort of these tests can be ascertained through review of the previously mentioned test protocols [2, 3] as well as documented utility acceptance or witness tests that prescribe efforts needed to connect to the grid.[4] Consideration of specific equipment needed to perform this testing also needs to take place. The aforementioned test protocols list, describes in part, some of the test equipment needed.

In planning commissioning tests, consideration should be given to technical standards that provide guidance on DER test procedures, e.g., IEEE 1547.1 "Standard for Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems" [8]and IEEE Std. 1547-2018 [9].

Consideration should also be given to the intended uses of the test data, at the time of commissioning and after. These uses may include recorded data and *derived information* that will be used at the time of commissioning (e.g., measured power and capacities), and at future points in the project's lifecycle (e.g., testing for degradation relative to as-commissioned energy storage capacity). Commissioning test data is also an important component of warranty obligations. Test design should consider the data characteristics needed (the measured attributes, units, time resolution) for established industry practice for derived performance values. For example, test data should support the calculation of system Availability Factor (AF) as defined in IEEE 1366 [10]. Other examples of derived performance metrics that project commissioning tests and resulting data should be consistent with (metrics, units, time frame and resolution) include reliability indices such as SAIDI/SAIFI. IEEE Std. 762 [11] provides information on utility distribution-oriented reliability metrics.

Preliminary Commissioning Schedule Development

This effort will begin to identify overall steps, parties responsible, and interdependencies between commissioning activities. Review of industry standard test procedures, associated test requirements, and testing methods analysis should take place to identify which plans will be needed to allow for integration to the grid and establishment of specified functionality. An interconnection request should be initiated at the earliest possible opportunity. These plans will indicate the level of effort and personnel requirements from all parties involved and can influence project specifications.

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[4] Various labels exist for utility integration tests – in this document, Witness testing is used to avoid confusion with other Acceptance tests that might apply.

Lessons Learned: Engage Utility Prior to Interconnection Request to Understand Utility Requirements	
Project Context	ESS owner submitted interconnection request and the utility review and interconnection study took well over a year plus time required for utility required system upgrades because of the review.
Project Experience	The ESS was installed, partially commissioned, and sat idle for months. Interconnection request approvals by the local utility can take longer than planned or expected.
Root Cause	Several factors led to the extensive delay; inexperience of the utility with energy storage interconnection requests, personnel shortages within the utility departments, backlog log of existing requests, understanding of the utility's requirements and terms of application.
Advice for Future Projects	As system owner, it is paramount to understand the interconnect requirements and process of the utility with which the ESS will be interconnected. If possible, meet with the utility prior to submission of the request to understand their requirements in detail to avoid delays and re-submission. Also, talk to other ESS owners that have dealt with the utility to understand the time an interconnection request may take and then plan accordingly.

During the planning phase, it may be important to include time and space for site mobilization. For relatively large systems, sites often have mobile offices. These are not just a single office trailer, but one that may contain conference rooms, offices with cubicles, etc. It is also during the planning phase that time considerations for the utility interconnection request must be considered. Depending on the experience of the local utility, interconnection request approvals can take months to well over a year or may be scheduled in annual/biannual "class years". Most utilities will have a defined process for when a project can first submit an interconnection request and what information is required. It is in the best interests of the project to work with the local utility early to understand the requirements. While most other aspects of commissioning can occur if the interconnect request is not yet approved, the energy storage system cannot operate connected to the grid until the approval is finalized. This has the potential to create delays in the utility integration tests that follow.

Many job functions are needed at various times to prepare for and carry out commissioning. For a utility system, these functions may reside in-house. For commercial, industrial, or municipal systems, the contracted entity may provide or hire these functions or skill sets. Based on needed utility integration tests, a variety of personnel may be needed to develop and execute the commissioning plan. These entities should be identified and individuals within utility functions assigned for provision of input and downstream effort scheduling. Example groups may include:

- System Protection and Control (P&C)
- Distributed Energy Resource (DER) Integration
- Substation engineering

- Communication/cybersecurity
- Data systems – analysis, archiving
- Distribution/transmission engineers
- Distribution/transmission operators
- Control room operators
- Network operators
- Maintenance
- Safety & Environmental, which could include on-site or local fire officials

In parallel to developing the test protocol during the planning phase, it is necessary to perform a cursory, pre-design review of applicable federal, state, or local regulations and/or criteria imposed by the system owner, insurer, financing parties, and/or independent engineers that may apply to the project.

- An initial scan should be performed to envision what codes and standards will apply to the project and which AHJ will be involved in assuring adherence.
- Depending on the location and ownership model, local permitting may be a project requirement. The permitting authorities therefore can be a key part of the commissioning process, as the project may require their external and explicit approval prior to project energization.
- Owner's risk management posture and associated company insurance requirements may influence the CSRs that are applicable. Traditional utility stances of self-inspection may be superseded in certain circumstances, especially considering recently published or emerging storage safety CSRs.
- Any expectations on documentation needed from commissioning for risk assessment should be defined early in the planning process.

Vendors, the main integrator, or storage supplier, will possibly be subcontracting vendors to complete the assembled system[5] (assuming non packaged). In terms of defining downstream procurement, initial concepts of flowing down terms and conditions should be considered in the Planning phase. They should also include requirements for site access, including mandated safety training for personnel to gain access to the site. It is important to ensure that all entities that are interdependent in the commissioning activity be held to scheduled roles. These entities may include specialty subcontractors responsible for:

- Fire detection and suppression
- Climate control including system ventilation and exhaust
- Control of the storage system
- Power conversion system (PCS)
- Controls/communications (underneath the utility network)

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[5] Currently, a number of vendors supply AC integrated battery energy storage systems, requiring less onsite integration work.

- Hazardous material handling

Contingencies should be considered for numerous reasons. If the schedule and inter-dependencies are tightly bound, the overall schedule may be sensitive to many effects. These can include shipping delays, tool breakdown, damage during shipping, and weather. The time of year and expected weather should be considered as much as the commissioning effort in order to alleviate conditions such as open electrical cabinets during wet weather.

Another challenge can occur if the sequencing of equipment arrival is spread out, such that temporary onsite storage is required. For example, if lithium ion battery modules arrive on site before their outdoor enclosures, then there may be requirements for dry, temperature controlled storage with fire detection and suppression.

The other main consideration for time and cost contingencies is the troubleshooting that will be encountered during commissioning. All systems contain components from a number of vendors, and it is practically guaranteed that troubleshooting will be required for systems to function correctly together.

Initial Scheduling/Budgeting

To adequately define commissioning needs for the procurement phase, all potential parties to the commissioning plan need to be identified and scheduled in as much detail as possible. Additionally, associated labor cost rates for individuals ultimately need to be identified for a rough budget estimate. As levels of effort for these participants are further defined in downstream procurement efforts, these costs will be solidified.

For the case of a contractor or vendor-supplied complete system, the solicitation will call for all commissioning costs and schedule to be part of the proposal or bid.

For a utility project, the planning phase may include making rough budget estimates based on personnel needs. For example, a 1 MW, 4 MWh lithium ion system sited at a utility substation, performing four-quadrant duties and a variety of storage functions, may need commissioning participation from the following entities.

- Utility Protection
- Utility DER Integration
- Utility Metering
- Utility DER Planning
- Utility Substation
- Utility IT/OT Communication system and Relay Communication
- Engineering, Procurement and Construction (EPC) firm
- Energy Storage Component Vendors
    - Site Controller
    - PCS
    - Energy Storage System
    - HVAC

- Fire Protection

Additionally, the utility's plant shutdown schedule (existing facilities only) should be planned in this phase of the project to allow Utilities/Owners to make arrangements for commissioning activities as listed below. This can include outages needed for interconnection and protection coordination.

Table 3-2 depicts potential durations and factors that may need consideration for specific efforts. These duration periods have typically applied for smaller systems, on the order of 1MW. Larger systems may require more time for testing and inspection.

A FAT is typically done at the manufacturing facility, and for large or modular systems is based on statistical results of a random selection of units or modules. The test results are a deliverable, even if the owner does not personally witness the testing.

Table 3-2
Projected involvement and representative duration of commissioning steps.

Step	Involved Party	Duration	Notes
"Rough in" preliminary inspection	• AHJ or other 3rd party • EPC	0.5 day	Dependent on AHJ schedule
Factory Acceptance Test (FAT)	• Utility representative • System Integrator • Site Controller Vendor • PCS Vendor • Battery Vendor	2 days	Coordinated through contract – many parties may be involved and travel to the factory. Any requirement for the FAT should be indicated early in procurement as there are costs involved that need to be exposed
Final Field Electrical/Civil Inspection	• AHJ or other 3rd party • EPC	0.5 day	Dependent on AHJ schedule
Pre-startup Vendor Inspection	• Component vendors or system integrators	2 days	Many vendors may be involved – all need to be coordinated by project manager
Protection equipment/system commissioning	• Utility Protection	2 days	Needs to be scheduled

Table 3-2 (continued)
Projected involvement and representative duration of commissioning steps.

Step	Involved Party	Duration	Notes
Start-up/Functional Testing (e.g., subsystem commissioning)			
Site Security	• Component vendors or system integrators	1 day	Necessary first step for Safety
Energy Storage Modules	• Component vendors or system integrators	2-5 days	Dependent on system size
Remote Communications	• Component vendors or system integrators • Utility IT	1 day	IT coordination and vendor coordination required
Controls	• Component vendors or system integrators	2 days	IT and vendor coordination required Shared
Fire Protection/ Safety Systems	• Component vendors or system integrators	1 day	Required before energization Shared
HVAC	• Component vendors or system integrators	1 day	Required before energization Shared
Ancillary	• Component vendors or system integrators	TBD	
Field Evaluation	• Testing/Certification Agency	2-10 days	Dependent on UL9540 requirements and any pre field activities
Interconnection	• Utility	1 day	Based on utility scheduling
Performance Testing	• Integrator • Utility test engineer	2-5 days	Dependent on test performed and associated durations

The FAT requirements and specifications should be clearly identified in advance since there are not only the installation, dismantling, and repacking costs, but also possible infrastructure and permitting costs and tasks.

First Pass Budget and Schedule Impacts

In developing the initial schedule and budget, the following steps can be taken:

1. Develop a commissioning timeline for the project – it is important to note that many commissioning activities are interwoven and dependent on other activities. This inter-relationship can be best shown with Gantt chart type dependencies. In order for efficient execution of the commissioning effort to take place, all parties need to conduct their respective activities on a strict and timely basis.
2. Determine the budgetary considerations, including costs of permitting, to execute this plan by both the utility or owner and suppliers. This involves defining the initial level of effort for each step and identifying the Subject Matter Experts needed to conduct each step for various groups, including:
    - Utility or Owner's Personnel
    - Vendors and Engineering, Procurement and Construction (EPC) companies
    - Independent Engineers
    - Other entities identified

Once the level of effort is determined, labor costs can be assigned and summed to give an approximation of the overall commissioning labor cost. Any special testing equipment and travel need to be identified and summed to the initial budget.

4

COMMISSIONING CONSIDERATIONS DURING PROJECT PROCUREMENT

With an initial budget and schedule defined in the planning process, the procurement effort needs to refine the draft commissioning budget (as a subset of the overall project budget) and establish rules, terms, or conditions on performance of commissioning activities. Guidance on this phase is split into two phases: 1) the solicitation or request for proposal (RFP) development, and 2) contract award.

Lessons Learned: Successful Commissioning Relies on the Procurement Phase	
Project Context	Detailed Commissioning Plans not included in solicitation / RFP
Project Experience	Appropriately skilled personnel not available at expected time of commissioning. Commissioning was delayed.
Root Cause	When the RFP was written, it did not request a detailed Commissioning Plan with roles and responsibilities called out, along with budget and schedule.
Advice for Future Projects	Include in the RFP a request for a detailed Commissioning Plan and named personnel with identified responsibilities.

Commissioning Activities during Solicitation / RFP Development

Activities during solicitation development include:

1. Request bidder to supply initial schedule expectation/Gantt chart that displays foreseen parties involved and interdependencies. In a broad sense (details discussed in later sections) the aforementioned entities will potentially have a role in the ultimate commissioning activity.
2. List mandatory or applicable Codes and Standards and Environmental permitting. Inclusion of non-applicable Codes and Standards and permitting requirements can lead to confusion and extend the duration of the procurement.
3. Inclusion of tests and communication protocol needed (with available test plans attached or referenced).
4. Inclusion of an expected division of responsibility matrix, with roles and responsibilities of each stakeholder defined, including those of any third parties acting on behalf of the utility, the supplier(s), or system integrators.
5. Explicit specification of expected terms, conditions, and payment milestones intended to enforce timely and effective participation in the commissioning process and overall project. Given the interdependencies noted, contracted relationships could carry terms that penalize the contractor and their subcontractors for non-performance or failure to comply with the commissioning schedule.

6. Request for a written commissioning plan in proposals submitted in order to validate or modify draft commissioning schedules, budgets, and steps.

Commissioning Activities during the Contract Award Process

Activities during the contract award process include:

7. Modify vendor proposal and align to pre-solicitation commissioning schedules.
   - Create firm milestones and penalties for non-compliance. Establish written terms for issue resolution with all major stake holders.
   - Identify all owner and vendor groups, subcontractors involved in commissioning.
8. Create contingency plan for missed deadlines in the commissioning process from owner perspective.
9. Determine and communicate site specific impacts to commissioning and the overall project.
   - Site access and security
   - Clearances for equipment
   - Delivery of equipment and personnel
   - Site Safety and Environmental Training
10. Verify applicable codes and standards and responsibility (along with all construction activities), for compliance in a Responsible, Accountable, Consult, and Inform (RACI) Matrix or similar which is aligned to overall project and commissioning specific schedule.
    - Include environmental as well as civil, mechanical, and electrical permitting requirements, and applicable Codes and Standards
    - Identify AHJ and their role in review and/or approval of the project
    - Allocate budgets to the Owner, EPC and others including equipment providers
    - Clearly delineate tests to be conducted and associated pass/fail criteria. Identify clear assignment of verification responsibilities and remedies for unacceptable results
    - Clarify the FAT – identify which specific systems/subsystems are to be factory or bench tested; identify who is to witness, as well as the location, to firmly identify costs and schedule impacts. It is also necessary at this point to understand the capabilities of the facilities used for the FAT and expected power levels to be tested.
11. Present applicable cyber security policies. For more information on cybersecurity, see the latest ESIC Electrical Energy Storage Data Submission Guidelines, Version 3 [12].
12. Identify vendor remote access capabilities.
    - IT engagement at this point can define expectations for vendor access
    - In some cases, pre- and post-commissioning access policies can be different
    - Provision of register mapping and communication protocol specification can help facilitate communication integration in the next phase

5
COMMISSIONING CONSIDERATIONS DURING PROJECT DEPLOYMENT AND INTEGRATION

This phase encompasses the manufacturing of the equipment, shipping, development of the site for installation, the installation of equipment, and finally the subsequent integration of the storage equipment to the utility grid. Tests and inspections that are to be conducted during this phase should be identified, understood, and validated prior to commencing this phase. Additionally, the specifications that are to be tested should be uniformly understood and agreed upon by all related parties so that the acceptable performance benchmarks are established. This phase is discussed below from the following aspects: 1) Safety Planning, 2) Construction and Installation, 3) Pre-Commissioning, 4) Commissioning, and 5) Site Acceptance.

The main intent of the commissioning activities is to ensure that the system remains within the established specifications during its full range of operation as per the specified SOO.

Safety Planning

Safety plan development should cover all commissioning activities, as noted in Section 2. Key aspects may include:

- Identification of site hazards
- Emergency shutdown procedures / fail-safe states
- Emergency Power Off (EPO) interlock strategies with related equipment / systems
- First responder action plans
- Documenting rules for site access
- Safety training procedures for site access
- Assigned personnel access
- Management of keys
- Lock out / Tag out (LOTO) procedures
- Personal Protective Equipment (PPE) provisioning
- Loading / unloading equipment (e.g., rigging instructions)
- Technician certification requirements
- Post commissioning removal of temporary equipment
- Post commissioning review and assessment

Construction and Installation Activities

The main commissioning-related actives during construction and installation include rough-in inspections, FAT, and final field inspection. The completion of these activities is typically associated with reaching a mechanical completion project milestone.

One effective way to integrate all parties effectively is issuance of a Daily Plan on the day before scheduled activities. This allows for contingencies to be addressed and creates clear assignments.

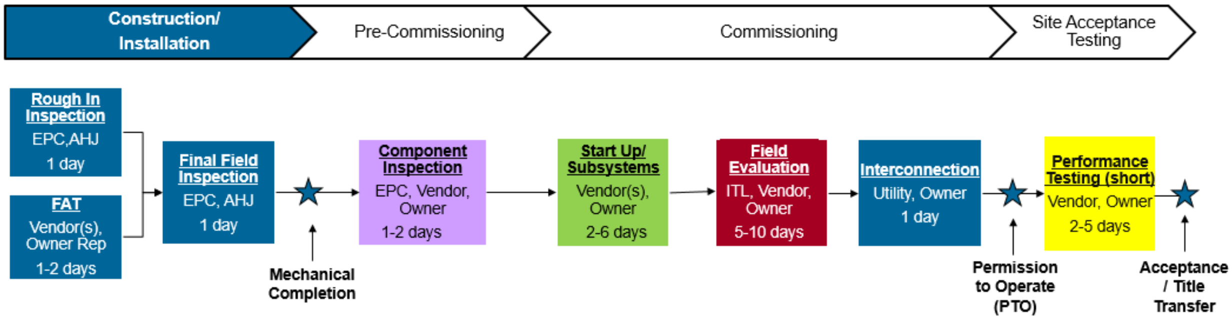

Figure 5-1
Commissioning-Related Activities – Construction/Installation Focus

Rough in inspection (AHJ or other 3rd party) – depending on the AHJ, permitting, and code requirements, a preliminary or "rough in" inspection may be required prior to final equipment placement to ascertain compliance to underground placed infrastructure and other items. Even when not required, it is recommended practice to inspect all installed components that will be covered up for proper installation prior to covering them up.

Factory Acceptance Test (FAT) – the FAT is traditionally centered on single pieces of equipment rather than field assembled systems. The FAT is typically witnessed and conducted at the originating factory floor prior to shipment. As stated above, the FAT could be used to test integration standards (UL 1741 for inverters) and to verify cross functionality and correct mapping. Tasks performed during a FAT, but not limited to, and considerations are provided below:

- Compliance test for the PCS (for UL 1741 compliance) but can be extended to a packaged system (UL 9540)
- Bench or hardware-in-the-loop testing of various control systems to integrate as a whole system and operate together. This is important to ensure cross functionality and correct register mapping to achieve:
  - Verification of sensors, metering, and alarms
  - Verification of remote control and monitoring
  - Verification of data systems
- Verification of all control functions, including remote control and monitoring (packaged systems) as well as verification of system performance, at full and partial power, energy ratings, and efficiency (packaged systems)
- Capabilities of the testing facility need to be clearly understood to correctly define the tests to be performed. A key example is testing an inverter with undersized load banks. This prevents the full charge/discharge capabilities from being tested but does allow for some function and protection-based testing
- The FAT may present an opportunity to reduce field activities related to UL9540 field assessment. If field evaluations are preceded by pre-field visits in the factory and ongoing

dialogues with the testing lab, the final field inspection can take 2-3 days. The pre-field visit and factory-related activities can be in the range of 4-5 days.

Lessons Learned: Integrated Site Acceptance Tests Required	
Project Context	Factory Acceptance Tests for energy storage and power subsystems
Project Experience	The battery subsystem passed a factory acceptance test and was shipped to the site. The power conversion subsystem, from a different vendor, passed a factory acceptance test and was shipped to the site. When integrated together, the system did not operate and extensive field work was required to fix the integrated system. Each vendor blamed the other for the problem.
Root Cause	Subsystems were sourced from different vendors who had never integrated their products previously.
Advice for Future Projects	Either purchase completely integrated systems or purchase separate subsystems that have been integrated successfully in previous projects. Otherwise plan for significant on-site integrated system acceptance testing.

Final Field Electrical/Civil Inspection (AHJ or other 3rd party) – similar to the rough-in inspection, this effort may be required prior to energization of any equipment. Deficiencies identified at this step could impact the downstream schedule while the deficiencies are corrected.

- Contingency – allow for short term fix period/schedule buffer prior to subsequent activities

Pre-Commissioning Activities

Pre-commissioning activities include the component inspections of all the equipment composing the storage system required before the system is energized.

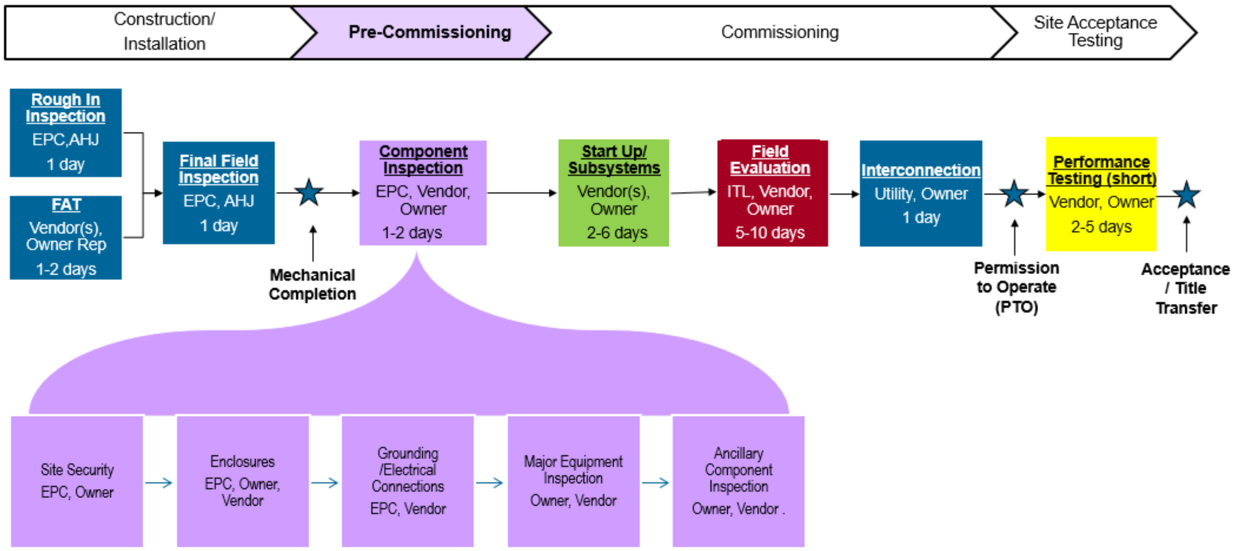

Figure 5-2
Commissioning-Related Activities – Pre-Commissioning Focus

Specific activities could include:

- Site Security – ensuring all intrusion monitoring is operable
- Enclosures are physically placed and secured per specifications and drawings
- Grounding/electrical terminations are completed per specifications
- Major Equipment inspections typically involve:
  - PCS
  - ESS Modules
  - ESS Enclosure
  - Utility transformers and switchgear
  - Data and communication systems
- Ancillary Components that need inspection could include
  - Metering
  - HVAC
  - Fire suppression and safety systems
  - Control modules

Detailed checklists are presented in Appendix D.

Commissioning Activities

The main portion of commissioning includes start-up or subsystem testing, potentially field evaluation if required by the project, and interconnection. These activities are required to receive permission to operate (PTO) and be able to operate connected to the utility grid.

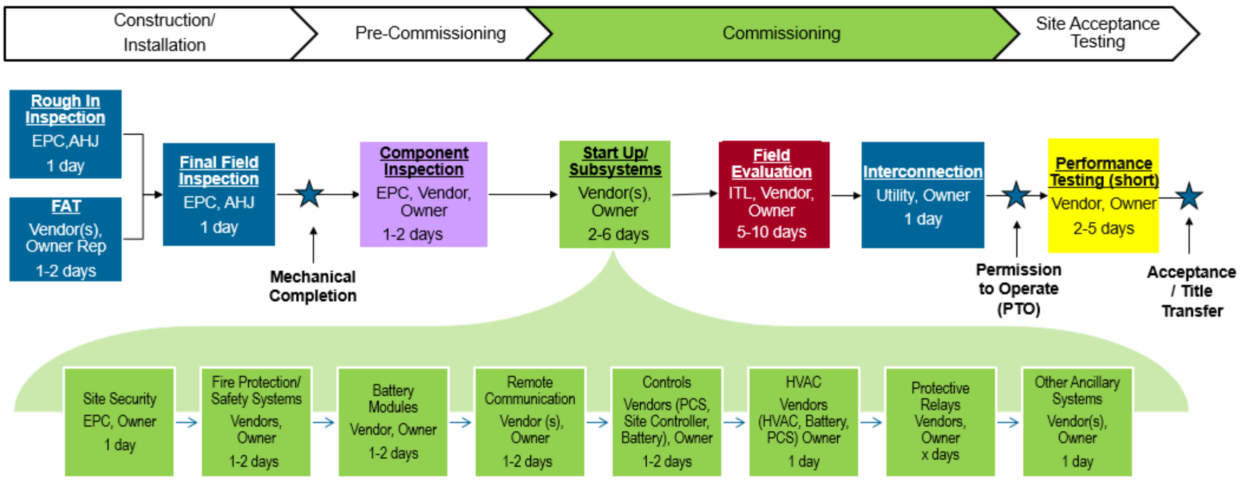

Figure 5-3
Commissioning-Related Activities – Startup Focus

Start-up/Functional Testing (e.g., Subsystem Commissioning)

Specific activities relating to start up and functional testing are depicted in the figure above. Specific activities related to this effort could include:

- Site Security – ensure perimeter locks in place – refer to safety plan.
  - Key management
  - Access management
- Protection equipment/system commissioning
  - This effort can be quite extensive and rely on numerous protection personnel. Specific programming depends on the location of the relay, the protection study associated with the location, the duties specified for the storage system and the manufacturer. (*EPRI Protection & Control Configuration Management*, TR 3002010188 could be utilized for this. [13])
- ESS Modules
  - A generic checklist associated with balancing individual modules is included in the Appendix
  - The time duration is dependent on the technology and number of modules in the system – a 2 MWH lithium ion system can take 1-3 days to balance and a timeline contingency buffer may need to be considered
- Remote Communications
  - This ensures all communication terminations are correct, IP addressing assignments correctly programmed, and that requirements from any attendant Cyber Security policy are in place
- Data System
  - Refer to EPRI Data Guides [12, 14] for data collection architecture, backup, sampling times, cyber security considerations, etc.

Lessons Learned: Make Data Collection System Part of Commissioning	
Project Context	Data acquisition system performance and remote access for a fielded energy storage system.
Project Experience	A system for remote data acquisition was part of the project definition (included in the solicitation), but testing was not required during commissioning. It took more than a year after commissioning for the remote data system to operate.
Root Cause	Remote data requirements were not well specified and verification was not required at commissioning.
Advice for Future Projects	Include data acquisition system definition and verification in project and commissioning plans.

- Controls
  - This effort needs to ensure a variety of control systems are correctly integrated and staged relationship wise. This can be an extensive effort as it may need to integrate:
    - a site controller
    - utility protection controls
    - various battery systems potentially including module, string, rack, and overall battery management systems
    - power conditioning system
  - For all these systems it is necessary to verify that all control and communication points are relayed correctly from one system to another and that the associated register mapping is correct
  - The control hierarchy needs to be verified so that the control systems respond correctly to relevant alarms and warning

Having a plan for how to carry out trouble shooting and ensuring the right personnel are involved at the site and in remote support is critical to successfully move through this portion of commissioning.

- Fire Protection/Safety Systems
  - This needs to be performed by a qualified vendor technician and could include system charging and verification of appropriate pressure requirement for enclosure.
  - It is also necessary to ensure that the fire protection and all other safety systems are appropriately tied and confirmed ready to operate to the appropriate control systems and reporting centers, potentially including constantly monitored systems and first responders.
- HVAC
  - It may be necessary to commission the HVAC system prior to any energization activities within battery enclosures. Correct operation of heating and cooling modes and associated thermostats needs to be verified.

- Adequate airflow needs to be ensured so that cooling or heating of the enclosure is as uniform as possible throughout the battery enclosure.
- A generic HVAC commissioning checklist is in Appendix D.
- It is necessary to ensure that HVAC controls are correctly tied to the appropriate system controls, including the battery management and fire suppression systems as applicable.

- Ancillary systems
  - Site intrusion alarms
  - Weather station
  - Meters
  - Fault alarms

Field Evaluation (UL9540 or similar)

UL9540 is a broad safety standard relating to storage systems, including "equipment for charging, discharging, control, protection, power conversion, communication, controlling the system environment, air, fire detection and suppression system, fuel or other fluid movement and containment, etc. The system may contain other ancillary equipment related to the functioning of the energy storage system." [6]

If a unit is assembled in the field, it may be necessary to test conformance to this standard via a field assessment. Depending on the level of pre-field activities, this field assessment can add significant time and cost to the commissioning activities. A summary checklist, covering a wide variety of technologies and integration techniques (see discussion on IEEE std.1547 below) is presented in Appendix D.

There have been instances of field evaluation of large systems (tens of MW and tens of MWh) aligned to the UL 9540 standard. These field evaluations are typically preceded by pre-field visits at the factory and ongoing dialogues with the testing lab. The final field inspection can take 2-3 days. The pre-field visit can be in the range of 4-5 days.

Interconnection

Interconnection activities confirm compliance with standards related to interconnection, including but not limited to IEEE 1547.1a (IEEE Standard Conformance Test Procedures) [8] and IEEE 1547.1 2018 Revision [9].[7]

The evolution of IEEE 1547-2018 & 1547.1 interconnect standards has encompassed new and broader functionality of the inverter and the DER resource it interconnects to the grid and can significantly impact commissioning activities.

Enhanced functionality may imply that supplemental protection equipment may be required for the DER interconnect. Supplemental DER devices may include capacitor banks, STATic synchronous COMpensators (STATCOMs), harmonic filters that are not part of a DER unit, protection devices, or plant controllers. The requirement for any supplemental equipment is determined by assessing the Point of Common Coupling (PCC) or the Reference Point of

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[6] Standard for Safety, ANSI/CAN/UL-9540:2016, Energy Storage Systems and Equipment.

[7] The Material in this section courtesy of Mark Siira, ComRent.

Applicability (RPA) and has implications for testing and conformance requirements under the evolving IEEE 1547 standards.

A key initial step involves determination of the RPA through protection planning that considers:

- Zero-sequence continuity (or not)
- Aggregate DER nameplate rating (500kVA)
- Annual average load demand (10%)

This process is detailed below in Figure 5-4.

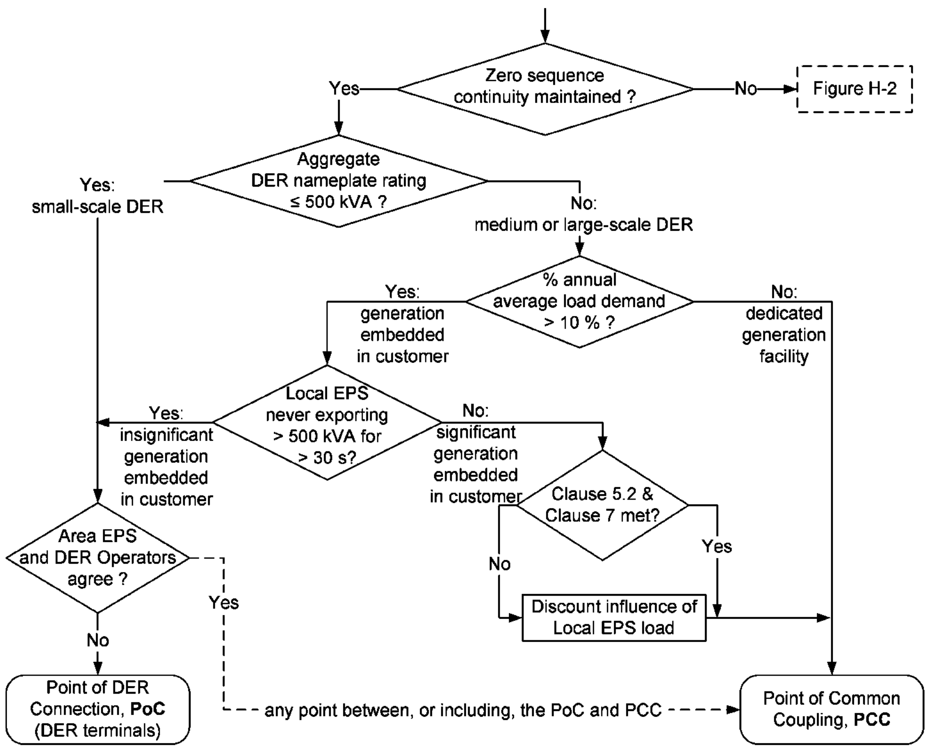

Figure 5-4
Reference Point of Applicability (RPA) Flow Chart [15]

Once the RPA or PCC is determined, the requirement for supplemental protection equipment can be made. This in turn will influence the commissioning process as follows in Figure 5-5.

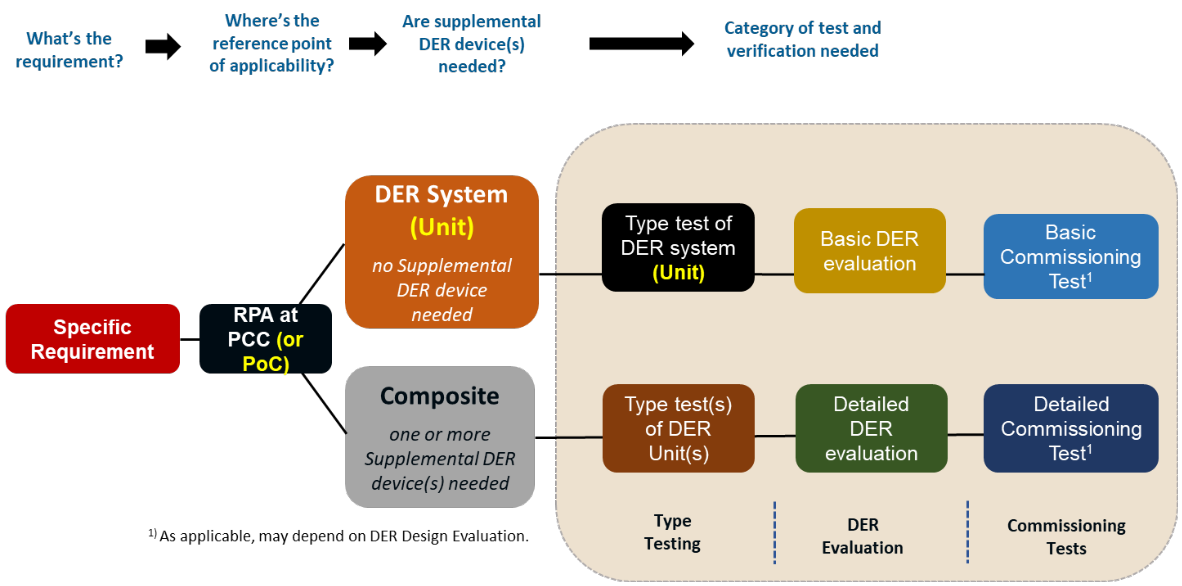

Figure 5-5
Flow down from Reference Point of Applicability determination

The detailed process and any required modeling and simulation can be very detailed and potentially follow the process below in Figure 5-6.

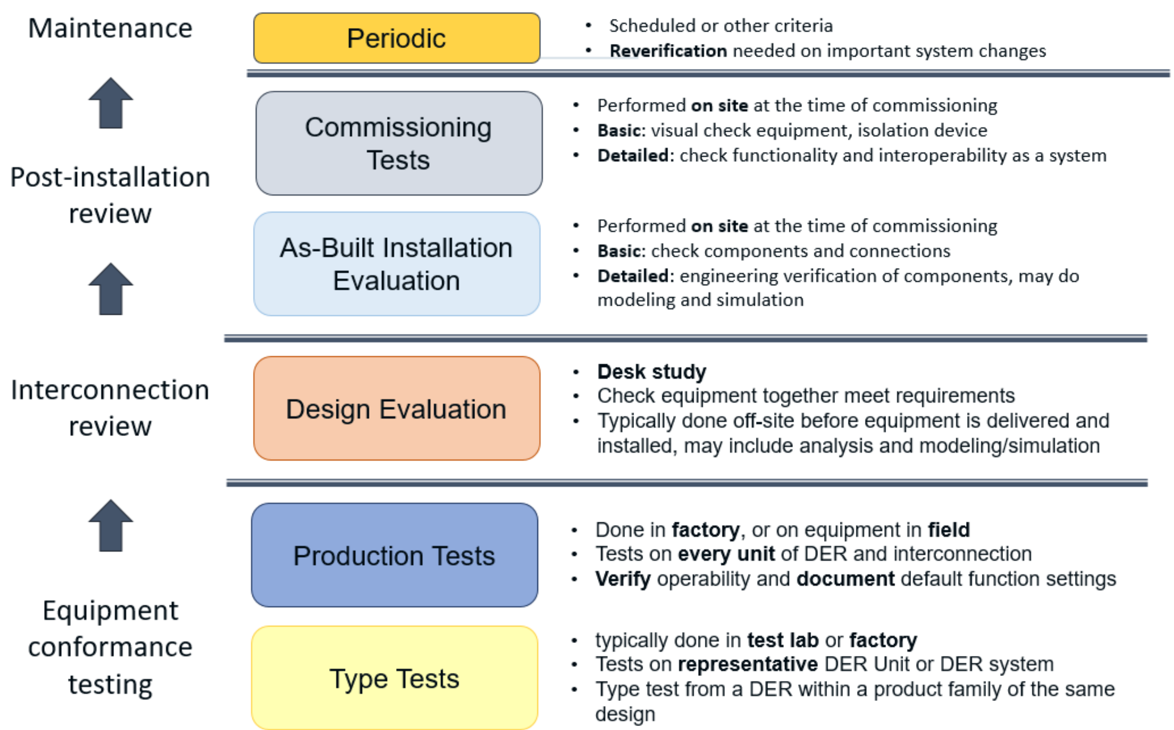

Figure 5-6
High Level Test and Validation Process

Site Acceptance Testing

Site acceptance testing is one of the final steps before the owner accepts the system and the title (ownership) of the system is transferred.

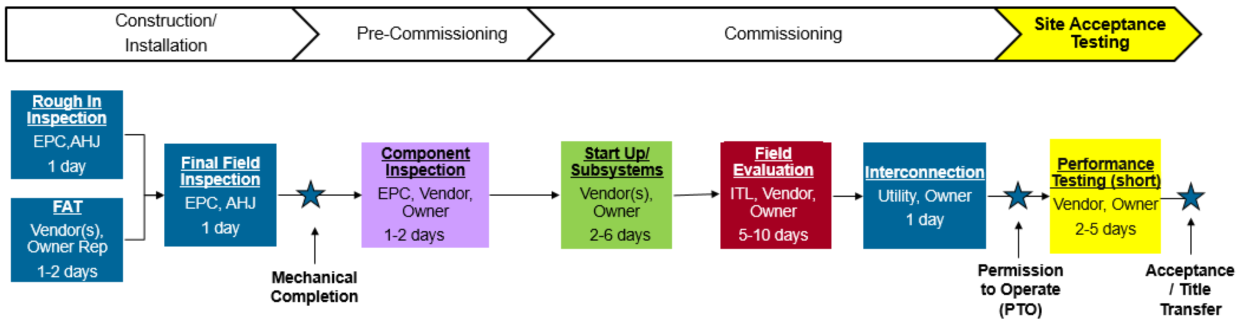

Figure 5-7
Commissioning-Related Activities – Site Acceptance Testing Focus

Final validation testing is performed once all equipment is installed and interconnected to the power system, with permission to exchange power (often occurs as a temporary permission and later an operational permission) to confirm correct and intended operation. If an SOO test has been defined previously, it should take place at this time. An example might be peak shaving. The tests involved, their potential duration, and testing requirements are detailed above in Table 3-1 and in related testing protocols.

- It should be noted that systems integrating on a network level or in a market participation role may face Independent System Operator (ISO)-related testing that can span 1 – 2 weeks.

The outcome at the end of this phase should be formal documentation indicating the system is acceptable and is transferred from the vender to the utility/owner/operator. Thoroughly documenting the explicit test conditions / protocols used in generating this baseline performance data is important so procedures can be repeated in the future to accurately assess degradation or other issues relevant to warrantee claims.

- The requirements included in the commissioning tests should flow into the operation and maintenance plans that are established for the ESS.
- The test data from the commissioning process can be used as a baseline for trending and benchmarking performance, assessment of degradation, and for future re-testing of the system. [16]

6
COMMISSIONING CONSIDERATIONS DURING PROJECT OPERATIONS AND MAINTENANCE

The operations and maintenance phase of an energy storage project begins when the system has been successfully commissioned and the owner has obtained approval to operate the system. This phase continues until the end of the project's operational life and also includes any planned or unplanned repair, renovation, renewal, or reconstruction of or addition to the system between initial commissioning and final decommissioning.

Lessons Learned: BESS Conditioning in the Event of Project Delays	
Project Context	Interconnection request approvals by the local utility can take longer than planned or expected. Battery energy storage systems (BESS) installed but unable to interconnect to the grid will experience self-discharge and may require conditioning.
Project Experience	Delays in the interconnection request process resulted in an installed BESS sitting idle at the site for several months. The project was notified by the vendor that the batteries were approaching a low state of charge and need to be re-charged. Because interconnection was not yet approved, the project was required to rent a diesel generator to charge the system, incurring unexpected cost to the project.
Root Cause	The delay in interconnection and inability of the BESS to connect to the grid resulted in the low state of charge for the batteries.
Advice for Future Projects	Plan for delays that may occur which impact a project's ability to connect the BESS to the grid. If possible, arrange with the vendor or manufacturer to keep the BESS stored and conditioned until interconnection is approved. If possible, arrange delivery of the system to coincide with interconnection approval.

Specific considerations for operations and maintenance plans include:

- Safety information should be accessible and all operations and maintenance personnel, as well as first responders, should be trained on the safety systems per relevant safety codes and vendor directives. Available information could include:
  - Safety equipment maintenance
  - Operator training
  - Safety protocols during operation, shutdown, maintenance, and restart
  - Incident preparedness
  - Incident response
  - Regular safety training updates and drills

- Material safety data sheets should be readily available and displayed appropriately
- It is expected that an operating and/or service manual for the ESS be provided that may include:
  - Operations guidelines
  - Maintenance schedules
  - A Tuning Guide detailing the tuning parameters set at the time of commissioning that might require adjustments during operation and maintenance (post commissioning). Such a guide should include provisions to record any future parameter changes so a chronological log can be maintained. This should also include a record of any firmware or software upgrades as applicable to each subsystem.
  - Alarm and fault codes
  - Data system manual
  - Troubleshooting guidelines
  - Start up and shutdown plan

Additional Considerations may include:

- Periodic interconnection tests or integrated system tests based on relevant standards. Any interconnection-related protective functions and associated ESS modules could be periodically tested at intervals specified by the manufacturer, system integrator, or the AHJ over the DER interconnection or the area electric power system (EPS) operator. Periodic test reports or a log for inspection shall be maintained.
- The area EPS operator may require an interconnection test be performed outside of the normal periodic testing to verify adherence to applicable standards at any time.
- Cyber security requirements may be updated throughout the life of the system and any party communicating with the control or data acquisition of the storage system may be affected by these changes. Other cyber security issues include:
  - Authentication maintenance may be engrained in policies requiring frequent changes to passwords and usernames for all parties
  - Firewall settings and updates may prescribe new Internet protocol (IP) addressing
  - Frequency of retesting can be determined by area EPS operator policies for protection system testing or industry practices.
- Periodic maintenance will be required for all systems including to maintain warranties. A sample of maintenance activities may include:
  - HVAC (contactors, filters, refrigerants, pest control, etc.)
  - Other cooling system filters
  - Breaker maintenance
  - Regular inspection of Safety Systems
  - Site and vegetation management
- Service contract or warranty-related agreements between a manufacturer or service provider (warranty provider) and the customer (site owner) to ensure the system remains functional throughout its operational life.

- Site access policies and logistics needed for site access should be in place and agreed upon at the onset of the operational phase by all participating parties.
- The test data from the project deployment and integration phase of the commissioning process may be used as a baseline for future ESS evaluations to indicate any performance degradation that may prompt service, warranty, or end-of-life action.
- Annual capacity testing on the batteries is often a requirement to maintain the warranty and ensure the system is in compliance with the flexible performance guarantee.

Recommissioning

Changes in operational uses, storage capacity, software update, or major component replacement may trigger a need to recommission a portion of or the entire system. Depending on the extent of the system changes, various levels of acceptance and verification tests outlined in the deployment and integration section may need to be performed again to confirm proper system operation.

- Firmware upgrades should be fully understood and perhaps demonstrated in a hardware in loop test environment (duplicating the control system topology and associated vendor control firmware in place).
- Some firmware upgrades may trigger re-testing of interconnection procedures.
- Note that firmware upgrades will most likely result in loss of tuning (engineering) parameters that were adjusted post commissioning, therefore control functions, performance related functions, and IT/cyber security policies must be re-tested.

The end of an ESS's operating life can be triggered by several events. Regardless of the cause, the termination of operation should include a deliberate and planned decommissioning process. Section 7 provides guidance for ESS decommissioning.

7

DECOMMISSIONING CONSIDERATIONS

This section addresses considerations related to the decommissioning of an energy storage system to minimize risks to the owner and/or customer, the environment, and those involved in the decommissioning process. System decommissioning occurs at the termination of a system's operation, and at some point, all ESSs will need to be permanently decommissioned. One potential trigger for decommissioning is when one or more components have reached the end of life condition. For battery technologies this may be defined as an energy capacity threshold. At this point it may make sense to decommission from a financial or safety perspective, but there may be an opportunity to replace components, recommission, and extend the life of the system. Additionally, there may be an opportunity to re-purpose the system to a less demanding application. Another major trigger for decommissioning is when the ESS is no longer needed to serve the grid at its given location. If there is still useful life remaining in the system after decommissioning, the system can be relocated and recommissioned at a new location.

A successful decommissioning process depends on an experienced and qualified team. The team should be augmented with appropriate subject matter experts selected to complement the specific technical concerns of the project being decommissioned. The specific types of expertise needed will be dependent on the type of facility being reviewed and decommissioned, as well as other factors such as complexity, hazards or risks.

It is preferred that personnel selected to participate in decommissioning, planning, and review have decommissioning experience. It is strongly recommended that the team leader should either be a project or systems engineer experienced in energy storage system installation, design, operation, and or management. A multi-disciplined review and decommissioning team (e.g., mechanical, electrical, chemical, industrial) should match, to the extent practicable, the contractor's decommissioning team. The review team should be augmented with subject matter experts as appropriate to review specialty matters such as criticality safety aspects of the given project/storage technology.

Lessons Learned: Forgetting Site and System Upkeep While Awaiting Decommissioning	
Project Context	Lithium ion BESS project awaiting decommissioning after owners discontinued use of the system.
Project Experience (what happened)	Site sat for over a year without proper thermal management. Modules were damaged when evaluated by the recycling partner, presenting a safety risk and far greater cost for handling and transportation.
Root Cause	Decommissioning was not planned in advance, and site responsibility/accountability was not established.
Advice for Future Projects	Maintain clear site responsibility and upkeep, even if awaiting decommissioning. Damaged modules are expensive and dangerous to handle and transport.

Decommissioning Plan

A decommissioning plan describes the process for decommissioning an energy storage facility and associated utility services and subsurface facilities. The information in this section is not intended to provide a detailed plan for the eventual decommissioning of an energy storage facility, but to demonstrate that decommissioning can be completed with existing technology in a manner that ensures the protection and safety of workers, members of the general public, and the environment, as well as the security of possible hazardous waste.

A decommissioning plan should be prepared prior to the commencement of any decommissioning activities. Appropriate methods and technologies available at that time will be reviewed, adopted, and described in a detailed plan. Planning for decommissioning is an ongoing process, and planning assumptions are expected to change with evolving technologies, international and operational experience, regulations, and cost estimates. A detailed decommissioning document should be reviewed and revised periodically in order to incorporate any changes in the planning that arise during the decommissioning process.

Decommissioning Plan Steps

Decommissioning scope, objective, end-state, and strategy should include:

- A description of the site and the structures, systems, and components to be decommissioned
- Schedule for decommissioning activities
- Estimate of the decommissioning cost, including estimate of packaging material.
- Transfer agreements from the owner to the party that is transporting the equipment from the site.
- Regulatory process and identification of applicable transport/logistics regulations
- License application and receipt
- Risk management assessment:
  - Ensure the project risks associated with the alternatives, including the preferred alternative, are systematically identified and managed using a documented and adequate process.

Risk identification and management is essential to the overall success of the project, and the risks associated with all of the alternatives need to be considered as part of the determination of the decommissioning process.

In some cases, the owner will request that the possession of the equipment be transferred once the equipment is loaded onto the truck for transport. This will typically involve the legal departments of the owner and vendor.

Safety plan:

- The safety plan integrates safety in the selection of decommissioning alternatives and processes.
- It considers safety for the workers and surrounding area.
- It can address the requirement for the completion of a preliminary hazards analysis (for chemical and construction hazards) for the preferred alternative and the associated

identification of safety class. It can also identify important safety systems, structures, and components for decommissioning activities.

- It provides the basis for development of the documented safety analysis and is key in defining the safety responsibilities and planning.
- It includes emergency responses and communication plans.

Environment assessment:

- Decommissioning activities, particularly the removal of project components and grading, could cause negative environmental effects similar to those of the construction phase. For example, there is the potential for disturbance (erosion/ sedimentation/ fuel spills) to adjacent watercourses or significant natural features.
- Mitigation measures similar to those employed during the construction phase of the project will be implemented during the decommissioning process.
- Mitigation measures will remain in place until the site is stabilized in order to mitigate erosion and silt/sediment runoff and any impacts on the significant natural features or water bodies located adjacent to the project location.
- Road traffic may temporarily increase due to the movement of decommissioning crews and equipment.
- There may be an increase in particulate matter (dust) in adjacent areas.
- Emissions from the diesel engines of construction machinery and equipment may cause localized impacts to air quality.
- Noise levels from heavy machinery and traffic at the project location may increase. Work should be undertaken during daylight hours and should conform to all local noise ordinances.
- Additional considerations: Existing land use adjacent to the ESS site; vegetation; wildlife habitats near the site; aquatic environment, if any.

Recycling and/or disposal considerations:

- An estimated inventory of the hazardous wastes will be generated during decommissioning.
- Most of the materials used in an ESS facility are reusable or recyclable, and some equipment may have manufacturer take-back and recycling requirements.
- Any remaining materials should be removed and disposed of at an appropriate facility.
- Suppliers for ESS systems should provide policies and procedures to maximize recycling and reuse, and should work with recyclers, local subcontractors, and waste management firms to segregate material to be disposed of, recycled, and/or reused.
- Processing required for removal, storage, handling, and transportation.
- Processing and characterization for packaging
- Packaging by waste type
- Processing required for waste removal
- Proper licenses and certifications for vehicles and individuals tasked with transportation
- Transportation mode and permits by waste type

- Disposal destinations
- Organization of waste materials
- Verifications or inspections required
- Demolition waste disposal

Additional pre-shutdown considerations:

- Site security
- Geology
- Seismicity
- Topography
- Quality assurance
- Documentation (records)
- Community relationships

Site and facility preparation:

- Safe removal of power and de-energization of ESS
- Disconnection of the equipment
- Equipment removal
- Site restoration

Post decommissioning:

- Final surveys
- End state report

8
REFERENCES

1. *ESIC Energy Storage Implementation Guide 2016*. EPRI, Palo Alto, CA: 2016. 3002008899.
2. *ESIC Energy Storage Test Manual 2016*. EPRI, Palo Alto, CA: 2016. 3002009313.
3. *Protocol for Uniformly Measuring and Expressing the Performance of Energy Storage Systems*, Pacific Northwest National Laboratory Richland, Washington and Sandia National Laboratories: 2016. PNNL−22010 Rev 2/SAND2016-3078R.
4. *Energy Storage Safety: 2016 Guidelines Developed by the Energy Storage Integration Council for Distribution-Connected Systems.* EPRI, Palo Alto, CA: 2016. 3002008308.
5. *International Fire Code- Chapter 12 Energy Systems* https://codes.iccsafe.org/content/IFC2021P1/chapter-12-energy-systems
6. Standard for Safety, ANSI/CAN/UL-9540:2016, Energy Storage Systems and Equipment; https://www.shopulstandards.com/ProductDetail.aspx?productId=UL9540_2_S_20200227
7. NFPA 855 Standard for the Installation of Stationary Energy Storage Systems; https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=855
8. *IEEE Std 1547.1a™-2015 (Amendment to IEEE Std 1547.1-2005) Standard Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems; Amendment 1*, 2015 The Institute of Electrical and Electronics Engineers, New York, NY: 2015.
9. *IEEE 1547-2018 - IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces,* The Institute of Electrical and Electronics Engineers, New York, NY: 2018.
10. *IEEE Guide for Electric Power Distribution Reliability Indices,* https://standards.ieee.org/standard/1366-2012.html
11. *IEEE Standard Definitions for Use in Reporting Electric Generating Unit Reliability,* Availability, and Productivity; https://standards.ieee.org/standard/762-2006.html
12. *Electrical Energy Storage Data Submission Guidelines, Version 3*. EPRI, Palo Alto, CA: 2023. 3002025977.
13. *EPRI Protection and Control Configuration Management.* EPRI, Palo Alto, CA: 2017. 3002010188.
14. *Electrical Energy Storage Data Submission Guidelines, Version 2*. EPRI, Palo Alto, CA: 2021. 3002022119.
15. IEEE Std 1547.3: Monitoring, information exchange and control (MIC) for DER
16. Understanding the Commissioning Process for Utility Systems, ComRent, https://www.comrent.com/commissioning-process-for-utility-systems

A
ACRONYMS AND ABBREVIATIONS

AF	Availability Factor
AHJ	authority having jurisdiction
ANSI	American National Standards Institute
BESS	battery energy storage system
BMS	Battery Management System
CAN	Controller Area Network
CPUC	California Public Utilities Commission
CSR	codes, standards, and regulations
DC	Direct Current
DER	distributed energy resources
DOE	U.S. Department of Energy
EMS	energy management system
EPC	Engineering, Procurement, and Construction
EPO	Emergency Power Off
EPRI	Electric Power Research Institute
EPS	electric power system
ESIC	Energy Storage Integration Council
ESS	energy storage system
FAT	factory acceptance test
FEMA	Federal Emergency Management Agency
FMEA	failure modes and effects analysis
HMA	Hazard Mitigation Assistance
HVAC	Heating, ventilation, and cooling
IBC	International Building Code
IEC	International Electrotechnical Commission

IEEE	Institute of Electrical and Electronics Engineers
IFC	International Fire Code
IP	Internet Protocol
ISO	Independent System Operator
IT/OT	Information Technology / Operational Technology
LOTO	Lock out / Tag out
NERC	North American Electric Reliability Corporation
NFPA	National Fire Protection Association
PoC	Point of Contact
PCS	power conditioning system
PNNL	Pacific Northwest National Laboratory
RFP	Request for Proposal
RPA	Reference Point of Applicability
SAT	site acceptance test
SCADA	supervisory control and data acquisition
SDS	Safety Data Sheets
SNL	Sandia National Laboratories
SOC	state of charge
SOO	Sequence of Operations
SSA	systems safety analysis
STATCOM	STATic synchronous COMpensator

B

PROECT PHASE SUMMARY, COMMISSIONING FOCUS

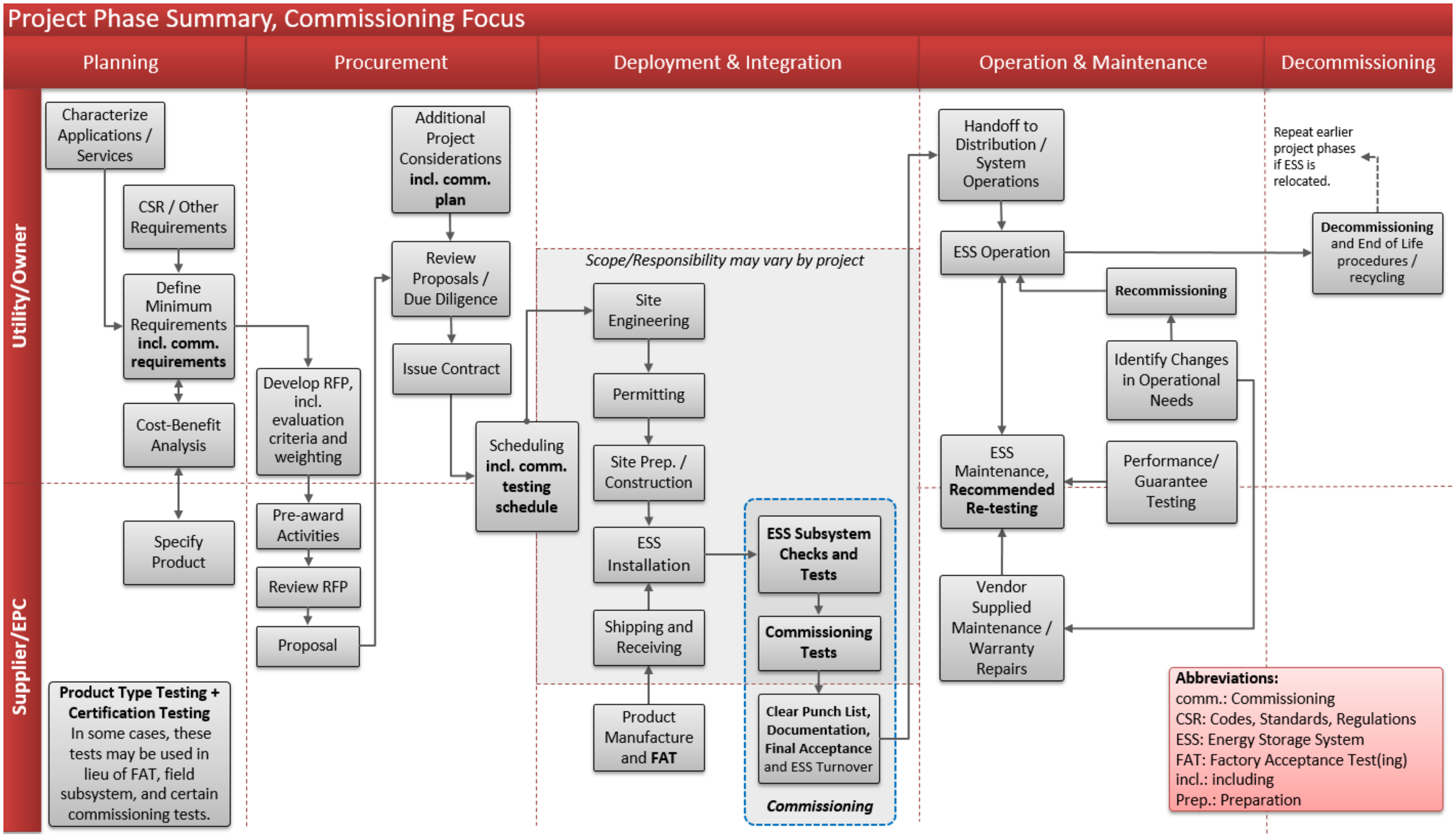

Figure B-1
Summarized Commissioning Process

C
TEST PROCEDURES FOR USE OR IN SUPPORT OF ESS COMMISSIONING

The ESIC Energy Storage Test Manual, published by ESIC [2] and the Protocol for Uniformly Measuring and Expressing the Performance of Energy Storage Systems [3], provide guidance on testing and characterizing energy storage systems. The manual includes a complete outline with high level scope and descriptions for tests that may be used in energy storage system evaluations. There are also detailed procedures for key performance and functional tests listed below. Additional detailed procedures will be developed in future revisions of the manual. A commissioning plan for any particular project may include some or all of the tests in the manual. The test manual can be downloaded from www.epri.com/esic.

Detailed procedures in the manual include:

- Auxiliary Load Determination
- Roundtrip Efficiency
- Available Energy Capacity
- Charge Duration
- Rated Continuous Power
- Response, Rise, and Settling Time
- Harmonic Distortion
- Self-Discharge Rate
- Startup and Shutdown Time
- Charge/Discharge Management
- Autonomous Frequency Regulation
- Volt-VAR Regulation
- Peak Power Limiting

D
SPECIFIC CHECKLISTS

Battery Commissioning Steps – Generic for Lithium Ion

1. Needs:
    - Engineering Drawings and Specifications and Manuals
        - FAT Report
    - Data acquisition and recording equipment
        - Batteries
        - PCS
    - Programming and Configuration Software
        - Batteries
        - PCS
    - Component Firmware
        - Batteries
        - PCS
2. Battery setup and configuration (done in parallel to PCS configuration
    - Preparation for auxiliary and control power - EPC
        - Confirm breakers off or open, ground jumpers attended to, UPS operable
    - Application of auxiliary and control power - EPC
        - Lock out/tag out verified, record volts, phase rotation, verify voltage at auxiliary transformer, energize auxiliary protection, energize UPS and record voltage, energize DC control devices
    - Potential Transformer PT calibration - EPC
        - Energize, record (via data recorder and PCS) phase volts, phase shift, document PT ratio and appropriate phase rotation
    - Main power application – tied to PCS below and step above
    - Equipment Visual Inspection and Device Configuration – Battery Manufacturer
        - Check all equipment for damage, markings for bolted cables, check grounding, auxiliary power connections to batteries, AC to BMS and all associated computers, check communication terminations
    - Internal Communication Verification – Battery Manufacturer
        - Check CAN and baud rates for all racks and associated control computers
3. PCS Functional Test – PCS Manufacturer (done in parallel to Batteries)
    - Lock out tag out
    - Ground Connection check
    - External Protection check

- Initial Inspection
  - Component/Device Configuration checks. Steps include visual inspection - Recloser to Main Transformer (MV), Main to PCS (LV), Batteries to PCS, Auxiliary to PCS, jumpers dip switch settings for monitors and relays, protective device settings configured correctly
- Circuit verification
- Preparation for Auxiliary & Control Power Application - remove grounding jumpers, confirm UPS operable
- Application of auxiliary and control power – EPC
  - See above – energize associated UPS and served load devices one at a time
  - Programmable Component / Device Loading & Configuration – Verify firmware is latest version
- Auxiliary Equipment Functional Testing
  - Verify correct fan operation direction and auxiliary load are functional
  - Emergency Stop Circuit Verifications - test entire circuit
  - I/O Verifications
  - Check control/communication termination locations and cable integrity between PCS and external devices
    - Digital inputs by forcing or jumpers, outputs by forcing and verifying
    - Analog – verify outputs by process calibrators
- Installed System Workmanship / Integrity Verifications

4. System Functional Testing
   - Customer communication verification (SCADA)
   - Customer Meter inputs verification – PV/ Revenue/Site Meter
   - Customer data acquisition verification
   - Battery communications to PCS
   - Preparation for Main power application (Auxiliary done above)
   - Main Power application – (soak)
5. System Start Up
   - PCS DC verification
6. Battery Testing
   - Battery Bank Initial Testing
   - Battery Section Initial Testing
   - Battery Diagnosis Test Check diagnostics via software only
   - Battery Section Full Charge / Discharge Testing
   - HVAC Verification Testing – measure temperature at x points within container
   - Battery Management System (BMS) Local Control Verifications (define BU)
   - Battery Lineup Calibration

7. Applications Testing
    - Reference Performance Test– also refer to Test Plan from ESIC

Air Cooled Condensing Units Commissioning Steps[8]

Installation

- Refrigerant pipe leak tested.
- Refrigerant pipe evacuated and charged (documenting lbs/kgs of refrigerant to fill systems may be required) in accordance with manufacturer's instructions.
- Check condenser fans for proper rotation.
- Any damage to coil fins has been repaired.
- Manufacturer's required maintenance/ operational clearance provided.

Electrical

- Power available to unit disconnect.
- Power available to unit control panel.
- Verify that power disconnect is located within sight of the unit it controls.

Controls

- Unit safety/protection devices tested.
- Control system and interlocks installed.
- Control system and interlocks operational.

Functional Performance Test

- Contractor shall demonstrate operation of refrigeration system as per specifications including the following: Start building air handler to provide load for condensing unit.
- Activate controls system start sequence as follows:
    - Start air handling unit. Verify control system energizes condensing unit start sequence.
    - Shut off air handling equipment to verify condensing unit de-energizes.

[8] U.S. Energy Department, Federal Energy Management Program, Guidelines and Checklist for Commissioning and Government Acceptance of ESPC Enable Projects, February 2014, Version 4.0 https://www.energy.gov/sites/prod/files/2014/03/f10/enable_checklist.docx

- Restart air handling equipment one minute after condensing unit shut down. Verify condensing unit restart sequence.
  - Verify condensing unit amperage each phase and voltage phase to phase and phase to ground.

- Check for unusual vibration, noise, etc.

Field Evaluation Based on UL 9540

There are detailed checklists that identity discreet steps that could be pursued in the course of a UL9540 field assessment effort. As part of the development of this report a detailed checklist was reviewed and found to have the following elements:[9]

- Construction review of Metallic and Non Metallic Materials
- Enclosures and Guarding of Hazardous Parts
- Walk In Systems Access/Protection
- Wiring and Electrical Connections
- General Electric Equipment/Fusing
- Spacing and Separation of Electrical Circuits
- Grounding and Insulation
- Safety Analysis and Control Systems
- Remote Controls
- Heating and Cooling Systems
- Fluid Based Mechanical Systems
- Containment of Moving Parts
- Hazardous Material Containment
- Combustible Concentrations
- Fire Detection and Suppression Systems
- Utility Grid Integration Including Special Purpose Systems (see above discussion on IEEE 1547)
- Storage Technologies and Specific Technology Requirements
- Normal Operation, Dielectric Voltage Withstand, Grounding, and Bonding and Insulation Resistance Tests
- Mechanical Tests
- Fluid Leak and Strength Tests
- Environmental Tests
- Signage/Markings Assessment
- Documentation (Manuals/Instructions)

[9] Summarized from a field procedure courtesy of CSA Group.

About EPRI

Founded in 1972, EPRI is the world's preeminent independent, non-profit energy research and development organization, with offices around the world. EPRI's trusted experts collaborate with more than 450 companies in 45 countries, driving innovation to ensure the public has clean, safe, reliable, affordable, and equitable access to electricity across the globe. Together, we are shaping the future of energy.

3002027455

EPRI
3420 Hillview Avenue, Palo Alto, California 94304-1338 • USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com