Best practices for solar system commissioning and acceptance

Before commercial operations start, solar systems need to pass a set of acceptance and performance tests conducted by the Engineering, Procurement and Construction (EPC) contractor. This is the process of assuring safe operation of a solar photovoltaic (PV) system and making sure it is compliant with environmental and planning requirements, meets design and performance objectives, and that any tests meet contractual requirements. System owners will usually only sign the acceptance certificate and formally take over the system once it meets all these requirements.

In the European market, this stage of acceptance is referred to as Provisional Acceptance Certification (PAC), which is followed by Intermediate (IAC) and Final Acceptance Certification (FAC) after one and two years of commercial operations, respectively. In the United States (US) market, these tests typically occur at Mechanical Completion (MC) and Substantial Completion (SC).

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EUROPEAN MARKET

Provisional acceptance

- System is fully installed, commissioned and connected to the grid
- Visual and mechanical checks
- Electrical tests
- Infrared scans
- Drone surveys
- All permits obtained
- Document handover
- Punchlist/snag list items completed
- System level Performance Ratio test
- Final system handoff to the owner.

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Intermediate acceptance (PAC + 1 year)

- Visual inspection and update to the snag list
- Performance Ratio test, typically considering one full year of operations
- Milestone payment or release of retention amount.

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Final acceptance (PAC + 2 years)

- Visual inspection, all snag list items completed
- Performance Ratio test, typically considering two full years of operations
- Milestone payment or release of retention amount.

US MARKET

Mechanical completion

- All equipment installed and connected
- Visual and mechanical checks
- String level electrical testing
- Grounding continuity
- Insulation resistance
- Soil compaction.

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Substantial completion (MC + months)

- System is connected to the grid
- Inverter and tracker commissioning
- Infrared scans
- Drone surveys
- System or circuit level performance tests
- Document handover.

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Final completion (SC + weeks/months)

- All punch list items completed
- All permits obtained
- Final payments to contractors and sub-contractors
- Final system handoff to owner.

VISUAL INSPECTION AND FUNCTIONAL TESTS

At, or before, PAC and SC, the EPC contractor is typically required to carry out a visual inspection of system construction and functional testing of the major components of the system. These tests are the first step of the acceptance process, which is a detailed technical check-up that can confirm correct installation of all components of the PV system. These tests on completion generally consist of a visual inspection to identify defects, unfinished work and non-compliance with contractual and planning requirements; functional tests of all key components required for the system to generate and supply electricity to the grid; and testing for appropriate connection to the electrical grid. Below is an example of typical visual inspection items and functions tests.

Examples of visual inspection items

- Power cables and conduit for physical damage.
- Torque marks on all electrical and mechanical bolted connections.
- Arrays for broken modules and wire management.
- Metal components such as mounting structures or electrical boxes for oxidation or corrosion.
- Module temperature sensor, pyranometers and anemometers for compliance with drawings.
- Combiner boxes for structural integrity and weather sealing.
- Soil compaction of roads and electrical trenches.

Examples of functional tests

- Continuity and resistance testing, which verify the integrity of grounding system, conductors, connections and other terminations.
- Polarity testing, which verify the correct polarity for DC circuits.
- Voltage and current testing, which verify that the PV array and system operating parameters are within specifications.
- Insulation resistance testing, which verifies the integrity of wiring and equipment and is used to detect degradation and faults due to wiring insulation.
- Infrared camera scans of operating electrical components to identify hotspots.
- Tracker, circuit breaker, switchgear and transformer testing (if applicable).

Generally, the contractor completes the visual inspection and functional tests, but the owner and an independent technical advisor may witness or conduct their own tests. For smaller solar systems, it may be feasible for the contractor to test down to each individual string. For larger sites, the contractor may test a sample from each type of component. They may also use drone surveys covering the entire system to complement these samples. (see remote site acceptance paper here).

Functional test procedures for large-scale solar systems can vary between markets and on the contractual strategy between the EPC contractor and the owner. However, they can use IEC 62446 as a guideline to help define the minimum commissioning tests, inspection criteria and documentation expected to prove the safe installation and accurate operation of the system.

PERFORMANCE TESTS

System performance tests at PAC and SC are typically carried out over a short period, ranging from three to ten days. The tests provide an immediate indication to the owner or investor whether the solar system's energy production at the time of commissioning is in line with EPC contractor guarantees and financial model assumptions.

As an owner, it is crucial to negotiate a suitable methodology and test duration from the outset in order to hold the EPC contractor to account for system performance. Tests with poor methodology or short durations can have high uncertainty, which increases the risk for owners. Natural Power has seen different methodologies included in EPC contracts for solar systems around the world. During the technical due diligence for lenders or owners, a detailed review the technical aspects of performance testing within the EPC contracts should be carried out to ensure that requirements are suitable for the solar system and market.

The industry has developed some standards that are relevant in the context of performance testing:

- IEC 61724-1 sets out the methodology for calculating Performance Ratio (PR), which helps to identify performance trends in a PV system and to compare the system performance to design expectations and guarantees. The definition of PR is the ratio between the actual energy produced and the theoretical amount of energy produced if the modules converted all the available solar energy into useable electricity according to their rated capacity.
- ASTM 2848-13 and IEC 61724-2 use a regression-based approach to compare the measured performance of the solar system at completion with the expected performance of the system based on the design. The US market typically uses the ASTM standard, while the IEC standards are more common in other international markets.

While these standards provide an excellent starting point to guide the definition of performance tests in EPC contracts, they may need to be adjusted to address system and location specific concerns. As an example, for systems in less sunny climates like the United Kingdom (UK), Canada or northern parts of the US, it is particularly important to set an appropriate duration and minimum irradiance requirements for the performance test so that performance can be assessed over a representative range of sunshine conditions. We would typically recommend including these requirements in the EPC contract. Solar system performance also depends on temperature, and it may be prudent to include a temperature correction in the methodology to consider these effects. Our recent conference poster on "Challenges of PV system acceptance testing in winter" provides detailed guidance for evaluating solar system performance during low-temperature, low-irradiance conditions.

Irradiance is a key input to most performance tests, and irradiance measurements must be reliable to calculate a useful estimate of system performance. As part of the performance test process, it is important to verify that the pyranometers are properly installed, calibrated and unshaded. Uncertainty in the measurement of the solar irradiance during the test will translate directly to uncertainty in the results of the performance test. IEC 61724 specifies the requirements for the measurement of global horizontal irradiance (GHI) and irradiance in the plane of array (POA).

Performance above the guaranteed contractual value gives owners and investors the confidence that their system was installed correctly, and it sets the baseline for monitoring the energy production during the operational phase of life.

HANDOVER PACK

All PV systems should come with adequate documentation providing details of the system design and all components and materials used in its construction. The documentation should also include health and safety information, and procedures for operating and maintaining the system. Owners can use IEC 62446 as a guide to define the minimal information and documents needed following the installation of a PV system. Specific examples include, but are not limited to, the:

- permitting information and any planning conditions that have been discharged;
- grid connection approval and documentation from the local utility;
- equipment datasheets, installation and maintenance manuals;
- health and safety documents;
- as-built drawing package;
- inspections records;
- warranty documents;
- flash test files.

Carrying out flash tests on the PV modules can confirm that their nominal power output is in line with the module specification. These tests are usually carried out at either the factory or on site. You would expect the average flash tested power of the modules installed to exceed the nominal power by approximately 0.50%–0.80% because PV modules are typically provided with a positive power tolerance.

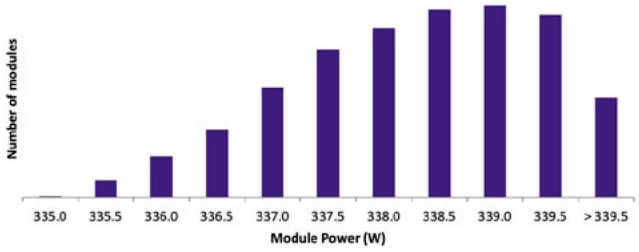

Figure 2: Flash test data from example shipment of 335 W modules.

It is important to review the handover pack to make sure it is complete. The information contained in the handover pack is critical for the effective maintenance of the system over time. Any missing documentation may also cause unforeseen headaches for the owner if they intend to sell the site at a future date, or if regulatory bodies, such as Ofgem in the UK, audit the site.

CONCLUSIONS

The acceptance of a solar system is a critical phase for any PV system owner. An independent review of site documentation and of visual and functional test results are key to confirming the quality of the installation and safe operations. In many cases, financing sources require acceptance tests, and the contractor needs to close all outstanding items before the release of final payments.

For more information on acceptance testing at solar facilities during the Covid-19 pandemic, see our white paper with case study here: **https://www.naturalpower.com/xhr/downloadRequest.php?id=24**

Further information on PV system acceptance testing in winter can be found in a poster presentation here: **https://www.naturalpower.com/xhr/downloadRequest.php?id=22**

To discuss how Natural Power can assist you during the site acceptance of your solar system and for performance testing review, contact:

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