

Notsi PV Project

Engineering, Procurement and Construction Contract

Schedule 8 – Tests

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1. Introduction

Facility specific requirements for commissioning and testing, over and above any requirements contained in Schedule 2 [*Employer's Requirements*] (which must be adhered to) are described below.

2. Inspection and Testing of Major Components

The Contractor shall be responsible for conducting all tests in such a way as to protect the safety of all persons and the Works and in accordance with relevant Law. The Contractor shall provide an appropriate training for all personnel on the Site who will be involved in or witnessing any Tests and shall ensure that such personnel comply with all applicable safety procedures at all times during performance of the Tests. The Contractor shall discontinue performance of any Tests in the event of any unsafe conditions.

2.1. Factory Inspection and Testing

Upon finalisation of preferred equipment suppliers, the Contractor shall advise the Employer as to the location of manufacture of each of the key equipment items (including modules, trackers, inverters, transformers, switchgear and others as reasonably requested by the Employer).

The factory inspection aspect of the Inspection and Test Plan ('ITP') shall include as a minimum:

- All tests required by relevant Standards;
- Location of manufacture;
- Scope of activities undertaken at the Facility;
- Review of production machines and key components, Suppliers, and certifications;
- Materials/equipment supply contracts;
- Technical review of materials/processes;
- Review of certifications for bill of materials, and in particular, confirmation that they relate to the BoM to be used for the relevant production run;
- Factory quality: including processes, certifications, quality control, levels of automation and staffing, health and safety records, ingoing and outgoing QA procedures and production tolerances;
- Quality control criteria and processes, including track record of warranty claims;
- QA statistics and recall volumes including reasons for recall (e.g. materials, manufacturing, design, shipping), including outcomes of recall process;
- Factory inspection and acceptance testing of components to be shipped;
- Procedures for rejection of equipment in the event that faults are identified; and,
- Finished goods management including sorting and packaging procedures for the relevant Materials.

For the avoidance of doubt minimum rejection criteria for key equipment includes (but is not limited to):

- Modules: Refer to Section 9.3.1 of Schedule 2 [*Employer's Requirements*];
- Transformers: Failure to meet routine and type tests as per IEC 60076 (e.g. winding resistance, ratio, insulation, temperature rise, dielectric withstand, and partial discharge);
- Switchgear: Failure of insulation resistance, contact resistance, control logic tests, interlock functionality, and protection relay settings; and

- Inverters: Failure of factory functional testing, electrical performance versus manufacturer's datasheet (AC/DC conversion efficiency, harmonic distortion, reactive power capability), SCADA and communication integration tests.

2.1.1. Pre-Shipment Factory Inspection and Testing

The Contractor shall undertake pre-shipment testing and inspection upon completion of manufacture and prior to shipping. For the avoidance of doubt, the Contractor may engage the manufacturer to complete the pre-shipment testing and inspection; however, such arrangement shall have no effect on the responsibilities and liabilities of the Contractor under the Contract.

Pre-shipment acceptance criteria of the major equipment manufacturers shall be in the ITP.

Should any equipment be rejected during a pre-shipment inspection, the Contractor shall provide the manufacturer's root cause analysis for the failure, and the corrective action plans implemented to prevent future failures.

The pre-shipment testing of modules shall incorporate the following tests, in accordance with IEC 61215, to be completed on a 100% sample:

- Visual inspection;
- Electroluminescence (EL) testing;
- Maximum power determination or 'flash' testing; and,
- Insulation test.

The Contractor shall supply the Employer with Test Results for the above-mentioned tests that shall include flash tests results and electroluminescence images in electronic format for all modules.

Gel contents tests shall be performed on one module per production batch of PV modules.

2.1.2. Production Witnessing of Key Equipment

The Employer shall have the right to inspect and witness production processes at all key equipment factories. The ITP shall identify specific witness and hold points that the Employer should attend.

The Employer reserves the right to bring Third Parties during such inspections.

2.2. Transport and Arrival to Site

The ITP shall comprehensively document all transportation and site arrival tests and inspections necessary to ensure the quality of the Works.

2.3. Mechanical Completion

Prior to Mechanical Completion of the Facility, the Contractor shall perform an in-situ visual inspection on all components of the Facility:

- The component is free of visible damages that might affect the safety of the component and of the personnel;

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- The component has been installed properly;
- The usage of materials and proper installations adequate with the environment in which the component is installed;
- The component is readily accessible for the operations set out in the O&M Agreement;
- The electrical installation has been performed according to the Contract and the Contractor's design documentation;
- The component has been installed according to the prescriptions imposed by the manufacturer;
- The readiness of the installation and of the calibration of all protection and signalling equipment forming part of the Facility, including Facility documentation and equipment documentation, equipment labelling; and,
- The provision of a certificate from the Contractor confirming that the Works have been constructed in accordance with applicable Law.

Visual checks are applicable on all the components that form part of the Facility, including the Grid Connection Works and fitting systems. The following parts as a minimum shall be subject to visual inspection:

- Inverters;
- Foundations;
- Trackers and mounting structure;
- Photovoltaic modules and DC installation;
- Mains, pits, cabling, electrical boxes and protection devices;
- Internal connections and interconnections with external installations;
- Monitoring System including any Uninterruptible Power Supply;
- Low voltage installation, including protection equipment and utility interconnection equipment;
- High voltage installation, including transformation, protections equipment and utility interconnection equipment;
- Connection Works as defined in Schedule 2 [*Employer's Requirements*];
- Security system;
- Grid connection line and fitting systems;
- Equipment labelling in agreement with plans; and,
- Health and safety signage.

Moreover, the visual inspection shall verify the installation of system components complies with the design. This shall include a review of the following:

- Labels and markings;
- Safety signs;
- Rated power of components;
- Number of components;
- Distances, heights and positions of components and systems;
- Size of cables, wires, busbars;
- Module flash tests; and
- Tightening torque of bolts.

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To achieve Mechanical Completion of the Facility, the correct positioning of the system components must be verified, in particular:

- Coordinates of structures, cabins, fence, power stations and cable paths;
- Compliance of the Works with the Authorisations as provided in Schedule 4 [*Authorisations*] and the constraints applicable to the Site area in terms of position of the equipment, occupation of the areas, compliance with the prescribed Site borders;
- The correct orientation and inclination of the photovoltaic modules; and,
- The presence of safety signs at the prescribed locations.

2.4. Punch List

The Contractor shall maintain a comprehensive punch list identifying any issues which must be addressed with respect to the Facility. The punch list shall be managed according to the following punch list priority levels:

- Type A: items to be cleared in order to achieve the Mechanical Completion;
- Type B: items that are not considered as a stop-point for safe energisation and which are however to be cleared as a condition to the Commercial Operation Date; and,
- Type C: minor items not considered as a stop-point for safe operation of the Site, but which have to be cleared within a fixed timeframe to be agreed between the Contractor and the Employer.

3. Commissioning Tests

The Commissioning Tests shall consist of:

- Pre-Commissioning Tests; and,
- Commissioning Tests.

A detailed description of each Commissioning Test is included in the following sections. All parts of each of the Commissioning Tests must be successfully completed to the Employer's satisfaction and shall be in compliance with IEC 62446.

The following procedures shall be complied with by all parties during the conduct of the tests. Any modification to these procedures shall require the Employer's prior approval and be treated as a variation to the Contract.

3.1. General Requirements

The Contractor shall take responsibility for and perform all test and commissioning activities necessary to enable connection of the Works to the Grid and to demonstrate the safe operation of the plant in accordance with the requirements of the Contract. The tests shall confirm the readiness of the Works to export 475MW_{AC} to the Grid.

3.2. Test Protocol

The Contractor shall submit to the Employer a test protocol summarising the Pre-Commissioning Tests and Commissioning Tests in a form substantially satisfactory to the Employer. The protocol shall be agreed between the Employer and Contractor before commencement of the tests.

Notwithstanding the requirements for communicating with the GNSP outlined in Section 3.4.6 the Contractor shall submit its proposed "Test Protocol" to the Employer for review and approval not later than thirty (30) Business Days prior to the scheduled commencement of any Tests. The Contractor's Test Protocol shall summarise the Pre-Commissioning Tests and Commissioning Tests in a form substantially satisfactory to the Employer comply with and detail all requirements contained in the Contract and include sample Test Result submissions.

The Employer shall review the Contractor's proposed Test Protocol and provide comments to the Contractor within ten (10) Business Days after receiving it from the Contractor. Approval by the Employer shall not excuse the Contractor from its responsibility to conduct testing or prevent the Contractor from performing the testing and commissioning activities in accordance with the Contract.

The basic content of the Commissioning Test Protocol shall include, but not be limited to, the following:

- Methodologies for the tests;
- Instrumentation used for the tests;
- Anticipated periods of execution of the tests;
- Conditions under which the tests must be carried out;
- Commissioning protocols released for the key components (inverters, transformers, etc.);

3.2.1. Data to be Provided by Contractor

The Contractor shall provide the Test Data for all Tests in the format agreed within the Test Protocol to be compliant with the model reports specified in IEC 62446 as well as auditable electronic format.

3.2.2. Certification by Contractor of Test Results

The Contractor shall certify to the Employer in writing that the Test Results and supporting data provided by the Contractor are complete, current and accurate.

The minimum required information for testing (following IEC 62446) shall be documented in the ITP.

3.3. Pre-Commissioning Tests

The Test scope shall include but is not limited to the functional test defined in IEC 62446 Grid connected photovoltaic systems – Minimum requirements for system documentation, commissioning tests and inspection and the electrical testing requirements of AS3000. The full scope of the Test is described in detail below.

3.3.1. Nameplate Capacity Test

The Contractor shall demonstrate that the installed capacity of the Works meets or exceeds the Name Plate Capacity. The installed capacity shall be calculated by summing the module flash Test Data for all modules installed as part of the Works.

3.3.2. Functional Tests

The Facility shall be subject to a functional test which should include confirmation that components operate within the expected parameters as well as respond correctly to transient conditions.

The test will include the Functional Test under IEC 62446.

As part of this set of functional tests the following shall be completed.

3.3.2.1. *I-V Curve Tracing*

I-V Curve measurements will be conducted on 5% of strings or one string per combiner box (if central inverters, or inverter input if string inverters), whichever is the greater (the Measured Sample). The measurements will be performed at the output of the relevant strings and shall be distributed across the plant, so as to be representative of the different installation crews and shall be agreed to by the Employer and defined within the Test Protocol.

A representative sample (5% of the Measured Sample) of I-V Curve measurements will be conducted in the presence of the Employer, to be coordinated by the Contractor.

In addition to the Measured Sample the strings of one combiner box (if central inverters or inverter input if string inverters) will be fully characterised by measurement over the course of the day at least of irradiances, in the plane of the array, of 100, 200, 300, 400, 500, 600, 700 W/m².

The minimum average irradiation during the test shall be greater than 400 W/m² in the plane of the array. In case a lower average value is recorded, the relevant measurement shall be disregarded, and the tests shall be repeated.

For the measurements of the I-V curves a curve tracer appropriate for the Facility and in line with current industry standard shall be used.

The I-V-curve tracer will be able to measure single strings or complete combiner boxes. Each string or junction box to be measured will be measured twice in immediate succession and in case of large deviations, one additional I-V curve of the same sub-array is to be measured.

The irradiance meter associated with the I-V curve tester shall have a precision better than or equal to $\pm 2\%$ and shall be mounted such that it matches the plane of the array.

Array peak power will be extrapolated to Standard Test Conditions according to the International Standard "IEC 60891 Procedure for temperature and irradiance corrections to measured I-V characteristics of crystalline silicon photovoltaic devices".

An electronic file (Excel) with measurements executed on the selected PV strings will be presented to the Employer. Test Results will be presented at STC conditions as it is directly converted by the I-V testing standard tool.

At the discretion of the Employer, abnormal test curves will be subject to further investigation.

3.3.2.2. Open Circuit Voltage Test

The test shall verify the open circuit Voltage VOC resulting from the PV strings of the Facility.

All strings shall be tested.

The test shall be conducted during periods of irradiance greater than 400 W/m².

The measured VOC shall comply with requirements of IEC 62446.

3.3.2.3. Short Circuit Current Test

The test shall verify the short-circuit current Isc resulting from the parallel in the electrical panels of the PV strings.

All strings shall be tested.

The test shall be conducted during periods of irradiance greater than 400 W/m².

The measured Isc shall comply with requirements of IEC 62446.

3.3.2.4. DC Box / Combiner Box Thermographic Tests

The contractor shall record thermographic images of a sample of the installed combiner boxes in the Works. Test requirements include:

- Sample size shall be not less than 10% of the installed combiner boxes and shall be representative of the different installation crews;
- Images must be taken when the plant is generating and during a period of not less than 700W/m² POA irradiance;
- Thermographic images are to be taken of the terminations with the front panel of the combiner box open;
- Images shall demonstrate that;
- Components are operating below rated temperatures;
- Temperatures on similar connections are do not vary by more than 10%;
- There are no over temperatures; and,
- The Contractor shall submit to the Employer a report summarising the findings and including all thermographic images for verification and approval by the Employer.

3.3.2.5. *Module Thermographic Tests*

For all Modules installed as part of the Works the Contractor shall conduct a thermographic inspection test.

Test requirements include:

- Modules are installed, connected and delivering electricity through to the Grid Connection Works;
- Minimum plane of array irradiance conditions of 600W/m², measured using the onsite meteorological stations installed as part of the Works;
- Thermographic images shall be recorded in cases where the Modules display areas with a temperature differential of 15°C or greater; and,
- Thermographic images shall be focused and of the entire module area.
- Modules shall be replaced by the Contractor if:
- Hot spot(s), with a temperature differential greater 20°C, are present in the Module;
- Inactive areas, limiting the power output, are present in the Module; and,
- Operating temperatures do not lie within the manufacturers stated range.

3.3.2.6. *Other Functional Tests*

In addition to the abovementioned tests, the Contractor shall execute the following tests:

- Earthing system;
- Ensure that all components are properly and firmly grounded in compliance with the Standards and applicable Law. Welding and bolt tightening shall be verified;
- Cables;
- All low-voltage DC and AC cables shall be tested for insulation resistance in accordance with IEC 60364-6, IEC 60364-7 and other applicable Standards;
- All low voltage cables shall be inspected and tested in accordance with IEC 60364-6, IEC 60364-7 and other applicable Standards;
- Polarity tests;
- Polarity of all circuits shall be verified against the design drawings;

- Low voltage switches;
- All low voltage switches shall be tested according to the applicable Standards;
- Verify that switches used in DC applications are rated and installed accordingly;
- Circuit breakers;
- All circuit breakers shall be tested according to the applicable Standards;
- Surge arrestors;
- All surge arrestors shall be tested according to the applicable Standards;
- Protective relays;
- All protective relays shall be tested according to the applicable Standards;
- Switchgears;
- All switchgear (LV, MV and HV) shall be tested according to the applicable Standards;
- Contractor shall review factory test documentation to confirm that all LV, MV and HV switchgears have passed all factory tests, including;
- Type test;
- Functional tests;
- Contact resistance;
- Insulation resistance; and,
- Other tests applicable to MV and HV equipment, such as high-voltage withstand, earth switch resistance, air pressure / vacuum / SF6 leakage tests (as applicable).

3.4. Commissioning Tests

The Commissioning Tests are performed to determine and verify the proper operation of the Facility and all its components.

Commissioning Tests shall include, but not be limited to, the following:

- Inverter commissioning;
- Tracker mounting structure commissioning;
- Power transformer commissioning;
- SCADA system functional test;
- Security system functional test;
- High-Voltage Substation commissioning; and,
- Connection Works commissioning.

The equipment shall be tested at Site. These tests shall prove whether the equipment meets the requirements and the safety conditions, whether it has been built and/or erected with satisfactory workmanship and whether the equipment is in conformity with the prevailing standards and regulations, the manufacturer's recommendations and installation/ commissioning procedures and with the present state of modern technology.

3.4.1. Inverter Commissioning

Inverters shall be commissioned by the inverter manufacturer or a trained commissioning engineer with approval of the manufacturer using the manufacturer's specified procedures.

Commissioning reports shall be issued in a format provided by the manufacturer.

The commissioner shall execute at least the following tests and checks:

- Visual inspection of the outer and inner part;
- Continuity check;
- Insulation check (with measurement of insulation resistance);
- Tests under voltage for power and auxiliary circuits;
- Check of ventilation system;
- Check of protection devices;
- Protection selectivity check;
- Emergency stop or DC isolator;
- Output current compared to expectations given meteorological conditions during the test;
- Output voltage;
- Check of filters and fuses;
- Software updates and data acquisition communication test; and,
- Noise level test.

All tests shall be executed according to all applicable Standards and manufacturer recommendations.

3.4.2. Transformer Commissioning

Power transformers (HV/MV – MV/LV – MV/MV – LV/LV transformers) shall be commissioned by an authorized representative of the manufacturer or trained personal using the manufacturer's specified procedures.

Commissioning reports shall be issued in a format provided by the manufacturer.

The commissioner shall execute at least the following tests and checks:

- Visual inspection;
- Check correct earthing;
- Check tightening torque of bolted connections;
- Insulation check (with measurement of insulation resistance) (primary to secondary – primary to earth – secondary to earth);
- Measurement of turns ratio and vector group;*
- Measurement of no-load losses and current;*
- Measurement of short circuit impedance and load losses;*
- Measurement of winding resistance;*
- Sweep frequency response test;
- AC voltage withstand test;*
- Test of on-load tap changer;*
- Check oil leakages (for oil transformers);
- Check oil level (for oil transformers);
- Check overpressure valve (for oil transformers);
- Check of protection devices;

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- Check of alarms (oil level, Bucholz, temperature);
- Check saturation of dehumidifying salt;
- Dielectric test (for oil transformers);
- Functional tests (feedings, ventilators, etc.);
- Noise level test; and,
- No-load test (when applicable).

All tests shall be executed according to IEC 60076, IEC 60270, IEC 60156 and all other applicable Standards to be detailed by the Contractor.

*Test to be completed at FAT and not repeated on-site.

3.4.3. SCADA System Functional Test

All SCADA system equipment shall be commissioned and tested using the manufacturer's specified procedures.

Tests shall verify the correct operation of the SCADA system, meters, sensors, weather station instruments, and all inverters, while verifying the correct data input logging from trackers, breakers, and other components monitored by the system.

The SCADA system shall be fully accessible remotely and should adhere to strict cybersecurity requirements, including:

This test shall verify that the data collected is correctly received by the SCADA System and can be used to produce any required performance or operation reports. Each row of data shall report the exact date and time in a suitable format.

A SCADA system commissioning protocol or report shall be provided.

3.4.4. Tracking System Commissioning

Prior to start-up of trackers, the following must be checked for compliance with installation requirements:

- Electrical connections (e.g. controllers, drives, modules, ...); and,
- Mechanical connections (e.g. fixed parts, moving parts, ...)

All safety devices must be checked for proper operation after the first start-up of the machine and before it is used for power generation. The commissioning of the tracker must be carried out by qualified personnel.

The commissioning must include at least the following tests:

- Check the tracking rotation synchronicity;
- Verify the correct installation and calibration of the inclinometers and limit switches;
- Verify that the tracking algorithm, date, time, and time zone are correctly set;
- Check the correct operation of the backtracking system (if present);
- Check that trackers IDs are matching on the control panel; and,

- Test the tracking system stow positions under simulated high-wind and hail conditions and verify automatic response times.

3.4.5. Security System Functional Test

Security system equipment shall be commissioned, tested and calibrated by a certified installer of the equipment manufacturer using the manufacturer's specified procedures.

Security system testing shall include testing of all operating modes and alarm conditions, including testing of:

- Cameras and dome cameras;
- Image analyser;
- Infrared sensors / projectors;
- Infrared barriers, microphone cables, microwave barriers (if any);
- Lights;
- Sirens (if any); and,
- Reaction time of security company.

A security system commissioning protocol or report shall be provided.

3.4.6. High-Voltage Substation Commissioning

The Contractor shall liaise with the GNSP in order to determine the necessary compliance requirements for testing and commissioning. Not less than three (3) months in advance of the commencement of the Commissioning Tests the Contractor must advise the GNSP and NERSA, in writing, of the Commissioning Test Protocol including test procedures and test equipment to be utilised during the Commissioning Tests. Should the GNSP or NERSA require that changes be made to the Commissioning Test Protocol the Contractor shall implement the changes without delay and resubmit.

The Employer shall be included in all communication and invited to participate in all meetings held with the GNSP and NERSA.

The Contractor shall proceed with the commissioning of the Substation as agreed with the GNSP and NERSA and in line with the relevant Law and Standards.

Before energisation, the Contractor shall verify completeness of the Substation and correct installation of all the components. A detailed inspection of the Substation shall be carried out. A check list shall be handed over to the Employer for approval forty (40) days before completion of the Works and this shall be used during the final inspection.

Following the inspection, a set of tests shall be executed which shall include, but not be limited to, the following:

- Commissioning of all the structures, supports, foundations, buildings as required by applicable Law and Standards;
- Commissioning of components and systems as described below in Section 3.4.7;

- Tests that confirm communication capabilities for remote monitoring, operation and protection systems of the Works by the Contractor, the GNSP and the facilities for the Works to receive and respond to instructions for semi-scheduled operation received by the GNSP; and,
- RETEC testing as per the Testing Protocol agreed with the GNSP and NERSA.

3.4.7. Commissioning of Components and Systems

All tests prescribed by the manufacturers shall be executed in accordance with the prescriptions contained in the respective installation and commissioning manuals. The following list of tests shall be complied with whenever manufacturers' tests are less restrictive than the detail presented here.

3.4.7.1. HV Circuit Breakers

- Check earthing;
- Completeness of installation and cleanliness of insulators;
- SF6 pressure;
- Functional tests;
- Tests for verifying opening / closing time;
- Measurement of power absorption of the coils; and,
- Measurement of resistance of the main contacts.

3.4.7.2. Current Transformers

- Check earthing;
- Completeness of installation and cleanliness of insulators;
- Check versus SF6 pressure or oil level;
- Check connections;
- Check ratios and data sheet parameters;
- Turn ratio test; and,
- Verification by injection of current to the primary.

3.4.7.3. Voltage Transformers

- Check earthing;
- Check tightening of bolts;
- Completeness of installation and cleanliness of insulators;
- Oil level; and,
- Check ratios and data sheet parameters.

3.4.7.4. HV Disconnectors

- Check earthing;
- Check tightening of bolts;
- Completeness of installation and cleanliness of insulators;
- Verify greasing of main contacts and moving parts;

- Check setting of limit switches;
- Check interlocking between earthing and disconnectors;
- Perform electrical manoeuvres;
- Perform mechanical manoeuvres;
- Functional tests; and,
- Measure resistance of main contacts.

3.4.7.5. Surge Dischargers

- Check earthing of supports;
- Check earthing of dischargers;
- Check earthing of counter;
- Check tightening of bolts;
- Completeness of installation and cleanliness of insulators;
- Measure insulation resistance;
- Register number of dischargers recorded by the counter before activation; and,
- Measure residual resistance before activation.

3.4.7.6. Transformers

Follow procedure in 3.4.2

3.4.7.7. MV Cables

- Check clamping;
- Check correct positioning and orientation of toroids;
- Check earthing of shields; and,
- Dielectric test.

3.4.7.8. MV Switchgear

- Check correct mounting and fixing;
- Check correct earthing;
- Verify correct setting of protections;
- Functional tests;
- Check SF6 gas pressure and humidity level;
- Measure insulation resistance; and,
- Perform dielectric tests.

3.4.7.9. Auxiliary Transformers

Follow procedure in 3.4.2.

3.4.7.10. AC and DC Panels

- Check correct mounting and fixing;
- Check correct earthing;

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- Verify correct protection settings; and,
- Functional tests.

3.4.7.11. Battery Chargers (Rectifiers)

- Check correct mounting and fixing;
- Check correct earthing;
- Check correct installation of battery units;
- Check levels of liquids (if applicable);
- Check proper functioning of HVAC system in the battery room;
- Check feeding voltage and phase sequence;
- Check output voltage (plant and battery side);
- Check polarity; and,
- Check alarms and signals.

3.4.7.12. Protection Devices

- Check correct mounting and fixing;
- Check correct earthing;
- Check feeding voltage;
- Verify correctness of settings;
- Functional tests; and,
- Check tripping of protections by injecting current.

3.4.7.13. Fire, Lighting, Diesel Generator, and Other Systems

- Check correct mounting and fixing;
- Check correct earthing;
- Verify correct setting of protections; and,
- Functional tests.

4. Performance Tests General Requirements

4.1. Introduction

The Testing Schedules include the methodology for the following Performance Tests as part of the acceptance procedure:

- Achieved Capacity Test (as set out in Section 5.1);
- Completion Performance Test (as set out in Section 5.2);
- Interim Performance Test (as set out in Section 6.1); and,
- Final Performance Test (as set out in Section 6.1).

The proposed methodology combines current market standard approaches and international best practices for the comparison of Facility performance against contractual performance guarantees. This document sets out the procedures and requirements for conducting the Performance Tests, including the process for determining Test Results and criteria for successful completion.

This methodology shall be agreed by the Parties prior to the Performance Tests commencement and followed by the parties during the conduct of the Performance Tests. Any modification to these procedures shall require the Employer's prior approval.

4.2. Tests and Acceptance

4.2.1. Notification of the Test Commencement Date

Not later than ten (10) Business Days prior to commencing any of the Performance Tests, the Contractor shall notify the Employer in writing of the specific date and time for commencement.

If the Contractor fails to provide any of the required notices within the agreed time, commencement of the corresponding test shall be deferred until the required notice periods are met or the Employer, in its sole discretion, approves commencement of the subject test.

4.2.2. Conduct of the Test

The following procedures shall be followed by all parties during the conduct of the tests. Any modification of these procedures shall require the Employer's prior written approval.

The Employer and the Contractor shall each appoint a test representative, who will be responsible for representing their respective companies during the conduct of the tests.

During the conduct of the Performance Tests, all incidents shall be recorded in the test logbook.

4.2.3. Facility Operation During the Test

During the conduct of the Performance Tests, the Contractor shall be responsible for the operation of the Facility in compliance with the O&M Agreement including, but not limited to, maintenance and sensors and equipment calibrations, cleaning of sensors, cleaning of the PV modules, detection and resolution of Facility issues, including PV monitoring data quality.

4.2.4. Data to be Provided by the Contractor

The Contractor shall provide the Test Data and Test Result for all Performance Tests in the auditable electronic format agreed by parties.

4.2.5. Certification by the Contractor of the Test Results

The Contractor shall certify in writing to the Employer that the Test Results and supporting Test Data provided by the Contractor are complete, current and accurate.

4.2.6. Acceptance or Rejection by Employer of Test Results

Within fifteen (15) Business Days following receipt of all required Test Results, supporting Test Data and Contractor's certification of the Test Results, the Employer shall notify the Contractor in writing that the Test Results submitted by the Contractor are either accepted, rejected or incomplete. If the Test Results are rejected, the Employer shall provide the basis for rejection. If the Test Results are incomplete, the Employer shall identify the missing information. Within ten (10) Business Days following full submission of the missing information by the Contractor, the Employer shall notify the Contractor in writing whether the Test Results are accepted or rejected.

4.2.7. Repeat of Performance Tests

If the Employer rejects Performance Test Results submitted by the Contractor, the Contractor shall undertake again the applicable test in accordance with these Testing Schedules and all applicable Contract requirements.

4.2.8. Dispute Resolution

If the Contractor disputes the Employer's rejection of any Test Results or if the Parties disagree on any of the Test Results the Parties shall follow the disputes resolution procedures set forth in the Contract.

4.2.9. Safety During Testing

The Contractor shall be responsible for safely conducting all Tests. The Contractor shall provide a safety briefing for all personnel on the Site who will be involved in or witnessing any Tests and shall ensure that such personnel comply with all applicable safety procedures at all times during the performance of the Tests.

4.3. Measurement Requirements

4.3.1. Documentation

PV Monitoring system documentation (equipment and functional specifications, user guides, calibration certificates and maintenance track records) shall be provided to the Employer for review prior to the commencement of the Tests.

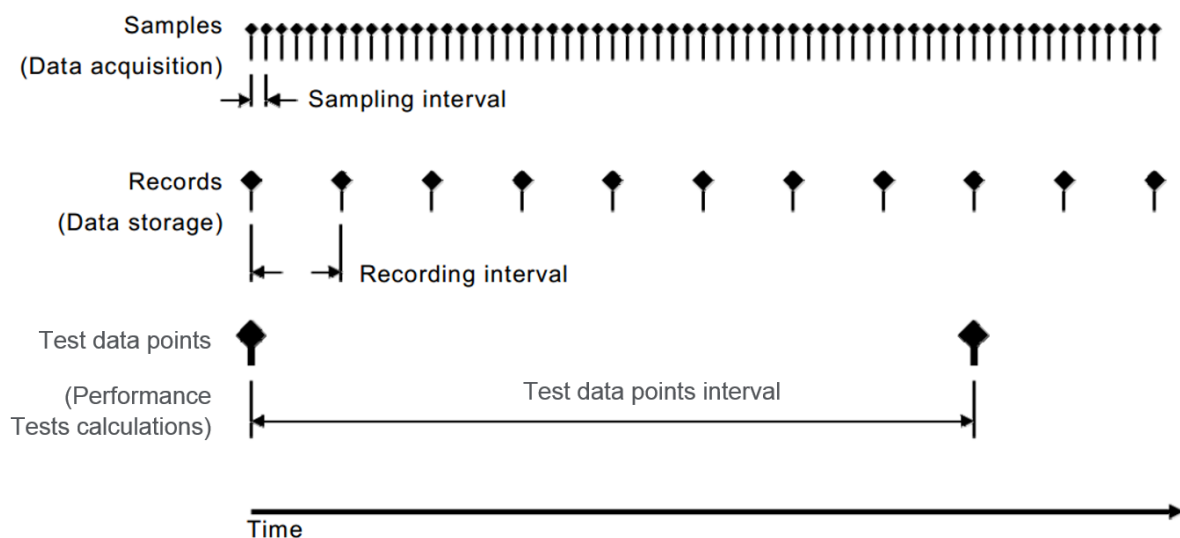
4.3.2. Sampling and Recording Intervals

For all measured parameters required for the Performance Tests, the PV monitoring system shall comply with the following data acquisition requirements:

- Maximum Sampling Interval: 3 seconds;
- Maximum Recording Interval: 1 minute; and,
- Test Data Point Interval: 10 minutes

For the purpose of the Performance Tests, the Test Data Point Interval shall be 10 minutes. For each Test Data Point Interval, a 10-min data point shall be calculated as the mean value of all 1-minute records corresponding to the Test Data Point Interval.

Figure 1: Sampling, recording, and Test Data Point intervals



4.3.3. Timestamps

Each 10-min Test Data Point Interval shall include a timestamp with the date (day, month, year) and time (hour, minute) corresponding to the beginning of the 10-min data point interval.

The time should refer either to local standard time (not daylight savings time) or universal time (UTC), to avoid winter/summer time changes.

Midnight shall be treated as the start of a new day (first 10-min data point of the day) and expressed as 00:00. The last 10-min data point of each day shall be at timestamp 23:50.

When multiple data acquisition units are involved that each independently applies timestamps, the clocks of the units shall be synchronized, preferably by an automated mechanism such as global positioning system (GPS) or network time protocol (NTP).

4.3.4. Measured Parameters

During the Tests Periods, the parameters in **Table 1** shall be recorded for the purpose of the Performance Tests.

The measured parameters required for the Performance Tests shall comply with the specifications defined in IEC 61724-1 for class A monitoring systems, unless expressed differently in these Schedules.

Table 1: Measured parameters

Parameter	Symbol	Unit
Global Inclined Irradiance (in-plane or POA irradiance)	GII	W/m ²
Global Horizontal Irradiance	GHI	W/m ²
Ambient air temperature	T _{amb}	°C
DC Power/Current at each string (if string monitoring is available)	P _{str} / A _{str}	kW / A
DC Power at each combiner box or inverter input	P _{cb}	kW
AC Power at each inverter	P _{inv}	kW
Output energy at the POC	E _{out}	kWh
Power factor at each inverter	PF _{inv}	-
Power factor at the POC	PF _{out}	-
Error in single axis tracker tilt angle	Δφ	°
AC Power curtailment request at the POC (reduce load command)	P _{req}	kW
Power factor demand at the POC	PF _{req}	-
Status of each inverter	S _{inv}	-

4.3.5. Instrumentation Requirements

Refer to Schedule 2 [*Employer's Requirements*].

4.3.6. Data Processing and Quality Checks

The measured data shall be checked, to identify missing or invalid data points and filter them out of subsequent analysis, following filtering criteria defined in **Table 2**. Such missing or invalid data shall be documented.

The Contractor shall include in the Test Results, measured data before and after applying the filtering criteria, highlighting any missing and/or invalid data to the Employer and Employer's representative. All recorded data shall be checked for consistency and gaps, to identify obvious anomalies before any detailed analysis is conducted.

Table 2: Filtering criteria

Flag Criteria	Description	Irradiance [W/m ²]	Ambient Temperature [°C]	Power [W _{AC}]
Out of Range	Value outside of reasonable bounds	< -6 or >1,500	< -10 or > 50	< -0.01 x rating or > 1.02 x rating
Abrupt changes	Values change unrealistically between data points Detected using derivative	> 800	> 4	> 80% rating
Missing data	Values are missing or duplicated	To be backfilled	To be backfilled	Assumed to be unavailability
Sensor reading issues	Deviation greater than sensor's uncertainty	> 5%	>1	N/A

Tracker angle shall be monitored. If the error in single-axis tracker tilt angle is $\Delta^\circ > 2$, the readings of its related GII pyranometers shall be discarded.

When the deviation between any pyranometer reading and the average value of the other pyranometers is greater than 5%, the measurements of the outlying pyranometer shall be disregarded and only the remaining pyranometers will be considered in the calculation of the mean value (10-min data point).

When the deviation between any ambient temperature sensor reading and the average value of the ambient temperature sensors is greater than 1°C, the measurements of the outlying sensor shall be disregarded and only the remaining temperature sensors will be considered in the calculation of the mean value (10-min data point).

4.3.7. Treatment of Missing or Invalid Data

Should the data processing steps outlined in Sections 4.3.6 result in no valid data for the interval, the missing or invalid data should be treated in the following ways:

- Irradiance and ambient temperature: Backfilling with satellite data, correlated with the available measured data, according to the following criteria;
 - If the gap is equal or greater than 1 hour ($\geq$ six 10-min consecutive Test Intervals), whole day data shall be backfilled with satellite data correlated to the available measured data of the day (if any);
 - If the gap is lower than 1 hour ($<$ six 10-min consecutive Test Intervals), missing 10-min data points shall be interpolated with the mean value of the previous and subsequent available measured data points;
- Electric parameters and single-axis tracker error angle with missing/invalid data shall be considered unavailable during the missing or invalid 10-min data point intervals.

In case of disputes with the data processing and quality checks, the criteria shall be subject to the discretion of the Technical Advisor ("TA").

5. Tests on Completion

The Tests on Completion include:

- The Achieved Capacity Test; and,
- The Completion Performance Test.

5.1. Achieved Capacity Test

The Achieved Capacity P_{AC} of the Works will be calculated as the maximum corrected capacity during the test period by extrapolating the measured power of the Works at the Delivery Point as follows:

$$P_{AC} = \min \left\{ \max \left\{ P_{meas_j} \frac{G_{STC}}{H_{meas_j}} [1 - \beta (T_{c_j} - T_{STC})] \right\}, 475 MW_{AC} \right\}$$

Where:

Variable	Units	Description
P_{meas_j}	MW _{AC}	Is the power output of the Facility as measured by the Facility Metering Installation at the Delivery point during period j
H_{meas_j}	W/m ²	is the average in-plane irradiance incident on the photovoltaic module plane measured by all inclined pyranometers
G_{STC_i}	W/m ²	Is the irradiance under STC = 1,000 W/m ²
T_{c_j}	°C	Is the average cell temperature calculated in accordance with Section 5.2.8
T_{STC}	°C	Is the cell temperature at STC = 25°C
β	%/°C	is the module temperature coefficient of power

The Achieved Capacity test shall be repeated until the Contracted Capacity is met as certified by the Independent Engineer or until a lesser Achieved Capacity is accepted in accordance with terms of the Contract.

5.2. Completion Performance Test

5.2.1. Purpose

The Completion Performance Test is a contractual requirement to be fulfilled prior to Taking Over, with the main purpose of quantifying the performance of the Facility relative to its expected performance, over a relatively short test period, to ensure that the plant is functioning as expected. It also pursues checking the reliability and durability of the Facility.

5.2.2. Performance Ratio

The Performance Ratio is the measurement of quality of the design, components and installation of the system. It is defined as the ratio between the actual energy produced and the energy that could theoretically be produced, before any system loss.

The PR is measured at the main Energy Meter located at the POC. To calculate the PR, all the following losses shall be accounted:

- Angular and spectral losses;
- Shading losses;
- Low irradiance losses;
- Temperature losses;
- Soiling losses;
- Ohmic losses on cables and joints;
- Mismatch losses;
- Losses at the inverters, MV transformers and other DC and AC components (including control devices, fuses, busbars, joints, current transformers and others);
- Losses related to the operation of auxiliary systems (self-consumption);
- Losses at the HV equipment (if foreseen); and,
- Maximum export capacity limitation.

5.2.3. Guarantee Values

For a successful Completion Performance Test, the Performance Ratio calculated over the Completion Performance Test Period, $PR_{FACILITY}$, must meet or exceed the Guaranteed Performance Ratio.

As Performance Ratio is subject to seasonal variation and the Completion Performance Test is of a short duration (a fraction of the period of seasonal variation), the Guaranteed Performance Ratio and the estimated PV cell temperature are defined per each month of the year for the sake of the Completion Performance Test.

The Monthly Guarantee Performance Ratio, PR_{min-k} , and the estimated irradiance-weighted PV cell temperature ($T_{e,k}$), for each month, are provided in Schedule 7 [*Performance Guarantees*].

When the Completion Performance Test occurs over two different months, k and $k + 1$, the Guaranteed Performance Ratio, Minimum Performance Ratio, and the estimated irradiance-weighted PV cell temperature shall be calculated proportionally to the time of the Test Period in each month, as shown below:

$$\bar{T}_e = \frac{(n_1 \times \bar{T}_{e-k} + n_2 \times \bar{T}_{e-k+1})}{n_1 + n_2}$$

$$PR_{MIN_FACILITY} = \frac{(n_1 \times PR_{MIN_FACILITY_MON_k} + n_2 \times PR_{MIN_FACILITY_MON_k+1})}{n_1 + n_2}$$

$$PR_{GUAR_FACILITY} = \frac{(n_1 \times PR_{GUAR_FACILITY_MON_k} + n_2 \times PR_{GUAR_FACILITY_MON_k+1})}{n_1 + n_2}$$

Where:

Variable	Description
n_1	Is the number of data points occurred in month k
n_2	Is the number of data points occurred in month $k + 1$
$n_1 + n_2$	Is the total number of data points during the Test Period

5.2.4. Test Duration and Conditions

The duration of the Completion Performance Test shall be fifteen (15) consecutive full days (the “Test Period”). The Contractor shall perform the Completion Performance Test for the entire Facility.

For the purposes of the calculation of $PR_{FACILITY}$ and Facility Availability, measured data shall be restricted to test intervals where the measured global inclined irradiance is $\geq 50 \text{ W/m}^2$.

In addition, the following minimum seasonal irradiance conditions shall apply for the test to be deemed acceptable:

- For the period from the start of April to the end of September the global inclined irradiance;
 - Must meet or exceed 400 W/m^2 for at least 20 hours during the Completion Performance Test period (120 ten-minute average data points);
 - At least during one (1) day, must meet or exceed 500 W/m^2 for at least seven (7) hours during the Completion Performance Test period (42 ten-minute average data points);
- For the period from the start of October to the end of March the global inclined irradiance;
 - Must meet or exceed 700 W/m^2 for at least 20 hours during the Completion Performance Test period (120 ten-minute average data points); and,
 - At least during one (1) day, must meet or exceed 600 W/m^2 for at least seven (7) hours during the Completion Performance Test period (42 ten-minute average data points).

The Completion Performance Test Period shall be extended until the above conditions are met.

5.2.5. Eligible Data Points

An eligible data point shall comply with the following conditions:

- Global inclined irradiance $\geq 50 \text{ W/m}^2$;
- Do not overlap any other test interval; and,
- Do not have any missing or flawed required measurement data.

The Completion Performance Test shall be suspended if it is disrupted due to one or more of the following events:

- Facility capacity is limited due to external events beyond the control of the Contractor, such as export curtailment (aside from maximum export capacity limitation), grid conditions sensibly deviating from the standard ones, and others;
- Snow, ice or any other obstructions cover a portion of the array; and,
- Force Majeure or grid failure/instability.

The test shall be resumed after the event causing disruption has ended.

5.2.6. Availability During the Completion Performance Test

During the Completion Performance Test, the availability of the Facility ("Completion Performance Test Availability") shall be 100%.

Availability of the Facility shall be measured at inverter level (in the case of string inverters) or inverter input level (in the case of central inverters) (the 'Equipment' level). For the avoidance of doubt, inverter input level shall be regarded as equivalent to string combiner box output level.

Availability of the Facility shall be calculated, for the Completion Performance Test Period, as follows:

$$Availability = \sum_{i=1}^M \frac{P_i * AV_{Equipment_i}}{P_0}$$

Where:

Variable	Units	Description
Availability	%	Facility Availability during the Test Period
P_0	kWp	Nominal DC Capacity of the Facility at STC
P_i	kWp	Nominal DC Capacity at STC connected to <i>Equipment_i</i>
$AV_{Equipment_i}$	-	Availability of <i>Equipment_i</i>
M	-	Total quantity of Equipment in the Facility
i	-	Index running over all Equipment within the Facility

The availability of each Equipment (the “Equipment Availability”) shall be calculated as follows:

$$A_{Equipment} = \frac{T_{Total\ operation\ time}}{T_{Total\ Initial\ Performance\ test\ time}}$$

Where:

Variable	Units	Description
$T_{Total\ Initial\ Performance\ test\ time}$	10-min periods	Total time, over the Completion Test period, in which the global inclined irradiance is $\geq 50\text{ W/m}^2$.
$T_{Total\ operation\ time}$	10-min periods	Total time, over the Completion Test period, in which the global inclined irradiance is $\geq 50\text{ W/m}^2$, and the power output of Equipment-i is greater than zero.

In the event of unavailability, the test will be suspended, and the testing period will be extended according to the following:

- The extension will be equal to the duration of the event that has led to the suspension of the test;
- In case the test is suspended more than 3 times, the test is cancelled and shall be repeated; and,
- In case the total interruption is more than 30% of the Test Period, the test is cancelled and shall be repeated.

The Equipment is deemed to be unavailable when the Equipment is does not export electrical energy at a global inclined solar irradiation of 50 W/m^2 or more at the PV module plane.

5.2.7. Completion Performance Test PR Calculation Methodology

The Performance Ratio for the Completion Performance Test shall be calculated as:

$$PR_{FACILITY} = \frac{E_{actual}}{E_{theoretical}}$$

Where:

Variable	Units	Description
$PR_{FACILITY}$	%	Performance Ratio calculated over the Completion Test period
E_{actual}	kWh	Actual exported energy at the POC during the Completion Test Period
$E_{theoretical}$	kWh	Energy that could theoretically be exported at the POC

$$E_{theoretical} = P_{nom} \cdot \sum_i \frac{G_i}{G_{STC}} \cdot (1 - (T_{cell, meas_i} - T_{e,k}) \cdot \frac{|\gamma|}{100}) \cdot \Delta t$$

Where:

Variable	Units	Description
P_{nom}	kWp	Nameplate DC Capacity of the Facility at STC
Δt	hours	Time duration of the i^{th} reporting period (constant over the Test Period) and equal to 10 minutes
G_{STC}	W/m ²	Irradiance at STC
G_i	W/m ²	Measured global inclined irradiance over the i^{th} test interval
γ	°C ⁻¹	Relative maximum-power module temperature coefficient
$T_{cell, meas_i}$	°C	PV cell temperature for the i^{th} test interval as calculated by applying the thermal model described in section 5.2.8
$T_{e,k}$	°C	Reference irradiance-weighted PV cell temperature for the Test Period as defined in Schedule 7 [<i>Performance Guarantees</i>].

5.2.8. Calculation of PV Cell Temperature

The PV cell temperature shall be calculated by applying the below thermal model:

$$T_{cell, meas_i} = T_{amb-i} + \frac{\alpha G_i (1 - \eta_{mod})}{U_C + U_V \cdot V}$$

Where:

Variable	Units	Description
$T_{cell, meas_i}$	°C	Calculated PV cell temperature for the i^{th} 10-min test interval
T_{amb-i}	°C	Measured ambient temperature of the i^{th} 10-min test interval
G_i	W/m ²	Measured global inclined irradiance over the i^{th} 10-min test interval
$\alpha = 0.9$	-	Absorption coefficient of solar irradiation of the modules
η_{mod}	-	Efficiency of the PV module related to the module area
$U_C = 29$	W/m ² K	Constant heat transfer factor
$U_V \cdot V = 0$	W/m ³ sK	Convective heat transfer factor
V	m/s	Wind Speed

5.2.9. Requirements for Successful Completion of the Completion performance Test

The Completion Performance Test will be considered as successfully completed if the following conditions are met:

- $PR_{FACILITY} \geq$ Guaranteed Performance Ratio;
- Facility availability = 100%; and,
- PV monitoring system availability = 100%.

5.2.10. Completion Performance Test Report

A test report shall be prepared and submitted to the Employer summarising the methodology, procedure, details and results of the test.

Processed data shall be prepared in an Excel spreadsheet with the following columns:

- Date and time;
- Global inclined irradiance measured for each GII pyranometer;
- Global inclined irradiance calculated mean value;
- Ambient temperature measured for each ambient temperature sensor;
- Ambient temperature calculated mean value;
- PV cell temperature calculated with the thermal model;
- Measured energy production measured at the revenue energy meter (meter output);
- Performance Ratio (calculated);
- Each string combiner box / string inverter nominal DC power;
- Total inverter power; and,
- Facility Availability (calculated).

Each day of the test will be represented with a summary of data over the course of the day. An additional summary will combine data over the whole Test Period. The spreadsheet will be readable by the Employer for the purposes of auditing.

6. Tests after Completion

6.1. Interim and Final Performance Tests

6.1.1. Purpose

The purpose of the Interim Performance Test and Final Performance Test is to quantify the performance of the Facility relative to its Performance Guarantees over the first and second operating years, respectively.

6.1.2. Guarantee Values

The Guaranteed Performance Ratio for the Interim Performance Test and Final Performance Test are provided in Schedule 7 [*Performance Guarantees*].

6.1.3. Test Duration and Conditions

The commencing and finalisation of the Interim and Final Performance Tests shall be agreed by the Parties to the test, in compliance with the Contract and these Testing Schedules.

The duration of the Interim Performance Test shall be the 12-month period from the date of Taking Over as stated on the Taking Over Certificate (the “**First Evaluation Period**”).

The duration of the Final Performance Test shall be the 12-month period from the 1st Anniversary of the date of Taking Over as stated on the Taking Over Certificate (the “**Second Evaluation Period**”).

Together, the First Evaluation Period and Second Evaluation Period are referred to as the “Evaluation Periods”.

The Contractor shall perform the Interim and Final Performance Tests for the entire Facility.

For the purposes of the calculation of the Performance Ratio for the Evaluation Periods and the Facility Availability, measured data shall be restricted to periods where the measured global inclined irradiance is $\geq 50 \text{ W/m}^2$.

6.1.4. Eligible Data Points

An eligible data point shall comply with the following conditions:

- Global Inclined Irradiance $\geq 50 \text{ W/m}^2$
- Do not overlap any other test interval; and,
- Do not have any missing or flawed required measurement data.

For the purpose of calculating the Performance Ratio for the Performance Ratio Test, the performance of the plant shall be corrected for actual availability by dividing the measured power output of the plant by the availability of the plant during each test interval and capping this corrected power output at the maximum export capacity of the plant.

For sake of clarity, the Guaranteed Performance Ratio for the Interim Performance Test and the Final Performance Test shall not in any way be adjusted to account for tolerances, measurement errors or availability of the Facility or its systems.

6.1.5. Availability Test

During each year of the Interim and Final Tests, the availability of the Facility shall be equal to, or higher than, the Guaranteed Availability as dealt with under the O&M Agreement.

Availability of the Facility shall be measured at DC Combiner box output or String inverter level (the 'Equipment' level).

Availability of the Facility shall be calculated, per each Test Period, as follows:

$$AV = \sum_{i=1}^M \frac{P_i * AV_{Equipment_i}}{P_{nom}}$$

Where:

Variable	Units	Description
AV	%	Facility Availability during the Test Period
P_{nom}	kWp	Nominal Contracted DC Capacity of the Facility at STC
P_i	kWp	Nominal DC Capacity at STC connected to $Equipment_i$
M	-	Total number of Equipment in the Facility
$AV_{Equipment_i}$	%	Availability of $Equipment_i$

$$AV_{Equipment} = \frac{T_{Total\ operation\ time}}{T_{Total\ test\ time} - T_{Total\ excluded\ time}}$$

Where:

Variable	Units	Description
$T_{Total\ test\ time}$	10-min periods	Total time, over the Test period, in which the global inclined irradiance is ≥ 50 W/m ² .
$T_{Total\ operation\ time}$	10-min periods	Total time, over the Test period, in which the global inclined irradiance is ≥ 50 W/m ² , and in which the power output of $Equipment_i$ is greater than zero.
$T_{Total\ excluded\ time}$	10-min periods	Total time, over the Test period, in which the global inclined irradiance is ≥ 50 W/m ² , and in which the $Equipment_i$ is unavailable (power=0) outside of the Contractor's responsibility.

Total excluded time is limited to times of $Equipment_i$ (or whole Facility) unavailability related to:

- Grid unavailability for reasons outside the control of the Contractor;

- Force Majeure;
- Downtimes or curtailments authorised or requested by the Employer or Eskom that affects the availability;
- Downtime for reasons attributable to the Employer; and,
- Other documented reasons agreed by the Parties.

The PV monitoring system availability shall be calculated computing the availability of the measured parameters required for the test, over all test intervals of the Test Period, in which the global inclined irradiance is $\geq 50 \text{ W/m}^2$.

6.1.6. Interim and Final Performance Test PR Calculation Methodology

The Performance Ratio for the Interim and Final Performance Tests shall be calculated as:

$$PR_n = \frac{E_{corr_n}}{\left(\frac{P_{nom}}{G_{STC}}\right) \cdot H_n}$$

Where:

Variable	Units	Description
PR_n	%	Performance Ratio calculated over the Interim Test Period (n=1) or the Final Test Period (n=2)
E_{corr_n}	kWh	Availability corrected energy production over the Test Period “n” at the POC
P_{nom}	kWp	Contracted DC Capacity of the Facility at STC
G_{STC}	W/m^2	Irradiance at STC equal to $1,000 \text{ W/m}^2$
n		Is the year of operation after Taking Over, with $n = 1$ for the Interim Performance Test and $n = 2$ for the Final Performance Test
H_n	Wh/m^2	Measured Global Inclined Irradiation over the Test Period “n”

$$E_{corr_n} = \sum_i \left[\min \left(\frac{E_{meas_i}}{AV_i \times C_f}, [P_{AC}] \times \Delta t \right) \right]$$

Where:

Variable	Units	Description
E_{corr_n}	kWh	Availability corrected energy production over the Test Period “n” at the POC
E_{meas_i}	kWh	Measured energy production as recorded by the Facility Meter at the POC during Test Interval i
AV_i	hours	Availability of the Facility during Test Interval i calculated in accordance with Section 6.1.5
C_f	%	Curtailment factor instructed by Eskom as a % of Achieved Capacity P_{AC}
P_{AC}	kW	Achieved Capacity of the Works as calculated in accordance with Section 5.1
Δt	hours	Time duration of the i^{th} test interval (constant over the Test Period) equal to $\frac{10}{60}$ hours (10 minutes)

$$H_n = \sum_i [G_i \cdot \Delta t]$$

Where:

Variable	Units	Description
H_n	Wh/m ²	Measured Global Inclined Irradiation over the Test Period “n”
G_i	W/m ²	Measured Global Inclined Irradiance over the i^{th} test interval
Δt	hours	Time duration of the i^{th} test interval (constant over the Test Period) equal to $\frac{10}{60}$ hours (10 minutes)

6.1.7. Requirements for Successful Completion of the Interim Performance Test and Final Performance Tests

The Interim and Final Performance Tests will be considered as successfully completed if the following conditions are met:

- $PR_n \geq PR_{GUAR_n}$
- Facility availability (while in-plane irradiance ≥ 50 W/m²) $\geq 99\%$ (Guaranteed availability);

Where:

Variable	Units	Description
PR_n	%	Performance Ratio calculated over the Interim Test Period (n=1) or the Final Test Period (n=2)
PR_{GUAR_n}	%	Guaranteed Performance Ratio over the Interim Test Period (n=1) or the Final Test Period (n=2) as defined in Schedule 7 [Performance] Guarantees
n	-	Is the year of operation after Completion, with $n = 1$ for the Interim Performance Test and $n = 2$ for the Final Performance Test

6.1.8. Interim Performance Test and Final Performance Test Reports

A test report shall be prepared and submitted to the Employer summarising the methodology, procedure, details and results of the test.

For each of Interim and Final Performance Tests, processed data shall be prepared in an Excel spreadsheet of 6 readings per hour (10-min reporting period) with the following columns:

- Date and time;
- Global inclined irradiance measured for each GII pyranometer;
- Global inclined irradiance calculated mean value;
- Ambient temperature measured for each ambient temperature sensor;
- Ambient temperature calculated mean value;
- Measured energy production measured at the revenue energy meter (meter output);
- Performance Ratio (calculated);
- Each string combiner box / string inverter nominal DC power;
- Total inverter power; and,
- Facility Availability (calculated).

Each month of the test will be represented on a separate worksheet with a summary of data over the course of the month. An additional summary sheet will combine data over the whole Test Period.

The spreadsheet will be readable by the Employer for the purposes of auditing.