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TECHNICAL SPECIFICATION

Photovoltaic system performance –
Part 3: Energy evaluation method

colour inside

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FOREWORD

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- 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- withdrawn,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.

The contents of the corrigendum of February 2018 have been included in this copy.

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