

INTERNATIONAL STANDARD

**Photovoltaic (PV) module performance testing and energy rating -
Part 2: Spectral responsivity, incidence angle and nominal module operating
temperature measurements**

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**Photovoltaic (PV) module performance testing and energy rating -
Part 2: Spectral responsivity, incidence angle and nominal module
operating temperature measurements**

FOREWORD

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IEC 61853 has been prepared by IEC technical committee 82: Solar photovoltaic energy systems. It is an International Standard.

This second edition cancels and replaces the first edition published in 2016. This edition constitutes a technical revision.

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

- a) New Clause 3 was added;
- b) New measurement methods are introduced in Clause 7;
- c) A new procedure for data filtering was added to Clause 8;
- d) Annex A (informative), Annex B (normative) and Annex C (informative) were added;
- e) The term "calibration" was removed;

- f) The wording in Clause 4 and Clause 5 was aligned with Edition 2 of IEC 61215;
- g) The tilt angle for NMOT measurements was harmonized to $(37 \pm 5)^\circ$ throughout the text;
- h) The distance of the bottom edge of the test module in NMOT measurements was raised to 1 m above the local horizontal plane or ground level;
- i) The tests have been modified to include methodologies for measuring bifacial PV modules.

The text of this International Standard is based on the following documents:

Draft	Report on voting
82/2626/FDIS	82/2660/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts in the IEC 61853-2 series, published under the general title *Photovoltaic (PV) module performance testing and energy rating*, can be found on the IEC website.

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

- reconfirmed,
- withdrawn, or
- revised.

INTRODUCTION

Photovoltaic (PV) modules are typically rated at standard test conditions (STC) of 25 °C cell temperature, 1 000 W m⁻² total irradiance, normal incidence and air mass (AM) 1,5 spectrum. However, PV modules in the field operate over a range of temperatures, total and spectral irradiances, and incidence angles. Hence, PV modules can also be rated based on the calculated energy production under a standardized set of environmental and climatic conditions.

This series proposes a standard method for energy rating and consists of four parts:

- IEC 61853-1: Irradiance and temperature performance measurements and power rating, which describes requirements for evaluating PV module performance in terms of power rating over a range of irradiances and temperatures;
- IEC 61853-2: Spectral responsivity, incidence angle, and nominal module operating temperature measurements, which describes test procedures for measuring the effect of varying angle of incidence and sunlight spectra as well as the estimation of module temperature from irradiance, ambient temperature, and wind speed;
- IEC 61853-3: Energy rating of PV modules, which describes the calculations for PV module energy ratings; and
- IEC 61853-4: Standard reference climatic profiles, which describes the standard time periods and weather conditions that can be used for the energy rating calculations.

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1 Scope

The IEC 61853 series establishes IEC requirements for evaluating PV module performance based on power (watts), energy (joule or watthours) and performance ratio. It is written to be applicable to all PV technologies, including bifacial PV modules, but can be unsuitable for any technology where the module performance changes with time (e.g. modules change their behaviour with light or thermal exposure), or which experience significant non-linearities in any of their characteristics used for the modelling.

The purpose of this second part of IEC 61853 is to define procedures for measuring the effects of angle of incidence of the irradiance on the output power of the device, to determine the operating temperature of a module for a specific set of ambient and mounting conditions and measure the spectral responsivity of the module.

NOTE 1 In the IEC 61853 series, spectral responsivity measurements are used for calculating spectral correction factors, in combination with standardized and location-specific spectral irradiance data from Part 4. Then they are applied in the energy rating calculation described in Part 3 to account for mismatches from the reference AM1.5 spectrum with respect to what can be detected by a reference irradiance detector (e.g. a pyranometer). It is important to note that without spectral responsivity data, the resulting deviations in the energy rating calculation can be significant; however, spectral responsivity alone does not provide information on energy gains or losses.

The described measurements are required as inputs into the module energy rating procedure described in IEC 61853-3 [28]¹. Results of the measurements described in this part, however, can also be used for other purposes, where relevant, e.g. yield prediction with commercially available simulation tools that require spectral responsivity or angle of incidence effect.

PV modules to be installed onto buildings (either as building integrated or as building applied photovoltaics, BIPV or BAPV, respectively) can exhibit very peculiar spectral, optical and thermal properties. This document can be applied for the energy rating of these modules and their specificity is illustrated in Annex A: however, it is important for the reader to be aware that in some of these circumstances the thermal performance of the module under test can be severely affected by the specific mounting configuration.

NOTE 2 IEC TS 63126 [1] presents an informative annex that can be used as a guidance to get information on operating module temperatures for several locations and mounting configurations. From the 98th percentile maps provided therein, the reader can infer a temperature offset that could be applied to evaluate the effect of mounting configurations to the operating temperatures to be used in the energy rating calculated in Part 3 of this series. The estimation of this offset, however, is outside the scope of this document.

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 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 TS 60904-1-2, *Photovoltaic devices - Part 1-2: Measurement of current-voltage characteristics of bifacial photovoltaic (PV) devices*

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

¹ Numbers in square brackets refer to the 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 60904-8:2014, *Photovoltaic devices - Part 8: Measurement of spectral responsivity of a photovoltaic (PV) device*

IEC 60904-9, *Photovoltaic devices - Part 9: Classification of solar simulator characteristics*

IEC 60904-10, *Photovoltaic devices - Part 10: Methods of linear dependence and linearity measurements*

IEC 61215 (all parts), *Terrestrial photovoltaic (PV) modules - Design qualification and type approval*

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

ISO 2859-1, *Sampling procedures for inspection by attributes - Part 1: Sampling schemes indexed by acceptance quality limit (AQL) for lot-by-lot inspection*

ISO 9059, *Solar energy - Calibration of field pyrhemometers by comparison to a reference pyrhemometer*

ISO 9060, *Solar energy - Specification and classification of instruments for measuring hemispherical solar and direct solar radiation*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC TS 61836 and the following apply.

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

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

3.1

angle of incidence

AOI

incidence angle

θ

angle between the direct radiant beam and the normal to the active surface (see Figure 1)

Note 1 to entry: For the purpose of the calculation of the angle of incidence in the indoor test with solar simulators, the centre of the flash lamp is considered. When the solar simulator cannot be approximated as a point-like source, the testing laboratory may take into account any deviation from the nominal angle of incidence as a source of measurement uncertainty.

Note 2 to entry: Unit: °

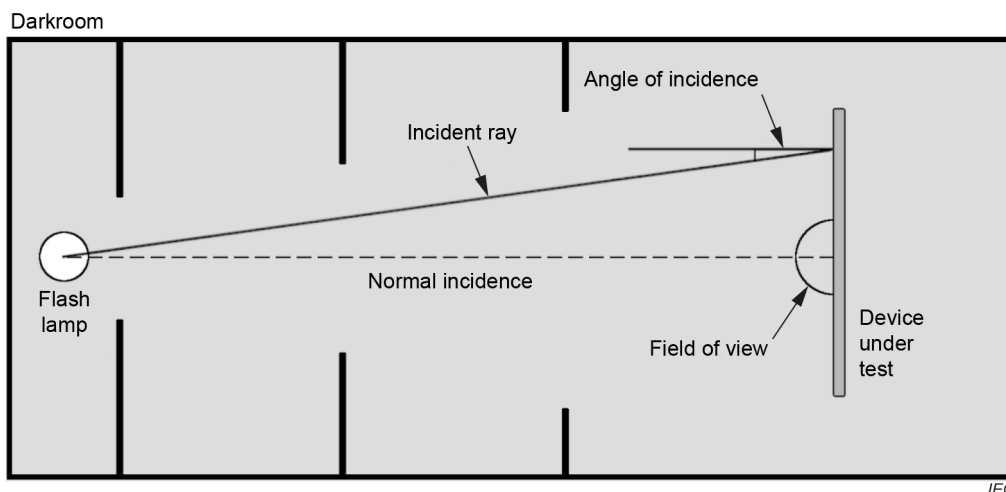


Figure 1 – Definitions of angle of incidence (3.1) and field of view (3.2) for measurements with indoor solar simulators (7.3 and 7.4)

3.2

field of view

solid angle as "seen" by the detector (acceptance angle), e.g. of a solar module, out of which the detector receives radiation

Note 1 to entry: In incidence angle measurements, it is equivalent to the 2π solid angle formed by the plane of the test sample (see Figure 1).

Note 2 to entry: Unit: sr

3.3

nominal module operating temperature

NMOT

mean equilibrium temperature of photovoltaic cells of a photovoltaic module mounted at $(37 \pm 5)^\circ$ tilt angle and operating at its maximum power under global in-plane irradiance 800 W m^{-2} , ambient temperature 20°C and wind speed 1 m s^{-1}

Note 1 to entry: Unit: $^\circ\text{C}$

3.4

relative internal angular transmittance

$$\tau_{\text{rel}}(\theta)$$

quotient of the transmittance from air to the PV cell at angle of incidence θ , and the transmittance at normal incidence $\theta = 0^\circ$

Note 1 to entry: Also known as incidence angle modifier, $\text{IAM}(\theta)$

Note 2 to entry: Unit: dimensionless

3.5

relative internal spectral angular transmittance

$$\tau_{\text{rel}}(\theta, \lambda)$$

incidence angle modifier

IAM

relative internal angular transmittance as a function of wavelength

Note 1 to entry: Unit: dimensionless

3.6**representative sample**

sample that includes all the components of the module that are functional for the specific test under consideration

3.7**spectral responsivity**

$$S(\lambda)$$

short-circuit electric current density generated by unit irradiance at a particular wavelength, plotted as a function of wavelength

Note 1 to entry: Unit: $A\ W^{-1}$

3.8**target volume**

volume spanned by the active element (cell, cells or entire module) upon rotation

Note 1 to entry: Unit: m^3 or cm^3

3.9**volume of influence**

the volume spanned by the active element plus one-half cell dimension in all directions upon rotation

Note 1 to entry: Unit: m^3 or cm^3

4 Sampling**4.1 General**

Up to three modules shall be selected randomly from a production batch or batches in accordance with the procedure given in ISO 2859-1. The modules shall be initially stabilised in accordance with 5.2 to assure the stability of the power values. One module (or equivalent representative sample) shall be used for each of the three tests, spectral responsivity, angle of incidence, and nominal module operating temperature measurements. A single module may be supplied if the tests are to be carried out in sequence. Up to three modules shall be supplied if tests are to be carried out in parallel. It shall be noted in the test report if a single or different modules have been used.

The modules shall have been manufactured from specified materials and components in accordance with the relevant drawings and process sheets and shall have been subjected to the manufacture's normal inspection, quality control and production acceptance procedures. The modules shall be complete in every detail and shall be accompanied by the manufacturer's handling and final assembly instructions regarding the recommended installation of any diodes, frames, brackets, etc.

When the devices under test (DUTs) are prototypes of a new design and not from production, this fact shall be noted in the test report.

4.2 Representative samples

Measurements of spectral responsivity and of the incidence angle effect may be performed on representative samples in the circumstances detailed in Clause 6 and Clause 7, respectively. In general, during the design and manufacturing of the representative samples, the cells, encapsulants and encapsulation methods, clearance and creepage distances around all edges shall be the same as on the actual full-size products.

If representative samples are used, the test report shall include a table listing the dimensions of the samples tested. The table shall contain the following statement: "Smaller samples were used for some tests as noted above. Use of smaller samples can affect test results".

When using representative samples, initial stabilization and maximum power determination before and after the test (see Clause 5) shall be performed on the representative samples as well.

5 Testing

5.1 General

In carrying out the tests, the manufacturer's handling, mounting, connection and cleaning instructions shall be observed.

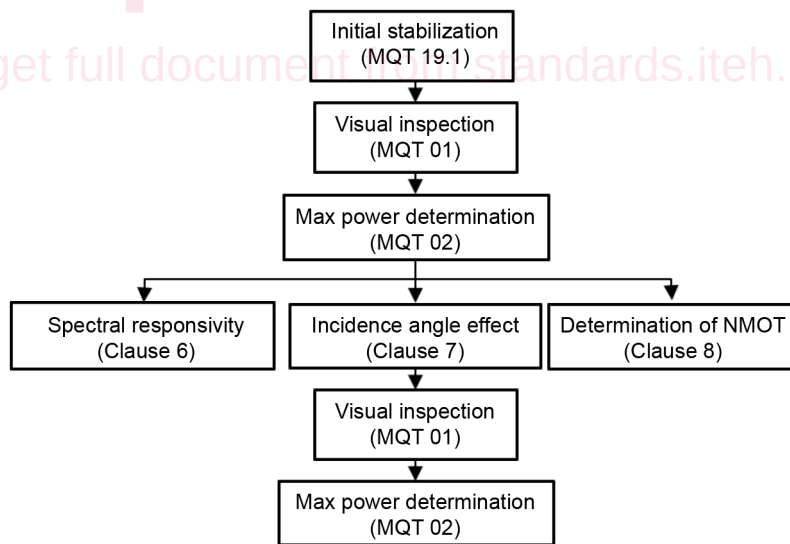
If the module under test is going to be used with a frame that covers the edges of the superstrate, then each test shall be performed with a similar frame in place.

5.2 Initial stabilization

Before beginning the measurements, all DUTs shall be electrically stabilized, as specified in technologically specific documents of the IEC 61215 series (MQT 19.1) based on the technology of the DUT.

5.3 Test flow

Figure 2 shows an overview of the testing procedure to be conducted.



IEC

**Figure 2 – Overview of the testing cycle to be carried out in IEC 61853-2
(with reference to Module Quality Tests (MQT) in IEC 61215-2)**

6 Procedure for spectral responsivity measurement

The spectral responsivity (SR) $S(\lambda)$ of a PV module has an impact on the amount of current produced at any given spectral irradiance. Normally it is not necessary to measure $S(\lambda)$ at all possible values of irradiance and temperature that a module encounters during outdoor operation. A single measurement should be sufficiently accurate for all expected operating conditions. The need for this can be verified by checking the linearity of short-circuit conditions measured in IEC 61853-1 [28]. Should a non-linearity of the short-circuit current with respect to irradiance or temperature larger than 3 % be observed, further investigation might be warranted to identify if $S(\lambda)$ changes as a function of irradiance and temperature. If $S(\lambda)$ of a particular module type is a function of irradiance or temperature, this result should appear in the test report.

To measure $S(\lambda)$, the procedure described in IEC 60904-8 shall be followed using the short-circuit condition, 25 °C cell temperature and an appropriate bias light, where required by IEC 60904-8. This procedure should be applied to the full-sized module, if possible, i.e. the module should be characterized in its entirety. If this is not possible, a smaller representative sample, optically equivalent in construction and materials, may be used or a single cell in the module should be characterized according to the measurements described in IEC 60904-8.

Optically equivalent representative samples may be 1-cell modules ("mini-modules") with the minimum size shown in Figure 3. For other cell arrangements, such as half-cut cells, an analogous configuration applies.

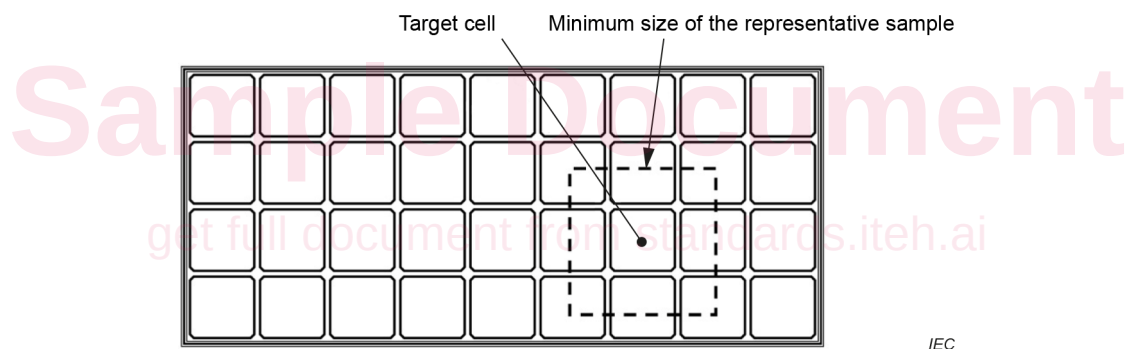


Figure 3 – Minimum size of a 1-cell minimodule

For bifacial modules, $S(\lambda)$ shall be measured on both sides of the testing sample and reported accordingly.

Coloured PV modules present additional challenges to SR measurements: these are addressed in Clause A.2.

The module power shall be measured before and after measurement of the SR, according to MQT 02 of IEC 61215. Any variation in the DUT's maximum power shall be noted in the test report.