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REDLINE VERSION

Guidelines for qualifying PV modules, components and materials for operation at high temperatures

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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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 TS 63126:2020. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

IEC TS 63126 has been prepared by IEC technical committee 82: Solar photovoltaic energy systems. It is a Technical Specification.

This second edition cancels and replaces the first edition published in 2020. This edition constitutes a technical revision.

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

a) Updated the Introduction and Scope to clarify the applicability of this document.
b) Defined "Level 0" as that qualified for in the IEC 61730 series and the IEC 61215 series.
c) For the purposes of minimizing testing needs, it is explicitly stated if a test or sequence is passed for a higher Level that it passes for lower levels too.
d) Backsheet weathering was changed to match what is in IEC 62788-2-1. For all three levels, the test condition is A3 with 4 000 h on the front side and 2 000 h on the back side.
e) Frontsheet weathering was kept at 4 000 h under A4 or A5 exposure conditions but options for exposure using A3 for longer times or using A3 with a dark insulator on the back are described.
f) The UV test of MST 54 is now only applied to the front side exposure in sequence B of IEC 61730. Previously, it was modified as part of IEC 61215 MQT 10 which is an equivalent exposure to MST 54.
g) Modified the backsheet testing for longer duration for frontside exposure and for the use of A3 for all levels.
h) For IEC 62788-7-1 for the optical transmittance of encapsulants, a longer exposure using the A3 condition is outlined in this document, but the original A4 and A5 options were not modified. A third option to insulate the backside with a dark light absorbing material to achieve elevated temperatures was also added.
i) The higher thermal cycling (TC) testing for Level 1 and Level 2 will only apply to the 200 TC leg of IEC 61730 and IEC 61215.
j) For sequence C of IEC 61730, the UV preconditioning test (MST 54) will no longer be modified as the 50 TC of this sequence is not modified.
k) For sequence B of IEC 61730, the higher temperature for the UV exposure (MST 54) dose will only be applied to the frontsheet of a module. The backsheet exposure will not be changed.
l) Relative to IEC 61215, the high temperature modification of the TC test only applies to sequence D and MQT 10 (UV preconditioning) is not modified, i.e. sequence C of IEC 61215 is not changed.
m) Improved method for estimating the T_{98} temperature. This includes a method utilizing an effective standoff distance for quick estimate of the system temperature. Or it can be used to estimate a minimum standoff distance for a given geographic location.
n) The testing for the junction box standard, IEC 62790 was clarified to explicitly state the upper ambient temperature for testing. Here ambient testing temperature for Level 2 was also reduced from 105 °C to 100 °C.
o) Changed the modifications to IEC 62852 to specify the ambient testing temperature instead of the ULT. Ambient test temperatures of 85 °C, 90 °C and 100 °C are used for Level 0, 1, and 2, respectively.

The text of this Technical Specification is based on the following documents:

Draft	Report on voting
82/2401/DTS	82/2472/RVDTS

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The language used for the development of this Technical Specification is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

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

- reconfirmed,
- withdrawn, or
- revised.

INTRODUCTION

Originally, the IEC 61215 series, the IEC 61730 series, IEC 62790 and IEC 62852 were considered suitable for an environmental temperature range of at least −40 °C to +40 °C ~~and for~~. For open-rack modules operating in such conditions a 98th-percentile module ~~operational~~ operating temperature of 70 °C or less ~~applies~~ is obtained. This environmental temperature range encompasses many locations and installation styles in these locations. As an example, it has been determined that thermally unrestricted, or open-rack-style structures, in most cases do not result in 98th-percentile module ~~operational~~ operating temperatures exceeding 70 °C and, as such, the originating standards are suitable as written. Cases where the module operating temperatures ~~exceeding~~ exceeds 70 °C~~, on the other hand,~~ at the 98th percentile typically ~~will~~ occur with roof-parallel or building-integrated roof top applications in climates with local environmental temperatures that exceed 40 °C.

This document is written for two purposes: to provide modified testing conditions for modules that will be deployed in climates that either have a higher environmental air temperature than 40 °C ~~and/~~or for module installation methods that restrict cooling, or both, ~~resulting~~ which are likely to result in higher ~~operational~~ operating temperatures than anticipated in the originating standards. This work will also aid in providing an alternative definition of "rack mount" in the context of the IEC 61215 series and IEC 61730 series. This term was initially used as a placeholder to restrict the scope of PV module type testing for those installation styles that permit open and unrestricted cooling from all surfaces of a PV module. Now that the testing has matured, there is a desire to refine definitions for the range of applicability of these standards.

This document ~~is intended to be used as an intermediate step to define~~ defines high temperature environment use requirements but does not include applications designed to combine photovoltaic and thermal energy applications. These requirements are ~~planned to be~~ being refined and in part incorporated into other standards ~~in the future~~. It is not necessarily cost effective for module materials to comply with Level 1 or Level 2 requirements defined in this document, unless the module temperature is expected to exceed 70 °C at the 98th percentile. Primarily, this will only be necessary in building applied applications in hot climates. Vertical building facades are not likely to operate at these high temperatures because of reduced in plane irradiance and good free convection on the outer surface. Module materials capable of temperature Level 1 or temperature Level 2 are expected to impose higher expectations of endurance and cost than normal modules.

Component standard IEC 62930 is considered to be adequate for modules operating at high temperatures without modification due to requiring cable to have a 120 °C or greater thermal endurance at a 20 000 h correlation lifetime. A guide for cable correction factors at higher cable ambient temperatures is given in IEC 62930:2017, Table A.4. Similarly, IEC 62979 [1][1] is considered adequate for bypass diode thermal runaway determination due to testing temperatures of 90 °C for roof-mounted modules and 75 °C for "rack mounted" modules.

Similar to electric cables, IEC 61730-1 requires a relative thermal index (RTI), thermal index (TI), or relative thermal endurance (RTE) of 90 °C or larger. A module operating in an environment and installation style resulting in a 98th percentile temperature of 70 °C requires an RTI, TI, or RTE safety factor of +20 °C to establish a 25-year lifetime when the polymer has a minimum activation energy of 46 kJ/mol and the correlation lifetime is 20 000 h. This work approximately applies that safety factor of +20 °C for polymer RTI, TI, or RTE when the 98th percentile operating temperature is above 70 °C.

[1] Numbered in square brackets refer to the Bibliography.

~~Finally,~~ Data from PV modules in hot climates and modelling were used to understand operating temperatures and resulted in two categories of high temperature operation, temperature Level 1 and temperature Level 2. These categories are defined within this document and it is relevant to indicate that Level 2 temperatures were not found in field data, but ~~may~~ can result from insulated substrate modules on pitched roofs facing the sun when ambient air temperature exceeds 40 °C. This ~~may~~ can be most consistent with building-integrated PV module roofs and, to allow for this possibility, the temperature Level 2 category remains in this document.

In Annex A, methods are given for estimating when a particular system design will need higher levels of qualification. Short of actual measurement at a particular site, one cannot precisely estimate the 98th percentile temperature. However, the suggested methods give a rough approximation of when Level 1 and Level 2 qualification are likely to be needed.

1 Scope

This document defines additional testing requirements for photovoltaic (PV) modules deployed under conditions leading to higher module temperature which are beyond the scope of IEC 61215-1 and IEC 61730-1 and the relevant component standards, IEC 62788-1-7, IEC 62788-2-1, IEC 62790 and IEC 62852. The testing conditions specified in IEC 61215-2 and IEC 61730-2 (and the relevant component standards IEC 62788-1-7, IEC 62788-2-1, IEC 62790 and IEC 62852) assumed that these standards are applicable for module deployment where the 98th percentile temperature (~~T_{98th}~~T_{98}), that is the temperature that a module would be expected to ~~equal or~~ exceed for 175,2 h per year, is less than 70 °C.

NOTE 175,2 h represents 2 % of a total year as some thermal failure modes are a function of time at temperature and not sensitive to day-only or night-only exposure.

Hybrid PV and thermal systems are out of scope of this document. Guidance on the selection of meteorological data for use in estimating T_{98} is outside the scope of this document and it is important to give it careful consideration. Annex A provides a method for estimating the temperature rating for PV modules without installation- or location-specific verification. With this, suitable installation practices and long-term durability testing can be prescribed. More accurate prescription of the temperature rating including local assessment and verification is outside the scope of this document. The effects of climate change are uncertain and not in the scope of this document. The intent of this specification is to address issues with higher temperatures but not for extended durability beyond that assessed in the IEC 61215 series or IEC 61730 series.

This document defines two temperature regimes, temperature Level 1 and temperature Level 2, which were designed considering deployment in environments with mounting configurations such that the ~~T_{98th}~~ T_{98} is less than or equal to 80 °C for temperature Level 1, and less than or equal to 90 °C for temperature Level 2. This document provides recommended additional testing conditions within the IEC 61215 series, IEC 61730 series, IEC 62788-1-7, IEC 62788-2-1, IEC 62790 and IEC 62852 for module operation in temperature Levels 1 and 2. Successfully passing a higher Level for a test, sequence of tests, or complete testing for a higher Level is an implied passing of the relevant lower-Level testing. For example, passing 200 thermal cycles for Level 2 is considered passing Level 0 and Level 1 for 200 thermal cycles.

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 61215 (all parts), *Terrestrial photovoltaic (PV) modules - Design qualification and type approval*

IEC 61215-2:~~2016~~2021, *Terrestrial photovoltaic (PV) modules - Design qualification and type approval - Part 2: Test procedures*

IEC 61730 (all parts), *Photovoltaic (PV) module safety qualification*

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 62788-1-7, *Measurement procedures for materials used in photovoltaic modules - Part 1-7: Encapsulants - Test procedure of optical durability*

~~IEC TS 62788-2:2017, *Measurement procedures for materials used in photovoltaic modules – Part 2: Polymeric materials – Frontsheets and backsheets*~~

IEC 62788-2-1, *Measurement procedures for materials used in photovoltaic modules – Part 2-1: Polymeric materials - Frontsheets and backsheets - Safety requirements*

IEC TS 62788-7-2, *Measurement procedures for materials used in photovoltaic modules – Part 7-2: Environmental exposures - Accelerated weathering tests of polymeric materials*

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

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

IEC 62930:2017, *Electric cables for photovoltaic systems with a voltage rating of 1,5 kV DC*

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This document defines high temperature environment use requirements but does not include applications designed to combine photovoltaic and thermal energy applications. These requirements are being refined and in part incorporated into other standards. It is not necessarily cost effective for module materials to comply with Level 1 or Level 2 requirements defined in this document, unless the module temperature is expected to exceed 70 °C at the 98th percentile. Primarily, this will only be necessary in building applied applications in hot climates. Vertical building facades are not likely to operate at these high temperatures because of reduced in plane irradiance and good free convection on the outer surface. Module materials capable of temperature Level 1 or temperature Level 2 are expected to impose higher expectations of endurance and cost than normal modules.

Component standard IEC 62930 is considered to be adequate for modules operating at high temperatures without modification due to requiring cable to have a 120 °C or greater thermal endurance at a 20 000 h correlation lifetime. A guide for cable correction factors at higher cable ambient temperatures is given in IEC 62930:2017, Table A.4. Similarly, IEC 62979 [1][1] is considered adequate for bypass diode thermal runaway determination due to testing temperatures of 90 °C for roof-mounted modules and 75 °C for "rack mounted" modules.

Similar to electric cables, IEC 61730-1 requires a relative thermal index (RTI), thermal index (TI), or relative thermal endurance (RTE) of 90 °C or larger. A module operating in an environment and installation style resulting in a 98th percentile temperature of 70 °C requires an RTI, TI, or RTE safety factor of +20 °C to establish a 25-year lifetime when the polymer has a minimum activation energy of 46 kJ/mol and the correlation lifetime is 20 000 h. This work approximately applies that safety factor of +20 °C for polymer RTI, TI, or RTE when the 98th percentile operating temperature is above 70 °C.

[1] Numbered in square brackets refer to the Bibliography.

Data from PV modules in hot climates and modelling were used to understand operating temperatures and resulted in two categories of high temperature operation, temperature Level 1 and temperature Level 2. These categories are defined within this document and it is relevant to indicate that Level 2 temperatures were not found in field data, but can result from insulated substrate modules on pitched roofs facing the sun when ambient air temperature exceeds 40 °C. This can be most consistent with building-integrated PV module roofs and, to allow for this possibility, the temperature Level 2 category remains in this document.

In Annex A, methods are given for estimating when a particular system design will need higher levels of qualification. Short of actual measurement at a particular site, one cannot precisely estimate the 98^{th} percentile temperature. However, the suggested methods give a rough approximation of when Level 1 and Level 2 qualification are likely to be needed.

1 Scope

This document defines additional testing requirements for photovoltaic (PV) modules deployed under conditions leading to higher module temperature which are beyond the scope of IEC 61215-1 and IEC 61730-1 and the relevant component standards, IEC 62788-1-7, IEC 62788-2-1, IEC 62790 and IEC 62852. The testing conditions specified in IEC 61215-2 and IEC 61730-2 (and the relevant component standards IEC 62788-1-7, IEC 62788-2-1, IEC 62790 and IEC 62852) assumed that these standards are applicable for module deployment where the 98th percentile temperature (T_{98}), that is the temperature that a module would be expected to exceed for 175,2 h per year, is less than 70 °C.

NOTE 175,2 h represents 2 % of a total year as some thermal failure modes are a function of time at temperature and not sensitive to day-only or night-only exposure.

Hybrid PV and thermal systems are out of scope of this document. Guidance on the selection of meteorological data for use in estimating T_{98} is outside the scope of this document and it is important to give it careful consideration. Annex A provides a method for estimating the temperature rating for PV modules without installation- or location-specific verification. With this, suitable installation practices and long-term durability testing can be prescribed. More accurate prescription of the temperature rating including local assessment and verification is outside the scope of this document. The effects of climate change are uncertain and not in the scope of this document. The intent of this specification is to address issues with higher temperatures but not for extended durability beyond that assessed in the IEC 61215 series or IEC 61730 series.

This document defines two temperature regimes, temperature Level 1 and temperature Level 2, which were designed considering deployment in environments with mounting configurations such that the T_{98} is less than or equal to 80 °C for temperature Level 1, and less than or equal to 90 °C for temperature Level 2. This document provides recommended additional testing conditions within the IEC 61215 series, IEC 61730 series, IEC 62788-1-7, IEC 62788-2-1, IEC 62790 and IEC 62852 for module operation in temperature Levels 1 and 2. Successfully passing a higher Level for a test, sequence of tests, or complete testing for a higher Level is an implied passing of the relevant lower-Level testing. For example, passing 200 thermal cycles for Level 2 is considered passing Level 0 and Level 1 for 200 thermal cycles.

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 61215 (all parts), *Terrestrial photovoltaic (PV) modules - Design qualification and type approval*

IEC 61215-2:2021, *Terrestrial photovoltaic (PV) modules - Design qualification and type approval - Part 2: Test procedures*

IEC 61730 (all parts), *Photovoltaic (PV) module safety qualification*

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 62788-1-7, *Measurement procedures for materials used in photovoltaic modules - Part 1-7: Encapsulants - Test procedure of optical durability*

IEC 62788-2-1, *Measurement procedures for materials used in photovoltaic modules – Part 2-1: Polymeric materials - Frontsheets and backsheets - Safety requirements*

IEC TS 62788-7-2, *Measurement procedures for materials used in photovoltaic modules – Part 7-2: Environmental exposures - Accelerated weathering tests of polymeric materials*

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

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

IEC 62930:2017, *Electric cables for photovoltaic systems with a voltage rating of 1,5 kV DC*