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INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Photovoltaic concentrators (CPV) – Performance testing – Part 2: Energy measurement

Concentrateurs photovoltaïques (CPV) – Essai de performances – Partie 2: Mesure de l'énergie

IEC 62670-2:2015-05(en-fr)

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMISSION ELECTROTECHNIQUE INTERNATIONALE

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PHOTOVOLTAIC CONCENTRATORS (CPV) – PERFORMANCE TESTING –

Part 2: Energy measurement

FOREWORD

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International Standard IEC 62670-2 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
82/940/FDIS	82/969/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication 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 publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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INTRODUCTION

IEC 62670 series establishes requirements for evaluating concentrator PV performance. It is written to be applicable to all concentrator PV technologies that have a geometric concentration ratio greater than 3× and require tracking.

Included in the IEC 62670 series of standards are definitions of the standard conditions and methods to be used for assessing CPV performance.

IEC 62670-1 defines a standard set of conditions so that power ratings noted on data sheets and nameplates have a standard basis.

IEC 62670-2 describes an on-sun, measurement based method for determining the energy output and performance ratio for CPV arrays, assemblies and power plants.

IEC 62670-3 (under consideration) describes methods for providing a CPV power assessment under a set of standard conditions, enabling assessments both indoors and outdoors.

IEC 62670-4 (under consideration) describes methods for calculating the prospective electrical energy output of CPV modules, arrays, assemblies and power plants based on the measurements carried out in IEC 62670-2.

PHOTOVOLTAIC CONCENTRATORS (CPV) – PERFORMANCE TESTING –

Part 2: Energy measurement

1 Scope

This part of IEC 62670 specifies the minimum requirements for determining the energy output and performance ratio for CPV modules, arrays, assemblies and power plants using an on-sun, measurement based method.

The purpose of this International Standard is to define testing methods, to establish a standard energy measurement for CPV modules, arrays, assemblies and power plants, and to specify the minimum reporting information.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

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

ISO 8601:2004, *Data elements and interchange formats – Information interchange – Representation of dates and times*

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

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

JCGM 100:2008, *Evaluation of measurement data – Guide to the expression of uncertainty in measurement*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply:

3.1
active AC energy
real AC energy (excluding reactive energy)

3.2
actively cooled
CPV system that requires some type of media (fluid, gas, etc.) to facilitate the transfer of thermal energy from one body to another. This could be by means of force air, pumps, thermo-electric cooler, gas transfer or any other means not covered by passive cooling.

3.3
concentrator
qualifies photovoltaic devices or systems that use concentrated sunlight

Note 1 to entry: Concentrator photovoltaic technology is usually designated as CPV.

3.4
concentrator optics
optical component that performs one or more of the following functions from its input to output: increasing the light intensity, filtering the spectrum, modifying light intensity distribution, or changing light direction

Note 1 to entry: Typically, it is a (refractive) lens or a (reflective) mirror. A primary optic receives un-concentrated sunlight directly from the sun. A secondary optic receives concentrated or modified sunlight from a primary optic and directs it to a cell or a tertiary optic.

3.5
coolant
fluid, gas or other media that is circulated through or around a CPV device and transfers the thermal energy out of the device

3.6
CPV receiver
group of one or more solar cells and secondary optics (if present) that accepts concentrated sunlight and incorporates the means for thermal and electric energy transfer

Note 1 to entry: A receiver can be made of several sub-receivers.

3.7
CPV module
group of receivers, optics, and other related components, such as interconnection and mounting, that accepts un-concentrated sunlight

Note 1 to entry: All above components are usually prefabricated as one unit, and the focus point is not field-adjustable.

3.8
CPV array
group of modules mounted on a tracking device and electrically interconnected

Note 1 to entry: Examples are illustrated in IEC 62108.

3.9
CPV assembly
group of receivers, optics, and other related components, such as interconnects and mounts, that accepts un-concentrated sunlight

Note 1 to entry: All above components would usually be shipped separately and need some field installation, and the focus point is field-adjustable.

3.10
CPV power plant
group of CPV assemblies or CPV arrays electrically interconnected to provide output power to a load

3.11
data acquisition system
DAS
system that typically measures analog values, converts them to digital values and stores them

3.12
device under test
DUT
CPV module(s), array(s), assembly/assemblies or power plant(s) the procedure described in this International Standard is applied to

3.13
direct normal irradiance
DNI
irradiance received from a small solid angle centered on the sun's disc on a plane perpendicular to the sun's rays

3.14
direct plane of array irradiance
DPOAI
irradiance received from a small solid angle centered on the sun's disc in the plane of the CPV array

3.15
global plane of array irradiance
GPOAI
total irradiance received from the sun as a combination of direct normal irradiance and all forms of diffuse light in the plane of the PV array

3.16
gross power/energy
is equal to the net power/energy plus the parasitic power/energy

3.17
net power/energy
is equal to the gross power/energy minus the parasitic power/energy

3.18
normal incidence pyrheliometer
NIP
radiometer designed for measuring the direct irradiance as described in ISO 9060

3.19
parasitic power/energy
power/energy used by the CPV power plant to operate including, but not restricted to, the power and energy used for tracking, control, cooling, drying, measurement, and data acquisition

3.20
passively cooled
cooling with a device that does not require an active energy supply

4 Description of the method

The method of energy measurement of a CPV system is shown in Table 1.

Table 1 – Steps of the energy measurement procedure

Step	Action
1	Select and describe DUT
2	Describe site, location, surroundings
3	Check calibration of DAS, install DAS
4	Start measurements Mandatory: Time, DNI, GPOAI[a], gross power/energy[b], parasitic power/energy[b], net power/energy[b], ambient temperature, wind speed Optionally: Module/receiver temperature, voltage(s), current(s), coolant temperature, wind direction, air humidity
5	Conduct and document operation and maintenance program, e.g. cleaning of modules and NIPs, greasing, tightening of chains Update logbook, e.g. on rainfall events or unscheduled maintenance events
6	Stop measurements
7	Recheck DAS
8	Inspect recorded measurements in order to identify incorrect data, determine DNI time series used to calculate the DNI energy
9	Calculate the DNI energy, gross energy, net energy, uncertainty values, performance ratio, optionally derived parameters
10	Create report

[a] Mandatory for systems that have a geometric concentration ratio of less than 10×.

[b] At least two of the three quantities need to be measured in order to calculate the third quantity.

5 Selection of subset under test

For the energy measurement of a CPV power plant, all components of the system that will be installed with the modules shall be incorporated, so that all parasitic loads of the system are present for the measurement. At times, it may be useful to apply the procedure to a subset of a power plant. In this case, the report shall document the subset that was chosen and the rationale for the choice.

6 Operation, maintenance and cleaning

The CPV modules, arrays, assemblies or power plant shall be operated as suggested by the manufacturer. If the DUT is actively cooled, the flow rate of the coolant and the coolant composition shall be set as suggested by the manufacturer. The flow rate and coolant composition shall be recorded in the testing report.

The scheduled maintenance program as suggested by the manufacturer for all components of the power plant shall be observed, including but not limited to cleaning, greasing, tightening of chains and scheduled change of parts. In particular, cleaning of modules/concentrator optics shall be done at the same frequency as suggested by the manufacturer. In the absence of a suggested frequency, the cleaning of concentrator optics will be performed at a reasonable frequency according to the site conditions.

All scheduled and unscheduled maintenance and cleaning activities shall be noted in the report in detail including time and duration of each event. For each cleaning event it shall be noted whether all of the modules/concentrator optics or only a part thereof were cleaned. In case of a partial cleaning the cleaned part shall be specified unambiguously, e.g. by providing the module or tracker identifiers of the cleaned part.

The NIPs should be cleaned ideally daily, but shall be cleaned at least once per week and each cleaning event shall be noted including time and duration in the report.

7 Downtimes and unavailability

All periods of non-functionality of either the CPV modules, arrays, assemblies or power plant or the sensors or the DAS shall be noted including time and duration and if possible the cause in the report.

8 Parasitic energy

The measurement shall accurately include the parasitic energy consumed by the DUT. Parasitic energy includes, but is not restricted to:

– Energy consumed by the tracking system, including the energy consumed for coming on track, going to stow, and parking the CPV system at night.
– Energy consumed by the control system.
– Energy consumed by the drying system where relevant.
– Energy consumed by the cooling pumps and cooling fans, including the cooling of the inverters, where relevant.
– Energy consumed by the electrical equipment such as inverters, transformers and switch gear.
– Energy consumed by the air conditioning or cooling system in the control room and in the inverter room of the power plant where relevant.

All energy consumed by monitoring and data acquisition equipment not essential for the operation of the power plant shall be considered part of the load and shall not be considered as parasitic energy. If only one or a few modules, arrays or assemblies within a power plant are tested following this International Standard, the parasitic energy drawn by the complete power plant will be divided by the total number of modules, arrays or assemblies in the power plant and multiplied by the number of modules, arrays or assemblies under test.

In cases where parasitic energy is consumed intermittently, e.g. the energy used by the tracking system, particular attention shall be paid to ensuring accurate measurement. When in doubt, the maximum possible parasitic energy shall be used. Details of the calculation will be included in the testing report.

9 Data acquisition

9.1 General requirements

9.1.1 Data acquisition system (DAS)

9.1.1.1 General

An automatic, microprocessor-based, DAS is required for this standard. The total uncertainty of the DAS shall be determined using JCGM 100:2008 as guidance and by checks as laid out below and detailed in the test report.

The DAS excluding sensors can be checked by applying the simulated input signals specified below, or by other means agreed upon between the manufacturer and the customer. The calibrations shall be checked at the beginning and the end of the test. If the check identifies that the calibration has drifted outside of the specification, an assessment of the associated uncertainty/error shall be completed and included in the report.

The channels of the DAS can be checked separately or at the same time.

9.1.1.2 Types of input signals to be checked

– Direct Normal Irradiance power density
– Ambient air temperature
– Wind speed
– Gross power/energy
– Parasitic power/energy
– Net power/energy
– Coolant temperature; only mandatory for actively cooled systems. If optional measurements are taken, the corresponding input signals shall be checked accordingly.

9.1.1.3 Check of linear response

This check is to be performed on analog input channels on which a linear scaling operation is applied. A constant DC or AC (as appropriate) signal shall be applied to the input terminals. The difference between the result measured by the DAS and the products of the input signal value and scaling factor shall be less than ±1 % of the full scale of the DAS. This procedure should be performed at input signals of 0 %, 20 %, 40 %, 60 %, 80 %, and 100 % of full scale. If the inputs are specified for bipolar signals, negative signals shall also be applied in the same way. If errors greater than 1 % of full scale are detected, then the scale factor should be corrected by software or hardware and re-verified.

9.1.1.4 Check of stability

This check is to be performed on all analog input channels. A constant DC signal of 100 % of full scale shall be applied to the input terminals for 6 h. The fluctuation of the measured value of this signal shall be kept within ±1 % of full scale. Should the fluctuation of the input signal exceed ±0,2 %, the results shall be compensated by using a voltmeter with uncertainty of less than ±0,2 %.

9.1.1.5 Check of integration

This check is to be performed on input channels from which measurements are to be processed using an averaging or integrating operation. An input signal of a rectangular wave having an amplitude Z_m shall be applied to the channel and its measured values integrated over time period τ_d (recommended to be at least 6 h). The amplitude Z_m for each channel is recommended to be the maximum input level expected from the sensor. The results obtained shall be equal to $Z_m \times \tau_d \pm 1$ %. The amplitude and time period shall be monitored by measuring instruments with a ±0,5 % precision.

9.1.1.6 Check of zero value integrals

This check is to be performed on input channels from which measurements are to be processed using an averaging or integrating operation. The channel shall be short-circuited, and its measured values integrated over time period τ_d of at least 6 h. The result shall be ±1 % of $Z_m \times \tau_d$ where Z_m is defined in 9.1.1.5.

9.1.2 Sampling interval

The sampling interval for measurands that vary directly with DNI power density shall be 60 s or less. For measurands which have larger time constants, a larger sampling may be selected if necessary, but shall be 5 min or less. For each measured value the time and date shall be recorded in the format defined in the ISO 8601 standard: *YYYY-MM-DDThh:mm:ss.sTZD* (e.g. 1997-07-16T19:20:30.45+01:00)

Where:

YYYY = four-digit year

MM = two-digit month (01=January, etc.)

DD = two-digit day of month (01 through 31, UTC)

hh = two digits of hour (00 through 23, UTC) (am/pm NOT allowed)

mm = two digits of minute (00 through 59, UTC)

ss = two digits of second (00 through 59)

s = one or more digits representing a decimal fraction of a second

TZD = time zone designator (+hh:mm or -hh:mm offset from UTC for local winter time)

9.2 Mandatory measurements

9.2.1 General

The measurements to be taken with the DAS are given in Table 2.

Table 2 – Mandatory measurements.

Quantity	Unit or format	Comment
Date and time	*YYYY-MM-DDThh:mm:ss.sTZD*	As defined in ISO 8601
Direct Normal Irradiance power density	$W \cdot m^{-2}$	
Global plane of array (GPOAI) power density	$W \cdot m^{-2}$	Only mandatory for systems that have a geometric concentration ratio of less than 10×
Ambient air temperature	°C	
Wind speed	$m \cdot s^{-1}$	
Gross power/energy	W (power) or Wh (energy)	At least two of these three quantities need to be measured in order to calculate the third quantity
Parasitic power/energy	W (power) or Wh (energy)	
Net power/energy	W (power) or Wh (energy)	

Additional measurements may be taken for diagnostic purposes.

9.2.2 Direct normal irradiance

The direct normal irradiance power density shall be measured with at least two calibrated NIPs fulfilling at least the first class requirements according to ISO 9060. The total uncertainty of the Direct Normal Irradiance power density measurements shall be determined. It shall be below 3 %.

The two, or, preferably, more, NIPs shall be mounted in a way to reduce periods of shading to a minimum, for example by mounting one NIP on the east side and the other on the west side. The raw values of all NIPs shall be recorded for determination of the DNI time series in 10.3.

The angular range of the tracker(s) carrying the NIPs should allow for tracking the sun under any elevation and azimuth angle occurring at the site. Any DNI energy not measured due to a possibly limited angular range of the tracker(s) shall be assessed in the report.

9.2.3 Global plane of array irradiance

The global plane of array irradiance power density shall be measured with at least two calibrated pyranometers fulfilling at least the first class requirements according to ISO 9847. The total uncertainty of the global plane of array irradiance power density measurements shall be determined. It shall be below 3 %. It is not necessary to obtain global plane of array irradiance measurements if the geometric concentration ratio of the CPV system being considered is more than 10×.