

INTERNATIONAL STANDARD

**Hybrid CPV/PV modules: General characteristics and measurement procedures -
Part 1: Performance measurement and power rating - Irradiance and temperature**

CONTENTS

FOREWORD.....	3
INTRODUCTION	5
1 Scope.....	6
2 Normative references	6
3 Terms and definitions.....	6
4 Sampling	8
5 DUT labelling - Indelible marking.....	8
6 Preliminary information by manufacturer	9
7 Testing	9
8 Report	9
9 Power angular responsivity	10
9.1 General	10
9.2 Determination of the collection coefficient	11
10 Power rating condition.....	15
10.1 General	15
10.2 Outdoor power rating of CPV/PV hybrid modules to be installed on fixed structure or on single axis tracker.....	16
10.2.1 General.....	16
10.2.2 Determination of AOI.....	17
10.2.3 Determination of CPV and PV mean cell temperature	18
10.2.4 Translation of the CPV/PV module power to 25 °C reference temperature.....	20
10.2.5 Clear sky model.....	20
10.2.6 Computation of the hybrid CPV/PV module effective nominal power	20
10.2.7 Power measurement procedure for hybrid CPV/PV module with a low FoV	21
10.2.8 Power measurement procedure for Hybrid CPV/PV module with a high FoV	22
10.2.9 Determination of the FoV	23
10.3 Outdoor power rating of CPV/PV hybrid modules installed on dual axis tracker.....	25
10.3.1 Power rating of the CPV array of the CPV/PV hybrid module	25
10.3.2 Power rating of the flat plate PV array of the CPV/PV hybrid module	26
Annex A (informative) General characteristics of CPV/PV hybrid modules	28
A.1 Hybrid CPV/PV module working condition	28
A.2 Hybrid CPV/PV condition	28
A.3 Global PV condition	28
A.4 CPV/PV hybrid module with fixed lens plane (and moving cells plane).....	29
A.5 CPV/PV hybrid module with moving lens plane	29
A.6 CPV/PV hybrid module with integrated tracking	30
A.6.1 General.....	30
A.6.2 CPV/PV hybrid module with internal actuators.....	30
A.6.3 CPV/PV hybrid module with external actuators.....	31
Annex B (informative) Transient test for hybrid CPV/PV module with internal solar tracking	32
Bibliography.....	33

Figure 1 – Schematic of a hybrid CPV/PV module.....	7
Figure 2 – Example of the hybrid CPV/PV module power variation as a function of AOI, compared with the $\cos(\text{AOI})$ behaviour (after [1])	7
Figure 3 – Schematic of the irradiance terms used in Formula (4) for the general case of a hybrid CPV/PV module mounted on a tilted fixed plane	12
Figure 4 – Example of fitting of Formula (7) and Formula (8) for the determination of the collection coefficients: a) $\varepsilon_{\text{PV}}(\theta, 25^\circ)$ and b) $\gamma_{\text{PV}}(\theta, 25^\circ\text{C})$	12
Figure 5 – Example of fitting of Formula (9), with $\tau(\text{AOI}) = 1$ for the determination of the collection coefficient φ_{PVext}	13
Figure 6 – Example of fitting of Formula (12) for the determination of the collection coefficient $\gamma_{\text{CPV}}(\theta, 25^\circ)$	14
Figure 7 – Schematic of the rear module illumination, when the hybrid CPV/PV module adopts bifacial PV solar cells	15
Figure 8 – Schematic of sun and tracker angles for the AOI computation	22
Figure 9 – Schematic of AOI computation from output coordinates measured by the point sensitive detector	23
Figure 10 – Determination of the FoV from the normalized module power, in case of symmetrical refraction; $\text{FoV} = 16^\circ$	24
Figure 11 – Sequence for the determination of the effective nominal power	24
Figure 12 – Sequence for the determination of the collection coefficients $P_1 = P_{\text{CPV}}$, $P_2 = P_{\text{PV(inn)}}$, $P_3 = P_{\text{PV(ext)}}$	25
Figure A.1 – Schematic of the working principle of a hybrid CPV/PV module.....	28
Figure A.2 – Example of a hybrid CPV/PV module power production during the day	29
Figure A.3 – Example of a CPV/PV hybrid module with a fixed lens plane and a moving cells plane (after [3]).....	30
Figure A.4 – Example of CPV/PV hybrid modules with a moving lenses plane.....	30
Figure A.5 – CPV/PV hybrid module with integrated tracking.....	31
Figure B.1 – Transient test steps for hybrid CPV/PV module with internal solar tracking	32
Table 1 – Standard test condition (STC) and standard operating conditions (SOC) for hybrid CPV/PV modules	15
Table 2 – Filtering criteria.....	16

INTERNATIONAL ELECTROTECHNICAL COMMISSION

**Hybrid CPV/PV modules: General characteristics
and measurement procedures -
Part 1: Performance measurement and power rating -
Irradiance and temperature**

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>. IEC shall not be held responsible for identifying any or all such patent rights.

IEC 63387-1 has been prepared by IEC technical committee 82: Solar photovoltaic energy systems. It is an International Standard.

The text of this International Standard is based on the following documents:

Draft	Report on voting
82/2634/FDIS	82/2670/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/publications.

A list of all parts in the IEC 63387 series, published under the general title *Hybrid CPV/PV modules: General characteristics and measurement procedures*, 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, or
- revised.

INTRODUCTION

The IEC 61853 [9]¹ and IEC 62670 series [10] establish requirements for evaluating, respectively, photovoltaic (PV) and concentrated photovoltaic (CPV) module performance, based on power, energy, and performance ratio (PR). They are applicable to most PV and CPV technologies; however they are not well suited to hybrid CPV/PV modules, whose performance can be a discontinuous function of the angle of incidence (AOI), whose geometry can include PV "dead" areas in addition to the module frame, and for which it is important to specify appropriate reference spectra for beam and diffuse components.

The reasons for preparing this document are therefore related to the need to define specific terms and procedures for the performance measurement of hybrid CPV/PV modules. As some hybrid CPV/PV modules incorporate integrated tracking actuators and internal moving parts, the development of specific qualification standards for such modules is also envisaged.

¹ Numbers in square brackets refer to the Bibliography.

1 Scope

This part of IEC 63387 specifies the methods for evaluating CPV/PV hybrid module performance in terms of power rating. Standard conditions for assessing the power produced by the module and the procedures to measure the power as a function of AOI, irradiance, and temperature are described. A methodology for determining a set of characterization parameter values for the hybrid CPV/PV module (FoV) is also included. In order to compare the performance of different hybrid CPV/PV modules whose output is discontinuous and time-dependent, the concept of effective nominal power is introduced.

This document is applicable to CPV/PV hybrid modules which include both solar cells designed to collect concentrated light (CPV cells array) and solar cells designed to collect diffuse or global light (PV cells array), the latter with bifacial or monofacial illumination. This document applies to hybrid CPV/PV modules with a geometrical concentration ratio $> 3\times$ for the CPV cells. For lower geometrical concentration ratio ($\leq 3\times$), the IEC 60904-1 [11] and IEC 61853 series [9] apply.

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 TS 60904-1-2, *Photovoltaic devices - Part 1-2: Measurement of current-voltage characteristics of bifacial photovoltaic (PV) devices*

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

IEC 62108, *Concentrator photovoltaic (CPV) modules and assemblies - Design qualification and type approval*

IEC 62670-1, *Photovoltaic concentrators (CPV) - Performance testing - Part 1: Standard conditions*

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

ISO 2859-1, *Sampling procedures for inspection by attributes - Part 1: Sampling schemes indexed by acceptance quality limit (AQL) for lot-by-lot inspection*

Bibliography

- [1] S. Askins et al., "*Performance of Hybrid Micro-Concentrator Module with Integrated Planar Tracking and Diffuse Light Collection*," Conf. Rec. IEEE Photovolt. Spec. Conf., no. June, pp. 2507–2512, 2019
- [2] J. F. Martínez, M. Steiner, M. Wiesenfarth, G. Siefer, S. W. Glunz, and F. Dimroth, "*Power rating procedure of hybrid concentrator/flat-plate photovoltaic bifacial modules*," Prog. Photovoltaics Res. Appl., vol. 29, no. 6, pp. 614–629, 2021
- [3] Jared S. Price, Xing Sheng, Bram M. Meulblok, John A. Rogers & Noel C. Giebink, "*Wide-angle planar microtracking for quasi-static microcell concentrating photovoltaics*" Nat Commun 6, 6223 (2015). <https://doi.org/10.1038/ncomms7223>
- [4] H. J. D. Johnsen, A. Aksnes, and J. Torgersen, "*High-performance stationary solar tracking through multi-objective optimization of beam-steering lens arrays*," Opt. Express, vol. 28, no. 14, p. 20503, 2020
- [5] Edoardo Celi, Gianluca Timò, Alessandro Minuto and Franco Trespidi, "*New CPV/PV Hybrid module with a self-powered, integrated, 3D meso solar tracker based on Shape Memory Alloys*," CPV-17, 17th Int. Conf. Conc. Photovolt. Syst., pp. 2–7, 2021
- [6] Steve Askins, César Dominguez, Gaël Nardin, "*HIPERION: Scale-up of hybrid planar micro-tracking solar panels for rooftop compatible*," AIP Conference Proceedings, 2550, 030001, 2022
- [7] M. Iqbal, *An Introduction to solar Radiation*. 1983
- [8] Matthew J. Reno et al., "*Global horizontal irradiance clear sky models: implementation and analysis*", SANDIA REPORT, SAND2012-2389, Printed March 2012
- [9] IEC 61853 (all parts), *Photovoltaic (PV) module performance testing and energy rating*
- [10] IEC 62670 (all parts), *Photovoltaic concentrators (CPV) - Performance testing*
- [11] IEC 60904-1 (all parts), *Photovoltaic devices - Part 1: Measurement of photovoltaic current-voltage characteristics*
- [12] IEC 60904-2, *Photovoltaic devices - Part 2: Requirements for photovoltaic reference devices*
- [13] IEC 60904-3, *Photovoltaic devices - Part 3: Measurement principles for terrestrial photovoltaic (PV) solar devices with reference spectral irradiance data*
- [14] IEC 60904-5, *Photovoltaic devices - Part 5: Determination of the equivalent cell temperature (ECT) of photovoltaic (PV) devices by the open-circuit voltage method*
- [15] IEC 61853-2:2016, *Photovoltaic (PV) module performance testing and energy rating - Part 2: Spectral responsivity, incidence angle and module operating temperature measurements*