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INTERNATIONAL STANDARD

NORME INTERNATIONALE

Photovoltaic devices –
Part 2: Requirements for photovoltaic reference devices

Dispositifs photovoltaïques –
Partie 2: Exigences applicables aux dispositifs photovoltaïques de référence

IEC 60904-2:2015-01(en-fr)

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PHOTOVOLTAIC DEVICES –

Part 2: Requirements for photovoltaic reference devices

FOREWORD

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International Standard IEC 60904-2 has been prepared by IEC Technical Committee 82: Solar photovoltaic energy systems.

This third edition cancels and replaces the second edition, published in 2007. It constitutes a technical revision.

The main technical changes with regard to the previous edition are as follows:

– addition of a test procedure in simulated sunlight of subsequent measurement of primary and secondary reference device;
– definition of standard test conditions;
– reduction of allowed diffuse component for secondary reference cell calibration to 20 %.

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

FDIS	Report on voting
82/893/FDIS	82/918/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.

A list of all parts in the IEC 60904 series, published under the general title *Photovoltaic devices*, 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

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PHOTOVOLTAIC DEVICES –

Part 2: Requirements for photovoltaic reference devices

1 Scope

This part of IEC 60904 gives requirements for the classification, selection, packaging, marking, calibration and care of photovoltaic reference devices.

This standard covers photovoltaic reference devices used to determine the electrical performance of photovoltaic cells, modules and arrays under natural and simulated sunlight. It does not cover photovoltaic reference devices for use under concentrated sunlight.

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: Measurements of photovoltaic current-voltage characteristics*

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*

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

IEC 60904-7, *Photovoltaic devices – Part 7: Computation of the spectral mismatch correction for measurements of photovoltaic devices*

IEC 60904-8, *Photovoltaic devices – Part 8: Measurement of spectral responsivity of a photovoltaic (PV) device*

IEC 60904-9, *Photovoltaic devices – Part 9: Solar simulator performance requirements*

IEC 60904-10, *Photovoltaic devices – Part 10: Methods of linearity measurement*

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

3 Terms and definitions

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

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3.1
calibration traceability
traceability as defined in IEC 60904-4

Note 1 to entry: Photovoltaic reference devices are distinguished by their position in a chain of calibration traceability.

3.2
primary reference device
photovoltaic reference device whose calibration is based on a radiometer or standard detector or standard light source traceable to SI units as defined in IEC 60904-4

3.3
secondary reference device
photovoltaic reference device calibrated in natural or simulated sunlight against a primary reference device

3.4
working reference device
photovoltaic reference device calibrated in natural or simulated sunlight against a secondary reference device

3.5
reference devices
specially calibrated photovoltaic devices which are used to measure natural or simulated irradiance or to set simulator irradiance levels for measuring the performance of other photovoltaic devices

3.6
reference cell
single photovoltaic cell used primarily for transfer of calibration values

Note 1 to entry: For practical reasons, such cells are small in surface area, and are usually mounted on a fixture which ensures reproducibility in mounting, thermal control and electrical connections. A typical sample is sketched in Figure 1.

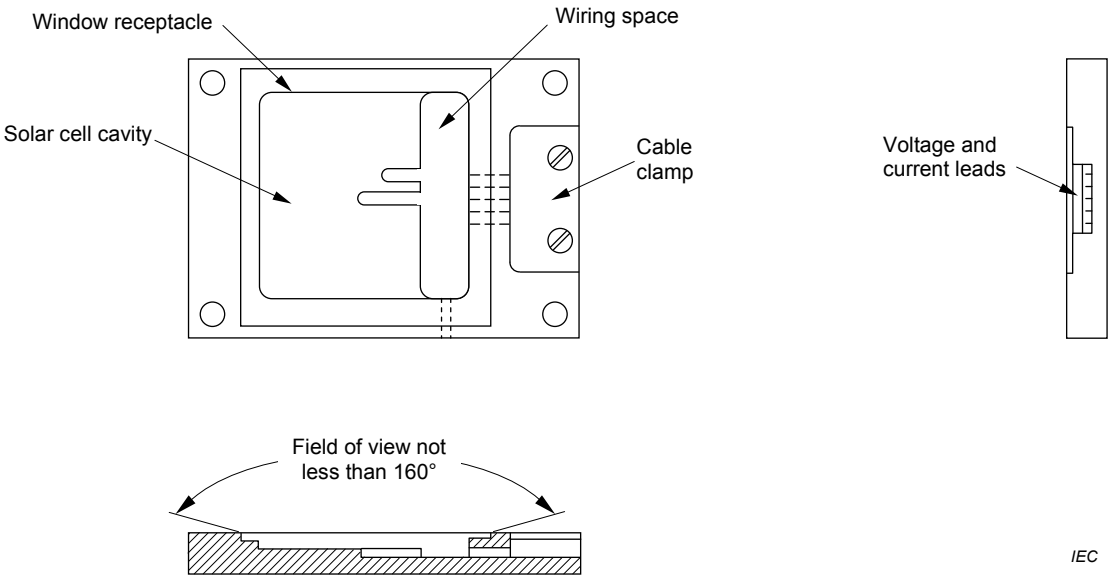

Figure 1 – Single-cell package

3.6.1
reference cell with protective cover but without encapsulant
photovoltaic reference cell similar to 3.6, but provided with a protective cover

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Note 1 to entry: Recommended use: as a laboratory primary, secondary and working reference, in particular when measuring the performance of other photovoltaic devices using solar simulators or natural sunlight with direct beam only.

3.6.2
encapsulated reference cell
photovoltaic reference cell similar to 3.6, but encapsulated in a protective assembly so as to withstand short-term outdoor exposure

Note 1 to entry: Recommended use: as a laboratory primary, secondary and working reference, in particular when measurements of the performance of other photovoltaic devices under natural sunlight are performed.

Note 2 to entry: If the encapsulation system has been demonstrated to withstand long-term outdoor exposure, applying test levels according to IEC 61215, such reference cells may also be suitable to be used as a monitoring device for long-term assessment of operational photovoltaic arrays.

3.7
multi-cell reference devices
photovoltaic device consisting of several photovoltaic cells

Note 1 to entry: Recommended use: as the diffuse component of natural sunlight and non-normal incidence of simulated sunlight interact with encapsulants and back sheets of a module and influence the amount of irradiance which a particular cell receives, it is recommended that reference devices used for measuring sub-assemblies of modules and arrays be encapsulated in a multi-cell package, matching the mechanical and optical features of the test specimen (module, sub-assemblies of modules, arrays) so as to respond to variations in the geometrical distribution of the incident radiation in the same way as the test specimen.

3.8
single reference cell in a multi-cell package
single photovoltaic cell mounted in such a package that frame, encapsulation system, shape, size and spacing of the cells surrounding it are the same as in the module to be tested

Note 1 to entry: The surrounding cells may be real or dummies that have the same optical properties.

3.9
reference module
photovoltaic module consisting of the encapsulation of a series and/or parallel connection of photovoltaic cells

Note 1 to entry: Recommended use: for measuring other modules in order to achieve correspondence of dimensions, mechanical construction, optical properties and electrical circuitry of the reference module and test module, so as to minimize discrepancies due to simulator non-uniformity, internal reflections or temperature distribution.

3.10 built-in shunt resistors
resistor connected across the output terminals of photovoltaic devices

Note 1 to entry: The resistor shunts the output of the photovoltaic device providing an output voltage to be measured and avoiding user-provided means of establishing short circuit condition.

4 Selection of reference device

4.1 General requirements

Depending on their intended use, reference devices need to meet different requirements in terms of their spectral responsivity, mechanical construction, optical properties, dimensions and electrical circuit. The spectral responsivity of the reference device, for example, is determined by the transmission of any protective cover in front of the device and the spectral responsivity of the device itself. Therefore the overall spectral responsivity can be adapted by using suitable filters as or in addition to the protective cover.

A reference device shall meet the following requirements:

a) photovoltaic characteristics shall be stable according to the requirements in Clause 11;

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b) the output signal of the reference device shall vary linearly with irradiance, as defined in IEC 60904-10, over the range of interest.

4.2 Additional requirements for single reference cell in a multi-cell package

The dotted line in Figure 2 indicates the minimum acceptable size of a multi-cell package.

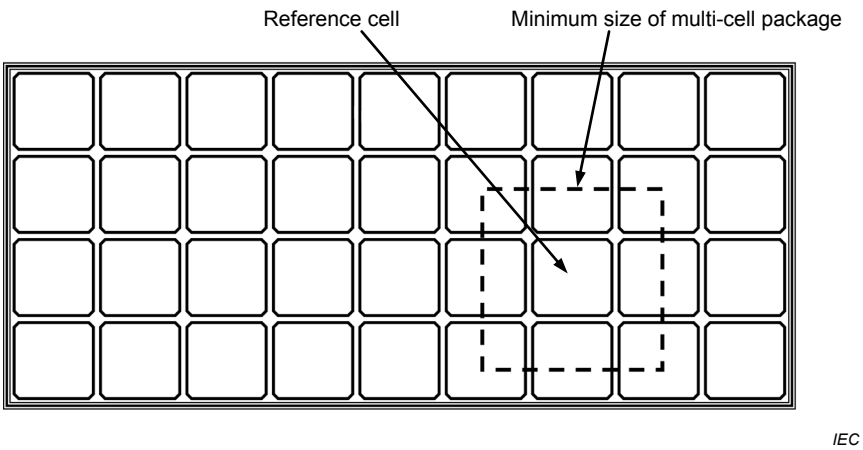

Figure 2 – Single reference cell in a multi-cell package

4.3 Additional requirements for reference modules

Additional requirements apply to reference modules:

a) Bypass diodes:

- general reference modules, that are used to measure a range of module types and geometries, should not contain bypass diodes. The presence or absence of bypass diodes shall be noted and considered in conjunction with the measurement conditions, in particular spatial non-uniformity of the irradiance on the module during measurement;
- for reference modules, that are intended to be matched to the module under test, the number, type and connection of bypass diodes (if present) shall match those in the module under test.

b) If they are made from discrete cells, these shall be matched as follows depending on the intended use of the reference module:

- if only the short circuit current of the reference module will be used the short circuit current of the individual cells shall be matched to within ± 1 %;
- if other parameters (such as maximum power) are used additionally or exclusively, both the short circuit current and the fill factor of the individual cells shall be matched to within ± 1 %.

The matching of the individual cells is the responsibility of the manufacturer of the reference module, bearing in mind that matching may also be influenced by encapsulation or lamination. The cell matching needs not be checked by the calibration laboratory. However, if I-V curves of the reference module indicate inconsistent response (i.e. steps are noted in the I-V curve), the I-V curve should be measured under light that is known to be uniform (e.g. natural sunlight) to determine whether there is evidence that the cells within the module are matched within 1 %. If the module exhibits evidence of > 1 % mismatch between cells, the module shall not be used as reference module.

4.4 Requirements for built-in shunt resistors

The resistor shall be chosen such as to ensure that the reference device operates sufficiently near to short-circuit condition, meeting the requirement:

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$$I_{SC} \times R_{CAL} < 0{,}03 \times V_{OC} \quad (1)$$

where

R_{CAL} is the shunt resistor;

I_{SC} is the short circuit current of the reference device at reference conditions;

V_{OC} is the open circuit voltage at reference conditions.

If a shunted reference cell does not meet the requirement of formula (1), it shall only be used at irradiances (± 5 %) and temperatures (± 2 °C) at which it was calibrated.

The long-term stability of such resistors shall also meet the stability requirements of the reference device. Calibration values of such reference devices shall be measured as the voltage drop across the shunt resistor and stated with the dimension [V] at standard test conditions (see Clause 7). The temperature coefficient of the built-in shunt resistor is part of the temperature coefficient of the calibration value of the reference device. As the uncertainty in the calibration may be strongly dependent on the shunt resistor stability and temperature coefficient, respective values should be provided with the reference cell data sheet.

If a shunted reference cell is to be used for low irradiance measurements, either a dedicated cell can be constructed with the restriction of formula (1), where the short circuit current is considered at the desired low irradiance rather than at STC. Alternatively a shunted cell can have a larger shunt resistor, but requires a separate calibration for each irradiance and temperature it is to be used at.

It is recommended that the shunt resistor be a removable 4-wire resistor, to allow for periodic checking of the reference device stability by taking an I-V curve per IEC 60904-1.

Formula (1) means that the measured output voltage of a shunted reference cell shall be less than 3 % of its open circuit voltage. For typical crystalline Silicon this equates to about 20 mV output.

5 Temperature measurement

Means shall be provided for determining the reference cell temperature or, for reference modules, the equivalent cell temperature (ECT), according to IEC 60904-5. The required uncertainty for temperature measurements shall be less than ± 2,0 °C for all reference devices. A minimum accuracy of ±1,0 °C for the temperature sensor is suggested to achieve this uncertainty in the temperature measurement.

6 Electrical connections

The electrical connections to reference cells shall consist of a four-wire contact system (Kelvin probe). Care shall be taken to avoid measurement errors due to voltage drops along the cell's contact bars and the package wiring.

The electrical connections to the reference module shall be designed to meet the requirements of IEC 60904-1.

7 Calibration

Each reference device shall be calibrated in terms of its calibration value at the desired reference conditions, normally standard test conditions (STC) (1 000 W·m^{-2}, 25 °C device temperature with the reference spectral irradiance distribution as defined in IEC 60904-3).

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