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INTERNATIONAL STANDARD

NORME INTERNATIONALE

Photovoltaic devices –
Part 10: Methods of linearity measurement

Dispositifs photovoltaïques –
Partie 10: Méthodes de mesure de la linéarité

IEC 60904-10:2009

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FOREWORD

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International Standard IEC 60904-10 has been prepared by IEC technical committee 82: Solar photovoltaic energy systems.

This second edition cancels and replaces the first edition published in 1998 and constitutes a technical revision.

The main technical changes with regard to the previous edition are as follows:

a) Added clause for two-lamp method for I_{sc} linearity.
b) Changed standard deviation as a metric for linearity to percent deviation from linearity. This was done because a non-linear device can have a low standard deviation and percent deviation is the quantitative number that matters for the parameter of interest.
c) Removed clause on spectral responsivity nonlinearity because it is not used by any PV testing / calibration group. For testing real PV devices it is difficult to make this error significant in the spectral mismatch correction factor while still passing I_{sc} linearity. Measuring the responsivity over the entire response range means that the device will probably fail the temperature linearity near the band edge.

d) Added a clause to allow short circuit linearity with temperature or total irradiance to be determined from absolute spectral responsivity measurements. This data is routinely reported in PTB primary reference cell calibration certificates.

e) Added report clause in compliance with ISO/IEC 17025 requirements.

f) Often the temperature coefficient of short circuit current is very small so measurement errors can result in percent deviations outside the accepted range. Therefore, the following text was added to 7.3c): “If the temperature coefficient of short circuit current is less than 0,1 %/K, then the device can be considered linear with respect to this parameter.”

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

FDIS	Report on Voting
82/582/FDIS	82/589/RVD

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

A list of all parts of IEC 60904 series, under the general title *Photovoltaic devices*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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

PHOTOVOLTAIC DEVICES –

Part 10: Methods of linearity measurement

1 Scope and object

This part of IEC 60904 describes procedures used to determine the degree of linearity of any photovoltaic device parameter with respect to a test parameter. It is primarily intended for use by calibration laboratories, module manufacturers and system designers.

Photovoltaic (PV) module and system performance evaluations, and performance translations from one set of temperature and irradiance conditions to another frequently rely on the use of linear equations (see IEC 60891 and IEC 61829). This standard lays down the linearity requirements and test methods to ensure that these linear equations will give satisfactory results. Indirectly, these requirements dictate the range of the temperature and irradiance variables over which the equations can be used.

The methods of measurement described in this standard apply to all PV devices and are intended to be carried out on a sample or on a comparable device of identical technology. They should be performed prior to all measurement and correction procedures that require a linear device. The methodology used in this standard is similar to that specified in IEC 60891 in which a linear (straight-line) function is fitted to a set of data points using a least-squares fit calculation routine. The variation of the data from this function is also calculated, and the definition of linearity is expressed as an allowable variation percentage.

A device is considered linear when it meets the requirements of 7.3.

General procedures for determining the degree of linearity for these and any other performance parameter are described in Clauses 5 and 6.

2 Normative references

The following referenced documents are indispensable for the application 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 60891, *Photovoltaic devices – Procedures for temperature and irradiance corrections to measured I-V characteristics*

IEC 60904-1, *Photovoltaic devices – Part 1: Measurement of photovoltaic current-voltage characteristics*

IEC 60904-3, *Photovoltaic devices – Part 3: Measurement principles for terrestrial photovoltaic (PV) solar devices with reference spectral irradiance data*

IEC 60904-8, *Photovoltaic devices – Part 8: Measurement of spectral response of a photovoltaic (PV) device*

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

IEC 61215, *Crystalline silicon terrestrial photovoltaic (PV) modules – Design qualification and type approval*

IEC 61646, *Thin-film terrestrial photovoltaic (PV) modules – Design qualification and type approval*

ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

3 Apparatus

a) Equipment necessary to measure an I-V curve (see IEC 60904-1).

b) Any equipment necessary to change the irradiance over the range of interest without affecting the relative spectral irradiance distribution and the spatial uniformity, such as mesh filters or neutral density filters.

NOTE The equipment and procedure used to change the irradiance are to be verified with a radiometer. The change in relative spectral irradiance distribution should not result in more than 0,5 % change in the short-circuit current of the device (see IEC 60904-7 and IEC 60904-8). Mesh filters are believed to be the best method for large surfaces.

c) Any equipment necessary to change the temperature of the test specimen over the range of interest.

d) A means for controlling the temperature of the test specimen and reference device, or a removable shade.

e) Equipment for measuring the spectral response of the test specimen (or a representative sample equivalent to the test specimen) in accordance with IEC 60904-8 to a repeatability of ± 2 % of the reading.

NOTE IEC 60904-7 provides methods for the computation of spectral mismatch error introduced in the testing of photovoltaic devices, and IEC 60904-8 provides guidance for spectral measurement.

4 Sample selection

This procedure shall be applied to a full-sized test specimen if possible. If this is not possible, a small sample equivalent in construction and materials should be used.

5 Procedure for current and voltage linearity test

There are three acceptable procedures for performing the linearity test of short-circuit current with respect to temperature and irradiance. There are two acceptable procedures for performing the linearity test of open-circuit voltage with respect to temperature and irradiance.

5.1 Procedure in natural sunlight

5.1.1 Measurement in natural sunlight shall only be made when:

- The total irradiance is at least as high as the upper limit of the range of interest.
- The irradiance variation caused by short-term oscillations (clouds, haze, or smoke) is less than ± 2 % of the total irradiance as measured by the reference device.
- The wind speed is less than 2 $m \cdot s^{-1}$.

5.1.2 Mount the reference device co-planar with the test specimen so that both are normal to the direct solar beam within ± 1°. Connect to the necessary instrumentation.

NOTE The measurements described in the following subclauses should be made as expeditiously as possible within a few hours on the same day to minimize the effect of changes in the spectral conditions. If not, spectral corrections may be required.

5.1.3 If the test specimen and reference device are equipped with temperature controls, set the controls at the desired level. If temperature controls are not used, shade the test specimen from the sun and allow it to stabilize within ± 1 °C of the ambient air temperature. The