SLOVENSKI STANDARD
SIST EN IEC 60904-3:2019

01-september-2019

Nadomešča:
SIST EN 60904-3:2016

Fotonapetostne naprave - 3. del: Postopki merjenja prizemnih fotonapetostnih (PV) sončnih naprav s podatki referenčnega spektralnega sevanja

Photovoltaic devices - Part 3: Measurement principles for terrestrial photovoltaic (PV) solar devices with reference spectral irradiance data

Photovoltaische Einrichtungen - Teil 3: Messgrundsätze für terrestrische photovoltaische (PV) Einrichtungen mit Angaben über die spektrale Strahlungsverteilung

Dispositifs photovoltaïques - Partie 3: Principes de mesure des dispositifs solaires photovoltaïques (PV) à usage terrestre incluant les données de l'éclairement spectral de référence

Ta slovenski standard je istoveten z: **EN IEC 60904-3:2019**

ICS:

17.240	Merjenje sevanja	Radiation measurements
27.160	Sončna energija	Solar energy engineering

SIST EN IEC 60904-3:2019 **en**

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN IEC 60904-3

July 2019

ICS 27.160

Supersedes EN 60904-3:2016

English Version

Photovoltaic devices - Part 3: Measurement principles for terrestrial photovoltaic (PV) solar devices with reference spectral irradiance data (IEC 60904-3:2019)

Dispositifs photovoltaïques - Partie 3: Principes de mesure des dispositifs solaires photovoltaïques (PV) à usage terrestre incluant les données de l'éclairement spectral de référence
(IEC 60904-3:2019)

Photovoltaische Einrichtungen - Teil 3: Messgrundsätze für terrestrische photovoltaische (PV)-Einrichtungen mit Angaben über die spektrale Strahlungsverteilung
(IEC 60904-3:2019)

This European Standard was approved by CENELEC on 2019-03-22. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

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CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

Ref. No. EN IEC 60904-3:2019 E

European foreword

The text of document 82/1342/CDV, future edition 4 of IEC 60904-3, prepared by IEC/TC 82 "Solar photovoltaic energy systems" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN IEC 60904-3:2019.

The following dates are fixed:

• latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2020-01-05
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2022-07-05

This document supersedes EN 60904-3:2016.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC shall not be held responsible for identifying any or all such patent rights.

Endorsement notice

The text of the International Standard IEC 60904-3:2019 was approved by CENELEC as a European Standard without any modification.

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

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.

NOTE 1 Where an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu.

Publication	Year	Title	EN/HD	Year
IEC 60891	-	Photovoltaic devices - Procedures for temperature and irradiance corrections to measured I-V characteristics	EN 60891	-
IEC 60904-1	-	Photovoltaic devices - Part 1: Measurement of photovoltaic current-voltage characteristics	EN 60904-1	-
IEC 60904-2	-	Photovoltaic devices - Part 2: Requirements for photovoltaic reference devices	EN 60904-2	-
IEC 60904-5	-	Photovoltaic devices - Part 5: Determination of the equivalent cell temperature (ECT) of photovoltaic (PV) devices by the open-circuit voltage method	EN 60904-5	-
IEC 60904-7	-	Photovoltaic devices - Part 7: Computation of the spectral mismatch correction for measurements of photovoltaic devices	EN 60904-7	-
IEC 60904-8	-	Photovoltaic devices - Part 8: Measurement of spectral responsivity of a photovoltaic (PV) device	EN 60904-8	-
IEC 60904-9	-	Photovoltaic devices - Part 9: Solar simulator performance requirements	EN 60904-9	-
IEC 61853-4	-		EN IEC 61853-4	-

IEC 60904-3

Edition 4.0 2019-02

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Photovoltaic devices –
Part 3: Measurement principles for terrestrial photovoltaic (PV) solar devices with reference spectral irradiance data

Dispositifs photovoltaïques –
Partie 3: Principes de mesure des dispositifs solaires photovoltaïques (PV) à usage terrestre incluant les données de l'éclairement énergétique spectral de référence

INTERNATIONAL
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PHOTOVOLTAIC DEVICES –

Part 3: Measurement principles for terrestrial photovoltaic (PV) solar devices with reference spectral irradiance data

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.
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International Standard IEC 60904-3 has been prepared by IEC technical committee 82: Solar photovoltaic energy systems.

This fourth edition cancels and replaces the third edition published in 2016. This edition constitutes a technical revision.

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

a) all spectral data were recalculated due to some minor calculation and rounding errors in the third edition; the global spectral irradiance returned to exactly the data of the second edition;
b) the angular distribution of the irradiance was clarified.

This publication contains an attached file in the form of an Excel spreadsheet. This file is intended to be used as a complement and does not form an integral part of the publication.

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

CDV	Report on voting
82/1342/CDV	82/1425/RVC

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 of 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 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.

PHOTOVOLTAIC DEVICES –

Part 3: Measurement principles for terrestrial photovoltaic (PV) solar devices with reference spectral irradiance data

1 Scope

This part of IEC 60904 applies to the following photovoltaic devices for terrestrial applications:

– solar cells with or without a protective cover;
– sub-assemblies of solar cells;
– modules; and
– systems.

NOTE The term "test specimen" is used to denote any of these devices.

The principles contained in this document cover testing in both natural and simulated sunlight.

Photovoltaic conversion is spectrally selective due to the nature of the semiconductor materials used in PV solar cells and modules. To compare the relative performance of different PV devices and materials a reference standard solar spectral distribution is necessary. This document includes such a reference solar spectral irradiance distribution.

This document also describes basic measurement principles for determining the electrical output of PV devices. The principles given in this document are designed to relate the performance rating of PV devices to a common reference terrestrial solar spectral irradiance distribution.

The reference terrestrial solar spectral irradiance distribution is given in this document in order to classify solar simulators according to the spectral performance requirements contained in IEC 60904-9.

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 60904-5, *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 60904-8, *Photovoltaic devices – Part 8: Measurement of spectral responsivity of a photovoltaic (PV) device*

IEC 60904-9, *Photovoltaic devices – Part 9: Solar simulator performance requirements*

IEC 61853-4, *Photovoltaic (PV) module performance testing and energy rating - Part 4: Standard reference climatic profiles*

3 Terms and definitions

No terms and definitions are listed in this document.

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

4 Measurement principles

In current practice the photovoltaic performance of a solar cell or module is determined by exposing it at a known temperature to stable sunlight, natural or simulated, and measuring its current-voltage (I-V) characteristic curve while measuring the magnitude of both the incident irradiance and the PV device temperature. Detailed I-V curve measurement procedures are included in IEC 60904-1. The measured performances can then be corrected to standard test conditions (STC) or other desired conditions of irradiance and temperature according to IEC 60891. The corrected power output at the maximum power voltage and STC is commonly referred to as the rated power.

Incident irradiance can be measured by means of a PV reference device (whose spectral responsivity shall be known) or, if measuring under natural sunlight, by means of a thermopile-type irradiance detector (pyranometer). If a PV reference device is used, it shall satisfy the requirements specified in IEC 60904-2. Temperature determination of the PV device under test shall be made according to IEC 60904-1 or IEC 60904-5.

Since a solar cell has a wavelength-dependent responsivity, its performance is significantly affected by the spectral distribution of the incident radiation, which in natural sunlight varies with factors such as location, weather, time of year, time of day, orientation of the receiving surface, etc., and with a simulator varies with its type and conditions of use according to IEC 60904-9. Regardless of whether the irradiance is measured with either a thermopile-type radiometer (that is not spectrally selective) or with a reference solar device, the spectral irradiance distribution of the incoming light shall be known in order to use IEC 60904-7 to calculate the spectral mismatch between the measured performance and the predicted performance under the global or direct reference solar spectral distribution defined in this document. When performing measurements according to the standard test conditions, the spectral mismatch between the PV device under test and the thermopile is usually much larger than the spectral mismatch between the PV reference device and the PV device under test.

When the spectral responsivity of the PV device is known as determined according to IEC 60904-8, it is also possible to use IEC 60904-7 to compute the performance of that PV device when exposed to light of any known spectral irradiance distribution.

5 Reference solar spectral and angular irradiance distribution

The reference solar spectral distributions are given in Table 1 and Figure 1.

The reference angular distribution is defined for both, the direct and the global spectral distribution, so that the complete radiation hits the solar device perpendicularly under normal incidence. Other, more realistic geometrical and ambient conditions for different climate zones are defined in IEC 61853-4.

The calculation of the spectral distributions was done using the following geometrical and environmental input parameters:

– global distribution (direct + diffuse + albedo) of sunlight (AM1.5 spectrum), corresponding to an integrated irradiance of 1 000 W·m^{-2} incident on a sun-facing plane surface tilted at 37° to the horizontal, and
– the direct distribution of sunlight (AM1.5d spectrum), corresponding to an integrated irradiance of 900 W·m^{-2} incident on a sun-facing plane surface perpendicular to the incident sunlight,

considering the wavelength-dependent albedo of a light bare soil, under the following atmospheric conditions:

– U.S. standard atmosphere with CO_2 concentration increased to current level (370 ppm), a rural aerosol model, and no pollution;
– precipitable water: 1,416 4 cm;
– ozone content: 0,343 8 atm-cm (or 343,8 DU);
– turbidity (aerosol optical depth): 0,084 at 500 nm;
– pressure: 101,325 kPa (i.e. sea level).

Data contained in Table 1 have been generated using the solar spectral model SMARTS, Version 2.9.2. A general description of this model and its suitability to reproduce actual solar spectral irradiance distributions can be found in "Proposed Reference Irradiance Spectra for Solar Energy Systems Testing" by C. A. Gueymard, C. Myers and K. Emery[1], and in the references therein. Table 1 can be obtained using the data contained in Annex A as an input to the model SMARTS Version 2.9.2. The resulting output spectral irradiance values have to be multiplied by a normalization factor (0,997 1) in order to get an integrated irradiance of 1 000 W·m^{-2} in the wavelength range 0 to infinity for the global irradiance. This same scaling factor is applied to the direct spectrum giving an integrated irradiance of 900 W·m^{-2} in the wavelength range 0 to infinity.

At the time of publication of this document the SMARTS Version 2.9.2 spectral model code is available, free of charge, subject to the author's license agreement, at http://www.nrel.gov/rredc/smarts. A copy of the model, not for distribution purposes, is kept under IEC TC 82 control.

The contents of Table 1 are included in an attached file in the form of an Excel spreadsheet.

[1] C. A. Gueymard, C. Myers and K. Emery, "Proposed Reference Irradiance Spectra for Solar Energy Systems Testing", *Solar Energy*, Vol 73, No. 6, pp. 443-467, 2002.

Table 1 – Reference solar spectral irradiance distribution

Wave-length nm	Global spectral irradiance $W \cdot m^{-2} \cdot nm^{-1}$	Global photon flux $m^{-2} \cdot s^{-1} \cdot nm^{-1}$	Cumulative global integrated irradiance $W \cdot m^{-2}$	Direct spectral irradiance $W \cdot m^{-2} \cdot nm^{-1}$	Direct photon flux $m^{-2} \cdot s^{-1} \cdot nm^{-1}$	Cumulative direct integrated irradiance $W \cdot m^{-2}$
280,0	4,72E-23	6,649E-05	0,00E+00	2,529E-26	3,564E-08	0,000E00
280,5	1,23E-21	1,733E-03	3,19E-22	1,089E-24	1,537E-06	2,785E-25
281,0	5,67E-21	8,025E-03	2,04E-21	6,108E-24	8,640E-06	2,077E-24
281,5	1,56E-19	2,213E-01	4,25E-20	2,740E-22	3,883E-04	7,210E-23
282,0	1,19E-18	1,691E+00	3,79E-19	2,826E-21	4,012E-03	8,472E-22
282,5	4,53E-18	6,443E+00	1,81E-18	1,323E-20	1,882E-02	4,862E-21
283,0	1,84E-17	2,621E+01	7,54E-18	6,745E-20	9,609E-02	2,503E-20
283,5	3,53E-17	5,032E+01	2,10E-17	1,457E-19	2,080E-01	7,832E-20
284,0	7,25E-16	1,036E+03	2,11E-16	4,969E-18	7,105E00	1,357E-18
284,5	2,48E-15	3,550E+03	1,01E-15	2,156E-17	3,088E01	7,990E-18
285,0	7,99E-15	1,146E+04	3,63E-15	8,974E-17	1,287E02	3,581E-17
285,5	4,25E-14	6,107E+04	1,62E-14	6,424E-16	9,232E02	2,188E-16
286,0	1,36E-13	1,964E+05	6,10E-14	2,343E-15	3,374E03	9,653E-16
286,5	8,36E-13	1,205E+06	3,04E-13	1,840E-14	2,654E04	6,152E-15
287,0	2,73E-12	3,942E+06	1,20E-12	7,234E-14	1,045E05	2,884E-14
287,5	1,09E-11	1,573E+07	4,60E-12	3,651E-13	5,284E05	1,382E-13
288,0	6,22E-11	9,011E+07	2,29E-11	2,798E-12	4,056E06	9,290E-13
288,5	1,71E-10	2,485E+08	8,12E-11	9,039E-12	1,313E07	3,888E-12
289,0	5,61E-10	8,162E+08	2,64E-10	3,488E-11	5,074E07	1,487E-11
289,5	2,07E-09	3,015E+09	9,22E-10	1,532E-10	2,233E08	6,189E-11
290,0	6,00E-09	8,758E+09	2,94E-09	5,130E-10	7,490E08	2,285E-10
290,5	1,37E-08	2,010E+10	7,87E-09	1,326E-09	1,940E09	6,883E-10
291,0	3,50E-08	5,120E+10	2,00E-08	3,885E-09	5,691E09	1,991E-09
291,5	1,09E-07	1,597E+11	5,60E-08	1,438E-08	2,111E10	6,558E-09
292,0	2,68E-07	3,932E+11	1,50E-07	4,067E-08	5,978E10	2,032E-08
292,5	4,26E-07	6,267E+11	3,23E-07	7,021E-08	1,034E11	4,804E-08
293,0	8,62E-07	1,272E+12	6,45E-07	1,571E-07	2,318E11	1,049E-07
293,5	2,26E-06	3,345E+12	1,43E-06	4,696E-07	6,938E11	2,616E-07
294,0	4,16E-06	6,160E+12	3,03E-06	9,428E-07	1,395E12	6,147E-07
294,5	6,57E-06	9,743E+12	5,72E-06	1,592E-06	2,360E12	1,248E-06
295,0	1,23E-05	1,820E+13	1,04E-05	3,215E-06	4,775E12	2,450E-06
295,5	2,77E-05	4,127E+13	2,04E-05	7,997E-06	1,190E13	5,253E-06
296,0	4,78E-05	7,117E+13	3,93E-05	1,469E-05	2,190E13	1,093E-05
296,5	7,11E-05	1,062E+14	6,90E-05	2,324E-05	3,469E13	2,041E-05
297,0	9,65E-05	1,443E+14	1,11E-04	3,309E-05	4,947E13	3,449E-05
297,5	1,86E-04	2,779E+14	1,81E-04	6,772E-05	1,014E14	5,970E-05
298,0	2,89E-04	4,336E+14	3,00E-04	1,109E-04	1,664E14	1,044E-04
298,5	3,57E-04	5,362E+14	4,62E-04	1,423E-04	2,138E14	1,677E-04
299,0	4,91E-04	7,386E+14	6,73E-04	2,026E-04	3,050E14	2,539E-04
299,5	8,58E-04	1,294E+15	1,01E-03	3,728E-04	5,620E14	3,978E-04

Wave-length nm	Global spectral irradiance W·m^{-2}·nm^{-1}	Global photon flux m^{-2}·s^{-1}·nm^{-1}	Cumulative global integrated irradiance W·m^{-2}	Direct spectral irradiance W·m^{-2}·nm^{-1}	Direct photon flux m^{-2}·s^{-1}·nm^{-1}	Cumulative direct integrated irradiance W·m^{-2}
300,0	0,0010	1,537E+15	0,00	4,550E-04	6,871E14	0,00
300,5	0,0012	1,878E+15	0,00	5,704E-04	8,629E14	0,00
301,0	0,0019	2,916E+15	0,00	9,166E-04	1,389E15	0,00
301,5	0,0027	4,073E+15	0,00	1,316E-03	1,998E15	0,00
302,0	0,0029	4,428E+15	0,01	1,453E-03	2,209E15	0,00
302,5	0,0043	6,505E+15	0,01	2,185E-03	3,327E15	0,00
303,0	0,0071	1,079E+16	0,01	3,722E-03	5,678E15	0,00
303,5	0,0090	1,368E+16	0,01	4,790E-03	7,319E15	0,01
304,0	0,0094	1,445E+16	0,02	5,083E-03	7,778E15	0,01
304,5	0,0119	1,827E+16	0,02	6,449E-03	9,885E15	0,01
305,0	0,0164	2,520E+16	0,03	8,908E-03	1,368E16	0,02
305,5	0,0187	2,870E+16	0,04	1,016E-02	1,562E16	0,02
306,0	0,0185	2,853E+16	0,05	1,012E-02	1,559E16	0,03
306,5	0,0210	3,247E+16	0,06	1,153E-02	1,780E16	0,03
307,0	0,0278	4,291E+16	0,07	1,520E-02	2,349E16	0,04
307,5	0,0355	5,500E+16	0,09	1,941E-02	3,005E16	0,05
308,0	0,0377	5,850E+16	0,11	2,069E-02	3,208E16	0,06
308,5	0,0413	6,415E+16	0,13	2,268E-02	3,523E16	0,07
309,0	0,0404	6,287E+16	0,15	2,223E-02	3,458E16	0,08
309,5	0,0432	6,728E+16	0,17	2,360E-02	3,677E16	0,09
310,0	0,0508	7,926E+16	0,19	2,775E-02	4,330E16	0,10
310,5	0,0653	1,021E+17	0,22	3,577E-02	5,592E16	0,12
311,0	0,0827	1,294E+17	0,26	4,526E-02	7,086E16	0,14
311,5	0,0838	1,315E+17	0,30	4,602E-02	7,217E16	0,16
312,0	0,0931	1,462E+17	0,34	5,075E-02	7,971E16	0,19
312,5	0,0987	1,553E+17	0,39	5,361E-02	8,434E16	0,21
313,0	0,1070	1,686E+17	0,44	5,815E-02	9,163E16	0,24
313,5	0,1073	1,693E+17	0,49	5,883E-02	9,284E16	0,27
314,0	0,1193	1,886E+17	0,55	6,508E-02	1,029E17	0,30
314,5	0,1302	2,062E+17	0,61	7,027E-02	1,113E17	0,33
315,0	0,1359	2,154E+17	0,68	7,347E-02	1,165E17	0,37
315,5	0,1180	1,875E+17	0,74	6,464E-02	1,027E17	0,40
316,0	0,1231	1,959E+17	0,80	6,689E-02	1,064E17	0,44
316,5	0,1499	2,389E+17	0,87	8,088E-02	1,289E17	0,47
317,0	0,1711	2,730E+17	0,95	9,275E-02	1,480E17	0,52
317,5	0,1819	2,908E+17	1,04	9,942E-02	1,589E17	0,57
318,0	0,1754	2,808E+17	1,13	9,554E-02	1,529E17	0,61
318,5	0,1854	2,972E+17	1,22	9,976E-02	1,599E17	0,66
319,0	0,2041	3,278E+17	1,32	1,094E-01	1,757E17	0,72
319,5	0,1953	3,142E+17	1,42	1,066E-01	1,715E17	0,77
320,0	0,2047	3,297E+17	1,52	1,124E-01	1,811E17	0,82