



TECHNICAL SPECIFICATION



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

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 27.160

ISBN 978-2-8322-6409-6

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

FOREWORD.....	4
1 Scope.....	6
2 Normative references	6
3 Terms and definitions	7
3.1 Bifacial PV device.....	7
3.2 Bifaciality.....	7
3.3 Rear irradiance driven power gain yield	7
4 General considerations.....	7
5 Apparatus.....	8
5.1 General.....	8
5.2 Solar simulator with adjustable irradiance levels for single-side illumination.....	8
5.3 Solar simulator with adjustable irradiance levels for double-side illumination	8
5.4 Natural sunlight.....	8
5.5 Non-irradiated background and background compensation	8
6 Additional <i>I-V</i> characterisations for bifacial devices	9
6.1 General.....	9
6.2 Determination of bifacialities	10
6.3 Determination of the rear irradiance driven power gain yield	11
6.3.1 General	11
6.3.2 Outdoor rear irradiance driven power gain yield measurement.....	12
6.3.3 Indoor rear irradiance driven power gain yield measurement with single-side illumination.....	13
6.3.4 Indoor rear irradiance driven power gain yield measurement with double-side illumination	14
7 <i>I-V</i> characterisation of bifacial PV devices in practice	15
7.1 General.....	15
7.2 <i>I-V</i> measurement of reference bifacial PV devices	15
7.3 <i>I-V</i> measurement of bifacial PV devices using a reference bifacial device	16
8 Report	17
Figure 1 – Scheme of a bifacial PV module and the required non-irradiated background and aperture	9
Figure 2 – Front- and rear-side characterization for bifaciality.....	10
Figure 3 – Outdoor measurement.....	12
Figure 4 – Examples of P_{\max} as a function of irradiance level on the rear side G_r (for outdoor or double-side illumination) or its 1-side equivalent irradiance G_f for a device of bifaciality $\varphi = 80\%$	14
Figure 5 – Transmittances of the device (T_{DUT}) and its encapsulant (T_{ENC}).....	15
Figure 6 – Example of $P_{\max, \text{BiFi}100}$ and $P_{\max, \text{BiFi}200}$ derived from the measurement of P_{\max} at STC conditions, $P_{\max, \text{STC}}$ and the BiFi coefficient of the reference used in formulae (8) and (9)	17

Table 1 – Maximum peak power, P_{max} , measured at different rear irradiances, G_r , (double-side with $G_f = 1\ 000$) or alternatively equivalent front irradiances, G_E , and the rear irradiance driven power gain yield, $BiFi$, derived from the slope of the linear fit on $P_{max}(G_r)$. Also calculated values $P_{max,BiFi100}$ and $P_{max,BiFi200}$	14
Table 2 – Example of $P_{max,BiFi100}$ and $P_{max,BiFi200}$ derived from the measurement at STC conditions ($G_r = 0$ and $G_f = 1\ 000$) and the rear irradiance driven power gain obtained from the bifacial reference device, $BiFi,ref$	17

INTERNATIONAL ELECTROTECHNICAL COMMISSION

PHOTOVOLTAIC DEVICES –

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

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as “IEC Publication(s)”). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

The main task of IEC technical committees is to prepare International Standards. In exceptional circumstances, a technical committee may propose the publication of a Technical Specification when

- the required support cannot be obtained for the publication of an International Standard, despite repeated efforts, or
- 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 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.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

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*