



UL 61215-2

STANDARD FOR SAFETY

Terrestrial Photovoltaic (PV) Modules –
Design Qualification and Type Approval
– Part 2: Test Procedures

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UL Standard for Safety for Terrestrial Photovoltaic (PV) Modules – Design Qualification and Type Approval
– Part 2: Test Procedures, UL 61215-2

Second Edition, Dated July 28, 2021

Summary of Topics

UL 61215-2 is an adoption of IEC 61215-2, Terrestrial Photovoltaic (PV) Modules – Design Qualification and Type Approval – Part 2: Test Procedures (Second Edition, issued February 2021). Please note that there are no National Differences.

The requirements are substantially in accordance with Proposal(s) on this subject dated May 21, 2021.

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JULY 28, 2021



ANSI/UL 61215-2-2021

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UL 61215-2

Terrestrial Photovoltaic (PV) Modules – Design Qualification and Type

Approval – Part 2: Test Procedures

First Edition – February, 2017

Second Edition

July 28, 2021

This ANSI/UL Standard for Safety consists of the Second Edition.

The most recent designation of ANSI/UL 61215-2 as an American National Standard (ANSI) occurred on July 7, 2021. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, Title Page, or Preface. The IEC Foreword is also excluded from the ANSI approval of IEC-based standards.

Comments or proposals for revisions on any part of the Standard may be submitted to UL at any time. Proposals should be submitted via a Proposal Request in UL's On-Line Collaborative Standards Development System (CSDS) at <https://csds.ul.com>.

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PREFACE

This UL Standard is based on IEC Publication IEC 61215-2: Second edition Terrestrial Photovoltaic (PV) Modules – Design Qualification and Type Approval – Part 2: Test Procedures. IEC publication IEC 61215-2 is copyrighted by the IEC.

This edition has been issued to satisfy UL Standards policy.

This is the UL Standard for Terrestrial Photovoltaic (PV) Modules – Design Qualification and Type Approval – Part 2: Test Procedures. UL 61215-2 is to be used in conjunction with the second edition of UL 61215-1.

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Note – Although the intended primary application of this Standard is stated in its Scope, it is important to note that it remains the responsibility of the users of the Standard to judge its suitability for their particular purpose.

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FOREWORD

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TERRESTRIAL PHOTOVOLTAIC (PV) MODULES – DESIGN QUALIFICATION AND TYPE APPROVAL – Part 2: Test procedures

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.

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9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 61215-2 has been prepared by IEC technical committee 82: Solar photovoltaic energy systems.

This second edition of IEC 61215-2 cancels and replaces the first edition of IEC 61215-2 issued in 2016; it constitutes a technical revision.

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

- a) Addition of cyclic (dynamic) mechanical load testing (MQT 20).
- b) Addition of a test for detection of potential-induced degradation (MQT 21).
- c) Addition of test methods required for bifacial PV modules.

d) Addition of test methods required for flexible modules. This includes the addition of the bending test (MQT 22).

e) Revision of simulator requirements to ensure uncertainty is both well-defined and minimized.

f) Correction to the hot spot endurance test, where the procedure for monolithically integrated (MLI) thin film technologies (MQT 09.2) previously included two sections describing a procedure only appropriate for silicon modules.

g) Selection of three diodes, rather than all, for testing in the bypass diode thermal test (MQT 18).

h) Removal of the nominal module operating test (NMOT), and associated test of performance at NMOT, from the IEC 61215 series.

Informative Annex A of IEC 61215-1:2021 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 standard is based on the following documents:

FDIS	Report on voting
82/1829/FDIS	82/1853/RVD

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

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

A list of all parts 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 publication will remain unchanged until the stability date indicated on the IEC web site under "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be

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

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

Whereas Part 1 of this standard 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 2: Test procedures

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 98th percentile operating temperatures exceed 70 °C, users are recommended to consider testing to higher temperature test conditions as described in IEC TS 63126¹. 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.

¹ Information on 98th percentile operating temperature as a function of system location and mounting configuration is included in IEC TS 63126.

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.

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.

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 IEC 61215-1:2021. 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 60068-1, *Environmental testing – Part 1: General and guidance*

IEC 60068-2-21, *Environmental testing – Part 2-21: Tests – Test U: Robustness of terminations and integral mounting devices*

IEC 60068-2-78:2012, *Environmental testing – Part 2-78: Tests – Test Cab: Damp heat, steady state*

IEC 60891, *Photovoltaic devices – Procedures for temperature and irradiance corrections to measured I-V characteristics*

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

IEC 60904-1-1, *Photovoltaic devices – Part 1-1: Measurement of current-voltage characteristics of multi-junction photovoltaic (PV) devices*

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

IEC 60904-2, *Photovoltaic devices – Part 2: Requirements for photovoltaic reference devices*

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

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

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

IEC 60904-9:2020, *Photovoltaic devices – Part 9: Classification of solar simulator characteristics*

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

IEC TR 60904-14, *Photovoltaic devices – Part 14: Guidelines for production line measurements of single-junction PV module maximum power output and reporting at standard test conditions*

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

IEC 61215-1:2021, *Terrestrial photovoltaic (PV) modules – Design qualification and type approval – Part 1: Test requirements*

IEC 61215-1-1, *Terrestrial photovoltaic (PV) modules – Design qualification and type approval – Part 1-1: Special requirements for testing of crystalline silicon photovoltaic (PV) modules*

IEC 61730-1:2016, *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 TS 62782, *Photovoltaic (PV) modules – Cyclic (dynamic) mechanical load testing*

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

IEC TS 62804-1:2015, *Photovoltaic (PV) modules – Test methods for the detection of potential-induced degradation – Part 1: Crystalline silicon*

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

² Under preparation. Stage at the time of publication: ADTS.

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC TS 61836 and IEC 61215-1:2021 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

accuracy <of a measuring instrument>

quality which characterizes the ability of a measuring instrument to provide an indicated value close to a true value of the measurand [consistent with the International Vocabulary of Metrology (VIM), 5.18]

Note 1 to entry: This term is used in the "true value" approach.

Note 2 to entry: Accuracy is all the better when the indicated value is closer to the corresponding true value.

[SOURCE: IEC 60050-311:2001, 311-06-08]

3.2

control device

irradiance sensor (such as a reference cell or module) that is used to detect drifts and other problems of the solar sun simulator

3.3

electrically stable power output level

state of the PV module where it will operate under long-term natural sunlight

3.4

repeatability <of results of measurements>

closeness of agreement between the results of successive measurements of the same measurand, carried out under the same conditions of measurement, i.e.:

- by the same measurement procedure,
- by the same observer,
- with the same measuring instruments,
- used under the same conditions,

– in the same laboratory,

at relatively short intervals of time [$\approx$ VIM 3.6].

Note 1 to entry: The concept of "measurement procedure" is defined in VIM 2.5.

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

3.5

Gate No. 1

a pass / fail comparison between the performance of a module and its nameplate specifications, as described in IEC 61215-1:2021

3.6

Gate No. 2

a pass / fail comparison between the performance of a module before versus after stress, as described in IEC 61215-1:2021

4 Test procedures

The subclauses below provide detailed instructions for performing each module quality test (MQT). Reporting and test sequence requirements for qualification are described in IEC 61215 1.

4.1 Visual inspection (MQT 01)

4.1.1 Purpose

To detect any visual defects in the module.

4.1.2 Procedure

Carefully inspect each module under an illumination of not less than 1 000 lux for conditions and observations as defined in IEC 61215-1.

Make note of and/or photograph any defects that may be major visual defects as defined in IEC 61215-1. Also make note of and/or photograph the nature and position of any cracks, bubbles or delaminations, etc., which may worsen and adversely affect the module performance in subsequent tests. Record any other relevant information regarding origin of failure and associated test or lab conditions.

4.1.3 Requirements

No evidence of major visual defects permitted, as defined in IEC 61215-1:2021.

4.2 Maximum power determination (MQT 02)

4.2.1 Purpose

To determine the maximum power of the module after stabilization as well as before and after the various environmental stress tests.

4.2.2 Apparatus

a) Apparatus for measuring I-V characteristics in accordance with IEC 60904-1.

b) A PV reference device in accordance with IEC 60904-2.

c) At least one of the following two options to reduce the spectral mismatch component of uncertainty shall be utilized:

- Perform a spectral mismatch correction. The spectral responsivity of the module shall be measured according to IEC 60904-8. The spectral response data may originate from the same lab that is performing IEC 61215-2:2021, or from a different lab. 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. The spectral distribution of the solar simulator shall then be utilized to correct for spectral mismatch according to IEC 60904-7.
- Use a matched reference cell or module. The reference device shall be of the same cell technology as the test module, to match spectral responsivity. There is no requirement on the cell or module size.

d) A radiant source: natural sunlight or a solar simulator of class CAA or better in accordance with IEC 60904-9. For very large modules, as defined in IEC 61215-1:2021, a class CBA simulator may be used.

NOTE 1 Class CBA is defined according to IEC 60904-9: The AM1.5 spectral match is categorized as C, non-uniformity of irradiance for the module size categorized as B, and temporal stability of irradiance categorized as A.

To achieve a high accuracy of power measurement, the spectral irradiance distribution of the solar simulator should cover the whole wavelength range that is spanned by the spectral responsivity of the PV device under test. See IEC TR 60904-14 and IEC 60904-9:2020.

e) A suitable mount for supporting the test specimen and the reference device in a plane normal to the radiant beam.

NOTE 2 MQT 02 measurement procedures are intended for minimal uncertainty, for example 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.

4.2.3 Procedure

Determine the current-voltage characteristic of the module in accordance with IEC 60904-1 at a specific set of irradiance and temperature conditions (a recommended range is a cell temperature between 20 °C and 50 °C and an irradiance between 700 W/m² and 1 100 W/m²) using the apparatus described in [4.2.2](#). In special circumstances when modules are designed for operation under a different range of conditions, the current-voltage characteristics can be measured using temperature and irradiance levels similar to the expected operating conditions. For linear modules (as defined in IEC 60904-10) temperature and irradiance corrections can be made in accordance with IEC 60891 in order to compare sets of measurements made on the same module before and after environmental tests. For nonlinear modules (as defined in IEC 60904-10) the measurement shall be performed within ±5 % of the specified irradiance and within ±2 °C of the specified temperature. However, every effort should be made to ensure that peak power measurements are made under similar operating conditions, that is minimize the magnitude of the correction by making all peak power measurements on a particular module at approximately the same temperature and irradiance.

For flexible modules, the maximum power determination shall be measured with the flexible module in the flat position.

4.3 Insulation test (MQT 03)

4.3.1 Purpose

To determine whether or not the module is sufficiently well insulated between live parts and accessible parts.

4.3.2 Apparatus

- a) DC. voltage source, with current limitation, capable of applying the voltage as specified in the third column of [Table 1](#) for the various module classes.
- b) An instrument to measure the insulation resistance.

4.3.3 Test conditions

The test shall be made on modules at ambient temperature of the surrounding atmosphere (see IEC 60068-1) and in a relative humidity not exceeding 75 %.

The voltage stress levels applied to the module are determined by the module's maximum system voltage (V_{sys}), the module class, and whether or not cemented joints are present. The definitions of module classes are taken from IEC 61140, and are discussed as related to PV modules in IEC 61730-1:2016, Clause 4. The definition of cemented joints is given in IEC 61730-1:2016, 3.4.2, and is further discussed in IEC 61730-1:2016, Clauses B.5 and B.9. The voltage stress levels applied in this test are the same as those applied for IEC 61730 2 MST 16.

4.3.4 Procedure

- a) Connect the shorted output terminals of the module to the positive terminal of a DC insulation tester with a current limitation.
- b) Connect the exposed metal parts of the module to the negative terminal of the tester. If the module has no frame or if the frame is a poor electrical conductor, wrap a conductive foil around the edges. Connect all foil covered parts to the negative terminal of the tester.
- c) Some module technologies may be sensitive to static polarization if the module is maintained at positive voltage to the frame. In this case, the connection of the tester shall be done in the opposite way. If applicable, information with respect to sensitivity to static polarization shall be provided by the manufacturer and documented in the test report.
- d) Read the "one-minute preconditioning" voltage, V_{Test1} from the third column of [Table 1](#). Increase the voltage applied by the tester at a rate not exceeding 500 V/s to a maximum equal to V_{Test1} . Maintain the voltage at this level for 1 min.
- e) Reduce the applied voltage to zero and short-circuit the terminals of the test equipment to discharge the voltage build-up in the module.
- f) Remove the short-circuit.
- g) Read the "two-minute stress" voltage, V_{Test2} from the fourth column of [Table 1](#). Increase the voltage applied by the test equipment at a rate not exceeding 500 V/s to V_{Test2} . Maintain the voltage at this level for 2 min. Then determine the insulation resistance.

h) Reduce the applied voltage to zero and short-circuit the terminals of the test equipment to discharge the voltage build-up in the module.

i) Remove the short-circuit and disconnect the test equipment from the module.

Table 1
Voltage stress levels

Module class	Are cemented joints present?	1 min preconditioning V_{Test1} V	2 min stress for measuring insulation resistance, V_{Test2} V
0	No	$1\,000 + 2 \times V_{sys}$	Greater of 500 or V_{sys}
II	No	$2\,000 + 4 \times V_{sys}$	Greater of 500 or V_{sys}
III	No	500	500
0	Yes	$1,35 \times (1\,000 + 2 \times V_{sys})$	Greater of 500 or V_{sys}
II	Yes	$1,35 \times (2\,000 + 4 \times V_{sys})$	Greater of 500 or V_{sys}
III	Yes	$1,35 \times (500)$	500

4.3.5 Test requirements

a) No dielectric breakdown or surface tracking.

b) For modules with an area of less than $0,1 \text{ m}^2$ the insulation resistance shall not be less than 400 MΩ.

c) For modules with an area larger than $0,1 \text{ m}^2$ the measured insulation resistance times the area of the module shall not be less than $40 \text{ M}\Omega \cdot \text{m}^2$.

4.4 Measurement of temperature coefficients (MQT 04)

Determine the temperature coefficients of current (α), voltage (β) and peak power (δ) from module measurements as specified in IEC 60891. The coefficients so determined are valid at the irradiance at which the measurements were made. See IEC 60904-10 for evaluation of module temperature coefficients at different irradiance levels. For bifacial modules determine the temperature coefficients utilizing the same procedure, but insuring no backside irradiation. The backside shall be covered such that the contribution from the non-exposed side of the module is limited to or below the levels specified for "non-irradiated background" in IEC TS 60904 1-2. If open-circuit voltage or short-circuit current cannot be measured due to module-integrated electronics, the associated temperature coefficient shall be reported as "not measurable due to module-integrated electronics." Open-circuit voltage or short-circuit current shall not be determined by any method other than direct measurement, such as extrapolation.

NOTE For linear modules in accordance to IEC 60904-10, temperature coefficients are valid over an irradiance range of $\pm 30 \%$ of this level.

4.5 Placeholder section, formerly NMOT

The nominal module operating temperature (NMOT) test, formerly MQT 05, is no longer a part of this document. This subclause is preserved so that, in the following subclauses of the document, the MQT numbers match the subclause numbers.

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