WHITE PAPER

Battery Energy Storage Systems

Independent Engineering Due Diligence

Methodology for Project Risk Identification and Mitigation

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Abstract

As power markets and the generation mix continue to evolve in the United States and elsewhere, the need for flexible power systems increases. To achieve power system flexibility, developers of new power projects and owners of existing projects have increased their use of battery energy storage systems (BESSs) as a cost-effective option. Until recently, BESSs were typically sponsor/owner financed. However, as more BESS projects are seeking external funding, investors need to rely upon independent engineers with battery storage expertise to perform due diligence evaluations to characterize project risk and recommend mitigation strategies in support of project financing.

This white paper highlights Sargent & Lundy's methodology for independent engineering (IE) due diligence review of BESSs. The goal of these reviews is to assist financiers in the due diligence of BESS projects to understand risks and mitigation options for potential investment opportunities. Our methodology is based on our extensive experience designing utility-scale BESSs and advising potential investors and owners with due diligence evaluations of renewable projects.

There are several critical aspects to consider when evaluating a BESS project for potential investment: the planned use case(s) and revenue streams; equipment selections and the system design; commercial agreements; and construction, commissioning, and operating plans. This white paper provides BESS-specific methodology and best practices for these reviews.

Among the critical aspects, the use case identification, fire protection design, and battery module supply warranty terms are of particular importance and unique to BESSs:

- Thorough identification and evaluation of the BESS use case, or cases, is important to verify consistency across the design, battery technology selection process, and financial modeling.
- Fire protection and suppression are also critical design considerations that must be verified to be in accordance with local and national standards.
- Battery warranty terms are of concern because commercial protections are contingent on adherence to the BESS's operational limitations (depth of discharge, cycles, temperature, etc.).

The interdependence of the BESS use case, system design, and commercial terms necessitates an integrated full scope due diligence review be performed.

To address these key considerations, Sargent & Lundy has developed a carefully considered methodology founded on both renewable energy project due diligence experience and our industry-leading BESS engineering design and advisory qualifications.

Introduction

A battery energy storage system (BESS) is an electrochemical system that stores energy to be discharged as electrical energy when dispatched. BESS implementation has increased significantly in the past decade, enabling utilities and system operators to meet various grid demands. BESSs have a variety of applications including capacity firming, frequency/voltage regulation, and transmission/distribution reliability improvement.

Many renewable energy developers, owners, and operators are integrating BESSs with renewable power projects to overcome challenges posed directly by wind and solar projects, which lack firm capacity due to their variable resources. One such challenge is the tendency for wind and solar generation peaks to not typically align with the demand peaks, causing excess generation to be curtailed without reaching the market, resulting in loss of potential revenue. BESSs enable these intermittent renewable energy sources to store surplus power and remain within interconnection limits, control ramp rates, reduce energy curtailments, and maximize revenue while providing firm, predictable energy capacity.

While energy storage is often used to balance the intermittent nature of renewable resources, the benefits of BESS grid integration can be more widespread. By providing ancillary services such as frequency and voltage regulation to the wider grid, BESSs contribute to system stability. BESSs can also alleviate transmission congestion and help defer certain upgrade costs while improving grid reliability.

With the growing demand, transmission system operators and government agencies have taken action to incentivize BESS project developments. Seven states have established energy storage targets and/or mandates: California, Massachusetts, Nevada, New Jersey, New York, Oregon, and Virginia. FERC Order No. 841 requires all regional organizations that manage the nation's electric grids to remove barriers to participation for energy storage resources in the wholesale electricity markets. As of February 2020, the US Department of Energy catalogued 481 operating utility-scale BESSs in the United States with a total rated power of 1.4 GW and total energy of 2.7 GWh[1]. NREL's Renewable Electricity Futures Study[2] estimated that 120 GW of storage would be needed across United States by 2050, consistent with other market forecasts projecting the BESS sector to grow substantially in the near and long term.

Wider deployment leads to several positive outcomes, including lower costs and better system design. Bloomberg New Energy Finance forecasts that for every doubling of cumulative volume, an 18% price reduction of battery packs is observed[3]. As with similar fast-developing technologies, battery system integrators and BESS developers learn from a growing resource of historical operating data to establish prudent operating practices that minimize risk and maximize performance.

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[1] *DOE Global Energy Storage Database*. February 18, 2020, https://www.sandia.gov/ess-ssl/global-energy-storage-database-home/

[2] Mai, Trieu, Debra Sandor, Ryan Wiser, and Thomas Schneider. *Renewable Electricity Futures Study,* Executive Summary. No. NREL/TP-6A20-52409-ES. National Renewable Energy Lab (NREL), Golden, CO (United States), 2012. https://www.nrel.gov/analysis/re-futures.html

[3] Goldie-Scot, Logan. *A Behind the Scenes Take on Lithium-ion Battery Prices. BloombergNEF. March, 2019.* https://about.bnef.com/blog/behind-scenes-take-lithium-ion-battery-prices/

As the US energy generation profile evolves, the need for flexible power systems increases. Until recently, nearly all utility-scale BESSs were sponsor/owner financed. As more BESS projects seek external funding, investors rely upon independent engineers with battery storage expertise to perform due diligence evaluations to characterize project risk and recommend mitigation strategies to support project financing. The unique risks posed by BESSs projects necessitate a diligence strategy tailored to their evaluation and mitigation.

This white paper highlights Sargent & Lundy's methodology for independent engineering (IE) due diligence reviews. The goal of the reviews is to assist financiers in the due diligence of BESS projects to understand risks and their mitigations for potential investment opportunities. Our methodology is based on our extensive experience designing utility-scale BESSs and advising potential investors and owners with due diligence evaluations on renewable projects.

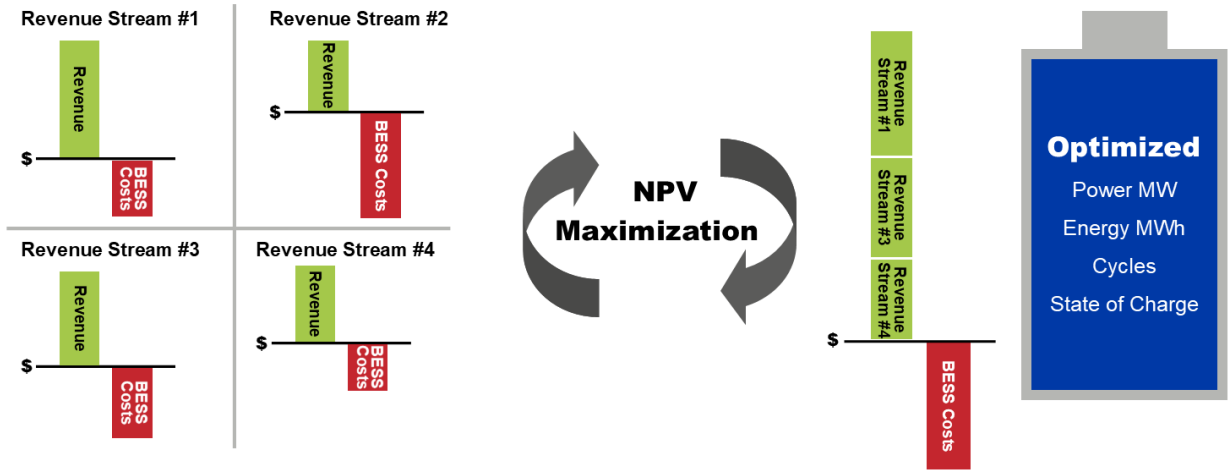
IE Review Methodology

Use Case Review

Independent power producers develop utility-scale BESS projects in competitive wholesale electricity markets with specific goals of capturing various revenue streams (referred to as "use cases"). While revenue streams vary based on the ISO/RTO territories, most common use cases include capacity resource payments, day-ahead/real-time energy market arbitrage, and various ancillary services such as frequency regulation, spinning reserves, voltage support, and blackstart capability.

During the planning stage of utility-scale BESS projects, developers typically perform revenue optimization analysis, often referred to as BESS use case analysis, to determine optimal revenue composition and corresponding ideal BESS power (MW) and energy (MWh) ratings and technologies. The analysis first includes an evaluation of optimal dispatch of the BESS to maximize the "stacked" values of all available revenue streams under the physical limits of the BESS and ISO/RTO market rules. The evaluation then includes net present value calculations of revenues and costs over the planned project life to select different BESS size and duration options. Figure 1 provides a graphical representation of this iterative optimization process.

Figure 1 — BESS Revenue and Design Optimization Process



Sargent & Lundy considers the use case analysis to be one of the most important tasks for successful planning and execution of BESS projects. Having precisely defined BESS use cases and technical requirements (e.g., number of cycles, throughputs, average state of charge levels) identified early in the project allows BESS integrators to design and build the project around the intended dispatch.

A focus of our IE reviews is to confirm consistency in the system design and commercial framework with the selected use case. Battery module technology designed for a certain state of charge and number of cycles will degrade faster when subjected to operating conditions outside its design parameters. Commercial risks arise from these excursions as manufacturers' warranties will specify the narrow operating conditions for which warranty coverage applies. These constraints need to be clearly defined to

project stakeholders and reflected in the operational management strategy. As part of our IE reviews, we identify technical design limitations and evaluate contractual provisions to confirm consistency with the project's planned use cases.

Design Review

Battery Technology

Battery technology is selected based on several characteristics in consideration of the intended use case(s). Although many alternatives exist, lithium-ion based BESSs have dominated the market. Average prices of lithium-ion batteries declined 87% between 2010 and 2019[4]. Based on price and performance, lithium-ion batteries are expected to account for most new installations in the near-term stationary energy storage sector. Today, lithium-ion batteries account for the largest share in the global BESS market due to the relatively long lifespan, high efficiency, high energy density, and low standby losses.

As part of the due diligence, Sargent & Lundy reviews the battery technology selection for appropriate performance characteristics reflecting the desired use case(s). The review includes an evaluation of both the battery type and chemistry. There are several chemistry types to consider within the lithium-ion battery category; these batteries are constructed using varying types of materials including lithium, cobalt, nickel, manganese, aluminum, and iron. Different chemistries yield advantages and disadvantages that impact projects, such as differing energy density, energy stability, and charge/discharge rates. Choosing the ideal chemistry for a specific project requires consideration of these performance characteristics with the intended use case(s) and site-specific parameters.

Another important consideration is the battery procurement source. The growth in the battery industry, specifically lithium-ion, has led to increased market competition as more companies are investing in these emerging technologies and producing novel battery systems. For this reason, it is important to review both the integrator and the battery manufacturer. Projects may use "Tier 1" suppliers (those with a proven track record and ability to honor warranty terms) to minimize the risk associated with battery procurement.

In addition to reviewing the manufacturer's history, certifications, market share, and financial health, it is important to review their testing, performance, and degradation data. The timeline of many development projects precludes independent third-party testing of batteries. This leads to reliance on data provided directly by the manufacturer, further increasing the importance of supplier due diligence. Sargent & Lundy reviews manufacturer test data in the context of other projects' actual performance to evaluate claims made by original equipment manufacturers.

While lithium-ion-based BESSs have dominated the market, many other energy storage technologies are used or are approaching commercial readiness. Sargent & Lundy has experience and familiarity with many of these other energy storage technologies, such as flow batteries, zinc-air batteries, liquid-air energy storage, pumped hydroelectric storage, gravity-based energy storage, and thermal energy storage.

[4] Bloomberg New Energy Finance, *2019 Battery Price Survey*, December 2019

Balance-of-Plant

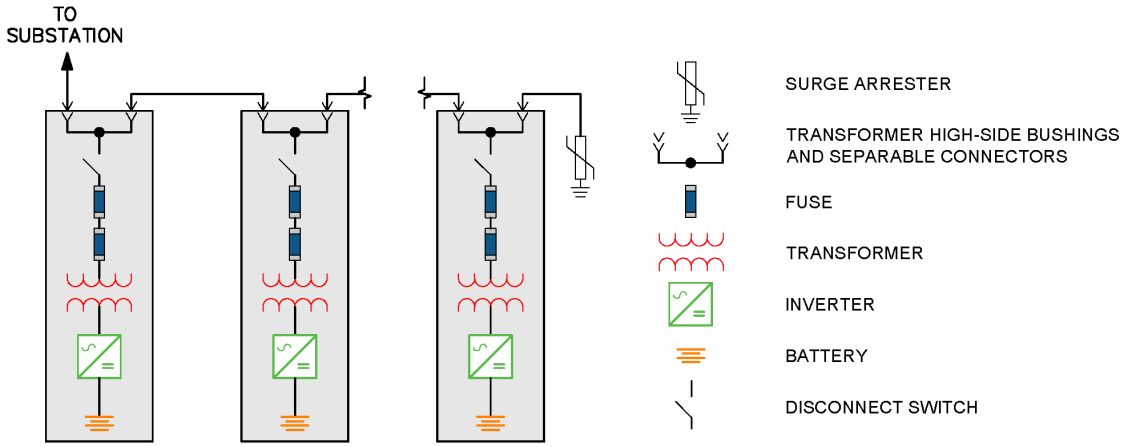
In any power generation facility, supporting infrastructure is required to export the energy from the generator to the utility grid. This infrastructure is commonly referred to as the balance of plant (BOP). While each generation technology is different, the BOP is typically divided into three main categories: electrical, mechanical, and civil/structural.

Electrical Design

The electrical BOP of BESS projects consists of power conversion systems (PCSs), collection systems, and substations. For most BESS projects, there are multiple PCSs, which are analogous to wind turbine generators or solar inverters in that energy from the generator is conditioned through power electronics and then elevated via a transformer to a typical collection system voltage of 34.5 kV. The collection system is an electrical network consisting of underground or overhead cables that links the individual generators together. Power conversion systems for a BESS are similar and consist of power electronics and a transformer to elevate the energy from the generator (DC power stored in batteries) to the collection system voltage. Similar to other types of generation, there is typically an interconnecting substation which may be existing from another generator or a new installation for the BESS. Substations are used to connect the generator to the electricity grid. This substation raises the voltage from the collection system voltage level to either a transmission or distribution level voltage for use by the interconnecting utility. As part of any due diligence, the PCSs, collection systems, and substations must be reviewed to confirm that they are designed with good industry practice and in accordance with applicable codes and standards.

The PCS includes inverters and medium-voltage transformers. The inverter is the component of the PCS that converts the DC energy stored within the batteries into AC. The medium-voltage transformer further increases this AC voltage from a lower voltage, typically around 600 V, to a more common distribution level voltage of 34.5 kV. These medium-voltage transformers are then connected in parallel to create a collection system where multiple PCSs can be connected to a single breaker at a substation as shown in Figure 2. As part of the electrical BOP IE review, the components of the PCS are reviewed for adequacy for the generation output of the BESS against the manufacturer datasheets and site-specific conditions.

Figure 2 — BESS Typical Configuration



Since the energy must be exported to the substation and then the point of interconnection, the collection system design must also be reviewed. This review consists of verifying that the cable selection, trench configuration, and installation method are in accordance with industry best practices, codes, and standards.

Like other power projects, the substation design must also be reviewed for ampacity and short circuit considerations and consideration of the protection, control, and metering aspects of the project. The metering equipment and protocol are critical to validate if the metering scheme is adequate to properly track the flow of energy and revenue among the BESS, utility, and shared facilities in accordance with project covenants. The interconnecting generation tie line connecting the substation to the interconnecting utility should also be reviewed for adequacy and consideration within the metering scheme loss allocation.

Mechanical Design

The most critical mechanical BOP systems that require IE review are the climate conditioning systems. BESSs require an operating environment that is conditioned to maintain ambient air within a precisely specified temperature and humidity range. Climate conditioning is critical to maintain performance and ensure compliance with the battery warranty terms. Air conditioning systems are provided for battery enclosure or integrated building level systems. Sargent & Lundy draws on our experience reviewing the thermal management systems for BESSs to verify the climate conditioning equipment and system design are suitable to maintain the required climatic conditions and prevent premature degradation or breach of battery warranty terms.

As part of the IE due diligence review, Sargent & Lundy also evaluates the overall thermal management system design and operation. The thermal management system sizing is reviewed against time-dependent battery cooling demand (accounting for cell aging) and site-specific conditions to confirm proper system capacity. This includes computational fluid dynamic analysis to verify proper airflow distribution and temperature uniformity throughout the facility. The selected HVAC equipment must be reviewed for capacity and applicability and for its ability to meet the system demands. Physical design drawings must be evaluated for technical accuracy, constructability, and conformance to local and national codes.

Civil/Structural Design

An independent engineering review of the civil and structural designs of the BESS enclosure buildings and containers and the substation civil works is necessary to verify adherence to industry codes and standards.

BESS enclosures often consist of storage containers, single-story prefabricated thin-gauge steel profiles and cladding, or traditional structural steel buildings. Sargent & Lundy reviews the structural calculations for consideration of proper wind loads for the site and site-specific seismic parameters for overall structure stability. Additionally, the substantial mass of the battery modules, racks, and auxiliary equipment must be accommodated by the substation (or alternative location) civil and structural works, which Sargent & Lundy verifies in consideration of applicable building codes governing the design.

Fire Protection Design

Fire protection and suppression are key considerations for design of BESS facilities. Several BESSs have released great amounts of energy in uncontrolled thermal events, causing severe damage to surrounding structures. Though not common occurrences, these events illustrate the need for proper fire protection and suppression systems. Thermal risks, in addition to impacting the BESS project physically and financially,

have the potential to impact other nearby projects' facilities since BESS projects are often collocated within the substations of other electrical generation projects.

Sargent & Lundy evaluates whether proper fire protection practices are in place. Due to the evolving nature of BESS technology and fire protection and suppression methods, Sargent & Lundy maintains representation on NFPA and international code committees, providing input to the drafting of the governing standards. This participation helps to ensure our due diligence reviews use the most up-to-date criteria reflecting governing standards from NFPA, NEC, UL, and IEEE for BESS and fire protection system design. Sargent & Lundy also updates and maintains a comprehensive checklist of documentation to verify project coordination with first responders and compliance with industry best practices and local codes.

Commercial & Financial Review

Commercial Agreements

A review of commercial agreements and suppliers should be conducted to confirm that operating and technical requirements of applicable agreements and contracts will be met once the BESS is operational. The review should include approvals, permits, and licenses to confirm that the project can operate in compliance with governing statutes and that there are no limiting restrictions after the commercial operation date. Warranty protection for component supply and workmanship should be suitable for the risk and expected impact to the project in the event of non-performance. Without appropriate commercial protections, projects can face substantial financial and operational risks.

Suppliers to the BESS market are often comprised of large industrial equipment makers, new market entrants, and often, joint ventures of new entrants and a larger conglomerate. For that reason, it is important that due diligence of the suppliers' and service providers' experience and ability to execute the contracted tasks be performed.

Sargent & Lundy performs technical reviews of the key agreements: battery supply, BESS integrator, EPC, operations and maintenance (O&M), shared facilities, and offtake agreements (power purchase/energy storage agreements). We review the scope of each agreement to verify coverage for the project and consistency with the intended BESS use case.

Power purchase/energy storage agreements (e.g., tolling, capacity sales, and hybrid power purchase agreements) define the revenue structure for the project. These agreements vary with respect to project ownership structure; operational control; energy, capacity, and ancillary service revenue; and minimum performance requirements. Technical review of these agreements is important to verify alignment between BESS system design, use case, and revenue structure in place for project compensation.

Battery supply and BESS integrator warranty terms are of particular concern because commercial protections are contingent on adherence to the BESS's operational limitations (depth of discharge, cycles, temperature, etc.). The interdependence of the BESS use case, system design, and commercial terms necessitates an integrated full scope independent review be performed.

O&M Budgeting

While preventative maintenance activities for BESSs are typically more predictable than for rotating power generation equipment, unscheduled O&M expenses can significantly impact a project's financial performance. An independent engineering review of project O&M budgeting is necessary to avoid unexpected expenses during operations. Sargent & Lundy serves as technical advisor and owner's engineer for dozens of operational battery projects and maintains a database of O&M costs and service contract bids for BESS projects. Proposed project O&M budgets are reviewed against these benchmarks to determine the likelihood of operating the asset within the budgeted amounts. Should proposed project O&M budgets diverge from typical O&M costs, Sargent & Lundy identifies this risk to project stakeholders.

It is common for existing solar power project operators to offer to extend their existing O&M contract to BESSs co-located within their project sites. If the O&M provider has relatively little experience as a BESS operator, IE review is critical to verify that preventative maintenance will be performed in accordance with industry best practices and within the terms of the battery supplier's warranty. To conduct this review, Sargent & Lundy maintains a typical BESS O&M work scope and frequency schedule, which we modify based on the particular requirements of the project-specific battery warranty terms. The expected O&M scope and frequency are then compared against the project's proposed O&M plans and any shortfalls are identified with mitigating recommendations.

Revenue Forecasting

The growth of renewable energy has led to an increase in price volatility in energy markets. A substantial portion of this volatility is present in the sub-hourly time frame. As a result, BESSs, which can charge and discharge on very short timescales, have grown in popularity to dampen volatility while creating economic value. The revenue structure for each project may be contractual or merchant or a hybrid of both.

Offtake agreements provide contractual terms governing project compensation, and they vary in structure depending on the use case, ownership structure, and operational arrangements. The contractual terms for revenue and performance metrics require technical interpretation due to their complexity and critical importance to the project's economics. The compensation terms and operational requirements must be appropriately reflected in the project revenue modeling to provide achievable revenue projections.

When evaluating a merchant or market revenue forecast of a battery use case, it is important that the analysis model use an appropriate timescale to capture the volatility intended to be captured by the BESS. An analytical system model using an inappropriate timescale will distort the project's revenue forecasts.

Independent review of the calculations underlying the project's revenue projections provides confidence for the top-line balance sheet forecast. In consideration of the use case, ownership, and offtake structure, we evaluate whether the modeling techniques used are sufficiently detailed to capture the cited value streams. Sargent & Lundy's experience providing high resolution market simulations and evaluating offtake agreements informs our reviews, which are designed to provide project stakeholders well-founded project revenue estimates with appropriate sensitivities.

Construction Review

Site Visits

Site visits are a key part of conducting independent engineering due diligence to verify construction execution, particularly in consideration of investment funding milestones. For that reason, Sargent & Lundy recommends performing at least two construction visits and a follow-up construction completion visit for a total of three site visits.

Sargent & Lundy's first construction monitoring site visit observes the civil and structural works in progress against their designs and reviews adherence to quality assurance/quality control procedures. We recommend the second construction visit take place in conjunction with local fire officials after the battery modules are delivered to the site. Sargent & Lundy's engineers confirm onsite receipt of the equipment specified in the battery supply agreement and observe the local fire department's site walkthrough to determine compliance with local ordinance and verify the installation of fire protection systems in accordance with design.

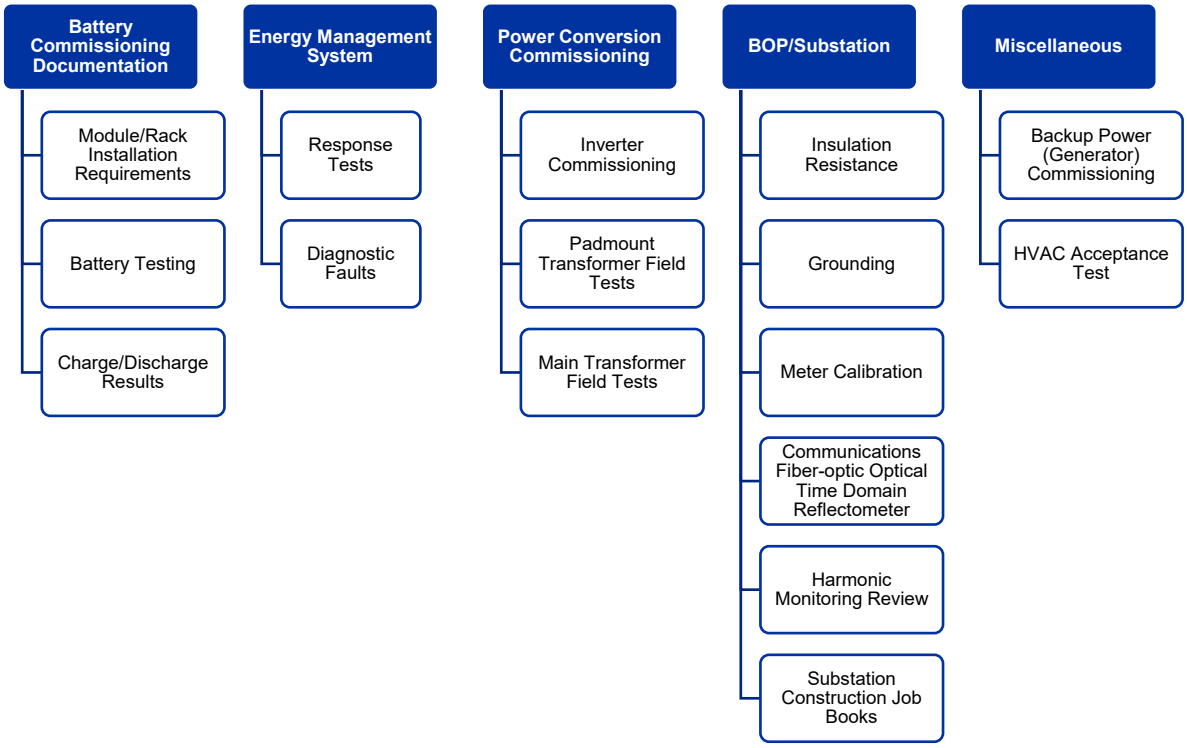
Following construction completion, Sargent & Lundy performs a final site visit to observe commissioning of the BESS and project completion in accordance with contractual terms. Acceptance test procedures and results are reviewed to determine whether the project can be expected to operate at the performance levels specified by the battery supplier and integrator.

Quality Assurance and Quality Control

As part of the IE review, the commissioning and acceptance reports are reviewed to verify that the testing meets the contractual requirements and demonstrates expected component performance. Battery commissioning records for cell voltage, current, power, state of charge, and temperature are reviewed and evaluated against these design parameters. Initial calibration and diagnostic test results from the BESS energy management system are reviewed to evaluate system functionality. All battery and energy management system non-conformances are identified for remediation and disposition by the supplier.

Additionally, the quality assurance/quality control records for the power conversion, substation, and BOP systems are reviewed to verify a satisfactory quality of workmanship, attention to detail, and adherence to design specifications at the time of construction. The major components of quality assurance/quality control records reviewed during IE due diligence are shown in Figure 3.

Figure 3 — BESS Quality Assurance/Quality Control Review Outline



Conclusions and Recommendations

This white paper highlights Sargent & Lundy's methodology for independent engineering (IE) due diligence review of BESSs. The goal is to assist financiers with the due diligence of BESS projects by identifying risks and providing mitigation recommendations. Our findings are based on our extensive experience designing utility-scale BESSs and advising potential investors and owners with due diligence evaluations.

There are several critical aspects to consider when evaluating a BESS project for potential investment: use case review, design review, commercial review, and construction review. This paper provides BESS-specific methodology and best practices for these reviews.

Sargent & Lundy believes the use case analysis is one of the most important tasks for successful planning and execution of BESS projects. Accordingly, our IE reviews are performed in consideration of the BESS use cases and their technical requirements (e.g., number of cycles, throughputs, average state of charge levels). IE due diligence reviews should identify technical design limitations and evaluate contractual provisions to confirm consistency with the project's planned use cases.

The IE design review is performed to ensure the battery technology and balance of plant (BOP) design is suitable for the intended function of the BESS. Sargent & Lundy's IE reviews determine whether the selected battery technology and chemistry are best suited to perform under the intended use case. As part of the electrical BOP IE review, the components necessary to import/export power from the BESS to the interconnecting grid are reviewed for adequacy to support the expected output. Mechanical HVAC systems need to demonstrate ability to meet the thermal demands of the battery equipment and maintain contractual terms. Civil structures and foundations are reviewed to verify suitability for the project terrain. Fire protection and suppression is a critical design consideration that must be verified to be in accordance with local and national standards.

A review of commercial agreements and suppliers should be conducted to confirm that operating and technical requirements of applicable agreements and contracts will be met once the BESS is operational. Contractual terms for warranties, guarantees, damages, and scope contained within the project agreements can have broad implications to BESS construction and operation. Sargent & Lundy examines the terms of these agreements for completeness and assesses the level of commercial protection offered in relation to the system's intended use. The proposed O&M budgeting and proposed service provider require an IE review to verify adequacy and avoid unexpected costs during operation. Independent review of the calculations underlying the project's revenue projections is also necessary to confirm that the financial modeling reflect the actual revenue streams.

During construction and commissioning, it is necessary to evaluate quality control documentation and component supply records to confirm that project implementation was performed and documented according to design and contractual terms. Sargent & Lundy recommends IE review consist of site visits and desktop review to verify equipment receipt and installation in accordance with design. Commissioning and acceptance reports need to be reviewed to verify that the testing meets the contractual requirements and demonstrates expected component performance.

Sargent & Lundy's methodology for IE due diligence review of BESSs addresses the key considerations using our extensive experience with energy storage projects to identify risks and recommend mitigations.

About Sargent & Lundy

Sargent & Lundy is one of the oldest and most experienced full-service architect engineering firms in the world. Founded in 1891, the firm is a global leader in power and energy with expertise in grid modernization, renewable energy, energy storage, nuclear power, and fossil fuels. Sargent & Lundy delivers comprehensive project services—from consulting, design, and implementation to construction management, commissioning, and operations/maintenance—with an emphasis on quality and safety. The firm serves public and private sector clients in the power and energy, gas distribution, industrial, and government sectors.

Sargent & Lundy's roles on electric power generation projects include full-design architect-engineer, owner's engineer, lender's independent engineer/technical advisor, and consultant. Our services include specialized technical advisory and consulting services to complete engineering and program management, encompassing procurement, construction management, technology transfer, and assistance with construction. Sargent & Lundy provides professional consulting, engineering, and design services throughout the lifecycle of power generation, transmission, and energy storage projects, from project concept and development, through detailed design and procurement, to construction and operation.

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