CHOOSING THE RIGHT COMMISSIONING PARTNER FOR SOLAR + BESS PROJECT SUCCESS

A REAL ENERGY WRITERS WHITE PAPER

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Contents

Executive Summary

Project commissioning is often viewed as an afterthought, a checklist task performed at the end of a solar installation. But for utility-scale solar photovoltaic (PV) and battery energy storage systems (BESS), proper commissioning allows developers to truly achieve the project's pre-set design requirements.

Commissioning is the process of ensuring that all the individual systems and components of an installation meet specific requirements for design, installation, testing, operation and maintenance. This makes it a critical component to the success or failure of a project.

Expert commissioning partners undertake rigorous quality assurance and quality control processes during each phase of construction to confirm that all equipment is properly functioning across the lifetime of a project. At the same time, they also examine all the small but critical details of a project, such as ensuring that appropriate as-built documents, operation and maintenance manuals, and warranties are in place.

If commissioning is poorly managed, however, technical issues that should have been identified and corrected prior to energization can be missed. This puts the project's financial success in jeopardy and increases safety risks, potentially leading to costly lawsuits, reputational damage and even fatal injury.

Proper commissioning is therefore a crucial step to ensuring that a project achieves both operational and financial success.

Choosing the right commissioning partner is one of the most important decisions undertaken during the development of a solar and storage project. This paper explains how effective commissioning and working with the right partner can help ensure that your project meets critical expectations for best performance and optimal financial return.

Standard Solar + BESS Commissioning: An Overview

The commissioning process begins at the very start of the solar + BESS project's concept phase and continues throughout the life of the system. This process includes specific tasks to be implemented during each phase of the project, from design through construction and ongoing maintenance and operations. There are myriad benefits to adhering to a strict commissioning process, including better coordination between design consultants and contractors, smoother start up and turnover by contractors, better system performance, a well-trained crew that can provide a safe and reliable operations and maintenance environment, and a system that is less expensive and easier to operate.

Solar + BESS commissioning verifies that the design meets the owner's project requirements and that all equipment and systems are installed according to industry standards and manufacturer specifications. Expert commissioning helps improve safety and quality control and ensures that the plant is fully operational, is maintaining all documentation and that operating personnel are fully trained.

> Ideally, commissioning experts are included at the earliest phases of project development for project design, testing and measurement. This helps establish clear objectives and ensures that the project meets all appropriate compliance guidelines. A thorough commissioning process should also set out the best practices for each element of the project to support a smooth commissioning process at the end of the construction phase.

While the solar + BESS commissioning process is unique for each project, the fieldwork for commissioning typically entails:

- Performing visual inspections and confirming final installation details of all installation components
- Conducting alternating current (AC) and direct current (DC) electrical installation verification tests, including insulation, grounding and polarity
- Verifying system functionality, emergency procedures and standard operations including:
  - System start-up/shutdown tests
  - Power conditioning systems fast stop and restart tests
  - Remote Power Setpoint Tracking of BESS
  - System response time tests
  - Ramp tests
  - Capacity tests
  - Efficiency tests
  - Voltage Response Function tests
  - Automatic Generation Control test
  - BESS enclosure smoke detection/fire alarm tests
- Ensuring equipment, including cables, connections and terminations, is properly installed and in compliance with all code and standards requirements
- Confirming all equipment is properly calibrated, appropriate set points are in place and correct software is installed
- Verifying all safety disconnects are properly installed, fuses are the correct amperage, and lockout/tagout procedures are followed, as applicable
- Completing full documentation of the system, including ensuring that any approved changes to the issued for construction drawings are incorporated into the as-built drawings
- Ensuring all required system and equipment labels are in place and correct.
- Performing site walk-through to identify any issues
- Identifying and completing any unresolved items on the punch list.
- Conducting user training to confirm system operations can be performed and maintained safely
- Confirming system power output and energy production meet performance expectations
- Completing site clean-up by removing all tools, equipment and debris
- Performing final confirmation of all checks and punch lists

When a solar PV facility is paired with battery storage, there are often additional commissioning steps associated with the energy management system to ensure the full installation is correctly commissioned.

Any effective commissioning process must include considerable testing to guarantee that the system is safe, installed correctly, and operating according to design specs. This may include data collection such as solar irradiation, temperature, and weather patterns to establish benchmarking for the site. Various tools and instruments can be deployed in the field to take these measurements and test components.

While it is often not practical to test every module in a larger solar array, critical insights can be gleaned through sample testing of strings, a representative percentage of modules or by identifying a selection of modules for electroluminescent testing for the detection of cracks.

In the U.S., the National Electrical Code's (NEC) NFPA 70 governs the requirements for most non-utility electrical installations, including solar and storage systems. It covers installation requirements, wiring and protection, wiring methods and materials, and equipment for general use.

> However, industry standards for commissioning may not include performance testing. A diligent commissioning agent will review design documents and specifications to ensure that relevant codes, best practices and owner's project requirements are met. The agent will also check that the entire system is configured to maximize energy production per specific site conditions and that it is operating at the optimal performance ratio.

Testing of installed components should take place throughout the development process. For instance, conducting mechanical tests like cable inspections or testing for adequate insulation between modules and their frames are important and may potentially impact the plant's lifetime performance. Addressing any issues throughout the development phase is key to ensuring good performance during the years that a solar (up to 40 years) + BESS (up to 25 years) plant is expected to operate.

Indeed, owners and their financial backers should steer clear of any commissioning process that does not include a comprehensive, standardized and consistent testing program to guarantee that the solar + BESS project operates safely and according to its design objectives. Specifically, this should be related to the power production of the facility, which is the key metric for financial viability in a solar + BESS project. Ultimately, given that the commissioning process forms the cornerstone of any bankable solar + BESS project, an appropriate contract must include thorough and state-of-the-art commissioning with the engineering, procurement, and construction (EPC) company or a third-party agent to ensure an optimal return on investment.

Commissioning costs are generally dictated by:

- size and location of a project
- breadth, depth, and duration of services provided
- technologies employed

Cost can also depend on whether the work is done by an EPC and rolled into construction costs, versus commissioning services provided by a third-party agent.

For systems larger than 5MW, the typical cost of commissioning is 1–2 cents per watt, while commissioning costs for systems around 500 kW typically range between 2.5–3.5 cents per watt. In either scenario, the cost of commissioning is ultimately a small price to pay to ensure proper installation and operations of systems throughout a project's expected service life.

Why Your Commissioning Partner Can Make or Break a Project

Focused on achieving an advantageous economic return, investors, owners and developers typically concentrate on the technical characteristics of a project such as solar panel conversion efficiency, inverter performance, battery capacity and the balance of system equipment. But if the operational strategy is to maximize revenue and financial performance, it is necessary to give robust attention to other elements of project design and implementation to guarantee optimal long-term output. Therefore, it is critical to choose a partner with a high level of knowledge and expertise across a broad scope of processes, technologies and regulatory landscapes.

Because some investors don't necessarily have in-house solar expertise, they often reach out to other companies for help. They may seek out individual partners such as design engineers; civil and geotechnical services providers; procurement and permitting, regulatory, registration, interconnection and construction contractors; and original equipment manufacturers. More typically, an EPC company is appointed to overall manage a project as well as the commissioning process. The use of third-party technical advisers to specifically support and drive the commissioning process is also becoming more common.

For projects above a certain megawatt threshold, it is also important to consider the needs of the independent system operator (ISO) and the local utility. For instance, a solar + BESS facility may work with both an ISO and a local utility through an interconnection agreement.

Registration, interconnection and operating requirements vary between local utilities (i.e., transmission and distribution that will receive exported electricity) and ISOs, which are responsible for controlling, operating and monitoring the regional electric power systems. ISOs often require that detailed commissioning plans are submitted during the Asset Registration process. These plans are reviewed prior to energizing the solar + BESS project to complete the required commissioning testing. ISOs also need live data from generation facilities as well as weather forecasts and special metering requirements. Some utilities require only basic information from facility owners, whereas others need a comprehensive suite of performance and output figures.

As such, the EPC company or third-party technical adviser should test the solar + BESS project's Remote Telemetry Units (RTU) to ensure that the supervisory control and data acquisition (SCADA) monitoring system is communicating with the ISO and local utility's systems as required. They can help with completing and submitting the commissioning plan required by some ISOs. *(Scroll down on linked the page to Asset Registration Documents/ Commissioning Plan Template.)*

Similarly, although ISOs typically require more thorough data to ensure they can operate the regional grids, there can be considerable variance between the different ISOs. For example, the California Independent System Operator (CAISO) and the Electric Reliability Council of Texas (ERCOT) have broadly comparable needs, though their protocols and standards differ. The interconnection requirements for CAISO are far more extensive than those for ERCOT.

> Understanding the requirements for the local utility and the ISO is critical to the commissioning process, so it is important to learn their specific system requirements to ensure that your project is on the right track.

If commissioning steps are omitted or poorly executed for any solar project, technical issues may not be identified. However, for solar projects that add energy storage, the risks and challenges of the commissioning process are amplified because the project takes on a new level of complexity.

Poor installation practices can cause the premature failure of major components such as inverters. For example, not all inverter manufacturers commission their equipment as part of the purchase process. Visiting the site, checking connections and voltages, installing the most up-to-date firmware and software, and starting up the inverter equipment are important steps that should not be overlooked. If an inverter isn't installed correctly, damage may result.

Thermal events and fires can damage large sections of a utility-scale project, while incorrectly installed or mismanaged use of equipment can void warranties, leaving owners with a hefty bill.

There have been a host of reported incidents related to poorly executed commissioning projects. In one case, inverters were installed at a lower elevation downgrade of the site and the associated conduits and cable glands were not properly sealed. Following some heavy rain, the inverter cabinet filled with runoff water and the unit failed. This problem could have been avoided by identifying it early in the design review of the project.

In another example, an inverter was commissioned by its manufacturer, and it was subsequently discovered that the software settings were not configured properly. This caused a 25% reduction in power production from the site. While this issue was relatively simple to address, months of energy production were lost as a result of poor commissioning practices. Similarly, a rooftop-mounted PV system was seemingly functioning according to specifications after commissioning. Months later, however, it was confirmed that energy production had been steadily dropping. A subsequent inspection identified that the grounding polarity had been inadvertently reversed on some of the module strings. While reconfiguring the wiring restored the system to full production within days, the loss of energy could have been identified prior to system energization with a better commissioning process.

Replacing equipment can also be costly. For a utility-scale solar and storage project, inverters may be sized anywhere from 2.5 MW to 5 MW and up to 10 MW. According to recent build cost ranges, inverters account for approximately $0.03 to $0.05 per watt of installed capacity, suggesting a figure of $75,000-$300,000 for each large utility-scale unit. A project can quickly become uneconomic if as few as 10% of the inverters fail because of poor installation that went unnoticed during the commissioning process. A project owner might be able to recover the costs of the failed equipment from the installer or insurance, but this could mean delays and new costs associated with pursuing any such claims.

In addition to electrical problems, mechanical issues can also cause loss of production. Concrete mounting platforms can crack or fail, mounting frames can sink into the ground, and improper racking installation can result in failure during high wind events. Poor installation practices at some projects have resulted in modules cracking because mountings were over torqued. Power and control cables may be mismatched or their insulation damaged during installation, resulting in potential fire conditions.

A well-executed commissioning process ensures that projects are safe for those installing, operating and maintaining them. For electricity infrastructure and large civil engineering projects, a multitude of dangers can present themselves if the commissioning process is flawed or insufficient. Effective commissioning practices help ensure safety, timeliness of project delivery and, ultimately, turnover, which in solar and storage projects equate to success.

Given the benefits and, perhaps more significantly, the pitfalls associated with a poor quality commissioning process, partnering with an EPC or a company with the right approach to commissioning is critical to a successful outcome.

The Edison Energy Standard for Solar + BESS Commissioning

As a strategic energy adviser, Edison Energy can be responsible for the solar + BESS commissioning, or it can represent the owner's interests and work with the commissioning company to ensure an effective process. Edison Energy has conducted commissioning for over 600 MW of ground mount, roof mount and carport solar installations to date.

No matter the pathway a client chooses, the commissioning process is vital from a contractual point of view. It is during commissioning that the title of the project transfers from the EPC to the owner with the issuance of a provisional acceptance certificate. At this time, the EPC not only hands over responsibility for the plant but also establishes the start of the warranty periods.

To achieve optimal outcomes across a project's development, Edison's commissioning process starts with a comprehensive upfront review of the design. The objective of this diligent design review is to determine whether the system is configured to capture maximum energy relative to site conditions. This review also ensures that the project is engineered to meet relevant codes, adheres to best practices and meets all the owner's specifications to achieve maximum revenue at minimum costs. Similarly, Edison confirms that the balance of system equipment and materials are designed for their intended purpose and remain operational for the anticipated lifetime of the system. These efforts reduce the need for any reworking of the system after just a few years in service.

Edison makes sure that key checkpoints are met throughout the commissioning process. For example, on the AC side, equipment such as switchgear, medium voltage cables, step-up transformers, reclosers, air switches and other components are validated for proper connection, grounding, programming and operation. Similarly, on the DC side, mechanical and electrical connections and performance across the solar array are checked and validated through I-V curve tracing.

Edison ensures that key components such as inverters, the mechanical insulation for grounding, overcurrent, bolt torques, terminations, wire management, phase rotation and all other relevant tests meet the IEEE1547 industry standard.

The SCADA monitoring system may also be of considerable value during the commissioning process because it can verify the accuracy of the information derived from inverters, meters, temperature sensors, wind speed meteorological devices and irradiance sensors as well as ancillaries such as IP addresses. A solar + BESS plant's SCADA system can also be used to efficiently perform multiple performance checks remotely.

Value-added elements are a mark of quality for superior commissioning partners such as Edison. For example, Edison conducts a walk-through after construction to compile a comprehensive punch list of any items that may have been missed during the quality assurance and quality control processes. This includes any applicable changes approved via requests for information and change orders during the construction process. As-built drawings are also updated and confirmed for accuracy.

> This value-added approach can extend to adopting cutting-edge technology to minimize costs for the project owners.

For example, Edison can employ drones fitted with thermographic infrared cameras to fly over solar arrays and identify hot spots to detect potential anomalies in all overcurrent devices, switches, cabinets, and other gear. Once a hot spot has been identified, operators are able to investigate the instrumentation and control systems, such as the SCADA, to pinpoint where the fault might be and address the cause on-site. This type of technological approach is a growing trend among the best commissioning partners, especially with larger systems where it is not feasible to physically test hundreds of thousands of solar modules located across hundreds of acres in a timely and efficient way.

A critical part of any effective commissioning process is project performance verification or checking that actual performance and kWh production match the design expectations. Edison Energy conducts a complete AC capacity testing procedure in compliance with ASTM E2848-13 (Standard Test Method for Reporting Photovoltaic Non-Concentrator System Performance). As part of this assessment, Edison provides a final report that documents all tests and actions taken to validate that the solar project operates per its performance baseline. This is the goal of a top-tier commissioning process, with Edison's owner service and construction management skills bringing integrity to a solar and battery project across all phases of the design, implementation and turnover process.

Safety First

Safety is a critical aspect of commissioning that cannot be overemphasized. This remains Edison's top priority during construction and operation.

Quality commissioning partners such as Edison safeguard staff by confirming that all Occupational Safety and Health Administration (OSHA) and site-specific safety procedures are being followed. OSHA regulations require that employers follow applicable standards and provide a safe and healthy workplace free of hazards. This includes appropriate training, such as that outlined in the NFPA 70E Standard for Electrical Safety in the Workplace, and promoting a workplace safety culture on-site with the expectation that all workers follow the relevant safety rules and procedures.

OSHA and site-specific safety requirements include job hazard analyses and the use of heavy equipment, powered industrial trucks, scaffolding and excavation safety, fall protection, safe lifting and rigging procedures, and appropriate personal protection equipment (PPE), as well as a thorough lockout and tagout process to control exposure to hazardous energized equipment. These procedures include an important daily "safety toolbox talk."

MV cable terminations

Best practices for PV installations also include appropriate risk assessments before conducting site work, ensuring appropriate PPE such as hard hats are not just supplied but worn, and that insulated and well-maintained electrical hand tools are used. Other safety considerations include using applicable warning signs and labels, keeping the site clean and tidy, ensuring that documentation is up to date, and removing tools from equipment enclosures prior to commissioning equipment.

Direct violation of OSHA standards as it pertains to fall protection

Workers are seen outside the warning line and are at the roof edge without the use of a Personal Fall Arrest (PFA) system. This type of violation is/was so severe that a work stoppage was instituted at the advisement of Edison Energy, and all personnel were retrained. Additional monitoring protocols were implemented to prevent future occurrences.

Conclusion

Proper commissioning is a fundamental part of a solar + BESS project's development and implementation, beginning with design review and extending all the way through to grid interconnection and energization. By ensuring that the commissioning process is executed diligently, asset owners minimize the potential for problems throughout a project's operational life. This is achieved by building in best practice approaches to every stage of the process.

With its technical knowledge of the development, installation and commissioning of solar + BESS, Edison delivers the necessary expertise to ensure a diligent and streamlined commissioning process.

With the right commissioning partner, either as the EPC or in a stand-alone oversight role, investors and owners can be assured that their project meets the highest standards for risk management, quality control, cost avoidance and safety. For more information on how Edison can help you achieve the maximum return on investment with our top-tier commissioning process, please contact our team at information@edisonenergy.com:

Dan Grdovic
PE, CEM, Director, Energy Optimization

Armand Echetebu
Director, Distributed Energy Resources

A quality commissioning process

- Confirms that the installation has been executed correctly to guarantee that any minor efficiency losses do not become a major commercial setback
- Extends from the very start of the project, beginning with design review and continuing through final performance verification
- Ensures that solar and storage projects are completed and operational in a timely, safe and commercially optimized way
- Brings in value-added benefits such as the use of cutting-edge technology to maximize financial performance

About Edison Energy

Edison Energy partners with large corporate, industrial, healthcare and institutional clients as a strategic energy adviser to develop, design, develop, and execute complex energy optimization programs and conservation projects. Using cutting-edge technologies, Edison performs comprehensive energy optimization audits and implements innovative strategies around distributed energy resources. Our scope of work includes project commissioning, combined heat and power (CHP), system retrofits, HVAC and electrical replacements and upgrades, building and energy controls, and state-of-the-art energy efficient lighting. With experience ranging from large-scale power generation to both traditional and complex integrated building and energy systems, Edison's energy optimization services focus on data analytics and monitoring, implementation of new energy technologies, and all aspects of renewables.

A wholly owned subsidiary of Edison International (NYSE: EIX), Edison Energy LLC is a global independent advisory firm that helps large corporate, industrial, and institutional clients better navigate the choices and risks of managing energy. As stakeholder expectations around corporate sustainability increase, Edison helps companies rise to this challenge by designing and implementing specialized strategies and solutions for clients across sustainability, renewables, energy optimization, transportation electrification, and energy supply. With a commitment to promoting a sustainable, resilient, and equitable future, Edison enables organizations to deliver on their strategic, financial, and sustainability goals by addressing today's key energy challenges: carbon, cost, complex choices, and creating energy justice across communities.

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