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INTERNATIONAL STANDARD

NORME INTERNATIONALE

Photovoltaic system performance – Part 1: Monitoring

Performances des systèmes photovoltaïques – Partie 1: Surveillance

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PHOTOVOLTAIC SYSTEM PERFORMANCE –

Part 1: Monitoring

FOREWORD

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

This second edition cancels and replaces the first edition, published in 2017. This edition constitutes a technical revision.

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

- Monitoring of bifacial systems is introduced.
- Irradiance sensor requirements are updated.
- Soiling measurement is updated based on new technology.
- Class C monitoring systems are eliminated.
- Various requirements, recommendations and explanatory notes are updated.

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

FDIS	Report on voting
82/1904/FDIS	82/1925/RVD

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

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 webstore.iec.ch in the data related to the specific document. At this date, the document will be

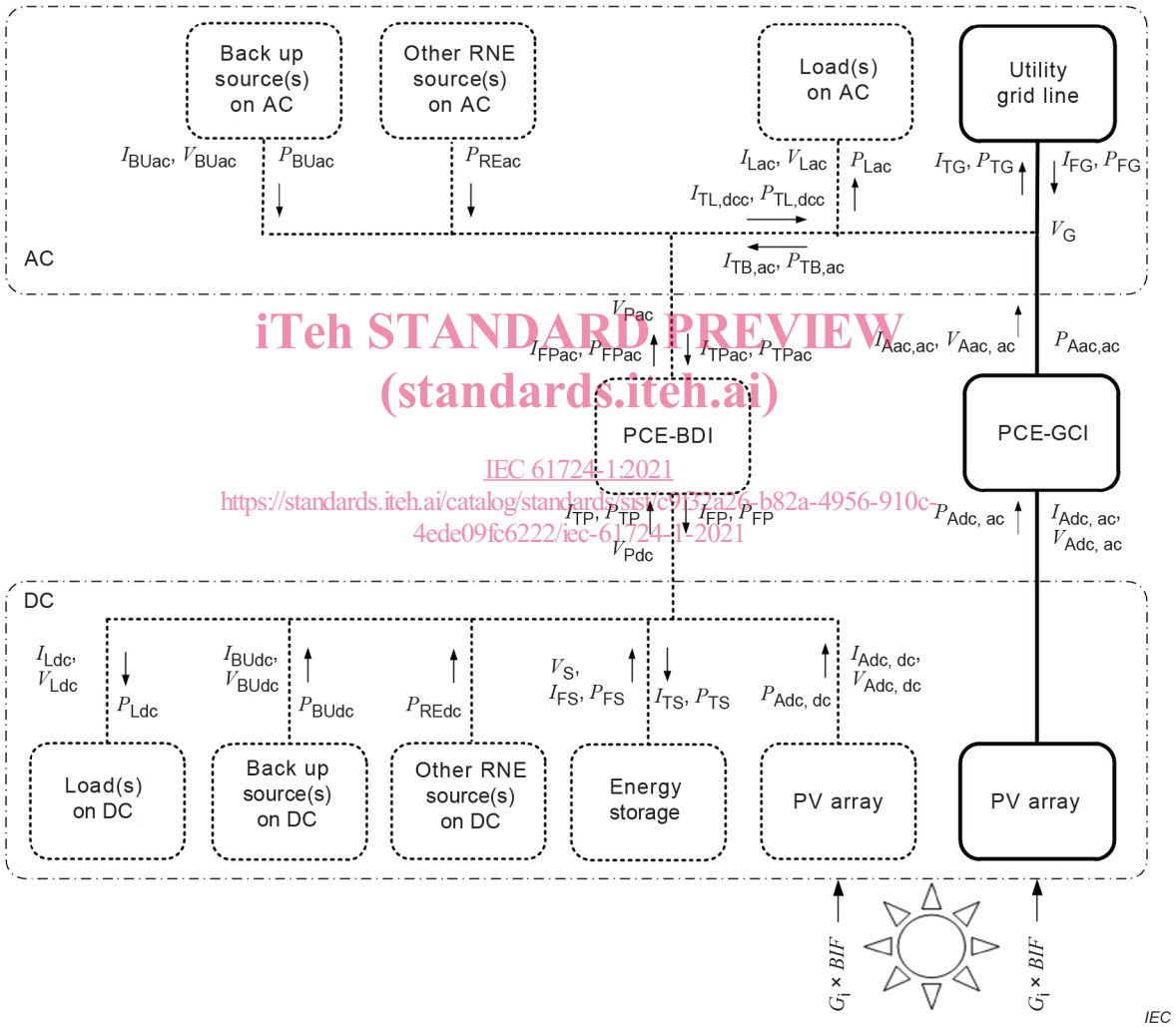
- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

INTRODUCTION

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

Figure 1 illustrates major elements comprising different PV system types. 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 E includes some details for systems with additional components.

The PV array may include both fixed-axis and tracker systems and both flat-plate and concentrator systems.



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 could include comparing performance to design expectations and guarantees as well as detecting and localizing faults.

For comparing performance to design expectations and guarantees, the focus should be on system-level data and consistency between prediction and test methods.

For detecting and localizing faults there should be greater resolution at sub-levels of the system and an emphasis on measurement repeatability and correlation metrics.

The monitoring system should be adapted to the PV system's size and user requirements. In general, larger PV systems should have more monitoring points and higher accuracy sensors than smaller and lower-cost PV systems.

PHOTOVOLTAIC SYSTEM PERFORMANCE –

Part 1: Monitoring

1 Scope

This part of IEC 61724 outlines terminology, equipment, and methods for performance monitoring and analysis of photovoltaic (PV) systems. It also 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 (IEV) – Part 131: Circuit theory*

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 61215 (all parts), *Terrestrial photovoltaic (PV) modules – Design qualification and type approval*

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

IEC TS 61724-2, *Photovoltaic system performance – Part 2: Capacity evaluation method*

IEC TS 61724-3, *Photovoltaic system performance – Part 3: Energy evaluation method*

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

IEC 62053-22, *Electricity metering equipment – Particular requirements – Part 22: Static meters for AC active energy (classes 0,1S, 0,2S and 0,5S)*

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 9060:2018, *Solar energy – Specification and classification of instruments for measuring hemispherical solar and direct solar radiation*

ISO 9488, *Solar energy – Vocabulary*

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

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
front side
side of a surface which normally faces the sky

3.8
rear side
side of a surface which normally faces the ground

3.9
monofacial PV device
PV device in which only the front side is used for power generation

3.10
bifacial PV device
PV device in which both front side and rear side are used for power generation

3.11
bifaciality coefficient
φ
ratio between an I-V characteristic of the rear side and the front side of a bifacial device, typically at Standard Test Conditions (STC), unless otherwise specified

Note 1 to entry: Bifaciality coefficients include the short-circuit current bifaciality coefficient φ_{Isc}, the open-circuit voltage bifaciality coefficient φ_{Voc} and the maximum power bifaciality coefficient φ_{Pmax}.

Note 2 to entry: Bifaciality coefficients are defined in IEC TS 60904-1-2.

3.12
irradiance
G
incident flux of radiant power per unit area

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

3.13
in-plane irradiance
G_i or POA
sum of direct, diffuse, and ground-reflected irradiance incident upon the front side of 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 $W \cdot m^{-2}$.

3.14
horizontal albedo
ρ_H
proportion of incident light reflected by a ground surface as measured in a horizontal plane

Note 1 to entry: It is a property of a ground surface and is a dimensionless quantity on a scale from 0 to 1.

3.15
in-plane rear-side irradiance ratio
ρ_i
ratio of the irradiance incident on the rear side of the modules in the PV array to the irradiance incident on the front side

Note 1 to entry: It is a dimensionless quantity but can exceed a value of 1 since, in addition to reflected light, diffuse and direct components of the solar resource may also be measured on the rear-side of the plane of array.

3.16
spectrally matched in-plane rear-side irradiance ratio
ρ_i^{SP}
in-plane rear-side irradiance ratio per 3.15 when both irradiance quantities are measured with a spectrally matched reference device or with the application of spectral correction factors per IEC 60904-7

3.17
spectrally matched reference device
reference device such as a PV cell or module with spectral response characteristics sufficiently close to those of the PV modules in the PV array such that spectral mismatch errors are small under the typical range of incident spectra

3.18
in-plane rear-side irradiance
G_i^{rear} or POA^{rear}
sum of direct, diffuse, and ground-reflected irradiance incident on the rear side of the modules in the PV array, also known as rear-side plane-of-array irradiance

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

Note 2 to entry: (If measured via in-plane rear-side irradiance ratio): $G_i^{rear} = \rho_i \times G_i$ or $G_{i,SP}^{rear} = \rho_i^{SP} \times G_i$.

3.19
bifacial reference device
bifacial PV device, such as a cell or module, having substantially the same properties, with respect to response to front-side and rear-side irradiance, as bifacial modules to be monitored

3.20
bifacial irradiance factor
BIF
dimensionless factor that can be directly multiplied by the front-side in-plane irradiance (G_i) to calculate the "effective" irradiance reaching a bifacial device from both the front and rear side collectively

Note 1 to entry: $BIF = (1 + \varphi_{Pmax} \times \rho_i)$ or $BIF^{sp} = (1 + \varphi_{Pmax} \times \rho_i^{SP})$. See 3.11, 3.15, 3.16.

Note 2 to entry: Rear-side POA irradiance can be measured simultaneously with front-side POA irradiance using a bifacial reference device. In that case, $BIF = G_i^{BiFi\,Ref\,Device} \div G_i$. For consistency, the front-side POA irradiance should be measured with the same or similar type of device as the bifacial reference device.

Note 3 to entry: "Effective" irradiance may include the effect of inhomogeneities in rear-side irradiance.

3.21
global horizontal irradiance
GHI
direct plus diffuse irradiance incident on the front side of a horizontal surface

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

Note 2 to entry: $GHI = DNI \cdot \cos Z + DHI$ where *Z* is the solar zenith angle.

3.22
circumsolar
immediately surrounding the solar disk

3.23
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: Expressed in units of $W \cdot m^{-2}$.

Note 2 to entry: $GHI = DNI \cdot \cos Z + DHI$ where Z is the solar zenith angle.