

INTERNATIONAL STANDARD



Photovoltaic system performance –
Part 1: Monitoring

ITeH Standards
(<https://standards.iteh.ai>)
Document Preview

[IEC 61724-1:2021](https://standards.iteh.ai/catalog/standards/iec/c9f32a26-b82a-4956-910c-4ede09fc6222/iec-61724-1-2021)

<https://standards.iteh.ai/catalog/standards/iec/c9f32a26-b82a-4956-910c-4ede09fc6222/iec-61724-1-2021>



THIS PUBLICATION IS COPYRIGHT PROTECTED
Copyright © 2021 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 Central Office
3, rue de Varembe
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 It also gives information on projects, replaced and withdrawn publications.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 online collection - oc.iec.ch

Discover our powerful search engine and read freely all the publications previews. With a subscription you will always have access to up to date content tailored to your needs.

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.

Electropedia - www.electropedia.org

The world's leading online dictionary on electrotechnology, containing more than 22 000 terminological entries in English and French, with equivalent terms in 18 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

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.

International Standards
standards.iteh.ai
Document Preview

[IEC 61724-1:2021](https://standards.iteh.ai/catalog/standards/iec/c9b32a26-b82a-4956-910c-4ede09fc6222/iec-61724-1-2021)

<https://standards.iteh.ai/catalog/standards/iec/c9b32a26-b82a-4956-910c-4ede09fc6222/iec-61724-1-2021>



IEC 61724-1

Edition 2.0 2021-07
REDLINE VERSION

INTERNATIONAL STANDARD



Photovoltaic system performance –
Part 1: Monitoring

Standards
(<https://standards.iteh.ai>)
Document Preview

[IEC 61724-1:2021](#)

<https://standards.iteh.ai/catalog/standards/iec/c9f32a26-b82a-4956-910c-4ede09fc6222/iec-61724-1-2021>

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 27.160

ISBN 978-2-8322-5086-0

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

CONTENTS

FOREWORD.....	6
INTRODUCTION.....	8
1 Scope.....	10
2 Normative references.....	10
3 Terms and definitions	11
4 Monitoring system classification.....	16
5 General	17
5.1 Measurement precision and uncertainty.....	17
5.2 Calibration	17
5.3 Repeated elements	17
5.4 Power consumption.....	17
5.5 Documentation.....	17
5.6 Inspection	18
6 Data acquisition timing and reporting	18
6.1 Samples, records, and reports.....	18
6.2 Timestamps	20
6.3 Parameter names.....	20
7 Measured parameters Required measurements.....	21
8 Irradiance.....	27
8.1 Sensor types.....	31
8.2 General requirements.....	31
8.2.1 Overview	31
8.2.2 Sensor requirements.....	31
8.2.3 Sensor locations	32
8.2.4 Recalibration.....	33
8.2.5 Soiling mitigation	33
8.2.6 Dew and frost mitigation.....	33
8.2.7 Inspection and maintenance.....	34
8.2.8 Sensor alignment.....	34
8.3 Measurements	34
8.3.1 Global horizontal irradiance.....	34
8.3.2 In-plane irradiance	34
8.3.3 In-plane rear-side irradiance.....	35
8.3.4 In-plane rear-side irradiance ratio.....	35
8.3.5 Horizontal albedo.....	35
8.3.6 Direct normal irradiance	35
8.3.7 Diffuse horizontal irradiance.....	35
8.3.8 Spectrally matched irradiance	35
8.3.9 In-plane irradiance for concentrator systems.....	36
8.3.10 Spectral irradiance for concentrator systems	37
8.3.11 Circumsolar ratio measurements for concentrator systems.....	37
8.3.12 Satellite remote sensing of irradiance	38
9 Environmental factors	39
9.1 PV module temperature.....	39
9.2 Ambient air temperature	41

9.3	Wind speed and direction	42
9.4	Soiling ratio.....	42
9.5	Rainfall	45
9.6	Snow	45
9.7	Humidity	45
10	Tracker system.....	45
10.1	Single-axis trackers.....	45
10.2	Dual-axis trackers for >20x systems	45
10.2.1	Monitoring.....	45
10.2.2	Pointing error sensor alignment.....	45
11	Electrical measurements.....	46
11.1	Inverter-level measurements	46
11.2	Plant-level measurements	47
12	Data processing and quality check	48
12.1	Daylight hours Night.....	48
12.2	Quality check	48
12.2.1	Removing invalid readings	48
12.2.2	Treatment of missing data	49
13	Calculated parameters.....	49
13.1	Overview.....	49
13.2	Summations	50
13.3	Irradiation	50
13.4	Electrical energy	51
13.4.1	General	51
13.4.2	DC output energy.....	51
13.4.3	AC output energy	51
13.5	Array power rating.....	51
13.5.1	DC power rating	51
13.5.2	AC power rating	52
13.6	Yields	52
13.6.1	General	52
13.6.2	PV array energy yield.....	52
13.6.3	Final system yield	52
13.6.4	Reference yield.....	52
13.6.5	Bifacial reference yield	53
13.7	Yield losses	53
13.7.1	General	53
13.7.2	Array capture loss.....	53
13.7.3	Balance of systems (BOS) loss.....	53
13.8	Efficiencies	54
13.8.1	Array (DC) efficiency.....	54
13.8.2	System (AC) efficiency	54
13.8.3	BOS efficiency	54
14	Performance metrics.....	54
14.1	Overview.....	54
14.2	Summations	55
14.3	Performance ratios.....	55
14.3.1	Performance ratio	55

14.3.2	Temperature-corrected performance ratios	56
14.3.3	Bifacial performance ratios	58
14.4	Performance indices	59
15	Data filtering	59
15.1	Use of available data	59
15.2	Filtering data to specific conditions	59
15.3	Reduced inverter, grid, or load availability	59
Annex A	(informative) Sampling interval	61
A.1	General considerations	61
A.2	Time constants	61
A.3	Aliasing error	61
A.4	Example	62
Annex B	(informative) Module backsheet temperature sensor selection and attachment	63
B.1	Objective	63
B.2	Sensor and material selection	63
B.2.1	Optimal sensor types	63
B.2.2	Optimal tapes	63
B.2.3	Cyanoacrylate adhesives and backsheet integrity	64
B.3	Sensor attachment method	64
B.3.1	Permanent versus temporary	64
B.3.2	Attachment location	64
B.3.3	Sensor attachment Bifacial modules	64
B.3.4	Method	64
Annex C	(normative) Soiling measurement using clean and soiled PV reference device pair	67
C.1	Overview	67
C.2	Equipment	67
C.3	Normalization	67
C.4	Measurement method 1 – max power reduction due to soiling	68
C.5	Measurement method 2 – short-circuit current reduction due to soiling	68
C.6	Non-uniform soiling	68
C.7	Daily average value	69
C.8	Renormalization	69
Annex D	(informative) Derate factors	70
Annex E	(normative) Systems with local loads, storage, or auxiliary sources	72
E.1	System types	72
E.2	Parameters and formulas	74
Bibliography	81
Figure 1	– Possible elements of PV systems	8
Figure 2	– Samples, records and reports	19
Figure B.1	– Sensor attachment, permanent	65
Figure B.2	– Sensor attachment, temporary	65
Figure B.3	– Sensor element wire strain relief	66
Figure E.1	– Energy flow between possible elements of different PV system types	72

~~Table 1 – Monitoring system classifications and suggested applications~~

Table 1 – Sampling and recording interval requirements	20
Table 2 – Measured parameters and requirements for each monitoring system class	22
Table 3 – Relation between system size (AC) and number of sensors for specific sensors Multiplier referenced in Table 2	27
Table 4 – Irradiance sensor requirements	32
Table 5 – Sensor choices and requirements for in-plane and global irradiance	
Table 6 – Irradiance sensor alignment accuracy	
Table 7 – Irradiance sensor maintenance requirements	
Table 5 – Inverter-level electrical measurement requirements	46
Table 6 – Plant-level AC electrical output measurement requirements	47
Table 7 – Calculated parameters	50
Table 8 – PV module temperature sensor maintenance requirements	
Table 8 – Performance metrics	55
Table 9 – Ambient air temperature sensor maintenance requirements	
Table 11 – Inverter-level electrical measurement requirements	
Table 12 – Plant-level AC electrical output measurement requirements	
Table 13 – Calculated parameters	
Table 14 – Performance metrics	
Table E.1 – Elements of different PV system types	73
Table E.2 – Parameters and formulas for different system types	74

Document Preview

[IEC 61724-1:2021](https://standards.iteh.ai)

<https://standards.iteh.ai/catalog/standards/iec/c9f32a26-b82a-4956-910c-4ede09fc6222/iec-61724-1-2021>

INTERNATIONAL ELECTROTECHNICAL COMMISSION

PHOTOVOLTAIC SYSTEM PERFORMANCE –

Part 1: Monitoring

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.

This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition IEC 61724-1:2017. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

International Standard IEC 61724-1 has been prepared by IEC technical committee 82: Solar photovoltaic energy systems.

This second edition cancels and replaces the first edition, published in 2017. This edition constitutes a technical revision.

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

- Monitoring of bifacial systems is introduced.
- Irradiance sensor requirements are updated.
- Soiling measurement is updated based on new technology.
- Class C monitoring systems are eliminated.
- Various requirements, recommendations and explanatory notes are updated.

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

FDIS	Report on voting
82/1904/FDIS	82/1925/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/standardsdev/publications.

A list of all parts in the IEC 61724 series, published under the general title *Photovoltaic system performance*, 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,
- replaced by a revised edition, or
- amended.

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.

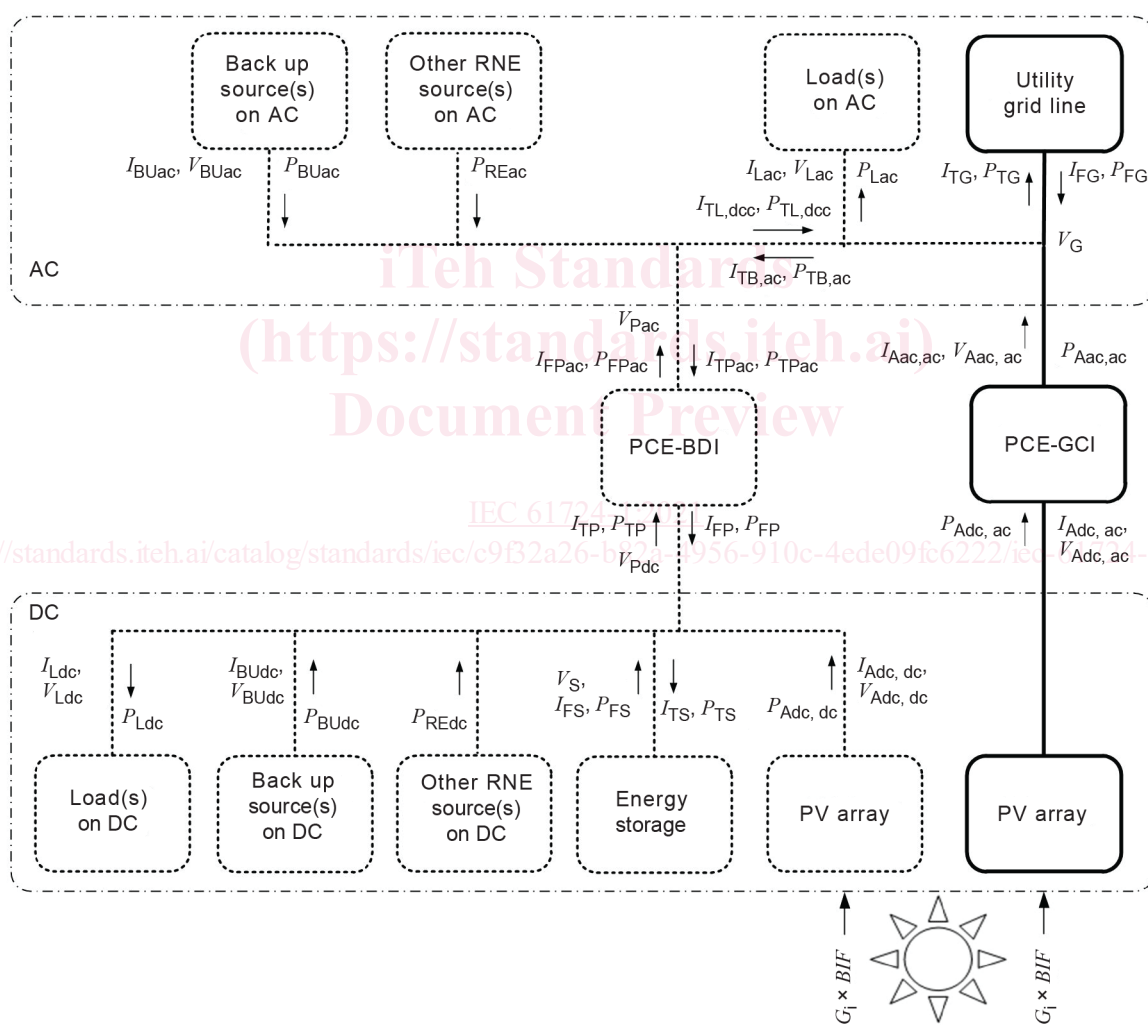
INTRODUCTION

This document defines classes of photovoltaic (PV) performance monitoring systems and serves as guidance for ~~various~~ monitoring system choices.

Figure 1 illustrates ~~possible~~ major elements comprising different PV system types.

The main clauses of this document are written for grid-connected systems without local loads, energy storage, or auxiliary sources, as shown by the bold lines in Figure 1. Annex E includes some details for systems with additional components.

The PV array may include both fixed-axis and ~~tracking~~ tracker systems and both flat-plate and concentrator systems. ~~Module-level electronics, if present, may be a component of the monitoring system.~~



Key

RNE: renewable energy

PCE: power conditioning equipment

BDI: bi-directional inverter

GCI: grid-connected inverter

Bold lines denote simple grid-connected system without local loads, energy storage, or auxiliary sources.

Figure 1 – Possible elements of PV systems

The purposes of a performance monitoring system are diverse and ~~can~~ could include ~~the following:~~

- ~~identification of performance trends in an individual PV system;~~
- ~~localization of potential faults in a PV system;~~
- ~~comparison of PV system performance to design expectations and guarantees;~~
- ~~comparison of PV systems of different configurations; and~~
- ~~comparison of PV systems at different locations.~~

comparing performance to design expectations and guarantees as well as detecting and localizing faults.

~~These diverse purposes give rise to a diverse set of requirements, and different sensors and/or analysis methods may be more or less suited depending on the specific objective. For example, For comparing performance to design expectations and guarantees, the focus should be on system-level data and consistency between prediction and test methods, while for analysing performance trends.~~

For detecting and localizing faults there ~~may~~ should be ~~a need for~~ greater resolution at sub-levels of the system and an emphasis on measurement repeatability and correlation metrics ~~rather than absolute accuracy.~~

The monitoring system should be adapted to the PV system's size and user requirements. In general, larger ~~and more expensive~~ PV systems should have more monitoring points and higher accuracy sensors than smaller and lower-cost PV systems. ~~This document defines three classifications of monitoring system with differentiated requirements which are appropriate to a range of purposes.~~

Document Preview

[IEC 61724-1:2021](#)

<https://standards.iteh.ai/catalog/standards/iec/c9b32a26-b82a-4956-910c-4ede09fc6222/iec-61724-1-2021>

PHOTOVOLTAIC SYSTEM PERFORMANCE –

Part 1: Monitoring

1 Scope

This part of IEC 61724 outlines terminology, equipment, and methods for performance monitoring and analysis of photovoltaic (PV) systems. ~~It addresses sensors, installation, and accuracy for monitoring equipment in addition to measured parameter data acquisition and quality checks, calculated parameters, and performance metrics.~~ It also serves as a basis for other standards which rely upon the data collected.

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 60050-131, *International Electrotechnical Vocabulary (IEV) – Part 131: Circuit theory*

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 60904-5, *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 60904-10, *Photovoltaic devices – Part 10: Methods of linearity measurement*~~

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

IEC 61557-12, *Electrical safety in low voltage distribution systems up to 1 000 V AC and 1 500 V DC – Equipment for testing, measuring or monitoring of protective measures – Part 12: Power metering and monitoring devices (PMD)*

IEC TS 61724-2, *Photovoltaic system performance – Part 2: Capacity evaluation method*

IEC TS 61724-3, *Photovoltaic system performance – Part 3: Energy evaluation method*

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

~~IEC 62053-21, *Electricity metering equipment (a.c.) – Particular requirements – Part 21: Static meters for active energy (classes 1 and 2)*~~

IEC 62053-22, *Electricity metering equipment – Particular requirements – Part 22: Static meters for AC active energy (classes 0,1S, 0,2S and 0,5S)*

IEC 62670-3, *Photovoltaic concentrators (CPV) – Performance testing – Part 3: Performance measurements and power rating*

IEC 62817:2014, *Photovoltaic systems – Design qualification of solar trackers*

ISO/IEC Guide 98-1, *Uncertainty of measurement – Part 1: Introduction to the expression of uncertainty in measurement*

ISO/IEC Guide 98-3, *Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

ISO 9060:2018, *Solar energy – Specification and classification of instruments for measuring hemispherical solar and direct solar radiation*

ISO 9488, *Solar energy – Vocabulary*

~~ISO 9846, *Solar energy – Calibration of a pyranometer using a pyrliometer*~~

~~ISO 9847, *Solar energy – Calibration of field pyranometers by comparison to a reference pyranometer*~~

~~WMO No. 8, *Guide to meteorological instruments and methods of observation*~~

~~ASTM G183, *Standard Practice for Field Use of Pyranometers, Pyrliometers and UV Radiometers*~~

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-131, IEC TS 61836, ISO 9488, and the following apply. 1:2021

<https://standards.iteh.ai/catalog/standards/iec/c9f32a26-b82a-4956-910c-4ede09fc6222/iec-61724-1-2021>

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

sample

data acquired from a sensor or measuring device

3.2

sampling interval

time between samples

3.3

record

data recorded and stored ~~in data log, based on acquired samples~~

3.4

recording interval

τ

time between records

3.5 report

aggregate value based on series of records

3.6 reporting period

time between reports

3.7 front side

side of a surface which normally faces the sky

3.8 rear side

side of a surface which normally faces the ground

3.9 monofacial PV device

PV device in which only the front side is used for power generation

3.10 bifacial PV device

PV device in which both front side and rear side are used for power generation

3.11 bifaciality coefficient φ

ratio between an I-V characteristic of the rear side and the front side of a bifacial device, typically at Standard Test Conditions (STC), unless otherwise specified

Note 1 to entry: Bifaciality coefficients include the short-circuit current bifaciality coefficient φ_{ISC} , the open-circuit voltage bifaciality coefficient φ_{Voc} and the maximum power bifaciality coefficient φ_{Pmax} .

<https://standards.iteh.ai/catalog/standards/iec/c9f32a26-b82a-4956-910c-4ede09fc6222/iec-61724-1-2021>

Note 2 to entry: Bifaciality coefficients are defined in IEC TS 60904-1-2.

3.12 irradiance

G

incident flux of radiant power per unit area

Note 1 to entry: Expressed in units of $\text{W}\cdot\text{m}^{-2}$.

3.13 in-plane irradiance

G_i or POA

sum of direct, diffuse, and ground-reflected irradiance incident upon the front side of an inclined surface parallel to the plane of the modules in the PV array, also known as plane-of-array (POA) irradiance

Note 1 to entry: Expressed in units of $\text{W}\cdot\text{m}^{-2}$.

3.14 horizontal albedo

ρ_H

proportion of incident light reflected by a ground surface as measured in a horizontal plane

Note 1 to entry: It is a property of a ground surface and is a dimensionless quantity on a scale from 0 to 1.