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Photovoltaic devices – Part 1: Measurement of photovoltaic current-voltage characteristics

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Title : IEC 60904-1 Ed.2: Photovoltaic devices - Part 1: Measurement of photovoltaic current-voltage characteristics

Introductory note: This standard describes procedures for the measurement of current-voltage characteristics of photovoltaic devices in natural or simulated sunlight. These procedures are applicable to a single solar cell, a sub-assembly of solar cells, or a PV module.

ATTENTION	ATTENTION
CDV soumis en parallèle au vote (CEI) et à l'enquête (CENELEC)	**Parallel IEC CDV/CENELEC Enquiry**

NORME INTERNATIONALE

C E I
I E C
60904-1Edition 2
(Draft G4, February 2005)

INTERNATIONAL STANDARD

Photovoltaic devices

Part 1: Measurement of photovoltaic current-voltage characteristics

WG2 Working Draft

Changes from First Edition

1) **Added Purpose**
2) **Added Normative References**
3) **Updated General Measurement Requirements (removing Fig 1 as obsolete)**
4) **Provided more detail and guidance on how to measure in sunlight or simulated sunlight.**
5) **Expanded Test Report Requirements based on ISO 17025.**

Contents

INTERNATIONAL ELECTROTECHNICAL COMMISSION

PHOTOVOLTAIC DEVICES
PART 1:
Measurement of photovoltaic current-voltage characteristics

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 cooperation 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 liaison 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.

2) The formal decisions or agreements of the IEC on technical matters, prepared by technical committees on which all the National Committees having a special interest therein are represented, express, as nearly as possible, an international consensus of opinion on the subjects dealt with.

3) They have the form of recommendations for international use published in the form of standards, technical reports or guides and they are accepted by the National Committees in that sense.

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5) The IEC provides no marking procedure to indicate its approval and cannot be rendered responsible for any equipment declared to be in conformity with one of its standards.

International Standard IEC 60904-1 has been prepared by IEC technical committee 82: Solar photovoltaic energy systems.

DIS	Report on Voting

1 Scope

This standard describes procedures for the measurement of current-voltage characteristics of photovoltaic devices in natural or simulated sunlight. These procedures are applicable to a single solar cell, a sub-assembly of solar cells, or a PV module.

NOTES

1. This standard may be applicable to multi-junction test specimens, if each sub-junction generates the same amount of current as it would under the reference AM1.5 spectrum in IEC 60904-3.
2. This standard may be applicable to PV devices designed for use under concentrated irradiation if they are irradiated using direct normal irradiance and a mismatch correction with respect to a direct normal reference spectrum is performed.

2 Purpose

The purpose of this standard is to lay down basic requirements for the measurement of current-voltage characteristic of photovoltaic devices, to define procedures for different measuring techniques in use and to show practises for minimising measurement uncertainty.

3 Normative references

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

IEC 60891: Procedures for temperature and irradiance corrections to measured I-V characteristics of crystalline silicon photovoltaic (PV) devices, Amendment No. 1

IEC 60904-2: Photovoltaic devices – Part 2: Requirements for reference solar cells

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 equivalent cell temperature (ECT) of photovoltaic (PV) devices by the open-circuit voltage method

IEC 60904-6: Photovoltaic devices – Part 6: Requirements for reference solar modules

IEC 60904-7: Photovoltaic devices – Part 7: Computation of spectral mismatch error introduced in the testing of a photovoltaic device

IEC 60904-9: Photovoltaic devices – Part 9: Solar simulator performance requirements

IEC 60904-10: Photovoltaic devices – Part 10: Methods for linearity measurements

ISO/IEC 17025: General requirements for competence of testing and calibration laboratories

4 General measurement requirements

a) The irradiance measurements shall be made using a PV reference device packaged and calibrated in conformance with IEC 60904-2 or IEC 60904-6 or a pyranometer. The PV reference device shall either be spectrally matched to the test specimen, or a spectral mismatch correction shall be performed in conformance with IEC 60904-7. The reference device must be linear in short-circuit current as defined in IEC 60904-10 over the irradiance range of interest.

NOTE To be considered spectrally matched, a reference device must be constructed using the same cell technology and encapsulation package as the test device. If this is not the case, the spectral mismatch must be reported.

b) The temperature of the reference device and the specimen shall be measured to an accuracy of ± 1°C with repeatability of ± 0.5°C. If the temperature of the reference device differs by more than 2°C from the temperature at which it was calibrated, the calibration value shall be adjusted to the measured temperature. If the reference device is a pyranometer, temperature measurement and temperature correction of its output signal is not required.

c) The active surface of the specimen shall be coplanar within ± 2° with the active surface of the reference device.

d) Voltages and currents shall be measured to an accuracy of ± 0.2% of the open-circuit voltage and short-circuit current using independent leads from the terminals of the specimen and keeping them as short as possible. The measurement ranges of the data acquisition should be carefully chosen. If the test specimen is a module, the 4-wire connection should start at the terminals or connectors. If the test specimen is a cell, the 4-wire connection should start at the cell bus bars.

NOTE The connection method for cells should be carefully evaluated. Differences may occur if soldered tabs are used as probe or non-soldered methods are implemented such as bars having contact springs or conductive plates having a large-area contact with the cell back contact. Non-soldered methods can result in higher fill factors than are observed in the module.

e) If appropriate short-circuit currents shall be measured at zero voltage, using a variable bias (preferably electronic) to offset the voltage drop across the external series resistance. Alternatively, short circuit current may be extrapolated from the current-voltage characteristic. The curve is extrapolated to zero voltage provided that voltage drop is not higher than 3% of the device open-circuit voltage and that there is a linear relationship between current and voltage.

f) The accuracy of the procedure for irradiance and temperature correction in conformance with IEC 60891 shall be verified periodically by measuring the performance of a specimen at selected irradiance and temperature levels and comparing the results with corresponding extrapolated data.

NOTE If temperature and irradiance correction is performed across wide ranges module correction parameters can considerably affect the test result. Care should be taken regarding the relevance of the module parameters used. In particular series resistance cannot be generalized to a batch of specimens of the same type.

Before the spectral response of a thin-film amorphous silicon device is measured, the device under test shall be stabilized (if necessary), as specified in the light soaking test procedure (see IEC 61646). Other photovoltaic technologies may require different pre-conditioning procedures.

5 Apparatus

5.1 For Measurements in natural sunlight

In addition to the general measurement requirements of clause 4 the following equipment is required to perform I-V characteristic measurements in natural sunlight:

a) A PV reference device that meets the conditions stated in 4 a).

b) Means for measuring temperature of the reference device that meets the conditions stated in 4 b), if necessary.

c) Equipment to determine the temperature of the test device using the Equivalent Cell Temperature (ECT) method specified in IEC 60904-5 or other means to measure the temperature of the test device as stated in 4 b).

d) A two-axis tracking system capable of tracking the sun to an accuracy of ± 5°.

e) A spectroradiometer capable of measuring the spectral irradiance of the sunlight in the range of the spectral response of the test specimen and the reference device, if spectral corrections are needed as defined in 4 a).

5.2 For Measurements in simulated sunlight

In addition to the general measurement requirements of clause 4 the following equipment is required to perform I-V characteristic measurements in simulated sunlight:

a) A PV reference device that is well matched to the test device over the ranges of irradiances, spectral distributions and temperatures of interest and meets the conditions stated in 4 a).

b) Means for measuring temperature of the reference device and the test specimen that meets the conditions stated in 4 b).

c) A Class BBB or better solar simulator in accordance with IEC 60904-9. The designated test area must be equal to or greater than the area that is spanned by the test specimen.

d) An irradiance sensor that tracks the instantaneous irradiance in the test plane. This irradiance sensor should be linear in the range of irradiances over which the measurements are taken (See IEC-60904-10).

e) A spectroradiometer capable of measuring the spectral irradiance of the simulator in the range of the spectral response of the test specimen and the reference device, if spectral corrections are needed as defined in 4 a).

NOTE Care should be taken in the use of an emission lamp such as Xenon for testing direct band gap cells. As the band gap changes due to temperature, it can pass through various emission lines in the lamp spectrum and give rise to large shifts in performance.

6 Measurements in natural sunlight

Measurements in natural sunlight shall be made only when global solar irradiance is not fluctuating by more than ± 1 % during a measurement. When the measurements are intended for reference to STC the irradiance shall be at least 800 Wm^{-2}.

The test procedure is as follows:

6.1 Mount the reference device as near as possible to and co-planar with the specimen on the two-axis tracker. Both shall be normal to the direct solar beam within ± 5°. Connect to the necessary instrumentation.

6.2 If the specimen and reference device are equipped with temperature controls, set the controls at the desired level.