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Edition 1.0 2017-03

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Photovoltaic system performance – Part 1: Monitoring

Performances des systèmes photovoltaïques – Partie 1: Surveillance

IEC 61724-1:2017-03(en-fr)

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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 61724-1 has been prepared by IEC technical committee 82: Solar photovoltaic energy systems.

This bilingual version (2019-01) corresponds to the monolingual English version, published in 2017-03.

This first edition cancels and replaces the first edition of IEC 61724, published in 1998. This edition constitutes a technical revision.

This edition (in conjunction with IEC TS 61724-2:2016 and IEC TS 61724-3:2016) includes the following significant technical changes with respect to IEC 61724:

a) IEC 61724 is now written with multiple parts. This document is IEC 61724-1, addressing PV system monitoring. IEC TS 61724-2 and IEC TS 61724-3 address performance analysis based on the monitoring data.
b) Three classes of monitoring systems are defined corresponding to different levels of accuracy and different intended applications.

c) Required measurements for each class of monitoring system are stated, along with the required number and accuracy of sensors.

d) Options for satellite-based irradiance measurement are provided.

e) Soiling measurement is introduced.

f) New performance metrics are introduced, including temperature compensated performance ratios and others.

g) Numerous recommendations and explanatory notes are included.

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

FDIS	Report on voting
82/1215/FDIS	82/1248/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.

The French version of this standard has not been voted upon.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 61724 series, published under the general title *Photovoltaic system performance*, 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

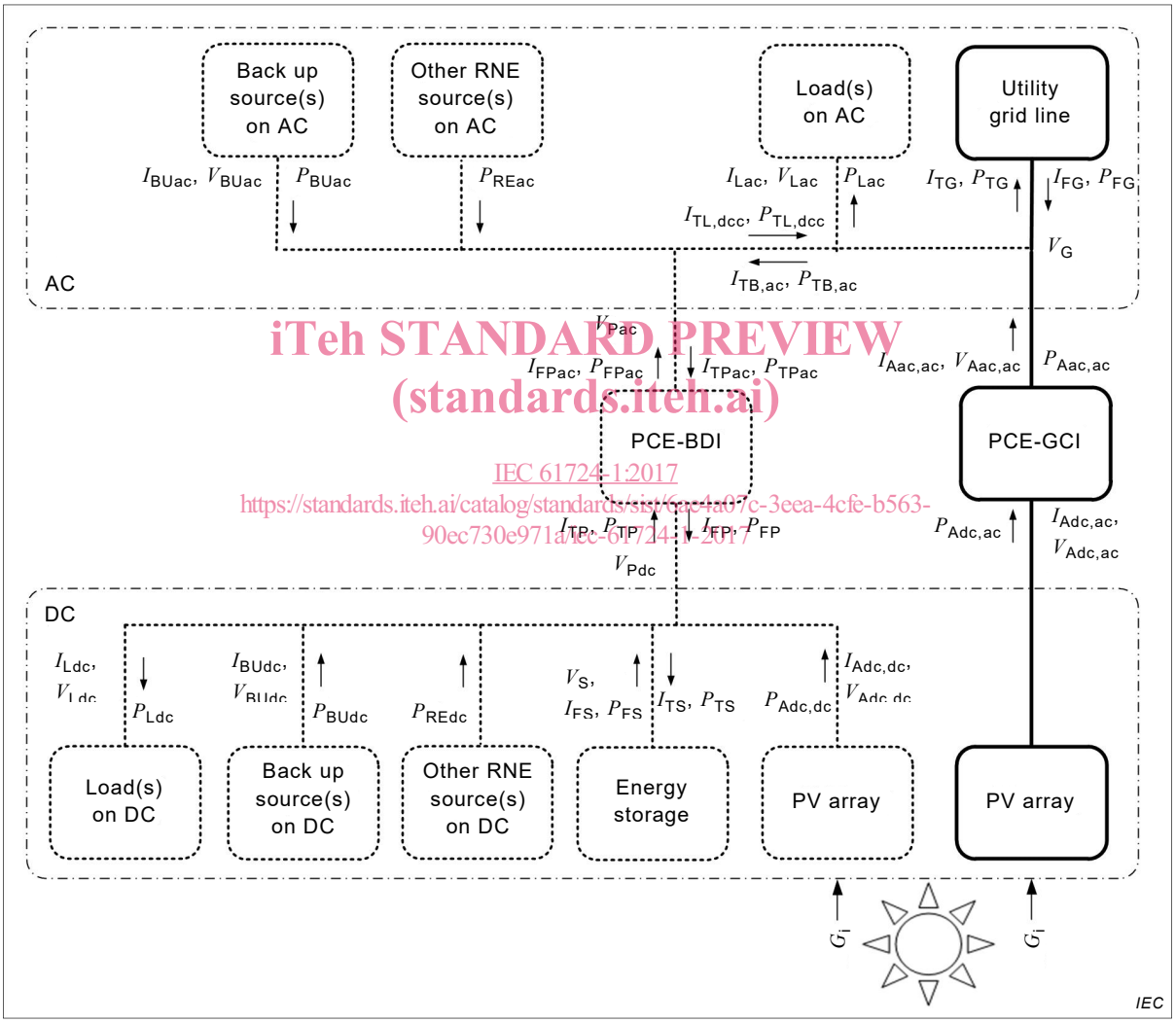
- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

INTRODUCTION

This International Standard defines classes of photovoltaic (PV) performance monitoring systems and serves as guidance for various monitoring system choices.

Figure 1 illustrates possible major elements comprising different PV system types. The PV array may include both fixed axis and tracking systems and both flat plate and concentrator systems. Module-level electronics, if present, may be a component of the monitoring system.

For simplicity, the main clauses of this document are written for grid-connected systems without local loads, energy storage, or auxiliary sources, as shown by the bold lines in Figure 1. Annex D includes details for systems with additional components.



Key

RNE renewable energy

PCE power conditioning equipment

BDI bi-directional inverter

GCI grid-connected inverter

Bold lines denote simple grid-connected system without local loads, energy storage, or auxiliary sources.

Figure 1 – Possible elements of PV systems

The purposes of a performance monitoring system are diverse and can include the following:

- identification of performance trends in an individual PV system;
- localization of potential faults in a PV system;
- comparison of PV system performance to design expectations and guarantees;
- comparison of PV systems of different configurations; and
- comparison of PV systems at different locations.

These diverse purposes give rise to a diverse set of requirements, and different sensors and/or analysis methods may be more or less suited depending on the specific objective. For example, for comparing performance to design expectations and guarantees, the focus should be on system-level data and consistency between prediction and test methods, while for analysing performance trends and localizing faults, there may be a need for greater resolution at sub-levels of the system and an emphasis on measurement repeatability and correlation metrics rather than absolute accuracy.

The monitoring system should be adapted to the PV system's size and user requirements. In general, larger and more expensive PV systems should have more monitoring points and higher accuracy sensors than smaller and lower-cost PV systems. This document defines three classifications of monitoring system with differentiated requirements which are appropriate to a range of purposes.

PHOTOVOLTAIC SYSTEM PERFORMANCE –

Part 1: Monitoring

1 Scope

This part of IEC 61724 outlines equipment, methods, and terminology for performance monitoring and analysis of photovoltaic (PV) systems. It addresses sensors, installation, and accuracy for monitoring equipment in addition to measured parameter data acquisition and quality checks, calculated parameters, and performance metrics. In addition, it serves as a basis for other standards which rely upon the data collected.

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 60050-131, *International Electrotechnical Vocabulary – Part 131: Circuit theory*

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 60904-5, *Photovoltaic devices – Part 5: Determination of the equivalent cell temperature (ECT) of photovoltaic (PV) devices by the open-circuit voltage method*

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

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

IEC 61557-12, *Electrical safety in low voltage distribution systems up to 1 000 V a.c. and 1 500 V d.c. – Equipment for testing, measuring or monitoring of protective measures – Part 12: Performance measuring and monitoring devices (PMD)*

IEC 62053-21, *Electricity metering equipment (a.c.) – Particular requirements – Part 21: Static meters for active energy (classes 1 and 2)*

IEC 62053-22, *Electricity metering equipment (a.c.) – Particular requirements – Part 22: Static meters for active energy (classes 0,2 S and 0,5 S)*

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

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

ISO/IEC Guide 98-1, *Uncertainty of measurement – Part 1: Introduction to the expression of uncertainty in measurement*

ISO/IEC Guide 98-3, *Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

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

ISO 9488, *Solar energy – Vocabulary*

ISO 9846, *Solar energy – Calibration of a pyranometer using a pyrheliometer*

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

WMO No. 8, *Guide to meteorological instruments and methods of observation*

ASTM G183, *Standard Practice for Field Use of Pyranometers, Pyrheliometers and UV Radiometers*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-131, IEC TS 61836, ISO 9488 and the following apply.

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

3.1
sample
data acquired from a sensor or measuring device

3.2
sampling interval
time between samples

3.3
record
data recorded and stored in data log, based on acquired samples

3.4
recording interval
τ
time between records

3.5
report
aggregate value based on series of records

3.6
reporting period
time between reports

3.7
irradiance
G
incident flux of radiant power per unit area

Note 1 to entry: Expressed in units of $W \cdot m^{-2}$.

3.8
in-plane irradiance
G_i or *POA*
the sum of direct, diffuse, and ground-reflected irradiance incident upon an inclined surface parallel to the plane of the modules in the PV array, also known as plane-of-array (POA) irradiance

Note 1 to entry: Expressed in units of $W \cdot m^{-2}$.

3.9
global horizontal irradiance
GHI
direct plus diffuse irradiance incident on a horizontal surface

Note 1 to entry: Expressed in units of $W \cdot m^{-2}$.

3.10
circumsolar
immediately surrounding the solar disk

3.11
direct normal irradiance
DNI
irradiance emanating from the solar disk and from the circumsolar region of the sky within a subtended full angle of 5° falling on a plane surface normal to the sun's rays

Note 1 to entry: Some *DNI* measurement instruments have a field of view with a subtended full angle of up to 6°.

Note 2 to entry: Expressed in units of $W \cdot m^{-2}$.

3.12
circumsolar ratio
CSR
fraction of measured direct normal irradiance (*DNI*) emanating from the circumsolar region of the sky, i.e. within the angular acceptance of the *DNI* sensor but outside the solar disk

3.13
diffuse horizontal irradiance
G_d or *DHI*
global horizontal irradiance excluding the portion emanating from the solar disk and from the circumsolar region of the sky within a subtended full angle of 5°

Note 1 to entry: Some diffuse irradiance measurement instruments exclude a circumsolar region within a subtended full angle of up to 6°.

Note 2 to entry: Expressed in units of $W \cdot m^{-2}$.

3.14
in-plane direct beam irradiance
$G_{i,b}$
in-plane irradiance emanating from the solar disk and from the circumsolar region of the sky within a subtended full angle of 5°, excluding scattering and reflections.

Note 1 to entry: The in-plane direct beam irradiance Gi,b = cos(θ)×DNI, where θ is the angle between the sun and the normal to the plane. When the plane of array is normal to the sun, Gi,b = DNI.

Note 2 to entry: Expressed in units of W·m^{-2}.

3.15
in-plane diffuse irradiance
$G_{i,d}$
in-plane irradiance excluding the direct beam irradiance

Note 1 to entry: $G_{i,d} = G_i - G_{i,b}$.

Note 2 to entry: Expressed in units of W·m^{-2}.

3.16
irradiation
H
irradiance integrated over a specified time interval

Note 1 to entry: Expressed in units of kW·h·m^{-2}.

3.17
standard test conditions
STC
reference values of in-plane irradiance (1 000 W·m^{-2}), PV cell junction temperature (25 °C), and the reference spectral irradiance defined in IEC 60904-3

3.18
soiling ratio
SR
ratio of the actual power output of the PV array under given soiling conditions to the power that would be expected if the PV array were clean and free of soiling

3.19
soiling level
SL
fractional power loss due to soiling, given by 1 − SR

3.20
active power
P
under periodic conditions, mean value, taken over one period, of the instantaneous product of current and voltage

Note 1 to entry: Under sinusoidal conditions, the active power is the real part of the complex power.

Note 2 to entry: Expressed in units of W.

3.21
apparent power
S
product of the r.m.s. voltage between the terminals of a two-terminal element or two-terminal circuit and the r.m.s. electric current in the element or circuit

Note 1 to entry: Under sinusoidal conditions, the apparent power is the modulus of the complex power.

Note 2 to entry: Expressed in units of VA.

3.22
power factor
λ
under periodic conditions, ratio of the absolute value of the active power P to the apparent power S:

$$\lambda = \frac{|P|}{S}$$

4 Monitoring system classification

The required accuracy and complexity of the monitoring system depends on the PV system size and user objectives. This document defines three classifications of monitoring systems providing varying levels of accuracy, as listed in Table 1.

The monitoring system classification shall be stated in any conformity declarations to this standard. The monitoring system classification may be referenced either by its letter code (A, B, C) or its name (high accuracy, medium accuracy, basic accuracy) as indicated in Table 1. In this document, the letter codes are used for convenience.

Class A or Class B would be most appropriate for large PV systems, such as utility-scale and large commercial installations, while Class B or Class C would be most appropriate for small systems, such as smaller commercial and residential installations. However, users of the standard may specify any classification appropriate to their application, regardless of PV system size.

Throughout this document, some requirements are designated as applying to a particular classification. Where no designation is given, the requirements apply to all classifications.

Table 1 – Monitoring system classifications and suggested applications

Typical applications	Class A High accuracy	Class B Medium accuracy	Class C Basic accuracy
Basic system performance assessment	X	X	X
Documentation of a performance guarantee	X	X	
System losses analysis	X	X	
Electricity network interaction assessment	X		
Fault localization	X		
PV technology assessment	X		
Precise PV system degradation measurement	X		

5 General

5.1 Measurement uncertainty

Where requirements on measurement uncertainties are stated in the document, they refer to the combined uncertainties of the measurement sensors and any signal-conditioning electronics.

Measurement uncertainties shall apply over the typical range of values of each measured quantity indicated in the document, as well as over the typical temperature range at which the system will operate. The effect of non-linearity of the measurement within the typical range shall be included within the stated uncertainty.