INTERNATIONAL STANDARD

IEC 61724

First edition
1998-04

Photovoltaic system performance monitoring – Guidelines for measurement, data exchange and analysis

Suivi des performances des systèmes photovoltaïques – Recommandations pour les mesures, et le transfert et l'analyse des données

Reference number
IEC 61724:1998(E)

Numbering

As from 1 January 1997 all IEC publications are issued with a designation in the 60000 series.

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* See web site address on title page.

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International Electrotechnical Commission
Международная Электротехническая Комиссия

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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PHOTOVOLTAIC SYSTEM PERFORMANCE MONITORING – GUIDELINES FOR MEASUREMENT, DATA EXCHANGE AND ANALYSIS

FOREWORD

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International Standard IEC 61724 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
82/189/FDIS	82/201/RVD

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

Annex A is for information only.

A bilingual version of this standard may be issued at a later date.

INTRODUCTION

This standard describes general guidelines for the monitoring and analysis of the electrical performance of photovoltaic (PV) systems. It does not describe the performance of discrete components, but concentrates on evaluating the performance of an array as part of a PV system.

The intent of the data analysis is to provide a performance summary suitable for comparing PV installations of different sizes, operating in different climates, and providing energy for different uses, in such a way that the relative merits of different designs or operating procedures become evident. Simpler methods might be more cost effective for small, solar home or domestic stand-alone systems.

Guidelines are also included which describe a file format to be used for the exchange of monitoring data between organizations.

The use of a microprocessor-based data acquisition system for monitoring is required.

PHOTOVOLTAIC SYSTEM PERFORMANCE MONITORING – GUIDELINES FOR MEASUREMENT, DATA EXCHANGE AND ANALYSIS

1 Scope

This International Standard recommends procedures for the monitoring of energy-related PV system characteristics such as in-plane irradiance, array output, storage input and output and power conditioner input and output; and for the exchange and analysis of monitored data. The purpose of these procedures is to assess the overall performance of PV systems configured as stand-alone or utility grid-connected, or as hybridised with non-PV power sources such as engine generators and wind turbines.

This standard may not be applicable to small stand-alone systems due to the relatively high cost of the measurement equipment.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 60904-2:1989, *Photovoltaic devices – Part 2: Requirements for reference solar cells*
Amendment 1 (1998)

IEC 60904-6:1994, *Photovoltaic devices – Part 6: Requirements for reference solar modules*
Amendment 1 (1998)

IEC 61194:1992, *Characteristic parameters of stand-alone photovoltaic (PV) systems*

IEC 61829:1995, *Crystalline silicon photovoltaic (PV) array – On-site measurement of I-V characteristics*

3 Measured parameters

Parameters to be measured are shown in table 1 and figure 1. Other parameters can be calculated from the measured data in real time by the data acquisition system's software. Note that all blocks in figure 1 can represent multiple components. The measured parameters and array characteristics are defined in IEC 61194.

The parasitic power drawn by all ancillary systems shall be considered a power loss of the PV plant and shall not be considered a load. All monitoring systems not essential for the operation of the PV plant shall be considered part of the load. The monitoring equipment may present a major part of the overall power consumption, and the end user should be made aware that supplemental power may be required to satisfy the total load requirement.

Table 1 – Parameters to be measured in real time

Parameter	Symbol	Unit
Meteorology		
Total irradiance, in the plane of the array[1)]	G_I	$W \cdot m^{-2}$
Ambient air temperature in a radiation shield	T_{am}	°C
Wind speed[2)]	S_W	$m \cdot s^{-1}$
Photovoltaic array		
Output voltage	V_A	V
Output current	I_A	A
Output power	P_A	kW
Module temperature	T_m	°C
Tracker tilt angle [5)]	ϕ_T	degrees
Tracker azimuth angle [5)]	ϕ_A	degrees
Energy storage[3)]		
Operating voltage	V_S	V
Current to storage[4)]	I_{TS}	A
Current from storage[4)]	I_{FS}	A
Power to storage[4)]	P_{TS}	kW
Power from storage[4)]	P_{FS}	kW
Load[3)]		
Load voltage	V_L	V
Load current	I_L	A
Load power[6)]	P_L	kW
Utility grid[3)]		
Utility voltage	V_U	V
Current to utility grid[4)]	I_{TU}	A
Current from utility grid[4)]	I_{FU}	A
Power to utility grid[4), 6)]	P_{TU}	kW
Power from utility grid[4), 6)]	P_{FU}	kW
Back-up sources[3)]		
Output voltage	V_{BU}	V
Output current	I_{BU}	A
Output power	P_{BU}	kW

[1)] Total irradiance, also known as the plane-of-array irradiance, defined as the radiant power, direct plus diffuse, incident upon unit area of an inclined surface.

[2)] Parameters such as wind speed are optional, but may be required by special contract or if the PV array is subject to extreme operating conditions.

[3)] AC and d.c. quantities may be distinguished by the addition of subscripts. In the case of multi-phase systems, parameters V_L , I_L and P_L shall be specified for each phase.

[4)] A single current or power sensor can normally be used for the measurement of current or power for directions of both input and output. A positive sign in the sensor's output signal represents input to the energy storage device or utility grid and a negative sign represents output from the storage device or utility grid. Input and output from a single sensor must be accumulated separately in software.

[5)] Tracker angles are optional for systems with tracking arrays. For single axis trackers ϕ_T is used to describe the position of the array about its tracking axis. For example, for a horizontal single axis tracker this parameter would give the angle from horizontal, east is negative and west is positive.

[6)] A direct measurement of the power output of the inverter portion of the power conditioner may be made if it improves accuracy.

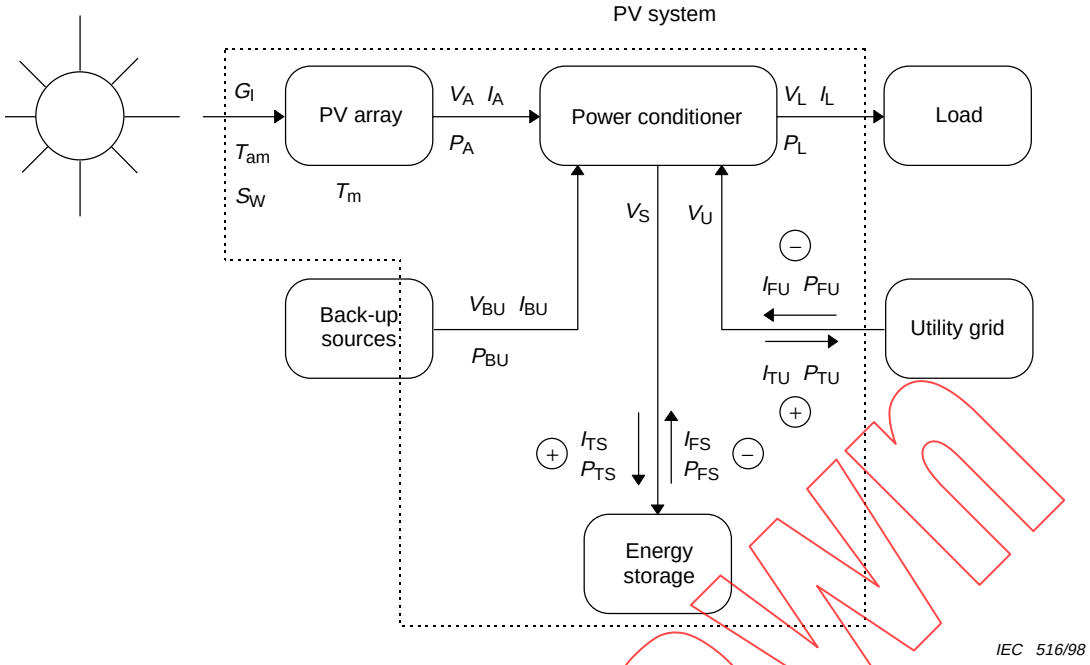

Figure 1 – Parameters to be measured in real time

4 Monitoring method

4.1 Measurement of irradiance

Irradiance data are recorded in the plane of the array for use in the performance analysis of the PV system. Horizontal data may also be recorded to permit comparisons with standard meteorological data from other locations.

In-plane irradiance shall be measured in the same plane as the photovoltaic array by means of calibrated reference devices or pyranometers. If used, reference cells or modules shall be calibrated and maintained in accordance with IEC 60904-2 or IEC 60904-6. The location of these sensors shall be representative of the irradiance conditions of the array. The accuracy of irradiance sensors, including signal conditioning, shall be better than 5 % of the reading.

4.2 Measurement of ambient air temperature

Ambient air temperature shall be measured at a location which is representative of the array conditions, by means of temperature sensors located in solar radiation shields. The accuracy of air temperature sensors, including signal conditioning, shall be better than 1 K.

4.3 Measurement of wind speed

Where applicable, wind speed shall be measured at a height and location which are representative of the array conditions. The accuracy of the wind speed sensors shall be better than 0,5 $m \cdot s^{-1}$ for wind speeds ≤5 $m \cdot s^{-1}$, and better than 10 % of the reading for wind speeds greater than 5 $m \cdot s^{-1}$.

4.4 Measurement of module temperature

PV module temperature shall be measured at locations which are representative of the array conditions by means of temperature sensors located on the back surface of one or more modules. The selection of module locations is specified under method A in IEC 61829. Care must be taken to ensure that the temperature of the cell in front of the sensor is not substantially altered due to the presence of the sensor. The accuracy of these sensors, including signal conditioning, shall be better than 1 K.

4.5 Measurement of voltage and current

The voltage and current parameters may be either d.c. or a.c. The accuracy of voltage and current sensors, including signal conditioning, shall be better than 1 % of the reading. AC voltage and current may not need to be monitored in every situation.

4.6 Measurement of electrical power

The electrical power parameters may be d.c. or a.c. or both. DC power can either be calculated in real time as the product of sampled voltage and current quantities or measured directly using a power sensor. If d.c. power is calculated, the calculations shall use sampled voltage and current quantities and not averaged voltage and current quantities[1)] . The d.c. input power and voltage on stand-alone inverters may have large amounts of a.c. ripple impressed. It may be necessary to use a d.c. wattmeter to accurately measure d.c. power. AC power shall be measured using a power sensor which properly accounts for the power factor and harmonic distortion. The accuracy of power sensors, including signal conditioning, shall be better than 2 % of the reading.

An integrating power sensor with high-speed response (for example, a kWh meter) may be used to avoid sampling errors.

4.7 Data acquisition system

An automatic data acquisition system is required for monitoring. The total accuracy of the monitoring system shall be determined by a calibration method such as given in annex A. The monitoring system should be based on commercially available hardware and software which is properly documented with user's manuals. Technical support should be available.

4.8 Sampling interval

The sampling interval for parameters which vary directly with irradiance shall be 1 min or less. For parameters which have larger time constants, an arbitrary interval may be specified between 1 min and 10 min. Special consideration for increasing the sampling frequency shall be given to any parameters which may change quickly as a function of system load. All parameters shall be continuously measured during the specified monitoring period.

NOTE – The rates of change for many of the parameters of interest can be relatively high. Irradiance, for example, can change at a rate exceeding 200 $W \cdot m^{-2} \cdot s^{-1}$ under partly cloudy conditions. While the intent within this international standard is not to capture electrical transient-level detail, a sufficient sampling rate is necessary to characterize average performance over the averaging interval. Generally, the parameters in table 1 should be sampled every minute. Module and ambient temperature may be sampled at slower rates, but it is preferable as well as more convenient to sample all parameters at a common rate. All parameters should be continuously measured during the specified monitoring period.

4.9 Data processing operation

The sampled data from each measured parameter shall be processed into time-weighted averages. Maximum or minimum quantities and transients of special interest may be determined where required. For integrating power sensors, the sampled data is summed and divided by the recording interval τ_r.

4.10 Recording interval, τ_r (expressed in hours)

The processed data values for each parameter shall be recorded hourly. More frequent recordings may be implemented where required, as long as one hour is an integer multiple of the recording interval τ_r.

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1) The error between d.c. power as calculated from the averaged product of sampled voltage and sampled current and d.c. power as calculated from the product of averaged voltage and averaged current depends on the sample rate and the variation in current. Errors can be significant for large current variations.