



# INTERNATIONAL STANDARD



---

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

INTERNATIONAL  
ELECTROTECHNICAL  
COMMISSION

---

ICS 27.160

ISBN 978-2-8322-6585-7

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

## CONTENTS

FOREWORD .....	3
1 Scope <del>and object</del> .....	5
2 Normative references .....	5
3 Terms and definitions .....	6
4 Measurement principles .....	6
5 Reference solar spectral and angular irradiance distribution .....	6
Annex A (informative) Use of SMARTS .....	64
<del>Bibliography .....</del>	<del>.....</del>

Figure 1 – Global and direct reference solar spectral irradiance distribution listed in Table 1 .....	107
---	-----

Table 1 – Reference solar spectral irradiance distribution .....	8
--	---

Table A.1 – Input data for generation of reference solar spectral irradiance distribution .....	108
---	-----

## INTERNATIONAL ELECTROTECHNICAL COMMISSION

### 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.
- 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. 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 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.

**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 publication using a colour printer.**

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

### 1 ~~Scope and object~~

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: Measurements 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*

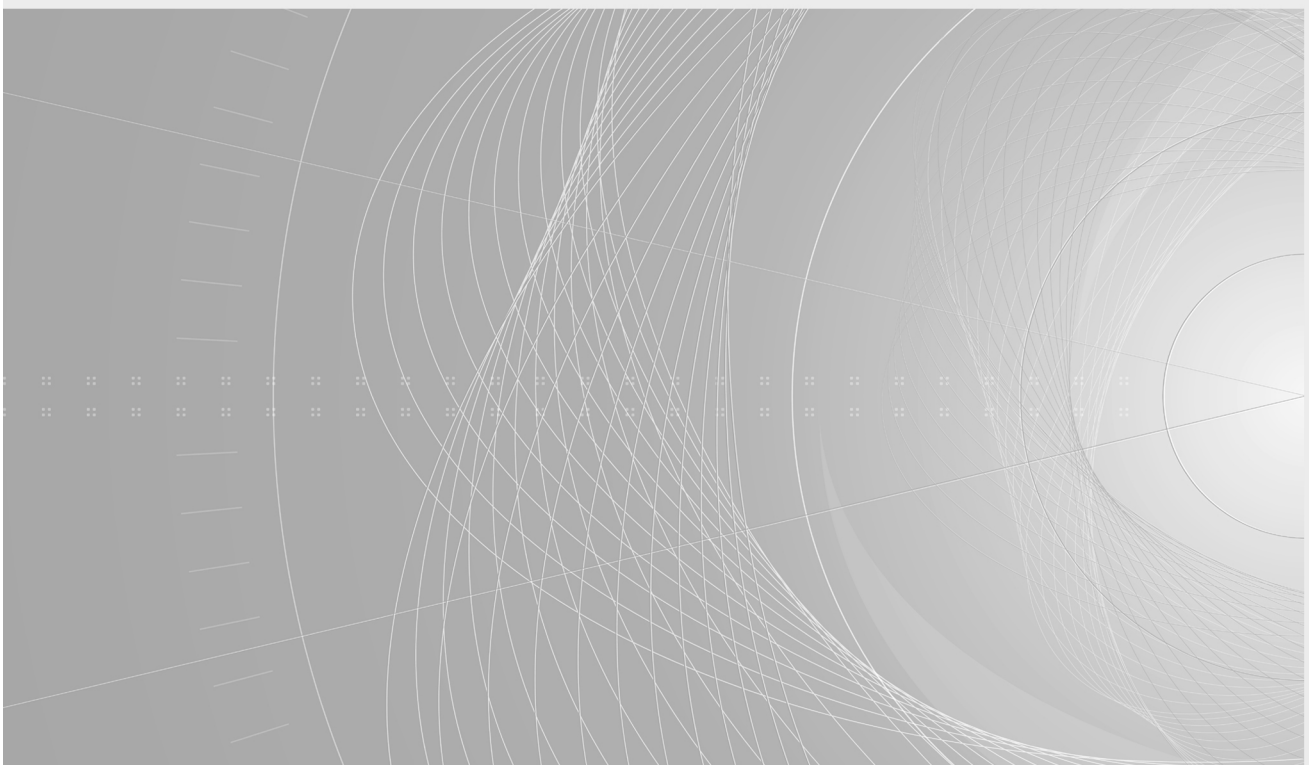
# INTERNATIONAL STANDARD

# 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**



## CONTENTS

FOREWORD .....	3
1 Scope .....	5
2 Normative references .....	5
3 Terms and definitions .....	6
4 Measurement principles .....	6
5 Reference solar spectral and angular irradiance distribution .....	6
Annex A (informative) Use of SMARTS .....	58
Figure 1 – Global and direct reference solar spectral irradiance distribution listed in Table 1 .....	57
Table 1 – Reference solar spectral irradiance distribution .....	8
Table A.1 – Input data for generation of reference solar spectral irradiance distribution .....	58



## INTERNATIONAL ELECTROTECHNICAL COMMISSION

### 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.
- 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 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*

## SOMMAIRE

AVANT-PROPOS .....	61
1 Domaine d'application .....	63
2 Références normatives .....	63
3 Termes et définitions .....	64
4 Principes de mesure .....	64
5 Distribution spectrale et angulaire de l'éclairage solaire de référence .....	65
Annexe A (informative) Utilisation de SMARTS .....	109
Figure 1 – Distribution spectrale de l'éclairage solaire global et direct de référence donnée dans le Tableau 1 .....	108
Tableau 1 – Distribution spectrale de l'éclairage solaire de référence .....	66
Tableau A.1 – Données d'entrée pour générer la distribution spectrale de l'éclairage solaire de référence .....	109

## COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

### DISPOSITIFS PHOTOVOLTAÏQUES –

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

#### AVANT-PROPOS

- 1) La Commission Electrotechnique Internationale (IEC) est une organisation mondiale de normalisation composée de l'ensemble des comités électrotechniques nationaux (Comités nationaux de l'IEC). L'IEC a pour objet de favoriser la coopération internationale pour toutes les questions de normalisation dans les domaines de l'électricité et de l'électronique. A cet effet, l'IEC – entre autres activités – publie des Normes internationales, des Spécifications techniques, des Rapports techniques, des Spécifications accessibles au public (PAS) et des Guides (ci-après dénommés "Publication(s) de l'IEC"). Leur élaboration est confiée à des comités d'études, aux travaux desquels tout Comité national intéressé par le sujet traité peut participer. Les organisations internationales, gouvernementales et non gouvernementales, en liaison avec l'IEC, participent également aux travaux. L'IEC collabore étroitement avec l'Organisation Internationale de Normalisation (ISO), selon des conditions fixées par accord entre les deux organisations.
- 2) Les décisions ou accords officiels de l'IEC concernant les questions techniques représentent, dans la mesure du possible, un accord international sur les sujets étudiés, étant donné que les Comités nationaux de l'IEC intéressés sont représentés dans chaque comité d'études.
- 3) Les Publications de l'IEC se présentent sous la forme de recommandations internationales et sont agréées comme telles par les Comités nationaux de l'IEC. Tous les efforts raisonnables sont entrepris afin que l'IEC s'assure de l'exactitude du contenu technique de ses publications; l'IEC ne peut pas être tenue responsable de l'éventuelle mauvaise utilisation ou interprétation qui en est faite par un quelconque utilisateur final.
- 4) Dans le but d'encourager l'uniformité internationale, les Comités nationaux de l'IEC s'engagent, dans toute la mesure possible, à appliquer de façon transparente les Publications de l'IEC dans leurs publications nationales et régionales. Toutes divergences entre toutes Publications de l'IEC et toutes publications nationales ou régionales correspondantes doivent être indiquées en termes clairs dans ces dernières.
- 5) L'IEC elle-même ne fournit aucune attestation de conformité. Des organismes de certification indépendants fournissent des services d'évaluation de conformité et, dans certains secteurs, accèdent aux marques de conformité de l'IEC. L'IEC n'est responsable d'aucun des services effectués par les organismes de certification indépendants.
- 6) Tous les utilisateurs doivent s'assurer qu'ils sont en possession de la dernière édition de cette publication.
- 7) Aucune responsabilité ne doit être imputée à l'IEC, à ses administrateurs, employés, auxiliaires ou mandataires, y compris ses experts particuliers et les membres de ses comités d'études et des Comités nationaux de l'IEC, pour tout préjudice causé en cas de dommages corporels et matériels, ou de tout autre dommage de quelque nature que ce soit, directe ou indirecte, ou pour supporter les coûts (y compris les frais de justice) et les dépenses découlant de la publication ou de l'utilisation de cette Publication de l'IEC ou de toute autre Publication de l'IEC, ou au crédit qui lui est accordé.
- 8) L'attention est attirée sur les références normatives citées dans cette publication. L'utilisation de publications référencées est obligatoire pour une application correcte de la présente publication.
- 9) L'attention est attirée sur le fait que certains des éléments de la présente Publication de l'IEC peuvent faire l'objet de droits de brevet. L'IEC ne saurait être tenue pour responsable de ne pas avoir identifié de tels droits de brevets et de ne pas avoir signalé leur existence.

La Norme internationale IEC 60904-3 a été établie par le comité d'études 82 de l'IEC: Systèmes de conversion photovoltaïque de l'énergie solaire.

Cette quatrième édition annule et remplace la troisième édition parue en 2016. Cette édition constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

- a) nouveau calcul de toutes les données spectrales en raison de la présence d'un certain nombre d'erreurs de calcul et d'arrondi dans la troisième édition; remplacement de l'éclairage spectral global par les données exactes de la deuxième édition;

b) clarification de la distribution angulaire de l'éclairage.

La présente publication contient un fichier joint de type feuille de calcul Excel. Ce fichier est destiné à être utilisé comme complément et ne fait pas partie intégrante de la publication.

Le texte de cette Norme internationale est issu des documents suivants:

CDV	Rapport de vote
82/1342/CDV	82/1425/RVC

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à l'approbation de cette Norme internationale.

Ce document a été rédigé selon les Directives ISO/IEC, Partie 2.

Une liste de toutes les parties de la série IEC 60904, publiées sous le titre général *Dispositifs photovoltaïques*, peut être consultée sur le site web de l'IEC.

Le comité a décidé que le contenu de ce document ne sera pas modifié avant la date de stabilité indiquée sur le site web de l'IEC sous "http://webstore.iec.ch" dans les données relatives au document recherché. A cette date, le document sera

- reconduit,
- supprimé,
- remplacé par une édition révisée, ou
- amendé.

## 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

#### 1 Domaine d'application

La présente partie de l'IEC 60904 s'applique aux dispositifs photovoltaïques suivants pour les applications terrestres:

- cellules solaires avec ou sans protecteur;
- assemblages de cellules solaires;
- modules; et
- systèmes.

NOTE Le terme "éprouvette d'essai" est utilisé pour désigner chacun de ces dispositifs.

Les principes contenus dans le présent document comprennent les essais réalisés sous un éclairement solaire naturel ainsi que sous un éclairement solaire simulé.

La conversion photovoltaïque est spectralement sélective en raison de la nature des matériaux à semiconducteurs utilisés dans les cellules et modules solaires PV. Pour comparer la performance relative de différents dispositifs et matériaux PV, une distribution spectrale de l'éclairement solaire normalisée de référence est nécessaire. Le présent document inclut une telle distribution spectrale de l'éclairement solaire de référence.

Le présent document décrit également des principes de mesure de base pour la détermination de la sortie électrique des dispositifs PV. Les principes indiqués dans le présent document sont prévus pour relier les caractéristiques assignées de performance des dispositifs PV à une distribution spectrale de l'éclairement solaire terrestre de référence commune.

La distribution spectrale de l'éclairement solaire terrestre de référence est indiquée dans le présent document pour classer les simulateurs solaires selon les exigences pour le fonctionnement spectral contenues dans l'IEC 60904-9.

#### 2 Références normatives

Les documents suivants cités dans le texte constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60891, *Dispositifs photovoltaïques – Procédures pour les corrections en fonction de la température et de l'éclairement à appliquer aux caractéristiques I-V mesurées*

IEC 60904-1, *Dispositifs photovoltaïques – Partie 1: Mesure des caractéristiques courant-tension des dispositifs photovoltaïques*

IEC 60904-2, *Dispositifs photovoltaïques – Partie 2: Exigences applicables aux dispositifs photovoltaïques de référence*



IEC 60904-5, *Dispositifs photovoltaïques – Partie 5: Détermination de la température de cellule équivalente (ECT) des dispositifs photovoltaïques (PV) par la méthode de la tension en circuit ouvert*

IEC 60904-7, *Dispositifs photovoltaïques – Partie 7: Calcul de la correction de désadaptation des réponses spectrales dans les mesures de dispositifs photovoltaïques*

IEC 60904-8, *Dispositifs photovoltaïques – Partie 8: Mesure de la sensibilité spectrale d'un dispositif photovoltaïque (PV)*

IEC 60904-9, *Dispositifs photovoltaïques – Partie 9: Exigences pour le fonctionnement des simulateurs solaires*

IEC 61853-4, *Essais de performance et caractéristiques assignées d'énergie des modules photovoltaïques (PV) – Partie 4: Profils climatiques de référence normalisés*