IEC 60904-8

Edition 3.0 2014-05

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Photovoltaic devices –
Part 8: Measurement of spectral responsivity of a photovoltaic (PV) device

Dispositifs photovoltaïques –
Partie 8: Mesure de la sensibilité spectrale d'un dispositif photovoltaïque (PV)

IEC 60904-8:2014-05(en-fr)

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FOREWORD

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International Standard IEC 60904-8 has been prepared by IEC technical committee 82: Solar photovoltaic energy systems.

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

The main technical changes with respect to the previous edition are listed below:

- Re-writing of the clause on testing
- Addition of a new clause for the measurement of series-connected modules
- Addition of the requirements of ISO/IEC 17025
- Additional figures

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

FDIS	Report on voting
82/822/FDIS	82/843/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.

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

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the stability 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- withdrawn,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 8: Measurement of spectral responsivity of a photovoltaic (PV) device

1 Scope

This International Standard specifies the requirements for the measurement of the spectral responsivity of both linear and non-linear photovoltaic devices. It is only applicable to single-junction devices. The spectral responsivity of a photovoltaic device is used in cell development and cell analysis, as it provides a measure of recombination and other processes occurring inside the semiconductor or cell material system.

The spectral responsivity of a photovoltaic device is used for the correction of the spectral mismatch if a PV device is calibrated in a setup where the measurement spectrum is different from the reference spectral irradiance data given in IEC 60904-3 and a reference device with a different spectral responsivity to the device under test is used. This procedure is given in IEC 60904-7.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

IEC 60904-7, *Photovoltaic devices – Part 7: Computation of the spectral mismatch correction for measurements of photovoltaic devices*

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*

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

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

3 Marking

Each photovoltaic device should carry a clear and indelible marking. This marking should be cross-referenced against:

– name, monogram or symbol of the manufacturer;
– base material and type of photovoltaic device;

– type number or identification, if available;
– serial number, if applicable.

When the photovoltaic devices to be tested are prototypes of a new design and not from production, this fact shall be noted in the test report (see Clause 10).

4 Testing

4.1 General

The photovoltaic device shall be subjected to one of the procedures for spectral responsivity measurements defined in Clauses 7 to 9.

4.2 Special considerations

Preconditioning – Before beginning the measurements, the device under test shall be stabilized (if necessary) by an appropriate light soaking test procedure, as specified in IEC 61215 or IEC 61646. Different photovoltaic technologies may require different pre-conditioning procedures.

4.3 Measurement under white bias light

The procedures in Clause 7 and 9 require a white bias light being applied to the device under test during the determination of spectral responsivity. Under bias light conditions, not the spectral responsivity but rather the differential spectral responsivity is measured. The spectral responsivity can be determined from the differential spectral responsivity by taking the non-linearity into account based on a series of differential spectral responsivity measurements at bias light levels generating short-circuit currents in the device ranging from 5 % to 110 % of that at standard test conditions (see Clause 5). Most crystalline silicon solar cells have a differential spectral responsivity at a bias light generating 30 % to 40 % of their short-circuit current at standard test conditions that is identical to the spectral responsivity at standard test conditions. Therefore, the measurement should be performed with such bias light levels if the non-linearity of a crystalline silicon PV device is not determined. If the non-linearity is confirmed to be negligible, i.e. the differential spectral responsivity is constant within the irradiance range of interest, the differential spectral responsivity at a specific bias light level may be used. For details see Clause 5.

4.4 Applying a bias voltage to the device under test

Generally, the spectral responsivity of a photovoltaic device is measured at short-circuit conditions (zero bias voltage) of the photovoltaic device and used for the purposes of cell analysis and calculating the spectral mismatch.

In order to measure the spectral responsivity of the specimen under a specific voltage, a bias voltage may need to be applied. The bias voltage of the device shall be controlled by an external voltage source. If a bias voltage is applied it shall be specified in the report.

5 General description of spectral responsivity measurement

The spectral responsivity of a photovoltaic (PV) device is measured by irradiating it by means of a narrow-bandwidth light source at a series of different wavelengths covering its responsivity range, and measuring the short-circuit current and monochromatic irradiance at each of these wavelengths (formula 1), or short-circuit current and monochromatic light beam power (formula 2). The first type of measurement results in the spectral irradiance responsivity with the unit $A/W \cdot m^{-2}$. In order to determine the spectral responsivity as defined in IEC/TS 61836 this needs to be divided by the area of the device under test whereas the second type results directly in the spectral responsivity in the unit A/W.

In order to determine the output current of the device, the bias light as well as the monochromatic light should irradiate the entire area of the device uniformly. It is important to illuminate effectively the entire area of the device, as light not directly falling onto the active area may also contribute to the measured signal. If the spectral responsivity is used for the calculation of the spectral mismatch correction according to IEC 60904-7 the illuminated area during the measurement of the spectral responsivity should be identical to that during the measurement of the current-voltage characteristics. This is normally the entire device area. If not it should be suitably delimitated by an aperture.

In case the area of the device is larger than the respective beam sizes the latter should be scanned appropriately across the entire device area to provide a uniform illumination. If both beams are scanned, the scanning should be synchronous with the bias light always illuminating a spot larger than the monochromatic light.

The temperature of the device should be controlled.

The current density of the device under test at each wavelength is divided by the respective irradiances to give spectral responsivity.

$$s(\lambda) = I_{sc}\,(\lambda)/E(\lambda)/A \tag{1}$$

where:

$s(\lambda)$ is the spectral responsivity of the device under test at the wavelength λ;

$I_{sc}(\lambda)$ is the short-circuit current of the device under test at the wavelength λ;

$E(\lambda)$ is the irradiance of the light source at the wavelength λ;

A is the area of the device under test.

The area of the device under test shall be noted in the test report.

Alternatively, the short-circuit current $I_{sc}(\lambda)$ and the radiant power incident on the device $P(\lambda)$ may be measured. The spectral responsivity is then determined as:

$$s(\lambda) = I_{sc}(\lambda)/P(\lambda) \tag{2}$$

where:

$I_{sc}(\lambda)$ is the short-circuit current of the device under test at the wavelength λ;

$P(\lambda)$ is the radiant power incident on the device at the wavelength λ.

The determination of $P(\lambda)$ requires the measurement of the area of the device under test. This area shall be noted in the test report.

In practice (see Clauses 7 and 9) a small modulated signal originating from the monochromatic light is superimposed on a large bias signal originating from the white bias light. In such cases the evaluated quantities need to be treated as differential and a wavelength dependent differential spectral responsivity (DSR) $\tilde{s}(\lambda, E)$ is determined for a specific bias light irradiance E. The spectral responsivity at standard test conditions $s(\lambda)|_{STC}$ will equal the differential spectral responsivity only if the device is strictly linear. If the non-linearity is confirmed to be negligible, the differential spectral response at a specific bias light level may be used. For example, if the differential spectral response or the resultant spectral mismatch factor is constant within the bias light levels to generate the I_{sc} between 5 % and 110 % of standard test conditions, the differential spectral response at a bias level of 100 % of standard test conditions may be used. In all other cases the DSR shall be measured at a sufficient number of bias irradiances and the resultant spectral responsivity can be calculated or a specific bias light irradiance E_0 shall be found with $\tilde{s}(\lambda, E_0) \approx s(\lambda)|_{STC}$.

6 Apparatus

6.1 General

A spectral responsivity measurement system consists of a continuous (chopped or unchopped) or pulsed monochromatic light source, an optional beam splitting assembly with a monitor detector, a device stage able to hold the device under test, a reference device, an optional bias light assembly and electrical instrumentation. Figures 1(a, b) and 2(a, b) show examples of test arrangements for the measurement of the DSR of a solar cell.

If an optical chopper is used (Figures 1 and 2) care needs to be taken that no bias light reflected of the optical chopper reaches the test plane.

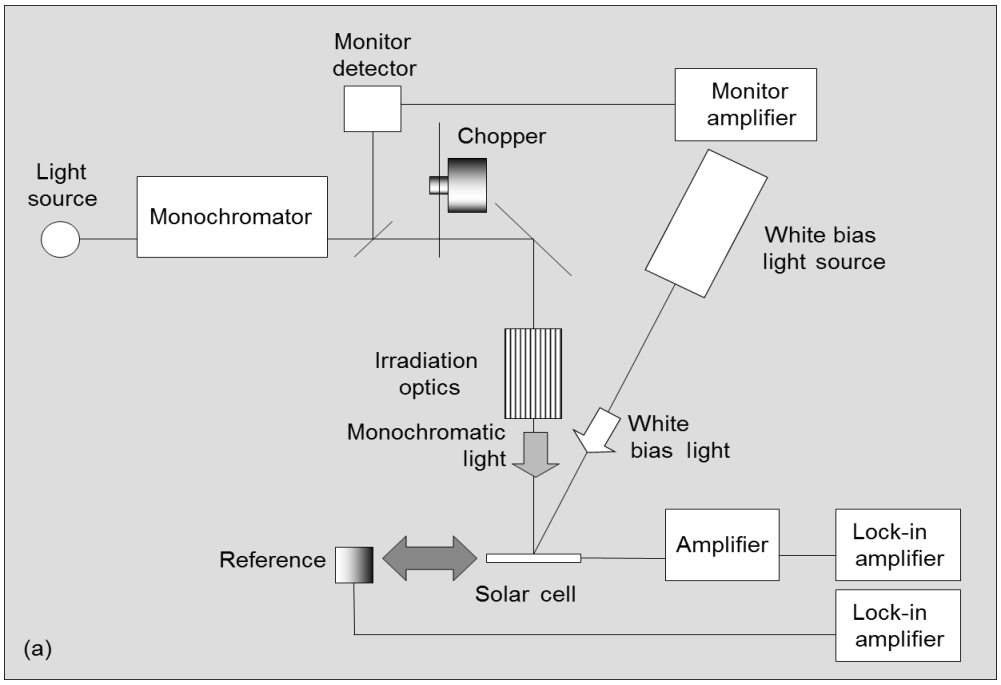

Figure 1a) – Monochromator ahead of chopper

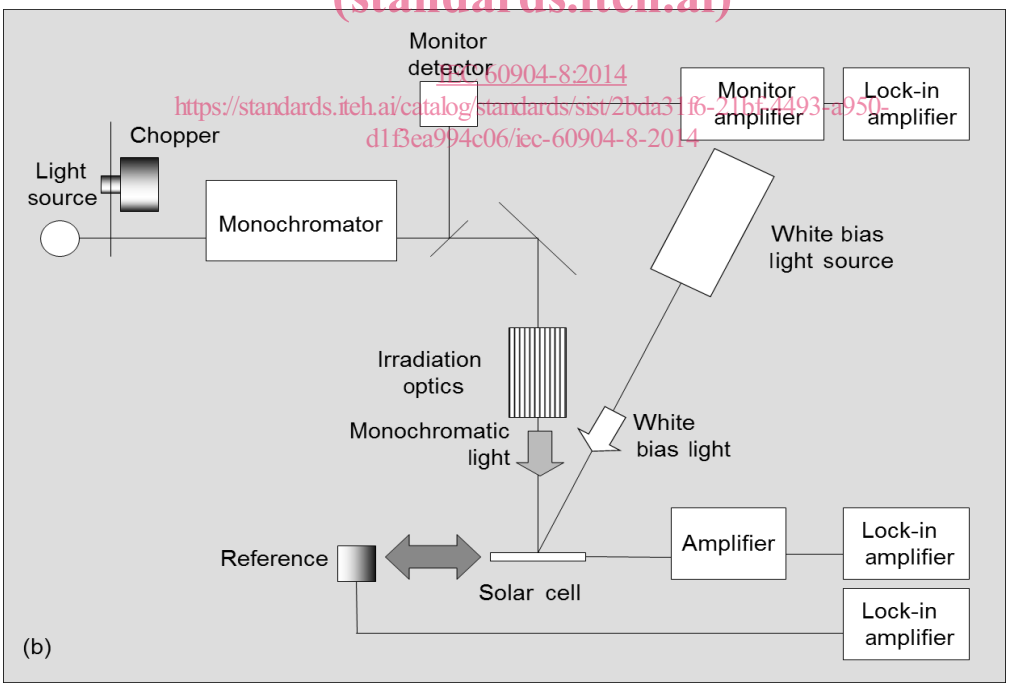

Figure 1b) – Chopper ahead of monochromator

Figure 1 – Example block diagram of a differential spectral responsivity measuring instrument using a continuous light source and a grating monochromator

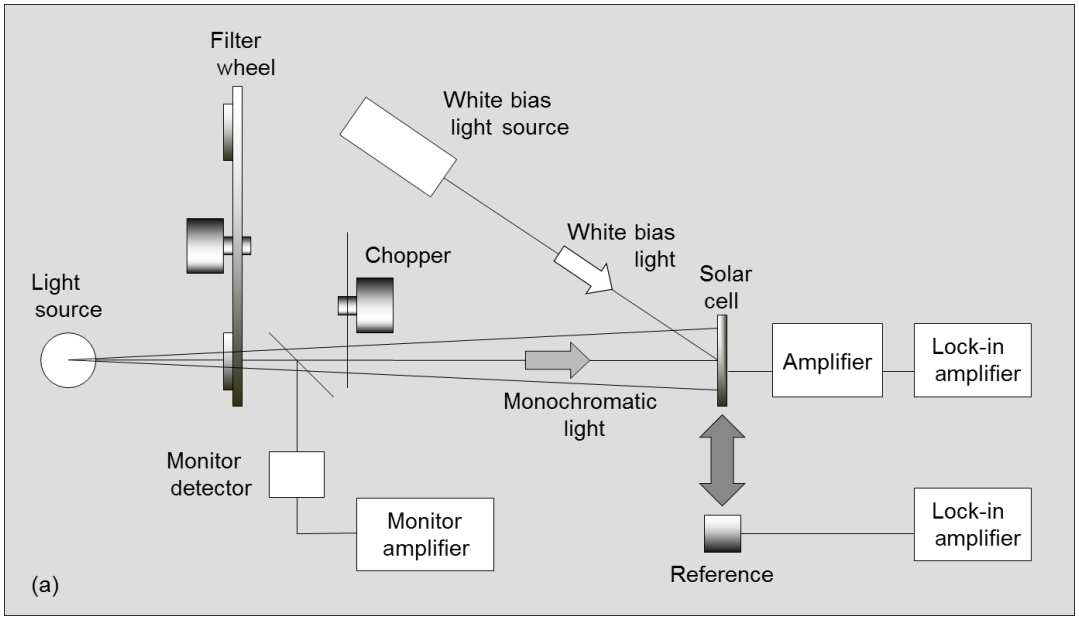

Figure 2a) – Filter ahead of chopper

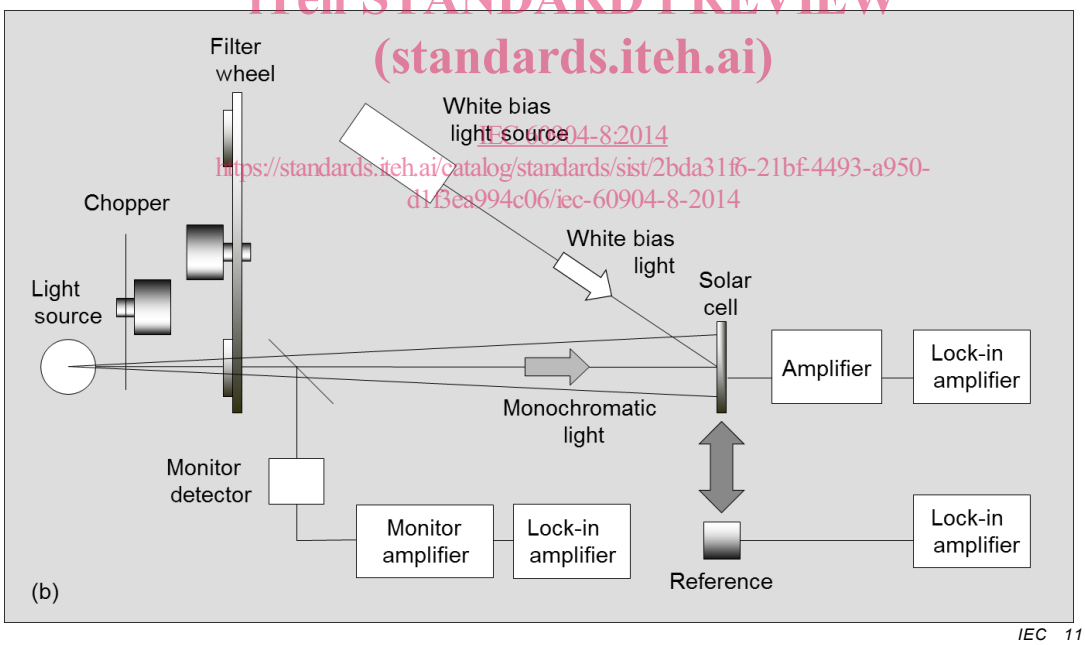

Figure 2b) – Chopper ahead of filter

Figure 2 – Example block diagram of a differential spectral responsivity measuring instrument using a continuous light source and bandpass filters

6.2 Monochromatic light source

The monochromatic light is usually generated by a light source and monochromator (for example a grating) or filter wheel with bandpass filters. The bandwidth (Full Width at Half Maximum, FWHM) of the monochromatic light should not exceed 20 nm for spectral responsivity measurements in the range between 300 nm and 1200 nm. In the range up to 3000 nm, the bandwidth should not exceed 50 nm.