

Technical Paper · U.S. Market Edition

**November 2026**

# Commissioning Sequence for Solar PV Plants

U.S. practice (NETA ATS · IEEE 1547 · NEC) · Example: 2.5 MWac PV plant

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## Abstract

This paper sets out the order in which a solar photovoltaic (PV) plant is commissioned, from mechanical completion to commercial operation, and maps each step to the documents used in the U.S. market. It is the opening paper of a series: each test named here has, or will have, its own guide with the method, the acceptance criteria and a blank record form.

The sequence has four stages separated by three hold points: readiness, cold commissioning with the plant isolated from the grid, energization and hot commissioning, and performance verification. The order inside each stage is not arbitrary. Grounding continuity comes before any insulation test to ground, polarity comes before string fuses are inserted, and the medium-voltage cable test is bracketed by two insulation readings. The paper explains each dependency.

The sequence is illustrated with an anonymized 2.5 MWac fixed-tilt PV plant in Brazil: 197 strings, 10 string inverters, one dry-type step-up transformer and a medium-voltage service entrance. Its commissioning plan has 16 tests, 11 cold and 5 hot. The paper also lists the tests that were outside that plan, in particular the verification of protective relay and inverter settings, and explains why those are the tests that matter most for grid reliability.


**Keywords:** PV plant commissioning, acceptance testing, cold commissioning, hot commissioning, hold point, ANSI/NETA ATS, IEC 62446-1, IEEE 1547, IEEE 2800, NEC Article 690, inverter-based resource.

**Notice – professional responsibility**

**Educational content.** This paper describes a commissioning sequence and illustrates it with an anonymized example. It is not a commissioning plan, test procedure, specification or recommendation for any specific project.

**No professional responsibility.** Solstice Performance Solutions LLC d/b/a Solstice Energy does not provide services that require professional engineering licensure in the United States and assumes no technical or professional responsibility for plans, tests, settings or decisions based on this paper.

**Engineer of Record and qualified persons.** The commissioning plan for a real installation is defined by the project documents, the Engineer of Record, the equipment manufacturers and the utility. Tests on electrical equipment must be performed by qualified persons under the safety program of the site.

**No warranty.** The information is provided as is. Standards, utility requirements and site conditions change; the reader is responsible for verifying every reference against the current editions and the project data.

# 1 Introduction and Scope

Commissioning is the last technical step before a PV plant starts to deliver energy, and the first record of its condition. A test done in the wrong order can damage equipment, hide a defect or put people at risk. A test left out is usually found later, as a trip, a fire or an energy shortfall.

Most guidance on PV commissioning describes individual tests. This paper covers what sits between them: the order, the dependencies, the hold points where one party hands the plant to another, and the records that show the plant was ready at each step.

**Scope:** the sequence of commissioning for ground-mounted PV plants with string or central inverters, a step-up transformer and a medium-voltage interconnection. The methods and acceptance criteria of each test are covered in the companion guides of this series, not here.

**Audience:** commissioning engineers, EPC project managers, owner's engineers and asset managers who plan, witness or review commissioning.

**Normative basis:** U.S. practice (ANSI/NETA, IEEE, NFPA and UL), together with IEC 62446-1, which is widely cited in U.S. PV contracts. Section 3 lists each document and what it contributes.

**Example data:** the plant in Section 4 is anonymized. Its data are representative of the original commissioning plan and do not identify the site, the owner or the utility.

# 2 The Commissioning Framework

## 2.1 Four stages

The work is divided into four stages. The names vary between contracts; the content does not.

- **Stage 1 – Readiness.** Construction is complete for the section to be tested, the documents are on site and the safety arrangements are in place. No test is performed in this stage.
- **Stage 2 – Cold commissioning.** Inspections and tests with the plant de-energized and isolated from the grid. The purpose is to show that the plant can be energized safely. In IEC 62446-1 these are mostly the Category 1 tests.
- **Stage 3 – Energization and hot commissioning.** The plant is connected and the equipment is started, set and checked under voltage and load. The Category 2 tests of IEC 62446-1, the I-V curve and the infrared inspection, belong here because they need the array in operation.
- **Stage 4 – Performance verification.** With the plant in stable operation, its energy performance is measured and compared with the expected value. The stage closes with the final report and the handover to operations.

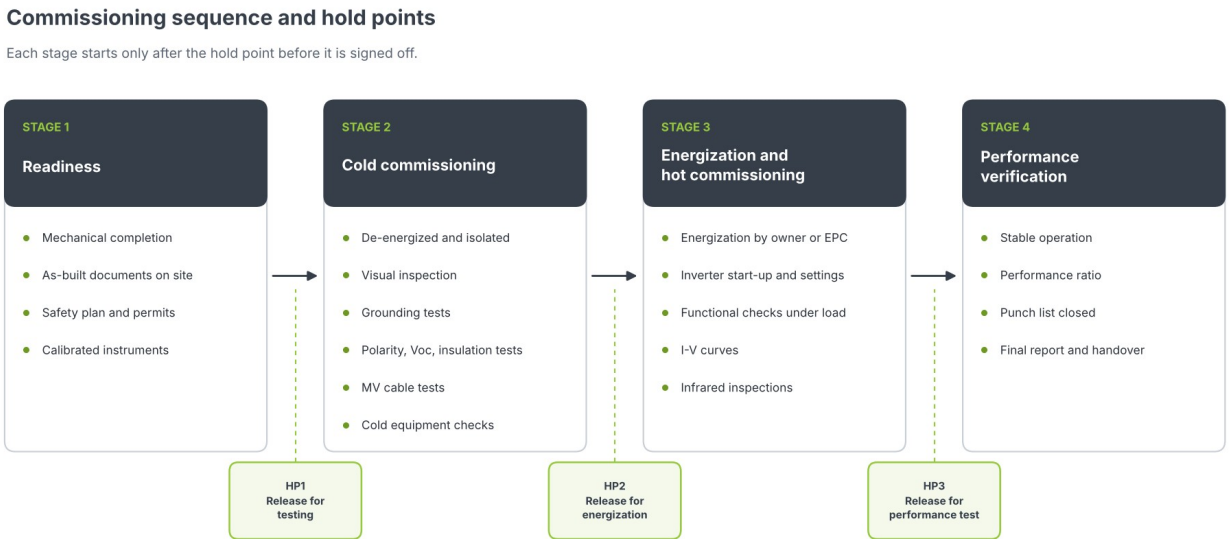



**Figure 1.** The four commissioning stages and the three hold points between them.

## 2.2 Hold points

A hold point is a formal release, in writing, from one party to the next. Work does not pass a hold point on a verbal instruction. The three hold points below are the minimum; a contract may add others, for example a release per inverter block.

| Hold point | Released by | What must be true |
|---|---|---|
| **HP1 – Release for testing** | Installer or EPC | Mechanical completion declared for the section; conductors terminated; string fuses out and DC disconnects open; AC breakers open; plant isolated from the grid; drawings, string list and cable schedule on site; work permits issued. |
| **HP2 – Release for energization** | Owner or EPC, with the utility | Cold commissioning complete; every nonconformity that prevents energization corrected and re-tested; protective relay and inverter settings applied and verified; utility permission to operate, or witness test scheduled. |
| **HP3 – Release for performance test** | Owner or EPC | All inverters running at their maximum power point; no curtailment beyond the design limit; monitoring and weather station validated; hot commissioning punch list reviewed. |

The division of responsibility at HP2 deserves attention. In the example plan, the commissioning team performed the tests, but switching on the utility line and energizing the plant were the responsibility of the owner and the EPC. Stating this in the plan avoids the most dangerous ambiguity on site: who is allowed to close which device.

# 3 Standards and References Applicable (U.S. Market)

No single U.S. document covers PV commissioning from end to end. The plan is assembled from several, each with its own role.

| Document | What it provides for commissioning |
|---|---|
| **ANSI/NETA ATS-2025** | Field inspections and tests to assess suitability for initial energization and final acceptance of electrical power equipment. The 2025 edition added a section on solar PV systems and one on battery energy storage systems. |
| **ANSI/NETA ECS-2024** | Electrical commissioning specifications: system-level verification against the owner's project requirements, after the equipment acceptance tests. |
| **IEC 62446-1:2016 + AMD1:2018** | Documentation, inspection and commissioning tests for grid-connected PV systems. Defines the Category 1 test regime for all systems and the Category 2 regime for larger or more complex systems. |
| **NFPA 70 (NEC)** | Installation requirements: Article 690 (PV systems), Article 691 (large-scale PV electric supply stations), Article 705 (interconnected power production sources) and Article 250 (grounding and bonding). The edition in force is the one adopted by the authority having jurisdiction. |
| **NFPA 70E and OSHA 29 CFR 1910** | Electrical safety in the workplace: energized work, arc-flash boundaries and personal protective equipment, lockout/tagout, qualified persons. |
| **NFPA 70B** | Electrical equipment maintenance. Sets the baseline that the commissioning records feed, including infrared inspection. |
| **IEEE Std 1547-2018 and IEEE Std 1547.1-2020** | Interconnection of distributed energy resources with the distribution system, and the conformance test procedures: type tests, design and as-built evaluation, and commissioning tests. |
| **UL 1741** | Product safety and grid-support certification of inverters. Confirms which functions and settings the inverter is certified for. |
| **IEEE Std 2800-2022 and IEEE Std 2800.2-2026** | Interconnection of inverter-based resources with transmission systems, and the recommended test and verification procedures, including commissioning tests and post-commissioning model validation. |
| **NERC PRC-028-1, PRC-029-1 and PRC-030-1** | Reliability Standards for inverter-based resources on the bulk power system: disturbance monitoring, ride-through performance, and analysis and mitigation of unexpected changes in output. |
| **IEEE Std 81, IEEE Std 80, IEEE Std 2778** | Ground resistance measurement, substation grounding safety, and grounding of solar plants for personnel protection. |
| **IEEE Std 400 and IEEE Std 400.2** | Field testing of shielded power cable systems, and testing with very low frequency (VLF) voltage. |
| **IEC TS 62446-3:2017** | Outdoor infrared thermography of PV modules and plants. |
| **ASTM E2848 and IEC 61724-1** | Capacity test reporting and performance monitoring, used in Stage 4. |

### 3.1 How to use these documents together

**NETA ATS and IEC 62446-1** answer the question of what to test. NETA ATS covers the electrical power equipment (cables, transformers, switchgear, relays, grounding) and, since 2025, the PV system itself. IEC 62446-1 is specific to the PV array and is the document most PV contracts cite for the DC side.

**The NEC** is not a test standard. It defines how the plant must be built, so it is the reference for the visual inspection.

**NFPA 70E and OSHA** govern how the work is done safely. They apply to every stage.

**IEEE 1547 or IEEE 2800** defines how the plant must behave at the interconnection, and their companion documents define how to verify it. Which one applies depends on where the plant connects, as explained below.

### 3.2 Distribution or bulk power system

A plant connected to a distribution feeder, like the 2.5 MWac example, follows IEEE Std 1547 and the utility's interconnection requirements. IEEE Std 1547.1 gives the commissioning tests, and the utility may witness them.

A plant connected to the transmission system follows the requirements of its transmission provider, which increasingly adopt IEEE Std 2800. If the plant is registered with NERC, the Reliability Standards also apply. PRC-029-1, which sets ride-through requirements for inverter-based resources, was approved by FERC in July 2025.

The sequence in this paper is the same in both cases. What changes is the depth of Stage 3: a transmission-connected plant adds plant-controller tests, ride-through settings verification and model validation.

## 4 Example Plant

The sequence is illustrated with the commissioning plan of a distributed PV plant in Brazil. The plan has 16 tests recorded on 29 checklists. The plant data are given as built; the tests are described with U.S. market references.

**Example plant (anonymized)**

| Item | Value |
|---|---|
| **DC capacity** | 3,634.65 kWp (5,910 bifacial modules of 615 Wp) |
| **AC capacity** | 2,500 kW (10 string inverters) |
| **Strings** | 197, maximum system voltage up to 1,500 V DC |
| **Mounting** | Fixed tilt (no trackers) |

| Item | Value |
|---|---|
| **Low-voltage collection** | 10 inverter circuits to one main low-voltage switchboard |
| **Transformer** | One dry-type step-up transformer |
| **Interconnection** | 13.8 kV distribution feeder, through a medium-voltage service entrance with protective relays |
| **Auxiliary systems** | Data logger, weather station, uninterruptible power supply, control room, video surveillance |
| **Commissioning plan** | 16 tests: 11 cold (tests 1 to 11) and 5 hot (tests 12 to 16) |

# 5 Stage 1: Readiness

## 5.1 Prerequisites

Cold commissioning starts only when the following are confirmed for the section to be tested:

- Electromechanical installation complete and formally released by the installer, with notice the day before work starts;
- String fuses removed or DC disconnects open, AC breakers open, and the plant isolated from the grid;
- Grounding and bonding connections made, and medium-voltage cable terminations finished;
- As-built or latest-revision drawings, string list, cable schedule and datasheets available on site;
- Ground clear and accessible between module rows;
- Job hazard analysis and work permits issued, and an owner's representative appointed.

## 5.2 Safety

The safety rules are part of the plan, not an attachment to it. The points below follow NFPA 70E and OSHA practice.

- **Qualified persons.** Everyone who tests is trained for the voltage level involved, and is named in the job hazard analysis and the work permit.
- **PV strings are always live.** A string produces voltage whenever there is light. All DC conductors are treated as energized.
- **Arc-flash protection.** Arc-rated clothing is worn from the moment strings are closed and in any work on energized circuits, at the level set by the arc-flash risk assessment.
- **Absence of voltage, lockout/tagout and temporary grounding** before any cold test on AC and medium-voltage circuits.
- **Barriers and discharge.** The area of insulation and high-voltage tests is fenced and signed, and circuits are discharged after every measurement.

- **Weather.** No testing in rain, drizzle, fog or lightning. Field work stops when a storm approaches.
- **Energization.** Switching on the utility side belongs to the owner, the EPC and the utility. Hot commissioning starts only after the formal release at HP2.

### 5.3 Instruments

Every instrument has a valid calibration certificate, traceable to a national standard, and is rated for the maximum system voltage. Certificates are delivered with the reports. The table lists the minimum set used in the example plan.

| Instrument | Minimum specification | Tests |
|---|---|---|
| **Digital multimeter** | CAT III 1,500 V DC / CAT IV 600 V | 2, 4, 13 |
| **Insulation tester, low voltage** | Test voltages 250 V to 1,000 V, suitable for PV circuits | 3, 6, 7 |
| **Insulation tester, medium voltage** | Up to 10 kV DC, with polarization index | 8 |
| **High-voltage cable test set** | Output suitable for the cable class, with leakage current record and safe discharge | 9 |
| **Low-resistance ohmmeter** | Four-wire method, test current of 200 mA or more, 1 mΩ resolution | 4 |
| **Earth ground tester** | Four-terminal, fall-of-potential, with interference filter and leads of 100 m (330 ft) or more | 5 |
| **I-V curve tracer** | 1,500 V DC, 20 A or more, with plane-of-array irradiance and module temperature sensors | 12 |
| **Handheld infrared camera** | Radiometric, 320 × 240 pixels or more, thermal sensitivity of 50 mK or better | 14 |
| **Drone with infrared camera** | Radiometric, 640 × 512 pixels or more, with visible camera and positioning for georeferencing | 15 |
| **Clamp meter and phase-rotation meter** | DC and AC current; absence of current before disconnecting | 2, 3, 12, 13 |
| **Thermo-hygrometer** | Ambient temperature and relative humidity | All |

# 6 Stage 2: Cold Commissioning

Cold commissioning covers the inspections and tests made with the plant disconnected from the grid: PV array, low-voltage AC circuits, medium-voltage circuits, transformer, grounding system and auxiliary equipment.

## 6.1 The tests

| Test | Description | U.S. market reference | Order |
|---|---|---|---|
| **1** | Visual inspection of the array, inverters, switchboard, transformer, service entrance and auxiliaries | NEC 690, 705, 250; IEC 62446-1; NETA ATS | 1st |
| **4** | Continuity of the grounding system and bonding conductors | IEC 62446-1; NETA ATS (grounding systems) | 2nd |
| **5** | Ground resistance by the fall-of-potential method | IEEE Std 81; NETA ATS (grounding systems) | In parallel |
| **2** | Polarity and open-circuit voltage of every string | IEC 62446-1 | 3rd |
| **3** | Insulation resistance of the DC circuits, every string | IEC 62446-1 | 4th |
| **6, 7** | Insulation resistance of the low-voltage AC circuits: inverters to switchboard, switchboard to transformer | NETA ATS (low-voltage cables) | 5th |
| **8** | Insulation resistance of the medium-voltage cables | NETA ATS (medium-voltage cables) | 6th |
| **9** | High-voltage withstand test of the medium-voltage cables, with insulation resistance before and after | IEEE Std 400, IEEE Std 400.2; NETA ATS | 7th |
| **10** | Transformer receiving inspection: nameplate and factory test report | NETA ATS (transformers); IEEE C57.12.01, C57.12.91 | In parallel |
| **11** | Cold checks of inverters, switchboard, transformer, auxiliaries, data logger, weather station, service entrance and control room | NETA ATS; manufacturer instructions | Before HP2 |

The test numbers are those of the example plan. The last column is the order of execution, which is different from the numbering.

## 6.2 Why this order

The tests depend on each other. The order below is followed per inverter and per circuit.

1. **Visual inspection first.** It finds the defects that would make the following tests unsafe or meaningless: damaged insulation, missing bonding jumpers, wrong cable routing, loose terminations.
2. **Grounding continuity before insulation tests.** An insulation test measures resistance to ground. If the ground reference is not continuous, a good reading proves nothing. Continuity must also be confirmed before people apply test voltage to metal structures.
3. **Ground resistance in parallel.** The fall-of-potential test uses its own leads outside the plant and does not depend on the other tests. It can run as an independent work front.

4. **Polarity and open-circuit voltage before fuses go in.** A reversed string connected in parallel with correct ones drives fault current through the fuses and the modules. The check is made with fuses out and disconnects open, and it is mandatory before they are closed.
5. **DC insulation resistance after polarity.** The test applies voltage to each pole. Polarity must already be known for the string under test.
6. **Low-voltage AC insulation** next, circuit by circuit, with surge protective devices and electronic loads disconnected.
7. **Medium-voltage cables last among the cable tests.** Insulation resistance is measured, then the withstand test is applied, then insulation resistance is measured again. The second reading shows whether the withstand test changed the cable.
8. **Cold equipment checks** can run on parallel fronts and must be finished before energization.

Each record sheet covers 100% of the equipment or circuits in scope, cites the reference document, and states the reference value next to the measured value.

### 6.3 A note on the medium-voltage cable test

For new cables with extruded insulation, such as XLPE and EPR, the withstand test is a very low frequency (VLF) AC test under IEEE Std 400.2, often combined with tangent delta or partial discharge measurement. DC withstand testing is no longer the preferred method for this type of cable. The 2025 edition of ANSI/NETA ATS added a table of medium-voltage cable acceptance test values and guidance on the choice of test method. A separate guide in this series covers the method.

## 7 Stage 3: Energization and Hot Commissioning

### 7.1 Prerequisites

- Cold commissioning complete, and every nonconformity that prevents energization closed;
- Plant connected and operating normally, with inverters at their maximum power point and no curtailment beyond the design limit, except for the string under I-V test;
- Weather suitable for each test: clear sky and stable irradiance;
- Work permits issued and the owner's representative present.

### 7.2 The tests

| Test | Description | U.S. market reference | Conditions |
|---|---|---|---|
| 13 | Inverter start-up and settings; energization and functional checks of inverters, switchboard, transformer, auxiliary supplies, control room, data logger and weather station | IEEE Std 1547.1 or IEEE Std 2800.2; UL 1741; utility requirements; manufacturer instructions | After HP2 |

| Test | Description | U.S. market reference | Conditions |
|---|---|---|---|
| **12** | I-V curve of every string | IEC 62446-1 (Category 2); IEC 60891 | Stable irradiance |
| **14** | Infrared inspection of inverters, switchboard, transformer, auxiliary panels and service entrance | NETA ATS (thermographic survey); NFPA 70B | Equipment under load |
| **15** | Aerial infrared inspection of 100% of the modules | IEC TS 62446-3 | Irradiance of 600 W/m² or more |
| **16** | Performance ratio | NREL weather-corrected performance ratio; ASTM E2848; IEC 61724-1 | Stage 4 |

### 7.3 Order within the stage

Test 13 comes first, because nothing else can be measured until the inverters run. It is also the test with the largest effect on how the plant behaves on the grid: it is where the country or grid code setting, the voltage and frequency trip limits, the ramp rates and the active and reactive power modes are entered and recorded.

The I-V curves and the two infrared inspections follow, in any order that the weather allows. They need irradiance and load, and they look for different things: the I-V curve shows the electrical behavior of each string, the handheld infrared inspection shows hot connections in the equipment, and the aerial inspection shows hot cells, bypass diodes and disconnected strings across the whole array.

The performance ratio, test 16, closes the sequence. It needs several days of stable operation and validated monitoring, so it is planned as Stage 4.

## 8 What the Example Plan Left Out

A commissioning plan states what is outside its scope. In the example, the following were excluded and left to others:

- Parameter setting, secondary injection and functional commissioning of the protective relays at the service entrance;
- Functional commissioning of the medium-voltage equipment: switchgear, breakers, disconnects, instrument transformers, surge arresters, contact resistance and interlocks;
- Routine and acceptance tests of the power transformer, covered by the factory test report;
- Touch and step voltage measurements;
- Integration with the owner’s SCADA beyond the data logger and the weather station;

- Switching on the utility line and the interface with the utility.

An exclusion is acceptable when another party is responsible and the hold point checks the result. It becomes a gap when nobody is. HP2 exists to close that gap: before energization, someone must confirm that the relays were set to the approved protection study and tested, whoever did it.

### 8.1 Why settings matter for grid reliability

The first two items on the list, with the inverter settings of test 13, are the ones that connect commissioning to the reliability of the grid. NERC has published several disturbance reports, including the Odessa reports, that describe solar plants reducing output or tripping during routine grid faults. The reports trace much of this behavior to protection and control settings inside the plants. In response, FERC issued Order No. 901 in 2023, and NERC developed the Reliability Standards listed in Section 3.

Those standards apply to plants on the bulk power system. The lesson applies to every plant: a setting that is wrong on the day of commissioning stays wrong until an event exposes it. A commissioning record that shows each setting as approved, as applied and as verified is inexpensive to produce in Stage 3 and very hard to reconstruct later.

Settings verification is therefore treated in this series as a test in its own right, with its own guide, and not as a line in the inverter start-up checklist.

## 9 Nonconformities and Re-test

- Every nonconformity is recorded with an identifier, a description, the evidence (photo or reading) and a class: preventing energization, or not.
- Nonconformities are reported to the owner's representative immediately and in writing, and consolidated in a punch list attached to the report.
- Correction is the responsibility of the installer or EPC, coordinated by the owner.
- Items corrected during the field campaign are re-tested and recorded. The re-test repeats the full test on the affected circuit, not only the failed reading.

Photographic records, visible and infrared, on the ground and aerial, are marked with location, date and time, so that each piece of evidence can be traced.

## 10 Minimum Report Content

The example plan delivers two reports: one after cold commissioning and one after hot commissioning. Each contains at least:

- **Identification:** plant, section tested, dates, testing organization, persons who tested and who witnessed.

- **Executive summary:** result per test, and the list of open nonconformities with their class.
- **Method:** reference documents and their editions, test voltages and durations, acceptance criteria.
- **Results per circuit:** the completed record sheets, with the reference value and the measured value side by side.
- **Settings record** (hot report): inverter and relay settings as approved, as applied and as verified.
- **Infrared and I-V analysis** (hot report): anomaly map, classification and recommended action.
- **Evidence:** photographs with location, date and time.
- **Annexes:** calibration certificates and raw data files.

In the example, the cold report is due 10 days after the tests and the hot report 7 days after. Short deadlines matter: the cold report is an input to HP2.

# 11 Common Errors and Best Practices

| Common error | Consequence | Best practice |
|---|---|---|
| **Insulation tests before grounding continuity is confirmed** | Readings with no valid reference; risk of touch voltage on structures | Follow the order of Section 6.2 and record continuity first |
| **String fuses inserted before the polarity check** | Reverse current through modules and fuses; fire risk | Make polarity a recorded step with fuses out |
| **Surge protective devices left connected during insulation tests** | False low readings or damaged devices | Disconnect and record; reconnect and record |
| **Energization on a verbal release** | Devices closed by the wrong party; no record of readiness | Written hold points with named signatories |
| **Inverter settings entered but not recorded** | No evidence of what was applied; hard to investigate a later trip | Export the settings file and keep it with the report |
| **Relay testing outside every scope** | Protection never verified against the approved study | Name the responsible party in the plan and check it at HP2 |
| **Infrared inspection at low irradiance or low load** | Defects not visible | Record irradiance and load; repeat if below the limit |
| **Performance test before monitoring is validated** | Result cannot be defended | Validate sensors and data channels before Stage 4 |
| **Sampling instead of 100% of strings** | Defects left in untested strings | Test every string unless the contract states a sampling plan |

## 11.1 Quick checklist

- Scope and exclusions written, with a responsible party for each exclusion.
- Three hold points defined, with signatories.
- Test order stated, with the dependencies.

- Reference document and acceptance value on every record sheet.
- Calibration certificates checked before the field campaign.
- Settings recorded as approved, as applied and as verified.
- Nonconformities classed and re-tested.
- Reports delivered before the next hold point.

# References

## Standards (U.S. market)

1. ANSI/NETA ATS-2025, *Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems*.
2. ANSI/NETA ECS-2024, *Standard for Electrical Commissioning Specifications for Electrical Power Equipment and Systems*.
3. IEC 62446-1:2016 + AMD1:2018, *Photovoltaic (PV) systems – Requirements for testing, documentation and maintenance – Part 1: Grid connected systems – Documentation, commissioning tests and inspection*.
4. IEC TS 62446-3:2017, *Photovoltaic (PV) systems – Part 3: Photovoltaic modules and plants – Outdoor infrared thermography*.
5. NFPA 70, *National Electrical Code (NEC)*, Articles 250, 690, 691 and 705. Use the edition adopted by the authority having jurisdiction.
6. NFPA 70E, *Standard for Electrical Safety in the Workplace*.
7. NFPA 70B, *Standard for Electrical Equipment Maintenance*.
8. IEEE Std 1547-2018, *IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces*.
9. IEEE Std 1547.1-2020, *IEEE Standard Conformance Test Procedures for Equipment Interconnecting Distributed Energy Resources with Electric Power Systems and Associated Interfaces*.
10. IEEE Std 2800-2022, *IEEE Standard for Interconnection and Interoperability of Inverter-Based Resources (IBRs) Interconnecting with Associated Transmission Electric Power Systems*.
11. IEEE Std 2800.2-2026, *IEEE Recommended Practice for Test and Verification Procedures for Inverter-Based Resources Interconnecting with Bulk Power Systems*.
12. UL 1741, *Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources*.
13. IEEE Std 81, *IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Grounding System*.

14. IEEE Std 80-2013, *IEEE Guide for Safety in AC Substation Grounding*.

15. IEEE Std 2778-2020, *IEEE Guide for Solar Power Plant Grounding for Personnel Protection*.

16. IEEE Std 400, *IEEE Guide for Field Testing and Evaluation of the Insulation of Shielded Power Cable Systems Rated 5 kV and Above*.

17. IEEE Std 400.2, *IEEE Guide for Field Testing of Shielded Power Cable Systems Using Very Low Frequency (VLF)*.

18. IEEE Std C57.12.01 and IEEE Std C57.12.91, general requirements and test code for dry-type transformers.

19. ASTM E2848, *Standard Test Method for Reporting Photovoltaic Non-Concentrator System Performance*.

20. IEC 61724-1:2021, *Photovoltaic system performance – Part 1: Monitoring*.

21. IEC 60891, *Photovoltaic devices – Procedures for temperature and irradiance corrections to measured I-V characteristics*.

22. NERC Reliability Standards PRC-028-1, PRC-029-1 and PRC-030-1.

23. OSHA 29 CFR 1910, Subpart S (Electrical), 1910.147 (lockout/tagout) and 1910.269.

Confirm the current edition of each document before use.

## Technical material consulted

24. FERC, Order No. 901, *Reliability Standards to Address Inverter-Based Resources*, 2023.

25. NERC, disturbance reports on inverter-based resources, including the Odessa disturbance reports.

26. NREL, *Weather-Corrected Performance Ratio*, technical report NREL/TP-5200-57991, 2013.

## Example data

- Commissioning plan of a 2.5 MWac PV plant in Brazil, cold and hot commissioning, 16 tests and 29 checklists, October 2026 (anonymized).

# Annex A: Sequence Record Template

The form below records the sequence and the hold points for one plant section. One sheet is used per inverter block or per circuit group.

| Item | Record |
|---|---|
| **Plant / section** | |
| **Testing organization** | |
| **HP1 – Release for testing** | Released by: ____ *Date:* _ |
| **Test 1 – Visual inspection** | Date: __ Result: __ Record no.: __ |
| **Test 4 – Grounding continuity** | Date: __ Result: __ Record no.: __ |
| **Test 5 – Ground resistance** | Date: __ Result: __ Record no.: __ |
| **Test 2 – Polarity and Voc** | Date: __ Result: __ Record no.: __ |
| **Test 3 – DC insulation resistance** | Date: __ Result: __ Record no.: __ |
| **Tests 6, 7 – LV AC insulation** | Date: __ Result: __ Record no.: __ |
| **Tests 8, 9 – MV cable tests** | Date: __ Result: __ Record no.: __ |
| **Tests 10, 11 – Equipment checks** | Date: __ Result: __ Record no.: __ |
| **Relay and inverter settings verified** | By: ____ *Date:* __ *Settings file:* |
| **Open nonconformities preventing energization** | None / List: _____ |
| **HP2 – Release for energization** | Released by: ____ *Date:* _ |
| **Tests 12 to 15 – Hot commissioning** | Date: __ Result: __ Record no.: __ |
| **HP3 – Release for performance test** | Released by: ____ *Date:* _ |
| **Test 16 – Performance ratio** | Period: __ Result: __ Record no.: __ |
| **Final report issued** | Date: __ Revision: __ |