

# INTERNATIONAL STANDARD



**Terrestrial photovoltaic (PV) modules – Design qualification and type approval –  
Part 1: Test requirements**

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**Terrestrial photovoltaic (PV) modules – Design qualification and type approval –  
Part 1: Test requirements**

INTERNATIONAL  
ELECTROTECHNICAL  
COMMISSION

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**TERRESTRIAL PHOTOVOLTAIC (PV) MODULES –  
DESIGN QUALIFICATION AND TYPE APPROVAL –****Part 1: Test requirements**

## FOREWORD

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**This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition IEC 61215-1:2016. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.**

International Standard IEC 61215-1 has been prepared by IEC technical committee 82: Solar photovoltaic energy systems.

This second edition of IEC 61215-1 cancels and replaces the first edition of IEC 61215-1, published in 2016; it constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) Addition of a test taken from IEC TS 62782.
- b) Addition of a test taken from IEC TS 62804-1.
- c) Addition of test methods required for flexible modules. This includes the addition of the bending test (MQT 22).
- d) Addition of definitions, references and instructions on how to perform the IEC 61215 design qualification and type approval on bifacial PV modules.
- e) Clarification of the requirements related to power output measurements.
- f) Addition of weights to junction box during 200 thermal cycles.
- g) Requirement that retesting be performed according to IEC TS 62915.
- h) Removal of the nominal module operating test (NMOT), and associated test of performance at NMOT, from the IEC 61215 series.

Informative Annex A explains the background and reasoning behind some of the more substantial changes that were made in the IEC 61215 series in progressing from edition 1 to edition 2.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
82/1828A/FDIS	82/1848/RVD

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

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

A list of all parts in the IEC 61215 series, published under the general title *Terrestrial photovoltaic (PV) modules – Design qualification and type approval*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to the specific document. At this date, the document will be

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

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## INTRODUCTION

Whereas Part 1 of this standards series describes requirements (both in general and specific with respect to device technology), the sub-parts of Part 1 define technology variations and Part 2 defines a set of test procedures necessary for design qualification and type approval. The test procedures described in Part 2 are valid for all device technologies.

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# TERRESTRIAL PHOTOVOLTAIC (PV) MODULES – DESIGN QUALIFICATION AND TYPE APPROVAL –

## Part 1: Test requirements

### 1 ~~Scope and object~~

~~This part of IEC 61215 lays down IEC requirements for the design qualification and type approval of terrestrial photovoltaic (PV) modules suitable for long-term operation in general open-air climates, as defined in IEC 60721-2-1.~~

This document lays down requirements for the design qualification of terrestrial photovoltaic modules suitable for long-term operation in open-air climates. The useful service life of modules so qualified will depend on their design, their environment and the conditions under which they are operated. Test results are not construed as a quantitative prediction of module lifetime.

In climates where 98<sup>th</sup> percentile operating temperatures exceed 70 °C, users are recommended to consider testing to higher temperature test conditions as described in IEC TS 63126. Users desiring qualification of PV products with lesser lifetime expectations are recommended to consider testing designed for PV in consumer electronics, as described in IEC TS 63163 (under development). Users wishing to gain confidence that the characteristics tested in IEC 61215 appear consistently in a manufactured product may wish to utilize IEC 62941 regarding quality systems in PV manufacturing.

This document is intended to apply to all terrestrial flat plate module materials such as crystalline silicon module types as well as thin-film modules. It does not apply to systems that are not long-term applications, such as flexible modules installed in awnings or tenting.

This document does not apply to modules used with concentrated sunlight although it may be utilized for low concentrator modules (1 to 3 suns). For low concentration modules, all tests are performed using the irradiance, current, voltage and power levels expected at the design concentration.

This document does not address the particularities of PV modules with integrated electronics. It may however be used as a basis for testing such PV modules.

~~The objective of this test sequence is to determine the electrical and thermal characteristics of the module and to show, as far as possible within reasonable constraints of cost and time, that the module is capable of withstanding prolonged exposure in climates described in the scope. The actual lifetime expectancy of modules so qualified will depend on their design, their environment and the conditions under which they are operated.~~

The objective of this test sequence is to determine the electrical characteristics of the module and to show, as far as possible within reasonable constraints of cost and time, that the module is capable of withstanding prolonged exposure outdoors. Accelerated test conditions are empirically based on those necessary to reproduce selected observed field failures and are applied equally across module types. Acceleration factors may vary with product design, and thus not all degradation mechanisms may manifest. Further general information on accelerated test methods including definitions of terms may be found in IEC 62506.

Some long-term degradation mechanisms can only reasonably be detected via component testing, due to long times required to produce the failure and necessity of stress conditions that are expensive to produce over large areas. Component tests that have reached a

sufficient level of maturity to set pass/fail criteria with high confidence are incorporated into the IEC 61215 series via addition to Table 1. In contrast, the tests procedures described in this series, in IEC 61215-2, are performed on modules.

## 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 60050 (all parts), International Electrotechnical Vocabulary (available at <http://www.electropedia.org>)~~

IEC 60269-6, *Low-voltage fuses – Part 6: Supplementary requirements for fuse-links for the protection of solar photovoltaic energy systems*

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 TS 60904-1-2:2019, *Photovoltaic devices – Part 1-2: Measurement of current-voltage characteristics of bifacial photovoltaic (PV) devices*

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

IEC 60904-10, *Photovoltaic devices – Part 10: Methods of linear dependence and linearity measurements*

IEC TS 60904-13, *Photovoltaic devices – Part 13: Electroluminescence of photovoltaic modules*

IEC 61140, *Protection against electric shock – Common aspects for installation and equipment*

IEC 61215-2, *Terrestrial photovoltaic (PV) modules – Design qualification and type approval – Part 2: Test procedures*

IEC 61730-1, *Photovoltaic (PV) module safety qualification – Part 1: Requirements for construction*

IEC 61730-2, *Photovoltaic (PV) module safety qualification – Part 2: Requirements for testing*

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

IEC 61853-1, *Photovoltaic (PV) module performance testing and energy rating – Part 1: Irradiance and temperature performance measurements and power rating*

~~IEC 61853-2, Photovoltaic (PV) module performance testing and energy rating – Part 2: Spectral response, incidence angle, and module operating temperature measurements<sup>1</sup>~~

IEC TS 62782, Photovoltaic (PV) modules – Cyclic (dynamic) mechanical load testing

IEC 62790, Junction boxes for photovoltaic modules – Safety requirements and tests

IEC TS 62804-1, Photovoltaic (PV) modules – Test methods for the detection of potential-induced degradation – Part 1: Crystalline silicon

IEC 62852, Connectors for DC-application in photovoltaic systems – Safety requirements and tests

IEC TS 62915, Photovoltaic (PV) modules – Type approval, design and safety qualification – Retesting

IEC 62941, Terrestrial photovoltaic (PV) modules – Quality system for PV module manufacturing

IEC TS 63163: –<sup>2</sup>Terrestrial photovoltaic (PV) modules for consumer products – Design qualification and type approval

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

ISO/IEC Guide 98-3, Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)

### 3 Terms, definitions and abbreviated terms

For the purposes of this document, the terms and definitions in ~~IEC 60050~~ and IEC TS 61836 apply, as well as the following.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

#### 3.1

##### **bins of power classes**

power (typically maximum power) sorting criteria from the PV module manufacturer

#### 3.2

##### **tolerances <on label>**

value range of electrical parameters on the label of the PV module as given by the manufacturer

---

<sup>1</sup> ~~To be published.~~

<sup>2</sup> Under preparation. Stage at the time of publication: ADTS.

### 3.3

#### **MQT**

Module Quality Test

### 3.4

#### **type approval**

conformity test made on one or more items representative of the production

[SOURCE: IEC 60050-581:2008, 581-21-08 – Type test]

### 3.5

#### **reproducibility <of measurements>**

closeness of agreement between the results of measurements of the same value of a quantity, when the individual measurements are made under different conditions of measurement:

- principle of measurement,
- method of measurement,
- observer,
- measuring instruments,
- reference standards,
- laboratory,
- under conditions of use of the instruments, different from those customarily used,

after intervals of time relatively long compared with the duration of a single measurement. [consistent with the International Vocabulary of Metrology (VIM), 3.7]

Note 1 to entry: The concepts of "principle of measurement" and "method of measurement" are respectively defined in VIM 2.3 and 2.4.

Note 2 to entry: The term "reproducibility" also applies to the instance where only certain of the above conditions are taken into account, provided that these are stated.

Note 3 to entry: It is recommended that laboratories determine their reproducibility according to the formulas and principles in ISO 5725-2.

[SOURCE: IEC 60050-311:2001, 311-06-07]

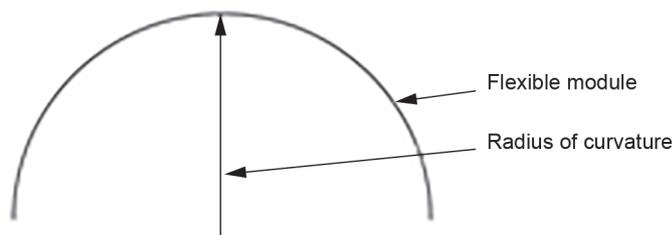
### 3.6

#### **flexible module**

PV module that exhibits a radius of curvature of 500 mm or less in at least one direction according to the manufacturer's specification and is capable of bending to conform to a flat or curved surface

Note 1 to entry: A curved module with a rigid shape is not considered a flexible module.

Note 2 to entry: Radius of curvature is defined as shown in Figure 1. During testing, the applied radius of curvature is no smaller than that specified by the manufacturer.



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**Figure 1 – Geometry that shows radius of curvature of a flexible module**

### 3.7

#### **representative sample**

sample that includes all the components of the module, except some repeated parts

Note 1 to entry: The representative samples shall use all key materials and subassemblies, as detailed in Clause 4.

### 3.8

#### **very large module**

module that exceeds the size of standard 2,2 m × 1,5 m commercially-available simulators

Note 1 to entry: A very large module exceeds 2,2 m in length or width, or exceeds 1,5 m in both dimensions. Thus a 3 m × 0,3 m module is considered very large, as is a 2,2 m × 2,2 m module.

Note 2 to entry: Very large modules are exempt from class A simulator spatial irradiance uniformity requirements, as detailed in IEC 61215-2 MQT 02.

Note 3 to entry: During test sequences representative samples may be substituted for very large modules, within the limits described in Clause 4.

Note 4 to entry: In future editions, the size threshold to be considered a very large module will likely increase to larger dimensions.

### 3.9

#### **bifacial PV modules**

modules that can convert irradiation received on both the front-side and rear-side into electric energy by means of the photovoltaic effect

### 3.10

#### **bifaciality coefficients**

ratios between the  $I$ - $V$  characteristics of the rear-side and the front-side of a bifacial module each measured under Standard Test Conditions (STC – IEC TS 61836), namely the short-circuit current bifaciality coefficient  $\phi_{I_{sc}}$ , the open-circuit voltage bifaciality coefficient  $\phi_{V_{oc}}$  and the maximum power bifaciality coefficient  $\phi_{P_{max}}$

Note 1 to entry: Bifaciality coefficients are fully defined in IEC TS 60904-1-2:2019, 6.2.

### 3.11

#### **bifacial nameplate irradiance**

##### **BNPI**

higher irradiance at which nameplate verification is performed for bifacial modules, corresponding to 1 000 W/m<sup>2</sup> on the module front and 135 W/m<sup>2</sup> on the module rear, applied in any method allowed by IEC TS 60904-1-2

### 3.12

#### **bifacial stress irradiance**

##### **BSI**

higher irradiance at which currents for stress are measured on bifacial modules, corresponding to 1 000 W/m<sup>2</sup> on the module front and 300 W/m<sup>2</sup> on the module rear, applied by any method allowed in IEC TS 60904-1-2,  $I$ - $V$  characteristic at which may be extrapolated from lower irradiances

## 4 Test samples

The PV module samples shall have been manufactured from specified materials and components in accordance with the relevant drawings and process sheets and have been subjected to the manufacturer's normal inspection, quality control and production acceptance procedures. The PV modules shall be complete in every detail and shall be accompanied by the manufacturer's handling, mounting, and connection instructions. When the PV 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 9).

The number of test samples required is derived from the applicable test sequences (see Clause 11).

Special test samples may be required for tests such as the bypass diode test MQT 18 (see IEC 61215-2).

For qualification of multiple bins of power classes within the boundaries given in ~~future~~ IEC TS 62915 at least 2 modules each, from the lower end, median and higher end power class shall be used for testing. If median power class does not exist the next higher class shall be used. If qualification of a single power class shall be extended to further bins of power classes within the boundaries given in IEC TS 62915 then at least 2 modules each, from the lower end, ~~median~~ and higher end power class shall be used for label verification (see Gate No.1 in 7.2.1). If a power class is extended only towards higher (or lower) bins, then modules only from the higher (or lower) bins, respectively, shall be used for verification of rated label values.

Qualification to multiple bins of power classes does not increase the minimum requirement of one control sample used in 7.2.3.

It is advisable to provide additional spare samples meeting the same output power requirements.

If applicable, the test samples shall be used to represent a group or family of products, or variations in the materials, or production processes used to produce the modules. The additional samples required for the test programme are then derived from IEC TS 62915.

For very large modules (as defined in 3.8), representative samples (as defined in 3.7) may be used for all qualification tests given in Clause 11 and IEC 61215-2. During the design and manufacturing of the representative samples, attention should be paid to reach the maximum similarity to the full-size product in all electrical, mechanical, and thermal characteristics related to quality and reliability. The cell, encapsulation methods, interconnects, terminations, clearance and creepage distances around all edges, and distance through solid insulation (relied upon insulation and cemented joints) shall be the same as on the actual full-size products. Limits are placed on how much one may reduce the dimensions of a very large module in making representative samples for qualification testing. The reduced dimension(s) shall be no less than one half the dimensions that define a very large module. In other words, when reducing the shorter dimension, the representative sample shall be at least 0,75 m wide. In reducing the longer dimension, the representative sample shall be at least 1,1 m long. If representative samples are used for any test, the test report shall include a table listing the dimensions of the product being qualified, and for each MQT, the dimensions of the samples tested. The table shall contain the statement, "Smaller samples were used for some tests as noted above. Use of smaller samples may affect test results." For determination of maximum power degradation during testing (7.2.3) on a representative sample,  $P_{\max}(\text{Lab\_GateNo.1})$  refers to the representative sample's initial stabilized measured power output. However, for verification of rated label values (7.2.2) a standard production product shall be measured, either at the test facility or utilizing a test at the manufacturer monitored by the testing entity.

If representative samples are utilized in Sequence E, then one extra module, full-sized, is required, and shall be subjected only to MQT 16 (static mechanical load test) and the requirements therein.

Any representative sample used for MQT 09 (hot-spot endurance test) shall contain the same number of cells per bypass diode (i.e. the same substring size) as the full-size product.

NOTE It is preferable in any test to measure a full-size sample, rather than a representative sample, when equipment size allows.

Prior to beginning the qualification test, care should be taken not to damage the samples in transit. Such care may include adherence to best practices in packing and shipping,<sup>[1]</sup><sup>3</sup> as well as electroluminescence imaging according to IEC TS 60904-13 before and after shipping to make sure cracks have not developed in transit.

For the requirements in the IEC 61215 series, a module shall be considered "bifacial" if the manufacturer claims bifaciality on the nameplate or datasheet, or if the module exhibits a maximum power bifaciality coefficient  $\geq 20\%$ . If a module is to be tested as a monofacial module, the test laboratory shall verify that the module is monofacial by at least one of the following methods:

- a) Information from the manufacturer showing that the rear of the cell is fully metallized;
- b) Spectrally-resolved backsheet transmission data from the module manufacturer; or
- c) Determination of bifaciality coefficient on one sample according to the procedure in IEC TS 60904-1-2.

## 5 Marking and documentation

### 5.1 Name plate

Each module shall include the following clear and indelible markings. Unless otherwise indicated, all the electrical parameters refer to STC:

- a) name, registered trade name or registered trade mark of manufacturer;
- b) type or model number designation;
- c) serial number (unless marked on other part of product);
- d) date and place of manufacture; alternatively serial number allowing to trace the date and place of manufacture;
- e) maximum system voltage;
- f) class of protection against electrical shock (as defined in IEC 61140 and IEC 61730-1);
- g) voltage at open-circuit or  $V_{oc}$  including tolerances. For bifacial modules, open-circuit voltage shall be reported at two irradiance levels. The first required irradiance level is  $1\,000\text{ W/m}^2$ . The second required irradiance is BNPI, as defined in 3.11.
- h) current at short-circuit or  $I_{sc}$  including tolerances. For bifacial modules, short-circuit current shall be reported at two irradiance levels, defined in 5.1g).
- i) module maximum power or  $P_{max}$  including binning and tolerances as defined in 3.1 and 3.2. For bifacial modules,  $P_{max}$  shall be reported at the two irradiance levels, defined in 5.1g).
- j) For bifacial modules the following information including tolerances, shall be given on the nameplate: The values for the short-circuit current bifaciality coefficient  $\phi_{Isc}$ , the open-circuit voltage bifaciality coefficient  $\phi_{Voc}$ , and the maximum power bifaciality coefficient  $\phi_{Pmax}$ , measured at STC as defined in IEC TS 60904-1-2.
- k) For flexible modules, the minimum radius of curvature.

~~All electrical data shall be shown as relative to standard test conditions ( $1\,000\text{ W/m}^2$ ,  $25\text{ }^\circ\text{C}$ , AM 1,5 according to IEC TS 61836).~~

<sup>3</sup> Numbers in square brackets refer to the Bibliography.

For items a) through i) all electrical data shall be shown as relative to STC (1 000 W/m<sup>2</sup>, 25 °C, AM1.5 according to IEC TS 61836), except for bifacial modules where two irradiance levels are required, as defined in 5.1g).

International symbols shall be used where applicable.

Compliance of marking is checked by inspection and MQT 06.1.

## 5.2 Documentation

### 5.2.1 Minimum requirements

Modules shall be supplied with documentation describing the methods of electrical and mechanical installation as well as the electrical ratings of the module. The documentation shall state the class of protection against electrical shock under which the module has been qualified and any specific limitations required for that class. The documentation shall assure that installers and operators receive appropriate and sufficient documentation for safe installation, use, and maintenance of the PV modules.

NOTE It is considered to be sufficient that one set of documentation is supplied with the module shipping unit.

### 5.2.2 Information to be given in the documentation

- a) all information required under 5.1 e) to i), and in addition j) for bifacial modules and k) for flexible modules;
- b) reversed current overload rating in accordance with IEC 61730-2 MST 26;
  - overcurrent protection device type and rating are e.g. given in IEC 60269-6. Overcurrent protection devices with a 1 h, 1,35  $I_n$  overload rating, where  $I_n$  is the rated value of the overcurrent protection device, are recommended;
  - recommended maximum series/parallel PV module configurations;
- c) manufacturer's stated tolerance for  $V_{oc}$ ,  $I_{sc}$  and maximum power output under standard test conditions;
- d) temperature coefficient for voltage at open-circuit;
- e) temperature coefficient for maximum power;
- f) temperature coefficient for short-circuit current.

All electrical data mentioned above shall be shown as relative to standard test conditions (1 000 W/m<sup>2</sup>, 25 °C, AM1.5 according to IEC TS 61836). Moreover the following parameters shall be specified:

- ~~g) nominal module operating temperature (NMOT);~~
- ~~h) performance at NMOT (MQT 06.2);~~
- g) performance at low irradiance (MQT 07).

International symbols shall be used where applicable.

Compliance is checked by inspection and MQT 04 through MQT 07.

The electrical documentation shall include a detailed description of the electrical installation wiring method to be used. This description shall include:

- h) the minimum cable diameters for modules intended for field wiring;
- i) any limitations on wiring methods and wire management that apply to the wiring compartment or box;
- j) the size, type, material and temperature rating of the conductors to be used;
- k) type of terminals for field wiring;

- l) specific PV connector model/types and manufacturer to which the module connectors shall be mated. Statement of the connector type only (such as "MC4 compatible ") is not sufficient information to satisfy this requirement. Connector model/types and manufacturers shall be included;
- m) the bonding method(s) to be used (if applicable); all provided or specified hardware shall be identified in the documentation;
- n) the type and ratings of bypass diode to be used (if applicable);
- o) limitations to the mounting situation (e.g., slope, orientation, mounting means, cooling);
- p) a statement indicating the fire rating(s) and the applied standard as well as the limitations to that rating (e.g., installation slope, sub structure or other applicable installation information);
- q) a statement indicating the design load per each mechanical means for securing the module as evaluated during the static mechanical load test according to MQT 16. At discretion of the manufacturer the test load and/or the safety factor  $\gamma_m$  may be noted, too.

To allow for increased output of a module resulting from certain conditions of use, the installation instructions shall include relevant parameters specified by manufacturer or the following statement or the equivalent:

*"Under normal conditions, a photovoltaic module is likely to experience conditions that produce more current and/or voltage than reported at standard test conditions. Accordingly, the values of  $I_{SC}$  and  $V_{OC}$  marked on this module should be multiplied by a factor of 1,25 when determining component voltage ratings, conductor current ratings, and size of controls connected to the PV output."*

### 5.2.3 Assembly instructions

These shall be provided with a product shipped in subassemblies, and shall be detailed and adequate to the degree required to facilitate complete and safe assembly of the product.

## 6 Testing

~~It is requested that the test laboratory uses a control module to be able to detect drifts in their measurement results.~~

~~The modules shall be divided into groups and subjected to the qualification test sequences in Figure 1. Qualification test sequences are to be carried out in the order specified. The MQT designations in the boxes refer to the corresponding test definitions in Part 2 of this standard. Technology specific test details are listed in the respective parts of this standard.~~

~~Intermediate measurements of maximum power (MQT 02) and insulation test (MQT 03) are not necessary, but they may be used to track changes.~~

The test laboratory shall use a laboratory simulator control module to be able to detect drifts in their measurement results. The laboratory simulator control module is different than the control module from sequence A, which is taken from the modules under test and is described in 7.2.3 related to the reproducibility  $r$ . The laboratory simulator control module is a stable module used on a periodic basis to check simulator output after calibration to a specific irradiance.

The modules shall be divided into groups and subjected to the qualification test sequences in Figure 2. Qualification test sequences are to be carried out in the order specified. The MQT designations in the boxes refer to the corresponding test definitions in IEC 61215-2. Technology-specific test details are listed in the respective parts of this standard. Required module component tests are listed in Table 1. For each component qualification, the test report shall note the test laboratory name and date when the requirement was met. Prior

certifications may be used to fulfill these requirements, as long as the certifications were performed in accordance with all conditions noted in Table 1.

Intermediate measurements of maximum power (MQT 02) and insulation test (MQT 03) are not required, but they may be used to track changes.

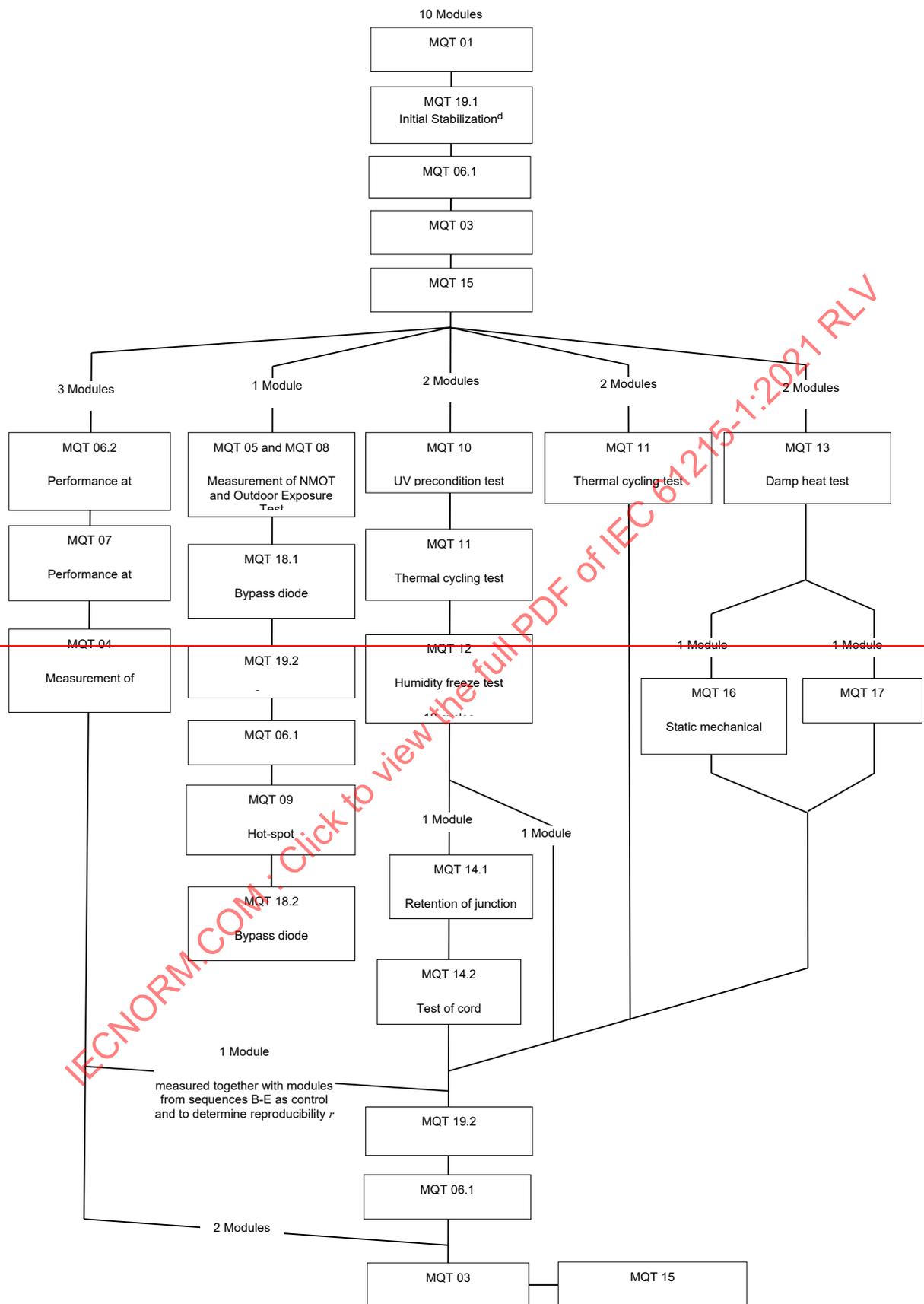
Any single test executed independently of a test sequence, e.g., on special test samples for MQT 09 and MQT 18, shall be preceded by the initial tests of MQT 01, MQT 02, MQT 03, and MQT 15 as appropriate.

In carrying out the tests, the tester shall strictly observe the manufacturer's handling, mounting, and connection instructions. Sequence A may be omitted if the module type has been tested according to IEC 61853-1. In this case the relevant test results from IEC 61853-1 shall be stated or referenced in the final report. For bifacial modules Sequence A cannot be omitted until IEC 61853-1 has been amended to take bifacial modules into account.

Test conditions are summarized in Table 3. The test levels in Table 3 are the minimum levels required for qualification. If the laboratory and the module manufacturer agree, the tests may be performed with increased severities. In this case this shall be noted in the test report.

For flexible modules (see 3.6), the mounting substrate and adhesive or attachment means shall also be included in the test. If more than one mounting substrate or adhesive or attachment means is allowed per the manufacturer's specification, then the tests shall use the combination that is considered to be the worst case. The chosen combination(s) shall be reported, as per Clause 9, j).

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<sup>a</sup>—These tests may be omitted if IEC 61853 has been performed on this module type. Test report shall be included in the design qualification report via IEC 61215.

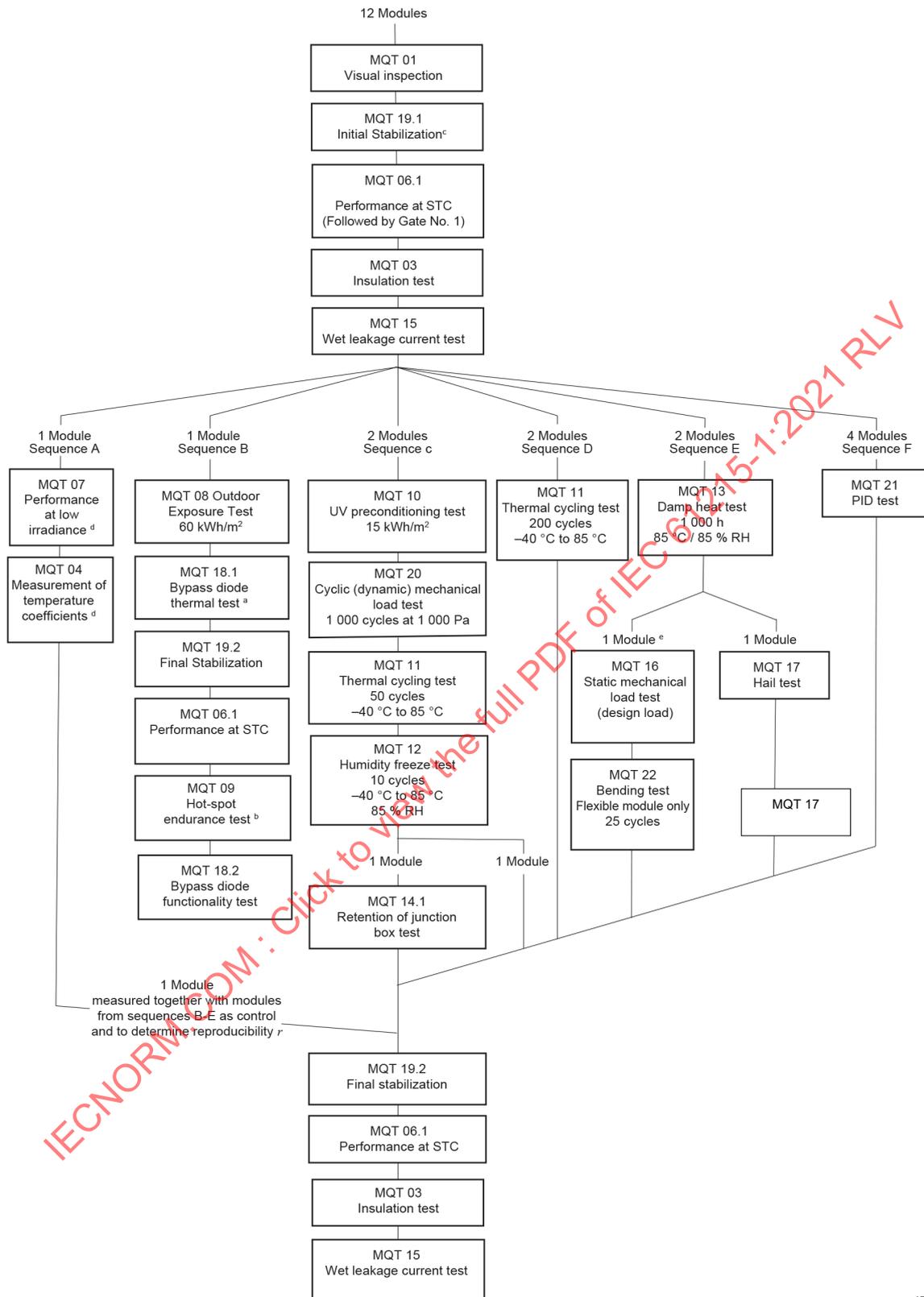
<sup>b</sup>—If the bypass diodes are not accessible in the standard modules, a special sample can be prepared for the bypass diode thermal test (MQT 18.1). The bypass diode should be mounted physically as it would be in a standard

~~module, with lead wires attached, as required in MQT 18 of IEC 61215-2. This sample does not have to go through the other tests in the sequence.~~

~~<sup>e</sup> For Hot-spot endurance test on a separate module the following test sequence is permissible: MQT 01, MQT 19.1, MQT 06.1, MQT 03, MQT 15, MQT 09, and MQT 18.2.~~

~~<sup>d</sup> The initial stabilization MQT 19.1 may include the verification of an alternate stabilization procedure (see IEC 61215-2) for the modules of Sequence A.~~

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<sup>a</sup> If the bypass diodes are not accessible in the standard modules, a special sample can be prepared for the bypass diode thermal test (MQT 18.1). The bypass diode should be mounted physically as it would be in a standard module, with lead wires attached, as required in MQT 18 of IEC 61215-2:2021. This sample does not have to go through the other tests in the sequence.

<sup>b</sup> In sequence B, a different module may be used for the Hot-spot endurance test (MQT 09) than is used for the bypass thermal diode test (MQT 18.1). For this separate module the following test sequence is permissible: MQT 01, MQT 19.1, MQT 06.1 (gate 1), MQT 03, MQT 15, MQT 09, and MQT 18.2.

- c The initial stabilization MQT 19.1 may include the verification of an alternate stabilization procedure (see IEC 61215-2:2021).
- d In Sequence A, tests MQT 07, and MQT 04 may be performed in any order. These tests may also be performed on separate modules (rather than sequential tests on one module), provided that each module used has proceeded through the entire test flow preceding sequence A.
- e If representative samples are utilized in Sequence E, one extra module, full-sized, is required, and shall be subjected only to MQT 16 and the requirements therein.

**Figure 2 – Full test flow for design qualification and type approval of photovoltaic modules**

**Table 1 – Required component tests**

Component	Shall pass this test
Junction box	IEC 61215-2:201x MQT 14.2, which cites IEC 62790 "Test of cord anchorage."
Connectors	IEC 62852. Compliance shall be obtained with the connector in combination with the same cable size and type as used in the modules under test.

## 7 Pass criteria

### 7.1 General

~~If two or more modules fail to meet the following test criteria, the design shall be deemed not to have met the qualification requirements. Should one module fail any test, two additional modules meeting the requirements of Clause 4 shall be subjected to the entire series of tests of the respective test sequence.~~

~~If one or both of these modules also fail, the design shall be deemed not to have met the qualification requirements. If, however, both modules pass the test sequence, the design shall be judged to have met the qualification requirements.~~

~~A module design shall be judged to have passed the qualification tests and therefore to be approved according to this standard, if each test sample meets all of the following criteria.~~

Modules under test are subject to several types of requirements. These include required markings (detailed in Clause 5), comparison of measured electrical quantities with the nameplate ( "gate No. 1 ", detailed in this clause), comparison of measured power before and after stress ( "gate No. 2 ", detailed in this clause), component requirements (detailed in Table 1), and the requirements of each MQT (summarized in Table 3 and Figure 2).

The design is deemed to have met the qualification requirements of 7.2.2 gate No. 1, if they meet the requirements of Table 2:

**Table 2 – Summary of Gate No. 1 requirements**

Sample size (in modules)	Requirement
<10	All modules shall pass. No failure is allowed.
≥10	A single failure is allowable. All other modules shall pass.

NOTE A sample size <10 is only encountered during retesting.

If modules fail to meet the requirements listed in Table 2 then two new samples shall be tested for each of the modules that failed to meet the gate No. 1 criteria. If a new failure occurs, the module supplier has two options. The first option is that the module labels for the existing sample set shall be redefined such that the requirements of Table 2 are met, and testing on that same sample set shall continue to the next step. The second option is that

the design is deemed not to have met the qualification requirements, and any further testing constitutes a new attempt at qualification and thus requires a completely new batch of modules. Module labels shall be redefined and samples shall be resubmitted for testing.

In addition, if two or more modules fail to meet the remaining test criteria (7.2.3 Gate No. 2, 7.2.4 electrical circuitry, 7.3 visual defects and 7.4 electrical safety), the design shall be deemed not to have met the qualification requirements. If one module fails any test, two additional modules meeting the requirements of Clause 4 shall be subjected to the entire series of tests of the respective test sequence. The requirement for two additional modules applies for tests where originally only one module was required, as well as for tests where originally two modules were required. For example, a failure in the hot-spot endurance test requires a test repetition with two additional modules. A single failure in the 50 thermal cycles test (one module not meeting the test requirements) requires a test repetition with two additional modules as well.

If one or both of these modules also fail, the design shall be deemed not to have met the qualification requirements. If, however, both modules pass the test sequence, the design shall be judged to have met the qualification requirements.

The module design shall meet the requirements of all criteria to be deemed as qualified according to this document. Each test sample shall be subject to the following criteria.

## 7.2 Power output and electric circuitry

### 7.2.1 Identification of rated values and tolerances

Gate No. 1 criteria detailed in the following subclauses require use of rated values and tolerances from the nameplate and product datasheet. This clause describes in detail, with examples, how to identify the relevant information. Application of the information in this clause results in consistent requirements when extraneous information is given, or when information appears to be missing or conflicting. Rated values and tolerances shall each be identified for module power, short-circuit current, and open-circuit voltage. Thus, this clause details how to identify these six pieces of information.

NOTE 1 Historically, some products have quoted multiple components of uncertainty, or have used different terminology for uncertainty, such as "tolerance," "production tolerance," "measurement uncertainty," etc. Also, some products have not provided a tolerance, which might be interpreted as 0 % tolerance or as missing information. While a manufacturer is not prohibited from providing additional information, or having 0 % tolerance, application of the rules in this clause provide a consistent manner to interpret such situations.

Information identified in this clause relates to STC current-voltage measurements, obtained in the manner prescribed by following the flow chart of Figure 2. Thus, the obtained values are those measured only after initial stabilization performed according to IEC 61215-2 MQT 19.1. Required stabilization procedures may differ from one product to the next, as specified in the technology-specific parts IEC 61215-1-x. The calculation of tolerances is the responsibility of the module manufacturer. Each tolerance ( $t_1$ ,  $t_2$  and  $t_3$ ) shall be explicitly stated as a single value for each of the performance parameters ( $P_{\max}$ ,  $V_{OC}$  and  $I_{SC}$  respectively). For bifacial modules, the six pieces of information (values and tolerances for module power, short-circuit current, and open-circuit voltage) shall also be identified at BNPI to evaluate Gate No. 1.

NOTE 2 ISO Guide 98-3 provides further guidance regarding how to combine multiple sources of uncertainty.

Formulas (1) and (2) in 7.2.2 verify that the modules produce at least as much power as the minimum indicated by combining the nameplate rating and tolerance. The minimum nameplate power rating,  $P_{\max}(\text{NP})$  is the module power output specified on the nameplate. If a single value for module power is stated on the nameplate,  $P_{\max}(\text{NP})$  is simply that value. If a range of module powers is stated on the nameplate,  $P_{\max}(\text{NP})$  is the power at the lowest end of that range. Subclause 5.2.2 requires that power binning and tolerance information from the nameplate is reproduced in the datasheet. In the case that  $P_{\max}(\text{NP})$  derived from the datasheet is different than that on the nameplate, the module shall be judged as not satisfying 5.2.2 and thus does not meet the requirements of IEC 61215-1.

The tolerance,  $t_1$ , is the tolerance in % for  $P_{\max}$  stated on the nameplate and datasheet, as required by 5.1i) and 5.2.2a). If the tolerance is asymmetric about  $P_{\max}(\text{NP})$ , the tolerance referring to the low power limit shall be utilized as  $t_1$ . If the tolerance is not stated on the nameplate or is not stated on the datasheet, then  $t_1 = 0$ . If tolerance is not reduced to a single value on the nameplate or data sheet (for example, if multiple tolerances or measurement uncertainty components are specified) the smallest number, not a combination of multiple numbers, shall be utilized.

Formulas (3) and (4) verify, for safety reasons, that the module does not produce more voltage at open circuit, or current at short-circuit, than the maximum indicated by combining the nameplate rating and tolerance. The maximum open circuit voltage  $V_{\text{oc}}(\text{NP})$  and maximum short-circuit current  $I_{\text{sc}}(\text{NP})$  are those specified on the nameplate. If a range for open-circuit voltages or short-circuit currents is stated on the nameplate,  $V_{\text{oc}}(\text{NP})$  or  $I_{\text{sc}}(\text{NP})$  is to be taken as the highest value in that range. The tolerance ( $t_2$  for open circuit voltage, or  $t_3$  for short-circuit current) is that specified on the nameplate and in the product documentation, as required by 5.1g), 5.1h), and 5.2.2c). If  $t_2$  (or  $t_3$ ) is asymmetric about  $V_{\text{oc}}(\text{NP})$  (or  $I_{\text{sc}}(\text{NP})$ ), the tolerance referring to the higher end of the range shall be utilized. If  $t_2$  or  $t_3$  is not stated in the documentation and on the nameplate, that tolerance shall be identified as 0. In the case that  $V_{\text{oc}}(\text{NP})$ ,  $I_{\text{sc}}(\text{NP})$ , or the tolerances in these quantities are different when derived from the datasheet than from the nameplate, the module shall be judged as not satisfying 5.2.2 and thus does not meet the requirements of IEC 61215-1. If a tolerance is not reduced to a single value on the nameplate or data sheet (for example, if multiple tolerances or measurement uncertainty components are specified) the smallest number, not a combination of multiple numbers, shall be utilized.

Figure 3 shows partial nameplates, datasheets, and derived values for four hypothetical products. These examples illustrate the rules for identifying rated values and tolerances that were described in the preceding subclauses.

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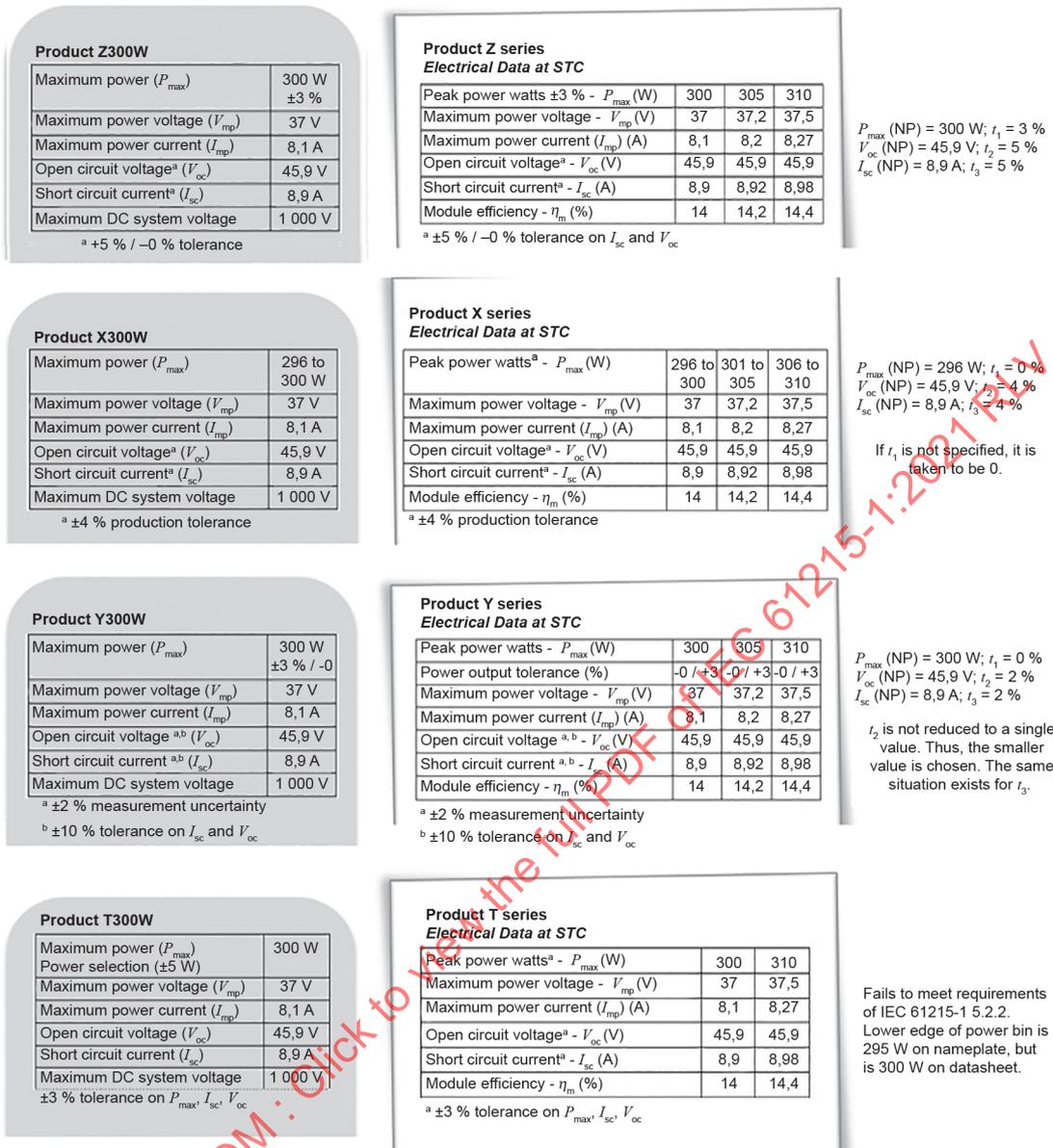


Figure 3 – Examples of hypothetical partial nameplates (left column), datasheets (center column), and derived rated values and tolerances (right column)

7.2.2 Verification of rated label values → Gate No. 1

All modules shall be stabilized following method MQT 19.1 from IEC 61215-2 (for technology specific requirements see sub-parts of IEC 61215-1). After stabilization the modules shall be measured in accordance with MQT 6.1 ( $P_{max}$ (Lab)). After the stabilization procedure all modules shall be within the power rating of the name plate ( $P_{max}$ (NP)) including stated measurement uncertainty  $m_1$ . Therefore, the following criterion shall be met:

$P_{max}$  Verification:

Each individual module shall meet the following criterion:

$$P_{max}(\text{Lab}) \cdot \left(1 + \frac{|m_1| [\%]}{100}\right) \geq P_{max}(\text{NP}) \cdot \left(1 - \frac{|t_1| [\%]}{100}\right)$$

where

$P_{\max}(\text{Lab})$  is the measured maximum STC power of each module in the stabilized state;

$P_{\max}(\text{NP})$  is the maximum rated nameplate power of each module without tolerances;

$m_1$  is the measurement uncertainty in % of laboratory for  $P_{\max}$  (expanded combined uncertainty (k=2), ISO/IEC Guide 98-3);

$t_1$  is the manufacturer's rated lower production tolerance in % for  $P_{\max}$ .

For  $\bar{P}_{\max}(\text{Lab})$ , the following criterion shall apply:

$$\bar{P}_{\max}(\text{Lab}) \cdot \left( 1 + \frac{|m_1| [\%]}{100} \right) \geq P_{\max}(\text{NP})$$

where

$\bar{P}_{\max}(\text{Lab})$  is the arithmetic average of the measured maximum STC power of the modules in stabilized condition.

For multiple bins of power classes this formula has to be applied to each power class under investigation.

$V_{\text{OC}}$  Verification:

Each individual module shall meet the following criterion:

$$V_{\text{OC}}(\text{Lab}) \cdot \left( 1 + \frac{|m_2| [\%]}{100} \right) \leq V_{\text{OC}}(\text{NP}) \cdot \left( 1 + \frac{|t_2| [\%]}{100} \right)$$

where

$V_{\text{OC}}(\text{Lab})$  is the measured maximum  $V_{\text{OC}}$  of each module in the stabilized state;

$V_{\text{OC}}(\text{NP})$  is the maximum rated nameplate  $V_{\text{OC}}$  of each module without tolerances;

$m_2$  is the measurement uncertainty in % of laboratory for  $V_{\text{OC}}$ ;

$t_2$  is the manufacturer's rated upper production tolerance in % for  $V_{\text{OC}}$ .

$I_{\text{SC}}$  Verification:

Each individual module shall meet the following criterion:

$$I_{\text{SC}}(\text{Lab}) \cdot \left( 1 + \frac{|m_3| [\%]}{100} \right) \leq I_{\text{SC}}(\text{NP}) \cdot \left( 1 + \frac{|t_3| [\%]}{100} \right)$$

where

$I_{\text{SC}}(\text{Lab})$  is the measured maximum  $I_{\text{SC}}$  of each module in the stabilized state;

$I_{\text{SC}}(\text{NP})$  is the maximum rated nameplate  $I_{\text{SC}}$  of each module without tolerances;

$m_3$  is the measurement uncertainty in % of laboratory for  $I_{\text{SC}}$ ;

$t_3$  is the manufacturer's rated upper production tolerance in % for  $I_{\text{SC}}$ .

All modules shall be stabilized following method MQT 19.1 from IEC 61215-2:2021 (for technology specific requirements, see sub-parts of IEC 61215-1). After stabilization the modules shall be measured in accordance with MQT 6.1 ( $P_{\max}(\text{Lab})$ ) and shall meet the following criteria:

$P_{max}$  verification:

Each individual module shall meet the following criterion:

$$P_{max}(Lab) \times \left(1 + \frac{1,65|m_1|}{100}\right) \geq P_{max}(NP) \times \left(1 - \frac{|t_1|}{100}\right) \quad (1)$$

where

$P_{max}(Lab)$  is the measured maximum power at STC of each module in the stabilized state;

$P_{max}(NP)$  is the minimum rated nameplate power of each module without tolerances;

$m_1$  is the measurement uncertainty in % of laboratory for  $P_{max}$  (expanded combined uncertainty (k=2), ISO/IEC Guide 98-3); the factor 1,65/2 is used to convert the confidence intervals from two-sided to one-sided at 95 % level of confidence;  $m_1$  shall include a component from spectral mismatch, based either on measured spectral response or the worst-case possibility for a given technology type;  $m_1$  shall be less than stated in the technology specific parts of this standards series;

$t_1$  is the manufacturer's rated lower tolerance in % for  $P_{max}$ .

For,  $\bar{P}_{max}(Lab)$  the following criterion shall apply:

$$\bar{P}_{max}(Lab) \times \left(1 + \frac{1,65|m_1|}{100}\right) \geq P_{max}(NP) \quad (2)$$

where

$\bar{P}_{max}(Lab)$  is the arithmetic average of the measured maximum STC power of the modules in stabilized condition.

For multiple bins of power classes this formula has to be applied to each power class under investigation.

NOTE Formula (2) is not intended for power verification of a batch in mass production as systematic differences between different labs and reference devices are unavoidable. In such cases, formula (1), which includes the relevant uncertainties, better describes the application to average values.

$V_{OC}$  verification:

Each individual module shall meet the following criterion:

$$V_{oc}(Lab) \times \left(1 + \frac{1,65|m_2|}{100}\right) \leq V_{oc}(NP) \times \left(1 + \frac{|t_2|}{100}\right) \quad (3)$$

where

$V_{OC}(Lab)$  is the measured maximum  $V_{OC}$  of each module in the stabilized state;

$V_{OC}(NP)$  is the maximum rated nameplate  $V_{OC}$  of each module without tolerances;

$m_2$  is the measurement uncertainty in % of laboratory for  $V_{OC}$ ; (expanded uncertainty (k=2), ISO/IEC Guide 98-3); the factor 1,65/2 is used to convert the confidence intervals from two-sided to one-sided at 95 % level of confidence;

$t_2$  is the manufacturer's rated upper tolerance in % for  $V_{OC}$ .

If  $V_{oc}$  cannot be measured due to module-integrated electronics (such as MOSFETs), the module is exempt from the  $V_{oc}$  verification requirement. This exemption shall be noted in the

test report.  $V_{OC}$  shall not be determined by any means other than direct measurement, such as extrapolation.

$I_{SC}$  verification:

Each individual module shall meet the following criterion:

$$I_{sc}(\text{Lab}) \times \left(1 + \frac{1,65}{2} \frac{|m_3|}{100}\right) \leq I_{sc}(\text{NP}) \times \left(1 + \frac{|t_3|}{100}\right) \quad (4)$$

where

- $I_{SC}(\text{Lab})$  is the measured maximum  $I_{SC}$  of each module in the stabilized state;
- $I_{SC}(\text{NP})$  is the maximum rated nameplate  $I_{SC}$  of each module without tolerances;
- $m_3$  is the measurement uncertainty in % of laboratory for  $I_{SC}$ ; (expanded uncertainty (k=2), ISO/IEC Guide 98-3); the factor 1,65/2 is used to convert the confidence intervals from two-sided to one-sided at 95 % level of confidence;
- $t_3$  is the manufacturer's rated upper tolerance in % for  $I_{SC}$ .

If  $I_{SC}$  cannot be measured due to module-integrated electronics (such as MOSFETs), the module is exempt from the  $I_{SC}$  verification requirement. This exemption shall be noted in the test report.  $I_{SC}$  shall not be determined by any means other than direct measurement, such as extrapolation.

$P_{max}$  verification of lowest power class:

Each individual module that is used for the qualification of low end power classes shall meet, in addition to the previous stated criteria for  $P_{max}$ ,  $V_{OC}$  and  $I_{SC}$ , the following criterion relating to an upper power limit:

$$P_{max}(\text{Lab}) \times \left(1 - \frac{1,65}{2} \frac{|m_1|}{100}\right) \leq P_{max4}(\text{NP}) \times \left(1 + \frac{|t_4|}{100}\right) \quad (5)$$

where

- $P_{max4}(\text{NP})$  is the maximum rated nameplate power of each lowest power class module, without tolerances;
- $t_4$  is the manufacturer's rated upper tolerance in % for  $P_{max4}(\text{NP})$ .  $t_4$  is selected subject to the same rules as for  $t_1$  (see Figure 3), except that if the tolerance is asymmetric about  $P_{max4}(\text{NP})$ , the tolerance referring to the high power limit shall be utilized.

The last criterion ensures that the modules of the lowest power class stay within the upper tolerance of that class. The last criterion is only applicable for the qualification of the lowest power class. It ensures that a module manufacturer can make modules in the lowest power class that are free from major flaws, and thus the lowest power class is not used as a repository for damaged modules after qualification is obtained using severely underrated modules.

For bifacial modules,  $P_{max}$ ,  $I_{SC}$ , and  $V_{OC}$  shall each be measured at the two irradiances specified in 5.1. The Gate No. 1 criteria for  $P_{max}$ ,  $I_{SC}$ , and  $V_{OC}$  shall be applied at both irradiances.

A systematic variation to either higher or lower output power or bifaciality coefficient will be stated in the final report.

### 7.2.3 Maximum power degradation during type approval testing → Gate No. 2

At the end of each test sequence or for sequence B after bypass diode test, the maximum power output drop of each module  $P_{\max}$  (Lab\_GateNo. 2) shall be less than 5 %, referenced to the module's initial measured output power  $P_{\max}$  (Lab\_GateNo. 1). Each test sample shall meet the following criterion:

$$\underline{P_{\max}(\text{Lab\_GateNo.2}) \geq 0,95 \times P_{\max}(\text{Lab\_GateNo.1}) \cdot \left(1 - \frac{r[\%]}{100}\right)}$$

$$P_{\max}(\text{Lab\_GateNo.2}) \geq 0,95 \times P_{\max}(\text{Lab\_GateNo.1}) \cdot \left(1 - \frac{r}{100}\right) \quad (6)$$

The reproducibility  $r$  in % shall be determined for  $P_{\max}$  and shall be used in the formula. The reproducibility shall be less than or equal to that stated in the technology specific parts of this standards series.

The reproducibility  $r$  is verified by comparing the control module(s) from sequence A after initial stabilization (beginning of the test) and after final stabilization (end of tests from sequence B to E). The second test shall be performed after completing all tests. The following applies:

- All modules from sequences B (after MQT 18.1), C, D and E are measured together with one control module from Sequence A.
- If a) cannot be used due to test flow (different completion time of sequence or customer requests restrictions) the following applies:

For each sequence B (after MQT 18.1), C, D and E one control module from sequence A shall be defined. The control module is stabilized and measured together with the modules from the applicable sequence B (after MQT 18.1), C, D or E. For each determined value  $r$  the requirement for  $r$  shall be fulfilled.

The reproducibility parameter  $r$  is not equal to the total measurement uncertainty of MQT 06.1. It is advisable that the same solar simulator is used for  $P_{\max}$  (Lab\_Gate No. 1) and  $P_{\max}$  (Lab\_Gate No. 2).

If the measured  $r$  exceeds the technology specific limit for the control module the laboratory needs to check with its own internal reference module(s) whether the test equipment is faulty, or the module under test is responsible for the poor reproducibility, or it is not in a stable state after applied procedure MQT 19.1. If all checks confirm the measurement equipment is performing correctly, this indicates that the control module has drifted by more than the technology specific limit. In this case, proceed by using the technology specific limit for  $r$ .

For bifacial modules, Gate No. 2 shall each be assessed only at the larger irradiance (BNPI) specified in 5.1g).

### 7.2.4 Electrical circuitry

Samples are not permitted to exhibit an open-circuit during the tests.

### 7.3 Visual defects

There is no visual evidence of a major visual defect, as defined in Clause 8.

### 7.4 Electrical safety

- The insulation test (MQT 03) requirements are met ~~after the tests~~ at the beginning and the end of each sequence.

- b) The wet leakage current test (MQT 15) requirements are met at the beginning and the end of each sequence.
- c) Specific requirements of the individual tests are met.

## 8 Major visual defects

The purpose of the visual inspection is to detect any visual defects that may cause a risk of reliability loss, including power output.

In some instances more ~~testing~~ detailed inspection may be required to finally decide if major visual defects exist or not.

For the purpose of design qualification and type approval the following observations are considered to be major visual defects:

- a) Broken, cracked, or torn external surfaces.
- b) Bent or misaligned external surfaces, including superstrates, substrates, frames and junction boxes to the extent that the operation of the PV module would be impaired.
- c) Bubbles or delaminations forming a continuous path between electric circuit and the edge of the module.
- d) If the mechanical integrity depends on lamination or other means of adhesion, the sum of the area of all bubbles shall not exceed 1 % of the total module area.
- e) Evidence of any molten or burned encapsulant, backsheet, frontsheet, diode or active PV component.
- f) Loss of mechanical integrity to the extent that the installation and operation of the module would be impaired.
- g) Cracked/broken cells which can remove more than 10 % of the cell's photovoltaic active area from the electrical circuit of the PV module.
- h) Voids in, or visible corrosion of any of the layers of the active (live) circuitry of the module extending over more than 10 % of any cell.
- i) Broken interconnections, joints or terminals.
- j) Any short-circuited live parts or exposed live electrical parts.
- k) Module markings (label) are no longer attached or the information is unreadable.

## 9 Report

Following type approval, a report of the qualification tests, with measured performance characteristics and details of any failures and re-tests, shall be prepared by the test agency ~~in accordance with ISO/IEC 17025~~. The report shall contain the detail specification for the module. Each test report shall include at least the following information:

- a) a title;
- b) name and address of the test laboratory and location where the tests were carried out;
- c) unique identification of the report and of each page;
- d) name and address of client, where appropriate;
- e) description and identification of the item tested, including indication if it has been evaluated for bifaciality and/or whether it has been evaluated as a flexible module;
- f) characterization and condition of the test item;
- g) date of receipt of test item and date(s) of test, where appropriate;
- h) identification of test methods used;
- i) reference to sampling procedure, where relevant;

- j) any deviations from, additions to, or exclusions from, the test method and any other information relevant to specific tests, such as environmental conditions, or the irradiation dose in kWh/m<sup>2</sup> at which stability is reached;
- k) measurements, examinations and derived results supported by tables, graphs, sketches and photographs as appropriate including:
- temperature coefficients of short-circuit current, open-circuit voltage and peak power, ~~NMOT,~~
  - power at ~~NMOT,~~ STC and low irradiance,
  - bifaciality coefficients at STC and low irradiance (for bifacial modules),
  - the maximum shaded cell temperature observed during the hot-spot endurance test,
  - spectrum of the lamp used for the UV preconditioning test,
  - mounting method(s) utilized in the static mechanical load test ~~and for measurement of NMOT,~~
  - the positive/negative test loads and the safety factor  $\gamma_m$  used in the static mechanical load test,
  - hail ball diameter and velocity used in the hail test,
  - maximum power loss observed after all of the tests, ~~and~~
  - for flexible modules, the diameter of the cylinder over which the module was bent during performance of MQT 22, and
  - conditions of potential induced degradation (PID) test (MQT 21) including applied rated system voltage, polarities, and mounting configuration;
  - choice of test method where procedures allow more than one option (e.g. Method A or B in MQT 18.2; final stabilization method in MQT 19.2, etc.)
  - if open-circuit voltage, short-circuit current, or associated temperature coefficients cannot be measured due to module-integrated electronics, these quantities shall be reported as "not measurable due to module-integrated electronics." Any resulting exemptions from Gate 1 requirements on  $I_{sc}$  or  $V_{oc}$  shall also be noted.
- l) any failures observed and any retests performed;
- m) a representation of the markings of the module type including manufacturer's power tolerances;
- n) the test lab name and date, for each component qualification required in Table 1;
- o) a summary of results from all pass criteria defined in Clause 7 in absolute and relative change. If tendencies to either higher or lower values are observed this has to be included in the report. The used stabilization procedure (irradiance, temperature, time) needs to be stated in detail;
- p) a statement of the estimated uncertainty of the test results (where relevant); state the reproducibility  $r$  from the control module that is used for Gate No. 2.
- q) a signature and title, or equivalent identification of the person(s) accepting responsibility for the content of the report, and the date of issue;
- r) where relevant, a statement to the effect that the results relate only to the items tested;
- s) a statement that the report shall not be reproduced except in full, without the written approval of the laboratory.

## 10 Modifications

Changes in material selection, components and manufacturing process can impact the qualification of the modified product. ~~Material in direct contact with each other shall be tested in all applicable combinations unless equality can be proven.~~

~~Detailed retesting requirements are defined in IEC TS 62915~~ Retesting shall be performed according to IEC TS 62915. The recommended test sequences have been selected to identify adverse changes to the modified product.

During retesting, tests that are performed on representative samples do not need to be repeated if the only change to a product is one of size, and the change in product size still allows use of the same representative sample size already tested.

The number of samples to be included in the retesting program and the pass/fail criteria are to be taken from the relevant clauses/subclauses of this document.

## 11 Test flow and procedures

For design qualification and type approval the following test flow and procedures apply. Table 3 summarizes the different tests. The full test flow is given in Figure 2. A description of the tests and test procedures is given in IEC 61215-2:2021. Technology-relevant differences ~~will be~~ are described in the respective technology specific part of this standards series.

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Table 3 – Summary of test levels

Test	IEC 61215:2005 or IEC 61646:2008	Title	Test conditions
MQT-01	10.1	Visual inspection	See detailed inspection list in Clause 8
MQT-02	10.2	Maximum power determination	See IEC 60904-1
MQT-03	10.3	Insulation test	For modules with a system voltage greater than 50 V d.c., dielectric withstand at 1 000 V d.c. + twice the maximum systems voltage for 1 min, followed by insulation resistance measurement at 500 V d.c. or maximum systems voltage for 2 min. For modules with a system voltage less than 50 V d.c., the test voltages are 500 V d.c.
MQT-04	10.4	Measurement of temperature coefficients	See IEC 60894 See IEC 60904-10 for guidance (see note <sup>a</sup> of Figure 1)
MQT-05	10.5	Measurement of NMOT	See IEC future 61853-2 Module operating near maximum power point Total solar irradiance: 800 W/m <sup>2</sup> Ambient temperature: 20 °C Wind speed: 1 m/s
MQT-06	10.6	Performance at STC (MQT-06.1) and NMOT (MQT-06.2)	Cell temperature of 25 °C at STC and module temperature at NMOT Irradiance: 1 000 W/m <sup>2</sup> and 800 W/m <sup>2</sup> with IEC 60904-3 reference solar spectral irradiance distribution Requirements see Clause 7
MQT-07	10.7	Performance at low irradiance (see note <sup>a</sup> of Figure 1)	Cell temperature: 25 °C Irradiance: 200 W/m <sup>2</sup> with IEC 60904-3 reference solar spectral irradiance distribution
MQT-08	10.8	Outdoor exposure test	60 kWh/m <sup>2</sup> total solar irradiation
MQT-09	10.9	Hot-spot endurance test	Exposure to 1 000 W/m <sup>2</sup> irradiance in worst-case hot-spot condition as per the technology specific part and IEC 61215-2
MQT-10	10.10	UV preconditioning	15 kWh/m <sup>2</sup> total UV irradiation in the wavelength range from 280 nm to 400 nm with 3 % to 10 % UV irradiance in the wavelength range from 280 nm to 320 nm
MQT-11	10.11	Thermal cycling test	50 (Sequence C) or 200 (Sequence D) cycles from –40 °C to +85 °C with current as per technology specific part up to +80 °C
MQT-12	10.12	Humidity freeze test	10 cycles from +85 °C, 85 % RH to –40 °C with circuitry continuity monitoring
MQT-13	10.13	Damp heat test	1 000 h at +85 °C, 85 % RH
MQT-14	10.14	Robustness of termination	Test of junction box retention and cord anchorage.
MQT-15	10.15	Wet leakage current test	Test voltage increase at a rate not exceeding 500 V/s to 500 V or the maximum system voltage for the module, whichever is greater. Maintain the voltage at this level for 1 min.
MQT-16	10.16	Static mechanical load test	Three cycles of uniform load specified by the manufacturer, applied for 1 h to front and back surfaces in turn. Minimum test load: 2 400 Pa
MQT-17	10.17	Hail test	25 mm diameter ice ball at 23,0 m/s, directed at 11 impact locations
MQT-18	10.18	Bypass diode thermal test	MQT-18.1: Bypass diode thermal test: 1 h at $I_{sc}$ and 75 °C 1 h at 1,25 times $I_{sc}$ and 75 °C MQT-18.2: Bypass diode functionality test At 25 °C perform voltage and current measurements
MQT-19	10.19	Stabilization	Three consecutive output power measurements P1, P2 and P3 using MQT-02. STC output power is determined using procedure MQT-06.1.

Test	Subclause in IEC 61215-2:2021	Title	Test conditions
MQT 01	4.1	Visual inspection	See list of major visual defects in Clause 8
MQT 02	4.2	Maximum power determination	See IEC 60904-1 for monofacial modules and IEC TS 60904-1-2 for bifacial modules
MQT 03	4.3	Insulation test	Test levels vary between 500 V minimum and $1,35 \times (2000 + 4 \times V_{sys})$ maximum depending on system voltage, module class, and presence of cemented joints. See MQT 03 procedure for further detail.
MQT 04	4.4	Measurement of temperature coefficients	See IEC 60891 See IEC 60904-10 for guidance
MQT 06.1	4.6	Performance at STC	Cell temperature of 25 °C at STC Irradiance: 1 000 W/m <sup>2</sup> (and BNPI, for bifacial modules) with IEC 60904-3 reference solar spectral irradiance distribution Requirements see Clause 7
MQT 07	4.7	Performance at low irradiance	Cell temperature: 25 °C Irradiance: 200 W/m <sup>2</sup> with IEC 60904-3 reference solar spectral irradiance distribution
MQT 08	4.8	Outdoor exposure test	60 kWh/m <sup>2</sup> total solar irradiation
MQT 09	4.9	Hot-spot endurance test	Exposure to irradiance in worst-case hot-spot condition as per the technology specific part and IEC 61215-2. For monofacial modules, irradiance is 1 000 W/m <sup>2</sup> . For bifacial modules the irradiance is BSI.
MQT 10	4.10	UV preconditioning	15 kWh/m <sup>2</sup> total UV irradiation in the wavelength range from 280 nm to 400 nm, with 3 % to 10 % UV irradiance in the wavelength range from 280 nm to 320 nm, at a module temperature of 60 °C. For bifacial modules, exposure is repeated on the rear side.
MQT 11	4.11	Thermal cycling test	50 (Sequence C) or 200 (Sequence D) cycles from -40 °C to +85 °C with current as per technology specific part up to +80 °C, with 5 N weight hanging from the junction box.
MQT 12	4.12	Humidity freeze test	10 cycles from +85 °C, 85 % RH to -40 °C with circuitry continuity monitoring
MQT 13	4.13	Damp heat test	1 000 h at +85 °C, 85 % RH
MQT 14	4.14	Robustness of termination	Test of junction box retention and cord anchorage.
MQT 15	4.15	Wet leakage current test	Test voltage increase at a rate not exceeding 500 V/s to 500 V or the maximum system voltage for the module, whichever is greater. Maintain the voltage at this level for 2 min. Solution temperature is $(22 \pm 2)$ °C.
MQT 16	4.16	Static mechanical load test	Three cycles of uniform load specified by the manufacturer, applied for 1 h to front and back surfaces in turn. Minimum test load: 2 400 Pa
MQT 17	4.17	Hail test	Ice ball impact directed at 11 locations. Required minimum ice ball diameter of 25 mm and speed of 23,0 m/s.
MQT 18	4.18	Bypass diode thermal test	MQT 18.1: Bypass diode thermal test: 1 h at $I_{sc}$ and 75 °C 1 h at 1,25 times $I_{sc}$ and 75 °C MQT 18.2: Bypass diode functionality test At 25 °C perform voltage and current measurements For bifacial modules, $I_{sc}$ in the conditions above is that measured at elevated irradiance BSI.
MQT 19	4.19	Stabilization	Three consecutive output power measurements $P_1$ , $P_2$ and $P_3$ using MQT 02. STC output power is determined using procedure MQT 06.1.
MQT 20	4.20	Cyclic (Dynamic) Mechanical load test	IEC TS 62782 1 000 cycles at 1 000 Pa
MQT 21	4.21	Potential induced degradation test	IEC TS 62804-1 +85 °C, 85 % RH at maximum system voltage for 96 h

Test	Subclause in IEC 61215-2:2021	Title	Test conditions
MQT 22	4.22	Bending test – for flexible modules only	25 cycles rolled up (without damage) around a cylinder with a diameter specified by the module manufacturer over which the flexible modules can be bent

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## Annex A (informative)

### Changes from previous edition

#### A.1 General

This annex is included with edition 2 of the IEC 61215 series to better explain the project team's reasoning in developing some of the changes made since edition 1. This annex is informative, describing the development history and rationale. This annex does not modify or complete any of the test procedures found in the IEC 61215 series.

The following changes are discussed in this annex:

- Procedures for bifacial modules
- Use of representative samples
- Addition of dynamic mechanical load test
- Addition of test for potential induced degradation
- Simulator requirements
- References to retest guidelines
- Weight on junction boxes
- Correction to monolithically-integrated hot-spot endurance test
- Number of modules in sequence
- Removal of nominal module operating temperature (NMOT)
- Very low currents during thin-film tests
- Limit bypass diode testing to three diodes
- Revert the insulation test to 2005 version
- Bending test
- Stabilization option for boron oxygen LID (MQT 19.3)

To create edition 2, a number of minor corrections and clarifications to the edition 1 wording were also made. These minor changes are not discussed in this annex.

#### A.2 Procedures for bifacial modules

The IEC 61215 new edition includes text related to bifacial modules, whereas edition 1 did not. The new edition includes several instructions related to bifacial modules:

- Procedures for measuring bifacial modules are included via references to IEC TS 60904-1-2.
- Where test levels need to be adjusted for bifacial modules due to potentially higher currents during operation, these increased values are specified.
- Additional reporting requirements (e.g. bifaciality coefficients) are described.
- Tests that may be omitted because referenced standards have not yet been modified to account for bifaciality are noted.

Qualification of bifacial modules requires measurement of several quantities beyond those required for monofacial modules. The short-circuit current bifaciality coefficient  $\phi_{ISC}$ , the open-circuit voltage bifaciality coefficient  $\phi_{VOC}$  and the maximum power bifaciality coefficient  $\phi_{Pmax}$  shall be listed on the nameplate, as per IEC 61215-1:2021, 5.1j). These coefficients are measured as part of IEC 61215-2:2021. MQT 6.1. Any significant deviation between the measured and listed values shall be noted in the test report, as per IEC 61215-1:2021, 7.2.2. MQT 07, performance at low irradiance, also requires calculation of the bifaciality coefficients at low irradiance.

Qualification of bifacial modules requires performance measurement (MQT 06.1) at three irradiances. These irradiances are

- 1 000 W/m<sup>2</sup> (the irradiance at STC, as defined in IEC TS 61836),
- conditions equivalent to 1 000 W/m<sup>2</sup> on the front side and 135 W/m<sup>2</sup> on the back side (BNPI, as defined in 3.11), and
- conditions equivalent to 1 000 W/m<sup>2</sup> on the front side and 300 W/m<sup>2</sup> on the back side (BSI, as defined in 3.12).

BNPI and BSI may be applied in any method allowed by IEC TS 60904-1-2, such as single-side illumination at equivalent irradiance, or double-side illumination. If single-side illumination is utilized, the simulator setting depends on the module bifaciality through the equivalent irradiance defined in 60904-1-2. Extrapolation of performance parameters at BSI from the values of 1 000 W/m<sup>2</sup> on front and 300 W/m<sup>2</sup> on back is possible if the flasher is unable to achieve high enough irradiance for BSI.

BNPI is used for nameplate verification. 135 W/m<sup>2</sup> rear irradiance is chosen for BNPI based on several published studies that find, with typical module spacing and light-colored soil, the rear-side irradiance is in the range of 100-150 W/m<sup>2</sup> when 1 000 W/m<sup>2</sup> is incident on the front side.[2] [3] [4] [5] [6] BNPI thus conveys an approximation of typical power gain due to bifaciality.

BSI is used to measure quantities that determine applied stress conditions. A 300 W/m<sup>2</sup> rear irradiance in BSI is used to represent worst case (most stressful) conditions with a reflective (0,5 albedo) ground cover.[7] To ensure safe products, this worst case condition is used to set the stress levels.

For bifacial modules, measurements at both STC and BNPI are used for Gate No. 1, while only measurements at BNPI are utilized for and Gate No. 2 criteria. For final Gate No. 2 measurements (post stress,) STC measurement and re-evaluation of bifaciality coefficients are not required, in order to keep cost of qualifying bifacial modules reasonable. Instead, Gate No. 2 is evaluated only at the more stringent condition, BNPI, where possible series resistance and other fill factor losses induced by stress are expected to be largest. By not requiring STC measurement or re-evaluation of the bifaciality coefficients for the final Gate No. 2 measurement, time-consuming (expensive) steps of re-calibration simulators at multiple intensities, only to obtain a less stringent test, is avoided. Requirements for measurement intensities and evaluation of bifaciality coefficients requirements are stated in IEC 61215-1:2021, 7.2.2 and 7.2.3, and in IEC 61215-2:2021, 4.6.3 "Measuring at STC (MQT 06.1)".

For several tests, stress levels are increased from values based on one-sun front side illumination, in order to account for potentially higher currents during bifacial module operation with backside illumination.

- The test current is increased for the bypass diode thermal test MQT 18.1. For bifacial modules, MQT 18.1 specifies 1,25 times the module short-circuit current at the elevated irradiance BSI. Use of this higher current is required in IEC 61215-2:2021,4.18.1.4b).
- The test current is also increased in the same manner for the bypass diode functionality test MQT 18.2, as specified in IEC 61215-2:2021,4.18.2.3.2 b).

- In MQT 11 the technology-specific current to be applied during thermal cycling is larger for bifacial modules. IEC 61215-1-1:2021 specifies that the technology specific current which needs to be applied according to test MQT 11 of IEC 61215-2:2021, shall be equal to the peak power current at the elevated irradiance BSI.
- In MQT 09, determination of the cell shading percent and the prolonged exposure are performed at the elevated irradiance BSI. If double-side illumination is used to produce BSI, both the back and the front of the cell are shaded in the same way. During cell selection, any cell that is permanently shaded by a module feature (such as the junction box) is added to the list of selected cells.

### A.3 Use of representative samples

At present, there are products intended to be qualified via IEC 61215, that are much larger (e.g. 6 m in one dimension) than typical test equipment. Requiring a test lab to obtain custom test equipment for one product is prohibitively expensive and would create an unfair barrier to qualification. Thus, representative samples may be used for applying stress and evaluating Gate No. 2 on very large modules. A representative sample is one that includes all the components of the module, except some repeated parts, and is therefore smaller than the actual product. A full-sized sample is still required for nameplate verification (Gate No. 1).

A representative sample may be utilized if a module is "very large," as defined in IEC 61215-1:2021. A "very large" module is taken to be anything that will not fit on the largest commercially-available AAA simulator, or in the necessary environmental chambers. The largest commercially-available AAA simulators seldom exceed dimensions of 2,6 m × 2,1 m. A survey of test labs by project team members showed that environmental chamber sizes currently impose a size limit for IEC 61215 qualification in various test labs ranging from 2,2 m to 2,4 m in module length, and 1,2 to 1,9 m in module width. The project team decided that defining a very large module as 2,2 m × 1,5 m is a reasonable compromise between not providing a barrier to certification for large products, but encouraging certification on full-size products when possible. By this definition, a module is considered very large if it exceeds 2,2 m in any dimension, or exceeds 1,5 m in both dimensions.

Limits are placed on how much one may reduce the dimensions of a very large module in making representative modules for qualification testing. The reduced dimension(s) shall be no less than one half the dimensions that define a very large module. In other words, when reducing the shorter dimension, the representative sample shall be at least 0,75 m wide. In reducing the longer dimension, the representative sample shall be at least 1,1 m long. Thus, a manufacturer is not allowed to use, for example, a one-cell mini-module for qualification testing. The use and dimensions of representative samples shall be noted in the test report.

If representative samples are utilized in Sequence E, then one extra module, full-sized, is required, and shall be subjected only to MQT 16 (the static load test) and the requirements therein. The extra module is required because mechanical load on a representative sample is not the same as doing it on a full-size module. (To give an extreme example, a 10 m × 10 m × 5 mm glass pane may collapse under its own weight, whereas a 1 m × 1 m × 5 mm glass pane may resist the 2 400 Pa loading.) However, a general way to convert load requirements from one sample size to the next, for all product designs, does not exist at the time of publication. Also, because of space limitations in the damp heat chamber, the full-size module cannot be required to undergo the entire sequence E. Thus, as a compromise, an extra full-size module in sequence E to supplement the representative sample. The full-size module will be evaluated for structural and safety failures (e.g. broken glass) via the visual inspection (MQT 01) that is embedded in MQT 16. If a design is susceptible to MQT 16 failures that involve DH (for example, a glue that debonds after DH), such effects are best detected using the representative sample.

If there are MLT failures that involve DH (for example, a glue that is not strong after DH), such effects will be captured by the test on the representative sample.

The project team considered whether more thermal cycles should be required when MQT 11 is performed on a representative sample. It was considered that thermomechanical fatigue tends to increase with sample size, and therefore extra thermal cycles might be needed to qualify a full-size product while stressing a smaller representative sample. However, finite element modelling concluded that the cell size, not the module size, is the critical dimension for thermomechanical fatigue, and thus extra thermal cycles are not warranted.

#### **A.4 Addition of dynamic mechanical load test**

A Dynamic Mechanical Load (DML) test has been added in the IEC 61215 new edition and is performed according to IEC TS 62782. The DML test was developed to evaluate the potential for cell breakage within PV modules[8]. The goal was to find a load that would break cells that were already damaged prior to the stress, but would not break intact cells during the stress. During experiments, a load level of 1 000 Pa was selected. Effect on the cells appeared to saturate at 1 000 cycles. These results formed the basis for the stress levels utilized in IEC TS 62782 and the IEC 61215 new edition. DML has subsequently been the subject of other studies.[9], [10], [11] The DML test is intended to detect cell damage that is inherent in processing (such as a tabber that applies too much pressure and cracks cells during module assembly). The DML test is not intended to introduce new cracks into the cells, nor to measure susceptibility of the module to mishandling, abuse, or extreme weather.

Several publications (e.g. [12], [13]) have noted that cracking cells in a module, then applying either DML or thermal cycles, can lead to power loss. However, there are several reasons to be cautious when considering applying DML or thermal cycling after mechanical stress for this qualification standard:

- Not all modules will experience extreme weather or mishandling. Qualification testing that tests for performance retention under these circumstances may lead to costly overdesign.
- There is not yet documented field correlation to determine over what time period power loss from mechanically-cracked cells occurs. Early studies how long it takes cracks to open up, and therefore (even roughly) what time period is relevant for the sequence: hail test + DML or TC. Some published studies are underway, but haven't seen cracks further affect power in the first 1 to 2 years. [14], [15]
- For people who just want to know relative performance without requiring relationship to field performance, static load + DML is in IEC TS 63209-1 for relative comparison.
- It is recommended to first develop and gain experience with a TS related to hail-resistance, module handling, and related performance losses. Such a document should consider that thermal cycles might be more effective than DML.

#### **A.5 Addition of test for potential induced degradation**

Potential induced degradation (PID) has been observed to cause power output degradation in some fielded modules. Examples of such reports can be found in the literature.[16], [17], [18], [19], [20] Thus, an accelerated test to screen for PID susceptibility has been added in edition 2 of the IEC 61215 series, as MQT 21.

The PID test, MQT 21, is performed in parallel with other tests, in a new Sequence F. Sequence F requires two modules per installation polarity allowed by the manufacturer. If only one installation polarity is allowed, only two modules receive PID stress. However, all four modules are subjected to Gate No. 1 verification, in order to keep Gate No. 1 statistics independent of the number of allowed installation polarities.

The test procedure for MQT 21 is based on the previously published IEC TS 62804-1. The 85 °C / 85 % RH / 96 h stress ("85/85/96") stress utilized in IEC 61215 edition 2 is one of three stress level options in IEC TS 62804-1. Numerous accelerated test studies preceded the development of IEC TS 62804-1. PID has been studied to the extent that reviews of PID, including experimental dependencies, derived acceleration, and underlying mechanisms, can be found in the literature.[21], [22] Literature reports vary regarding acceleration factors. Equivalent outdoor exposure for the 85/85/96 stress utilized in IEC 61215 edition 2 has been estimated by different groups between 2 to 20 years,[23], [24], [25], [26], [27] for the effect of a humid climate (e.g. Florida, USA) on a crystalline Si module. The differences in the literature reports may reflect a need for utilization of different physical models in some studies, experimental uncertainty, and different behavior among the products tested.

All products (modules based on crystalline Si cells, or thin film cells) are subjected to the same stress conditions when executing MQT 21. The same stress conditions are applied even though it is likely that acceleration factors differ from one product to the next, particularly for thin film modules, where the underlying physical mechanism for PID is different than that in c-Si modules. It is estimated that the acceleration factors for thin film modules are substantially smaller than that of typical c-Si modules.[28], [29], [30] The methodology of defining stress levels that are empirically observed to separate failed versus successful fielded products, then applying these conditions to all modules, is rooted in the JPL block buy study,[31] which formed the basis for several of the IEC 61215 series stress tests. A few sentences explicitly stating the methodology of the IEC 61215 series (constant stress conditions across products) were added to the scope.

The 85 °C / 85 % RH / 96 h level is probably more stressful (in terms of years of equivalent exposure) than some other MQT's, for c-Si in most use environments. However, this relatively harsh condition was selected because:

- Data show thin film modules need a higher accelerated stress level than Si modules to reproduce early-life PID failures.
- Prior to the inclusion of a PID test in IEC 61215, several major module manufacturers had already selected the 85 °C / 85 % RH / 96 h stress level for internal qualification programs.
- Use of a light soak may lead to some power recovery, therefore justifying increasing the stress level.
- Increased use of modules in potentially harsh PID-prone environments, such as very rainy climates, may warrant a harsher test.

The way in which modules are mounted has been observed to affect PID.[32] [33] Thus, during the chamber test in IEC 61215 (and IEC TS 62804-1), on request by the manufacturer, modules might be mounted as described in the installation manual during testing, if the manufacturer states that PID resistance is achieved via mounting method.

PID stress on CIGS may be applied with a modest forward voltage bias applied across the internal circuit. These are the same conditions approved for the damp heat test (MQT 13) in IEC 61215-1-4:2021. The voltage bias prevents effects that do not occur when stress is applied under field-representative illumination.

A wet leakage current test (MQT 15) is part of the final measurements within MQT 21. This wet leakage current test is to be performed within 8 hours of the end of the PID stress, as in IEC TS 62804-1. The inclusion of the test, with a time limit, is motivated by the increase in leakage current seen in some modules during in-situ monitoring, and may have a time scale for reversibility that is similar to the PID.

A final stabilization, MQT 19.2, is performed prior to gate 2 on all modules that have been subjected to PID stress. The conditions for this final stabilization are described in the technology-specific parts (IEC 61215-1-x).

For crystalline Si modules, the final stabilization is a short light soak (2,0 kWh/m<sup>2</sup>) meant to reverse the effects of PID-polarization, which results from the movement of charge within the module,[34] as opposed to PID-shunting (PID-s), which results from movement of Na within the module, a slower process. Tests on some modules show that PID-polarization (PID-p) does not occur when PID stress is applied with field-representative illumination,[35] and thus should not be allowed to cause design qualification failure when administering a dark PID stress test. UV has been shown to be important in reversing PID-p.[36] Thus, the class CCC solar listed as required apparatus in MQT 19.2 shall fulfill the class C spectral requirements over at least the short-wavelength portion of the *extended* wavelength range described in IEC 60904-9, for stabilizations performed after PID testing. For bifacial modules, light is applied to the rear side during this stabilization.[37] Since a small amount of PID-s may reverse during a short light soak,[38] the light soak is applied to the front of monofacial modules, to obtain a consistent comparison of test results across module types.

For thin-film modules, the final stabilization is included to put metastabilities into the light-soaked state and obtain an accurate Gate No. 2 performance measurement. Thus, the thin-film light soak is performed in nearly the same manner as other thin-film final stabilizations (MQT 19.2). One additional requirement exists for final stabilization of thin-film modules after PID stress: Once the stabilization criterion is met, the light soak shall be terminated within two irradiation intervals (as defined in the technology-specific parts of MQT 19). This time limit is included to prevent attempts to reverse Na migration with extremely long light soaks that are many times that needed to account for metastability.

After the completion of MQT 21, module storage conditions between subsequent tests are controlled. Between these test steps, the modules are to be maintained indoors, in the dark, and at temperatures 25 °C or below. No more than 48 h elapse between the end of MQT 21 and the beginning of MQT 19.2. There is also time limit between MQT 19.2 and MQT 06.1: It is either 48 h or the time limit specified in the technology-specific stabilization procedure, whichever is shorter. These controls are intended to prevent attempts to reverse Na migration before Gate No. 2 via anomalous storage time and conditions.

## A.6 Simulator requirements

### A.6.1 General

Edition 2 revises both the spectral and uniformity requirements for simulators. (Notation for simulator classifications are defined according to IEC 60904-9. The AM1.5 spectral match is denoted by the first letter of the three-letter simulator classification. For example, a CBA simulator is categorized with a type C spectral match, a type B spatial uniformity, and a type A temporal stability.) The revision applies to simulator requirements in MQT 02 (maximum power determination), MQT 6.1 (performance at STC), and MQT 07 (performance at low irradiance).

IEC 61215-2:2016 allowed three options for simulators during the measurement listed above:

- a) a class BBA or better simulator plus a reference device of the same size and cell technology as the test sample,
- b) a BBA or better simulator, plus the spectral responsivity of the module, plus the spectral distribution of the solar simulator, and a data correction according to IEC 60904-7, or
- c) a AAA simulator. Several changes have been made to these requirements:
  - Type A spatial uniformity is required.
  - A simulator with type C or better spectral class may be utilized.
  - There are more possibilities for how one obtains data to use in a spectral mismatch correction (IEC 60904-7). The spectral response data may be taken by any test lab that is accredited for that measurement. The sample used to obtain the spectral response data may be the test module or may be a reference cell made with the same bill of materials as the test module.

- It is specifically stated that the component of uncertainty due to spectral mismatch shall be included  $m_1$ , the uncertainty used in evaluating Gate No. 1. Maximum allowable values for  $m_1$  are specified in the technology-specific parts.
- Use of either spectral mismatch correction or a matched reference module (or cell) is required.

The procedures in MQT 02 and MQT 6.1 are based on the most accurate measurement protocols that are practical with current technology. This high level of accuracy is appropriate for the nameplate verification and design qualification of IEC 61215. However, other types of documents refer to IEC 61215 maximum power determination. Such documents include warranties, quality assurance documents, and extended stress tests. A note has been included to remind users that less stringent requirements may be appropriate for non-IEC 61215 applications. The note reads: "MQT 02 measurement procedures are intended for minimal uncertainty, as performed by an accredited testing laboratory. Lesser requirements, such as use of CAB class simulators, may be appropriate for other applications, such as quality control in the factory. Applications that only require repeatability, such as comparing module performance before and after an extended stress, may wish to relax spectral mismatch correction requirements."

### A.6.2 Rationale for changes to spectral requirements

Revisions to the spectral requirements were made to limit possible spectral mismatch in a systematic manner, while still allowing test labs several practical choices as to how to achieve an acceptably accurate measurement.

The previous text of IEC 61215 allowed using a solar simulator with Class A spectral match for power rating measurements without spectral correction. This option was originally intended to provide one way to achieve a low spectral mismatch. However, more recent work has shown that requiring a Class A spectrum is neither necessary nor sufficient for low spectral mismatch.[40], [41], [42], [43] In other words, using a Class A spectrum does not guarantee a smaller spectral mismatch error than using a Class B or Class C spectrum. In some cases, spectral mismatch errors can even be larger for a Class A spectrum compared to Class C.[44], [45] The actual spectral mismatch error depends on the procedures, reference samples, and test samples used.

Therefore, the revised text of IEC 61215 has relaxed the spectral requirement to Class C, but includes wording regarding procedures to reduce spectral mismatch errors. The wording is basically the same as IEC 60904-7: either the solar simulator irradiance is calibrated using a reference sample having spectral response that is similar to the device under test, or a full calculation of the spectral mismatch error is made per IEC 60904-7.

Support for this position can be found in several literature studies. Excerpts from some of these studies are reproduced here (with bold type added for emphasis):

- ...**classification** of a solar simulator **does not provide any information about measurement errors**...related to photovoltaic performance measurements...such errors are dependent on the actual measurement devices and procedures used.[40]
- ...**spectral class** of a solar simulator **is not necessarily an indicator for the precision of measurement**. With appropriate reference devices and measurement procedures also class C spectral match yields a good comparability for c-Si PV modules.[41]
- ...the simulator with **the best spectral match (A+) need not yield the best MMF** [spectral mismatch factor].[42]
- **No benchmarking of solar simulators is therefore possible based only on the spectral match** information.[42]

...not always the spectrum of higher class would lead to the lower [spectral] mismatch factor. [43]

It is specifically stated that the component of uncertainty due to spectral mismatch shall be included in  $m_1$ , and maximum allowable values for  $m_1$  are specified in the technology-specific parts. As stated in IEC 61215-1:2021,  $m_1$  is to be calculated based either on measured spectral response or the worst-case possibility for a given technology type. Worst case possibilities can be evaluated from a combination of published data and the lab's database of measurements.

This approach provides several options for test labs unable to invest in a module spectral response system, while keeping uncertainty within reasonable bounds via limits on  $m_1$ . A lab may choose reference modules such that no spectral mismatch correction is needed. Size requirements on the matched reference module have been removed. The lab may also measure cell spectral response, where a reference cell with the same bill of materials as the test module is available. The lab may also obtain spectral response data on such a reference cell, or on the test module, from another accredited test lab.

### A.6.3 Rationale for changes to uniformity requirements

The change in simulator uniformity requirements from B to A was made based on an analysis of uncertainty in power rating which includes contributions from several factors including irradiance nonuniformity, current mismatch between cells within a module, spectral mismatch, module temperature, contact resistance, and the procedure(s) used to calibrate simulator irradiance. Uncertainty values listed below (in Table A.1) are from Figure 7 of the referenced work,[46] using a coverage factor  $k = 2$ .

**Table A.1 – Published uncertainty values as a function of simulator uniformity class**

Irradiance nonuniformity	Approximate power rating uncertainty due to all effects, when simulator irradiance is calibrated using a reference module's...	
	...maximum power	...short-circuit current
2 % (class A limit)	2,6 %	3,2 %
5 % (class B limit)	3,2 %	6,2 %

For modules with higher fill factor, such as new high-efficiency Si modules, effects of irradiance nonuniformity may be greater, since higher fill factor implies that a change in current changes the module power output more sharply. Based on this information, the project team decided the uncertainties for 5 % irradiance nonuniformity would be too large for some measurements, such as the maximum power determination of Gate No. 1.

Polls of working group 2 members representing test labs were performed during a working group 2 meeting and during a IEC 61215 new edition project team meeting. All such members in attendance indicated that they already use simulators with class A uniformity.

The new edition includes one exception to the new uniformity requirement. For evaluation of Gate No. 2, "very large" modules (as defined in IEC 61215-1:2021, 3.8) may be measured with a class B uniformity simulator. It is recognized that class A uniformity simulators larger than 2,2 m × 1,5 m are rarely commercially available at present, and thus imposing use of a class A uniformity simulator on a very large module creates an unfair barrier to qualification. At present, only a small fraction of the market is expected to utilize the exemption for very large modules. In future years, as module sizes and availability of very large simulators evolves, the size definition for a very large module should be adjusted accordingly.

## A.7 References to retest guidelines

IEC 61215 Edition 2 requires the use of IEC TS 62915 to determine if a retesting is needed. This requirement is stated as, "Retesting shall be performed according to IEC TS 62915." To avoid any future contradiction between IEC 61215-1 and IEC TS 62915, all further description of conditions that might generate the need for retesting have been removed from IEC 61215-1:2021.

## A.8 Weight on junction boxes

Poor adhesion of the junction box to the module has been observed in both fielded modules and accelerated tests.[47], [48], [49], [50] Thus, in edition 2, the thermal cycling test (MQT 11) is modified to include a 5N weight hanging from the junction box.

## A.9 Correction to monolithically-integrated hot-spot endurance test

IEC 61215-2 Edition 2 revises a portion of the monolithically-integrated (MLI) hot spot endurance test to correct errors in IEC 61215-2:2016. In IEC 61215-2:2016, incompatible procedures for testing wafer-based vs. MLI modules were inadvertently mixed in some of the MLI sections. Minor revisions were also made in places where the procedure was unclear or impossible to perform.

The hot-spot endurance test (MQT 09) is designed to determine the ability of the module to withstand hot-spot heating effects, such as those that could be caused by mismatched cells or shadowing. While there are test variations for different module types and circuitry, the test has certain commonalities across all module types:

- A worst-case shading condition is determined.
- This condition causes a current near  $I_{mp}$  (for unshaded conditions) to flow through the short-circuited module.
- The module is exposed to elevated temperature (50 °C) and the worst-case shading condition for at least 1 h.
- After stress, the module shall have no visual defects, a functional  $I-V$  curve, insulation resistance meeting the requirements of MQT 03, and wet leakage current meeting the requirements of MQT 15.

NOTE 1 Tests are derived from earlier editions of IEC 61215-2 and IEC 61646.

Despite these commonalities, some differences in test procedure between modules containing singulated or wafer-based cells and those containing MLI cells are necessary for the following reasons:

- a) It is difficult to shade a single MLI cell reproducibly, since cells have high aspect ratio (e.g. 0,5 cm × 1 m dimensions), and there are reflections inside the glass that make shading around edges not sharp. The wafer-based cell procedures involve shading a single cell.
- b) Some MLI cells may experience a decrease in shunt resistance when shaded.[51], [52] For the wafer-based modules, shading of individual cells is performed as a way to select cells that have certain pre-existing shunt resistances (low or high). For MLI cells, the act of shading individual cells is not likely to screen the cells, but rather to alter them. Thus, it is logical to apply shading stress to MLI cells, but not in an attempt to select which cells to test, as in the wafer-based procedure.

- c) Thin film cells often have a different nature of reverse bias characteristics than do Si cells. Thin-film reverse bias characteristics are in many cases not linear, [53], [54], [55] or are only linear over a voltage range that is too small for a comparison of shunt resistances according to the method of IEC 61215-2:2016, Figure 4. Thus, even if items a) and b) on this list could be overcome, it is still unlikely that one could use the method of Figure 4 to select cells of highest and lowest shunt resistance.
- d) The Si cell method assumes that shading one cell can reduce the current generated by the short-circuited module to  $I_{mp}$  (measured under full irradiance) or an even lower current. However, this reduction may not be achievable by fully shading one MLI cell. The difficulty occurs because there are typically many more MLI cells in a module, and the cells may be more conductive at a lower reverse bias compared to Si cells.

Because of the differences listed above, the thin film hot-spot test has relied upon shading blocks of cells, and finding how many cells shall be shaded to achieve the current reduction noted in the above list as d).

NOTE 2 This method of shading blocks of cells was utilized in IEC 61646:2008 (10.9) and IEC 61215-2:2016 (4.9.5.3.2, 4.9.5.3.4, and 4.9.5.3.5).

However, some errors were included in the MLI portion of IEC 61215-2:2016 MQT 09:

- 4.9.5.3.3 (MLI, SP case) erroneously called for the wafer-based single-cell shading method. (The single-cell shading method cannot be performed on MLI modules for reasons a) to d) listed above.)
- Three different MLI sections describing how to do the hot spot test on MLI SP modules were included in edition 1, but the three different SP cases actually require the same procedure. These three subclauses from edition 1 are 4.9.5.3.3 "Case SP", 4.9.5.3.4 "Case SP with inaccessible cell circuit and internal reverse bias protection", and 4.9.5.3.5 "Case SP with inaccessible cell circuit and no reverse bias protection". In all cases, the MLI cell circuit is treated as inaccessible, so there should be no distinction between 4.9.5.3.3 and 4.9.5.3.5. Furthermore, in MLI products, a single external bypass diode is utilized. Lateral conduction in the high aspect ratio MLI devices is limited by the conductivity of the transparent conducting thin film, so MLI products do not use internal bypass diodes. The test procedure is performed with the module short-circuited, making the external bypass diode irrelevant to the test procedure. (It turns on only when the module is in reverse bias.) Thus, there is no need to distinguish between cases 4.9.5.3.3 and 4.9.5.3.4.

These errors are corrected in the new edition of IEC 61215-2:2021. Several changes were made to do so:

- 4.9.5.3.3, 4.9.5.3.4, and 4.9.5.3.5 from IEC 61215-2:2016 are combined into a single "Case SP" section. Thus, in the new edition of IEC 61215-2:2021, there are three cases for MLI modules in MQT 09: S, SP, and PS. These are the same three cases formerly utilized in IEC 61646:2008.
- The single-cell shading method used for the wafer-based modules is not utilized for any case in MLI modules.
- In some places, minor changes to wording were made to clarify, but not modify, the test procedure.

Minor revisions were also made in places where the MLI hot-spot endurance procedure was unclear or impossible to perform:

- The symbol "N" rather than "P" is used to denote the number of parallel strings to avoid confusion with power, which is also denoted by "P."
- The acceptable range for currents is now based on  $I_{mp}$ , not  $P_{mp}$ . These two ways of specifying the range yield nearly the same results, and specifying the current is much clearer. IEC 61215-2:2016 was not explicit regarding how to determine the range in translating from  $P$  to  $I$ . (For example, is the tester allowed to interpolate between points using a previously-measured  $I-V$  curve?)

- The acceptable window for current during extended stress is widened by changing the lower limit from 99 % to 95 % of the maximum. If the simulator irradiance can change by  $\pm 2$  % over the test (as is explicitly stated), it is not reasonable to ask to keep the current within a 1 % window. For some modules, it was observed that shading even one cell dropped the current below the specified range.
- A minimum mask size of two cell widths is specified. For reason a) described earlier in this section, test reproducibility suffers if the mask size is reduced further.
- When moving the mask across the module, a minimum number of steps is specified.
- The acceptable irradiance range for cell selection with an optional simulator is modified from "800 to 1 000 W/m<sup>2</sup>" previously to "800 to 1 100 W/m<sup>2</sup>" in the new edition. With this change, any irradiance produced by the required simulator for 1 h stress (at 1 000  $\pm$  100 W/m<sup>2</sup>) is also acceptable for cell selection procedures.
- Other small clarifying changes to the wording have been made.

### A.10 Number of modules in sequence

Sequence A, as defined in either IEC 61215-1:2016 or IEC 61215-1:2021, is comprised of MQT 07 (performance at low irradiance) and MQT 04 (measurement of temperature coefficients). Two changes were made to sequence A to allow it to be performed more efficiently, but without losing valuable information.

First, the number of modules required for sequence A has been reduced from three in IEC 61215-1:2016, to one in IEC 61215-1:2021. A study of temperature coefficients showed that for modules of a given cell technology, one cannot distinguish between the temperature coefficients of different products. For sample sets of three to five modules of each product type, the variability of temperature coefficients within each product type is as large as the difference between the products. The variability may be due either due to measurement uncertainty or product inconsistency. An example of data from this study is shown in Figure A.1. Boxes represent the variability within each product type, and the error bars show the measurement uncertainty. As the purpose of the IEC 61215 series is design qualification, not forecasting energy production, it is not defensible to require the measuring of many modules in sequence A in an attempt to reduce the uncertainty on the derived quantities. Furthermore, decreasing the number of modules in sequence A by two does not worsen the statistics on modules passing Gate No. 1, since four modules have been added to sequence F.

Second, it is explicitly stated in edition 2 that the measurements of sequence A may be performed in any order, or may be performed on two separate modules, if desired.

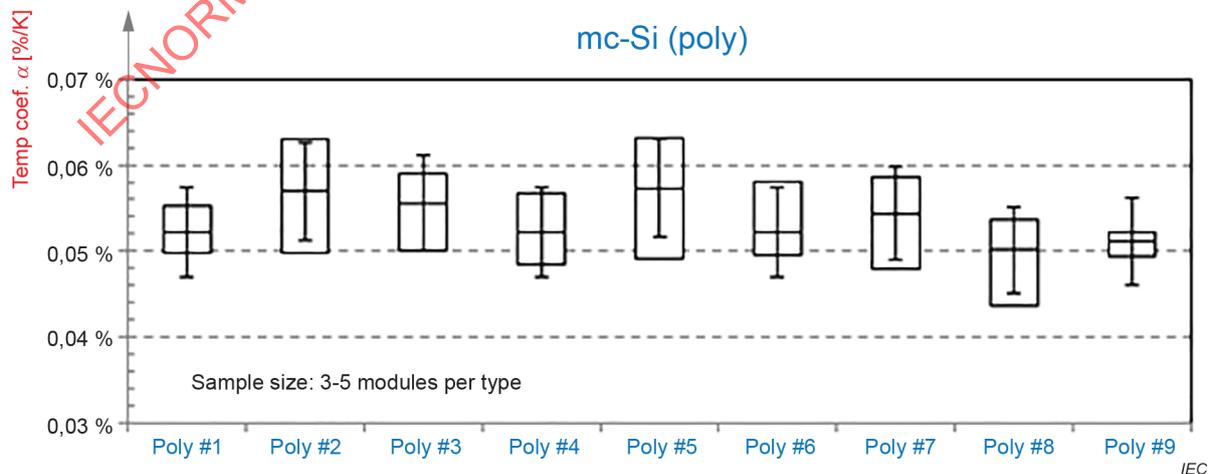


Figure A.1 – Derived temperature coefficients ( $\alpha$ ) for nine different mc-Si products types

## A.11 Removal of nominal module operating temperature (NMOT)

Edition 1 of the IEC 61215 series (published in 2016) was the first time that NMOT has been required for PV module design qualification. Earlier versions of IEC 61215 and similar standards required only nominal operating cell temperature (NOCT). In 2017, a number of test laboratories around the world reported that the strict data filtering required by the NMOT procedure was causing NMOT measurements to take more than 6 months in some locations, an unacceptable time period for IEC 61215 qualification. The NMOT procedure is described in IEC 61853-2, which is referenced by IEC 61215-2:2021.

To rectify the unacceptable measurement time, three alternatives were proposed:

- a) Put exceptions to the NMOT data filtering (as specified in IEC 61853-2) into the IEC 61215 test, making the test completion time shorter when performed as a part of IEC 61215.
- b) Amend IEC 61853-2 to allow the test to be completed more quickly.
- c) Remove the NMOT test from IEC 61215 edition 2.

In choosing between these alternatives, the project team considered the following information:

- It is undesirable to create two different versions of the same test by putting many exceptions in the referencing standard. Upkeep on the test procedure shall be performed in both locations, and the two tests yield information that is named the same but is not equivalent.
- The purpose of the IEC 61853 series is to "characterize the modules at a wide range of temperatures, irradiances, angles of incidence, and spectra," in order to "accurately predict the energy production of the modules under various field conditions," as taken from the IEC 61853-2:2016 introduction. The IEC 61853 series defines a methodology for energy prediction.
- The goal of IEC 61215 is module design qualification, i.e. whether a module of a particular design is likely to last in the field.
- Thus, NMOT does not relate to the objective of IEC 61215.
- NMOT tests have an uncertainty (typically  $\pm 4$  °C) that is larger than the actual operating temperature difference between most module types.
- Datasheet NMOT and NOCT values are not heavily used. It is more common to use thermal model coefficients (such as those provided with PVsyst, for example) to account for thermal effects in energy generation.
- To make NMOT a useful measurement, it may be required to increase – not decrease – data collection time, or to perform data collection in individualized side-by-side tests designed for comparing a small set of different module types.
- Thus limiting the data collection time in IEC 61853-2 in order to keep IEC 61215 qualification time reasonable may prevent the NMOT test from ever yielding meaningful data.

The above points led the project team to remove the NMOT test (MQT 05) and the associated "performance at NMOT" test (MQT 06.2).

### A.12 Very low currents during thin-film tests

Edition 2 contains revisions to mitigate the difficulty of controlling very low currents in thin film modules during some tests. In two tests, a fraction of the module's STC peak power current ( $I_{mp}$ ) is applied during a test. This application of current occurs during the humidity-freeze test (MQT 12), and during the thermal cycling test (MQT 11). In MQT 12, 0,5 %  $I_{mp}$  is applied, as specified in IEC 61215-2. In MQT 11, the applied current is specified in the technology-specific parts. For CdTe, a-Si, or CIGS, the applied currents are 0,1  $I_{mp}$ , as specified in IEC 61215-1-2:2021, IEC 61215-1-3:2021, and IEC 61215-1-4:2021. For smaller cells, these specified currents may be so small that they are impractical to monitor and control. Thus, the wording in each of these cases has been revised to call for the previously-designated fraction of  $I_{mp}$ , or 100 mA, whichever is larger.

### A.13 Limit bypass diode testing to three diodes

Edition 2 contains a revision to keep the bypass diode testing procedure practical, even in some newer module designs that have dozens of bypass diodes embedded in the laminate. The edition 1 bypass diode test (MQT 18) required repetition of the test procedure on all bypass diodes, and electrical access to each diode. If a standard production module did not allow electrical access to each diode, the manufacture needed to provide a special module with electrical access to the diodes to complete the test. The procedure was written to suit modules having a few diodes in a junction box. All diodes were tested, since the positioning of the diode within the junction box (e.g. edge or middle) is likely to be important in determining the thermal environment when the diodes are flowing current. However, for newer designs containing dozens of bypass diodes embedded in the module package, making a special sample that allows access to each diode is no longer practical. Furthermore, the individual testing of each diode is very-time consuming, without yielding useful information beyond what one obtains from testing a few diodes. Thus, in edition 2, for modules containing four or more bypass diodes, MQT 18 is only performed on three of them. The three diodes are selected for test based on their location, which may be important to the thermal environment. Selecting the diodes for test based on location has precedent in IEC 62108:2016, 10.11 for CPV module and assembly design qualification.

### A.14 Revert the insulation test to 2005 version

Changes were made to the insulation test (MQT 03) from the IEC 61215:2005 to IEC 61215-2:2016. These changes involved how foil covering is used during the test, as summarized in Table A.2.

**Table A.2 – Summary of foil placement during insulation test in three different versions.**

Module type	IEC 61215:2005 Foil placement	IEC 61215-2:2016 Foil placement	IEC 61215-2:2021 Foil placement
Frameless	Edges and back	Edges, plus all polymeric surfaces	Edges
Framed with poor conductor	Edges and back	Edges, plus all polymeric surfaces	Edges
Framed	None	All polymeric surfaces	None

A major concern associated with the IEC 61215-2:2016 foil configuration is the inability to detect surface tracking when all polymeric surfaces are covered, since one of the test requirements is "no dielectric breakdown or surface tracking." It is also undesirable that the capacitance introduced by covering a large area disables the test equipment's arc discharge detection. As arc discharge is a precursor to dielectric breakdown, useful information is lost. It is also possible that various test laboratories may approach covering the junction box with foil differently, thus causing variability in the test. Edition 2 therefore reverts to the 2005 version

of the test, and also removes the 2005 requirement of covering the entire back of a frameless module with foil.

The applied levels in MQT 03 have been harmonized with IEC 61730. Thus, a module that is undergoing simultaneous safety and design qualification need not have the test performed twice under slightly different conditions. Furthermore, a module cannot pass design qualification if it would fail an insulation test necessary for safety.

### **A.15 Bending test**

Edition 2 adds a bending test (MQT 22) for modules that are described as "flexible" on the manufacturer label or datasheet. The modules are bent around a cylinder to the minimum radius specified on the label or datasheet.

### **A.16 Stabilization option for boron oxygen LID (MQT 19.3)**

Boron-oxygen light-induced degradation (BO-LID) is a well-known effect in Si.[61] Recently, published studies have indicated that temporary changes in the states of BO-LID defects may impact IEC 61215 qualification tests. Data suggest that thermal cycling may cause a transition from the degraded state to the regenerated state,[62] causing an apparent increase in performance after thermal cycling for modules shipped in a with BO-LID defects in the initial ("A") or degraded ("B") state. Furthermore, damp heat may cause modules shipped in the stabilized state ("C") to undergo an apparent decrease in performance that is not field-representative.[62],[63] Damp heat may also cause degraded BO-LID defects to transition from B to A for modules that are not stabilized, causing an apparent performance increase.

The project team unanimously agreed that the IEC 61215 series should deal with stabilization of modules with BO-LID defects more comprehensively than the previous version. However, before making large changes, the project team would like to complete an experimental study of each option for stabilization suggested by team members. Thus, this edition of the IEC 61215 series only addresses the most urgent case: modules that may fail a test because of BO-LID changes that are not field-representative. To address this case, BO-LID stabilization (MQT 19.3) is introduced in IEC 61215-2:2021, following conditions recommended in the literature.[63] Performing this stabilization after damp heat testing is required for Si modules in IEC 61215-1-1:2021.

The important, but less urgent, cases of modules that may exhibit an apparent performance increase due to BO-LID effects during stress tests will be addressed in a future amendment.

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# INTERNATIONAL STANDARD

## NORME INTERNATIONALE



**Terrestrial photovoltaic (PV) modules – Design qualification and type approval –  
Part 1: Test requirements**

**Modules photovoltaïques (PV) pour applications terrestres – Qualification de la  
conception et homologation –  
Partie 1: Exigences d'essai**

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# INTERNATIONAL ELECTROTECHNICAL COMMISSION

## TERRESTRIAL PHOTOVOLTAIC (PV) MODULES – DESIGN QUALIFICATION AND TYPE APPROVAL –

### Part 1: Test requirements

#### FOREWORD

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International Standard IEC 61215-1 has been prepared by IEC technical committee 82: Solar photovoltaic energy systems.

This second edition of IEC 61215-1 cancels and replaces the first edition of IEC 61215-1, published in 2016; it constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) Addition of a test taken from IEC TS 62782.
- b) Addition of a test taken from IEC TS 62804-1.
- c) Addition of test methods required for flexible modules. This includes the addition of the bending test (MQT 22).
- d) Addition of definitions, references and instructions on how to perform the IEC 61215 design qualification and type approval on bifacial PV modules.

- e) Clarification of the requirements related to power output measurements.
- f) Addition of weights to junction box during 200 thermal cycles.
- g) Requirement that retesting be performed according to IEC TS 62915.
- h) Removal of the nominal module operating test (NMOT), and associated test of performance at NMOT, from the IEC 61215 series.

Informative Annex A explains the background and reasoning behind some of the more substantial changes that were made in the IEC 61215 series in progressing from edition 1 to edition 2.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
82/1828A/FDIS	82/1848/RVD

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

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

A list of all parts in the IEC 61215 series, published under the general title *Terrestrial photovoltaic (PV) modules – Design qualification and type approval*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to the specific document. At this date, the document will be

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

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## INTRODUCTION

Whereas Part 1 of this standards series describes requirements (both in general and specific with respect to device technology), the sub-parts of Part 1 define technology variations and Part 2 defines a set of test procedures necessary for design qualification and type approval. The test procedures described in Part 2 are valid for all device technologies.

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# TERRESTRIAL PHOTOVOLTAIC (PV) MODULES – DESIGN QUALIFICATION AND TYPE APPROVAL –

## Part 1: Test requirements

### 1 Scope

This document lays down requirements for the design qualification of terrestrial photovoltaic modules suitable for long-term operation in open-air climates. The useful service life of modules so qualified will depend on their design, their environment and the conditions under which they are operated. Test results are not construed as a quantitative prediction of module lifetime.

In climates where 98<sup>th</sup> percentile operating temperatures exceed 70 °C, users are recommended to consider testing to higher temperature test conditions as described in IEC TS 63126. Users desiring qualification of PV products with lesser lifetime expectations are recommended to consider testing designed for PV in consumer electronics, as described in IEC TS 63163 (under development). Users wishing to gain confidence that the characteristics tested in IEC 61215 appear consistently in a manufactured product may wish to utilize IEC 62941 regarding quality systems in PV manufacturing.

This document is intended to apply to all terrestrial flat plate module materials such as crystalline silicon module types as well as thin-film modules. It does not apply to systems that are not long-term applications, such as flexible modules installed in awnings or tenting.

This document does not apply to modules used with concentrated sunlight although it may be utilized for low concentrator modules (1 to 3 suns). For low concentration modules, all tests are performed using the irradiance, current, voltage and power levels expected at the design concentration.

This document does not address the particularities of PV modules with integrated electronics. It may however be used as a basis for testing such PV modules.

The objective of this test sequence is to determine the electrical characteristics of the module and to show, as far as possible within reasonable constraints of cost and time, that the module is capable of withstanding prolonged exposure outdoors. Accelerated test conditions are empirically based on those necessary to reproduce selected observed field failures and are applied equally across module types. Acceleration factors may vary with product design, and thus not all degradation mechanisms may manifest. Further general information on accelerated test methods including definitions of terms may be found in IEC 62506.

Some long-term degradation mechanisms can only reasonably be detected via component testing, due to long times required to produce the failure and necessity of stress conditions that are expensive to produce over large areas. Component tests that have reached a sufficient level of maturity to set pass/fail criteria with high confidence are incorporated into the IEC 61215 series via addition to Table 1. In contrast, the tests procedures described in this series, in IEC 61215-2, are performed on modules.

### 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 60269-6, *Low-voltage fuses – Part 6: Supplementary requirements for fuse-links for the protection of solar photovoltaic energy systems*

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 TS 60904-1-2:2019, *Photovoltaic devices – Part 1-2: Measurement of current-voltage characteristics of bifacial photovoltaic (PV) devices*

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

IEC 60904-10, *Photovoltaic devices – Part 10: Methods of linear dependence and linearity measurements*

IEC TS 60904-13, *Photovoltaic devices – Part 13: Electroluminescence of photovoltaic modules*

IEC 61140, *Protection against electric shock – Common aspects for installation and equipment*

IEC 61215-2, *Terrestrial photovoltaic (PV) modules – Design qualification and type approval – Part 2: Test procedures*

IEC 61730-1, *Photovoltaic (PV) module safety qualification – Part 1: Requirements for construction*

IEC 61730-2, *Photovoltaic (PV) module safety qualification – Part 2: Requirements for testing*

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

IEC 61853-1, *Photovoltaic (PV) module performance testing and energy rating – Part 1: Irradiance and temperature performance measurements and power rating*

IEC TS 62782, *Photovoltaic (PV) modules – Cyclic (dynamic) mechanical load testing*

IEC 62790, *Junction boxes for photovoltaic modules – Safety requirements and tests*

IEC TS 62804-1, *Photovoltaic (PV) modules – Test methods for the detection of potential-induced degradation – Part 1: Crystalline silicon*

IEC 62852, *Connectors for DC-application in photovoltaic systems – Safety requirements and tests*

IEC TS 62915, *Photovoltaic (PV) modules – Type approval, design and safety qualification – Retesting*

IEC 62941, *Terrestrial photovoltaic (PV) modules – Quality system for PV module manufacturing*

IEC TS 63163: –<sup>1</sup>*Terrestrial photovoltaic (PV) modules for consumer products – Design qualification and type approval*

ISO/IEC Guide 98-3, *Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

### 3 Terms, definitions and abbreviated terms

For the purposes of this document, the terms and definitions in IEC TS 61836 apply, as well as the following.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

#### 3.1

##### **bins of power classes**

power (typically maximum power) sorting criteria from the PV module manufacturer

#### 3.2

##### **tolerances <on label>**

value range of electrical parameters on the label of the PV module as given by the manufacturer

#### 3.3

##### **MQT**

Module Quality Test

#### 3.4

##### **type approval**

conformity test made on one or more items representative of the production

[SOURCE: IEC 60050-581:2008, 581-21-08 – Type test]

#### 3.5

##### **reproducibility <of measurements>**

closeness of agreement between the results of measurements of the same value of a quantity, when the individual measurements are made under different conditions of measurement:

- principle of measurement,
- method of measurement,
- observer,
- measuring instruments,
- reference standards,
- laboratory,

---

<sup>1</sup> Under preparation. Stage at the time of publication: ADTS.

– under conditions of use of the instruments, different from those customarily used, after intervals of time relatively long compared with the duration of a single measurement. [consistent with the International Vocabulary of Metrology (VIM), 3.7]

Note 1 to entry: The concepts of "principle of measurement" and "method of measurement" are respectively defined in VIM 2.3 and 2.4.

Note 2 to entry: The term "reproducibility" also applies to the instance where only certain of the above conditions are taken into account, provided that these are stated.

Note 3 to entry: It is recommended that laboratories determine their reproducibility according to the formulas and principles in ISO 5725-2.

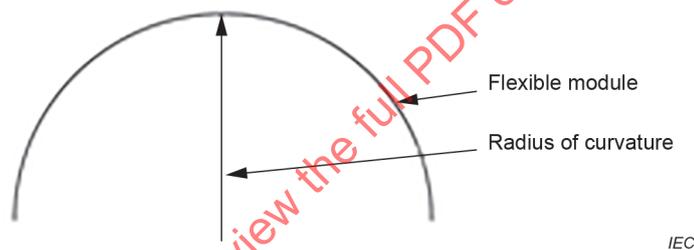
[SOURCE: IEC 60050-311:2001, 311-06-07]

**3.6 flexible module**

PV module that exhibits a radius of curvature of 500 mm or less in at least one direction according to the manufacturer's specification and is capable of bending to conform to a flat or curved surface

Note 1 to entry: A curved module with a rigid shape is not considered a flexible module.

Note 2 to entry: Radius of curvature is defined as shown in Figure 1. During testing, the applied radius of curvature is no smaller than that specified by the manufacturer.



**Figure 1 – Geometry that shows radius of curvature of a flexible module**

**3.7 representative sample**

sample that includes all the components of the module, except some repeated parts

Note 1 to entry: The representative samples shall use all key materials and subassemblies, as detailed in Clause 4.

**3.8 very large module**

module that exceeds the size of standard 2,2 m × 1,5 m commercially-available simulators

Note 1 to entry: A very large module exceeds 2,2 m in length or width, or exceeds 1,5 m in both dimensions. Thus a 3 m × 0,3 m module is considered very large, as is a 2,2 m × 2,2 m module.

Note 2 to entry: Very large modules are exempt from class A simulator spatial irradiance uniformity requirements, as detailed in IEC 61215-2 MQT 02.

Note 3 to entry: During test sequences representative samples may be substituted for very large modules, within the limits described in Clause 4.

Note 4 to entry: In future editions, the size threshold to be considered a very large module will likely increase to larger dimensions.

**3.9 bifacial PV modules**

modules that can convert irradiation received on both the front-side and rear-side into electric energy by means of the photovoltaic effect

### 3.10

#### **bifaciality coefficients**

ratios between the  $I$ - $V$  characteristics of the rear-side and the front-side of a bifacial module each measured under Standard Test Conditions (STC – IEC TS 61836), namely the short-circuit current bifaciality coefficient  $\phi_{ISC}$ , the open-circuit voltage bifaciality coefficient  $\phi_{Voc}$  and the maximum power bifaciality coefficient  $\phi_{Pmax}$

Note 1 to entry: Bifaciality coefficients are fully defined in IEC TS 60904-1-2:2019, 6.2.

### 3.11

#### **bifacial nameplate irradiance**

##### **BNPI**

higher irradiance at which nameplate verification is performed for bifacial modules, corresponding to 1 000 W/m<sup>2</sup> on the module front and 135 W/m<sup>2</sup> on the module rear, applied in any method allowed by IEC TS 60904-1-2

### 3.12

#### **bifacial stress irradiance**

##### **BSI**

higher irradiance at which currents for stress are measured on bifacial modules, corresponding to 1 000 W/m<sup>2</sup> on the module front and 300 W/m<sup>2</sup> on the module rear, applied by any method allowed in IEC TS 60904-1-2,  $I$ - $V$  characteristic at which may be extrapolated from lower irradiances

## 4 Test samples

The PV module samples shall have been manufactured from specified materials and components in accordance with the relevant drawings and process sheets and have been subjected to the manufacturer's normal inspection, quality control and production acceptance procedures. The PV modules shall be complete in every detail and shall be accompanied by the manufacturer's handling, mounting, and connection instructions. When the PV 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 9).

The number of test samples required is derived from the applicable test sequences (see Clause 11).

Special test samples may be required for tests such as the bypass diode test MQT 18 (see IEC 61215-2).

For qualification of multiple bins of power classes within the boundaries given in IEC TS 62915 at least 2 modules each, from the lower end, median and higher end power class shall be used for testing. If median power class does not exist the next higher class shall be used. If qualification of a single power class shall be extended to further bins of power classes within the boundaries given in IEC TS 62915 then at least 2 modules each, from the lower end and higher end power class shall be used for label verification (see Gate No.1 in 7.2.1). If a power class is extended only towards higher (or lower) bins, then modules only from the higher (or lower) bins, respectively, shall be used for verification of rated label values.

Qualification to multiple bins of power classes does not increase the minimum requirement of one control sample used in 7.2.3.

It is advisable to provide additional spare samples meeting the same output power requirements.

If applicable, the test samples shall be used to represent a group or family of products, or variations in the materials, or production processes used to produce the modules. The additional samples required for the test programme are then derived from IEC TS 62915.

For very large modules (as defined in 3.8), representative samples (as defined in 3.7) may be used for all qualification tests given in Clause 11 and IEC 61215-2. During the design and manufacturing of the representative samples, attention should be paid to reach the maximum similarity to the full-size product in all electrical, mechanical, and thermal characteristics related to quality and reliability. The cell, encapsulation methods, interconnects, terminations, clearance and creepage distances around all edges, and distance through solid insulation (relied upon insulation and cemented joints) shall be the same as on the actual full-size products. Limits are placed on how much one may reduce the dimensions of a very large module in making representative samples for qualification testing. The reduced dimension(s) shall be no less than one half the dimensions that define a very large module. In other words, when reducing the shorter dimension, the representative sample shall be at least 0,75 m wide. In reducing the longer dimension, the representative sample shall be at least 1,1 m long. If representative samples are used for any test, the test report shall include a table listing the dimensions of the product being qualified, and for each MQT, the dimensions of the samples tested. The table shall contain the statement, "Smaller samples were used for some tests as noted above. Use of smaller samples may affect test results." For determination of maximum power degradation during testing (7.2.3) on a representative sample,  $P_{\max}(\text{Lab\_GateNo.1})$  refers to the representative sample's initial stabilized measured power output. However, for verification of rated label values (7.2.2) a standard production product shall be measured, either at the test facility or utilizing a test at the manufacturer monitored by the testing entity.

If representative samples are utilized in Sequence E, then one extra module, full-sized, is required, and shall be subjected only to MQT 16 (static mechanical load test) and the requirements therein.

Any representative sample used for MQT 09 (hot-spot endurance test) shall contain the same number of cells per bypass diode (i.e. the same substring size) as the full-size product.

NOTE It is preferable in any test to measure a full-size sample, rather than a representative sample, when equipment size allows.

Prior to beginning the qualification test, care should be taken not to damage the samples in transit. Such care may include adherence to best practices in packing and shipping,<sup>[1]<sup>2</sup></sup> as well as electroluminescence imaging according to IEC TS 60904-13 before and after shipping to make sure cracks have not developed in transit.

For the requirements in the IEC 61215 series, a module shall be considered "bifacial " if the manufacturer claims bifaciality on the nameplate or datasheet, or if the module exhibits a maximum power bifaciality coefficient  $\geq 20\%$ . If a module is to be tested as a monofacial module, the test laboratory shall verify that the module is monofacial by at least one of the following methods:

- a) Information from the manufacturer showing that the rear of the cell is fully metallized;
- b) Spectrally-resolved backsheet transmission data from the module manufacturer; or
- c) Determination of bifaciality coefficient on one sample according to the procedure in IEC TS 60904-1-2.

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<sup>2</sup> Numbers in square brackets refer to the Bibliography.

## 5 Marking and documentation

### 5.1 Name plate

Each module shall include the following clear and indelible markings. Unless otherwise indicated, all the electrical parameters refer to STC:

- a) name, registered trade name or registered trade mark of manufacturer;
- b) type or model number designation;
- c) serial number (unless marked on other part of product);
- d) date and place of manufacture; alternatively serial number allowing to trace the date and place of manufacture;
- e) maximum system voltage;
- f) class of protection against electrical shock (as defined in IEC 61140 and IEC 61730-1);
- g) voltage at open-circuit or  $V_{oc}$  including tolerances. For bifacial modules, open-circuit voltage shall be reported at two irradiance levels. The first required irradiance level is 1 000 W/m<sup>2</sup>. The second required irradiance is BNPI, as defined in 3.11.
- h) current at short-circuit or  $I_{sc}$  including tolerances. For bifacial modules, short-circuit current shall be reported at two irradiance levels, defined in 5.1g).
- i) module maximum power or  $P_{max}$  including binning and tolerances as defined in 3.1 and 3.2. For bifacial modules,  $P_{max}$  shall be reported at the two irradiance levels, defined in 5.1g).
- j) For bifacial modules the following information including tolerances, shall be given on the nameplate: The values for the short-circuit current bifaciality coefficient  $\phi_{Isc}$ , the open-circuit voltage bifaciality coefficient  $\phi_{Voc}$ , and the maximum power bifaciality coefficient  $\phi_{Pmax}$ , measured at STC as defined in IEC TS 60904-1-2.
- k) For flexible modules, the minimum radius of curvature.

For items a) through i) all electrical data shall be shown as relative to STC (1 000 W/m<sup>2</sup>, 25 °C, AM1.5 according to IEC TS 61836), except for bifacial modules where two irradiance levels are required, as defined in 5.1g).

International symbols shall be used where applicable.

Compliance of marking is checked by inspection and MQT 06.1.

### 5.2 Documentation

#### 5.2.1 Minimum requirements

Modules shall be supplied with documentation describing the methods of electrical and mechanical installation as well as the electrical ratings of the module. The documentation shall state the class of protection against electrical shock under which the module has been qualified and any specific limitations required for that class. The documentation shall assure that installers and operators receive appropriate and sufficient documentation for safe installation, use, and maintenance of the PV modules.

NOTE It is considered to be sufficient that one set of documentation is supplied with the module shipping unit.

#### 5.2.2 Information to be given in the documentation

- a) all information required under 5.1 e) to i), and in addition j) for bifacial modules and k) for flexible modules;
- b) reverse current overload rating in accordance with IEC 61730-2 MST 26;

- overcurrent protection device type and rating are e.g. given in IEC 60269-6. Overcurrent protection devices with a 1 h,  $1,35 I_n$  overload rating, where  $I_n$  is the rated value of the overcurrent protection device, are recommended;
- recommended maximum series/parallel PV module configurations;
- c) manufacturer's stated tolerance for  $V_{OC}$ ,  $I_{SC}$  and maximum power output under standard test conditions;
- d) temperature coefficient for voltage at open-circuit;
- e) temperature coefficient for maximum power;
- f) temperature coefficient for short-circuit current.

All electrical data mentioned above shall be shown as relative to standard test conditions (1 000 W/m<sup>2</sup>, 25 °C, AM1.5 according to IEC TS 61836). Moreover the following parameters shall be specified:

- g) performance at low irradiance (MQT 07).

International symbols shall be used where applicable.

Compliance is checked by inspection and MQT 04 through MQT 07.

The electrical documentation shall include a detailed description of the electrical installation wiring method to be used. This description shall include:

- h) the minimum cable diameters for modules intended for field wiring;
- i) any limitations on wiring methods and wire management that apply to the wiring compartment or box;
- j) the size, type, material and temperature rating of the conductors to be used;
- k) type of terminals for field wiring;
- l) specific PV connector model/types and manufacturer to which the module connectors shall be mated. Statement of the connector type only (such as "MC4 compatible ") is not sufficient information to satisfy this requirement. Connector model/types and manufacturers shall be included;
- m) the bonding method(s) to be used (if applicable); all provided or specified hardware shall be identified in the documentation;
- n) the type and ratings of bypass diode to be used (if applicable);
- o) limitations to the mounting situation (e.g., slope, orientation, mounting means, cooling);
- p) a statement indicating the fire rating(s) and the applied standard as well as the limitations to that rating (e.g., installation slope, sub structure or other applicable installation information);
- q) a statement indicating the design load per each mechanical means for securing the module as evaluated during the static mechanical load test according to MQT 16. At discretion of the manufacturer the test load and/or the safety factor  $\gamma_m$  may be noted, too.

To allow for increased output of a module resulting from certain conditions of use, the installation instructions shall include relevant parameters specified by manufacturer or the following statement or the equivalent:

*"Under normal conditions, a photovoltaic module is likely to experience conditions that produce more current and/or voltage than reported at standard test conditions. Accordingly, the values of  $I_{SC}$  and  $V_{OC}$  marked on this module should be multiplied by a factor of 1,25 when determining component voltage ratings, conductor current ratings, and size of controls connected to the PV output."*

### 5.2.3 Assembly instructions

These shall be provided with a product shipped in subassemblies, and shall be detailed and adequate to the degree required to facilitate complete and safe assembly of the product.

## 6 Testing

The test laboratory shall use a laboratory simulator control module to be able to detect drifts in their measurement results. The laboratory simulator control module is different than the control module from sequence A, which is taken from the modules under test and is described in 7.2.3 related to the reproducibility  $r$ . The laboratory simulator control module is a stable module used on a periodic basis to check simulator output after calibration to a specific irradiance.

The modules shall be divided into groups and subjected to the qualification test sequences in Figure 2. Qualification test sequences are to be carried out in the order specified. The MQT designations in the boxes refer to the corresponding test definitions in IEC 61215-2. Technology-specific test details are listed in the respective parts of this standard. Required module component tests are listed in Table 1. For each component qualification, the test report shall note the test laboratory name and date when the requirement was met. Prior certifications may be used to fulfill these requirements, as long as the certifications were performed in accordance with all conditions noted in Table 1.

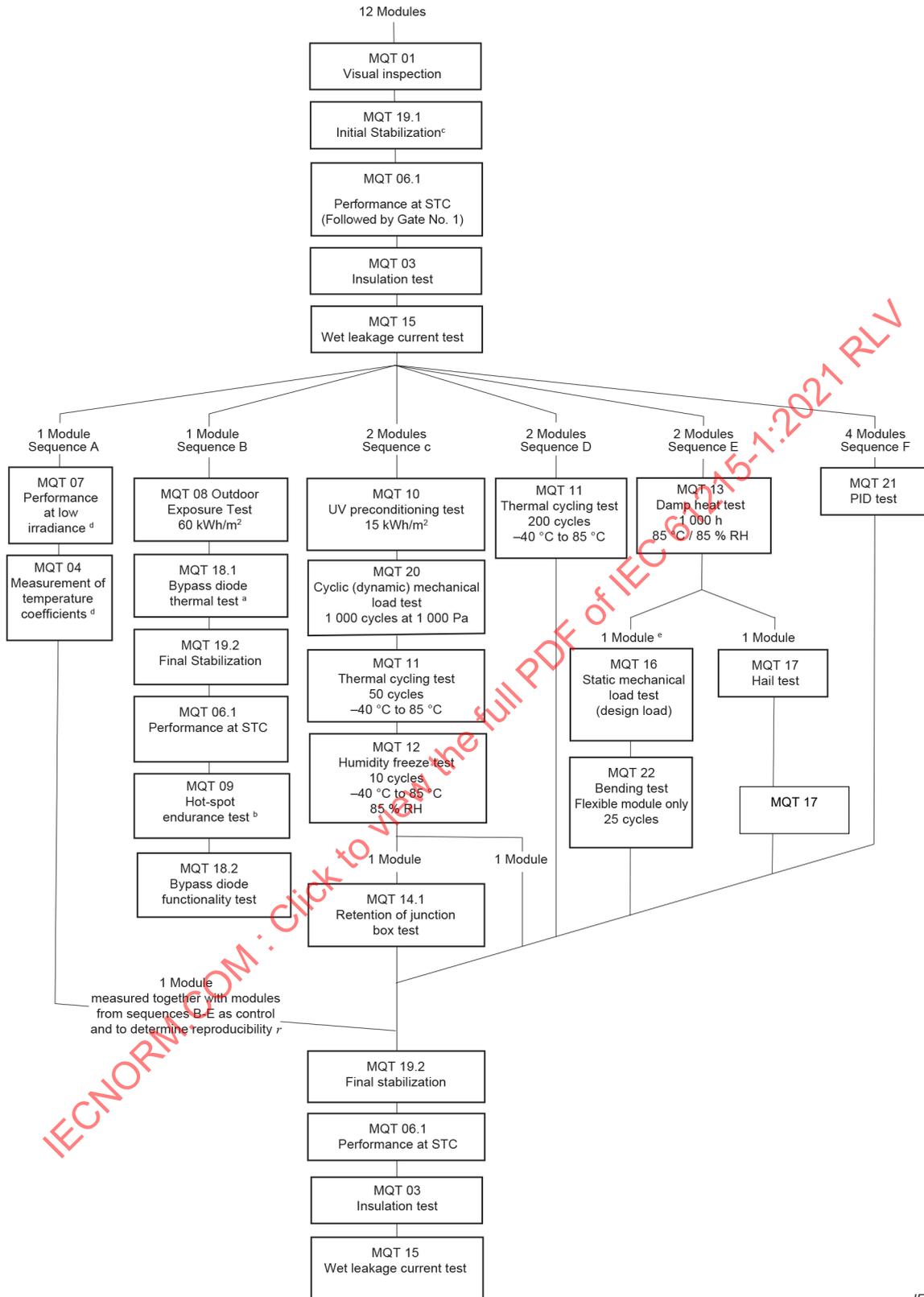
Intermediate measurements of maximum power (MQT 02) and insulation test (MQT 03) are not required, but they may be used to track changes.

Any single test executed independently of a test sequence, e.g., on special test samples for MQT 09 and MQT 18, shall be preceded by the initial tests of MQT 01, MQT 02, MQT 03, and MQT 15 as appropriate.

In carrying out the tests, the tester shall strictly observe the manufacturer's handling, mounting, and connection instructions. Sequence A may be omitted if the module type has been tested according to IEC 61853-1. In this case the relevant test results from IEC 61853-1 shall be stated or referenced in the final report. For bifacial modules Sequence A cannot be omitted until IEC 61853-1 has been amended to take bifacial modules into account.

Test conditions are summarized in Table 3. The test levels in Table 3 are the minimum levels required for qualification. If the laboratory and the module manufacturer agree, the tests may be performed with increased severities. In this case this shall be noted in the test report.

For flexible modules (see 3.6), the mounting substrate and adhesive or attachment means shall also be included in the test. If more than one mounting substrate or adhesive or attachment means is allowed per the manufacturer's specification, then the tests shall use the combination that is considered to be the worst case. The chosen combination(s) shall be reported, as per Clause 9, j).



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<sup>a</sup> If the bypass diodes are not accessible in the standard modules, a special sample can be prepared for the bypass diode thermal test (MQT 18.1). The bypass diode should be mounted physically as it would be in a standard module, with lead wires attached, as required in MQT 18 of IEC 61215-2:2021. This sample does not have to go through the other tests in the sequence.

<sup>b</sup> In sequence B, a different module may be used for the Hot-spot endurance test (MQT 09) than is used for the bypass thermal diode test (MQT 18.1). For this separate module the following test sequence is permissible: MQT 01, MQT 19.1, MQT 06.1 (gate 1), MQT 03, MQT 15, MQT 09, and MQT 18.2.

- <sup>c</sup> The initial stabilization MQT 19.1 may include the verification of an alternate stabilization procedure (see IEC 61215-2:2021).
- <sup>d</sup> In Sequence A, tests MQT 07, and MQT 04 may be performed in any order. These tests may also be performed on separate modules (rather than sequential tests on one module), provided that each module used has proceeded through the entire test flow preceding sequence A.
- <sup>e</sup> If representative samples are utilized in Sequence E, one extra module, full-sized, is required, and shall be subjected only to MQT 16 and the requirements therein.

## Figure 2 – Full test flow for design qualification and type approval of photovoltaic modules

**Table 1 – Required component tests**

Component	Shall pass this test
Junction box	IEC 61215-2:201x MQT 14.2, which cites IEC 62790 "Test of cord anchorage."
Connectors	IEC 62852. Compliance shall be obtained with the connector in combination with the same cable size and type as used in the modules under test.

## 7 Pass criteria

### 7.1 General

Modules under test are subject to several types of requirements. These include required markings (detailed in Clause 5), comparison of measured electrical quantities with the nameplate ( "gate No. 1 ", detailed in this clause), comparison of measured power before and after stress ( "gate No. 2 ", detailed in this clause), component requirements (detailed in Table 1), and the requirements of each MQT (summarized in Table 3 and Figure 2).

The design is deemed to have met the qualification requirements of 7.2.2 gate No. 1, if they meet the requirements of Table 2:

**Table 2 – Summary of Gate No. 1 requirements**

Sample size (in modules)	Requirement
<10	All modules shall pass. No failure is allowed.
≥10	A single failure is allowable. All other modules shall pass.

NOTE A sample size <10 is only encountered during retesting.

If modules fail to meet the requirements listed in Table 2 then two new samples shall be tested for each of the modules that failed to meet the gate No. 1 criteria. If a new failure occurs, the module supplier has two options. The first option is that the module labels for the existing sample set shall be redefined such that the requirements of Table 2 are met, and testing on that same sample set shall continue to the next step. The second option is that the design is deemed not to have met the qualification requirements, and any further testing constitutes a new attempt at qualification and thus requires a completely new batch of modules. Module labels shall be redefined and samples shall be resubmitted for testing.

In addition, if two or more modules fail to meet the remaining test criteria (7.2.3 Gate No. 2, 7.2.4 electrical circuitry, 7.3 visual defects and 7.4 electrical safety), the design shall be deemed not to have met the qualification requirements. If one module fails any test, two additional modules meeting the requirements of Clause 4 shall be subjected to the entire series of tests of the respective test sequence. The requirement for two additional modules applies for tests where originally only one module was required, as well as for tests where originally two modules were required. For example, a failure in the hot-spot endurance test requires a test repetition with two additional modules. A single failure in the 50 thermal cycles test (one module not meeting the test requirements) requires a test repetition with two additional modules as well.

If one or both of these modules also fail, the design shall be deemed not to have met the qualification requirements. If, however, both modules pass the test sequence, the design shall be judged to have met the qualification requirements.

The module design shall meet the requirements of all criteria to be deemed as qualified according to this document. Each test sample shall be subject to the following criteria.

## 7.2 Power output and electric circuitry

### 7.2.1 Identification of rated values and tolerances

Gate No. 1 criteria detailed in the following subclauses require use of rated values and tolerances from the nameplate and product datasheet. This clause describes in detail, with examples, how to identify the relevant information. Application of the information in this clause results in consistent requirements when extraneous information is given, or when information appears to be missing or conflicting. Rated values and tolerances shall each be identified for module power, short-circuit current, and open-circuit voltage. Thus, this clause details how to identify these six pieces of information.

NOTE 1 Historically, some products have quoted multiple components of uncertainty, or have used different terminology for uncertainty, such as "tolerance," "production tolerance," "measurement uncertainty," etc. Also, some products have not provided a tolerance, which might be interpreted as 0 % tolerance or as missing information. While a manufacturer is not prohibited from providing additional information, or having 0 % tolerance, application of the rules in this clause provide a consistent manner to interpret such situations.

Information identified in this clause relates to STC current-voltage measurements, obtained in the manner prescribed by following the flow chart of Figure 2. Thus, the obtained values are those measured only after initial stabilization performed according to IEC 61215-2 MQT 19.1. Required stabilization procedures may differ from one product to the next, as specified in the technology-specific parts IEC 61215-1-x. The calculation of tolerances is the responsibility of the module manufacturer. Each tolerance ( $t_1$ ,  $t_2$  and  $t_3$ ) shall be explicitly stated as a single value for each of the performance parameters ( $P_{\max}$ ,  $V_{OC}$  and  $I_{SC}$  respectively). For bifacial modules, the six pieces of information (values and tolerances for module power, short-circuit current, and open-circuit voltage) shall also be identified at BNPI to evaluate Gate No. 1.

NOTE 2 ISO Guide 98-3 provides further guidance regarding how to combine multiple sources of uncertainty.

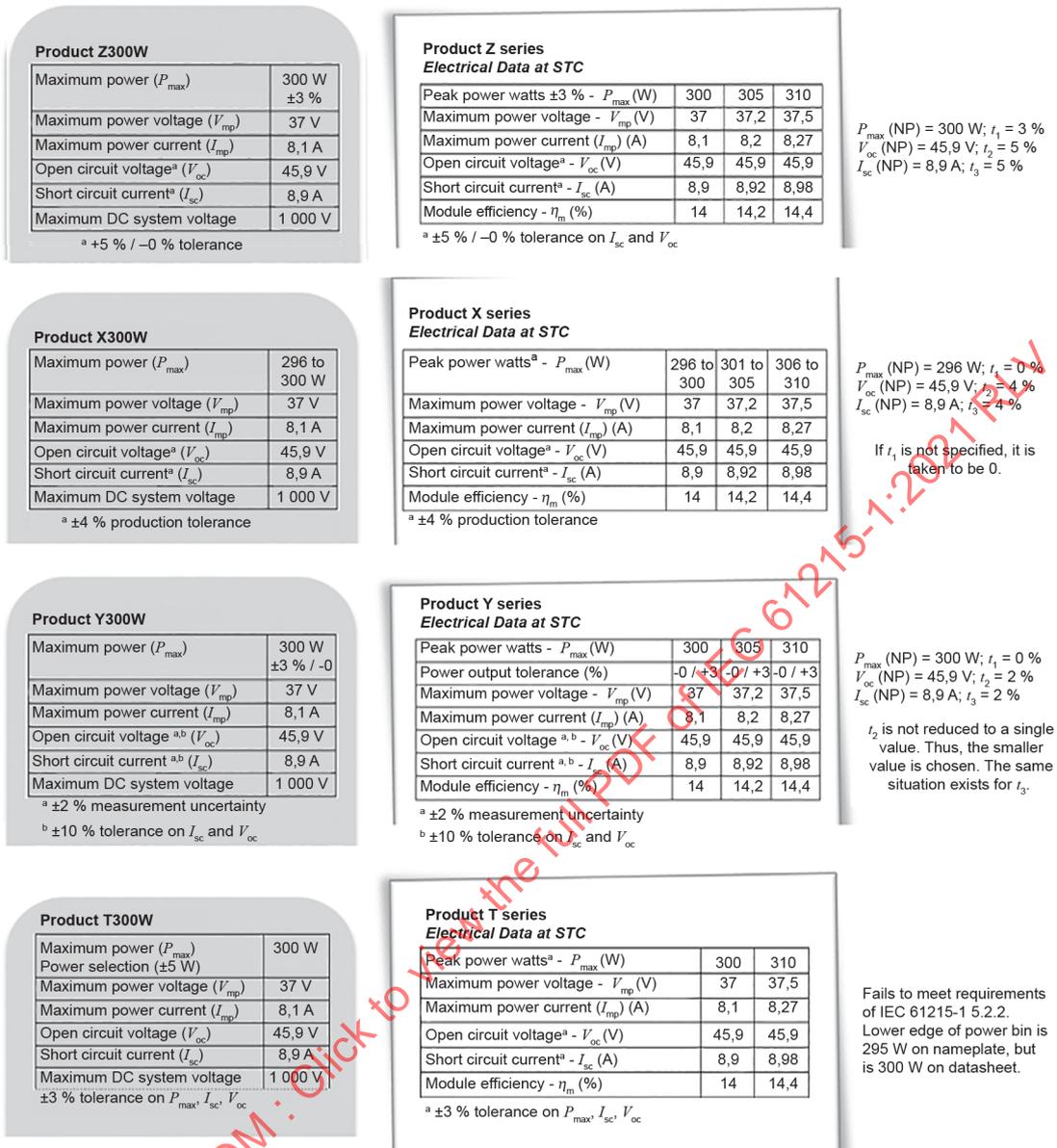
Formulas (1) and (2) in 7.2.2 verify that the modules produce at least as much power as the minimum indicated by combining the nameplate rating and tolerance. The minimum nameplate power rating,  $P_{\max}(\text{NP})$  is the module power output specified on the nameplate. If a single value for module power is stated on the nameplate,  $P_{\max}(\text{NP})$  is simply that value. If a range of module powers is stated on the nameplate,  $P_{\max}(\text{NP})$  is the power at the lowest end of that range. Subclause 5.2.2 requires that power binning and tolerance information from the nameplate is reproduced in the datasheet. In the case that  $P_{\max}(\text{NP})$  derived from the datasheet is different than that on the nameplate, the module shall be judged as not satisfying 5.2.2 and thus does not meet the requirements of IEC 61215-1.

The tolerance,  $t_1$ , is the tolerance in % for  $P_{\max}$  stated on the nameplate and datasheet, as required by 5.1i) and 5.2.2a). If the tolerance is asymmetric about  $P_{\max}(\text{NP})$ , the tolerance referring to the low power limit shall be utilized as  $t_1$ . If the tolerance is not stated on the nameplate or is not stated on the datasheet, then  $t_1 = 0$ . If tolerance is not reduced to a single value on the nameplate or data sheet (for example, if multiple tolerances or measurement uncertainty components are specified) the smallest number, not a combination of multiple numbers, shall be utilized.

Formulas (3) and (4) verify, for safety reasons, that the module does not produce more voltage at open circuit, or current at short-circuit, than the maximum indicated by combining the nameplate rating and tolerance. The maximum open circuit voltage  $V_{\text{oc}}(\text{NP})$  and maximum short-circuit current  $I_{\text{sc}}(\text{NP})$  are those specified on the nameplate. If a range for open-circuit voltages or short-circuit currents is stated on the nameplate,  $V_{\text{oc}}(\text{NP})$  or  $I_{\text{sc}}(\text{NP})$  is to be taken as the highest value in that range. The tolerance ( $t_2$  for open circuit voltage, or  $t_3$  for short-circuit current) is that specified on the nameplate and in the product documentation, as required by 5.1g), 5.1h), and 5.2.2c). If  $t_2$  (or  $t_3$ ) is asymmetric about  $V_{\text{oc}}(\text{NP})$  (or  $I_{\text{sc}}(\text{NP})$ ), the tolerance referring to the higher end of the range shall be utilized. If  $t_2$  or  $t_3$  is not stated in the documentation and on the nameplate, that tolerance shall be identified as 0. In the case that  $V_{\text{oc}}(\text{NP})$ ,  $I_{\text{sc}}(\text{NP})$ , or the tolerances in these quantities are different when derived from the datasheet than from the nameplate, the module shall be judged as not satisfying 5.2.2 and thus does not meet the requirements of IEC 61215-1. If a tolerance is not reduced to a single value on the nameplate or data sheet (for example, if multiple tolerances or measurement uncertainty components are specified) the smallest number, not a combination of multiple numbers, shall be utilized.

Figure 3 shows partial nameplates, datasheets, and derived values for four hypothetical products. These examples illustrate the rules for identifying rated values and tolerances that were described in the preceding subclauses.

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Figure 3 – Examples of hypothetical partial nameplates (left column), datasheets (center column), and derived rated values and tolerances (right column)

### 7.2.2 Verification of rated label values → Gate No. 1

All modules shall be stabilized following method MQT 19.1 from IEC 61215-2:2021 (for technology specific requirements, see sub-parts of IEC 61215-1). After stabilization the modules shall be measured in accordance with MQT 6.1 ( $P_{max}(Lab)$ ) and shall meet the following criteria:

$P_{max}$  verification:

Each individual module shall meet the following criterion:

$$P_{max}(Lab) \times \left(1 + \frac{1,65|m_{11}|}{100}\right) \geq P_{max}(NP) \times \left(1 - \frac{|t_{11}|}{100}\right) \quad (1)$$

where

$P_{\max}(\text{Lab})$  is the measured maximum power at STC of each module in the stabilized state;

$P_{\max}(\text{NP})$  is the minimum rated nameplate power of each module without tolerances;

$m_1$  is the measurement uncertainty in % of laboratory for  $P_{\max}$  (expanded combined uncertainty (k=2), ISO/IEC Guide 98-3); the factor 1,65/2 is used to convert the confidence intervals from two-sided to one-sided at 95 % level of confidence;  $m_1$  shall include a component from spectral mismatch, based either on measured spectral response or the worst-case possibility for a given technology type;  $m_1$  shall be less than stated in the technology specific parts of this standards series;

$t_1$  is the manufacturer's rated lower tolerance in % for  $P_{\max}$ .

For,  $\bar{P}_{\max}(\text{Lab})$  the following criterion shall apply:

$$\bar{P}_{\max}(\text{Lab}) \times \left( 1 + \frac{1,65|m_1|}{100} \right) \geq P_{\max}(\text{NP}) \quad (2)$$

where

$\bar{P}_{\max}(\text{Lab})$  is the arithmetic average of the measured maximum STC power of the modules in stabilized condition.

For multiple bins of power classes this formula has to be applied to each power class under investigation.

NOTE Formula (2) is not intended for power verification of a batch in mass production as systematic differences between different labs and reference devices are unavoidable. In such cases, formula (1), which includes the relevant uncertainties, better describes the application to average values.

$V_{\text{OC}}$  verification:

Each individual module shall meet the following criterion:

$$V_{\text{oc}}(\text{Lab}) \times \left( 1 + \frac{1,65|m_2|}{100} \right) \leq V_{\text{oc}}(\text{NP}) \times \left( 1 + \frac{|t_2|}{100} \right) \quad (3)$$

where

$V_{\text{OC}}(\text{Lab})$  is the measured maximum  $V_{\text{OC}}$  of each module in the stabilized state;

$V_{\text{OC}}(\text{NP})$  is the maximum rated nameplate  $V_{\text{OC}}$  of each module without tolerances;

$m_2$  is the measurement uncertainty in % of laboratory for  $V_{\text{OC}}$ ; (expanded uncertainty (k=2), ISO/IEC Guide 98-3); the factor 1,65/2 is used to convert the confidence intervals from two-sided to one-sided at 95 % level of confidence;

$t_2$  is the manufacturer's rated upper tolerance in % for  $V_{\text{OC}}$ .

If  $V_{\text{oc}}$  cannot be measured due to module-integrated electronics (such as MOSFETs), the module is exempt from the  $V_{\text{oc}}$  verification requirement. This exemption shall be noted in the test report.  $V_{\text{oc}}$  shall not be determined by any means other than direct measurement, such as extrapolation.

$I_{\text{SC}}$  verification:

Each individual module shall meet the following criterion:

$$I_{sc}(\text{Lab}) \times \left( 1 + \frac{1,65}{100} |m_3| \right) \leq I_{sc}(\text{NP}) \times \left( 1 + \frac{|t_3|}{100} \right) \quad (4)$$

where

- $I_{sc}(\text{Lab})$  is the measured maximum  $I_{sc}$  of each module in the stabilized state;
- $I_{sc}(\text{NP})$  is the maximum rated nameplate  $I_{sc}$  of each module without tolerances;
- $m_3$  is the measurement uncertainty in % of laboratory for  $I_{sc}$ ; (expanded uncertainty (k=2), ISO/IEC Guide 98-3); the factor 1,65/2 is used to convert the confidence intervals from two-sided to one-sided at 95 % level of confidence;
- $t_3$  is the manufacturer's rated upper tolerance in % for  $I_{sc}$ .

If  $I_{sc}$  cannot be measured due to module-integrated electronics (such as MOSFETs), the module is exempt from the  $I_{sc}$  verification requirement. This exemption shall be noted in the test report.  $I_{sc}$  shall not be determined by any means other than direct measurement, such as extrapolation.

$P_{max}$  verification of lowest power class:

Each individual module that is used for the qualification of low end power classes shall meet, in addition to the previous stated criteria for  $P_{max}$ ,  $V_{oc}$  and  $I_{sc}$ , the following criterion relating to an upper power limit:

$$P_{max}(\text{Lab}) \times \left( 1 - \frac{1,65}{100} |m_1| \right) \leq P_{max4}(\text{NP}) \times \left( 1 + \frac{|t_4|}{100} \right) \quad (5)$$

where

- $P_{max4}(\text{NP})$  is the maximum rated nameplate power of each lowest power class module, without tolerances;
- $t_4$  is the manufacturer's rated upper tolerance in % for  $P_{max4}(\text{NP})$ .  $t_4$  is selected subject to the same rules as for  $t_1$  (see Figure 3), except that if the tolerance is asymmetric about  $P_{max4}(\text{NP})$ , the tolerance referring to the high power limit shall be utilized.

The last criterion ensures that the modules of the lowest power class stay within the upper tolerance of that class. The last criterion is only applicable for the qualification of the lowest power class. It ensures that a module manufacturer can make modules in the lowest power class that are free from major flaws, and thus the lowest power class is not used as a repository for damaged modules after qualification is obtained using severely underrated modules.

For bifacial modules,  $P_{max}$ ,  $I_{sc}$ , and  $V_{oc}$  shall each be measured at the two irradiances specified in 5.1. The Gate No. 1 criteria for  $P_{max}$ ,  $I_{sc}$ , and  $V_{oc}$  shall be applied at both irradiances.

A systematic variation to either higher or lower output power or bifaciality coefficient will be stated in the final report.

### 7.2.3 Maximum power degradation during type approval testing → Gate No. 2

At the end of each test sequence or for sequence B after bypass diode test, the maximum power output drop of each module  $P_{\max}$  (Lab\_GateNo. 2) shall be less than 5 %, referenced to the module's initial measured output power  $P_{\max}$  (Lab\_GateNo. 1). Each test sample shall meet the following criterion:

$$P_{\max}(\text{Lab\_GateNo. 2}) \geq 0,95 \times P_{\max}(\text{Lab\_GateNo. 1}) \cdot \left(1 - \frac{r}{100}\right) \quad (6)$$

The reproducibility  $r$  in % shall be determined for  $P_{\max}$  and shall be used in the formula. The reproducibility shall be less than or equal to that stated in the technology specific parts of this standards series.

The reproducibility  $r$  is verified by comparing the control module(s) from sequence A after initial stabilization (beginning of the test) and after final stabilization (end of tests from sequence B to E). The second test shall be performed after completing all tests. The following applies:

- All modules from sequences B (after MQT 18.1), C, D and E are measured together with one control module from Sequence A.
- If a) cannot be used due to test flow (different completion time of sequence or customer requests restrictions) the following applies:

For each sequence B (after MQT 18.1), C, D and E one control module from sequence A shall be defined. The control module is stabilized and measured together with the modules from the applicable sequence B (after MQT 18.1), C, D or E. For each determined value  $r$  the requirement for  $r$  shall be fulfilled.

The reproducibility parameter  $r$  is not equal to the total measurement uncertainty of MQT 06.1. It is advisable that the same solar simulator is used for  $P_{\max}$  (Lab\_Gate No. 1) and  $P_{\max}$  (Lab\_Gate No. 2).

If the measured  $r$  exceeds the technology specific limit for the control module the laboratory needs to check with its own internal reference module(s) whether the test equipment is faulty, or the module under test is responsible for the poor reproducibility, or it is not in a stable state after applied procedure MQT 19.1. If all checks confirm the measurement equipment is performing correctly, this indicates that the control module has drifted by more than the technology specific limit. In this case, proceed by using the technology specific limit for  $r$ .

For bifacial modules, Gate No. 2 shall each be assessed only at the larger irradiance (BNPI) specified in 5.1g).

### 7.2.4 Electrical circuitry

Samples are not permitted to exhibit an open-circuit during the tests.

### 7.3 Visual defects

There is no visual evidence of a major visual defect, as defined in Clause 8.

### 7.4 Electrical safety

- The insulation test (MQT 03) requirements are met at the beginning and the end of each sequence.
- The wet leakage current test (MQT 15) requirements are met at the beginning and the end of each sequence.
- Specific requirements of the individual tests are met.

## 8 Major visual defects

The purpose of the visual inspection is to detect any visual defects that may cause a risk of reliability loss, including power output.

In some instances more detailed inspection may be required to finally decide if major visual defects exist or not.

For the purpose of design qualification and type approval the following observations are considered to be major visual defects:

- a) Broken, cracked, or torn external surfaces.
- b) Bent or misaligned external surfaces, including superstrates, substrates, frames and junction boxes to the extent that the operation of the PV module would be impaired.
- c) Bubbles or delaminations forming a continuous path between electric circuit and the edge of the module.
- d) If the mechanical integrity depends on lamination or other means of adhesion, the sum of the area of all bubbles shall not exceed 1 % of the total module area.
- e) Evidence of any molten or burned encapsulant, backsheet, frontsheet, diode or active PV component.
- f) Loss of mechanical integrity to the extent that the installation and operation of the module would be impaired.
- g) Cracked/broken cells which can remove more than 10 % of the cell's photovoltaic active area from the electrical circuit of the PV module.
- h) Voids in, or visible corrosion of any of the layers of the active (live) circuitry of the module extending over more than 10 % of any cell.
- i) Broken interconnections, joints or terminals.
- j) Any short-circuited live parts or exposed live electrical parts.
- k) Module markings (label) are no longer attached or the information is unreadable.

## 9 Report

Following type approval, a report of the qualification tests, with measured performance characteristics and details of any failures and re-tests, shall be prepared by the test agency. The report shall contain the detail specification for the module. Each test report shall include at least the following information:

- a) a title;
- b) name and address of the test laboratory and location where the tests were carried out;
- c) unique identification of the report and of each page;
- d) name and address of client, where appropriate;
- e) description and identification of the item tested, including indication if it has been evaluated for bifaciality and/or whether it is has been evaluated as a flexible module;
- f) characterization and condition of the test item;
- g) date of receipt of test item and date(s) of test, where appropriate;
- h) identification of test methods used;
- i) reference to sampling procedure, where relevant;
- j) any deviations from, additions to, or exclusions from, the test method and any other information relevant to specific tests, such as environmental conditions, or the irradiation dose in kWh/m<sup>2</sup> at which stability is reached;

- k) measurements, examinations and derived results supported by tables, graphs, sketches and photographs as appropriate including:
- temperature coefficients of short-circuit current, open-circuit voltage and peak power,
  - power at STC and low irradiance,
  - bifaciality coefficients at STC and low irradiance (for bifacial modules),
  - the maximum shaded cell temperature observed during the hot-spot endurance test,
  - spectrum of the lamp used for the UV preconditioning test,
  - mounting method(s) utilized in the static mechanical load test,
  - the positive/negative test loads and the safety factor  $\gamma_m$  used in the static mechanical load test,
  - hail ball diameter and velocity used in the hail test,
  - maximum power loss observed after all of the tests,
  - for flexible modules, the diameter of the cylinder over which the module was bent during performance of MQT 22, and
  - conditions of potential induced degradation (PID) test (MQT 21) including applied rated system voltage, polarities, and mounting configuration;
  - choice of test method where procedures allow more than one option (e.g. Method A or B in MQT 18.2; final stabilization method in MQT 19.2, etc.)
  - if open-circuit voltage, short-circuit current, or associated temperature coefficients cannot be measured due to module-integrated electronics, these quantities shall be reported as "not measurable due to module-integrated electronics." Any resulting exemptions from Gate 1 requirements on  $I_{sc}$  or  $V_{oc}$  shall also be noted.
- l) any failures observed and any retests performed;
- m) a representation of the markings of the module type including manufacturer's power tolerances;
- n) the test lab name and date, for each component qualification required in Table 1;
- o) a summary of results from all pass criteria defined in Clause 7 in absolute and relative change. If tendencies to either higher or lower values are observed this has to be included in the report. The used stabilization procedure (irradiance, temperature, time) needs to be stated in detail;
- p) a statement of the estimated uncertainty of the test results (where relevant); state the reproducibility  $r$  from the control module that is used for Gate No. 2.
- q) a signature and title, or equivalent identification of the person(s) accepting responsibility for the content of the report, and the date of issue;
- r) where relevant, a statement to the effect that the results relate only to the items tested;
- s) a statement that the report shall not be reproduced except in full, without the written approval of the laboratory.

## 10 Modifications

Changes in material selection, components and manufacturing process can impact the qualification of the modified product.

Retesting shall be performed according to IEC TS 62915. The recommended test sequences have been selected to identify adverse changes to the modified product.

During retesting, tests that are performed on representative samples do not need to be repeated if the only change to a product is one of size, and the change in product size still allows use of the same representative sample size already tested.

The number of samples to be included in the retesting program and the pass/fail criteria are to be taken from the relevant clauses/subclauses of this document.

## 11 Test flow and procedures

For design qualification and type approval the following test flow and procedures apply. Table 3 summarizes the different tests. The full test flow is given in Figure 2. A description of the tests and test procedures is given in IEC 61215-2:2021. Technology-relevant differences are described in the respective technology specific part of this standards series.

**Table 3 – Summary of test levels**

Test	Subclause in IEC 61215-2:2021	Title	Test conditions
MQT 01	4.1	Visual inspection	See list of major visual defects in Clause 8
MQT 02	4.2	Maximum power determination	See IEC 60904-1 for monofacial modules and IEC TS 60904-1-2 for bifacial modules
MQT 03	4.3	Insulation test	Test levels vary between 500 V minimum and $1,35 \times (2000 + 4 \times V_{sys})$ maximum depending on system voltage, module class, and presence of cemented joints. See MQT 03 procedure for further detail.
MQT 04	4.4	Measurement of temperature coefficients	See IEC 60891 See IEC 60904-10 for guidance
MQT 06.1	4.6	Performance at STC	Cell temperature of 25 °C at STC Irradiance: 1 000 W/m <sup>2</sup> (and BNPI, for bifacial modules) with IEC 60904-3 reference solar spectral irradiance distribution Requirements see Clause 7
MQT 07	4.7	Performance at low irradiance	Cell temperature: 25 °C Irradiance: 200 W/m <sup>2</sup> with IEC 60904-3 reference solar spectral irradiance distribution
MQT 08	4.8	Outdoor exposure test	60 kWh/m <sup>2</sup> total solar irradiation
MQT 09	4.9	Hot-spot endurance test	Exposure to irradiance in worst-case hot-spot condition as per the technology specific part and IEC 61215-2. For monofacial modules, irradiance is 1 000 W/m <sup>2</sup> . For bifacial modules the irradiance is BSI.
MQT 10	4.10	UV preconditioning	15 kWh/m <sup>2</sup> total UV irradiation in the wavelength range from 280 nm to 400 nm, with 3 % to 10 % UV irradiance in the wavelength range from 280 nm to 320 nm, at a module temperature of 60 °C. For bifacial modules, exposure is repeated on the rear side.
MQT 11	4.11	Thermal cycling test	50 (Sequence C) or 200 (Sequence D) cycles from –40 °C to +85 °C with current as per technology specific part up to +80 °C, with 5 N weight hanging from the junction box.
MQT 12	4.12	Humidity freeze test	10 cycles from +85 °C, 85 % RH to –40 °C with circuitry continuity monitoring
MQT 13	4.13	Damp heat test	1 000 h at +85 °C, 85 % RH
MQT 14	4.14	Robustness of termination	Test of junction box retention and cord anchorage.
MQT 15	4.15	Wet leakage current test	Test voltage increase at a rate not exceeding 500 V/s to 500 V or the maximum system voltage for the module, whichever is greater. Maintain the voltage at this level for 2 min. Solution temperature is $(22 \pm 2)$ °C.
MQT 16	4.16	Static mechanical load test	Three cycles of uniform load specified by the manufacturer, applied for 1 h to front and back surfaces in turn. Minimum test load: 2 400 Pa
MQT 17	4.17	Hail test	Ice ball impact directed at 11 locations. Required minimum ice ball diameter of 25 mm and speed of 23,0 m/s.
MQT 18	4.18	Bypass diode thermal test	MQT 18.1: Bypass diode thermal test:

Test	Subclause in IEC 61215-2:2021	Title	Test conditions
			1 h at $I_{sc}$ and 75 °C 1 h at 1,25 times $I_{sc}$ and 75 °C MQT 18.2: Bypass diode functionality test At 25 °C perform voltage and current measurements For bifacial modules, $I_{sc}$ in the conditions above is that measured at elevated irradiance BSI.
MQT 19	4.19	Stabilization	Three consecutive output power measurements $P_1$ , $P_2$ and $P_3$ using MQT 02. STC output power is determined using procedure MQT 06.1.
MQT 20	4.20	Cyclic (Dynamic) Mechanical load test	IEC TS 62782 1 000 cycles at 1 000 Pa
MQT 21	4.21	Potential induced degradation test	IEC TS 62804-1 +85 °C, 85 % RH at maximum system voltage for 96 h
MQT 22	4.22	Bending test – for flexible modules only	25 cycles rolled up (without damage) around a cylinder with a diameter specified by the module manufacturer over which the flexible modules can be bent

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## Annex A (informative)

### Changes from previous edition

#### A.1 General

This annex is included with edition 2 of the IEC 61215 series to better explain the project team's reasoning in developing some of the changes made since edition 1. This annex is informative, describing the development history and rationale. This annex does not modify or complete any of the test procedures found in the IEC 61215 series.

The following changes are discussed in this annex:

- Procedures for bifacial modules
- Use of representative samples
- Addition of dynamic mechanical load test
- Addition of test for potential induced degradation
- Simulator requirements
- References to retest guidelines
- Weight on junction boxes
- Correction to monolithically-integrated hot-spot endurance test
- Number of modules in sequence
- Removal of nominal module operating temperature (NMOT)
- Very low currents during thin-film tests
- Limit bypass diode testing to three diodes
- Revert the insulation test to 2005 version
- Bending test
- Stabilization option for boron oxygen LID (MQT 19.3)

To create edition 2, a number of minor corrections and clarifications to the edition 1 wording were also made. These minor changes are not discussed in this annex.

#### A.2 Procedures for bifacial modules

The IEC 61215 new edition includes text related to bifacial modules, whereas edition 1 did not. The new edition includes several instructions related to bifacial modules:

- Procedures for measuring bifacial modules are included via references to IEC TS 60904-1-2.
- Where test levels need to be adjusted for bifacial modules due to potentially higher currents during operation, these increased values are specified.
- Additional reporting requirements (e.g. bifaciality coefficients) are described.
- Tests that may be omitted because referenced standards have not yet been modified to account for bifaciality are noted.

Qualification of bifacial modules requires measurement of several quantities beyond those required for monofacial modules. The short-circuit current bifaciality coefficient  $\phi_{ISC}$ , the open-circuit voltage bifaciality coefficient  $\phi_{VOC}$  and the maximum power bifaciality coefficient  $\phi_{Pmax}$  shall be listed on the nameplate, as per IEC 61215-1:2021, 5.1j). These coefficients are measured as part of IEC 61215-2:2021, MQT 6.1. Any significant deviation between the measured and listed values shall be noted in the test report, as per IEC 61215-1:2021, 7.2.2. MQT 07, performance at low irradiance, also requires calculation of the bifaciality coefficients at low irradiance.

Qualification of bifacial modules requires performance measurement (MQT 06.1) at three irradiances. These irradiances are

- 1 000 W/m<sup>2</sup> (the irradiance at STC, as defined in IEC TS 61836),
- conditions equivalent to 1 000 W/m<sup>2</sup> on the front side and 135 W/m<sup>2</sup> on the back side (BNPI, as defined in 3.11), and
- conditions equivalent to 1 000 W/m<sup>2</sup> on the front side and 300 W/m<sup>2</sup> on the back side (BSI, as defined in 3.12).

BNPI and BSI may be applied in any method allowed by IEC TS 60904-1-2, such as single-side illumination at equivalent irradiance, or double-side illumination. If single-side illumination is utilized, the simulator setting depends on the module bifaciality through the equivalent irradiance defined in 60904-1-2. Extrapolation of performance parameters at BSI from the values of 1 000 W/m<sup>2</sup> on front and 300 W/m<sup>2</sup> on back is possible if the flasher is unable to achieve high enough irradiance for BSI.

BNPI is used for nameplate verification. 135 W/m<sup>2</sup> rear irradiance is chosen for BNPI based on several published studies that find, with typical module spacing and light-colored soil, the rear-side irradiance is in the range of 100-150 W/m<sup>2</sup> when 1 000 W/m<sup>2</sup> is incident on the front side.[2] [3] [4] [5] [6] BNPI thus conveys an approximation of typical power gain due to bifaciality.

BSI is used to measure quantities that determine applied stress conditions. A 300 W/m<sup>2</sup> rear irradiance in BSI is used to represent worst case (most stressful) conditions with a reflective (0,5 albedo) ground cover.[7] To ensure safe products, this worst case condition is used to set the stress levels.

For bifacial modules, measurements at both STC and BNPI are used for Gate No. 1, while only measurements at BNPI are utilized for and Gate No. 2 criteria. For final Gate No. 2 measurements (post stress,) STC measurement and re-evaluation of bifaciality coefficients are not required, in order to keep cost of qualifying bifacial modules reasonable. Instead, Gate No. 2 is evaluated only at the more stringent condition, BNPI, where possible series resistance and other fill factor losses induced by stress are expected to be largest. By not requiring STC measurement or re-evaluation of the bifaciality coefficients for the final Gate No. 2 measurement, time-consuming (expensive) steps of re-calibration simulators at multiple intensities, only to obtain a less stringent test, is avoided. Requirements for measurement intensities and evaluation of bifaciality coefficients requirements are stated in IEC 61215-1:2021, 7.2.2 and 7.2.3, and in IEC 61215-2:2021, 4.6.3 "Measuring at STC (MQT 06.1)".

For several tests, stress levels are increased from values based on one-sun front side illumination, in order to account for potentially higher currents during bifacial module operation with backside illumination.

- The test current is increased for the bypass diode thermal test MQT 18.1. For bifacial modules, MQT 18.1 specifies 1,25 times the module short-circuit current at the elevated irradiance BSI. Use of this higher current is required in IEC 61215-2:2021,4.18.1.4b).
- The test current is also increased in the same manner for the bypass diode functionality test MQT 18.2, as specified in IEC 61215-2:2021,4.18.2.3.2 b).

- In MQT 11 the technology-specific current to be applied during thermal cycling is larger for bifacial modules. IEC 61215-1-1:2021 specifies that the technology specific current which needs to be applied according to test MQT 11 of IEC 61215-2:2021, shall be equal to the peak power current at the elevated irradiance BSI.
- In MQT 09, determination of the cell shading percent and the prolonged exposure are performed at the elevated irradiance BSI. If double-side illumination is used to produce BSI, both the back and the front of the cell are shaded in the same way. During cell selection, any cell that is permanently shaded by a module feature (such as the junction box) is added to the list of selected cells.

### A.3 Use of representative samples

At present, there are products intended to be qualified via IEC 61215, that are much larger (e.g. 6 m in one dimension) than typical test equipment. Requiring a test lab to obtain custom test equipment for one product is prohibitively expensive and would create an unfair barrier to qualification. Thus, representative samples may be used for applying stress and evaluating Gate No. 2 on very large modules. A representative sample is one that includes all the components of the module, except some repeated parts, and is therefore smaller than the actual product. A full-sized sample is still required for nameplate verification (Gate No. 1).

A representative sample may be utilized if a module is "very large," as defined in IEC 61215-1:2021. A "very large" module is taken to be anything that will not fit on the largest commercially-available AAA simulator, or in the necessary environmental chambers. The largest commercially-available AAA simulators seldom exceed dimensions of 2,6 m × 2,1 m. A survey of test labs by project team members showed that environmental chamber sizes currently impose a size limit for IEC 61215 qualification in various test labs ranging from 2,2 m to 2,4 m in module length, and 1,2 to 1,9 m in module width. The project team decided that defining a very large module as 2,2 m × 1,5 m is a reasonable compromise between not providing a barrier to certification for large products, but encouraging certification on full-size products when possible. By this definition, a module is considered very large if it exceeds 2,2 m in any dimension, or exceeds 1,5 m in both dimensions.

Limits are placed on how much one may reduce the dimensions of a very large module in making representative modules for qualification testing. The reduced dimension(s) shall be no less than one half the dimensions that define a very large module. In other words, when reducing the shorter dimension, the representative sample shall be at least 0,75 m wide. In reducing the longer dimension, the representative sample shall be at least 1,1 m long. Thus, a manufacturer is not allowed to use, for example, a one-cell mini-module for qualification testing. The use and dimensions of representative samples shall be noted in the test report.

If representative samples are utilized in Sequence E, then one extra module, full-sized, is required, and shall be subjected only to MQT 16 (the static load test) and the requirements therein. The extra module is required because mechanical load on a representative sample is not the same as doing it on a full-size module. (To give an extreme example, a 10 m × 10 m × 5 mm glass pane may collapse under its own weight, whereas a 1 m × 1 m × 5 mm glass pane may resist the 2 400 Pa loading.) However, a general way to convert load requirements from one sample size to the next, for all product designs, does not exist at the time of publication. Also, because of space limitations in the damp heat chamber, the full-size module cannot be required to undergo the entire sequence E. Thus, as a compromise, an extra full-size module in sequence E to supplement the representative sample. The full-size module will be evaluated for structural and safety failures (e.g. broken glass) via the visual inspection (MQT 01) that is embedded in MQT 16. If a design is susceptible to MQT 16 failures that involve DH (for example, a glue that debonds after DH), such effects are best detected using the representative sample.

If there are MLT failures that involve DH (for example, a glue that is not strong after DH), such effects will be captured by the test on the representative sample.

The project team considered whether more thermal cycles should be required when MQT 11 is performed on a representative sample. It was considered that thermomechanical fatigue tends to increase with sample size, and therefore extra thermal cycles might be needed to qualify a full-size product while stressing a smaller representative sample. However, finite element modelling concluded that the cell size, not the module size, is the critical dimension for thermomechanical fatigue, and thus extra thermal cycles are not warranted.

#### **A.4 Addition of dynamic mechanical load test**

A Dynamic Mechanical Load (DML) test has been added in the IEC 61215 new edition and is performed according to IEC TS 62782. The DML test was developed to evaluate the potential for cell breakage within PV modules[8]. The goal was to find a load that would break cells that were already damaged prior to the stress, but would not break intact cells during the stress. During experiments, a load level of 1 000 Pa was selected. Effect on the cells appeared to saturate at 1 000 cycles. These results formed the basis for the stress levels utilized in IEC TS 62782 and the IEC 61215 new edition. DML has subsequently been the subject of other studies.[9], [10], [11] The DML test is intended to detect cell damage that is inherent in processing (such as a tabber that applies too much pressure and cracks cells during module assembly). The DML test is not intended to introduce new cracks into the cells, nor to measure susceptibility of the module to mishandling, abuse, or extreme weather.

Several publications (e.g. [12], [13]) have noted that cracking cells in a module, then applying either DML or thermal cycles, can lead to power loss. However, there are several reasons to be cautious when considering applying DML or thermal cycling after mechanical stress for this qualification standard:

- Not all modules will experience extreme weather or mishandling. Qualification testing that tests for performance retention under these circumstances may lead to costly overdesign.
- There is not yet documented field correlation to determine over what time period power loss from mechanically-cracked cells occurs. Early studies how long it takes cracks to open up, and therefore (even roughly) what time period is relevant for the sequence: hail test + DML or TC. Some published studies are underway, but haven't seen cracks further affect power in the first 1 to 2 years. [14], [15]
- For people who just want to know relative performance without requiring relationship to field performance, static load + DML is in IEC TS 63209-1 for relative comparison.
- It is recommended to first develop and gain experience with a TS related to hail-resistance, module handling, and related performance losses. Such a document should consider that thermal cycles might be more effective than DML.

#### **A.5 Addition of test for potential induced degradation**

Potential induced degradation (PID) has been observed to cause power output degradation in some fielded modules. Examples of such reports can be found in the literature.[16], [17], [18], [19], [20] Thus, an accelerated test to screen for PID susceptibility has been added in edition 2 of the IEC 61215 series, as MQT 21.

The PID test, MQT 21, is performed in parallel with other tests, in a new Sequence F. Sequence F requires two modules per installation polarity allowed by the manufacturer. If only one installation polarity is allowed, only two modules receive PID stress. However, all four modules are subjected to Gate No. 1 verification, in order to keep Gate No. 1 statistics independent of the number of allowed installation polarities.

The test procedure for MQT 21 is based on the previously published IEC TS 62804-1. The 85 °C / 85 % RH / 96 h stress ("85/85/96") stress utilized in IEC 61215 edition 2 is one of three stress level options in IEC TS 62804-1. Numerous accelerated test studies preceded the development of IEC TS 62804-1. PID has been studied to the extent that reviews of PID, including experimental dependencies, derived acceleration, and underlying mechanisms, can be found in the literature.[21], [22] Literature reports vary regarding acceleration factors. Equivalent outdoor exposure for the 85/85/96 stress utilized in IEC 61215 edition 2 has been estimated by different groups between 2 to 20 years,[23], [24], [25], [26], [27] for the effect of a humid climate (e.g. Florida, USA) on a crystalline Si module. The differences in the literature reports may reflect a need for utilization of different physical models in some studies, experimental uncertainty, and different behavior among the products tested.

All products (modules based on crystalline Si cells, or thin film cells) are subjected to the same stress conditions when executing MQT 21. The same stress conditions are applied even though it is likely that acceleration factors differ from one product to the next, particularly for thin film modules, where the underlying physical mechanism for PID is different than that in x-Si modules. It is estimated that the acceleration factors for thin film modules are substantially smaller than that of typical c-Si modules.[28], [29], [30] The methodology of defining stress levels that are empirically observed to separate failed versus successful fielded products, then applying these conditions to all modules, is rooted in the JPL block buy study,[31] which formed the basis for several of the IEC 61215 series stress tests. A few sentences explicitly stating the methodology of the IEC 61215 series (constant stress conditions across products) were added to the scope.

The 85 °C / 85 % RH / 96 h level is probably more stressful (in terms of years of equivalent exposure) than some other MQT's, for c-Si in most use environments. However, this relatively harsh condition was selected because:

- Data show thin film modules need a higher accelerated stress level than Si modules to reproduce early-life PID failures.
- Prior to the inclusion of a PID test in IEC 61215, several major module manufacturers had already selected the 85 °C / 85 % RH / 96 h stress level for internal qualification programs.
- Use of a light soak may lead to some power recovery, therefore justifying increasing the stress level.
- Increased use of modules in potentially harsh PID-prone environments, such as very rainy climates, may warrant a harsher test.

The way in which modules are mounted has been observed to affect PID.[32] [33] Thus, during the chamber test in IEC 61215 (and IEC TS 62804-1), on request by the manufacturer, modules might be mounted as described in the installation manual during testing, if the manufacturer states that PID resistance is achieved via mounting method.

PID stress on CIGS may be applied with a modest forward voltage bias applied across the internal circuit. These are the same conditions approved for the damp heat test (MQT 13) in IEC 61215-1-4:2021. The voltage bias prevents effects that do not occur when stress is applied under field-representative illumination.

A wet leakage current test (MQT 15) is part of the final measurements within MQT 21. This wet leakage current test is to be performed within 8 hours of the end of the PID stress, as in IEC TS 62804-1. The inclusion of the test, with a time limit, is motivated by the increase in leakage current seen in some modules during in-situ monitoring, and may have a time scale for reversibility that is similar to the PID.

A final stabilization, MQT 19.2, is performed prior to gate 2 on all modules that have been subjected to PID stress. The conditions for this final stabilization are described in the technology-specific parts (IEC 61215-1-x).

For crystalline Si modules, the final stabilization is a short light soak (2,0 kWh/m<sup>2</sup>) meant to reverse the effects of PID-polarization, which results from the movement of charge within the module,[34] as opposed to PID-shunting (PID-s), which results from movement of Na within the module, a slower process. Tests on some modules show that PID-polarization (PID-p) does not occur when PID stress is applied with field-representative illumination,[35] and thus should not be allowed to cause design qualification failure when administering a dark PID stress test. UV has been shown to be important in reversing PID-p.[36] Thus, the class CCC solar listed as required apparatus in MQT 19.2 shall fulfill the class C spectral requirements over at least the short-wavelength portion of the *extended* wavelength range described in IEC 60904-9, for stabilizations performed after PID testing. For bifacial modules, light is applied to the rear side during this stabilization.[37] Since a small amount of PID-s may reverse during a short light soak,[38] the light soak is applied to the front of monofacial modules, to obtain a consistent comparison of test results across module types.

For thin-film modules, the final stabilization is included to put metastabilities into the light-soaked state and obtain an accurate Gate No. 2 performance measurement. Thus, the thin-film light soak is performed in nearly the same manner as other thin-film final stabilizations (MQT 19.2). One additional requirement exists for final stabilization of thin-film modules after PID stress: Once the stabilization criterion is met, the light soak shall be terminated within two irradiation intervals (as defined in the technology-specific parts of MQT 19). This time limit is included to prevent attempts to reverse Na migration with extremely long light soaks that are many times that needed to account for metastability.

After the completion of MQT 21, module storage conditions between subsequent tests are controlled. Between these test steps, the modules are to be maintained indoors, in the dark, and at temperatures 25 °C or below. No more than 48 h elapse between the end of MQT 21 and the beginning of MQT 19.2. There is also time limit between MQT 19.2 and MQT 06.1: It is either 48 h or the time limit specified in the technology-specific stabilization procedure, whichever is shorter. These controls are intended to prevent attempts to reverse Na migration before Gate No. 2 via anomalous storage time and conditions.

## A.6 Simulator requirements

### A.6.1 General

Edition 2 revises both the spectral and uniformity requirements for simulators. (Notation for simulator classifications are defined according to IEC 60904-9. The AM1.5 spectral match is denoted by the first letter of the three-letter simulator classification. For example, a CBA simulator is categorized with a type C spectral match, a type B spatial uniformity, and a type A temporal stability.) The revision applies to simulator requirements in MQT 02 (maximum power determination), MQT 6.1 (performance at STC), and MQT 07 (performance at low irradiance).

IEC 61215-2:2016 allowed three options for simulators during the measurement listed above:

- a) a class BBA or better simulator plus a reference device of the same size and cell technology as the test sample,
- b) a BBA or better simulator, plus the spectral responsivity of the module, plus the spectral distribution of the solar simulator, and a data correction according to IEC 60904-7, or
- c) a AAA simulator. Several changes have been made to these requirements:
  - Type A spatial uniformity is required.
  - A simulator with type C or better spectral class may be utilized.
  - There are more possibilities for how one obtains data to use in a spectral mismatch correction (IEC 60904-7). The spectral response data may be taken by any test lab that is accredited for that measurement. The sample used to obtain the spectral response data may be the test module or may be a reference cell made with the same bill of materials as the test module.

- It is specifically stated that the component of uncertainty due to spectral mismatch shall be included  $m_1$ , the uncertainty used in evaluating Gate No. 1. Maximum allowable values for  $m_1$  are specified in the technology-specific parts.
- Use of either spectral mismatch correction or a matched reference module (or cell) is required.

The procedures in MQT 02 and MQT 6.1 are based on the most accurate measurement protocols that are practical with current technology. This high level of accuracy is appropriate for the nameplate verification and design qualification of IEC 61215. However, other types of documents refer to IEC 61215 maximum power determination. Such documents include warranties, quality assurance documents, and extended stress tests. A note has been included to remind users that less stringent requirements may be appropriate for non-IEC 61215 applications. The note reads: "MQT 02 measurement procedures are intended for minimal uncertainty, as performed by an accredited testing laboratory. Lesser requirements, such as use of CAB class simulators, may be appropriate for other applications, such as quality control in the factory. Applications that only require repeatability, such as comparing module performance before and after an extended stress, may wish to relax spectral mismatch correction requirements."

### A.6.2 Rationale for changes to spectral requirements

Revisions to the spectral requirements were made to limit possible spectral mismatch in a systematic manner, while still allowing test labs several practical choices as to how to achieve an acceptably accurate measurement.

The previous text of IEC 61215 allowed using a solar simulator with Class A spectral match for power rating measurements without spectral correction. This option was originally intended to provide one way to achieve a low spectral mismatch. However, more recent work has shown that requiring a Class A spectrum is neither necessary nor sufficient for low spectral mismatch.[40], [41], [42], [43] In other words, using a Class A spectrum does not guarantee a smaller spectral mismatch error than using a Class B or Class C spectrum. In some cases, spectral mismatch errors can even be larger for a Class A spectrum compared to Class C.[44], [45] The actual spectral mismatch error depends on the procedures, reference samples, and test samples used.

Therefore, the revised text of IEC 61215 has relaxed the spectral requirement to Class C, but includes wording regarding procedures to reduce spectral mismatch errors. The wording is basically the same as IEC 60904-7: either the solar simulator irradiance is calibrated using a reference sample having spectral response that is similar to the device under test, or a full calculation of the spectral mismatch error is made per IEC 60904-7.

Support for this position can be found in several literature studies. Excerpts from some of these studies are reproduced here (with bold type added for emphasis):

- ...**classification** of a solar simulator **does not provide any information about measurement errors**...related to photovoltaic performance measurements...such errors are dependent on the actual measurement devices and procedures used.[40]
- ...**spectral class** of a solar simulator **is not necessarily an indicator for the precision of measurement**. With appropriate reference devices and measurement procedures also class C spectral match yields a good comparability for c-Si PV modules.[41]
- ...the simulator with **the best spectral match (A+)** need not yield the best MMF [spectral mismatch factor].[42]
- **No benchmarking of solar simulators is therefore possible based only on the spectral match** information.[42]

...not always the spectrum of higher class would lead to the lower [spectral] mismatch factor. [43]

It is specifically stated that the component of uncertainty due to spectral mismatch shall be included in  $m_1$ , and maximum allowable values for  $m_1$  are specified in the technology-specific parts. As stated in IEC 61215-1:2021,  $m_1$  is to be calculated based either on measured spectral response or the worst-case possibility for a given technology type. Worst case possibilities can be evaluated from a combination of published data and the lab's database of measurements.

This approach provides several options for test labs unable to invest in a module spectral response system, while keeping uncertainty within reasonable bounds via limits on  $m_1$ . A lab may choose reference modules such that no spectral mismatch correction is needed. Size requirements on the matched reference module have been removed. The lab may also measure cell spectral response, where a reference cell with the same bill of materials as the test module is available. The lab may also obtain spectral response data on such a reference cell, or on the test module, from another accredited test lab.

### A.6.3 Rationale for changes to uniformity requirements

The change in simulator uniformity requirements from B to A was made based on an analysis of uncertainty in power rating which includes contributions from several factors including irradiance nonuniformity, current mismatch between cells within a module, spectral mismatch, module temperature, contact resistance, and the procedure(s) used to calibrate simulator irradiance. Uncertainty values listed below (in Table A.1) are from Figure 7 of the referenced work,[46] using a coverage factor  $k = 2$ .

**Table A.1 – Published uncertainty values as a function of simulator uniformity class**

Irradiance nonuniformity	Approximate power rating uncertainty due to all effects, when simulator irradiance is calibrated using a reference module's...	
	...maximum power	...short-circuit current
2 % (class A limit)	2,6 %	3,2 %
5 % (class B limit)	3,2 %	6,2 %

For modules with higher fill factor, such as new high-efficiency Si modules, effects of irradiance nonuniformity may be greater, since higher fill factor implies that a change in current changes the module power output more sharply. Based on this information, the project team decided the uncertainties for 5 % irradiance nonuniformity would be too large for some measurements, such as the maximum power determination of Gate No. 1.

Polls of working group 2 members representing test labs were performed during a working group 2 meeting and during a IEC 61215 new edition project team meeting. All such members in attendance indicated that they already use simulators with class A uniformity.

The new edition includes one exception to the new uniformity requirement. For evaluation of Gate No. 2, "very large" modules (as defined in IEC 61215-1:2021, 3.8) may be measured with a class B uniformity simulator. It is recognized that class A uniformity simulators larger than 2,2 m × 1,5 m are rarely commercially available at present, and thus imposing use of a class A uniformity simulator on a very large module creates an unfair barrier to qualification. At present, only a small fraction of the market is expected to utilize the exemption for very large modules. In future years, as module sizes and availability of very large simulators evolves, the size definition for a very large module should be adjusted accordingly.

## A.7 References to retest guidelines

IEC 61215 Edition 2 requires the use of IEC TS 62915 to determine if a retesting is needed. This requirement is stated as, "Retesting shall be performed according to IEC TS 62915." To avoid any future contradiction between IEC 61215-1 and IEC TS 62915, all further description of conditions that might generate the need for retesting have been removed from IEC 61215-1:2021.

## A.8 Weight on junction boxes

Poor adhesion of the junction box to the module has been observed in both fielded modules and accelerated tests.[47], [48], [49], [50] Thus, in edition 2, the thermal cycling test (MQT 11) is modified to include a 5N weight hanging from the junction box.

## A.9 Correction to monolithically-integrated hot-spot endurance test

IEC 61215-2 Edition 2 revises a portion of the monolithically-integrated (MLI) hot spot endurance test to correct errors in IEC 61215-2:2016. In IEC 61215-2:2016, incompatible procedures for testing wafer-based vs. MLI modules were inadvertently mixed in some of the MLI sections. Minor revisions were also made in places where the procedure was unclear or impossible to perform.

The hot-spot endurance test (MQT 09) is designed to determine the ability of the module to withstand hot-spot heating effects, such as those that could be caused by mismatched cells or shadowing. While there are test variations for different module types and circuitry, the test has certain commonalities across all module types:

- A worst-case shading condition is determined.
- This condition causes a current near  $I_{mp}$  (for unshaded conditions) to flow through the short-circuited module.
- The module is exposed to elevated temperature (50 °C) and the worst-case shading condition for at least 1 h.
- After stress, the module shall have no visual defects, a functional  $I-V$  curve, insulation resistance meeting the requirements of MQT 03, and wet leakage current meeting the requirements of MQT 15.

NOTE 1 Tests are derived from earlier editions of IEC 61215-2 and IEC 61646.

Despite these commonalities, some differences in test procedure between modules containing singulated or wafer-based cells and those containing MLI cells are necessary for the following reasons:

- a) It is difficult to shade a single MLI cell reproducibly, since cells have high aspect ratio (e.g. 0,5 cm × 1 m dimensions), and there are reflections inside the glass that make shading around edges not sharp. The wafer-based cell procedures involve shading a single cell.
- b) Some MLI cells may experience a decrease in shunt resistance when shaded.[51], [52] For the wafer-based modules, shading of individual cells is performed as a way to select cells that have certain pre-existing shunt resistances (low or high). For MLI cells, the act of shading individual cells is not likely to screen the cells, but rather to alter them. Thus, it is logical to apply shading stress to MLI cells, but not in an attempt to select which cells to test, as in the wafer-based procedure.

- c) Thin film cells often have a different nature of reverse bias characteristics than do Si cells. Thin-film reverse bias characteristics are in many cases not linear, [53], [54], [55] or are only linear over a voltage range that is too small for a comparison of shunt resistances according to the method of IEC 61215-2:2016, Figure 4. Thus, even if items a) and b) on this list could be overcome, it is still unlikely that one could use the method of Figure 4 to select cells of highest and lowest shunt resistance.
- d) The Si cell method assumes that shading one cell can reduce the current generated by the short-circuited module to  $I_{mp}$  (measured under full irradiance) or an even lower current. However, this reduction may not be achievable by fully shading one MLI cell. The difficulty occurs because there are typically many more MLI cells in a module, and the cells may be more conductive at a lower reverse bias compared to Si cells.

Because of the differences listed above, the thin film hot-spot test has relied upon shading blocks of cells, and finding how many cells shall be shaded to achieve the current reduction noted in the above list as d).

NOTE 2 This method of shading blocks of cells was utilized in IEC 61646:2008 (10.9) and IEC 61215-2:2016 (4.9.5.3.2, 4.9.5.3.4, and 4.9.5.3.5).

However, some errors were included in the MLI portion of IEC 61215-2:2016 MQT 09:

- 4.9.5.3.3 (MLI, SP case) erroneously called for the wafer-based single-cell shading method. (The single-cell shading method cannot be performed on MLI modules for reasons a) to d) listed above.)
- Three different MLI sections describing how to do the hot spot test on MLI SP modules were included in edition 1, but the three different SP cases actually require the same procedure. These three subclauses from edition 1 are 4.9.5.3.3 "Case SP", 4.9.5.3.4 "Case SP with inaccessible cell circuit and internal reverse bias protection", and 4.9.5.3.5 "Case SP with inaccessible cell circuit and no reverse bias protection". In all cases, the MLI cell circuit is treated as inaccessible, so there should be no distinction between 4.9.5.3.3 and 4.9.5.3.5. Furthermore, in MLI products, a single external bypass diode is utilized. Lateral conduction in the high aspect ratio MLI devices is limited by the conductivity of the transparent conducting thin film, so MLI products do not use internal bypass diodes. The test procedure is performed with the module short-circuited, making the external bypass diode irrelevant to the test procedure. (It turns on only when the module is in reverse bias.) Thus, there is no need to distinguish between cases 4.9.5.3.3 and 4.9.5.3.4.

These errors are corrected in the new edition of IEC 61215-2:2021. Several changes were made to do so:

- 4.9.5.3.3, 4.9.5.3.4, and 4.9.5.3.5 from IEC 61215-2:2016 are combined into a single "Case SP" section. Thus, in the new edition of IEC 61215-2:2021, there are three cases for MLI modules in MQT 09: S, SP, and PS. These are the same three cases formerly utilized in IEC 61646:2008.
- The single-cell shading method used for the wafer-based modules is not utilized for any case in MLI modules.
- In some places, minor changes to wording were made to clarify, but not modify, the test procedure.

Minor revisions were also made in places where the MLI hot-spot endurance procedure was unclear or impossible to perform:

- The symbol "N" rather than "P" is used to denote the number of parallel strings to avoid confusion with power, which is also denoted by "P."
- The acceptable range for currents is now based on  $I_{mp}$ , not  $P_{mp}$ . These two ways of specifying the range yield nearly the same results, and specifying the current is much clearer. IEC 61215-2:2016 was not explicit regarding how to determine the range in translating from  $P$  to  $I$ . (For example, is the tester allowed to interpolate between points using a previously-measured  $I-V$  curve?)

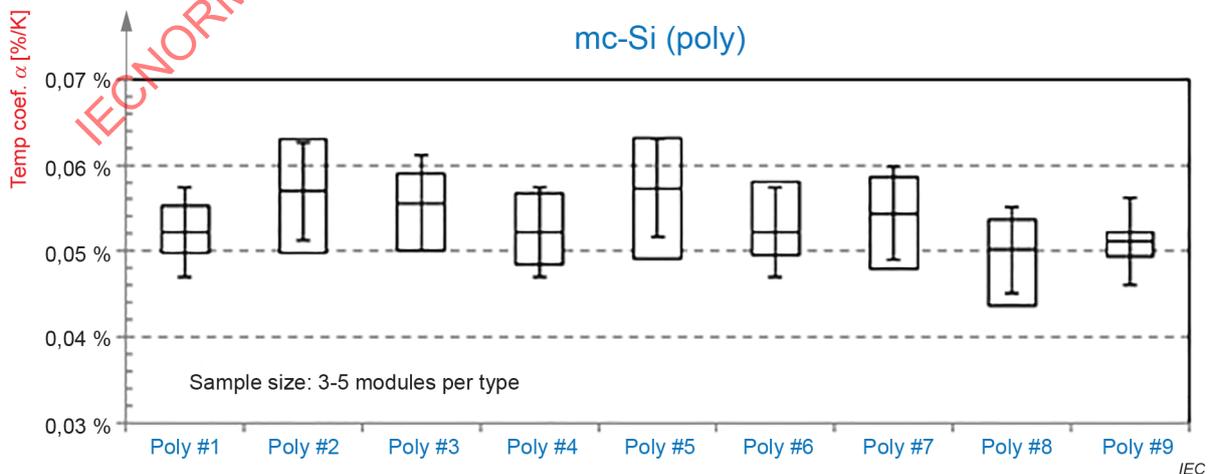
- The acceptable window for current during extended stress is widened by changing the lower limit from 99 % to 95 % of the maximum. If the simulator irradiance can change by  $\pm 2\%$  over the test (as is explicitly stated), it is not reasonable to ask to keep the current within a 1 % window. For some modules, it was observed that shading even one cell dropped the current below the specified range.
- A minimum mask size of two cell widths is specified. For reason a) described earlier in this section, test reproducibility suffers if the mask size is reduced further.
- When moving the mask across the module, a minimum number of steps is specified.
- The acceptable irradiance range for cell selection with an optional simulator is modified from "800 to 1 000 W/m<sup>2</sup>" previously to "800 to 1 100 W/m<sup>2</sup>" in the new edition. With this change, any irradiance produced by the required simulator for 1 h stress (at 1 000  $\pm$  100 W/m<sup>2</sup>) is also acceptable for cell selection procedures.
- Other small clarifying changes to the wording have been made.

**A.10 Number of modules in sequence**

Sequence A, as defined in either IEC 61215-1:2016 or IEC 61215-1:2021, is comprised of MQT 07 (performance at low irradiance) and MQT 04 (measurement of temperature coefficients). Two changes were made to sequence A to allow it to be performed more efficiently, but without losing valuable information.

First, the number of modules required for sequence A has been reduced from three in IEC 61215-1:2016, to one in IEC 61215-1:2021. A study of temperature coefficients showed that for modules of a given cell technology, one cannot distinguish between the temperature coefficients of different products. For sample sets of three to five modules of each product type, the variability of temperature coefficients within each product type is as large as the difference between the products. The variability may be due either due to measurement uncertainty or product inconsistency. An example of data from this study is shown in Figure A.1. Boxes represent the variability within each product type, and the error bars show the measurement uncertainty. As the purpose of the IEC 61215 series is design qualification, not forecasting energy production, it is not defensible to require the measuring of many modules in sequence A in an attempt to reduce the uncertainty on the derived quantities. Furthermore, decreasing the number of modules in sequence A by two does not worsen the statistics on modules passing Gate No. 1, since four modules have been added to sequence F.

Second, it is explicitly stated in edition 2 that the measurements of sequence A may be performed in any order, or may be performed on two separate modules, if desired.



**Figure A.1 – Derived temperature coefficients (α) for nine different mc-Si products types**

## A.11 Removal of nominal module operating temperature (NMOT)

Edition 1 of the IEC 61215 series (published in 2016) was the first time that NMOT has been required for PV module design qualification. Earlier versions of IEC 61215 and similar standards required only nominal operating cell temperature (NOCT). In 2017, a number of test laboratories around the world reported that the strict data filtering required by the NMOT procedure was causing NMOT measurements to take more than 6 months in some locations, an unacceptable time period for IEC 61215 qualification. The NMOT procedure is described in IEC 61853-2, which is referenced by IEC 61215-2:2021.

To rectify the unacceptable measurement time, three alternatives were proposed:

- a) Put exceptions to the NMOT data filtering (as specified in IEC 61853-2) into the IEC 61215 test, making the test completion time shorter when performed as a part of IEC 61215.
- b) Amend IEC 61853-2 to allow the test to be completed more quickly.
- c) Remove the NMOT test from IEC 61215 edition 2.

In choosing between these alternatives, the project team considered the following information:

- It is undesirable to create two different versions of the same test by putting many exceptions in the referencing standard. Upkeep on the test procedure shall be performed in both locations, and the two tests yield information that is named the same but is not equivalent.
- The purpose of the IEC 61853 series is to "characterize the modules at a wide range of temperatures, irradiances, angles of incidence, and spectra," in order to "accurately predict the energy production of the modules under various field conditions," as taken from the IEC 61853-2:2016 introduction. The IEC 61853 series defines a methodology for energy prediction.
- The goal of IEC 61215 is module design qualification, i.e. whether a module of a particular design is likely to last in the field.
- Thus, NMOT does not relate to the objective of IEC 61215.
- NMOT tests have an uncertainty (typically  $\pm 4$  °C) that is larger than the actual operating temperature difference between most module types.
- Datasheet NMOT and NOCT values are not heavily used. It is more common to use thermal model coefficients (such as those provided with PVsyst, for example) to account for thermal effects in energy generation.
- To make NMOT a useful measurement, it may be required to increase – not decrease – data collection time, or to perform data collection in individualized side-by-side tests designed for comparing a small set of different module types.
- Thus, limiting the data collection time in IEC 61853-2 in order to keep IEC 61215 qualification time reasonable may prevent the NMOT test from ever yielding meaningful data.

The above points led the project team to remove the NMOT test (MQT 05) and the associated "performance at NMOT" test (MQT 06.2).

### A.12 Very low currents during thin-film tests

Edition 2 contains revisions to mitigate the difficulty of controlling very low currents in thin film modules during some tests. In two tests, a fraction of the module's STC peak power current ( $I_{mp}$ ) is applied during a test. This application of current occurs during the humidity-freeze test (MQT 12), and during the thermal cycling test (MQT 11). In MQT 12, 0,5 %  $I_{mp}$  is applied, as specified in IEC 61215-2. In MQT 11, the applied current is specified in the technology-specific parts. For CdTe, a-Si, or CIGS, the applied currents are 0,1  $I_{mp}$ , as specified in IEC 61215-1-2:2021, IEC 61215-1-3:2021, and IEC 61215-1-4:2021. For smaller cells, these specified currents may be so small that they are impractical to monitor and control. Thus, the wording in each of these cases has been revised to call for the previously-designated fraction of  $I_{mp}$ , or 100 mA, whichever is larger.

### A.13 Limit bypass diode testing to three diodes

Edition 2 contains a revision to keep the bypass diode testing procedure practical, even in some newer module designs that have dozens of bypass diodes embedded in the laminate. The edition 1 bypass diode test (MQT 18) required repetition of the test procedure on all bypass diodes, and electrical access to each diode. If a standard production module did not allow electrical access to each diode, the manufacture needed to provide a special module with electrical access to the diodes to complete the test. The procedure was written to suit modules having a few diodes in a junction box. All diodes were tested, since the positioning of the diode within the junction box (e.g. edge or middle) is likely to be important in determining the thermal environment when the diodes are flowing current. However, for newer designs containing dozens of bypass diodes embedded in the module package, making a special sample that allows access to each diode is no longer practical. Furthermore, the individual testing of each diode is very-time consuming, without yielding useful information beyond what one obtains from testing a few diodes. Thus, in edition 2, for modules containing four or more bypass diodes, MQT 18 is only performed on three of them. The three diodes are selected for test based on their location, which may be important to the thermal environment. Selecting the diodes for test based on location has precedent in IEC 62108:2016, 10.11 for CPV module and assembly design qualification.

### A.14 Revert the insulation test to 2005 version

Changes were made to the insulation test (MQT 03) from the IEC 61215:2005 to IEC 61215-2:2016. These changes involved how foil covering is used during the test, as summarized in Table A.2.

**Table A.2 – Summary of foil placement during insulation test in three different versions.**

Module type	IEC 61215:2005 Foil placement	IEC 61215-2:2016 Foil placement	IEC 61215-2:2021 Foil placement
Frameless	Edges and back	Edges, plus all polymeric surfaces	Edges
Framed with poor conductor	Edges and back	Edges, plus all polymeric surfaces	Edges
Framed	None	All polymeric surfaces	None

A major concern associated with the IEC 61215-2:2016 foil configuration is the inability to detect surface tracking when all polymeric surfaces are covered, since one of the test requirements is "no dielectric breakdown or surface tracking." It is also undesirable that the capacitance introduced by covering a large area disables the test equipment's arc discharge detection. As arc discharge is a precursor to dielectric breakdown, useful information is lost. It is also possible that various test laboratories may approach covering the junction box with foil differently, thus causing variability in the test. Edition 2 therefore reverts to the 2005 version

of the test, and also removes the 2005 requirement of covering the entire back of a frameless module with foil.

The applied levels in MQT 03 have been harmonized with IEC 61730. Thus, a module that is undergoing simultaneous safety and design qualification need not have the test performed twice under slightly different conditions. Furthermore, a module cannot pass design qualification if it would fail an insulation test necessary for safety.

### **A.15 Bending test**

Edition 2 adds a bending test (MQT 22) for modules that are described as "flexible" on the manufacturer label or datasheet. The modules are bent around a cylinder to the minimum radius specified on the label or datasheet.

### **A.16 Stabilization option for boron oxygen LID (MQT 19.3)**

Boron-oxygen light-induced degradation (BO-LID) is a well-known effect in Si.[61] Recently, published studies have indicated that temporary changes in the states of BO-LID defects may impact IEC 61215 qualification tests. Data suggest that thermal cycling may cause a transition from the degraded state to the regenerated state,[62] causing an apparent increase in performance after thermal cycling for modules shipped in a with BO-LID defects in the initial ("A") or degraded ("B") state. Furthermore, damp heat may cause modules shipped in the stabilized state ("C") to undergo an apparent decrease in performance that is not field-representative.[62],[63] Damp heat may also cause degraded BO-LID defects to transition from B to A for modules that are not stabilized, causing an apparent performance increase.

The project team unanimously agreed that the IEC 61215 series should deal with stabilization of modules with BO-LID defects more comprehensively than the previous version. However, before making large changes, the project team would like to complete an experimental study of each option for stabilization suggested by team members. Thus, this edition of the IEC 61215 series only addresses the most urgent case: modules that may fail a test because of BO-LID changes that are not field-representative. To address this case, BO-LID stabilization (MQT 19.3) is introduced in IEC 61215-2:2021, following conditions recommended in the literature.[63] Performing this stabilization after damp heat testing is required for Si modules in IEC 61215-1-1:2021.

The important, but less urgent, cases of modules that may exhibit an apparent performance increase due to BO-LID effects during stress tests will be addressed in a future amendment.

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## COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

**MODULES PHOTOVOLTAÏQUES (PV) POUR APPLICATIONS  
TERRESTRES – QUALIFICATION DE LA CONCEPTION ET  
HOMOLOGATION –****Partie 1: Exigences d'essai****AVANT-PROPOS**

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Cette deuxième édition de l'IEC 61215-1 annule et remplace la première édition de l'IEC 61215-1 parue en 2016, dont elle constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

- a) Ajout d'un essai issu de l'IEC TS 62782.
- b) Ajout d'un essai issu de l'IEC TS 62804-1.

- c) Ajout de méthodes d'essai exigées pour les modules flexibles. Cette disposition inclut l'ajout de l'essai de flexion (MQT 22).
- d) Ajout de définitions, références et instructions concernant le mode de réalisation de la qualification de la conception et de l'homologation IEC 61215 des modules photovoltaïques bifaces.
- e) Clarification des exigences relatives aux mesurages de la puissance de sortie.
- f) Ajout de poids à la boîte de jonction pendant 200 cycles thermiques.
- g) Exigence stipulant de réaliser un contre-essai conformément à l'IEC TS 62915.
- h) Suppression de l'essai nominal de fonctionnement du module (NMOT - *nominal module operating test*), et de l'essai associé de performances à la température nominale de fonctionnement du module (NMOT - *nominal module operating temperature*), issus de la série IEC 61215.

L'Annexe informative A explique le contexte et le raisonnement qui justifient certaines modifications les plus importantes apportées à la série IEC 61215 dans l'évolution de l'édition 1 à l'édition 2.

Le texte de cette Norme internationale est issu des documents suivants:

FDIS	Rapport de vote
82/1828A/FDIS	82/1848/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à l'approbation de cette Norme internationale.

La version française de la norme n'a pas été soumise au vote.

Ce document a été rédigé selon les Directives ISO/IEC, Partie 2.

Une liste de toutes les parties de la série IEC 61215, publiées sous le titre général *Modules photovoltaïques (PV) pour applications terrestres – Qualification de la conception et homologation*, peut être consultée sur le site web de l'IEC.

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## INTRODUCTION

Alors que la Partie 1 de la présente série de normes décrit les exigences (en termes généraux et spécifiques par rapport à la technologie du dispositif), les sous-parties de la Partie 1 définissent les variations technologiques, tandis que la Partie 2 définit un ensemble de procédures d'essai nécessaires pour la qualification de la conception et l'homologation. Les procédures d'essai décrites dans la Partie 2 sont valides pour toutes les technologies de dispositifs.

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# MODULES PHOTOVOLTAÏQUES (PV) POUR APPLICATIONS TERRESTRES – QUALIFICATION DE LA CONCEPTION ET HOMOLOGATION –

## Partie 1: Exigences d'essai

### 1 Domaine d'application

Le présent document établit les exigences concernant la qualification de conception des modules photovoltaïques terrestres appropriés à un fonctionnement de longue durée dans des climats à l'air libre. La durée de vie utile des modules ainsi qualifiés dépend de leur conception, de leur environnement et de leurs conditions de fonctionnement. Les résultats d'essai ne sont pas une prévision quantitative de la durée de vie des modules.

Sous des climats pour lesquels les températures de fonctionnement du 98<sup>e</sup> centile dépassent 70 °C, il est recommandé que les utilisateurs tiennent compte des essais dans des conditions d'essai à des températures plus élevées telles qu'elles sont décrites dans l'IEC TS 63126. Il est recommandé que les utilisateurs qui recherchent la qualification de produits PV dont la durée de vie prévue est inférieure tiennent compte des essais conçus pour les PV de l'électronique grand public, tels qu'ils sont décrits dans l'IEC 63163 (en cours d'élaboration). Les utilisateurs qui souhaitent avoir l'assurance que les caractéristiques soumises à l'essai dans l'IEC 61215 apparaissent de manière constante dans un produit fabriqué peuvent souhaiter utiliser l'IEC 62941 pour ce qui concerne les systèmes de qualité pour la fabrication des modules photovoltaïques.

Le présent document est destiné à s'appliquer à tous les matériaux de modules à plaque plane pour applications terrestres, tels que les types de modules au silicium cristallin et les modules à couches minces. Il ne s'applique pas aux systèmes qui ne constituent pas des applications de longue durée, comme les modules flexibles installés dans des auvents ou des tentes.

Le présent document ne s'applique pas aux modules utilisés avec un ensoleillement intense, même s'il peut être utilisé pour les modules à faible concentration (ensoleillement 1 à 3). Pour les modules à faible concentration, tous les essais sont réalisés en utilisant les niveaux d'éclairement, de courant, de tension et de puissance prévus à la concentration théorique.

Le présent document ne traite pas des particularités des modules PV à électronique intégrée. Toutefois, il peut être utilisé comme fondement pour soumettre à l'essai de tels modules PV.

L'objet de cette séquence d'essais est de déterminer les caractéristiques électriques du module et d'indiquer, dans la mesure du possible avec des contraintes de coût et de temps raisonnables, que le module est capable de supporter une exposition prolongée en site naturel. Les conditions d'essai accélérées sont fondées de manière empirique sur les conditions nécessaires pour reproduire les défaillances sur le terrain observées sélectionnées et sont appliquées de manière égale aux types de modules. Les facteurs d'accélération peuvent varier avec la conception du produit et ainsi les mécanismes de dégradation peuvent ne pas tous se produire. D'autres informations générales concernant les méthodes d'essai accélérées y compris les définitions des termes peuvent être consultées dans l'IEC 62506.

Certains mécanismes de dégradation à long terme ne peuvent raisonnablement être détectés que par l'intermédiaire d'essais des composants, car une longue période est nécessaire à l'apparition des défaillances et car des conditions de contraintes chères à produire sur des zones étendues sont nécessaires. Les essais de composants qui ont atteint un niveau de maturité suffisant pour établir un degré élevé de confiance des critères d'acceptation/de refus

sont intégrés dans la série IEC 61215 au sein du Tableau 1. À l'inverse, les procédures d'essai décrites dans cette série sont effectuées sur des modules dans l'IEC 61215-2.

## 2 Références normatives

Les documents suivants sont cités dans le texte de sorte qu'ils constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60269-6, *Fusibles basse tension – Partie 6: Exigences supplémentaires concernant les éléments de remplacement utilisés pour la protection des systèmes d'énergie solaire photovoltaïque*

IEC 60891, *Dispositifs photovoltaïques – Procédures pour les corrections en fonction de la température et de l'éclairement à appliquer aux caractéristiques I-V mesurées*

IEC 60904-1, *Dispositifs photovoltaïques – Partie 1: Mesurage des caractéristiques courant-tension des dispositifs photovoltaïques*

IEC TS 60904-1-2:2019, *Photovoltaic devices - Part 1: Measurement of current-voltage characteristics of bifacial photovoltaic (PV) devices* (disponible en anglais seulement)

IEC 60904-3, *Dispositifs photovoltaïques – Partie 3: Principes de mesure des dispositifs solaires photovoltaïques (PV) à usage terrestre incluant les données de l'éclairement énergétique spectral de référence*

IEC 60904-10, *Dispositifs photovoltaïques – Partie 10: Méthodes de mesure de la dépendance linéaire et de la linéarité*

IEC TS 60904-13, *Photovoltaic devices – Part 13: Electroluminescence of photovoltaic modules* (disponible en anglais seulement)

IEC 61140, *Protection contre les chocs électriques - Aspects communs aux installations et aux matériels*

IEC 61215-2, *Modules photovoltaïques (PV) pour applications terrestres – Qualification de la conception et homologation – Partie 2: Procédures d'essai*

IEC 61730-1, *Qualification pour la sûreté de fonctionnement des modules photovoltaïques (PV) – Partie 1: Exigences pour la construction*

IEC 61730-2, *Qualification pour la sûreté de fonctionnement des modules photovoltaïques (PV) – Partie 2: Exigences pour les essais*

IEC TS 61836, *Solar photovoltaic energy systems – Terms, definitions and symbols* (disponible en anglais seulement)

IEC 61853-1, *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*

IEC TS 62782, *Photovoltaic (PV) modules – Cyclic (dynamic) mechanical load testing* (disponible en anglais seulement)

IEC 62790, *Boîtes de jonction pour modules photovoltaïques - Exigences de sécurité et essais*

IEC TS 62804-1, *Photovoltaic (PV) modules – Test methods for the detection of potential-induced degradation – Part 1: Crystalline silicon* (disponible en anglais seulement)

IEC 62852, *Connecteurs pour applications en courant continu pour systèmes photovoltaïques – Exigences de sécurité et essais*

IEC TS 62915, *Photovoltaic (PV) modules – Type approval, design and safety qualification – Retesting* (disponible en anglais seulement)

IEC 62941, *Modules photovoltaïques (PV) pour applications terrestres – Système de qualité pour la fabrication des modules photovoltaïques*

IEC TS 63163 –<sup>1</sup> *Terrestrial photovoltaic (PV) modules for consumer products – Design qualification and type approval* (disponible en anglais seulement)

Guide ISO/IEC 98-3, *Incertitude de mesure – Partie 3: Guide pour l'expression de l'incertitude de mesure (GUM:1995)*

### 3 Termes, définitions et termes abrégés

Pour les besoins du présent document, les termes et définitions de l'IEC TS 61836, ainsi que les suivants s'appliquent.

L'ISO et l'IEC tiennent à jour des bases de données terminologiques destinées à être utilisées en normalisation, consultables aux adresses suivantes:

- IEC Electropedia: disponible à l'adresse <http://www.electropedia.org/>
- ISO Online browsing platform: disponible à l'adresse <http://www.iso.org/obp>

#### 3.1

##### **tranches de classes de puissance**

critères de tri de la puissance (habituellement la puissance maximale) du fabricant du module PV

#### 3.2

##### **tolérances <sur l'étiquette>**

plage de valeurs des paramètres électriques figurant sur l'étiquette du module PV, telle que fournie par le fabricant

#### 3.3

##### **MQT**

essai de qualité du module

Note 1 à l'article: L'abréviation "MQT" est dérivée du terme anglais développé correspondant "Module Quality Test".

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<sup>1</sup> En cours d'élaboration. Stade au moment de la publication: ADTS.

### 3.4 homologation

essai de conformité effectué sur un ou plusieurs échantillons représentatifs de la production

[SOURCE: IEC 60050-581:2008, 581-21-08 – essai de type]

### 3.5 reproductibilité <des mesures>

étroitesse de l'accord entre les résultats des mesures de la même valeur d'une grandeur, dans le cas où les mesures individuelles sont effectuées en faisant varier les conditions de mesure:

- principe de mesure,
- méthode de mesure,
- observateur,
- appareils de mesure,
- étalons de référence,
- laboratoire,
- dans des conditions d'utilisation des appareils de mesure différentes de celles usuellement employées,

après des intervalles de temps assez longs par rapport à la durée d'une seule mesure [conformément au Vocabulaire International de Métrologie (VIM) 3.7]

Note 1 à l'article: Les notions de "principe de mesure" et de "méthode de mesure" sont définies respectivement dans le VIM, en 2.3 et 2.4.

Note 2 à l'article: Le terme "reproductibilité" s'applique également au cas où seules certaines des conditions ci-dessus sont prises en considération, dans la mesure où ces conditions sont indiquées.

Note 3 à l'article: Il est recommandé que les laboratoires déterminent leur reproductibilité conformément aux formules et principes de l'ISO 5725-2.

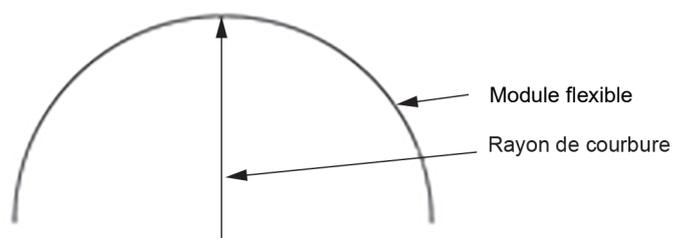
[SOURCE: IEC 60050-311:2001, 311-06-07]

### 3.6 module flexible

module photovoltaïque ayant un rayon de courbure inférieur ou égal à 500 mm, dans au moins une direction selon la spécification du fabricant et capable de flexion afin d'être conforme à une surface plane ou à une surface courbe

Note 1 à l'article: Un module courbe de forme rigide n'est pas considéré comme un module flexible.

Note 2 à l'article: Le rayon de courbure est défini tel que cela est représenté à la Figure 1. Lors d'un essai, le rayon de courbure appliqué n'est pas inférieur à celui spécifié par le fabricant.



IEC

Figure 1 – Représentation géométrique du rayon de courbure d'un module flexible

### 3.7

#### **échantillon représentatif**

échantillon qui inclut tous les composants du module, sauf certaines parties reproduites

Note 1 à l'article: Les échantillons représentatifs doivent utiliser tous les matériaux et sous-ensembles essentiels, comme cela est décrit à l'Article 4.

### 3.8

#### **module de très grande taille**

module dont la taille dépasse celle des simulateurs classiques du commerce (2,2 m × 1,5 m)

Note 1 à l'article: Un module de très grande taille dépasse 2,2 m de longueur ou de largeur, ou dépasse 1,5 m dans les deux dimensions. Ainsi, un module de 3 m × 0,3 m est considéré comme un module de très grande taille, tout comme un module de 2,2 m × 2,2 m.

Note 2 à l'article: Les modules de très grande taille sont exemptés des exigences d'uniformité de l'éclairage spatial d'un simulateur de classe A, comme cela est décrit dans l'essai MQT 02 de l'IEC 61215-2.

Note 3 à l'article: Pendant les séquences d'essais, des échantillons représentatifs peuvent se substituer aux modules de très grande taille, dans les limites décrites à l'Article 4.

Note 4 à l'article: Dans les versions ultérieures, les dimensions de seuil pour qu'un module soit considéré comme de très grande taille seront probablement augmentés.

### 3.9

#### **modules photovoltaïques bifaces**

modules qui peuvent convertir l'irradiation reçue à la fois sur la face avant et sur la face arrière en énergie électrique par le biais de l'effet photovoltaïque

### 3.10

#### **coefficients de bifacialité**

rappports entre les caractéristiques  $I-V$  de la face arrière et de la face avant d'un module biface, chaque caractéristique étant mesurée dans les conditions normales d'essai (STC - *Standard Test Conditions*) (IEC TS 61836), à savoir le coefficient de bifacialité sous courant de court-circuit  $\phi_{ISC}$ , le coefficient de bifacialité sous tension de circuit ouvert  $\phi_{VOC}$  et le coefficient de bifacialité sous puissance maximale  $\phi_{Pmax}$

Note 1 à l'article: Les coefficients de bifacialité sont définis de manière exhaustive au 6.2 de l'IEC TS 60904-1-2:2019.

### 3.11

#### **éclairage de plaque signalétique biface**

##### **BNPI**

éclairage le plus élevé auquel est effectuée la vérification de la plaque signalétique des modules bifaces qui correspond à 1 000 W/m<sup>2</sup> à l'avant du module et à 135 W/m<sup>2</sup> à l'arrière du module, appliqué à toute méthode admise par l'IEC TS 60904-1-2

Note 1 à l'article: L'abréviation "BNPI" est dérivée du terme anglais développé correspondant "bifacial nameplate irradiance".

### 3.12

#### **éclairage de contrainte biface**

##### **BSI**

éclairage le plus élevé auquel sont mesurés les courants de contrainte sur les modules bifaces qui correspond à 1 000 W/m<sup>2</sup> à l'avant du module et à 300 W/m<sup>2</sup> à l'arrière du module, appliqué par toute méthode admise par l'IEC TS 60904-1-2, caractéristique  $I-V$  à laquelle peut extrapolé à partir d'éclairages inférieurs

Note 1 à l'article: L'abréviation "BSI" est dérivée du terme anglais développé correspondant "bifacial stress irradiance".

## 4 Échantillons d'essai

Les échantillons de modules PV doivent avoir été fabriqués à partir des matériaux et composants spécifiés conformément aux schémas et fiches de procédés correspondants, et doivent avoir été soumis aux procédures normales d'examen, de contrôle qualité et d'acceptation de la production du fabricant. Les modules PV doivent être complets jusque dans les moindres détails et doivent être accompagnés des instructions de manipulation, de montage et de raccordement du fabricant. Lorsque les modules PV à soumettre aux essais sont des prototypes d'une nouvelle conception et non issus de la production, ce fait doit être noté dans le rapport d'essai (voir l'Article 9).

Le nombre d'échantillons d'essai exigés est déduit à partir des séquences d'essais applicables (voir l'Article 11).

Certains essais tels que l'essai de la diode de dérivation MQT 18 peuvent exiger des échantillons d'essai spéciaux (voir l'IEC 61215-2).

Pour la qualification de plusieurs tranches de classes de puissance dans les limites données par l'IEC TS 62915, au moins 2 modules par classe de puissance (supérieure, intermédiaire et inférieure) doivent être utilisés lors des essais. Si la classe de puissance intermédiaire n'existe pas, la classe supérieure suivante doit être utilisée. Si la qualification d'une seule classe de puissance doit être étendue à d'autres tranches de classes de puissance dans les limites données par l'IEC TS 62915, alors au moins deux modules par classe de puissance (supérieure et inférieure) doivent être utilisés lors de la vérification des valeurs d'étiquette (voir point 1 de 7.2.1). Si une classe de puissance est étendue uniquement vers des tranches supérieures (ou inférieures), alors seuls les modules des tranches supérieures (ou inférieures), respectivement, doivent être utilisés pour vérifier les valeurs d'étiquette assignées.

La qualification selon plusieurs classes de puissance ne renforce pas l'exigence minimale d'un échantillon de contrôle utilisé en 7.2.3.

Il est conseillé de fournir des échantillons de réserve supplémentaires satisfaisant aux mêmes exigences de puissance de sortie.

Le cas échéant, les échantillons d'essai doivent être utilisés pour représenter un groupe ou une famille de produits, ou des variations dans la composition des matériaux, ou les procédés de fabrication utilisés pour la fabrication des modules. Les échantillons supplémentaires exigés pour le programme d'essai sont alors dérivés de l'IEC TS 62915.

Pour les modules de très grande taille (tels qu'ils sont définis au 3.8), des échantillons représentatifs (tels qu'ils sont définis en 3.7) peuvent être utilisés pour tous les essais de qualification indiqués à l'Article 11 et dans l'IEC 61215-2. Lors de la conception et de la fabrication des échantillons représentatifs, il convient d'accorder une attention particulière à l'obtention de la similarité maximale au produit en taille réelle pour toutes les caractéristiques électriques, mécaniques et thermiques associées à la qualité et à la fiabilité. La cellule, les méthodes d'encapsulation, les interconnexions, les sorties, les distances d'isolement et les lignes de fuite à proximité des bords, et la distance d'isolement dans une isolation solide (isolation attendue et joints scellés) doivent être les mêmes uniquement dans les produits en taille réelle. Des limites sont appliquées concernant le degré de réduction des dimensions d'un module de très grande taille qui peut être utilisé lors de la constitution d'échantillons représentatifs pour l'essai de qualification. La ou les dimensions réduites ne doivent pas être inférieures à la moitié des dimensions qui définissent un module de très grande taille. Autrement dit, lorsque la dimension la plus courte est réduite, l'échantillon représentatif doit être d'au moins 0,75 m de largeur. Lorsqu'on réduit la dimension la plus longue, l'échantillon représentatif doit être d'au moins 1,1 m de longueur. Si des échantillons représentatifs sont utilisés pour un essai quelconque, le rapport d'essai doit comprendre un tableau donnant les dimensions du produit en qualification, et pour chaque MQT, les dimensions des échantillons soumis à l'essai. Le tableau doit contenir l'énoncé "Des échantillons plus petits ont été utilisés

pour certains essais comme cela est indiqué ci-dessus. L'utilisation de tels échantillons peut affecter les résultats d'essai." Pour la détermination de la dégradation de puissance maximale lors d'un essai (7.2.3) sur un échantillon représentatif,  $P_{\max}(\text{Lab\_GateNo.1})$  fait référence à la puissance de sortie mesurée stabilisée initiale de l'échantillon représentatif. Toutefois, pour la vérification des valeurs d'étiquette assignées (7.2.2), un produit de fabrication courante doit être mesuré, soit au laboratoire d'essai, soit en réalisant un essai dans les locaux du fabricant sous surveillance de l'entité qui réalise l'essai.

Si des échantillons représentatifs sont utilisés dans la séquence d'essais E, un module supplémentaire, de taille réelle, est alors exigé, et ne doit être soumis qu'au MQT 16 (essai de charge mécanique statique) et aux exigences qu'il contient.

Tout échantillon représentatif utilisé pour le MQT 09 (essai de tenue à l'échauffement localisé) doit contenir le même nombre de cellules par diode de dérivation (c'est-à-dire la même taille de sous-chaîne) que le produit en taille réelle.

NOTE Dans tout essai, il est préférable de mesurer un échantillon en taille réelle, plutôt qu'un échantillon représentatif, lorsque la taille de l'équipement le permet.

Préalablement à l'essai de qualification, il convient de veiller à ne pas endommager les échantillons transportés. Cette attention peut inclure le respect des meilleures pratiques de conditionnement et d'expédition,<sup>[1]<sup>2</sup></sup> ainsi que l'application d'une imagerie par électroluminescence conformément à l'IEC TS 60904-13, avant et après l'expédition afin de vérifier l'absence de fissures par suite du transport.

Pour les exigences propres à la série IEC 61215, un module doit être considéré comme biface si le fabricant revendique cette caractéristique sur la plaque signalétique ou la fiche technique, ou si le module présente un coefficient de bifacialité sous puissance maximale  $\geq 20\%$ . Si un module doit être soumis à l'essai en tant que module monoface, le laboratoire d'essai doit vérifier que le module est monoface au moyen d'une des méthodes suivantes au moins:

- a) Information du fabricant indiquant que l'arrière de la cellule est entièrement métallisé;
- b) Données de transmission de la face arrière résolues spectralement fournies par le fabricant; ou
- c) Détermination du coefficient de bifacialité sur un échantillon conformément à la procédure de l'IEC TS 60904-1-2.

## 5 Marquage et documentation

### 5.1 Plaque signalétique

Chaque module doit porter les marquages clairs et indélébiles suivants: Sauf indication contraire, tous les paramètres électriques font référence aux STC:

- a) le nom, la raison sociale ou la marque déposée du fabricant;
- b) la désignation du type ou du numéro de modèle;
- c) le numéro de série (sauf marquage à un autre emplacement sur le produit);
- d) la date et le lieu de fabrication; en variante, un numéro de série permettant de connaître la date et le lieu de fabrication;
- e) la tension de réseau maximale;

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<sup>2</sup> Les chiffres entre crochets renvoient à la Bibliographie.

- f) la classe de protection contre les chocs électriques (telle qu'elle est définie dans l'IEC 61140 et l'IEC 61730-1);
- g) la tension en circuit ouvert ou  $V_{OC}$  tolérances incluses; Pour les modules bifaces, le tension en circuit ouvert. doit être consigné dans le rapport d'essai à deux niveaux d'éclairement. Le premier niveau d'éclairement exigé est de 1 000 W/m<sup>2</sup>. Le second niveau d'éclairement exigé est le BNPI, tel qu'il est défini en 3.11.
- h) le courant en court-circuit ou  $I_{SC}$  tolérances incluses; Pour les modules bifaces, le courant de court-circuit doit être consigné dans le rapport d'essai à deux niveaux d'éclairement, définis en 5.1g).
- i) la puissance maximale du module ou  $P_{max}$  y compris les tranches et les tolérances telles qu'elles sont définies en 3.1 et 3.2. Pour les modules bifaces,  $P_{max}$  doit être consignée aux deux niveaux d'éclairement, définis en 5.1 g).
- j) Pour les modules bifaces, les informations suivantes y compris les tolérances, doivent être indiquées sur la plaque signalétique: Les valeurs du coefficient de bifacialité sous courant de court-circuit  $\phi_{ISC}$ , du coefficient de bifacialité sous tension en circuit ouvert  $\phi_{VOC}$ , et du coefficient de bifacialité sous puissance maximale  $\phi_{P_{max}}$ , mesurées aux STC, telles qu'elles sont définies dans l'IEC TS 60904-1-2.
- k) Le rayon de courbure minimal pour les modules flexibles.

Pour les points a) à i), toutes les données électriques doivent être présentées par rapport aux STC (1 000 W/m<sup>2</sup>, 25 °C, AM1,5 conformément à l'IEC TS 61836), sauf pour les modules bifaces qui exigent deux niveaux d'éclairement, tels qu'ils sont définis en 5.1g).

Les symboles internationaux doivent être utilisés le cas échéant.

La conformité du marquage est vérifiée par examen et par un essai MQT 06.1.

## 5.2 Documentation

### 5.2.1 Exigences minimales

Les modules doivent être accompagnés d'une documentation décrivant les méthodes d'installation électrique et mécanique, ainsi que les caractéristiques assignées électriques du module. La documentation doit préciser la classe de protection contre les chocs électriques dans laquelle le module a été qualifié, ainsi que toutes les limitations spécifiques exigées pour cette classe. La documentation doit fournir aux installateurs et opérateurs la documentation appropriée et suffisante pour permettre une installation, une utilisation et une maintenance en toute sécurité des modules PV.

NOTE Il est considéré comme étant suffisant de fournir un ensemble de documentation avec le colis d'expédition du module.

### 5.2.2 Informations à inclure dans la documentation

- a) toutes les informations exigées en 5.1 de e) à i), ainsi que j) pour les modules bifaces et k) pour les modules flexibles;
- b) le courant inverse de régime de surcharge assigné conformément à l'IEC 61730-2 MST 26;
  - le type et les caractéristiques assignées du dispositif de protection contre les surintensités sont donnés dans l'IEC 60269-6 par exemple. Il est recommandé d'utiliser des dispositifs de protection contre les surintensités avec un régime de surcharge assigné de  $1,35 I_n$ , de 1 h, où  $I_n$  est la valeur assignée du dispositif de protection contre les surintensités;
  - les configurations de modules PV en parallèle/série maximales recommandées;
- c) la tolérance, indiquée par le fabricant, pour  $V_{OC}$ ,  $I_{SC}$  et la puissance de sortie maximale dans les conditions normales d'essai;
- d) le coefficient de température pour la tension en circuit ouvert;
- e) le coefficient de température pour la puissance maximale;

f) le coefficient de température pour le courant de court-circuit.

Toutes les données électriques mentionnées ci-dessus doivent être présentées par rapport aux conditions normales d'essai (1 000 W/m<sup>2</sup>, 25 °C, AM1,5 conformément à l'IEC TS 61836). Par ailleurs, les paramètres suivants doivent être spécifiés:

g) les performances sous faible éclaircissement (MQT 07).

Les symboles internationaux doivent être utilisés le cas échéant.

La vérification est effectuée par examen et par les essais MQT 04 à MQT 07.

La documentation électrique doit inclure une description détaillée de la méthode de câblage de l'installation électrique à utiliser. Cette description doit inclure:

- h) le diamètre minimal des câbles des modules destinés au raccordement à l'installation;
- i) toutes les limitations relatives aux méthodes de câblage et gestion des câbles qui s'appliquent au boîtier de câblage;
- j) la taille, le type, le matériau et les caractéristiques assignées de température des conducteurs à utiliser;
- k) le type de bornes à utiliser pour le raccordement à l'installation;
- l) le modèle/les types et le fabricant du connecteur PV spécifique auquel les connecteurs du module doivent être accouplés. La seule déclaration du type de connecteur (telle que "compatible MC4") n'est pas une information suffisante pour satisfaire à cette exigence. Le modèle/les types de connecteurs et les fabricants doivent être inclus;
- m) la ou les méthodes de liaison équipotentielle à utiliser (le cas échéant); tous les matériels fournis ou spécifiés doivent être identifiés dans la documentation;
- n) le type et les caractéristiques assignées de la diode de dérivation à utiliser (le cas échéant);
- o) les limitations à la situation de montage (par exemple, pente, orientation, dispositifs de montage, refroidissement);
- p) une déclaration indiquant le ou les classements au feu, la norme appliquée, ainsi que les limitations liées à ce classement (par exemple, pente de l'installation, sous-structure ou autres informations d'installation applicables);
- q) une déclaration indiquant la charge théorique de chacun des dispositifs mécaniques utilisés pour maintenir en place le module évalué pendant l'essai de charge mécanique statique selon MQT 16. Selon le choix du fabricant, la charge d'essai et/ou le facteur de sécurité  $\gamma_m$  peuvent également être notés.

Pour augmenter le rendement d'un module consécutivement à certaines conditions d'utilisation, les instructions d'installation doivent contenir les paramètres pertinents spécifiés par le fabricant ou l'énoncé suivant (ou un énoncé équivalent):

*"Dans des conditions normales, un module photovoltaïque est susceptible d'être soumis à des conditions qui produisent plus de courant et/ou de tension que ceux consignés dans des conditions normales d'essai. Par conséquent, il convient de multiplier les valeurs de  $I_{SC}$  et  $V_{OC}$  indiquées sur ce module par 1,25 lorsqu'il s'agit de déterminer les tensions assignées du composant, les courants assignés du conducteur et la taille des commandes connectées à la sortie PV."*

### 5.2.3 Instructions d'assemblage

Les instructions d'assemblage doivent accompagner un produit expédié sous forme de sous-assemblages, et doivent être détaillées et adaptées au degré exigé afin de permettre un assemblage complet et sûr du produit.

## 6 Essais

Le laboratoire d'essai doit utiliser un module de commande du simulateur en laboratoire capable de détecter les dérives des résultats de mesure. Le module de commande du simulateur en laboratoire diffère du module de commande de la séquence d'essais A, qui est issu des modules soumis à l'essai et est décrit en 7.2.3 en lien avec la reproductibilité  $r$ . Le module de commande du simulateur en laboratoire est un module stable utilisé de manière périodique pour vérifier la sortie du simulateur après l'étalonnage à un éclairement spécifique.

Les modules doivent être répartis en groupes et soumis aux séquences d'essais de qualification représentés à la Figure 2. Les séquences d'essais de qualification doivent être exécutées dans l'ordre spécifié. Les désignations MQT figurant dans les encadrés font référence aux définitions d'essai correspondantes dans l'IEC 61215-2. Les informations détaillées sur les essais spécifiques à la technologie figurent dans les parties respectives de la présente norme. Les essais de composants de modules exigés sont énumérés dans le Tableau 1. Pour chaque qualification de composant, le rapport d'essai doit mentionner le nom du laboratoire d'essai et la date à laquelle l'exigence a été satisfaite. Des certifications antérieures peuvent être utilisées pour satisfaire à ces exigences, tant que les certifications ont été réalisées conformément à toutes les conditions énumérées dans le Tableau 1.

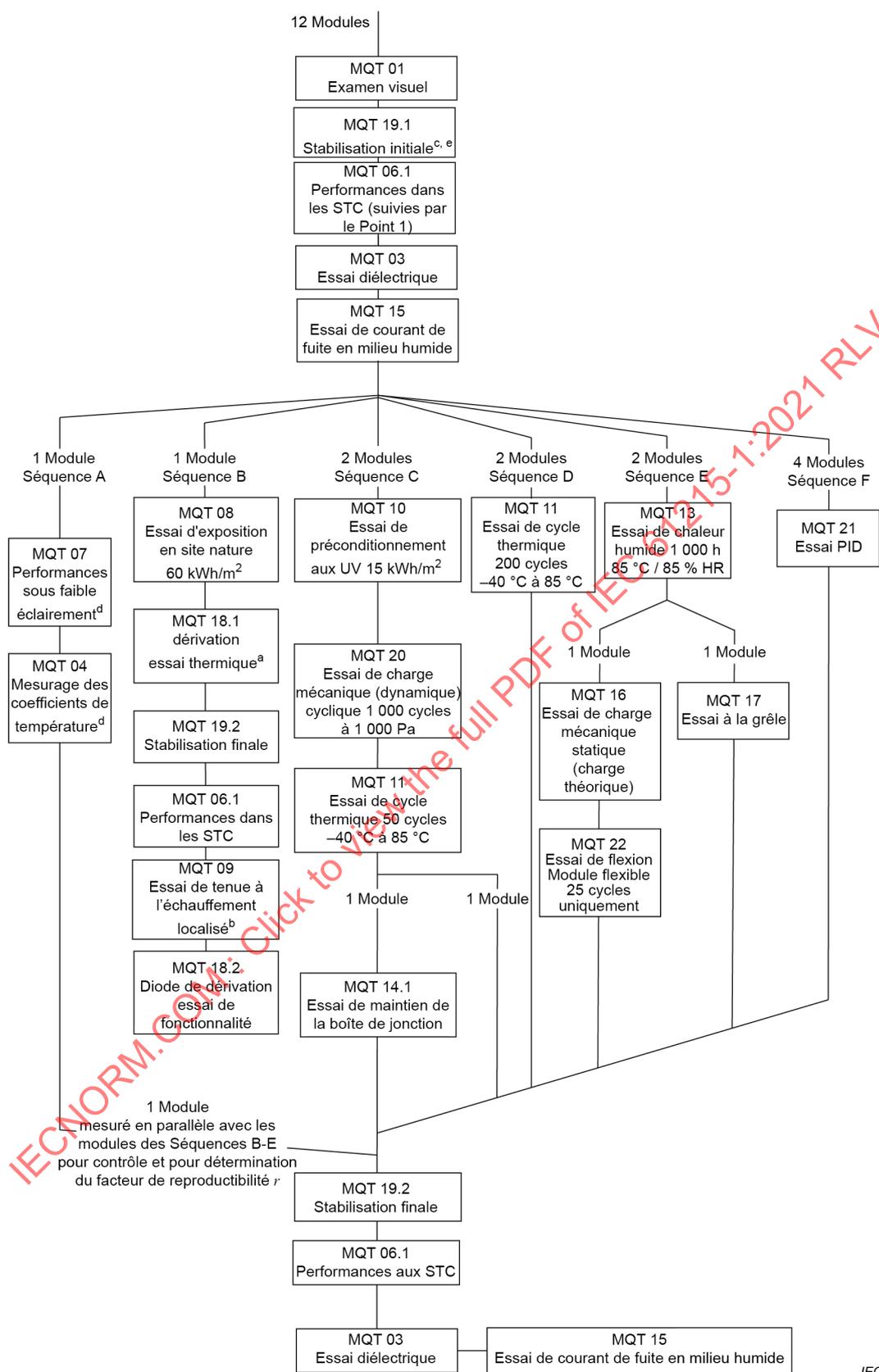
Il n'est pas exigé d'effectuer des mesurages intermédiaires de la puissance maximale (MQT 02) ou un essai diélectrique (MQT 03). Ils peuvent toutefois être utilisés pour suivre les modifications.

Tout essai isolé qui est réalisé indépendamment d'une séquence d'essais (par exemple, sur des échantillons d'essai spéciaux pour MQT 09 et MQT 18) doit être précédé par les essais initiaux de MQT 01, MQT 02, MQT 03 et MQT 15 selon le cas.

En effectuant les essais, le technicien d'essai doit observer scrupuleusement les instructions de manipulation, de montage et de raccordement spécifiées par le fabricant. La séquence d'essais A peut être omise si le type de module a été soumis à l'essai conformément à l'IEC 61853-1. Dans ce cas, les résultats d'essai correspondants de l'IEC 61853-1 doivent être indiqués ou référencés dans le rapport final. La séquence d'essais A ne peut être omise pour les modules bifaces jusqu'à ce que l'IEC 61853-1 ait été amendée afin de tenir compte de ce type de modules.

Les conditions d'essai sont synthétisées dans le Tableau 3. Les niveaux d'essai donnés dans le Tableau 3 correspondent aux niveaux minimaux exigés pour la qualification. Si le laboratoire et le fabricant du module se mettent d'accord, les essais peuvent être réalisés en augmentant les sévérités. Dans ce cas, ce fait doit être mentionné dans le rapport d'essai.

Pour les modules flexibles (voir 3.6), le substrat de montage et la colle, ou les moyens de fixation doivent être également inclus dans l'essai. Si plusieurs substrats de montage ou colles, voire plusieurs moyens de fixation sont admis conformément à la spécification du fabricant, alors les essais doivent utiliser la combinaison considérée comme le cas le plus défavorable. La ou les combinaisons choisies doivent être consignées dans le rapport conformément à l'Article 9, j).



<sup>a</sup> Si les diodes de dérivation ne sont pas accessibles dans les modules normalisés, un échantillon spécial peut être préparé pour l'essai thermique de la diode de dérivation (MQT 18.1). Il convient de monter physiquement la diode de dérivation comme elle l'est dans un module normalisé, avec les fils conducteurs connectés, comme l'exige l'essai MQT 18 de l'IEC 61215-2:2021. Cet échantillon ne doit pas être soumis aux autres essais de la séquence d'essais.

<sup>b</sup> Dans la séquence d'essais B, un module différent peut être utilisé pour l'essai de tenue à l'échauffement localisé (MQT 09) et pour l'essai de diode thermique de dérivation (MQT 18.1). Pour ce module séparé, la

séquence d'essais suivante est admissible: MQT 01, MQT 19.1, MQT 06.1 (point 1), MQT 03, MQT 15, MQT 09, et MQT 18.2.

- c La stabilisation initiale MQT 19.1 peut inclure la vérification d'une autre procédure de stabilisation (voir l'IEC 61215-2:2021).
- d Dans la séquence d'essais A, les essais MQT 07 et MQT 04 peuvent être effectués dans un ordre quelconque. Ces essais peuvent également être effectués sur des modules séparés (plutôt que des essais séquentiels sur un module), à condition que chaque module utilisé ait été soumis à la série d'essais complète précédant la séquence d'essais A.
- e Si des échantillons représentatifs sont utilisés dans la séquence d'essais E, un module supplémentaire, en taille réelle, est exigé. Il ne doit être soumis qu'au MQT 16 et aux exigences qu'il contient.

**Figure 2 – Série d'essais complète pour la qualification de la conception et l'homologation des modules photovoltaïques**

**Tableau 1 – Essais de composants exigés**

Composant:	Doit satisfaire à cet essai
Boîte de jonction	IEC 61215-2:201x MQT 14.2, qui cite l'IEC 62790 "Essai du serré-cordon".
Connecteurs	IEC 62852 La conformité doit être obtenue au moyen du connecteur combiné avec la même taille et le même type de câble que ceux qui sont utilisés pour les modules en essai.

## 7 Critères d'acceptation

### 7.1 Généralités

Les modules en essai sont soumis à plusieurs types d'exigences. Ces exigences comprennent les marquages exigés (détaillés à l'Article 5), la comparaison des grandeurs électriques mesurées avec la plaque signalétique ("point 1", détaillé dans le présent article), la comparaison de la puissance mesurée avant et après la contrainte ("point 2", détaillé dans le présent article), les exigences des composants (détaillés dans le Tableau 1) et les exigences de chaque MQT (synthétisées dans le Tableau 3 et à la Figure 2).

La conception est réputée avoir satisfait aux exigences de qualification de 7.2.2 (point 1), si les exigences du Tableau 2 sont satisfaites:

**Tableau 2 – Synthèse des exigences du point 1**

Effectif d'échantillon (des modules)	Exigence
<10	Tous les modules doivent satisfaire aux critères. Aucune défaillance n'est admise.
≥10	Une seule défaillance est admissible. Tous les autres modules doivent satisfaire aux critères.

NOTE Un effectif d'échantillon <10 est observé uniquement lors d'un contre-essai.

Si les modules ne satisfont pas aux exigences énumérées dans le Tableau 2, alors deux nouveaux échantillons doivent être soumis à l'essai pour chacun des modules qui n'a pas satisfait aux critères du point 1. En cas de nouvelle défaillance, deux options s'offrent au fournisseur des modules. La première option est la suivante: les étiquettes de module pour l'ensemble d'échantillons existant doivent être redéfinies de manière à satisfaire aux exigences du Tableau 2, et l'essai portant sur ce même ensemble d'échantillons doit passer à l'étape suivante. La seconde option est la suivante: la conception est réputée ne pas avoir satisfait aux exigences de qualification, et tout essai supplémentaire constitue une nouvelle tentative de qualification et exige ainsi un lot de modules entièrement nouveau. Les étiquettes de modules doivent être redéfinies et les échantillons doivent être resoumis à l'essai.

De plus, si deux modules ou plus ne satisfont pas aux critères d'essai restants (7.2.3 point 2, 7.2.4 circuits électriques, 7.3 défauts visuels et 7.4 sécurité électrique), la conception doit être réputée ne pas avoir satisfait aux exigences de qualification. Si un module ne satisfait pas à l'un des essais, deux modules supplémentaires satisfaisant aux exigences de l'Article 4 doivent être soumis à l'intégralité des essais de la séquence d'essais correspondante. L'exigence relative à deux modules supplémentaires s'applique aux essais pour lesquels un seul module était initialement exigé, ainsi qu'aux essais pour lesquels deux modules étaient initialement exigés. Par exemple, une défaillance à l'essai de tenue à l'échauffement localisé exige une répétition de l'essai avec deux modules supplémentaires. Une seule défaillance à l'essai de 50 cycles thermiques (un module ne satisfait pas aux exigences d'essai) exige également une répétition de l'essai avec deux modules supplémentaires.

Si l'un des deux ou si les deux modules ne satisfont pas à l'essai non plus, la conception doit être réputée ne pas avoir satisfait aux exigences de qualification. Toutefois, si les deux modules satisfont à la séquence d'essais, la conception doit être considérée comme ayant satisfait aux exigences de qualification.

La conception des modules doit satisfaire aux exigences de tous les critères pour être réputée qualifiée selon le présent document. Chaque échantillon d'essai doit être soumis aux critères suivants:

## 7.2 Puissance de sortie et circuits électriques

### 7.2.1 Identification des valeurs et des tolérances assignées

Les critères du point 1 détaillés dans les paragraphes suivants exigent d'utiliser les valeurs et les tolérances assignées de la plaque signalétique et de la fiche technique du produit. Le présent article décrit de manière détaillée, au moyen d'exemples, comment identifier les informations pertinentes. L'application des informations contenues dans le présent article entraîne des exigences cohérentes lorsque des informations superflues sont données, ou lorsque des informations semblent manquer ou être en conflit avec d'autres. Les valeurs et les tolérances assignées doivent chacune être identifiées pour la puissance des modules, ainsi que le courant de court-circuit et la tension en circuit ouvert. Ainsi, le présent article décrit de manière détaillée comment identifier ces six éléments d'information.

NOTE 1 Par le passé, certains produits ont cité plusieurs composantes d'incertitude, ou ont utilisé des terminologies différentes concernant l'incertitude, telles que "tolérance", "tolérance de production", "incertitude de mesure", etc. Par ailleurs, certains produits ne fournissent pas de tolérance, ce qui peut être interprété soit comme une tolérance de 0 %, soit comme une information manquante. Lorsqu'il n'est pas interdit au fabricant de fournir des informations supplémentaires ou d'avoir une tolérance de 0 %, l'application des règles du présent article offre un moyen cohérent d'interpréter ce type de situations.

Les informations identifiées dans le présent article se rapportent aux mesurages courant-tension dans les STC, obtenus selon la méthode indiquée en suivant l'organigramme de la Figure 2. Ainsi, les valeurs obtenues sont celles mesurées uniquement après réalisation de la stabilisation initiale conformément à l'IEC 61215-2:202x MQT 19.1. Les procédures de stabilisation exigées peuvent différer d'un produit à l'autre, comme le spécifient les parties spécifiques à la technologie (IEC 61215-1-x). Le calcul des tolérances relève de la responsabilité du fabricant de modules. Chaque tolérance ( $t_1$ ,  $t_2$  et  $t_3$ ) doit être indiquée de manière explicite comme une valeur unique de chacun des paramètres de performances ( $P_{\max}$ ,  $V_{OC}$  et  $I_{SC}$  respectivement). Pour les modules bifaces, les six informations (valeurs et tolérances de puissance du module, courant de court-circuit, et tension en circuit ouvert) doivent également être identifiées au BNPI pour évaluer le point 1.

NOTE 2 L'ISO Guide 98-3 fournit des recommandations supplémentaires concernant le mode de combinaison de plusieurs sources d'incertitude.

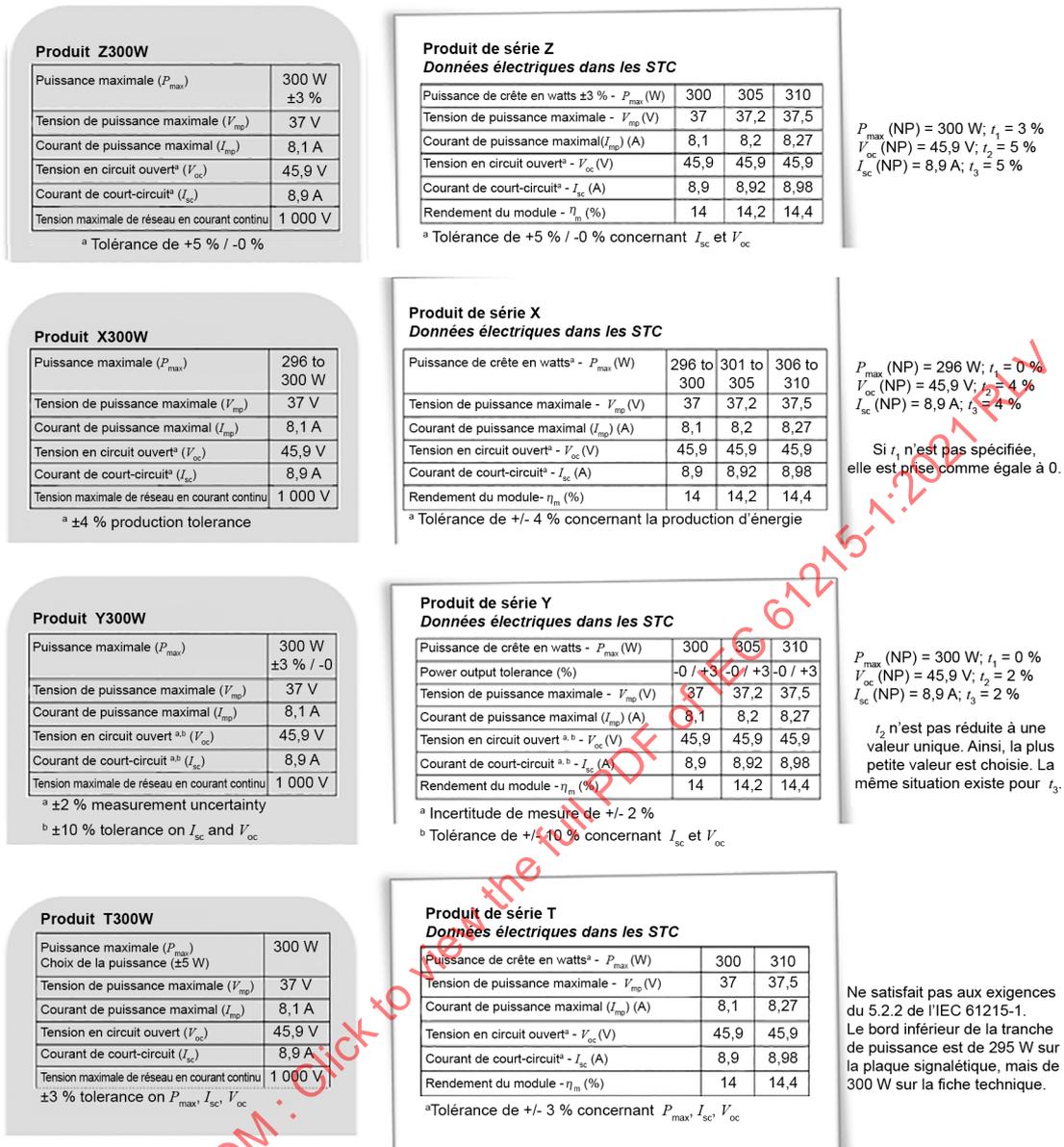
Les formules (1) et (2) de 7.2.2 vérifient que les modules produisent une puissance au moins équivalente à la puissance minimale indiquée par combinaison des caractéristiques assignées de la plaque signalétique et de la tolérance. La puissance assignée minimale de plaque signalétique,  $P_{\max}(NP)$  est la puissance de sortie du module spécifiée sur la plaque signalétique. Si une valeur unique de puissance du module est indiquée sur la plaque

signalétique,  $P_{\max}(\text{NP})$  représente simplement cette valeur. Si une plage de puissances de modules est indiquée sur la plaque signalétique,  $P_{\max}(\text{NP})$  est la puissance à l'extrémité la plus basse de cette plage. Le paragraphe 5.2.2 exige que les informations concernant les tranches de puissance et la tolérance figurant sur la plaque signalétique soient reproduites sur la fiche technique. Dans le cas où  $P_{\max}(\text{NP})$  tirée de la fiche technique est différente de celle indiquée sur la plaque signalétique, le module doit être considéré comme ne satisfaisant pas à 5.2.2 et il ne satisfait donc pas aux exigences de l'IEC 61215-1.

La tolérance,  $t_1$ , est la tolérance en % pour  $P_{\max}$  indiquée sur la plaque signalétique et la fiche technique, comme l'exigent 5.1i) et 5.2.2a). En cas d'asymétrie de la tolérance par rapport à  $P_{\max}(\text{NP})$ , la tolérance faisant référence à la limite de puissance basse doit être utilisée comme valeur  $t_1$ . Si la tolérance n'est pas indiquée sur la plaque signalétique ou qu'elle n'est pas indiquée sur la fiche technique, alors  $t_1 = 0$ . En cas de non-réduction de la tolérance à une valeur unique sur la plaque signalétique ou la fiche technique (par exemple, si plusieurs tolérances ou plusieurs composantes de l'incertitude de mesure sont spécifiées), le plus petit nombre, et non une combinaison de plusieurs nombres, doit être utilisé.

Les formules (3) et (4) vérifient, pour des raisons de sécurité, que le module ne produit pas une plus grande tension en circuit ouvert, ou un courant plus élevé en court-circuit, que la tension ou le courant maximaux indiqués par combinaison des caractéristiques assignées de la plaque signalétique et de la tolérance. La tension en circuit ouvert maximale  $V_{\text{oc}}(\text{NP})$  et le courant de court-circuit maximal  $I_{\text{sc}}(\text{NP})$  sont ceux spécifiés sur la plaque signalétique. Si une plage de tensions en circuit ouvert ou de courants de court-circuit est indiquée sur la plaque signalétique,  $V_{\text{oc}}(\text{NP})$  ou  $I_{\text{sc}}(\text{NP})$  doit être prise comme la valeur la plus élevée de cette plage. La tolérance de production ( $t_2$  pour la tension en circuit ouvert, ou  $t_3$  pour le courant de court-circuit) est celle spécifiée sur la plaque signalétique et dans la documentation de produit, comme l'exigent 5.1g), 5.1h), et 5.2.2c). En cas d'asymétrie de  $t_2$  (ou  $t_3$ ) par rapport à  $V_{\text{oc}}(\text{NP})$  (ou  $I_{\text{sc}}(\text{NP})$ ), la tolérance faisant référence à l'extrémité supérieure de la plage doit être utilisée. Si la valeur  $t_2$  ou  $t_3$  n'est pas indiquée dans la documentation et sur la plaque signalétique, cette tolérance doit être identifiée comme nulle. Dans le cas où  $V_{\text{oc}}(\text{NP})$ ,  $I_{\text{sc}}(\text{NP})$ , ou les tolérances de ces grandeurs sont différentes lorsqu'elles sont tirées de la fiche technique par rapport à celles indiquées sur la plaque signalétique, le module doit être considéré comme ne satisfaisant pas à 5.2.2. Il ne satisfait donc pas aux exigences de l'IEC 61215-1. En cas de non-réduction de la tolérance à une valeur unique sur la plaque signalétique ou la fiche technique (par exemple, si plusieurs tolérances ou plusieurs composantes de l'incertitude de mesure sont spécifiées), le plus petit nombre, et non une combinaison de plusieurs nombres, doit être utilisé.

La Figure 3 représente les plaques signalétiques, fiches techniques et valeurs déduites partielles pour quatre produits hypothétiques. Ces exemples illustrent les règles d'identification des valeurs et des tolérances assignées décrites dans les paragraphes précédents.



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Figure 3 – Exemples de plaques signalétiques (colonne de gauche), fiches techniques (colonne du milieu) et valeurs et tolérances assignées déduites (colonne de droite) partielles hypothétiques

### 7.2.2 Vérification des valeurs d'étiquette assignées → Point 1

Tous les modules doivent être stabilisés selon la méthode MQT 19.1 de l'IEC 61215-2:2021 (pour les exigences spécifiques à la technologie, voir les sous-parties de l'IEC 61215-1). Après stabilisation, les modules doivent être mesurés conformément à MQT 6.1 ( $P_{max}$ (Lab)) et doivent satisfaire aux critères suivants:

Vérification de  $P_{max}$ :

Chaque module individuel doit satisfaire au critère suivant:

$$P_{max}(Lab) \times \left(1 + \frac{1,65|m_{11}|}{100}\right) \geq P_{max}(NP) \times \left(1 - \frac{|t_{11}|}{100}\right) \quad (1)$$