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Photovoltaic system performance –
Part 2: Capacity evaluation method

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INTERNATIONAL
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PHOTOVOLTAIC SYSTEM PERFORMANCE –

Part 2: Capacity evaluation method

FOREWORD

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- 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 61724-2, which is a technical specification, has been prepared by IEC technical committee 82: Solar photovoltaic energy systems.

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

Enquiry draft	Report on voting
82/1101/DTS	82/1159/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 document 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- withdrawn,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.

INTRODUCTION

The performance of a PV system is dependent on the weather, seasonal effects, and other intermittent issues, so measurement of the performance of a PV system is expected to give variable results. IEC 62446-1, *Photovoltaic (PV) systems – Requirements for testing, documentation and maintenance – Part 1 Grid connected – Documentation, commissioning tests and inspection*, describes a procedure for ensuring that the plant is constructed correctly, but does not attempt to verify that the output of the plant meets the design specifications. IEC 61724-1[1], *Photovoltaic system performance – Part 1: Monitoring*, defines the performance data that may be collected, but does not define how to analyze that data in comparison to predicted performance. ASTM E2848-13 *Standard test method for reporting photovoltaic non-concentrator system performance* describes a method for determining the power output of a photovoltaic system based on a regression. IEC TS 61724-3 *Photovoltaic system performance – Part 3: Energy evaluation method* describes a one-year test that evaluates performance over the full range of operating conditions and is the preferred method for evaluating system performance. However, it is essential that plant performance can also be quantified with a shorter test, even if there can be higher uncertainty associated with that test. This document is designed to complete an evaluation in a short time as a complement to IEC TS 61724-3. As a capacity test, it measures power (not energy) at a specified set of reference conditions (which can differ from standard test conditions that have been designed to facilitate indoor measurements). The method in IEC TS 61724-2 is a non-regression-based method for determining power output.

This method uses the design parameters of the plant to quantify a correction factor for comparing the plant's measured performance to the performance targeted under reference conditions. In other words, the measured performance, adjusted by the correction factor, is then compared with the target plant performance to identify whether the plant operates above or below expectations at the target reference conditions.

Multiple aspects of PV system quality are dependent on both the weather and the system's 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 that can be difficult to simulate precisely. However, the module-mounting configuration also affects the module temperature, and the mounting is an aspect of the system that is being tested. This document presents a 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.

It is to be noted that when the output of a PV system exceeds the capability of the inverter, the output of the system is defined more by the inverter operation than by the PV modules. In this case, the measurement of the capacity of the plant to generate electricity is complicated by the need to differentiate situations in which the inverter is saturated and when the output of the PV system reflects the module performance. For PV plants with high DC-to-AC power ratios, the operation of the plant can reflect the capability of the inverters for the majority of the day, with the capability of the DC array only being measurable for a short time in the morning and in the evening. In this case, it can be necessary to disconnect parts of the DC array to reduce the DC-to-AC power ratio during the measurement period.

IEC TS 61724-2 is applicable to times when the system is fully available.

Methods presented in this document can be used in place of ASTM E2848-13 to determine photovoltaic system performance.

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1 Under preparation. Stage at time of publication: IEC/FDIS 61724-1:2016

PHOTOVOLTAIC SYSTEM PERFORMANCE –

Part 2: Capacity evaluation method

1 Scope

This part of IEC 61724 defines a procedure for measuring and analyzing the power production of a specific photovoltaic system with the goal of evaluating the quality of the PV system performance. The test is intended to be applied during a relatively short time period (a few relatively sunny days).

In this procedure, actual photovoltaic system power produced is measured and compared to the power expected for the observed weather based on the design parameters of the system. The expected power under reference and measured conditions are typically derived from the design parameters that were used to derive the performance target for the plant as agreed to prior to the commencement of the test. For cases when a power model was not developed during the plant design, a simple model that increases transparency is presented in the annexes as a possible approach.

The intent of this document is to specify a framework procedure for comparing the measured power produced against the expected power from a PV system on relatively sunny days. This test procedure is intended for application to grid-connected photovoltaic systems that include at least one inverter and the associated hardware.

The performance of the system is quantified both during times when the inverters are maximum-power-point tracking and during times when the system power is limited by the output capability of the inverter or interconnection limit, reducing the system output relative to what it would have been with an inverter with generation freely following irradiance, if this condition is relevant.

This procedure can be applied to any PV system, including concentrator photovoltaic systems, using the irradiance (direct or global) that is relevant to the performance of the system.

This test procedure was designed and drafted with a primary goal of facilitating the documentation of a performance target, but it can also be used to verify 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 intent is to create a methodology that can be used whenever the goal is to verify system performance at a specific reference condition chosen to be a frequently observed condition. A more complete evaluation of plant performance can be accomplished by using the complementary Technical Specification IEC TS 61724-3, *Photovoltaic system performance – Part 3: Energy evaluation method*.

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[2], *Photovoltaic system performance – Part 1: Monitoring*

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

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

ASME, *Performance Test Code 19.1*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 61724-1, IEC TS 61836, the ASME Performance Test Code 19.1 and the following and definitions 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

3.1
constrained operation
operation of a plant in a condition when all inverters are limited by the capability of the inverters (otherwise referred to as inverter saturation) rather than by the output from the PV array, as is observed for a system with high DC rating relative to the AC rating and when the irradiance is high

3.2
correction factor
ratio of the power expected for the reference conditions to the power expected for the measured conditions

3.3
curtailed operation
output of the inverter(s) is limited due to external reasons such as inability of the local grid to receive the power or contractual agreement

3.4
expected power
power generation of a PV system that is expected for actual weather data collected at the site during operation of the system based on the design parameters of the system

3.5
measured power
electric power that is generated by the PV system

Note 1 to entry: See also 3.14 to define the location of measurement.

3.6
model
simulation model used to calculate the predicted or expected PV power generation based on the design parameters of the system

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2 Under preparation. Stage at time of publication: IEC/FDIS 61724-1:2016.

3.7
parties to 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 parties to the test may in some cases be a single individual or company.

3.8
performance target
power generation expected from a PV system under reference conditions based on the design parameters of the system

3.9
POA
plane of array
physical plane in which the modules are deployed according to the orientation of the system under test

3.10
system operation
attributes of the system performance that can be traced to the quality of operations and maintenance service provided

Note 1 to entry: For example, low availability of the system may be a result of slow response to a disruption.

Note 2 to entry: If different entities are responsible for the installation and the operations, then it is useful to distinguish between aspects of the performance that are traced to the initial installation and those that are traced to the operation.

3.11
system quality
attributes of the system performance that can be traced to the quality of the system design, the quality of the system components and the quality of installation

Note 1 to entry: Generally, the installer is held responsible for the system quality.

3.12
target power
power generation expected from a PV system at target reference conditions (TRC) based on the design parameters of the system

3.13
target reference conditions
TRC
reference conditions at which the expected power is the target power, which include irradiance, ambient temperature, wind, and any other parameter used to define the target performance

Note 1 to entry: See 6.1.3.

3.14
test boundary
physical differentiation between what is considered to be part of the system under test and what is outside of the system

Note 1 to entry: In addition to defining the physical boundaries and which electricity meter is quantifying the electricity production, the test boundary definition includes the location, type, and accuracy class of all measurement devices.

Note 2 to entry: To facilitate the description of the test method, this document defines a default test boundary. Ambient temperature and wind speed lie outside of this default test boundary. When this standard is applied using class A (high precision) measurements as defined in IEC 61724-1, soiling will lie inside of the default test boundary, consistent with the IEC 61724-1 class A requirement that the sensors be cleaned, quantifying the irradiance without interference from soiling. When this standard is applied using class B (medium precision) measurements as defined in IEC 61724-1, soiling will lie outside of the default test boundary and it is expected that sensors will not be cleaned, allowing soiling to be considered as part of the weather. The alignment of the array is brought inside of the test boundary by confirming the alignment of the plane of array sensor. 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 here and as an example for how to define the test boundary. However, if the purpose of application of the test is to measure degradation rates on small systems, it may be preferable to measure module temperature in consistent locations on the modules.

3.15
unconstrained operation
outputs of all inverters freely following the DC array's capability to respond to the solar insolation rather than being limited by the capability of the inverters or curtailing influences

3.16
maximum-power-point tracking
inverter accurately maximizing the DC array's output

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 at which the test may be performed is the smallest level of AC power generating assembly capable of independent on-grid operation.

When PV plant construction is divided into phases, it is recommended that the test be applied at the highest level, that which encompasses the entire PV project. However, the test may be applied to smaller subsets of the plant as they become available for interconnection. If desired, upon full plant completion the test may be applied again in a way that encompasses the entire plant, taking into account expected degradation in accordance with the model accepted by the parties to the test as well as soiling levels if not able to wash the entire array before testing. In every case, the system boundary and test boundary shall be explicitly defined.

Some PV modules show measurable performance changes within hours or days of being installed in the field; others do not. The time duration of the test should be negotiated between the parties using the manufacturer's guidance for the number of days of exposure or the irradiance exposure needed for the plant to reach the targeted performance along with the details of the actual installation and interconnection dates. Any metastability (variation in module efficiency that depends on previous operating conditions) and degradation assumptions (including those with short and long time constants) should be agreed to by all parties and documented as part of the target description.

NOTE 1 Newly installed modules can undergo light induced degradation (LID), a transient effect that reduces the photovoltaic conversion efficiency of the modules when exposed to light.

NOTE 2 The efficiency of some modules can vary over a year depending on irradiation and temperature history due to metastabilities.

It is recommended that the test include data from at least two days if sufficient stable data are acquired. The test may be extended to seven or more days if desired to assess repeatability or if weather is volatile. The filtering criteria for selecting relatively stable times are described in Clause 6.

The test may be completed at any time of year, though the deviation from reference conditions and the effects of variable angle of incidence may increase the uncertainty at some times of the year.

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