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INTERNATIONAL STANDARD

NORME INTERNATIONALE

Photovoltaic (PV) module performance testing and energy rating – Part 1: Irradiance and temperature performance measurements and power rating

Essais de performance et caractéristiques assignées d'énergie des modules photovoltaïques (PV) – Partie 1: Mesures de performance en fonction de l'éclairement et de la température, et caractéristiques de puissance

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PHOTOVOLTAIC (PV) MODULE PERFORMANCE TESTING AND ENERGY RATING –

Part 1: Irradiance and temperature performance measurements and power rating

FOREWORD

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International Standard IEC 61853-1 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
82/613/FDIS	82/622/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 2.

A list of all parts of the IEC 61853 series can be found, under the general title *Photovoltaic (PV) module performance testing and energy rating*, on the IEC website.

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- withdrawn,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.

INTRODUCTION

This International Standard series establishes IEC requirements for evaluating PV module performance based on power (watts), energy (watt-hours) and performance ratio (PR). It is written to be applicable to all PV technologies including non-linear devices, but the methodology does not take into account transient behaviour such as light induced changes and/or thermal annealing.

Included in the IEC 61853 series of standards are: a guide to mapping module performance over a wide range of temperature and irradiance conditions; methods for characterising spectral and angular effects; definition of reference climatic profiles (temperature and irradiance); methods for evaluating instantaneous power and energy results; and a method for stating these results in the form of a numerical rating.

PHOTOVOLTAIC (PV) MODULE PERFORMANCE TESTING AND ENERGY RATING –

Part 1: Irradiance and temperature performance measurements and power rating

1 Scope and object

This part of IEC 61853 describes requirements for evaluating PV module performance in terms of power (watts) rating over a range of irradiances and temperatures. IEC 61853-2 describes test procedures for measuring the performance effect of angle of incidence; the estimation of module temperature from irradiance, ambient temperature and wind speed; and impact of spectral response on energy production. IEC 61853-3 describes the calculations of PV module energy (watt-hours) ratings. IEC 61853-4 describes the standard time periods and weather conditions that can be utilized for calculating standardized energy ratings.

The object of this part of IEC 61853 is to define a testing and rating system, which provides the PV module power (watts) at maximum power operation for a set of defined conditions. A second purpose is to provide a full set of characterization parameters for the module under various values of irradiance and temperature. This set of measurements is required in order to perform the module energy rating described in IEC 61853-3.

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 60410, *Sampling plans and procedures for inspection by attributes*

IEC 60891:2009, *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 60904-2, *Photovoltaic devices – Part 2: Requirements for reference solar devices*

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

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

IEC 60904-10, *Photovoltaic devices – Part 10: Methods of linearity measurement*

IEC 61215:2005, *Crystalline silicon terrestrial photovoltaic (PV) modules – Design qualification and type approval*

IEC 61646:2008, *Thin film terrestrial photovoltaic (PV) modules – Design qualification and type approval*

3 Sampling

For performance qualification testing three modules shall be selected at random from a production batch or batches in accordance with the procedure given in IEC 60410. The modules shall be pre-conditioned in accordance with Clause 5 to ensure the stability of the power values.

The modules shall have been manufactured from specified materials and components in accordance with the relevant drawings and process sheets and shall have been subjected to the manufacture's normal inspection, quality control and production acceptance procedures. The modules shall be complete in every detail and shall be accompanied by the manufacturer's handling and final assembly instructions regarding the recommended installation of any diodes, frames, brackets, etc.

When the modules to be tested are prototypes of a new design and not from production, this fact shall be noted in the test report (see Clause 6).

4 Marking

Each module shall carry the following clear and indelible markings:

– name, monogram or symbol of the manufacturer;
– type or model number;
– serial number;
– polarity of terminals or leads (colour coding is permissible);
– nominal and minimum values of maximum output power at STC after preconditioning, as specified by the manufacturer for the product type (see Clause 5).

The date and place of manufacture shall be marked on the module or be traceable from the serial number.

For future production the power ratings for NOCT, LIC, HTC and LTC determined by this standard as defined in Clause 7 and Table 1 and determined via the procedure in 9.2 shall be marked on a label, or be stated in the manufacturer's literature provided with each module of this type.

5 Testing and pass criteria

The modules shall be subjected to the procedure for irradiance and temperature performance measurements defined in Clause 8. In carrying out the tests, the manufacturer's handling, mounting and connection instructions shall be observed.

Special considerations: Preconditioning - Before beginning the measurements, the device under test shall be stabilized by light soaking, as specified in IEC 61215 (Clause 5) or IEC 61646 (10.19).

The values of STC power measured after preconditioning shall fall within the power range specified by the manufacturer of this product.

NOTE The pass/fail criteria must consider the laboratory uncertainty of the measurement. As an example, if the laboratory extended uncertainty of the STC measurement is ±5 %, then a nominal nameplate rated power greater than 95 % of the laboratory measured power would meet the pass criteria.

After generating the matrix of parameters in Section 8 the modules should be remeasured at STC to verify that the performance is stable.

6 Report

Following completion of the procedure, a certified report of the performance tests, with measured power characteristics shall be prepared by the test agency in accordance with the procedures of ISO/IEC 17025. Each certificate or test report shall include at least the following information:

a) a title;

b) name and address of the test laboratory and location where the calibration or tests were carried out;

c) unique identification of the certification or report and of each page;

d) name and address of client, where appropriate;

e) description and identification of the item calibrated or tested;

f) characterization and condition of the calibration or test item;

g) date of receipt of test item and date(s) of calibration or test, where appropriate;

h) identification of calibration or test method used;

i) reference to sampling procedure, where relevant;

j) any deviations from, additions to or exclusions from the calibration or test method, and any other information relevant to a specific calibration or test, such as environmental conditions;

k) a statement as to whether the simplified method in section 8 was used to complete the matrix. If the simplified method was used, the test report should give the values of relative temperature coefficients for maximum power and open circuit voltage for the two different irradiances used to validate the use of the simplified method;

l) measurements, examinations and derived results, including as a minimum table 2 for I_{sc}, P_{max}, V_{oc} and V_{max}, values of the module thermal coefficients α_I, β_I, the average power and the values for each of the three test modules at all reference power conditions (defined in section 7) and the temperature coefficient of module power (W) at the maximum power point (γ_I);

m) a statement of the estimated uncertainty of the calibration or test result (where relevant);

n) a statement as to whether the measured STC power agrees with the manufacturer's rated power range within the test laboratories measurement uncertainty;

o) a signature and title, or equivalent identification of the person(s) accepting responsibility for the content of the certificate or report, and the date of issue;

p) where relevant, a statement to the effect that the results relate only to the items calibrated or tested;

q) a statement that the certificate or report shall not be reproduced except in full, without the written approval of the laboratory.

7 Power rating conditions

7.1 General

The reference power conditions are shown in Table 1 and are described in more detail in the following subclauses. The first three reference power conditions are defined in IEC 61215/IEC 61646. The modules shall be tested and the maximum power determined for

the following rating conditions. For each rating condition the Air Mass 1,5 spectral irradiance distribution as given in IEC 60904-3 shall be used as well as normal incidence irradiance.

7.2 STC (Standard Test Conditions)

– Cell temperature: 25 °C.

– Irradiance: 1 000 $W \cdot m^{-2}$.

7.3 NOCT (Nominal Operating Cell Temperature)

– Cell temperature: NOCT (As determined in accordance with 10.5 of IEC 61215 or IEC 61646).

– Irradiance: 800 $W \cdot m^{-2}$.

7.4 LIC (Low Irradiance Condition)

– Cell temperature: 25 °C.

– Irradiance: 200 $W \cdot m^{-2}$.

7.5 HTC (High Temperature Condition)

– Cell temperature: 75 °C.

– Irradiance: 1 000 $W \cdot m^{-2}$.

7.6 LTC (Low Temperature Condition)

– Cell temperature: 15 °C.

– Irradiance: 500 $W \cdot m^{-2}$.

Table 1 – Summary of reference power conditions (at AM 1,5)

Condition	Irradiance $W \cdot m^{-2}$	Temperature °C
STC Standard Test Conditions	1 000	25 of cell
NOCT Nominal Operating Cell Temperature (Determined according to IEC 61215 or IEC 61646)	800	20 of ambient
LIC Low Irradiance Condition	200	25 of cell
HTC High Temperature Condition	1000	75 of cell
LTC Low Temperature Condition	500	15 of cell
NOTE The conditions provided in this table may be measured directly as part of the performance matrix defined in Clause 8.		

8 Procedure for irradiance and temperature performance measurements

8.1 Purpose

To determine the impact of irradiance and temperature on module performance:

The power delivery of photovoltaic devices is a direct function of module temperature and incident irradiance level. PV device performance is linear with temperature for many

crystalline silicon materials, but no general relation can be given for thin film materials. The short circuit current is often linear with respect to irradiance. The logarithmic variation of open circuit voltage and nonlinear variations of fill factor with the irradiance often render the maximum power a nonlinear function of light levels. Rather than using extensive modelling of these processes, the relations will be measured as functions of irradiance and temperature.

NOTE If I_{SC} of the module has been demonstrated to be linear (IEC 60904-10), I_{SC} can be utilized as the measurement of the irradiance level used in the test.

Matrices of module performance with respect to temperature and irradiance shall be measured. Separate tables for I_{sc}, V_{oc}, V_{max} and P_{max} shall be generated using sufficient data to assure statistical validity to the measurements (see 8.3.11 and 8.5.11). The tables for V_{oc} and V_{max} are not utilized for energy ratings, but are useful characteristics of the module type particularly for system design purposes.

Measurements need not be taken at exactly the irradiances and temperatures specified. Translation of I-V curves from the actual irradiance and/or temperature values to the values prescribed by the tables can be performed in accordance with IEC 60891. Such interpolation should be over no more than 100 $W \cdot m^{-2}$. All such interpolations shall be noted in the test report and their impact on uncertainly shall be included in the uncertainly analysis. Nevertheless, measurements shall be taken at or beyond the extremes of irradiance specified in Table 2 within the measurement accuracy of the instrumentation and the constraints of section 8.3.2.

A table of each of the parameters I_{sc}, P_{max}, V_{oc} and V_{max}, shall be made according to the example in Table 2.

NOTE 1 To assess nonlinearities, measurements at 300 W/m^2 and 50 W/m^2 can be helpful.

NOTE 2 Tables of the parameters I_{max} and Fill Factor (*FF*) can be generated from the four measured parameters.

Table 2 – I_{sc}, P_{max}, V_{oc} and V_{max} versus irradiance and temperature

Irradiance	Spectrum		Module temperature		
$W \cdot m^{-2}$		15 °C	25 °C	50 °C	75 °C
1 100	AM1,5	NA			
1 000	AM1,5				
800	AM1,5				
600	AM1,5				
400	AM1,5				NA
200	AM1,5			NA	NA
100	AM1,5			NA	NA

AM1,5 is defined in IEC 60904-3.

There are four procedures for performing the test matrix of module performance with respect to temperature and irradiance. The simplified procedure can only be utilized for linear modules per IEC 60904-10. Two of the procedures are performed outdoors in natural sunlight (one requiring a tracker and one that does not require a tracker). The fourth method is performed indoors using a solar simulator.

8.2 Simplified procedure for linear modules

For modules that have been determined to be linear (per IEC 60904-10), the maximum power dependence on irradiance and the maximum power dependence on temperature are independent. In this case it is sufficient to measure: