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TECHNICAL SPECIFICATION

colour inside

Photovoltaic devices –
Part 1-2: Measurement of current-voltage characteristics of bifacial photovoltaic (PV) devices

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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PHOTOVOLTAIC DEVICES –

Part 1-2: Measurement of current-voltage characteristics of bifacial photovoltaic (PV) devices

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Technical Specification are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC TS 60904-1-2, 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:

Draft TS	Report on voting
82/1403/DTS	82/1508/RVDTS

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 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 document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

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- withdrawn,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

A bilingual version of this publication may be issued at a later date.

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PHOTOVOLTAIC DEVICES –

Part 1-2: Measurement of current-voltage characteristics of bifacial photovoltaic (PV) devices

1 Scope

This part of IEC 60904 describes procedures for the measurement of the current-voltage (I-V) characteristics of bifacial photovoltaic devices in natural or simulated sunlight. It is applicable to single PV cells, sub-assemblies of such cells or entire PV modules.

The requirements for measurement of I-V characteristics of standard (monofacial) PV devices are covered by IEC 60904-1, whereas this document describes the additional requirements for the measurement of I-V characteristics of bifacial PV devices.

This document may be applicable to PV devices designed for use under concentrated irradiation if they are measured without the optics for concentration, and irradiated using direct normal irradiance and a mismatch correction with respect to a direct normal reference spectrum is performed.

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

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

IEC TS 62446-3, *Photovoltaic (PV) systems - Requirements for testing, documentation and maintenance - Part 3: Photovoltaic modules and plants - Outdoor infrared thermography*

IEC 62788-1-4, *Measurement procedures for materials used in photovoltaic modules – Part 1-4: Encapsulants – Measurement of optical transmittance and calculation of the solar-weighted photon transmittance, yellowness index, and UV cut-off wavelength*

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 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 bifacial PV device

PV device, both surfaces of which (front and rear sides) are used for power generation

3.2 bifaciality

property expressing the ratio between the main characteristics of the rear side and the front side of a bifacial PV device quantified by specific bifaciality coefficients

Note 1 to entry: Unless otherwise specified, the bifacialities are typically referred to Standard Test Conditions STC. The main bifacialities are:

- Short-circuit current bifaciality: φ_{ISC}
- Open-circuit voltage bifaciality: φ_{VOC}
- Maximum power bifaciality: $\varphi_{Pmax.}$

3.3 rear irradiance driven power gain yield

BiFi

quantity which indicates the power gain, in addition to that obtained at STC conditions, per unit of rear irradiance

Note 1 to entry: It is expressed in W/(Wm^{-2}).

4 General considerations

The final performance of bifacial PV devices in a power plant depends not only on the spatial distribution of the irradiance incident onto the front surface, but additionally on that incident onto rear surface of the device, which is strongly affected by site-specific conditions, such as albedo, reflective surface size, the racking system, the device's elevation and its tilt angle. Due to these dependences and in order to obtain comparable measurement results, I-V characterisation is extended to quantify the bifaciality of the device and the rear irradiance driven power gain yield it can yield. Bifaciality is an intrinsic property of the device, unlike the site-specific conditions such as albedo. The measurement conditions for bifacial devices should strive to generate extra photocurrent proportional to their bifaciality. In general, this can be achieved with a test spectrum close to the reference spectrum such as provided by natural sunlight under suitable conditions or with a solar simulator whose irradiance level is

adjustable. However, measurement conditions will never be perfect and will deviate from the reference conditions. This document sets limits on the permissible deviations for obtaining valid measurements. Smaller deviations are preferable, but may not be achievable in all cases. In any case, the deviations of the measurement conditions from the reference conditions shall be accounted for in the analysis of measurement uncertainty.

5 Apparatus

5.1 General

In addition to the apparatus requirements described in IEC 60904-1, one of the equipment sets described in 5.2, 5.3 and 5.4 and that described in 5.5 is necessary for the characterisation of bifacial devices.

5.2 Solar simulator with adjustable irradiance levels for single-side illumination

A solar simulator, as defined in IEC 60904-9, with adjustable irradiance level shall be used for the *I-V* characterisation of bifacial devices. Simulators shall be able to provide irradiance levels above 1 000 Wm^{-2} (typically up to 1 200 Wm^{-2}). The simulator's non-uniformity of irradiance shall be below 5 % and shall remain below this value at irradiance levels used for the characterisation of bifacial devices. The non-uniformity of irradiance, the spectral distribution and the temporal instabilities of irradiance shall be measured at the irradiance levels used for the characterisation of bifacial devices and those values used for corrections (such as spectral mismatch correction) and uncertainty evaluation.

For irradiances used above STC (>1 000 Wm^{-2}), the spatial uniformity, spectral distribution and temporal instability at 1 100 Wm^{-2} and 1 200 Wm^{-2} shall be measured.

5.3 Solar simulator with adjustable irradiance levels for double-side illumination

A solar simulator, as defined in IEC 60904-9, with the additional capability to simultaneously illuminate the bifacial device on both sides shall be used. Such simulators shall be able to provide irradiance at different levels on both sides. The non-uniformity of irradiance, the spectral distribution and the temporal instabilities of irradiance shall be measured on both sides when the test area is simultaneously illuminated on both sides. The non-uniformity of irradiance shall be below 5 % on both sides, at the irradiance levels used for the characterisation of bifacial devices and those values used for corrections (such as spectral mismatch correction) and uncertainty evaluation.

5.4 Natural sunlight

In addition to the general measurement requirements described in IEC 60904-1, at least 2 additional PV reference devices, as described in IEC 60904-2, are required to measure the irradiance level on the rear side and the rear-side irradiance non-uniformity. Their spectral responsivity should be as close as possible to the one of the device under test.

Care shall be taken to minimize the shadowing if placing sensors to measure the temperature of bifacial devices under natural sunlight or using double-side illumination. This needs to be considered in the measurement uncertainty analysis. Alternatively, contactless (IRT) or equivalent cell temperature calculation can be used as described in IEC TS 62446-3 and IEC 60904-5 respectively.

5.5 Non-irradiated background and background compensation

To measure the *I-V* characteristics of both front and rear surfaces of bifacial devices, the contribution from the light incident on the opposite side of the device under test shall be eliminated completely during the measurement by creating a non-irradiating background. The background is considered to be non-irradiating if the irradiance on the surface under test does not exceed 3 Wm^{-2}, at any point, on the non-exposed side of the device.

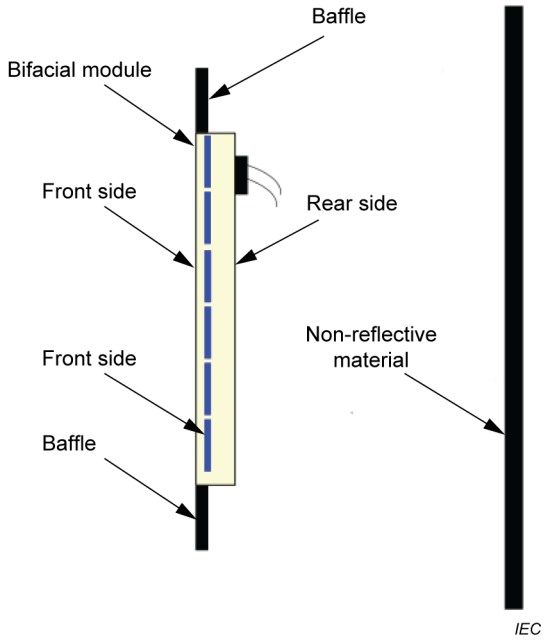

Figure 1 – Scheme of a bifacial PV module and the required non-irradiated background and aperture

In order to fulfil this requirement, in the case of PV modules, it is highly recommended to limit the size of the test area to that of the device under test using baffles as illustrated in Figure 1. Materials with minimized reflection in the wavelength range corresponding to the spectral responsivity of the test specimen, placed at a suitable distance from its non-exposed side, shall be used to reduce the irradiance level (non-reflective material).

To measure the irradiance on the non-exposed side, choose at least 5 points as shown in Figure 1, with symmetrical distribution, for instance, P1-P3-P5-P7-P9, P2-P4-P5-P6-P8 or P1-P2-P3-P7-P8-P9.

In the case of PV bare cells, the use of non-reflective materials to manufacture cell holders may be insufficient to reach irradiance values below 3 Wm^{-2}. In that case, background compensation may be performed by extrapolating the short-circuit current as a function of the background irradiance.

6 Additional *I-V* characterisations for bifacial devices

6.1 General

The procedure for measurement of the *I-V* characteristics of standard (monofacial) PV devices is described in IEC 60904-1 and its provisions are also valid for the measurement of bifacial PV devices except where explicitly amended by this document. The procedure for the measurement of the *I-V* characteristics of a bifacial PV device is based on the same basic principles as in IEC 60904-1, but requires some additional considerations and also provides supplementary characteristics specific to bifacial devices.

The measurement conditions for I-V characteristics of bifacial devices require more attention than for monofacial devices as the measurement results for bifacial devices are more prone to effects due to the measurement conditions deviating from the reference conditions. For instance, the parasitic reflections from the rear side of the device under test can increase significantly the measurement uncertainty. The measurement results should be corrected for the deviations of the measurement conditions from the reference conditions wherever possible. The uncertainty of this correction and furthermore the uncertainty arising from