BS EN 61829:2016

BSI Standards Publication

Photovoltaic (PV) array — On-site measurement of current-voltage characteristics

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National foreword

This British Standard is the UK implementation of EN 61829:2016. It is identical to IEC 61829:2015. It supersedes BS EN 61829:1998 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee GEL/82, Photovoltaic Energy Systems.

A list of organizations represented on this committee can be obtained on request to its secretary.

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English Version

Photovoltaic (PV) array - On-site measurement of current-voltage characteristics (IEC 61829:2015)

Champ de modules photovoltaïques (PV) - Mesurage sur site des caractéristiques courant-tension (IEC 61829:2015)

Photovoltaische (PV) Modulgruppen - Messen der Strom-/Spannungskennlinien am Einsatzort (IEC 61829:2015)

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European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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European foreword

The text of document 82/1008/FDIS, future edition 2 of IEC 61829, prepared by IEC/TC 82 "Solar photovoltaic energy systems" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 61829:2016.

The following dates are fixed:

• latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2016-08-26
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2019-02-26

This document supersedes EN 61829:1998.

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The text of the International Standard IEC 61829:2015 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 60904-5	NOTE	Harmonized as EN 60904-5.
IEC 61853-1:2011	NOTE	Harmonized as EN 61853-1:2011 (not modified).
ISO/IEC 17025	NOTE	Harmonized as EN ISO/IEC 17025.

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE 1 When an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu

Publication	Year	Title	EN/HD	Year
IEC 60891	-	Photovoltaic devices - Procedures for temperature and irradiance corrections to measured I-V characteristics	EN 60891	-
IEC 60904-1	-	Photovoltaic devices - Part 1: Measurement of photovoltaic current-voltage characteristics	EN 60904-1	-
IEC 60904-2	-	Photovoltaic devices - Part 2: Requirements for photovoltaic reference devices	EN 60904-2	-
IEC 60904-3	-	Photovoltaic devices - Part 3: Measurement principles for terrestrial photovoltaic (PV) solar devices with reference spectral irradiance data	EN 60904-3	-
IEC 60904-4	-	Photovoltaic devices - Part 4: Reference solar devices - Procedures for establishing calibration traceability	EN 60904-4	-
IEC 60904-7	-	Photovoltaic devices - Part 7: Computation of the spectral mismatch correction for measurements of photovoltaic devices	EN 60904-7	-
IEC 60904-10	-	Photovoltaic devices - Part 10: Methods of linearity measurement	EN 60904-10	-

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

PHOTOVOLTAIC (PV) ARRAY – ON-SITE MEASUREMENT OF CURRENT-VOLTAGE CHARACTERISTICS

FOREWORD

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International Standard IEC 61829 has been prepared by IEC technical committee 82: Solar photovoltaic energy systems.

This second edition cancels and replaces the first edition published in 1995. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) it addresses many outdated procedures;
b) it accommodates commonly used commercial I-V curve tracers;
c) it provides a more practical approach for addressing field uncertainties;
d) it removes and replaces procedures with references to other updated and pertinent standards, including the IEC 60904 series, and IEC 60891.

The result is a much more practical and useful standard.

The text of this standard is based on the following documents:

FDIS	Report on voting
82/1008/FDIS	82/1041/RVD

Full information on the voting for the approval of this standard 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.

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

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

INTRODUCTION

The performance of photovoltaic (PV) systems over their decades-long life time is determined by comparing measured power production with the expected production as estimated from recorded weather conditions. Continuous measurements of system- or subsystem-level operating output can detect underperforming arrays but are not well suited for tracking degradation with any accuracy, or for identifying the weaknesses or failure modes that may exist within the array. Field I-V curve measurements offer a practical method of *in situ* benchmarking or troubleshooting for modules, strings and arrays. This International Standard specifies methods and approaches for field I-V curve measurements and calculations, and includes guidance for addressing the uncertainties associated with measurement devices and array configurations. Consistent and proper application of I-V curve measurement procedures helps to ensure that a PV system's performance is adequately characterized over time.

PHOTOVOLTAIC (PV) ARRAY – ON-SITE MEASUREMENT OF CURRENT-VOLTAGE CHARACTERISTICS

1 Scope

This International Standard specifies procedures for on-site measurement of flat-plate photovoltaic (PV) array characteristics, the accompanying meteorological conditions, and use of these for translating to standard test conditions (STC) or other selected conditions.

Measurements of PV array current-voltage (I-V) characteristics under actual on-site conditions and their translation to reference test conditions (RTC) can provide:

- data for power rating or capacity testing;
- verification of installed array power performance relative to design specifications;
- detection of possible differences between on-site module characteristics and laboratory or factory measurements;
- detection of possible performance degradation of modules and arrays with respect to on-site initial data;
- detection of possible module or array failures or poor performance.

For a particular module, on-site measurements translated to STC can be directly compared with results previously obtained in a laboratory or factory for that module. Corrections for differences in the spectral or spatial response of the reference devices may need to be assessed as specified in IEC 60904.

On-site array measurements are affected by diode, cable, and mismatch losses, soiling and shading, degradation due to aging, and other uncontrolled effects. Therefore, they are not expected to be equal to the product of the number of modules and the respective module data.

If a PV array is formed with sub-arrays of different tilt, orientation, technology, or electrical configuration, the procedure specified in this International Standard is applied to each unique PV sub-array of interest.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

IEC 60904-1, *Photovoltaic devices – Part 1: Measurement of photovoltaic current-voltage characteristics*

IEC 60904-2, *Photovoltaic devices – Part 2: Requirements for photovoltaic reference devices*

IEC 60904-3, *Photovoltaic devices – Part 3: Measurement principles for terrestrial photovoltaic (PV) solar devices with reference spectral irradiance data*

IEC 60904-4, *Photovoltaic devices – Part 4: Reference solar devices – Procedures for establishing calibration traceability*

IEC60904-7, *Photovoltaic devices – Part 7: Computation of the spectral mismatch correction for measurements of photovoltaic devices*

IEC 60904-10, *Photovoltaic devices – Part 10: Methods for linearity measurements*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
pyranometer
radiometer normally used to measure global irradiance on a horizontal plane

Note 1 to entry: A pyranometer can also be used to measure diffuse irradiance when used with a shade ring or disc.

Note 2 to entry: A pyranometer can also be used to measure total irradiance on an inclined plane, which would include radiation reflected from the foreground.

[SOURCE: IEC TS 61836:2007, 3.5.7 b)]

3.2
radiometer
instrument for measuring the intensity of solar irradiance

Note 1 to entry: See also IEC 60050-845:1987, 845-05-06.

Note 2 to entry: Commonly, a radiometer is a thermal instrument using thermocouples or thermopiles and is independent of wavelength.

[SOURCE: IEC TS 61836:2007, 3.5.7]

3.3
spectroradiometer
instrument used to measure spectral irradiance distribution of an incident radiation as a function of wavelength

[SOURCE: IEC TS 61836:2007, 3.5.7 d)]

4 Apparatus

4.1 Irradiance measurements in natural sunlight

The irradiance measurements shall be made using a PV reference device packaged and calibrated in conformance with IEC 60904-2 or with a pyranometer. PV reference devices shall have spectral matching addressed by one of the following methods.

a) The reference device is spectrally matched to the modules in the array under test.

b) A spectral mismatch correction should be performed in conformance with IEC 60904-7. The reference device shall be linear in short-circuit current as defined in IEC 60904-10 over the irradiance range of interest.

c) If spectral measurements are not practical, uncertainties associated with the irradiance measurement and specific sensors used should be reported as part of the analysis. Measurements should be completed under clear-sky conditions with the nearest clouds at least 15° from the sun and the sensor mounted in the plane of the items under test as discussed elsewhere.

To be considered spectrally matched, a reference device shall be constructed using the same cell technology and encapsulation package as the modules in the array under test. If this is not the case, the spectral mismatch shall be reported or an estimate of the uncertainty shall be made as part of the analysis. Spectral mismatch is of particular concern with thin film modules.

For modules that concentrate sunlight with an optical concentration ratio of greater than 3:1, at least one radiometer shall provide a collimated measure of direct normal irradiance (IEC 60904-4).

The temperature of the reference device shall be measured using instrumentation with an accuracy of ±1 °C with repeatability of ±0,5 °C. If the reference device has internal correction for temperature or if the reference device is a pyranometer with a temperature coefficient $<$ 0,02 %/°C, temperature measurement is not required. However, the mounting of a thermopile shall be consistent with the conditions used for calibrating it.

A suitable means is required to check that the reference device and the modules are coplanar within ±2° accuracy.

NOTE A digital level or other calibrated device can be used to confirm coplanar modules.

An additional pyranometer is required for checking the uniformity of the in-plane radiance. This radiometer shall provide a stable output, but need not be calibrated since it is only used for relative measurements.

If spectral corrections will be made, a spectroradiometer is required that is capable of measuring the spectral irradiance of the sunlight in the range of the spectral response of the test specimen and the reference device.

4.2 Module temperature measurements

The temperature of the module backsheets of the array under test shall be measured using instrumentation with an accuracy of ±1 °C with repeatability of ±0,5 °C. It is recommended to mechanically attach a flat thermal sensor with fine leads directly to the backsheet in the middle of a module and at least 10 cm from any junction box, but opposite an active part of the module. The attachment method should not change the temperature of the module, as may be identified by infrared imaging from the front of the module. An optical thermometer may be used only if the backsheet emissivity has been calibrated well enough that the optical thermometer accuracy is within 1 °C. A handheld contact thermometer may be used only if it has been verified that the accuracy is within 1 °C.

NOTE Most handheld thermometers conduct heat into the handle of the thermometer causing a temperature reading that is less than the actual backsheet temperature.

4.3 Electrical measurements

A self-contained I-V curve tracing unit shall be able to accommodate the anticipated array voltage, current, and power levels. The rate at which the unit sweeps the curve should be fast enough to avoid changes in irradiance during the curve but slow enough to ensure that the PV modules are achieving steady state conditions. Other equipment suitable for sweeping the array through a significant portion of its I-V curve may be used though any limitations with respect to the above requirements shall be clearly stated in the measurement report.

The I-V curve tracing unit shall be able to measure voltages and currents with an accuracy of ±1 % of the open-circuit voltage and short-circuit current using independent leads from the terminals of the array under test and keeping all wires that would add series resistance as short as possible. If only two leads are used, the error introduced shall be included in the uncertainty analysis. The measurement ranges of the data acquisition should be carefully chosen to match the array being measured.

The instrumentation should be capable of measuring current at zero voltage, using a variable bias (preferably electronic) to offset the voltage drop across the external series resistance. If the instrumentation is not capable of reaching zero voltage bias, extrapolation may be used, but the instrumentation shall be able to reach a voltage bias of 3 % of the device open-circuit voltage.

5 Measurement procedure

5.1 Choose and record appropriate conditions for measurement

The ideal conditions for an outdoor I-V curve test are clear skies (no clouds and no fog) and little wind. Variable irradiance and wind both introduce temperature transients in the array that confound the accuracy of the measurements. In practice, time and contractual constraints limit the periods in which it is possible to perform a test. Therefore, it is the responsibility of the person(s) conducting the test to ensure that all tests are performed under the most stable conditions possible, and that special attention is given to noting variable irradiance, wind, and array temperatures. For example, even though irradiance during the course of the I-V measurement does not vary more than 2 %, it may be that the irradiance increased by 30 % in the 5 min leading up to the test, and that the array temperature may not have equilibrated before the test was run.

Record the weather conditions, qualitatively, and periodically note when and how conditions change over the period during which I-V curves are being taken. It is recommended to take a picture of the sky and record the time periodically.

NOTE This information is for identifying potentially erroneous data, and is not directly used in the analysis.

5.2 Clean the modules

The cleanliness of the module surfaces shall be consistent with the intent of the test. The state of cleanliness, whether or not cleaning has been attempted, shall be reported.

If the intent of the test is to detect any possible differences between fielded modules and laboratory or factory measurements, either

a) the array shall be cleaned thoroughly immediately prior to the measurement, or
b) a representative string shall be tested immediately prior to and immediately after a thorough cleaning. The level of soil on the array is determined by comparing the results of the string I-V test before and after the cleaning. Such an assessment of soiling should be conducted under very stable irradiance conditions, and care should be taken to allow the string's temperature to fully stabilize after the washing.

If the intent of the test is to document the performance of the array in a soiled state, then no cleaning is expected, but the soiled state shall be documented through such things as photographs and weather records defining the most recent rain.

5.3 Check for shading

Verify that there is no shading of the direct beam component of irradiance on the array under test and that the environmental conditions meet the requirements of IEC 60904-1, with the following exception: For measurements to be extrapolated to STC (Standard Test Conditions, see Annex A), the total in-plane irradiance shall be at least 700 W/m^2 and the incident sun beam shall be within a cone of 45° full-aperture angle around the module normal.

There may be times when it is desirable to measure an I-V curve when the array is partially shaded either by nearby objects or self-shading. This procedure may be used for the measurement procedure, but the correction of the shaded *I-V* curve to standard test conditions is outside of the scope of this International Standard, since the meaning of the standard conditions is unclear in this case.

5.4 Confirm uniformity of irradiance over the test array

Using a suitable pyranometer, check the uniformity of the in-plane irradiance over the area to be tested as needed and select a module on which the irradiance is typical. This step is useful if row-based array orientations, for example, create some non-uniformity in diffuse irradiance. Pyranomter measurements may be used to reveal variations and select the modules with irradiance that is most representative of the irradiance on the total array. The choice of these selected modules is based on the principle and example indicated in Figure 1. If the purpose of the *I-V* measurements is to document stability of the array over time, then the uniformity need not be checked, but the geometry of the test should remain consistent to facilitate consistent results.

Selecting a typical module may be straightforward when measuring a single string if the modules are all located in one row. Combiner box level measurements include modules that span several rows, so uniformity should be checked over the applicable rows. Selection of a typical irradiance model may be limited by the length of the pyranometer conductors, therefore any variation from what is considered typical should be noted in the report.

In the event that a particular module or string is not accessible, such as in a complicated roof-mounted system, and the measurement is conducted from a combiner box, it is acceptable to place and orient the reference device in a practical location that best approximates the condition of the module or string. The uncertainty associated with these measurement approaches shall be evaluated and included in the report.

5.5 Mount the reference device

Mount the reference device as near as possible to and co-planar with the module identified in 4.4. The reference device should be placed such that no shade of the direct beam component of irradiance is present on the device and any reflection or diffuse shading is consistent with the reflection and diffuse shading apparent to the array under test. Connect to the necessary instrumentation.

The reference device shall be mounted such that it is coplanar within ±2° of the average orientation of the active surfaces of the modules under test.

If the modules are not coplanar, the choice of irradiance plane of measurement shall be described in the report. If the array under test has inconsistent alignment, separate measurements should be done for each subsection of the array, and/or the variability of alignment of the array should be noted in the report.

5.6 Prepare to measure the array temperature

Select one or more modules whose operating temperatures are representative of the array under test. The choice of these selected modules is based on the principle and example indicated in Figure 1 and should be determined by making sample measurements as follows:

a) at minimally one centrally located module;

b) at minimally one module that has been identified as one of the coolest because of being upstream in the wind or because of being near the ground with the best cooling caused by convection;

c) at minimally one module that has been identified as one of the hottest because of being downstream in the wind, because of being at the top of the array when cooling is caused by convection, or because of being in a location that has little circulation.

For each selected module, attach the appropriate thermocouple device in at least one location.

NOTE 1 IEC 61853-1:2011, 8.3.1 recommends three locations to address non-uniformity within the module; however, this may be impractical for large numbers of tests.

NOTE 2 In some cases it may be possible to recruit module temperature measurements from permanently installed temperature sensors on module backsheets. If this is possible, it is important to synchronize all test equipment clocks with the on-site data acquisition system and check to ensure that modules measured with such permanently installed sensors are indeed representative of the array under test.

In the event that the backs of the modules are not accessible, such as in some roof-mounted systems, it is acceptable to measure the temperature from the front of the module or to use a model for module temperature that has been previously validated. The uncertainty associated with these measurement approaches shall be evaluated and included in the report.

5.7 Disconnect the array

Disconnect the array to be measured from any load such as battery or power conditioning equipment. If necessary, isolate the portion of the array to be tested by disconnecting switches and fuses as needed.

5.8 Connect the measurement system to the array to be measured

Connect the variable load/I-V curve tracing unit to the array to be tested, considering the best location for measurement.

In general, the location of the connection to the array for voltage and current testing should be carefully considered relative to the intent of the test.

If the intent of the test is to detect possible differences between the modules on site and laboratory or factory test data, then the voltage and current measurements should take place as close to the modules as possible, with cabling and other DC components between the modules at the point of measurement minimized.

The DC combiner box output is a convenient location for testing arrays. Strings may be tested from the respective inputs to the DC combiner box or they may be disconnected from their home runs at the location of the module string to minimize the length of cable between the module string and the test equipment.

If the intent of the test is to quantify the power performance of the array, then the ideal location for test is at the inputs to the inverter or as close to the inverter as can be accessed. In the event that the test equipment cannot accept the short-circuit current of the array at this level, then disconnects within the array should be used to reduce the current to the test equipment.

It is preferable to use I-V curve tracing units that use a four-terminal measurement method. Separate connections for the current and voltage measurements eliminate the lead and contact resistance from the measurement. Use of this method avoids the need to compensate for the series resistance of the test wires and connections, even with extended length cables. Report the point of connection.

5.9 Record electrical data and measurement conditions

Record the following:

a) the temperature of the test array;
b) the irradiance sensor output;
c) a qualitative assessment of the variability of irradiance, temperature and wind speed in the 15 min prior to the test;

d) the temperature of the irradiance sensor (if required);
e) the current-voltage characteristic of the test array;
f) the temperature of the test array;
g) the irradiance sensor output;
h) the temperature of the irradiance sensor (if required);
i) an image of the sky to show clouds relative to the sun position (optional).

The temperature and irradiance measurements are conducted before and after the *I*-*V* scan to verify that they have not changed more than 1 °C or 0,5 %, respectively. If slow (manual) load scanning is used, record V_{oc} of the reference device immediately prior to the *I*-*V* scan.

Scan the *I*-*V* curve by varying the load such that there will be a sufficient number of points to define a smooth *I*-*V* characteristic. If slow (manual) load scanning is used (e.g. using a rheostat as load), the irradiance must be recorded simultaneously with each *I*-*V* point to obtain the irradiance, *G,* corresponding to that point. The total variation in radiance over the whole scan should be no more than 2 %. If not, repeat the scan. If a fast load scanning device such as a capacitor load (total scan time less than 0,1 s) is used, it is sufficient to record the current of the reference device at the start and end of the scan.

If slow (manual) scanning is used, remeasure the V_{oc} of the reference device. If this value differs by more than 1 % from the one obtained in 5.9 a), repeat the measurement from there.

The short-circuit current shall be measured at zero voltage, using a variable bias (preferably electronic) to offset the voltage drop across the external series resistance. Alternatively, short circuit current may be extrapolated from the current-voltage characteristic. The curve may be extrapolated to zero voltage provided that voltage drop is not higher than 3 % of the device open-circuit voltage and that there is a linear relationship between current and voltage.

Enough *I*-*V* pair measurements should be taken during the sweep to provide better than 1 % current and voltage resolution at the maximum power point.

5.10 Record spectral data

If a pyranometer or an unmatched reference device is used for irradiance measurements, perform a measurement of spectral irradiance using a spectroradiometer. During the period of measurement, multiple spectroradiometric scans should be completed to evaluate the stability of these measurements. At a minimum, the spectral irradiance must be measured just before and just after the *I*-*V* curve is measured.

When no spectral irradiance data are available the match of the reference device to the specimen and the air mass conditions should be checked carefully. Measurement should be performed on a clear sunny day (no observable clouds around the sun, with diffuse contents of solar irradiance not higher than 30 %). For thin films, irradiance should be within 20 % of the reference irradiance (Annex A).

5.11 Typical and extreme module selection

Extreme modules are those that have more or less than average sky exposure or cooling due to their location in the array, relative to the more central modules. The apparent sky consideration is not related to direct shade, but to the limiting of the module’s view of open sky. Cooling is dependent on wind direction (and speed), location within convection cells, and wherever air movement is impeded by local obstructions. Therefore, the extreme modules are those at ends of rows, the bottom or top of rows containing more than 2 stacked modules, etc. Central modules are those centred both vertically and horizontally to the extent possible. See Figure 1. Sampling of measurements using pyranometers and checking temperatures is the best basis for verifying the central module selection.

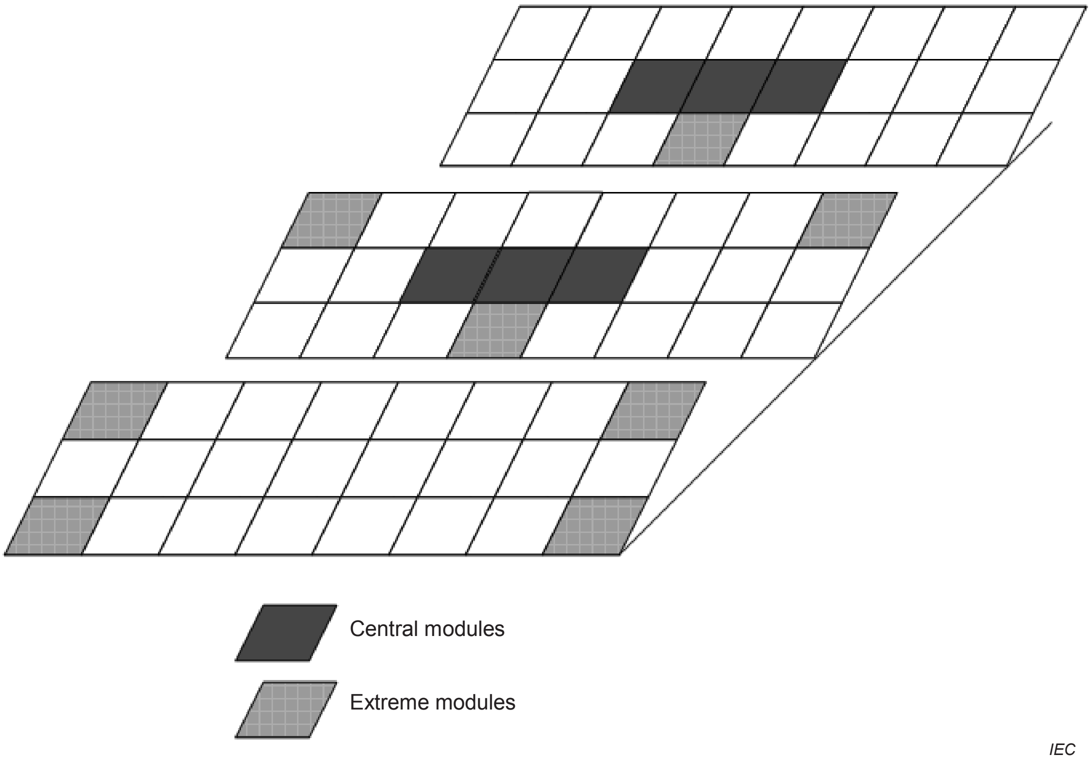

Figure 1 – Examples of extreme and central modules

6 Analysis

6.1 Adjust the measured irradiance for any deviation from reference conditions

Unless using a pyranometer, correct the measured current (or voltage) of the irradiance reference device using the following equation:

$$I_{SRO} = I_{MR3} + \alpha_R (T_{RO} - T_3)$$

where

- T_{RO} is the standard temperature of the reference device for which its calibration value is given;
- T_3 is the measured temperature of the reference device;
- I_{SRO} is the short-circuit current (or voltage output) of the reference device translated to the reference device temperature for which the device has been calibrated, T_{RO};
- I_{MR3} is the measured short-circuit current (in mA or mV) (or voltage output) of the reference device at the measured temperature T_3;
- α_R is the current (or voltage) temperature coefficient of the reference device (in units of mA/°C or mV/°C) within the temperature and irradiance range of interest.

If a pyranometer or unmatched reference device was used as the reference device, calculate the effective irradiance for the array under test under the AM1,5 spectrum (see IEC 60904-3) using its spectral response data (apply IEC 60904-7).

6.2 Compute the average temperature of the array under test

Take the average of the central module temperature measurements as specified in 5.6 and use high and low values on the outlier modules to define the uncertainty for the report.

6.3 Compute the junction temperature

Adjust the temperature calculated in 6.2 for the difference between the actual junction temperature and the measured back-of-module temperature. If the junction temperature has not been measured by another technique, assume that the temperature difference is 2 °C for 1 000 W/m^2 and scale linearly this difference to the measured irradiance.

6.4 Translate the measurement to the desired test condition

Correct the measured current-voltage characteristic to the desired irradiance and temperature conditions in accordance with IEC 60891 (for linear devices) using the irradiance and temperature values computed in 6.1 and 6.3. For non- linear devices, refer to IEC 60904-10 for guidance in determining over what range the device can be considered to be linear. The series resistance value will either be given by the supplier or determined by measurement as in IEC 60891.

If the measured I-V curve shows evidence of variable irradiance or variable module performance within the array, evaluate the uncertainty associated with the correction.

6.5 Correct for soiling losses

If expected as part of the measurement procedure, correct the measured current-voltage characteristic for any known and quantifiable effects such as soiling. If the soiling level of the array was measured according to 5.2, increase the current values by an amount equivalent to the soiling loss measured.

It may be advisable to correct for wiring ohmic losses as well if there are long cable runs between the array under test and the test device. This can be done using standard resistive values for the conductor and the current measured. It is not recommended to try to correct for module mismatch or degradation because measurement error may be significantly larger than the estimated losses themselves.

7 Test report

A test report with measured performance characteristics and test results shall be prepared by the test agency in accordance with ISO 17025. The test report shall contain the following data:

a) a title;
b) name and address of the test laboratory and location where the tests were carried out;
c) unique identification of the report and of each page;
d) name and address of client;
e) a description and identification of the array under test;
f) description of the test environment, including weather conditions, location and alignment of sensor and possible sources of reflection and shading around the test array. If the modules in the array are not coplanar, document how the irradiance sensor was aligned relative to the variable alignment of the modules;
g) date of installation and date of energization of array under test, if known;
h) date(s) of test;
i) reference to sampling procedure, where relevant;
j) identification of calibration of relevant equipment;
k) any deviations from, additions to or exclusions from the test method, and any other information relevant to a specific test;
l) description and identification of primary and/or secondary reference device (cell or PV module);

m) identification of the method for temperature and irradiance correction of the measured characteristic;

n) the quantitative corrections that resulted from the temperature and irradiance corrections;

o) test results supported by tables and graphs, including irradiance level, temperatures of the array under test and reference device, module parameters used for correction of the current-voltage characteristic;

p) either the mismatch correction value used in the measurement or an estimate of the error introduced by using the mismatched reference device;

q) a statement of the estimated uncertainty of test results;

r) a signature and title, or equivalent identification of the person(s) accepting responsibility for the content of the test report, and the date of issue;

s) a statement to the effect that the results relate only to the array tested;

t) a statement that the test report shall not be reproduced except in full, without the written approval of the laboratory.

Annex A
(informative)

Reference values and reference device

A.1 Reference test conditions (RTC)

These are reference values of ambient temperature, in-plane irradiance and spectral distribution, specified for power rating of PV arrays as defined for the desired measurement. RTC are usually standard test conditions.

A.2 Standard test conditions (STC)

These are reference values of module temperature, in-plane irradiance and spectral distribution used for indoor (simulator) measurements:

– module temperature: 25 °C;

– in-plane irradiance: 1 000 W/m^2;

– spectral distribution: AM 1,5 (global).

NOTE See IEC 60904-3.

A.3 Reference device

A reference device is a specially calibrated solar cell, multi-cell package or module which is used to measure irradiance and in this procedure to provide junction temperature reference.

For measurements in natural sunlight, when the direct solar beam is not at or near normal incidence, it is recommended to use a reference module of the same type and size as those being tested or a multi-cell package consisting of a calibrated cell surrounded by other cells (dummy or real) in such a way that frame, encapsulation system, shape, size and spacing are the same as in the modules being tested.

Bibliography

IEC 60904-5, *Photovoltaic devices – Part 5: Determination of equivalent cell temperature (ECT) of photovoltaic (PV) devices by the open-circuit voltage method*

IEC 61853-1:2011, *Photovoltaic (PV) module performance testing and energy rating – Part 1: Irradiance and temperature performance measurements and power rating*

ISO 17025, *General requirements for the competence of testing and calibration laboratories*

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BSI Group Headquarters

389 Chiswick High Road London W4 4AL UK

bsi.