

INTERNATIONAL STANDARD

IEC 61683

First edition
1999-11

**Photovoltaic systems –
Power conditioners –
Procedure for measuring efficiency**

iTeh STANDARD PREVIEW

*Systèmes photovoltaïques –
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Conditionneurs de puissance –*

Procédure de mesure du rendement
IEC 61683-1999
<https://standards.iteh.ai/catalog/standards/sist/27303a7e-a7b7-48fb-a0a9-7e5e5f8a3a7f/iec-61683-1999>



Reference number
IEC 61683:1999(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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Commission Electrotechnique Internationale
International Electrotechnical Commission
Международная Электротехническая Комиссия

PRICE CODE

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For price, see current catalogue

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**PHOTOVOLTAIC SYSTEMS – POWER CONDITIONERS –
PROCEDURE FOR MEASURING EFFICIENCY**

FOREWORD

- 1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the 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, the IEC publishes International Standards. 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. The 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 61683 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
82/229/FDIS	82/233/RVD

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

This publication has been drafted in accordance with the ISO/IEC Directives, Part 3.

Annexes A, B, C and D are for information only.

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

The committee has decided that this publication remains valid until 2003. At this date, in accordance with the committee's decision, the publication will be

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- withdrawn;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

INTRODUCTION

Among the principal characteristics of power conditioners, efficiency is considered as an important factor. A standardized procedure for measuring the efficiency of power conditioners is necessary for their widespread use in photovoltaic systems by increasing the reliability of their claimed efficiency.

Generally speaking, power conditioner efficiency is affected by the following parameters:

- power level;
- input voltage;
- output voltage;
- power factor;
- harmonic content;
- load non-linearity;
- temperature.

These parameters are considered to be included in the test condition of this standard explicitly or implicitly.

The purpose of this standard is to provide the means to evaluate the intrinsic efficiency of power conditioners by a direct measurement of input and output power in the factory. Therefore, indirect items such as maximum power point tracking accuracy are outside the scope of this document. It is expected that those will be dealt with in future relevant IEC standard(s).

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PHOTOVOLTAIC SYSTEMS – POWER CONDITIONERS – PROCEDURE FOR MEASURING EFFICIENCY

1 Scope

This standard describes guidelines for measuring the efficiency of power conditioners used in stand-alone and utility-interactive photovoltaic systems, where the output of the power conditioner is a stable a.c. voltage of constant frequency or a stable d.c. voltage. The efficiency is calculated from a direct measurement of input and output power in the factory. An isolation transformer is included where it is applicable.

2 Normative reference

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, 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. For undated references, the latest edition of the normative document referred to applies. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 60146-1-1:1991, *Semiconductor convertors – General requirements and line commutated convertors – Part 1-1: Specifications of basic requirements*

3 Definitions

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For the purposes of this standard, the following definitions apply. All efficiency definitions are applied to electric power conversion alone and do not consider any heat production. The above normative references contain other definitions.

In annex A, the definition of power conditioner is given. Power efficiency and conversion factor are explained in annex B.

3.1

rated output efficiency

ratio of output power to input power when the power conditioner is operating at its rated output

3.2

partial output efficiency

ratio of output power to input power when the power conditioner is operating below its rated output

3.3

energy efficiency

ratio of output energy to input energy during an identified period

3.4

efficiency tolerance

permissible tolerance between the manufacturer's specified efficiency and the measured efficiency

3.5

PV array simulator

simulator which has I-V characteristics equivalent to a PV array

3.6

no-load loss

input power of the power conditioner when its load is disconnected or its output power is zero

3.7

standby loss

for a utility interactive power conditioner, power drawn from the utility grid when the power conditioner is in standby mode. For a stand-alone power conditioner, d.c. input power when the power conditioner is in standby mode

3.8

maximum power point tracking (MPPT)

control strategy whereby the power conditioner input voltage is always at or near the maximum power point of the PV array

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4 Efficiency measurement conditions

Efficiency shall be measured under the matrix of conditions as described in the following clauses and table 1. Specific conditions may be excluded by mutual agreement when those conditions are outside the manufacturer's allowable operating range. The resulting data shall be presented in tabular form and may also be presented graphically.

NOTE For example, stand-alone power conditioners are typically designed to handle short-term overload significantly above the rated power. The test at 120 % of rated capacity is included to give an indication of the performance of the power conditioner under these conditions. Some power conditioners are not designed to provide more than their rated output and might be damaged if operated at 120 % of rated capacity. In such cases, test documentation shall note that the test was excluded due to limitation in the power conditioner.

4.1 DC power source for testing

For power conditioners operating with fixed input voltage, the d.c. power source shall be a storage battery or constant voltage power source to maintain the input voltage.

For power conditioners that employ maximum power point tracking (MPPT) and shunt-type power conditioners, either a photovoltaic array or a photovoltaic array simulator shall be utilized.

4.2 Temperature

All measurements are to be made at an ambient temperature of $25\text{ °C} \pm 2\text{ °C}$. Other ambient temperatures may be allowed by mutual agreement. However, the temperature used must be clearly stated in all documentation.

4.3 Output voltage and frequency

The output voltage and frequency shall be maintained at the manufacturer's stated nominal values.

Table 1 – Efficiency recording sheet

Input voltage: _____ (± _____ V)

Total load, % of rated VA		5	10	25	50	75	100	120
Grid-connected	Resistive load	–	()*	()	()	()	()	()
Stand-alone	Resistive load	()	()	()	()	()	()	()
	Reactive load							
	PF = 0,25 or minimum	–	–	()	()	–	()	–
	PF = 0,50 (> minimum)	–	–	()	()	–	()	–
	PF = 0,75 (> minimum)	–	–	()	()	–	()	–
	Non-linear load							
	NL = 25 % of rated VA	–	–	()	()	–	()	–
	NL = 50 % of rated VA	–	–	–	()	–	()	–
	Complex load	–	–	–	()	–	()	–

* The symbol () denotes a condition to be tested.

4.4 Input voltage

Measurements performed in each of the following tests shall be repeated at three power conditioner input voltages:

- manufacturer's minimum rated input voltage;
- the inverter's nominal voltage or the average of its rated input range;
- 90 % of the inverter's maximum input voltage.

In the case where a power conditioner is to be connected with a battery at its input terminals, only the nominal or rated input voltage may be applied.

4.5 Ripple and distortion

Record input voltage and current ripple for each measurement. Also record output voltage and current distortion (if a.c.) or ripple (if d.c.). Ensure that these measurements remain within the manufacturer's specified values. Note that ripple and distortion may not be specified at low power levels, but readings shall be recorded.

4.6 Resistive loads/utility grid

At unity power factor, or at the intrinsic power factor of grid-connected inverters without power factor adjustment, measure the efficiency for power levels of 10 %, 25 %, 50 %, 75 %, 100 % and 120 % of the inverter's rating. Stand-alone inverters shall also be measured at a power level of 5 % of rated. The power conditioner test should be conducted with a specified resistive and reactive grid impedance.

4.7 Reactive loads

For stand-alone inverters, measure the efficiency with a load which provides a power factor equal to the manufacturer's specified minimum level (or 0,25, whichever is greater) and at power levels of 25 %, 50 % and 100 % of rated VA. Repeat for power factors of 0,5 and 0,75 (do not go below the manufacturer's specified minimum PF) and power levels of 25 %, 50 %, and 100 % of rated VA.

4.8 Resistive plus non-linear loads

For stand-alone inverters, measure the efficiency with a fixed non-linear load (total harmonic distortion (THD) = $(80 \pm 5) \%$) equal to $(25 \pm 5) \%$ of the inverter's rated VA plus sufficient resistive load in parallel to achieve a total load of 25 %, 50 % and 100 % of rated VA. Repeat the measurements with a fixed non-linear load equivalent to $(50 \pm 5) \%$ of the inverter's rated VA plus sufficient resistive load in parallel to achieve a total load of 50 % and 100 % of rated VA. The type of non-linear load must be clearly stated in all documentation.

4.9 Complex loads

When a non-linear plus a sufficient reactive load condition is specified for stand-alone inverters, measure the efficiency with a fixed non-linear load (THD = $(80 \pm 5) \%$) equal to $(50 \pm 5) \%$ of the inverter's rated VA plus a sufficient reactive load (PF = 0,5) in parallel to achieve a total load of 50 % and 100 % of rated VA. The type of complex load shall be clearly stated in all documentation.

5 Efficiency calculations

5.1 Rated output efficiency

Rated output efficiency shall be calculated from measured data as follows:

$$\eta_R = (P_o / P_i) \times 100 \quad (1)$$

where

η_R is the rated output efficiency (%);

P_o is the rated output power from power conditioner (kW);

P_i is the input power to power conditioner at rated output (kW).

NOTE Any auxiliary input power (kW), such as for the inverter's control system (or gate driver) shall be included in P_i in equation (1).

5.2 Partial output efficiency

Partial output efficiency shall be calculated from measured data as follows:

$$\eta_{par} = (P_{op} / P_{ip}) \times 100 \quad (2)$$

where

η_{par} is the partial output efficiency (%);

P_{op} is the partial output power from power conditioner (kW);

P_{ip} is the input power to power conditioner at partial output (kW).

NOTE Any auxiliary input power (kW) such as for the inverter's control system (or gate driver) shall be included into P_i in equation (2).

5.3 Energy efficiency

Energy efficiency shall be calculated from measured data as follows:

$$\eta_E = (W_o / W_i) \times 100 \quad (3)$$

where

η_E is the energy efficiency (%);

W_o is the output energy during a specified operating period (kWh);

W_i is the input energy during a specified operating period (kWh).

NOTE 1 The operating period and the load profile shall be determined by mutual agreement between user and manufacturer.

NOTE 2 Some auxiliary input energy (kWh) such as for the inverter's control system (or gate driver) shall be included in W_i in equation (3).

NOTE 3 See annex C for an explanation of weighted-average energy efficiency η_{wt} which can supplant the energy efficiency.

5.4 Efficiency tolerances

When an efficiency value has been guaranteed, the tolerance of this value shall be within the value at rated conditions indicated in table 2.

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Table 2 – Efficiency tolerances
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Item	Tolerance	Remarks
Efficiency of power conditioner	$\pm 0,2(1-\eta)\eta$ (%)	η : guaranteed efficiency
NOTE The efficiency tolerance is derived in annex D. See 4.3 of IEC 60146-1-1. The tolerance corresponds to +0,2 per unit of the losses with a minimum efficiency tolerance of –0,002 per unit.		

6 Efficiency test circuits

6.1 Test circuits

Figure 1 shows recommended test circuits for power conditioners which have a single-phase a.c. output or d.c. output. It can as well be regarded as a single-phase representation of a test set-up for multiphase power conditioners.

Figures 1a and 1b shall be applied to stand-alone and utility-interactive power conditioners respectively.

The proposed test circuits in figure 1 are not mandatory, but together with the test descriptions, are intended to establish a base for mutual agreement between user and manufacturer.

The type of power source shall be indicated on all tests and shall adhere to the requirements of 4.1.