IEC 62670-3

Edition 1.0 2017-02

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Photovoltaic concentrators (CPV) – Performance testing –
Part 3: Performance measurements and power rating

Concentrateurs photovoltaïques (CPV) – Essai de performances –
Partie 3: Mesurages de performances et rapport de puissance

IEC 62670-3:2017-02(en-fr)

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

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
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 corrigenda or an amendment might have been published.

IEC Catalogue - webstore.iec.ch/catalogue
The stand-alone application for consulting the entire bibliographical information on IEC International Standards, Technical Specifications, Technical Reports and other documents. Available for PC, Mac OS, Android Tablets and iPad.

IEC publications search - www.iec.ch/searchpub
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 It also gives information on projects, replaced and withdrawn publications.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 also once a month by email.

Electropedia - www.electropedia.org
The world's leading online dictionary of electronic and electrical terms containing 20 000 terms and definitions in English and French, with equivalent terms in 16 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC Glossary - std.iec.ch/glossary
65 000 electrotechnical terminology entries in English and French extracted from the Terms and Definitions clause of IEC publications issued since 2002. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

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: csc@iec.ch.

A propos de l'IEC
La Commission Electrotechnique Internationale (IEC) est la première organisation mondiale qui élabore et publie des Normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

A propos des publications IEC
Le contenu technique des publications IEC est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

Catalogue IEC - webstore.iec.ch/catalogue
Application autonome pour consulter tous les renseignements bibliographiques sur les Normes internationales, Spécifications techniques, Rapports techniques et autres documents de l'IEC. Disponible pour PC, Mac OS, tablettes Android et iPad.

Recherche de publications IEC - www.iec.ch/searchpub
La recherche avancée permet de trouver des publications IEC en utilisant différents critères (numéro de référence, texte, comité d'études,…). Elle donne aussi des informations sur les projets et les publications remplacées ou retirées.

IEC Just Published - webstore.iec.ch/justpublished
Restez informé sur les nouvelles publications IEC. Just Published détaille les nouvelles publications parues. Disponible en ligne et aussi une fois par mois par email.

Electropedia - www.electropedia.org
Le premier dictionnaire en ligne de termes électroniques et électriques. Il contient 20 000 termes et définitions en anglais et en français, ainsi que les termes équivalents dans 16 langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (IEV) en ligne.

Glossaire IEC - std.iec.ch/glossary
65 000 entrées terminologiques électrotechniques, en anglais et en français, extraites des articles Termes et Définitions des publications IEC parues depuis 2002. Plus certaines entrées antérieures extraites des publications des CE 37, 77, 86 et CISPR de l'IEC.

Service Clients - webstore.iec.ch/csc
Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions contactez-nous: csc@iec.ch.

IEC 62670-3

Edition 1.0 2017-02

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Photovoltaic concentrators (CPV) – Performance testing – Part 3: Performance measurements and power rating

Concentrateurs photovoltaïques (CPV) – Essai de performances – Partie 3: Mesurages de performances et rapport de puissance

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

ICS 27.160

ISBN 978-2-8322-3859-2

Warning! Make sure that you obtained this publication from an authorized distributor.
Attention! Veuillez vous assurer que vous avez obtenu cette publication via un distributeur agréé.

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

PHOTOVOLTAIC CONCENTRATORS (CPV) – PERFORMANCE TESTING –

Part 3: Performance measurements and power rating

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.

International Standard IEC 62670-3 has been prepared by IEC technical committee 82: Solar photovoltaic energy systems.

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

FDIS	Report on voting
82/1204/FDIS	82/1233/RVD

Full information on the voting for the approval of this International Standard 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 62670 series, published under the general title *Photovoltaic concentrators (CPV) – Performance testing*, 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.

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 CONCENTRATORS (CPV) – PERFORMANCE TESTING –

Part 3: Performance measurements and power rating

1 Scope

This part of IEC 62670 defines measurement procedures and instrumentation for determining concentrator photovoltaic performance at concentrator standard operating conditions (CSOC) and concentrator standard test conditions (CSTC), defined in IEC 62670-1, including power ratings.

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 60904-2, *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 60904-4:2009, *Photovoltaic devices – Part 4: Reference solar devices – Procedures for establishing calibration traceability*

IEC 60904-10, *Photovoltaic devices – Part 10 Methods of linearity measurement*

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

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

ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

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

ISO 9060:1990, *Solar energy – Specification and classification of instruments for measuring hemispherical solar and direct solar radiation*

3 Concepts

The following concepts are used through this document.

a) CSOC – concentrator standard operating conditions per IEC 62670-1 (direct normal irradiance (DNI) 900 W/m^2, 20 °C ambient temperature, 2 m/s wind speed, AM1.5D spectrum per IEC 60904-3).

b) CSTC – concentrator standard test conditions per IEC 62670-1 (DNI 1 000 W/m^2, 25 °C cell temperature, AM1.5D spectrum per IEC 60904-3).

c) SMR – spectral matching ratio, $\mathrm{SMR}(i,j) = \dfrac{I_i / I_j}{I_{i,\mathrm{ref}} / I_{j,\mathrm{ref}}}$ where I_i and I_j are the short-circuit current or short-circuit current densities under prevailing spectral conditions per the i and j distinct subcells in the multi-junction solar cell. $I_{i,\mathrm{ref}}$ and $I_{j,\mathrm{ref}}$ are the associated short-circuit currents/current densities under the AM 1.5 direct spectrum as defined by IEC 60904-3. The subcell is assigned a number in the ordering of their band gap energy (Eg) starting with 1 for the highest Eg and up to n for the lowest Eg. In this manner a multi-junction solar cell with n distinct sub cells has $(n^2-n)/2$ unique SMR values. For example, for $n = 3$ (three-junction device) there is SMR(1,2), SMR(1,3) and SMR(2,3). For a lattice matched triple junction cell: GaInP is junction 1, GaInAs is junction 2, and Ge is junction 3.

SMR as applied to outdoor I-V curves does NOT imply that the outputs from subcells will match the DUT but to a more generic set of subcells used by the test laboratory to characterize deviations in the prevailing outdoor spectrum from the reference AM1.5D spectrum. A specific DUT match is not required as precipitable water vapor, aerosols, and airmass are the dominant variables which drive changes in the outdoor spectrum. It has been shown that filtering based on measurements in three sub-bands of the spectrum is sufficient to minimize CPV DUT performance variation. Component reference cells (8.1.4) can be used to determine SMR values or the SMR can be calculated under the prevailing spectrum. In this case I_1, I_2 and I_3 are generally defined as the direct normal spectral irradiance in sub-bands from 370 nm to 650 nm, 650 nm to 870 nm and 870 nm to 1 650 nm respectively. This is equivalent to assuming a set of component reference cells which have external quantum efficiencies (EQE) of 100 % in the defined bands.

SMR as applied to indoor I-V curves DOES refer to outputs from the subcells that match the DUT. The indoor measurements specifically refer to matching subcells as the spectrum under simulated sunlight is known to deviate from the characteristic shape of the outdoor spectrum. Therefore three sub-bands are not always sufficient to minimize variation in CPV DUT performance. SMR can be determined from device specific component reference cells or can be calculated from the measured spectrum and the spectral responses of device specific component reference cells.

d) Separate SMR crossing – event in outdoor data measurements where the given SMR value is within the defined boundaries around unity and the event is separated by at least an hour from other events where the SMR value is within the defined boundaries around unity.

e) MPP – global maximum power point of an I-V curve.

f) V_{mp} – the voltage at MPP.

g) I_{mp} – the current at MPP.

h) DNI– direct normal irradiance.

i) GNI– global normal irradiance.

j) η – efficiency of the DUT at MPP for an individual I-V curve.

k) DUT – device under test.

l) Aperture – aperture area of the DUT, measured from inside edge to inside edge of the DUT frame. If no clear transition from lens to frame is present an opaque tape can be used to mask off the edge of lens area and define the edge of the aperture area. This shall be completed prior to the collection of I-V curves. If this method is not applicable to the DUT, alternate methods can be considered. The test report shall document the procedure used for determining aperture area.

m) Opening half-angle – half-angle of a device with a collimating tube defined as the arctan(R/L) per Figure 1.

n) Field of view or opening full-angle– two times the opening half angle.

o) Slope angle – angle of a device with a collimating tube defined as the arctan[$(R-r)/L$] per Figure 1.

p) Limit angle – angle of a device with a collimating tube defined as the arctan[$(R+r)/L$] per Figure 1.

q) Primary and secondary axis pointing error – measured angle between the pointing vector of the tracker and the pointing vector of the sun (see Figure 2) [adapted from IEC 62817:2014, 7.2]. Typically the pointing vector of the tracker is defined by the sensor that is used for measuring pointing error. The sensor has a plane which is responsive to the direct beam from the sun. Therefore the normal vector to this measurement plane is representative of the pointing vector of the tracker or the pointing vector of the DUT. Although pointing error as defined is a single angular deviation, the sensor measures this error in two separate angles in relation to reference plane

$$\text{pointing error} = \sqrt{\text{primary axis pointing error}^2 + \text{secondary axis pointing error}^2}$$

In this document, primary and secondary axis pointing error are defined by the above equation. As it is also assumed that the plane of the DUT is aligned with the pointing error sensor, the primary and secondary axes are also representative for the DUT.

r) Acceptance angle – minimum full angle through which the DUT can be rotated (with respect to the sun) while continuing to produce 90 % of its DNI normalized maximum power. Although a two dimensional plot is necessary to fully determine acceptance angle, herein acceptance angle refers to the minimum full angle as resulting from angular measurement sweeps limited to the primary and secondary axes of the DUT (see 9.8.5). For example the DUT described in Figure 3. Figure 3 shows acceptance angle measurement results of 0,75° for the primary axis and 0,7° for the secondary axis. Therefore the acceptance angle for this DUT is reported as 0,7°. Caution should be noted that Figure 3 shows measurement results that are symmetric around the zero point (normal angle of incidence) but a DUT can have asymmetric results.

s) Half acceptance angle – half acceptance angle is defined as the acceptance angle defined above divided by two. This definition is introduced as it is more relevant to filtering restrictions placed on pointing error later in this document. Although asymmetry around the zero angle of incidence is not consistent with this definition of half angle, the definition is retained for simplicity.

t) 98 % acceptance angle and 98 % half acceptance angle – the definitions acceptance angle and half acceptance angle given above apply with the exception that when preceded by 98 % the terms now refer to full and half angles through which DUT orientation can be rotated while continuing to produce 98 % of its DNI normalized maximum power (not the original 90 %). For example the DUT in Figure 3 shows a 98 % acceptance angle of 0,32° and a 98 % half angle measurement of 0,16°.

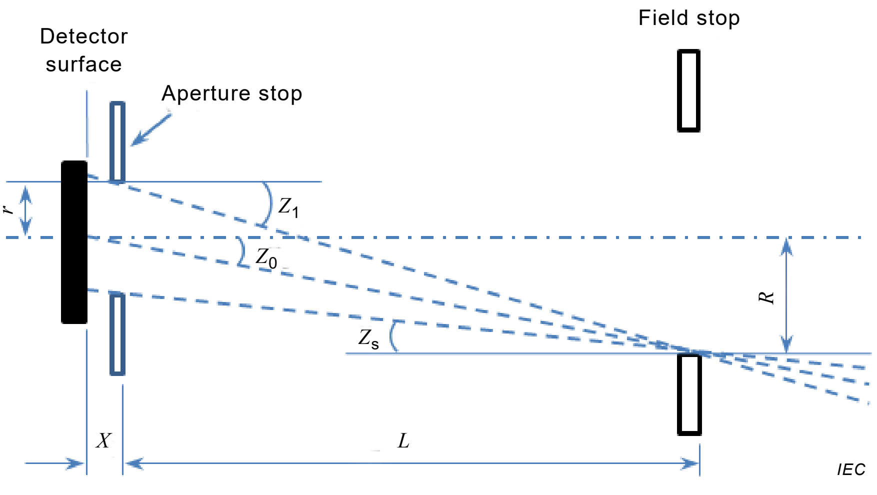


Figure 1 – Collimating tube geometry

In Figure 1 the field stop represents the limiting entry point for light into the collimating tube and has a radius of R. The aperture stop represents further limitation of the light which can reach the detector and has a radius of r. L is the distance between the front of the field stop and aperture stop. It is assumed that the distance, X, between the aperture stop and the detector is small and negligible.

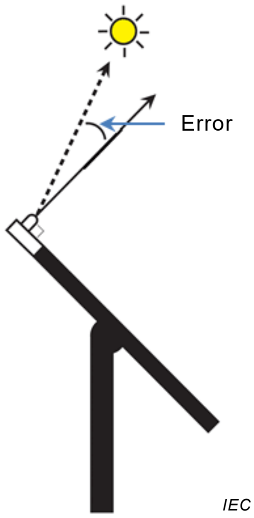


Figure 2 – Solar tracker pointing error

IEC 62817 defines pointing error of a solar tracker as the measured angle between the pointing vector of the tracker and the vector of the sun's rays. As shown here the pointing vector of the tracker is the vector which is normal to the plane of sensor that measures pointing error.

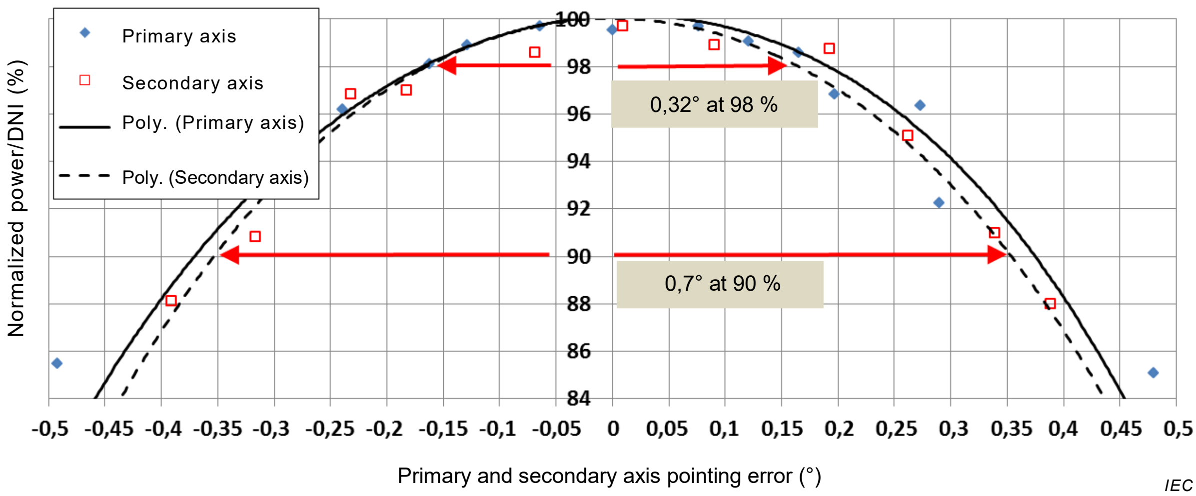


Figure 3 – Example of acceptance angle data for a CPV DUT

In Figure 3 the secondary axis acceptance angle in slightly less than the primary axis acceptance angle and therefore the secondary axis is used in reporting. The DUT has an acceptance angle of 0,7°(half acceptance angle of 0,35°) and a 98 % acceptance angle of 0,32° (98 % half acceptance angle of 0,16°).

4 Sampling

For performance qualification testing three specimens shall be selected at random from a production batch or batches in accordance with the procedure given in ISO 2859-1. For measurements of prototype devices which are not from production, sampling shall not apply. This shall be noted in the test report.

When the results will be used for ascribing a name-plate rating, the modules or assemblies, hereafter referred to as device under test (DUT), shall have been manufactured from specified materials and components in accordance with the relevant drawings and process sheets and shall have been subjected to the manufacture's normal inspection, quality control and production acceptance procedures. The DUT shall be complete in every detail and shall be accompanied by the manufacturer's handling and final assembly instructions regarding the recommended installation of any diodes, frames, brackets, etc.

5 DUT marking and information

5.1 Indelible marking

Each DUT shall carry the following clear and indelible markings:

- name, monogram or symbol of the manufacturer;
- type or model number;
- serial number;
- polarity of terminals or leads (colour coding is permissible);
- the date and place of manufacture shall be marked on the DUT or be traceable from the serial number.

5.2 Preliminary information indicated by manufacturer

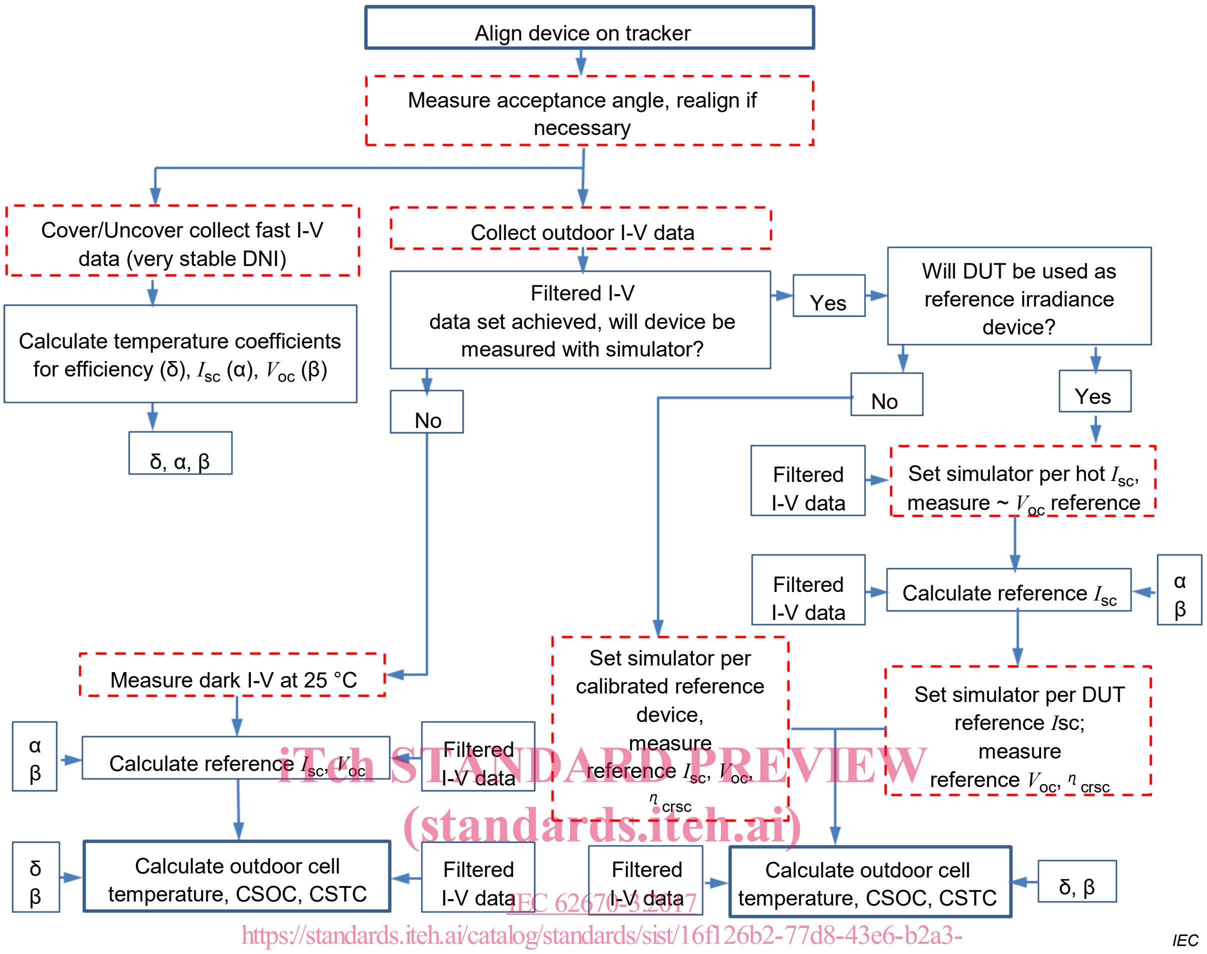
Indicative values shall be provided by the manufacturer to the test laboratory for the purpose of measurement setup:

- expected maximum power point (MPP), V_{oc}, and I_{sc} at CSOC;
- acceptance angle;
- installation instructions.

6 Testing

The DUT shall be subjected to the procedure for irradiance and temperature performance measurements defined in Clause 9. In carrying out the tests, where applicable the tester shall observe the manufacturer's handling, mounting and connection instructions.

Testing of the DUT shall follow the test sequence as defined in Figure 4.



NOTE The dashed boxes indicate actual measurements while solid boxes indicate calculations or decisions in the flow chart.

Figure 4 – Flow chart of performance testing for the DUT

7 Report

Following completion of the procedure, a certified report of the performance tests, with measured power characteristics shall be prepared by the test agency in accordance with the procedures of ISO IEC 17025. Each certificate or test report shall include at least the following information.

a) a title;

b) name and address of the test laboratory and location (including latitude, longitude and altitude if outdoor measurements were included) where the calibration or tests were carried out;

c) unique identification of the certification or report and of each page;

d) name and address of client, where appropriate;

e) description and identification of the item calibrated or tested;

f) characterization and condition of the calibration or test item;

g) date of receipt of test item, date(s) of calibration, and dates and time of outdoor testing, where appropriate;

h) identification of calibration or test method used;

i) reference to sampling procedure, where relevant;

j) any deviations from, additions to or exclusions from the calibration or test method, and any other information relevant to a specific calibration or test, such as environmental conditions;

k) measurements, examinations and derived results, include the following as a minimum: a histogram of all CSOC data points and the mean CSOC power, the mean power at CSTC (include a histogram of all translated data points if outdoor data is used to determine CSTC), DUT temperature coefficients, and the reference V_{oc} and I_{sc} used for cell temperature calculations;

l) a statement of the estimated uncertainty of test results;

m) a statement as to whether the measured CSOC powers agree with the manufacturer's indicated values within the test laboratory's measurement uncertainty (if appropriate);

n) a signature and title, or equivalent identification of the person(s) accepting responsibility for the content of the certificate or report, and the date of issue;

o) where relevant, a statement to the effect that the results relate only to the items calibrated or tested;

p) a statement that the certificate or report shall not be reproduced except in full, without the written approval of the laboratory;

q) identification of the tracker used, the tracker pointing error sensor including sensor calibration data and date, and the documented tracker accuracy characterization per IEC 62817:2014, Clause 7;

r) identification of the wind sensor used, the location of the wind sensor and the calibration of the wind sensor;

s) identification of the normal incidence pyrheliometer (NIP) used and the calibration of the pyrheliometer;

t) identification of the current and voltage sensors used and their calibration;

u) identification of the alignment method used for the DUT;

v) identification of distance between NIP and DUT;

w) identification of the component reference cells or spectroradiometer used and the calibration;

x) identification of the cleaning dates for the DUT, the NIP, and the component reference cells if applicable;

y) statement of determination of aperture area.

A copy of this report shall be kept by the manufacturer for reference purposes.

8 Standard apparatus requirements

8.1 Irradiance measurement equipment

8.1.1 Normal incidence pyrheliometer (NIP)

The DNI measurements shall be made using a first class normal incidence pyrheliometer in accordance with ISO 9060:1990. The reference device shall be linear in measurement as defined in IEC 60904-10 over the irradiance range of interest.

8.1.2 Global normal irradiance pyranometer

GNI measurements shall be made using a PV reference device packaged and calibrated in conformance with IEC 60904-2 or a pyranometer.

8.1.3 Spectral measurement device

For outdoor measurements, the spectral measurement device shall be capable of determining the direct normal spectral irradiance at least in the 3 distinct ranges of wavelengths necessary