IEC TS 60904-1-2

Edition 2.1 2026-03

TECHNICAL SPECIFICATION

CONSOLIDATED VERSION

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

ICS 27.160

ISBN 978-2-8327-1152-1

IEC TS 60904-1-2:2024-11+AMD1:2026-03 CSV(en)

THIS PUBLICATION IS COPYRIGHT PROTECTED
Copyright © 2026 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

IEC Secretariat
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC
The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications
The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform
The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, …). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished
Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc
If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch
Discover our powerful search engine and read freely all the publications previews, graphical symbols and the glossary. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org
The world's leading online dictionary on electrotechnology, containing more than 22 500 terminological entries in English and French, with equivalent terms in 25 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

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

CONTENTS

FOREWORD 3
1 Scope 5
2 Normative references 5
3 Terms and definitions 6
4 General considerations 8
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 9
5.5 Non-irradiated background 9
5.6 Temperature sensors 11
6 Additional I-V characterisations for bifacial devices 11
6.1 General 11
6.2 Determination of bifaciality 12
6.3 Determination of the rear irradiance power gain 13
6.3.1 General 13
6.3.2 Outdoor rear irradiance power gain measurement 14
6.3.3 Indoor rear irradiance power gain measurement with single-side illumination 15
6.3.4 Indoor rear irradiance power gain measurement with double-side illumination 17
7 I-V characterisation of bifacial PV devices in practice 17
7.1 General 17
7.2 I-V measurement of bifacial PV devices 17
7.3 I-V measurement of bifacial PV devices using a reference bifacial device 18
8 Report 20
Bibliography 21

Figure 1 – Two reference devices (described in IEC 60904-2) to measure irradiance on front and rear sides of device under test during outdoor measurements 9
Figure 2 – Scheme of a bifacial PV module and the required non-irradiated background and aperture 10
Figure 3 – Suggested points to measure the irradiance at the rear face of a PV module with 72 cells 11
Figure 4 – Front and rear-side characterization of bifaciality 12
Figure 5 – Examples of P_{max} as a function of irradiance level on the rear side G_{r} (for outdoor or double-side illumination) or its one-side equivalent irradiance G_{e} for a device of bifaciality $\varphi_{I_{\mathrm{SC}}}$ = 89 % 16
Figure 6 – Transmittances of the device (T_{DUT}) and its encapsulant (T_{ENC}) 18
Figure 7 – Example of $P_{\mathrm{max,BNPI}}$ derived from the measurement of P_{max} at STC conditions, $P_{\mathrm{max,STC}}$ and the $BiFi$ coefficient of the reference used in Formula (10) 19

Table 1 – Maximum power, P_{max}, measured at different rear irradiances, G_r, (double-sided with G_f = 1 000 Wm^{-2}) 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 $P_{max}(G_r)$ 16

Table 2 – Example of $P_{max,BNPI}$ derived from the measurement at STC conditions (G_r = 0 and G_f = 1 000) and the rear irradiance power gain obtained from the bifacial reference device, $BiFi_{ref}$ 19

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) IEC draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). IEC takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, IEC had not received notice of (a) patent(s), which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at https://patents.iec.ch or www.iso.org/patents. IEC shall not be held responsible for identifying any or all such patent rights.

This consolidated version of the official IEC Standard and its amendment has been prepared for user convenience.

IEC TS 60904-1-2 edition 2.1 contains the second edition (2024-11) [documents 82/2278/DTS and 82/2309/RVDTS] and its amendment 1 (2026-03) [documents 82/2552/DTS and 82/2579/RVDTS].

In this Redline version, a vertical line in the margin shows where the technical content is modified by amendment 1. Additions are in green text, deletions are in strikethrough red text. A separate Final version with all changes accepted is available in this publication.

IEC TS 60904-1-2 has been prepared by IEC technical committee 82: Solar photovoltaic energy systems. It is a Technical Specification.

This second edition cancels and replaces the first edition published in 2019. This edition constitutes a technical revision.

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

a) The scope has been updated and refers to IEC TS 63202-3 for the measurement of non-encapsulated solar cells.
b) The requirements for the non-uniformity of irradiance have been updated and now refer to classifications introduced in IEC 60904-9.
c) The requirement for non-irradiated background has been revised.
d) Spectral mismatch corrections are no longer mandatory, unless required by another standard. Spectral mismatch would have to be considered in the measurement uncertainty.
e) The requirement regarding the calculation of bifaciality has been modified: Equivalent irradiance shall not be calculated based on the minimum bifaciality value between I_{SC} and P_{max}, but on the bifaciality of I_{SC}.

The text of this Technical Specification is based on the following documents:

Draft	Report on voting
82/2278/DTS	82/2309/RVDTS

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 Technical Specification 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 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 and its amendment 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.

1 Scope

This part of IEC 60904 describes procedures for the measurement of the current-voltage (I-V) characteristics of single junction bifacial photovoltaic devices in natural or simulated sunlight. It is applicable to encapsulated solar cells, sub-assemblies of such cells or entire PV modules. For measurements of I-V characteristics of non-encapsulated solar cells, IEC TS 63202-3 applies.

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 can 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 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: Photovoltaic reference devices – Procedures for establishing calibration traceability*

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: Classification of solar simulator characteristics*

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

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

3.2
front side
side of the PV device declared by the manufacturer as the front side, which is the side designed to be oriented toward the sun

Note 1 to entry: If no declaration is provided, the front side is the side with the higher maximum power measured under standard test conditions (STC).

3.3
rear side
side of the PV device declared by the manufacturer as the rear side, that is the side designed to point away from the sun

Note 1 to entry: If no declaration is provided, the rear side is the side with the lower maximum power measured under STC.

3.4
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 bifaciality refers to standard test conditions (STC). The bifaciality of the performance parameters is expressed as:

– Short-circuit current bifaciality: $\varphi_{I_{SC}}$

– Open-circuit voltage bifaciality: $\varphi_{V_{OC}}$

– Maximum power bifaciality: $\varphi_{P_{max,BiFi}}$.

3.5
equivalent irradiance
G_E
irradiance required to illuminate the front of the device under test, so that it produces the same power output as if it were illuminated from the device front with irradiance 1 000 Wm^{-2} and from the rear with irradiance G_r

3.6
rear face irradiance
G_r
irradiance arriving at the rear face of the DUT

3.7
bifacial nameplate irradiance
BNPI
irradiance at which nameplate characteristics are reported for bifacial modules, specifically 1 000 Wm^{-2} on the module front and 135 Wm^{-2} on the module rear

3.8
maximum power at BNPI
$P_{max,BNPI}$
maximum power output of the DUT under BNPI

Note 1 to entry: The quantity can be measured or calculated.

3.9
short-circuit current at BNPI
$I_{SC,BNPI}$
short-circuit current of the DUT under BNPI

Note 1 to entry: The quantity can be measured or calculated.

3.10
open-circuit voltage at BNPI
$V_{OC,BNPI}$
open-circuit voltage of the DUT under BNPI

Note 1 to entry: The quantity can be measured or calculated.

3.11
rear irradiance power gain
BiFi
quantity which indicates the power gain, in addition to that obtained at STC conditions, per unit of rear irradiance

Note 1 to entry: Rear irradiance power gain is the slope derived from the linear fit of the P_{max} versus rear irradiance, G_r.

Note 2 to entry: $BiFi$ is expressed in $W/(Wm^{-2})$ or m^2.

3.12
relative rear irradiance power gain
$\boldsymbol{BiFi_{rel}}$
rear irradiance power gain, $BiFi$ normalized by front-side irradiance and maximum power output at STC

Note 1 to entry: $BiFi_{rel}$ is unitless.

3.13
$\boldsymbol{BiFi_{ref}}$
rear irradiance power gain of the bifacial device used as a reference