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TECHNICAL SPECIFICATION

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Photovoltaic system performance –
Part 3: Energy evaluation method

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

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PHOTOVOLTAIC SYSTEM PERFORMANCE –

Part 3: Energy evaluation method

FOREWORD

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The main task of IEC technical committees is to prepare International Standards. In exceptional circumstances, a technical committee may propose the publication of a technical specification when

- the required support cannot be obtained for the publication of an International Standard, despite repeated efforts, or
- the subject is still under technical development or where, for any other reason, there is the future but no immediate possibility of an agreement on an International Standard.

Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC TS 61724-3, which is a technical specification, has been prepared by IEC technical committee 82: Solar photovoltaic energy systems.

IEC 61724-1, IEC TS 61724-2 and IEC TS 61724-3 cancel and replace the first edition of IEC 61724, issued in 1998, and constitute a technical revision.

The main technical changes with regard to the first edition of IEC 61724 (1998) are as follows:

– This first edition of IEC TS 61724-3 provides a method for quantifying the annual energy generation for a PV plant relative to that expected for the measured weather.

The text of this technical specification is based on the following documents:

Enquiry draft	Report on voting
82/1069/DTS	82/1121/RVC

Full information on the voting for the approval of this technical specification can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 61724 series, published under the general title *Photovoltaic system performance*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- transformed into an International standard,
- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

The performance of a PV system is dependent on the weather, seasonal effects, and other intermittent issues, so demonstrating that a PV system is performing as predicted requires determining that the system functions correctly under the full range of conditions relevant to the deployment site. IEC 62446 describes a procedure for ensuring that the plant is constructed correctly and powered on properly by verification through incremental tests, but does not attempt to verify that the output of the plant meets the design specification. IEC 61724-1 defines the performance data that may be collected, but does not define how to analyze that data in comparison to predicted performance. IEC TS 61724-2 and ASTM E2848-11 describe methods for determining the power output of a photovoltaic system, and are intended to document completion and system turn on, and report a short term power capacity measurement of a PV system, but are not intended for quantifying performance over all ranges of weather or times of year. IEC 62670-2 also describes how to measure the energy from a CPV plant, but does not describe how to compare the measured energy with a model.

The method described in this Technical Specification is intended to address testing of a specific deployed PV system over the full range of relevant operating conditions and for a sustained time (generally a complete year) to verify long-term expectations of energy production to capture all types of performance issues, including not only response to different weather conditions, but also outages or instances of reduced performance of the plant that may arise from grid requirements, operational set points, hardware failure, poor maintenance procedures, plant degradation, or other problems. The performance of the system is characterized both by quantifying the energy lost when the plant is not functioning (unavailable) and the extent to which the performance meets expectations when it is functioning.

Multiple aspects of PV system performance are dependent on both the weather and the system quality, so it is essential to have a clear understanding of the system being tested. For example, the module temperature is primarily a function of irradiance, ambient temperature, and wind speed; all of which are weather effects. However, the module-mounting configuration also affects the module temperature, and the mounting is an aspect of the system that is being tested. This technical specification presents a best-practice process for test development and clarifies how measurement choices can affect the outcome of the test so that users can benefit from streamlined test design with consistent definitions, while still allowing flexibility in the application of the test so as to accommodate as many unique installations as possible.

IECRE's Annual PV Project Performance Certificate incorporates measurements from this Technical Specification. Although this technical specification allows application in multiple ways, to maintain a consistent definition of the meaning of the IECRE certificate, when this technical specification is used for measurements for IECRE reporting, the method may be required to use a minimum level of accuracy for the measurements or other details as documented by IECRE.

PHOTOVOLTAIC SYSTEM PERFORMANCE –

Part 3: Energy evaluation method

1 Scope

This part of IEC 61724, which is a Technical Specification, defines a procedure for measuring and analyzing the energy production of a specific photovoltaic system relative to expected electrical energy production for the same system from actual weather conditions as defined by the stakeholders of the test. The method for predicting the electrical energy production is outside of the scope of this technical specification. The energy production is characterized specifically for times when the system is operating (available); times when the system is not operating (unavailable) are quantified as part of an availability metric.

For best results, this procedure should be used for long-term performance (electrical energy production) testing of photovoltaic systems to evaluate sustained performance of the system over the entire range of operating conditions encountered through the duration of the test (preferably one year). Such an evaluation provides evidence that long-term expectations of system energy production are accurate and covers all environmental effects at the site. In addition, for the year, unavailability of the system (because of either internal or external causes) is quantified, enabling a full assessment of electricity production.

In this procedure, inverter operation and other status indicators of the system are first analyzed to find out whether the system is operating. Times when inverters (or other components) are not operating are characterized as times of unavailability and the associated energy loss is quantified according to the expected energy production during those times. For times when the system is operating, actual photovoltaic system energy produced is measured and compared to the expected energy production for the observed environmental conditions, quantifying the energy performance index, as defined in IEC 61724-1. As a basis for this evaluation, expectations of energy production are developed using a model of the PV system under test that will serve as the guarantee or basis for the evaluation and is agreed upon by all stakeholders of the project. Typically, the model is complex and includes effects of shading and variable efficiency of the array, but the model can also be as simple as a performance ratio, which may be more commonly used for small systems, such as residential systems.

The procedure evaluates the quality of the PV system performance, reflecting both the quality of the initial installation and the quality of the ongoing maintenance and operation of the plant, with the assumption and expectation that the model used to predict performance accurately describes the system performance. If the initial model is found to be inaccurate, the design of the system is changed, or it is desired to test the accuracy of an unknown model, the model may be revised relative to one that was applied earlier, but the model should be fixed throughout the completion of this procedure.

The aim of this technical specification is to define a procedure for comparing the measured electrical energy with the expected electrical energy of the PV system. The framework procedure focuses on items such as test duration, data filtering methods, data acquisition, and sensor choice. To reiterate, the procedure does not proscribe a method for generating predictions of expected electrical energy. The prediction method and assumptions used are left to the user of the test. The end result is documentation of how the PV system performed relative to the energy performance predicted by the chosen model for the measured weather; this ratio is defined as the performance index in IEC 61724-1.

This test procedure is intended for application to grid-connected photovoltaic systems that include at least one inverter and the associated hardware.

This procedure is not specifically written for application to concentrator (> 3X) photovoltaic (CPV) systems, but may be applied to CPV systems by using direct-normal irradiance instead of global irradiance.

This test procedure was created with a primary goal of facilitating the documentation of a performance guarantee, but may also be used to verify accuracy of a model, track performance (e.g., degradation) of a system over the course of multiple years, or to document system quality for any other purpose. The terminology has not been generalized to apply to all of these situations, but the user is encouraged to apply this methodology whenever the goal is to verify system performance relative to modeled performance. Specific guidance is given for providing the metrics requested for the IECRE certification process, providing a consistent way for system performance to be documented.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 61724-1, *Photovoltaic system performance – Part 1: Monitoring*[1]

IEC TS 61836, *Solar photovoltaic energy systems – Terms definitions and symbols*

ISO/IEC Guide 98-1:2009, *Uncertainty of measurement – Part 1: Introduction to the expression of uncertainty in measurement*

ISO/IEC Guide 98-3:2008, *Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement*

ISO 5725 (all parts), *Accuracy (trueness and precision) of measurement methods and results*

ISO 8601:2004, *Data elements and interchange formats – Information interchange – Representation of dates and times*

ASME, *Performance test codes 19.1*

ASTM G113 – 09, *Standard terminology relating to natural and artificial weathering tests of nonmetallic materials*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 61724-1, ASTM G113, IEC TS 61836, and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

1 To be published.

3.1
energy availability
metric of energy throughput capability that quantifies the expected energy when the system is operating relative to the total expected energy

Note 1 to entry: The energy availability is calculated from the energy unavailability and may be expressed as a percentage or a fraction.

3.2
energy unavailability
metric that quantifies the energy lost when the system is not operating (as judged by an automatic indication of functionality such as the inverter status flag indicating that the inverter is actively converting DC to AC electricity or not). The energy unavailability is the ratio of the expected energy (as calculated from the original model and the measured weather data) that cannot be delivered because of inverters or other components being off line divided by the total expected energy for the year

Note 1 to entry: The energy unavailability may be expressed as a percentage or a fraction. Energy unavailability may be caused by issues either internal or external to the PV system as defined by those applying the test.

3.3
external-cause-excluded energy availability
metric that quantifies the expected energy when the system is operating relative to the total expected energy during times when it was possible for the plant to be operating

Note 1 to entry: Exclusions are made for times when the grid is not operating or for other times when the plant was not operating for reasons outside of the control of the plant.

3.4
predicted energy
energy generation of a PV system that is calculated with a specific performance model, using historical weather data that is considered to be representative for the site, whereby the specific performance model has been agreed to by all stakeholders to the test (see Figure 1)

Note 1 to entry: The historical weather data may be gathered from a weather station that is within reasonable proximity to the site.

3.5
expected energy
energy generation of a PV system that is calculated with the same specific performance model as that used in the predicted energy model, using actual weather data collected at the site during operation of the system for the year in question

Note 1 to entry: The weather data is collected locally at the site.

Note 2 to entry: The expected energy is used to calculate the energy performance index.

3.6
measured energy
electric energy that is measured to have been generated by the PV system during the test over the same duration as the expected energy model

Note 1 to entry: See also 3.13 test boundary to define the location of measurement.

3.7
performance index
electricity generation of a PV system relative to expected, as defined in IEC 61724-1 and calculated as described in this technical specification

3.8
energy performance index
electricity generation of a PV system relative to the expected energy over a specified time period, as defined in IEC 61724-1 and calculated in this technical specification. The energy

performance index may refer to all times or only times of availability as defined by the all-in energy performance index or the in-service energy performance index, respectively

3.9
all-in energy performance index
electricity generation of a PV system relative to the total expected energy over a specified time period, including times when the system is not functioning

3.10
in-service energy performance index
electricity generation of a PV system relative to the expected energy over a specified time period during times when the system is functioning (excluding times when inverters or other components are detected to be off line)

3.11
power performance index
electricity generation of a PV system relative to expected power production for a specified set of conditions, as defined in IEC 61724-1 and calculated as in IEC TS 61724-2

3.12
primary sensor
sensor that has been designated as the source of data for the test. Primary sensors may be designated for the irradiance, temperature, wind speed or other measurements. The electrical measurements are defined as part of the system definition

3.13
test boundary
a (physical) differentiation between what is considered to be part of the system under test and what is outside of the system for purposes of quantifying the performance index

Note 1 to entry: Quantification of the energy unavailability may be affected by events outside of the test boundary.

3.14
stakeholders of the test
individuals or companies that are applying the test

Note 1 to entry: Commonly, these parties may be the PV customer and the PV installer, with the test method applied to define completion of a contract, but the test method may be applied in a variety of situations and the stakeholders of the test may in some cases be a single individual or company.

3.15
test
test that compares the measured output of a PV system over a prolonged time period to the output that was expected for the PV system for the measured set of weather conditions, as defined by this technical specification (see 3.4)

3.16
model
simulation model used to calculate both predicted and expected PV generation from weather data. The model is also used to calculate expected energy during times of unavailability

Note 1 to entry: Typically, the model is expected to be the same that was used to describe the plant before construction, but the model may be updated to reflect changes in the plant design, or any model may be used if the goal is to test the accuracy of the model. It is assumed that the model is appropriate for the situation.

3.17
inverter clipping
the inverter output is limited by the capability of the inverter rather than by the input power from the PV array

4 Test scope, schedule and duration

This test may be applied at one of several levels of granularity of a PV plant. The users of the test shall agree upon the level(s) at which the test will be applied. The smallest level to which the test may be applied is the smallest AC power generating assembly capable of independent on-grid operation.

PV plant construction is often divided into phases. Phases may have separate or shared interconnection points and may be spread over a period of months or even years. In general, it is recommended that the test be applied at the highest level, that which encompasses the entire PV project. However, for very large plants scheduled for interconnection in parts, with the first and last interconnection separated by a period of more than 6 months. It is recommended that the test be applied to smaller subsets of the plant as they become available for interconnection. In such cases, upon full plant completion the test may be applied again in a way that encompasses the entire plant, but in these cases the expected energy is modified to include expected plant performance degradation in accordance with the model accepted by the stakeholders of the test.

Some PV modules show measurable performance changes within hours or days of being installed in the field, others do not. The start of the test should be negotiated between the stakeholders using the manufacturer’s guidance for the number of days or the irradiance exposure needed for the plant to reach the modeled performance along with the details of the actual installation and interconnection dates. Any degradation assumptions should be agreed to by all stakeholders and documented as part of the model description.

It is recommended that the test lasts 365 days. The actual test term should be agreed upon in advance. If the test is not continued for a full year, seasonal variations (including shading, spectrum, temperature, and wind) may cause the performance to deviate from what would be obtained over a full year.

The performance metric, in-service energy performance index, is reported only for times when the inverters and other components are on line. Expected energy for times when the inverters or other components are off line is quantified in the energy unavailability metric. The energy unavailability metric may be further divided into situations with internal and external causes, as agreed to by the stakeholders.

All stakeholders agree on a detailed test procedure before the test commences as described in Clauses 5 and 6.

5 Equipment and measurements

Using the default test boundary (used for simplified discussion here), the weather is characterized by:

- Global horizontal irradiance (direct and diffuse may also be measured).
- Ambient temperature.
- Wind speed.
- Rainfall or soiling (if the test agreement assumes a clean system).

If additional characterization of the weather is required for implementation of the model, these data shall be collected in a manner consistent with the model. If the model uses a different test boundary then the default test boundary is modified. For example, if plane-of-array irradiance is specified as an input to the model, defining the albedo to be outside of the test boundary, then the weather is characterized by the plane-of-array irradiance rather than the global horizontal irradiance.

Some models use other inputs such as atmospheric pressure and humidity since these can affect the incident light spectrum and the PV performance. Whereas it is encouraged to monitor many aspects of the PV system operation to best understand the status of the system and optimize its performance, the use of data from the system as a characterization of the weather inputs to the model risks compromising the integrity of the test. When data are used for such characterization there is the risk that some aspects of the system performance are then considered to be part of the uncontrolled weather. For example, if modules are mounted without adequate ventilation, the temperature of the system may increase beyond the design value, reducing system output. Similarly, a tracked system that does not track correctly will measure a plane-of-array irradiance that is lower than what it would have been with optimal tracking. Although frequent rain and snow will affect system performance, the design of the system may aid in shedding snow and/or being resistant to soiling.

The system output is characterized by:

- Real AC power delivered to the grid.
- Apparent AC power or AC power factor.

The model simulating the PV system performance should include an assumption about the power factor, which may affect the predicted energy. The recorded power factor (or any similar input to the model) should be then used when calculating the expected energy, as described below.

The definition of the AC energy, including the point of measurement (such as at a utility-grade meter at the point of interconnection) is documented as part of the test boundary definition. If parasitic loads outside the system boundary exist (e.g., trackers and night-time electricity use by inverters and transformers), the contract or test definition defines whether adjustments are made for these, and, if so, these adjustments are characterized.

Measurement equipment and procedures for all measured parameters are recommended to conform to IEC 61724-1, Class A requirements. However, a Class B or Class C evaluation (per the contract) may also be completed and documented in the final report.

All details of data collection (including sensor number, maintenance, calibration and cleaning) follow IEC 61724-1 according to the chosen Class of measurement with the exception of:

- The choice of sensor and sensor positioning shall be consistent with the performance model that is being used for the test.

  NOTE Often the final uncertainty of the measurement is dominated by the uncertainty of the irradiance measurement, so high-accuracy sensors are desired.
- The frequency of cleaning of irradiance sensors may vary by site and should be documented.
- Verification of accurate positioning of the sensors is accomplished through comparison of data from a clear day with modelled irradiance for a clear day and the results included in the documentation of the uncertainty of the application of the test.
- When irradiance sensors are deployed in the plane of the array, the ground albedo should be measured to demonstrate consistency with that assumed in the model and the results included in the documentation of the uncertainty of the application of the test.
- For Class A tests, because the irradiance measurement is so crucial to the test, the calibrations should be independently verified either by using sensors calibrated at different test locations or at different times so as to prevent a systematic bias to the calibration.

6 Procedure

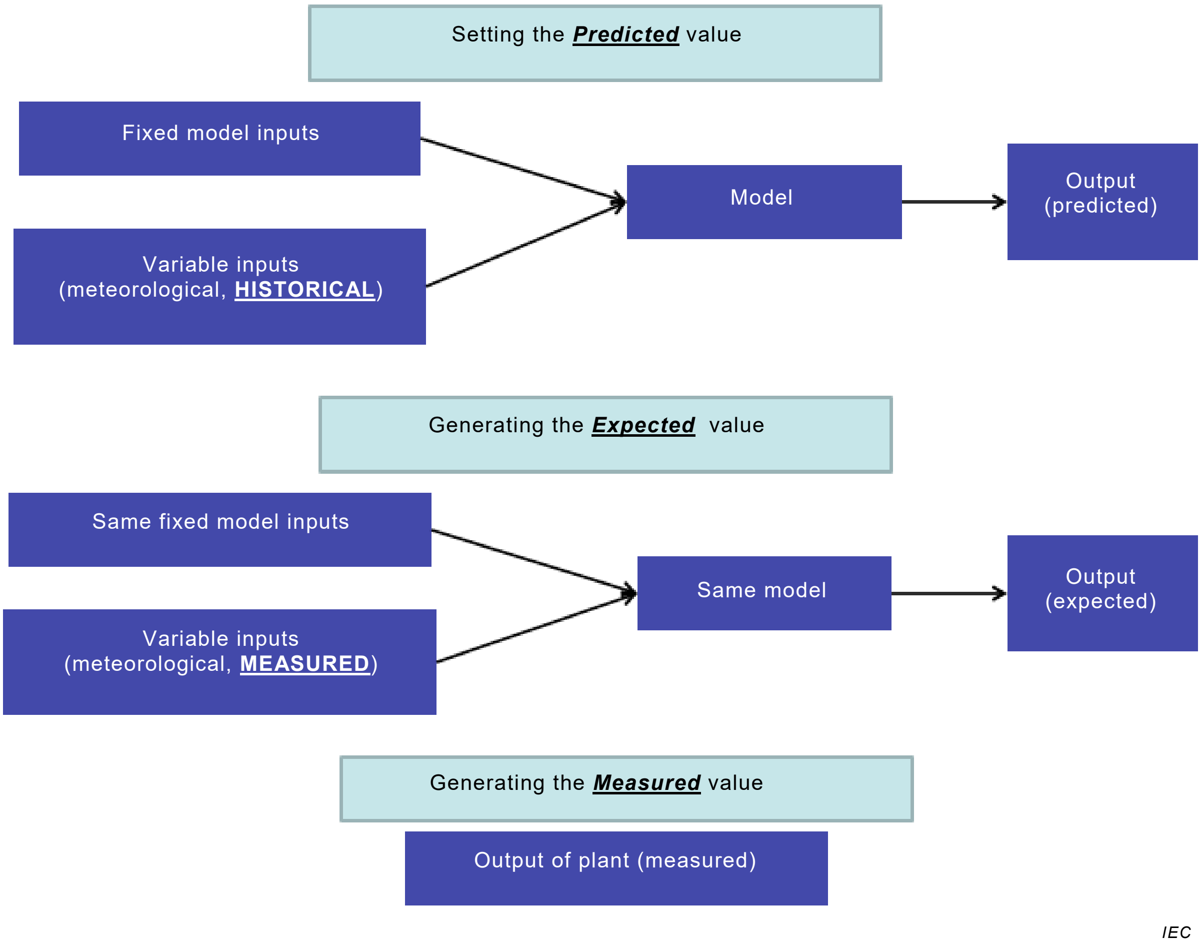
6.1 Overview

The terms “predicted” and “expected” energy are defined in 3.4 and 3.5 to avoid ambiguity when differentiating the prediction based on historical weather data from the prediction based on the measured weather data for the time of interest. The methods used for calculating the “predicted” and “expected” energies are aligned for consistency. If the historical and measured weather data differ in their format, the applied model may be inadvertently changed. Care shall be taken to address the differences in the weather data used for the two calculations so that the model used for calculating the “predicted” energy is the same as the model used for calculating the “expected” energy.

The comparison of measured energy to expected energy is simplified by collecting the new weather data in the same format as the historical data. In this case both parties agree upon and document data in an identical format.

The comparison of the modeled and test results to evaluate the energy performance index is documented in detail in the following subclauses. The following list summarizes 6.2 to 6.9:

- Define test boundary to align with the intended system boundary.
- Calculate and document the predicted energy using the chosen model by listing all inputs including historical weather data, assumptions regarding soiling, shading, outages, etc.; the raw data should be included in the final report as an appendix. The predicted energy may assume 100 % availability or may be reduced to account for expected times of unavailability.
- Complete the measurement of data from the operating system over the test period.
- Identify times when the system is unavailable for a variety of reasons that may be external or internal to the plant.
- Evaluate the measured data to identify and document anomalies that may require extra treatment. Such anomalies include missing or erroneous data that are replaced.
- Calculate and aggregate the expected energy for the full time period, replacing missing data, as needed.
- Aggregate the measured energy, replacing missing data, as needed.
- Compare the expected and measured energies from the plant to derive the energy performance index.
- Compute the uncertainty of the measurement.



Times of unavailability are not addressed in this figure.

Figure 1 – Schematic showing relationship of predicted, expected, and measured energies to reflect how the model is applied consistently to historical and measured weather data

6.2 Calculation and documentation of predicted energy and the method that will be used to calculate the expected energy

6.2.1 General

As shown in Figure 1, the first step in the process, typically, is to predict the performance of the PV system based on historical weather data using a model that has been agreed to by the stakeholders. The model is defined in terms of the model inputs, calculation process, and how the measured meteorological data will be input into the model. It is expected that the information required per this subclause (6.2) is documented before the beginning of the test; although the final comparison of expected and measured energy does not use the predicted energy directly, the predicted energy is usually required for project planning. The model may assume 100 % availability or may specify a predicted unavailability as part of the prediction, reducing the predicted energy for the year accordingly.

6.2.2 Definition of test boundary to align with intended system boundary

This test method is intended to quantify the performance of a system, but the result of the test may depend on what is considered to be part of the system. The stakeholders of the test shall agree on the definition of the system including:

- The meter(s) that define the output of the system.

- Aspects of system design that are being tested such as whether modules are mounted according to the design (tilt, azimuth, height, racking design) allowing the expected cooling and capture of sunlight.
- Location and type of all measurement devices.
- Aspects of system operation that are being tested such as whether the soiling level will be considered as part of the test.

NOTE To facilitate the description of the test method, this document defines a default test boundary. Global horizontal irradiance, ambient temperature, wind speed, and any other meteorological measurements such as humidity and atmospheric pressure lie outside of this default test boundary. All other aspects of the system are considered to be part of the PV system that is under test, including the module temperature and the plane-of-array irradiance. The parties to the test may define the test boundary however they wish; the default test boundary is defined only as a tool to clarify the application of the test method described in this document and as an example for how to define the test boundary. When models include the effects of rainfall, it can be useful to also move rainfall outside of the default test boundary.

6.2.3 Definition of the meteorological inputs used for the prediction

The sources of the global horizontal irradiance, ambient temperature, wind speed, and any other meteorological data such as atmospheric pressure and humidity are described and the raw data are included as an appendix in the final report. It is expected that this will be documented as specifically as possible before the test (e.g. sensor type, location, cleaning and calibration schedules, and any additional relevant information). Refer to IEC 61724-1 for recommendations regarding measurements for the chosen accuracy of measurement (Class A, B, or C).

6.2.4 Definition of the PV inputs used for the prediction

Table 1 shows the information requested about each input data type. This example table defines the information that is requested about each parameter. Enough information should be given so that the prediction could be duplicated.

Table 1 – Example PV performance input parameters to the model for the initial prediction

Input parameter	Value	Source of information
Module P_{max} at STC (or CSTC) = 1 000 W/m^2, 25 °C cell temperature	205 W	Data sheet
Module power temperature coefficient	–0,35 %/°C	Data sheet
Number of modules	200	System drawings
Number of strings	20	System drawings
Tilt	30°	System drawings
Azimuth	180°	System drawings
Inverter		
All module parameters used in model are enumerated in this table or in separate tables including assumptions made about – Shading – Soiling and/or cleaning schedule – Non-module (e.g. inverter or resistive) loss factors – Operations and maintenance availability assumptions – Utility availability and curtailment, other outages – Inverter clipping – Snow losses Model details (angle of incidence, series resistance, spectral and other parameters).		

Some factors may be considered outside of the simulation tool. Also, a simple model such as performance ratio may be used, in which case, this table becomes very simple.

6.2.5 Definition of measured data that will be collected during the test

The test plan shall include documentation for each input data type. The test may identify a primary irradiance/temperature/wind sensor that will be used as long as data appear to be valid. Alternatively, if multiple sensors of any type are used, the test plan may indicate use of the mean of the sensors. The choice of how to average data from multiple sensors should be defined at the beginning of the test, but some data may be discarded by mutual consent of the stakeholders if there is evidence that the data are in error by more than the expected uncertainty.

If cleanliness of the modules is considered to be a part of the system quality (as in the default test boundary for Class A measurements) then rainfall or other inputs to a soiling model are measured and the soiling level does not need to be measured. If module fouling is not considered to be a part of the system under test (e.g. not part of an energy guarantee as defined by the stakeholders), then additional measurements will be needed to calculate soiling loss that will be credited to the energy measurement. It is also documented whether and how soiling and snow effects are included in the performance model.

Table 2 provides examples of the types of data needed; some models may use different inputs, including spectral measurements.

If a model uses plane-of-array irradiance as a direct input, the modeler should calculate the required sensor alignment to limit bias error to the desired uncertainty and the alignment requirement should be specified in Table 2.

Similarly, the modeler should evaluate the effect of the location of the wind sensor and include the wind-sensor mounting requirements in Table 2.

Table 2 – Example table documenting the meteorological and other input parameters to the model for the calculation of the expected energy

Input parameter	Type of sensor	Location, orientation, and/or positioning of sensor	Number of sensors	Calibration and maintenance (indicate who will provide maintenance if it is not the system operator)	Alignment check (indicate who will check the alignment if it is not the installer)	Data frequency and analysis
Horizontal global irradiance	Pyranometer model # XXX*	Mounted at height of 2 m as located in drawing Y*	3	Once per year; cleaned weekly	Within 1° Confirmation of view of full sky as defined by model at beginning and end of test	Average data over 1 h and use mean value from all functioning sensors
Ambient** temperature	Type T thermocouple	As located in drawing Y*	2	Calibration before and after test	None	Average data over 1 h and use mean value from all functioning sensors
Wind speed	Anemometer Model X*	As located in drawing Y*	1	Calibration before and after test	None	Average data over 1 h
AC energy	Utility-grade meter: model XXX*	Output of entire system as shown on drawing Y, meter ###*	1	Once per year	Not applicable	Integrated energy is read daily
Power factor						Use information from inverter manual
Indication that inverters are MPP tracking correctly	Table is filled in as in examples above					
Parasitic energy losses						
Data checking				Indicate who is responsible for daily checks		Daily checking is recommended
Handling of missing data						Indicate any deviations from 6.5
Add lines for additional parameters						

* X, Y, or ## are used as place holders for the actual information.

** The module temperature may also be measured.

6.2.6 Definition of the model calculations

The modeling procedure shall be defined with as much detail as required so that a technically competent individual can reproduce the calculation of predicted energy. The description may be documented through a reference that is readily available. The model definition is outside the scope of this document.

Some common models neglect to include the effects of snow and soiling. The model should define assumptions about the cleaning (manual or by precipitation) of the array (as well as the cleaning of irradiance sensors, as included in Table 2) and about snow coverage. These assumptions shall be documented as part of the model description. It is recommended that the system operator takes responsibility for the cleanliness of the array and that the losses are assumed to be independent of the weather. The decrease in output may be quantified from direct measurement of cleaned and naturally soiled modules, but the parties should recognize that soiling can be exacerbated by poor system design and operation. If correction is desired for lost production from snow coverage, it is recommended to screen for such days and adjust the expected energy manually if the model does not directly include losses associated with snow.

The model definition should be clear regarding exclusion of nighttime data, which is recommended. However, if parasitic loads are included in the model, then these loads shall be measured through the night. The specifics of handling data near sunrise and sunset should be defined both with regard to whether they are included in the model and with regard to whether the measured irradiance data are confirmed to be shade free near sunrise and sunset. In general, following the guidelines provided in IEC 61724-1 is encouraged. It is recommended to capture times of unavailability that occur when inverters are not functioning at dawn and dusk. The low light levels and low modeled output typically render these times unimportant, but if inverters are slow to start up in the morning or trip off in the evening while the irradiance is still relatively high, this loss should be captured as a reduced availability.

The model definition should also include a plan about how missing data will be handled, especially in the case of more than one week of missing data.

All of the choices discussed above, including parties responsible for any cleaning and the frequency of cleaning, should be documented in the test plan.

If the system is predicted to be unavailable because the grid is predicted to be unavailable to receive electricity under specific conditions, then this will be captured both in the predicted and expected production.

6.2.7 Predicted energy for the specified system and time period

Using the inputs and processes described in 6.2.2 through 6.2.6, state the resulting predicted energy for the designated system and how this relates to the system outputs that are defined in Table 2. The energy may be predicted for DC and/or AC output and additional predictions may be supplied for parasitic losses, such as for operating trackers. If the system is not well described by a separate document, the modeled system shall be described in this section including all details that are relevant to the model, such as the number of modules, mounting configuration, etc. If the test may be applied in a phased way, the system description may define each subsystem. If the time period may be long enough to result in degradation of the array and/or if the test will be delayed to allow for light-induced changes, these shall be described.

6.2.8 Uncertainty definition

Test uncertainty should be computed following methods presented in the ASME performance test codes 19.1, ISO/IEC Guide 98-1:2009, ISO/IEC Guide 98-3:2008, ISO 5725, or ISO GUM. The uncertainty definition and its role in defining the pass/fail test outcome comparing the expected and measured energy shall be agreed upon. The uncertainty in the availability (unavailability) should be considered as part of the total uncertainty, if applicable. It is highly recommended that this agreement be documented in advance of the test. Typically, the uncertainty agreed to by the stakeholders will form a dead band around any guarantee. This dead band disadvantages the parties of the test, so should be kept as small as possible.

Both systematic (bias) and random (precision) uncertainties are included in the analysis. The contributions to the uncertainty depend on the model that is used, but generally include uncertainty in the measurements of the irradiance, temperature, and electrical energy generated.

More detailed descriptions of identifying uncertainties associated with the measured data are described in 6.9. These should be reviewed and agreed upon as part of the initial definition of uncertainty even though they cannot be applied until after the data are collected.

Strategies for reducing uncertainty are best implemented before data are acquired and include:

- Use higher quality irradiance sensors.
- Use multiple sensors either to add redundancy, to help in detecting sensor drift/fault, or to document variability of that parameter, especially when the plant design may induce variability through variable module alignment and/or because of variations in the terrain, for example.
- Execute comprehensive, daily data checks including values out of range and missing data, nighttime measurements that deviate from zero, and comparison between similar systems to detect deviations. Any issues should be promptly resolved.
- Pay special attention to possible shading of irradiance sensors.
- Compare data to other data streams obtained nearby to detect and resolve problems quickly. On sunny days, data may be compared directly; on cloudy days, comparison of integrated data may provide more accurate identification of problems.
- Carefully identify missing or erroneous data including variations in data collection frequency and/or duplicate records.

6.3 Measurement of data

The data specified in Table 2 are collected and recorded at the specified frequency and in the specified format with every effort made to avoid gaps in data, to maintain sensor function and calibration through early detection of failures, and to strictly adhere to agreed-upon procedures. The cleaning of sensors should be documented through a log of the date/time of cleaning and notes on any unusual observations (a photograph is recommended, especially if there is a soiling monitor).

6.4 Identification of data associated with unavailability

The data should be screened for times when any inverter is off line (not converting DC to AC electricity) or some other component is off line. The expected energy production associated with the unavailability is tabulated and aggregated to provide the expected energy for the times during the year when the plant is unavailable. The status flag of the inverter provides a convenient method for identifying components that are off line. However, some plants may be instrumented for the purpose of monitoring the health of the system and may be able to detect outages when they occur at a component level. Times of unavailability that occur at the beginning and end of the day because of slow inverter start up or early inverter shut down should be captured.

The times of unavailability may be separated into two categories to differentiate causes of unavailability that are internal and external to the system, as agreed to by the stakeholders. Preferably, this differentiation is defined before the test begins.

6.5 Identification of erroneous data and replacement or adjustment of such data and preparation of model input dataset

6.5.1 General

Data are examined for errors; the exact procedure may vary depending on the data that are collected. While it is recommended to document approved methods for filtering data prior to testing, system complexity makes this difficult and a new, mutually agreed-upon process may be needed during the test; the filters that are applied and the data that are removed shall be documented in the report. The following (6.5.2 to 6.5.14) are suggestions and may not be applicable in all situations.

6.5.2 Data checks for each data stream

Each data stream is checked for data out of range, missing data, or unreasonable trends as described in IEC 61724-1. An example procedure is given in more detail in Table 3. Depending on the local conditions, the details of the plant design, and the addition of other data streams, the filtering criteria may be modified, but all four types of filters (range, missing data, dead value, and abrupt change) shall be applied and documented as part of the final report. Flagged data are examined to determine the underlying cause and whether the flag should be retained.

Table 3 – Example of data filtering criteria, to be adjusted according to local conditions

		Suggested criteria for flag (15 min data)			
Flag type	**Description**	**Irradiance** W/m^2	**Temperature** °C	**Wind speed** m/s	**Power (AC power rating)**
Range	Value outside of reasonable bounds	< –6 or > 1 500	> 50 or < –30	>32 or < 0	> 1,02 × rating or < –0,01 × rating
Missing	Values are missing or duplicates	n/a	n/a	n/a	n/a
Dead	Values stuck at a single value over time. Detected using derivative.	< 0,0001 while value is > 5	< 0,0001	?	?
Abrupt change	Values change unreasonably between data points. Detected using derivative.	> 800	> 4	> 10	> 80 % rating
May be adjusted depending on the tilt of the system and the season of data acquisition.					

As part of the data filtering, the data should be binned into times when inverters (or other system parts if desired) were on line and off line. In the case where a single inverter is off line, but the system output is measured at a single point for the entire system, the expected energy is partitioned to reflect the expected energy from the functioning inverters (or other system parts, if desired) and the expected energy from the offline inverters and aggregated separately. The energy aggregated for times when the system was off line may be separated into two categories: problems caused by internal and external reasons. An example of the binning can be found in Annex A.

6.5.3 Shading of irradiance sensor

6.5.3.1 General

Because of the sensitivity of the test to the irradiance data, special attention should be given to the irradiance data. Specifically, irradiance data that may result from accidental shading of a sensor or sensor malfunction should be removed before taking the average of the data from the remaining sensors. A recommended procedure for identifying such data in the case where multiple sensors are being used is:

6.5.3.2 Step 1

Identify a clear day in each quarter.

6.5.3.3 Step 2

Compute the average irradiance value for each sensor during each time interval and compare each individual value with the average value for all sensors. If this difference is greater than the uncertainty of the sensors, inspect the data to identify a probable cause. (Note that if the data are taken more frequently than once per minute, the data should be averaged over a time period of at least 1 min.)

6.5.3.4 Step 3

Look for drift of the calibrations of the sensors.

6.5.3.5 Step 4

Discard data that can be traced to malfunctioning of the sensor or data acquisition system.

Discard data from sensors that are out of calibration.

This action should be done only with mutual consent of the stakeholders.

6.5.3.6 Step 5

Discard individual data points that are compromised by sensor maintenance or cleaning.

6.5.3.7 Step 6

If all data for some time periods are removed, this time period is treated as missing data. The missing data, cause for removal of the data, and the impact of the removal of the data are presented in the report. This action should be done only with mutual consent of the stakeholders.

6.5.4 Calibration accuracy

Accurate calibrations are needed for all sensors to provide a test result with low uncertainty. In addition to confirming that the calibrations were completed as planned, the nighttime data should be checked to confirm accurate zero-point calibration, noting that it is common for a pyranometer to show a negative signal of 1 W/m^2 to 3 W/m^2.

6.5.5 Final check

To assist in identifying problematic data or operating events, simulate the plant model using the measured weather data as input. Compare the resulting expected power with the measured power. All areas where there is a noticeable divergence should be investigated for root causes. After diagnosed, the events can be assessed with a determination of how to address any identified anomalies. This decision should be based on guidelines in this document or the project contracts, and in all cases should be by concurrence from all stakeholders.

6.5.6 Using data from multiple sensors

6.5.6.1 General

If the data inspection identifies error in the output of a sensor, that data should be discarded before taking the average of the data pool. This action should be done only with mutual consent of the stakeholders.

6.5.6.2 Multiple irradiance sensors

The irradiance used as input to the model should be the average of the available measurements, except where one measurement is determined to be erroneous, in which case the input to the model should be the average of the remaining measurements, as described previously. Irradiance data from nearby meteorological stations or from satellite data may be used when it is expected to improve the accuracy of the test and with mutual consent of the parties. The type of irradiance sensor, its mounting, maintenance, accuracy, resolution and calibration status of such sensors shall be consistent with the initial model definition.

6.5.6.3 Multiple ambient temperature sensors

The ambient temperature used as input to the model should be the average of the available measurements, except where a measurement is determined to be erroneous, in which case the input to the model should be the average or median of the remaining measurements. Temperature data from nearby meteorological stations, from numerical weather models, or from satellite data may be used when it is expected to improve the accuracy of the test and with mutual consent of the stakeholders. The type of temperature sensor, accuracy, resolution and calibration status of such sensors shall be consistent with the initial model definition.

6.5.7 Substitution of back-up data for erroneous or missing data

In the case where irradiance, wind, temperature and/or production data are missing from the sensors, but are available from another source that is representative of the actual data, the data from the other source may be substituted. The report documents:

a) the rationale for determining that the other measurements are representative, and

b) the uncertainty associated with this substitution.

6.5.8 Out-of-range data or data that are known to be incorrect

Out-of-range data and poor data that result from equipment malfunction (e.g., drift out of calibration, tracker dysfunction, etc.) will be treated as described previously. The method for determining equipment malfunction is based on nearby sensor data or clear sky models, rather than by comparison to the modeled output of the PV system. These data should be identified on a daily basis during the data acquisition so that problems can be resolved before significant impact on the test result.

6.5.9 Missing data

When no data are identified to replace missing weather data and if the inverter was not functioning during that time period, the expected energy for the time period is modeled from the historical weather data and is aggregated with the expected energy for the times of unavailability.

When no data are identified to replace missing weather data and the inverter is functioning, then the expected energy is taken to equal the measured energy during that time period.

If both the measured energy output and the weather data are missing, but the plant was known to be functioning during that time period, the predicted energy (calculated from the model using the historical weather data) is used for both the expected and measured energy during that time period.

If the missing data affect more than a week of performance out of a year, the bias introduced by the above approach may become unacceptable and the parties to the test shall agree upon the best way to handle the missing data, including the possibility that the test may be considered invalid if too many data are missing.

Whenever there is missing data, the method of substitution of data and the uncertainty associated with the substitution shall be included in the report.

6.5.10 Partially missing data or partial unavailability

When data are available for part of a time period (e.g., if the model is using hourly averages and the data are available only for part of the hour) if < 10 % of the electricity or irradiance data are missing, the average of the available data for that time period may be used. For temperature and wind data, this requirement is < 20 % and < 50 %, respectively. When the fraction of missing data is small enough to use the data for that hour, the existing data are averaged for that hour. If the fraction of missing data exceeds these guidelines, the data should be treated as missing data as indicated in 6.5.9. In any case, data for the same time period are handled consistently between both the irradiance and PV performance data. Specifically, if data are substituted because of anomalies associated with inverter start up or shut down, reliable data will be retained for the fraction of the hour when data are available in order to reflect the state of the system as accurately as possible during these hours because the energy generated during these hours typically differs significantly from the expected energy.

6.5.11 Curtailment because of external requirement

In the case of curtailment because of external requirement limiting the uptake of grid that was accounted for by the original model, then the model should correct for this accurately. The expected energy should be calculated in the same way. If curtailment is inconsistently implemented or the algorithm is modified in any way during the test, this shall be documented in the test report.

If the external requirement for limiting the uptake of the grid differs from the original model (either requiring no connection to the grid or an input to the grid that is less than what was originally modeled), the difference between the two external requirements shall be documented as a time of unavailability if the new external requirement is reduced.

In general, unavailability caused by unplanned curtailment is considered to be an external cause of unavailability.

6.5.12 Inverter clipping (constrained operation)

In the case of inverter clipping because the inverter has reached its output capability, it is assumed that the model originally quantified the output assuming this clipping. The expected energy should be calculated in the same way.

6.5.13 Planned outage or force majeure

If a planned outage was documented in the original contract as excludable, then the predicted energy for this time period should be documented in the report to help understand the causes for the reported unavailability. In all cases the expected energy during any outage is included as part of the unavailability calculations and is categorized as caused by externally caused unavailability.

6.5.14 Grid support events (e.g. deviation from unity power factor)

Sometimes the power factor of power plant operation may not be unity. Deviations from a unity power factor can affect power output and should be considered when developing the model. Measurements of the power factor commonly found on the grid where the PV system will be installed may be collected during the planning phase of the project to determine if operation away from a unity power factor may be required. The power factor should be documented during the measurement period and the expected real energy should be calculated using the actual power factor. The method for addressing deviations from unity power factor shall be agreed to by all parties.

6.6 Calculation of expected energy

6.6.1 General

The expected energy generated by the facility is calculated by inputting the measured variable input data during the test period into the performance model. The following is a step-by-step procedure for calculating the expected energy.

6.6.2 Measure inputs

Measure all variable inputs, including meteorological data and plant-specific parameters necessary to update the predicted average-year performance model to account for the actual conditions during the test period. These are specified in Table 2.

6.6.3 Acceptability of data

As necessary, validate the measured variable input data per 6.5.

6.6.4 Time interval consistency

Ensure that the time interval of the measured variable input data is consistent with the input requirements of the performance model. For example, if running an hourly simulation program as the performance model, and higher than one hour resolution data are measured, create an hourly data file by averaging the measured variable inputs at the collected time interval. This procedure should have been defined in 6.2.5. See 6.9 for further details.

6.6.5 Time stamp alignment

Documentation of time stamps should follow ISO 8601:2004. Make sure that hourly data, such as hour ending, hour beginning, or middle-of-hour average, are at the proper time stamp. Also confirm alignment between the collected data and the software conventions for time stamp format (preferably following ISO 8601), treatment of “summer” or “daylight savings” time, inclusion of leap days, and indication of midnight as 0:00 or 24:00, if applicable.

6.6.6 Calculate expected energy during times of unavailability

Input measured meteorological data into the performance model using the details in 6.2 to calculate the expected energy for times of unavailability during the test period.

Document all times of unavailability and the associated expected energy that was not realized during the test period, and, if desired, separate these into energy associated with internally and externally caused unavailability, commenting on any identified causes for unavailability. If the causes of unavailability are identified in this way, then the external-cause-excluded energy availability should be calculated as described in 6.8.1. The effect of non-unity power factor should be included in calculating the real energy.

6.6.7 Calculate expected energy during times of availability

Input measured meteorological data into the performance model using the details in 6.2 to calculate the expected energy for times of availability during the test period. Both real and apparent expected energy should be calculated.

6.6.8 Calculate total expected energy

The total expected energy is calculated as the sum of the expected energies during the times of unavailability and availability as calculated in 6.6.6 and 6.6.7. Both real and apparent expected energy should be calculated.

6.6.9 Analyse discrepancies

If the expected energy deviates from the predicted energy significantly (by more than 10 %), then a root cause diagnosis should be completed. For example, such a diagnosis might be that the weather for the year was unexpected, the simulation model is different than the as-built plant, or there was unusual missing data. The test report should comment on whether the test should still be considered valid.

6.7 Calculation of measured energy

The measured energy is the result of all energy generated by the facility as measured at the metering location during the test period after subtracting out energy associated with parasitic power losses. If substitutions were made for missing data, care should be taken that the measured energy production is estimated in a way that is consistent with how the expected energy for that time period was defined.

6.8 Calculation of metrics from measured data

6.8.1 Calculation of energy performance index and availability

The measured energy (6.7) and expected energy (6.6) are compared:

$$\text{Energy performance index} = \text{Measured} / \text{Expected} \quad (1)$$

$$\text{Energy performance index with units of \%} = (\text{Measured} / \text{Expected}) \times 100\ \% \quad (2)$$

Alternatively, the measured data may be adjusted by the ratio of the predicted/expected energy and compared directly with the initial prediction.

The all-in energy performance index is calculated using the total expected energy, as calculated in 6.6.8.

The in-service energy performance index is calculated using the expected energy during times of availability, as described in 6.6.7.

The external-cause-excluded energy availability is calculated excluding the expected energy during times of unavailability that were caused by circumstances outside of the control of the plant.

The comparison of measured and expected energy includes a consideration of the uncertainties calculated in 6.9, as guided by the initial agreement or test plan.

The energy unavailability is calculated as the ratio of the expected energy for times of unavailability (as defined in 6.6.6) to the total expected energy (as defined in 6.6.8). This ratio may be expressed as a fraction or a percentage.

The energy availability is calculated from the energy unavailability when the energy unavailability is expressed as a fraction:

$$\text{Energy availability} = 1 - \text{energy unavailability} \quad (3)$$

Or, the energy availability is calculated from the energy unavailability when the energy unavailability is expressed as a percentage:

$$\text{Energy availability} = 100\ \% - \text{energy unavailability} \quad (4)$$

6.8.2 Calculation of capacity factor

The capacity factor is a metric commonly applied to power plants and facilitates comparison between PV and other power plants. Its calculation is based on the AC rating of the plant (the lesser of the array DC power rating or the sum of the inverter ratings in the system, as defined in IEC 61724-1) and defines the fraction of electrical energy that was generated compared with what the plant would have generated if it operated at the AC rated power 100 % of the time.

$$\text{Capacity factor} = (E_{out} \text{ / AC rating}) / (24 \times \textit{days}) \quad (5)$$

Where E_{out} is in kWh, the AC rating is in kW as calculated from the sum of the inverter ratings, and *days* is the number of days of the test, typically 365 or 366.

6.8.3 Calculation of performance ratio

The performance ratio (as defined in future IEC 61724-1, 10.3.1) reflects the electrical energy generated relative to the amount of irradiation and the array DC power rating of the plant. It is calculated from:

$$\textit{Performance ratio} = (E_{out} / P_0) / (H_i / G_{i,ref}) \quad (6)$$

where

E_{out} is in kWh,

P_0 is the array DC power rating in kW,

H_i is the plane-of-array irradiation in kW/m^2, and

$G_{i,ref}$ is the irradiance used for rating the modules, usually 1 kW/m^2.

6.9 Uncertainty analysis

As part of the performance guarantee or test plan, the agreement states whether the uncertainty of the measurement is considered. Thus, it can be essential to quantify the uncertainty of the measurement and analysis as part of determining whether the measured performance meets expectations.

The data are collected with an accuracy that is consistent with or better than the descriptions provided in IEC 61724-1 for the chosen Class of measurement. While the measurement accuracy defines the Class of the measurement, the final uncertainty associated with the conclusion of the test will also depend on the fraction of data that is discarded and other factors that are not defined in IEC 61724-1. Subclause 6.2.8 provides additional guidance regarding the uncertainty analysis. The method for calculating the uncertainty should follow what was agreed upon originally. Any changes or refinements shall be agreed upon by all stakeholders to the test.

The uncertainty should be determined for the test result, not for the original prediction. Uncertainties associated with the model used for the original prediction are neglected because the agreement is based on the original prediction. However, uncertainties associated with the measured weather data will introduce uncertainty in the calculated expected energy, which is calculated using the same model.

Both systematic (bias) and random (precision) uncertainties are included in the analysis. The contributions to the uncertainty depend on the model that is used, but generally include uncertainty in the measurements of the irradiance, temperature, and electricity generated.

The uncertainties associated with each sensor are taken from the manufacturer's specification and/or from the calibration report provided by the calibration laboratory. As noted previously, if inspection of the data identifies sensor data with drift or other error outside of the manufacturer's specifications, this data may be discarded by mutual consent of the parties. If such data are not discarded, then the uncertainty is increased to be commensurate with the observed discrepancy.

The uncertainty analysis should also include systematic errors that may arise from misplacement or inappropriate installation of the sensors including:

- irradiance sensor placement (tilt, azimuth, and height);
- albedo difference between model and what is found next to a plane-of-array sensor;

- positioning of temperature sensors relative to model;
- positioning of wind sensor relative to model;
- soiling that has not been addressed;
- snow coverage that has not been addressed.

7 Test procedure documentation

This technical specification attempts to strike a balance between providing prescriptive and specific guidance for testing and allowing the flexibility needed to accommodate each individual and unique system. As a result, it is necessary to define a detailed system-specific test plan for each application of this test method prior to test commencement. This test procedure includes all specific requirements and agreements for test execution and data reduction. All parties to the test should have a sufficient opportunity to review and approve this test procedure. It is recommended that the test procedure contains the following sections:

a) Purpose.
b) Guarantee values and basis for guarantee or performance prediction.
c) Test schedule.
d) Stakeholders and respective roles and responsibilities for details of installation, operation, and data analysis, including responsibility for:
    1) Calibrations.
    2) On-going data quality.
    3) Cleaning of sensors.
    4) Cleaning of array.
    5) Detection of system issues.
    6) Resolution of system issues.
    7) Determination of curtailment (if applicable).
    8) Analysis of data.
    9) Writing/review of final report.
    10) Any other relevant roles.
e) Plant operating and maintenance requirements.
f) Instrumentation.
g) Pre-test uncertainty analysis.
h) Detailed data treatment and reduction methods.
i) Criteria for a successful test.
j) Instrumentation cut-sheets and calibration certificates.
k) Historical meteorological data as an annex.
l) Summary of measured and analysed data as an annex, including the data that have been replaced for each reporting period.

8 Test report

The final test report shall include both the test procedure (either explicitly or by reference) as well as the following items:

a) Description of the party doing the test.
b) Description of the site being tested, including latitude, longitude, and altitude.
c) Description of the site quality attributes such as system integrator name, operations and maintenance operations provider names, etc.

d) Description of the system configuration including the manufacturer and model type of key components used such as PV modules, inverters, MV transformers, etc.

e) Description of the system being tested, specifically the meteorological aspects including Table 2, which describes all of the inputs to the model. Specific note should be made of whether there are parasitic loads and how these are documented by the test.

f) Description of the historical meteorological data that were used for the initial prediction as in Table 1 and/or inclusion of the raw data as an annex if the referenced data are not publically available.

g) A summary of the initial performance prediction that was made based on the historical data.

h) A summary of the definition of the meteorological data taken during the test as described in Table 2, including calibration data for all sensors (sensor identification, test laboratory, date of test, and observed changes in calibration).

i) A summary of the definition of the system output data collected during the test as defined in Table 2, including records of completed calibrations.

j) The raw data that were collected during the test, including note of which data, if any, were flagged as being associated with times of unavailability (recommended to be an annex to the report).

k) An explanation of why data (if any) were replaced.

l) A list of any deviations from the test procedure and why these were taken.

m) Summary of (see example in Annex A):

   1) the expected electrical production calculated from the measured weather data during times of availability (6.6.7),

   2) the expected electrical production during times of unavailability (6.6.6), separated into the two categories according to cause (internal or external, if desired),

   3) the total expected electrical production during the entire test period (6.6.8),

   4) the measured electrical production (6.7),

   5) the calculated energy availability (6.8),

   6) the all-in and in-service energy performance indices as either a fraction or a percentage (6.8),

   7) preferably, include a breakdown of the causes for the energy performance index being less than 100 %.

n) Description of uncertainty analysis and statement of uncertainty associated with the expected performance and availability, based on the uncertainty of the weather measurements (see 6.9).

o) Description of uncertainty analysis and statement of the uncertainty associated with the measured performance (see 6.9).

For items that are duplicated on both lists, the final report should duplicate the original information, verify that the project was executed as originally planned, or note modifications that occurred during the test period.

Annex A
(informative)

Example calculation – Calculations for the energy performance indices

A set of fictitious measurements is summarized in Table A.1. The calculations for the energy performance indices and other metrics are then applied to this dataset as a clarifying example.

Table A.1 – Fictitious data to demonstrate calculation

Date range	**Description**	**Irradiation** kWh/m_2	**Expected energy** MWh					**Measure d'energy** MWh
			System is availa-ble	**System is unavaila-ble for internal reason**	**System is unavailable for external reason**	**Total for times of unavaila-bililty**	**Total**	
Jan. 1 – June 30	Uninterrupted operation	1 000	900	0	0	0	**900**	**910**
July 1 – July 2	One of ten inverters is off line	10	9	1	0	1	**10**	**9**
July 3 – July 23	Uninterrupted operation	100	100	0	0	0	**100**	**99**
July 24 – July 27	Grid is off line because of transformer failure	20	0	0	20	20	**20**	**0**
July 28 – Dec 31	Uninterrupted operation	800	800	0	0	0	**800**	**801**
Totals		**1 930**	**1 809**	**1**	**20**	**21**	**1 830**	**1 819**

Summary of calculations:

a) Expected electrical production calculated from the measured weather data during times of availability (6.6.7) = 1 809 MWh.

b) Expected electrical production during times of unavailability (6.6.6) = 1 MWh for internal reasons, 20 MWh for external reasons, or 21 MWh for all times of unavailability.

c) Total expected electrical production during the entire test period (6.6.8) = 1 830 MWh.

d) Measured electrical production (6.7) = 1 819 MWh.

e) Energy availability (6.8.1) = 1 809/1 830 = 0,989 = 98,9 %.

f) All-in energy performance index (6.8.1) = 1 819/1 830 = 99,4 % including external outages or = 1 819/1 810 = 100,5 % without external outages.

g) In-service energy performance index (6.8.1) = 1 819/1 809 = 100,6 %.

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[2] To be published.

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