

INTERNATIONAL STANDARD

NORME INTERNATIONALE



Photovoltaic (PV) module safety qualification – Part 1: Requirements for construction

Qualification pour la sûreté de fonctionnement des modules photovoltaïques (PV) – Partie 1: Exigences pour la construction



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IEC 61730-1 has been prepared by IEC technical committee 82: Solar photovoltaic energy systems. It is an International Standard.

This third edition cancels and replaces the second edition published in 2016. This edition constitutes a technical revision.

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

- a) Revision of Clauses 2 and 3.
- b) Addition of requirements for qualification of specific components according to their standard documents (junction box, connectors, frontsheets/backsheets).
- c) Significant changes to the definition and testing of relied upon insulation materials (RUI). These requirements are described in the pre-qualification document for frontsheets and backsheets (IEC 62788-2-1). This includes:
 - 1) clarifications on the concept and measurement of DTI, and related materials test requirements;

- 2) frontsheet/backsheet weathering requirements.
- d) Removal of all reference to "open rack", with updates according to an intended use for applications according to the application's 98th percentile module operating temperature.
- e) Modules meeting Class 0 for use in restricted access areas are not required to pass the breakage test, (MST 32).
- f) Marking and documentation subclauses have been revised and aligned with the IEC 61215 series.
- g) Electronic copies are now allowed instead of paper copies of required safety documentation.
- h) Requirements for bifacial modules:
 - 1) addition of new term, aBSI;
 - 2) relevant tests have been changed to account for higher current of bifacial modules;
 - 3) for bifacial modules, marking that indicates which side is designed as the front side, or if both are designed for prolonged exposure to direct sunlight ($> 300 \text{ W/m}^2$);
 - 4) relevant parameters for installing bifacial modules clarified;
 - 5) overprotection rating;
 - 6) documentation has been modified.
- i) In 6.2, marking requirements for connectors have been added.
- j) Related to the intended use temperature range:
 - 1) Clause 5 and 6.2 have been modified to include temperature ratings, with $> 70 \text{ °C}$ 98th percentile module operating temperature as the default maximum. Guidance for factors which could impact the module operating temperature for a system design/location are provided, and responsibility for proper installation is placed upon the installer.
 - 2) Changes to insulation coordination sections (6.6, Annex B and Annex C).
 - 3) Subclauses on insulation coordination (6.6.3) and distance through solid insulation (6.6.4) have been updated to clearly state the insulation coordination requirements, and are aligned with Annex B.
 - 4) Annex B has been revised to show the basis for the dimensioning related to insulation coordination and is aligned with 6.6.3 and 6.6.4.
 - 5) Annex C has been created to show specific use cases and describe how changes to materials or use of additional testing can modify the required dimensioning. Diagrams have been updated.
 - 6) A new term, distance through functional insulation (DTFI), has been defined to describe the spacing between fully encapsulated live parts of different potential (the larger of creepage and clearance for the relevant voltage).
 - 7) Testing requirements to verify a clearance value less than the listed value (but not below the creepage distance) are defined.
 - 8) Requirements for junction boxes, cables and connectors, and polymeric frontsheets/backsheets have been removed (these are now covered in their respective standards).
 - 9) In Table 2, functional insulation is required for insulation between live parts of different potential inside a PV module for all module types.
 - 10) In Table 3 and Table 4:
 - i) lines related to pollution degree 3 have been removed, since this is not applicable to module laminates passing the requirements of IEC 61730-2;
 - ii) the minimum values for DTI have been increased to include the minimum 0,030 mm thickness (pinhole considerations);
 - iii) lines related to reinforced insulation have been combined;
 - iv) lines related to basic insulation have been combined, and functional insulation included on those lines;

v) lines for DTFI have been added.

- 11) Insulation coordination requirements for Class III modules have been removed from Table 4, and functional insulation requirements are included in text (no DTI thickness requirement).

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

Draft	Report on voting
82/2140/FDIS	82/2165/RVD

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

The language used for the development of this International Standard is English.

A list of all parts in the IEC 61730 series, under the general title *Photovoltaic (PV) module safety qualification*, can be found on the IEC website.

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/standardsdev/publications.

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PHOTOVOLTAIC (PV) MODULE SAFETY QUALIFICATION –

Part 1: Requirements for construction

1 Scope

This part of IEC 61730 specifies and describes the fundamental construction requirements for photovoltaic (PV) modules in order to provide safe electrical and mechanical operation. Specific topics are provided to assess the prevention of electrical shock, fire hazards, and personal injury due to mechanical and environmental stresses. This document pertains to the particular requirements of construction. IEC 61730-2 defines the requirements for testing. Modules with modified construction are qualified as described in IEC TS 62915.

This document lays down requirements for terrestrial PV modules suitable for long-term operation in open-air climates with 98th percentile module operating temperatures of 70 °C or less. Guidelines for modules to be used at higher operating temperatures are described in IEC TS 63126. The useful service life of modules so qualified will depend on their design, their environment, and the conditions under which they are operated. Therefore, test results are not construed as a quantitative prediction of module lifetime.

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.

PV modules covered by this document are limited to a maximum DC system voltage of 1 500 V.

This document defines the basic requirements for various applications of PV modules, but it cannot be considered to encompass all national or regional codes. Specific requirements, e.g. for building, floating, marine and vehicle applications, are not covered.

This document does not address specific requirements for products that combine a PV module with power conversion equipment, monitoring or control electronics, such as integrated inverters, converters or output disabling functions, which are addressed in IEC 62109-3.

While it is possible that parts of this document are applicable to flat plate PV modules with internally generated low-level concentration below three times, it was not written specifically to address these concerns.

This document is designed to coordinate with the test sequences in the IEC 61215 series, so that a single set of samples can be used to perform both the safety and design qualification of a PV module.

Additional construction requirements outlined in relevant ISO standards, or the national or local codes which govern the installation and use of these PV modules in their intended locations, can apply in addition to the requirements contained within this document.

Any change to materials, design, or internal spacing are subject to a re-evaluation of the PV module or its component(s), as applicable, according to the IEC 61730 series and IEC TS 62915.

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 60216-1, *Electrical insulating materials – Thermal endurance properties – Part 1: Ageing procedures and evaluation of test results*

IEC 60216-2, *Electrical insulating materials – Thermal endurance properties – Part 2: Determination of thermal endurance properties of electrical insulating materials – Choice of test criteria*

IEC 60216-5, *Electrical insulating materials – Thermal endurance properties – Part 5: Determination of relative temperature index (RTE) of an insulating material*

IEC 60243-1:2013, *Electric strength of insulating materials – Test methods – Part 1: Tests at power frequencies*

IEC 60243-2:2013, *Electric strength of insulating materials – Test methods – Part 2: Additional requirements for tests using direct voltage*

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

IEC 60364-7-712, *Low voltage electrical installations – Part 7-712: Requirements for special installations or locations – Solar photovoltaic (PV) power supply systems*

IEC 60417, *Graphical symbols for use on equipment*, available at <https://www.graphical-symbols.info/equipment>

IEC 60529, *Degrees of protection provided by enclosures (IP code)*

IEC 60664-1:2020, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*

IEC 60695-11-10, *Fire hazard testing – Part 11-10: Test flames – 50 W horizontal and vertical flame test methods*

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

IEC 60950-1:2005, *Information technology equipment – Safety – Part 1: General requirements*

IEC 61032:1997, *Protection of persons and equipment by enclosures – Probes for verification*

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

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

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 62548, *Photovoltaic (PV) arrays – Design requirements*

IEC 62788-1 (all parts), *Measurement procedures for materials used in photovoltaic modules – Part 1: Encapsulants*

IEC 62788-1-2, *Measurement procedures for materials used in photovoltaic modules – Part 1-2: Encapsulants – Measurement of volume resistivity of photovoltaic encapsulants and other polymeric materials*

IEC TS 62788-2, *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 62790:2020, *Junction boxes for photovoltaic modules – Safety requirements and tests*

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

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

IEC TS 63126, *Guidelines for qualifying PV modules, components and materials for operation at high temperatures*

IEC TR 63225, *Incompatibility of connectors for DC-application in photovoltaic systems*

ISO 1456, *Metallic and other inorganic coatings – Electrodeposited coatings of nickel, nickel plus chromium, copper plus nickel and of copper plus nickel plus chromium*

ISO 1461, *Hot dip galvanized coatings on fabricated iron and steel articles – Specifications and test methods*

ISO 2081, *Metallic and other inorganic coatings – Electroplated coatings of zinc with supplementary treatments on iron or steel*

ISO 2093, *Electroplated coatings of tin – Specification and test methods*

ISO 7010, *Graphical symbols – Safety colours and safety signs – Registered safety signs*, available at <https://www.iso.org/obp>

ISO 9224:2012, *Corrosion of metals and alloys – Corrosivity of atmospheres – Guiding values for the corrosivity categories*

EN 50618, *Electric cables for photovoltaic systems*

UL 746B, *Standard for Polymeric Materials – Long Term Property Evaluations*

IEC/IEEE 82079-1, *Preparation of information for use (instructions for use) of products – Part 1: Principles and general requirements*

3 Terms, definitions, symbols and abbreviated terms

For the purposes of this document, the terms and definitions given in IEC 60664-1, IEC TS 60904-1-2, IEC 61140, IEC TS 61836, IEC 61215-1 and the following apply.

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 General terms and definitions

3.1.1

functional earthing

earthing for purposes other than electrical safety

[SOURCE: IEC 60050-195:2021, 195-01-13]

3.1.2

internal wiring

wiring and electrical connections that are made within the apparatus by its manufacturer

[SOURCE: IEC 60050-426:2020, 426-11-32]

3.1.3

external wiring

wiring that is not *internal wiring* (3.1.2), including, but not limited to, output cables

3.1.4

laminated

product made by bonding together two or more layers of the same or different materials

Note 1 to entry: It includes all components prior to attaching the junction box, frame or rail, and nameplate.

[SOURCE: IEC 60050-212:2010, 212-15-52, modified – Note 1 to entry has been added]

3.1.5

manufacturer

legal entity that manufactures a product, or that has a product designed or manufactured, and that markets the product under its name or trademark

3.1.6

module quality test

MQT

PV module quality test in accordance with IEC 61215-2

3.1.7

module safety test

MST

PV module safety test in accordance with IEC 61730-2

3.2 Components

3.2.1

backsheet

outer layer or combination of outer layers of the PV module, located as substrate on the back of the PV module and providing protection of the inner components of the PV module from external stresses and weather elements, as well as providing electrical insulation

3.2.2

connector

component which terminates conductors for the purpose of providing connection to and disconnection from a suitable mating component

[SOURCE: IEC 60050-581:2008, 581-06-01]

3.2.3

encapsulant

<general> material used between the substrate and superstrate to provide environmental protection for photovoltaic cells in a photovoltaic module

[SOURCE: IEC TS 61836:2016, 3.1.30, modified – Domain has been added.]

3.2.4

enclosure

part of an assembly providing a specified degree of protection of equipment against external influences and a specified degree of protection against approach to or contact with live parts

[SOURCE: IEC 60050-441:1984, 441-13-01, modified – In the definition, the words "and against contact with moving parts" have been deleted.]

3.2.5

frontsheet

outer layer or combination of outer layers of the PV module, located as superstrate on the front of the PV module and providing protection of the inner components of the PV module from external stresses and weather elements, as well as providing electrical insulation

3.2.6

insulation barrier

raised or recessed configuration of an insulator to increase creepage distance between conducting surfaces

[SOURCE: IEC 60050-581:2008, 581-22-15]

3.2.7

junction box

closed or protected enclosure in which circuits are electrically connected

[SOURCE: IEC TS 61836:2016, 3.2.16]

3.2.8

potting

sealing of components and associated conductors with a compound to exclude contaminants

[SOURCE: IEC 60050-581:2008, 581-24-20]

3.2.9

terminal

conductive part of a device, electric circuit or electric network, provided for connecting that device, electric circuit or electric network to one or more external conductors

Note 1 to entry: Can contain one or several contacts and the term therefore includes sockets, connectors, etc.

[SOURCE: IEC 60050-151:2001, 151-12-12, modified – The original Note 1 to entry has been replaced.]

3.3 Installation and application

3.3.1

building attached PV

BAPV

system in which the PV modules are mounted on a building envelope and do not fulfil the criteria for *building integrated PV* (3.3.2)

3.3.2**building integrated PV
BIPV**

system in which the PV modules form a building component providing additional functions as defined in 5.5 b)

3.3.3**installation**

<fixed wiring> permanent wiring system such as a raceway or conduit that prevents or reduces wire and cable movement

3.3.4**installation**

<non-fixed wiring> unconstrained wiring system that consists of cables or wires able to move freely

3.3.5**non-restricted access area**

area to which all persons including those who are not skilled, trained or instructed in electrical safety have general access

EXAMPLE Any PV installations which are not protected against public access by any means.

Note 1 to entry: A building's roof is considered non-restricted access area, unless explicitly marked as restricted area.

3.3.6**restricted access area**

area accessible only to electrically skilled persons and electrically instructed persons with the proper authorization

EXAMPLE Utility-scale PV installations which are protected against public access by fences, location, etc., and where only persons skilled, trained or instructed in electrical safety have access.

[SOURCE: IEC 60050-195:2021, 195-04-04, modified – The example has been added.]

3.4 Insulation concepts**3.4.1****accessible part**

part which can be touched by means of the standard test finger

Note 1 to entry: The standard test finger is as in Figure 2, test probe B of IEC 61032:1997.

[SOURCE: IEC 60050-442:1998, 442-01-15, modified – Note 1 to entry has been added.]

3.4.2**live part**

conductive part intended to be energized under normal operating conditions

[SOURCE: IEC 60050-195:2021, 195-02-19, modified – The second part of the definition has been deleted because not applicable to DC.]

3.4.3**insulation system**

insulating material, or an assembly of insulation materials, to be considered in relation with associated conducting parts, as applied to a particular type or size or part of electrical equipment

[SOURCE: IEC 60050-411:2007, 411-39-25]

3.4.4

electric insulation

insulation

<electricity> part of an electrotechnical product which separates conducting parts at different electric potentials during operation or insulates such parts from the surroundings

[SOURCE: IEC 60050-212:2010, 212-11-07, modified – The admitted term has been added as synonym and the domain has been specified.]

3.4.5

basic insulation

insulation that provides basic protection against electric shock

Note 1 to entry: This concept does not apply to insulation used exclusively for functional purposes.

[SOURCE: IEC 60050-195:2021, 195-06-06, modified – In the definition, "against electric shock" has been added.]

3.4.6

double insulation

insulation comprising both *basic insulation* (3.4.5) and *supplementary insulation* (3.4.9)

[SOURCE: IEC 60050-195:2021, 195-06-08]

3.4.7

functional insulation

insulation between conductive parts, necessary for the proper functioning of the equipment

Note 1 to entry: Functional insulation by definition does not protect against electric shock. It can, however, reduce the likelihood of ignition and fire.

[SOURCE: IEC 60050-195:2021, 195-02-41, modified – Note 1 to entry has been added.]

3.4.8

reinforced insulation

insulation of hazardous-live parts (3.4.2) that provides a degree of protection against electric shock equivalent to *double insulation* (3.4.6)

Note 1 to entry: Reinforced insulation may comprise several layers which cannot be tested singly as basic insulation or supplementary insulation.

[SOURCE: IEC 60050-195:2021, 195-06-09, modified – In the definition, "hazardous-live parts" has been added.]

3.4.9

supplementary insulation

independent insulation applied in addition to *basic insulation* (3.4.5), that provides fault protection

EXAMPLE It can be used in order to reduce the risk of electric shock in the event of a failure of the basic insulation.

[SOURCE: IEC 60050-195:2021, 195-06-07, modified – The example has been added.]

3.4.10

solid insulation

solid insulating material, or a combination of solid insulating materials, placed between two conductive parts or between a conductive part and a body part

Note 1 to entry: It includes both thin films and cemented joints, with related but different testing and dimensioning requirements.

[SOURCE: IEC 60050-903:2015, 903-04-14, modified – The example has been deleted and Note 1 to entry has been added.]

3.4.11

cemented joint

joint comprised of two insulating materials where the interface has been demonstrated to be cemented, and thus considered as *solid insulation* (3.4.10) with no interface for creepage

3.4.12

relied upon insulation

RUI

solid insulation (3.4.10) system providing protection against electric shock in the final application, with material's requirements for thickness, thermal endurance and resistance against environmental stress factors

Note 1 to entry: Thin films used as polymeric backsheet or frontsheet can consist of RUI plus additional layers that have other functions, e.g. they protect the polymeric materials from UV radiation.

3.4.13

breakdown voltage

V_{B-DC}

DC voltage at which electric breakdown occurs under prescribed test conditions, or in use

Note 1 to entry: Breakdown voltage testing in context of PV modules and components materials applies direct current (DC).

[SOURCE: IEC 60050-212:2010, 212-11-34, modified – The symbol and Note 1 to entry have been added.]

3.4.14

material group

category of insulation materials according to IEC 60664-1

3.4.15

comparative tracking index

CTI

numerical index value related to the maximum voltage that a material can withstand without formation of a permanent and electrically conductive carbon (tracking) path and without occurrence of a persistent flame, when evaluated under specified test conditions defined in IEC 60112

Note 1 to entry: The mentioned maximum test voltage is not in conjunction with any system or operational voltage, but it is used for evaluation of material groups.

[SOURCE: IEC 60050-212:2010, 212-11-59, modified – The definition has been rephrased by also clarifying that CTI is an index value to evaluate material groups according to IEC 60112. Note 1 to entry has also been added.]

3.4.16

clearance

cl

shortest distance in air, between two conductive parts or between a conductive part and an accessible surface

[SOURCE: IEC 60050-581:2008, 581-27-76, modified – The definition has been extended by "or between a conductive part and an accessible surface".]

3.4.17

creepage distance

cr

shortest distance along the surface of a solid insulating material between two conductive parts or between conductive *live parts* (3.4.2) and *accessible parts* (3.4.1)

[SOURCE: IEC 60050-581:2008, 581-21-23, modified – The abbreviation has been added. In the definition, a second pair of parts has been added.]

3.4.18

distance through insulation

DTI

thickness of relied upon insulation (RUI) in a PV module, with the minimum allowable value defined by the maximum working voltage

3.4.19

distance through solid insulation

shortest distance through solid insulation between two conductive parts

[SOURCE: IEC 60050-426:2020, 426-04-14]

3.4.20

distance through functional insulation

shortest distance through material not qualified as relied upon insulation between two conductive parts

3.5 Ratings

3.5.1

rated value

value of a quantity used for specification purposes, established for a specified set of operating conditions of a component, device, equipment, or system

[SOURCE: IEC 60050-151:2001, 151-16-08]

3.5.2

rating

set of rated values and operating conditions

[SOURCE: IEC 60050-151:2001, 151-16-11]

3.5.3

rated current of overcurrent protection device

current rating of fuse or circuit breaker according to IEC 60269-6

3.5.4

pollution degree

numeric classification characteristic of the expected pollution of the micro-environment

[SOURCE: IEC 60050-581:2008, 581-21-07, modified – In the definition, "numeral characterizing" has been changed to "numeric classification characteristic of".]

3.5.5

maximum rated altitude

maximum altitude at which the module is rated to be deployed at the rated system voltage in the nameplate

Note 1 to entry: This implies the module has either been designed with larger clearance distances (Table 5) or tested for the applicable higher impulse voltage rating at a given fixed clearance spacing to qualify for that altitude.

3.5.6

maximum rated operating temperature

$[T_{98}]_{\max}$

maximum 98th percentile module operating temperature at which the module is rated to be deployed at the rated temperature on the nameplate

3.6 Temperatures

3.6.1

environmental temperature

air temperature defined in degrees Celsius and measured and documented by meteorological services for the installation's geographic location

3.6.2

temperature index

TI

numerical value of the Celsius temperature expressed in degrees Celsius characterizing the thermal capability of an insulating material or an insulation system

[SOURCE: IEC 60050-212:2010, 212-12-11, modified – Notes have been removed.]

3.6.3

relative temperature index

RTI

temperature index of an insulating material or system obtained from the time which corresponds to the known temperature index of a reference material or system when both are subjected to the same ageing and diagnostic procedures in a comparative test

[SOURCE: IEC 60050-212:2010, 212-12-12]

3.6.4

relative thermal endurance index

RTE

numerical value of the Celsius temperature expressed in degrees Celsius at which the estimated time to endpoint of an insulating material is the same as the estimated time to endpoint of a control material at a temperature equal to its assessed thermal endurance

[SOURCE: IEC 60050-212:2010, 212-12-14, modified – Notes have been removed.]

3.6.5

98th percentile module operating temperature

temperature at which a module is operating below more than 98 % of the time when deployed in a PV system

Note 1 to entry: The 98th percentile module operating temperature is calculated by ranking measured or calculated module temperature data taken at hourly (or more frequent) time intervals for a typical calendar year.

Note 2 to entry: For a standard year, the 98th percentile module operating temperature is met or exceeded for 175,2 h.

3.7 Voltages

3.7.1

rated system voltage

$[V_{\text{sys}}]_{\max}$

maximum voltage between any *live part* (3.4.2) and *accessible part* (3.4.1) or earth against which the *electric insulation* (3.4.4) of the PV module is designed to stand under operating conditions as specified by the manufacturer

3.7.2

working voltage

highest RMS value of the DC voltage across any particular insulation which can occur when the equipment is operated at rated voltage

[SOURCE: IEC 60050-581:2008, 581-21-19, modified – The definition has been limited to DC and "supplied" has been replaced by "operated".]

3.8 Bifacial photovoltaics

3.8.1

bifacial PV module

module that can generate electric power by converting UV-VIS-IR radiation received on both front and rear sides by means of the photovoltaic effect

3.8.2

bifaciality coefficient

ratio between the main characteristics of the rear side and the front side of a bifacial PV device

Note 1 to entry: Usually bifacial coefficients are referred to Standard Test Conditions (STC).

Note 2 to entry: Three types of coefficient are defined in IEC TS 60904-1-2. They are:

- bifaciality coefficient for short-circuit current, $\phi_{I_{sc}}$;
- bifaciality coefficient for open-circuit voltage, $\phi_{V_{oc}}$;
- bifaciality coefficient for maximum power point, $\phi_{P_{max}}$.

3.8.3

bifacial nameplate irradiance

BNPI

irradiance at which currents are measured on bifacial modules, corresponding to 1 000 W/m² on the module front and 135 W/m² on the module rear, applied by any method allowed in IEC TS 60904-1-2

3.8.4

bifacial stress irradiance

BSI

higher irradiance at which currents for stress are measured on bifacial modules, corresponding to 1 000 W/m² on the module front and 300 W/m² on the module rear, applied by any method allowed in IEC TS 60904-1-2

3.8.5

applied bifacial stress irradiance

aBSI

irradiance corresponding to the combination of 1 000 W/m² on the front side of the module with the value that is greater of 300 W/m² or the manufacturer's claimed irradiance value for the rear side of the module

4 Symbols and abbreviated terms

$I_{SC-BNPI}$	short-circuit current for bifacial PV modules at BNPI
I_{SC-BSI}	short-circuit current for bifacial PV modules at BSI
I_{mp-BSI}	current at maximum power point of bifacial PV modules exposed to BSI
$I_{SC-aBSI}$	short-circuit current for bifacial PV modules under aBSI conditions of irradiance
$I_{mp-aBSI}$	current at maximum power point of bifacial PV modules exposed to aBSI conditions of irradiance

5 Classification, applications and intended use

5.1 General

Protection against electric shock will be achieved by combinations of constructional measures used to build the module together with how the module is installed.

The degree of protection that the PV modules achieve shall be classified according to the descriptions provided in Table 1, based on requirements in IEC 61140. Each PV module shall be classified for protection against electric shock by attributing to it the same class to which it complies according to IEC 61140. The use of the protections in the different classes for the PV modules is described in 5.2 to 5.4. PV modules complying with Class I of IEC 61140 are not covered in this document.

EXAMPLE A PV module that satisfies the requirements for protection against electric shock as identified by Class II of IEC 61140 is classified as a Class II PV module.

In relation to this, the PV modules shall be marked in accordance with 6.2.2.

Table 1 – Classes for protection against electric shock

Class (as defined in IEC 61140)	Application in this document
0	Application in restricted access area
II	Application in non-restricted access area
III	Basic protection by limitation of voltage (ELV)

5.2 PV modules of Class 0

5.2.1 General

Class 0 PV modules have individual and/or system level electrical outputs at hazardous levels of voltage, current and power.

5.2.2 Insulation

These PV modules are provided with basic insulation only as provision for basic protection and with no provisions for fault protection. All conductive components that are not separated from hazardous live parts by at least basic insulation shall be treated as if they are hazardous live parts.

5.2.3 Application

Class 0 PV modules are intended for use in restricted access areas that are protected from public access by fences or other measures of the location that prevent general access. Such PV modules are only to be accessed by persons knowledgeable of the inherent hazards associated with their use and failure modes.

5.3 PV modules of Class II

5.3.1 General

Class II PV modules have individual and/or system level electrical outputs at hazardous levels of voltage, current and power.

5.3.2 Insulation

These PV modules are provided with:

- basic insulation as basic protection, and
- supplementary insulation as precaution for fault protection,

or

- double insulation as basic and supplementary insulation, or reinforced insulation.

Accessible conductive parts and accessible surfaces of insulation material shall be:

- separated from hazardous live parts by double or reinforced insulation,

or

- designed with constructional measures which provide comparable protection.

All conductive parts which are separated from hazardous live parts only by basic insulation or by constructional design means which provide comparable protection shall be separated from accessible surfaces by supplementary insulation. All conductive parts which are not separated from hazardous live parts at least by basic insulation shall be considered as hazardous live parts.

5.3.3 Application

These PV modules are intended for installations where non-restricted access to the PV module and contact to insulated live parts can occur.

5.4 PV modules of Class III

5.4.1 General

Class III PV modules shall not have electrical ratings larger than:

- 240 W for the maximum power point,
- 35 V DC for the open-circuit voltage, and
- 8 A for the short-circuit current,

when tested under STC. The three maximum rating conditions shall apply concurrently.

5.4.2 Insulation

Class III PV modules have inherently limited capability of electrical output. Therefore, their use, misuse and failure are unlikely to result in a risk of electric shock or fire. Based upon these electrical output limitations, no requirements for construction or insulation are given beyond functional insulation.

5.4.3 Application

These PV modules are intended for installations where non-restricted access to the PV module and contact to uninsulated live parts can occur, e.g. in consumer electronics. Class III PV modules shall not be combined in series strings operating at more than 35 V in V_{OC} and shall

not have a system voltage rating above 35 V. These PV modules are not intended for use in parallel with other PV modules or energy sources unless their combination provides protection from reverse current and from overvoltage protection.

5.5 Rating categories and special applications

PV modules can be installed in many different applications and system configurations.

Modules are intended for use in the temperature range from a lower environmental temperature of $-40\text{ }^{\circ}\text{C}$ to the upper-limit set by a 98th percentile module operating temperature of $70\text{ }^{\circ}\text{C}$, unless tested according to IEC TS 63126.

Modules qualified for a 98th percentile module operating temperature equal to or less than $70\text{ }^{\circ}\text{C}$ will allow for use in PV arrays designed with unrestricted airflow to the back of the module anywhere in the world. Systems designed with restricted airflow in very hot locations may result in a 98th percentile module operating temperature greater than $70\text{ }^{\circ}\text{C}$, and require modules tested to higher temperature conditions as provided in IEC TS 63126.

System design and installation factors which can affect the module operating temperature include (but are not limited to): site specific environmental conditions (irradiance, temperature, wind speed), and mounting distance, array size, array spacing, anti-nesting features which could reduce airflow. Installers must consider these factors in design of systems. Refer to IEC TS 63126 for more information.

NOTE 1 Specific geographic restrictions can apply; maps in IEC TS 63126 provide examples.

NOTE 2 An IEC document describing a method for calculating the 98th percentile module operating temperature for different mounting and geographical combinations is in progress.

For special applications, such as the examples listed below, additional requirements can apply:

- Building attached PV (BAPV).
- Building integrated PV (BIPV, see IEC 63092-1).

The building's functions in the context of BIPV are one or more of the following:

- mechanical rigidity and structural integrity;
- primary weather impact protection: rain, snow, wind, hail;
- energy economy, such as shading, daylighting, thermal insulation;
- fire protection;
- noise protection.

Thus, the BIPV module is a prerequisite for the integrity of the building's functionality. If the integrated PV module is dismounted (in the case of structurally bonded modules, dismounting includes the adjacent building component), the PV module would have to be replaced by an appropriate building component.

Inherent electro-technical properties of PV such as antenna function, power generation and electromagnetic shielding, etc. alone do not qualify PV modules as building integrated.

- Applications in areas where snow and/or wind load are expected to exceed loads as tested in IEC 61730-2.

NOTE 3 For nonuniform snow loads, see IEC 62938.

- Areas with high salt exposure (IEC 61701).
- Agricultural application (e.g. IEC 62716).
- Application in explosive atmospheres (IEC 60079).
- For concentration levels above 3X, see IEC 62688.
- Module-applied electronics (see IEC 62109-3).

NOTE 4 Guidance for PV modules used in floating solar and vehicle applications is under development.

6 Requirements for design and construction

6.1 General

This document is suitable for modules operating at a 98th percentile module operating temperature of 70 °C or less. Applications in hot climates using mounting methods that restrict airflow could lead to a 98th percentile operating temperature in excess of 70 °C. Guidance for extended testing for these applications is provided in IEC TS 63126.

Where applicable, materials and components shall comply with the safety requirements specified in the relevant IEC standards. However, compliance with the IEC standard relevant for the material and/or component does not necessarily ensure compliance with the requirements of this document.

All PV modules shall be suitable for operation in unprotected outdoor locations, i.e. exposed to direct and indirect (albedo) solar radiation and up to 100 % relative humidity as well as to rain. PV modules shall be designed to withstand the electrical, mechanical, thermal and environmental (temperature, mechanical load, humidity, UV/weather, pollution, etc.) stresses occurring in their intended use. They shall not present any danger to the user or to the environment. Compliance is verified by evaluation of materials, components, and PV module construction as well as by tests specified in IEC 61730-2.

A PV module can either be completely assembled when shipped from the factory or be provided in subassemblies. The provided subassemblies of the product shall not involve any action that is likely to affect compliance with the requirements of the IEC 61730 series.

Incorporation of a PV module into the final assembly shall not require any alteration of the PV module from its originally evaluated form.

All methods of PV module mounting and wiring that are specified in the installation instructions shall be evaluated for compliance with the IEC 61730 series. This includes, but is not limited to, wiring methods, physical connection and/or attachment between PV modules and support structures as well as combinations of wiring connections and mounting system where the wiring is integral to the frame. Compliance with the IEC 61730 series assesses the impact of the mounting and wiring methods on the safety of the PV modules but does not assess the safety or suitability of the mounting or wiring methods for their intended use. These methods can also be subject to additional requirements or to local code requirements.

The module is considered to be in compliance with this document only when the module is mounted and wired according to one of the methods specified by the mounting instructions.

IEC 60364-7-712 and IEC 62548 provide guidance for interconnection between PV modules and systems.

The construction of a PV module shall be such that equipotential bonding continuity, if applicable, is not interrupted by installation.

Any adjustable or movable structural part shall be provided with a locking device to reduce the likelihood of unintentional movement, if any such movement could result in a risk of fire, electric shock, or mechanical hazards.

NOTE Physical properties or constructions that provide an interference or form fit to prevent unintended movement or rotation of the component comply with this requirement.

PV modules shall not have accessible burrs, sharp edges or sharp points that can cause injury. Edges and points shall comply with the sharp edge test (MST 06) of IEC 61730-2.

The parts of a PV module shall be prevented from loosening or turning if such loosening or turning can result in a risk of fire, electric shock or mechanical hazard. Compliance for components is verified by specific tests described in the relevant International Standards or by the screw connection test (MST 33) of IEC 61730-2.

All electrical data to be reported in the marking or in the documentation accompanying a PV module shall be given for standard test conditions (1 000 W/m², 25 °C, spectral irradiance equal to AM1.5 according to IEC TS 61836). For bifacial PV modules, all electrical data shall be shown as relative to STC, BNPI and aBSI on the front side of the module, plus bifaciality coefficients at STC according to IEC TS 60904-1-2 and IEC 61215-1. Markings can also be subject to additional local code requirements.

6.2 Marking and documentation

6.2.1 General

Instructions related to safety shall be given in an official language of the country where the equipment is to be installed.

6.2.2 Marking

6.2.2.1 General

Each PV module's nameplate shall include the following clear and indelible markings together with their values, where applicable:

- a) name, registered trade name, or registered trademark of manufacturer;
- b) type or model number designation;
- c) serial number;
- d) date and place of manufacture; alternatively, serial number assuring traceability of date and place of manufacture;
- e) "maximum system voltage" or " V_{sys} ";
- f) class of protection against electrical shock, in accordance with Clause 5 of this document;
- g) "voltage at open-circuit" or " V_{OC} " including manufacturing tolerances. For bifacial modules, open-circuit voltage at two irradiance levels as defined in IEC 61215-1;
- h) "current at short-circuit" or " I_{SC} " including manufacturing tolerances. For bifacial modules, short-circuit current at STC, BNPI and aBSI;
- i) "PV module maximum power" or " P_{max} " including manufacturing tolerances as defined in IEC 61215-1. For bifacial modules, P_{max} at two irradiance levels as defined in IEC 61215-1;
- j) for bifacial modules, a clear indication which side is designed as the front side, or if both are designed for prolonged exposure to direct sunlight (> 300 W/m²).
- k) for flexible modules, the minimum radius of curvature;
- l) positive ("+" or downward) and negative ("–" or upward) design load ratings in pascal (Pa) excluding the test load safety factor, as verified in the static mechanical load test (MST 34). Additional markings for mechanical load ratings as required in the IEC 61215 series, as applicable.

NOTE MST 34 is equivalent to MQT 16 in IEC 61215-2, and the design load is equal to the test load divided by the safety factor γ_m .

Examples for a single upward and downward load rating:

- "Min. Design Load ± 1600 Pa", or
- "Min. Design Load -1600 Pa, $+3600$ Pa"

Examples for design loads dependent upon specific mounting configurations:

- "Min. Design Load ± 1600 Pa; see manual for instructions"
- "Min. Design Load ± 800 Pa to ± 1600 Pa; see manual for instructions"

m) maximum overcurrent protection rating;

n) a module temperature rating of 70 °C, (or if tested to IEC TS 63126 Level 1 or Level 2, 80 °C or 90 °C);

EXAMPLE Module $[T_{98}]_{\max}$ 80 °C

o) connector manufacturer and model used; refer to manual for designated mating connectors;

p) a link (website or QR code) to required documentation if a paper copy of the documentation required in 6.2.3 is not included with the module, included after either the statement "Safety information" or the symbol ISO 7010-M002:2011-05, Refer to instruction manual/booklet:



EXAMPLE 1 Monofacial module

Module Manufacturer A, Model A				
Serial number				
		STC		
V_{OC}	[V] ±3 %	49,42		
I_{SC}	[A] ±3 %	13,63		
P_{max}	[W] −0 %, +3 %	525		
V_{sys}	[V]	1 500		
Min. Design Load [Pa]		±1 600		
Module $[T_{98}]_{max}$ [°C]		70		
Maximum series fuse [A]		25		
Connector, see manual for designated connectors		Connector Manufacturer A Type A		
STC: 1 000 W/m ² , AM1.5, Cell 25°C				

EXAMPLE 2 Bifacial module with $\leq 300 \text{ W/m}^2$ bifaciality (BSI) or with $> 300 \text{ W/m}^2$ bifaciality (aBSI)

Module Manufacturer B, Model B			
Serial number			
	STC	BNPI	BSI ^b
I_{SC} [A]	13,63 ±3 %	14,85 ±3 %	17,32 ±3 %
V_{OC} [V]	49,42 ±3 %	49,8 ±3 %	
P_{max} [W]	525 -0 %, +3 %	600 -0 %, +3 %	
V_{sys} [V]	1 500		
Min. Design Load [Pa]	±1 600		
Module $[T_{98}]_{max}$ [°C]	70		
Maximum series fuse [A]	30		
Bifaciality coefficient ^a	$\varphi_{V_{OC}} = 0,99$ $\varphi_{I_{SC}} = 0,7$ $\varphi_{P_{max}} = 0,7$		
Connector, see manual for designated connectors	Connector Manufacturer B Type B		
STC: 1 000 W/m ² , AM1.5, Cell 25 °C, BNPI: front 1 000 W/m ² , rear 135 W/m ² BSI: front 1 000 W/m ² , rear 300 W/m ² ^a Only required for IEC 61215 series. ^b Depending on bifaciality, BSI (≤ 300 W/m ²) or aBSI (> 300 W/m ²) is required.			

International symbols shall be used, where applicable.

Compliance of the nameplate is to be verified according to the visual inspection (MST 01) and the durability of markings (MST 05) of IEC 61730-2.

PV connectors or wiring shall be marked in accordance with IEC 62852 with a symbol "Do not disconnect under load", as shown in Annex A of this document. The symbol and/or the warning notice shall be imprinted or labelled close to the connector. PV connectors shall be clearly marked indicating the terminal polarity.

For Class II and Class 0 PV modules, the symbol  (IEC 60417-6042:2010-11: Caution, risk of electric shock) shall be applied near the PV module's means of electrical connection.

PV modules shall be marked to indicate the classes of protection against electric shock for which they are suitable, as follows:

PV module classification (in relation to Clause 5)	Marking	Symbol
Class II	Marking according to IEC 60417-5172:2003-02: Class II equipment	
Class 0	No marking	No symbol
Class III	Marking according to IEC 60417-51802003-02: Class III equipment	

PV modules provided with a functional earth terminal shall be provided with a symbol according to Figure 3.

PV modules provided with terminals for field wiring that are rated only for use with copper wire shall be marked, at or adjacent to the terminals, with the statement "Use copper wire only", "Cu only", or the equivalent.

PV modules provided with terminals for field wiring that is rated only for use with a different specific wiring material shall be marked with a similar statement referring to the rated material.

PV modules provided with terminals for field wiring that is rated for use with all types of wiring material do not need to be marked.

6.2.2.2 Symbols

6.2.2.2.1 Equipotential bonding

A wiring terminal or bonding location of a PV module intended to accommodate a field installed bonding conductor for equipotential bonding shall be identified with the appropriate symbol IEC 60417-5021:2002-10 shown in Figure 1. Alternatively, the symbol IEC 60417-5017:2006-08 shown in Figure 2 may be used. No other terminal or location shall be identified in this manner.

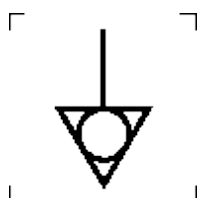


Figure 1 – IEC 60417-5021:2002-10

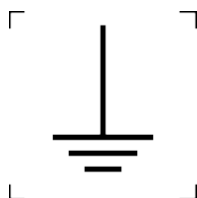


Figure 2 – IEC 60417-5017:2006-08

6.2.2.2.2 Functional earthing

A wiring terminal or bonding location of a PV module intended to accommodate a field installed functional earthing conductor shall be identified with the appropriate symbol (IEC 60417-5018:2011-07) shown in Figure 3.

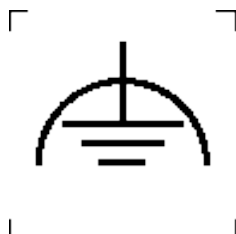


Figure 3 – IEC 60417-5018:2011-07

6.2.3 Documentation

6.2.3.1 General

Documentation describing the methods of their electrical and mechanical installation as well as their electrical, thermal, and mechanical ratings shall be made available. The documentation shall state the class of protection against electric shock under which the module was qualified and classified, and any specific limitations required for that class.

The documentation shall assure that installers and operators receive appropriate and sufficient instructions for safe installation, use and maintenance of the PV modules that it accompanies.

The documentation shall be supplied in at least one of the official languages of the country where the PV modules will be installed. International symbols shall be used where applicable.

Assembly instructions 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.

Documentation may be provided in paper form in each shipping unit or as an electronic link. The web address shall be marked on the device or provided in an information sheet enclosed with each shipping unit. The web address may be in the form of a Uniform Resource Locator (URL – http://www.____.com/____/), or a Quick Response Code (QRcode). The web address link shall take the user to an internet page containing the required information or a direct link to the required information. The file shall be in a file format that is commonly used and shall be downloadable.

The needs for maintaining and supporting information during the life cycle of the supported product shall be taken into account when planning the preparation of information for use as in IEC/IEEE 82079-1.

The following information shall be included in the documentation:

- all information as required by 6.2.2.1 with exception of c) and d);
- recommended maximum series/parallel module configurations;
- temperature coefficient for open-circuit voltage;
- temperature coefficient for maximum power;
- temperature coefficient for short-circuit current;

6.2.3.2 Suitable environmental and mounting conditions

The documentation shall state the environmental and mounting conditions for which the module has been qualified, which by default always include:

- the maximum rated altitude the PV module is designed for; de-ratings may be applied;
- a statement indicating the negative (upward) and positive (downward) design load ratings for each mechanical means for securing the module as evaluated during the static mechanical load test according to MST 34. At the discretion of the manufacturer, the test load and/or the safety factor γ_m may also be noted;
- for bifacial modules, designation of which side(s) of the module have been tested for front side exposures. Unless tested as a front side, the back side is restricted for use with indirect or limited direct sunlight (less than 300 W/m²). If both sides of a module are intended for use with prolonged exposure to direct sunlight (> 300 W/m²), each side shall meet requirements for front side.

- a temperature range from a lower limit of environmental temperature of $-40\text{ }^{\circ}\text{C}$ to the upper limit set by a 98th percentile module operating temperature of $70\text{ }^{\circ}\text{C}$, ($80\text{ }^{\circ}\text{C}$ or $90\text{ }^{\circ}\text{C}$ if tested to Level 1 or Level 2 conditions as described in IEC TS 63126);
- guidance on geographic areas, mounting conditions and system design and installation factors where the anticipated 98th percentile module operating temperature will be greater than $70\text{ }^{\circ}\text{C}$; (or $80\text{ }^{\circ}\text{C}$ or $90\text{ }^{\circ}\text{C}$ if tested to Level 1 or Level 2 conditions).

EXAMPLE:

- Modules can be installed anywhere in the world if mounted with unrestricted airflow.
- It is possible that modules installed with restricted airflow are not allowed for use in some hot locations, depending on system design parameters. Installers should assess if the system design at a specific geographic location will result in a 98th percentile module operating temperature greater than $70\text{ }^{\circ}\text{C}$ ($80\text{ }^{\circ}\text{C}$ or $90\text{ }^{\circ}\text{C}$ if tested to Level 1 or Level 2 conditions), and must consider these factors in design of systems (refer to IEC TS 63126 for more information):
 - site specific environmental conditions: irradiance, temperature, wind speed;
 - system design: mounting distance, array size, array spacing, and anti-nesting features which could reduce airflow.

NOTE 1 Specific geographic restrictions can apply; maps in IEC TS 63126 provide examples.

NOTE 2 An IEC document describing a method for estimating the 98th percentile module operating temperature for different mounting and geographical combinations is in progress.

- To facilitate proper system sizing in normal operation, the manufacturer shall describe factors that can increase voltage or current beyond the STC values given in the documentation. In relation to this, the following or equivalent statements shall be included:

"A photovoltaic module is likely to experience conditions that produce higher current and/or voltage than reported at standard test conditions. Factors to consider include module temperature and front side irradiance (and, for bifacial modules, ground or roof albedo, row spacing, and installation height). Accordingly, the values of V_{OC} and I_{SC} (or for bifacial modules, $I_{SC-aBSI}$) marked on this PV module should be multiplied by a factor of 1,25 when determining voltage and current ratings for components connected to the PV output."

"The safety factor of 1,25 given for the minimum voltage rating of the components in the example statement above may be modified during the design of a system according to the minimum temperature of the location of the installation and the temperature coefficient for V_{OC} . The safety factor of 1,25 given for conductor current ratings values for I_{SC} (or for bifacial modules, $I_{SC-aBSI}$) may be adjusted based on the maximum values of irradiance incident on the front side of the module (and the rear side for bifacial modules). To this purpose, a full simulation for the specific location and module orientation (and for bifacial modules, ground albedo, row spacing and installation height) is required. Further guidance for the choice of a safety factor other than 1,25 is given in IEC 62548."

The documentation shall state that artificially concentrated sunlight producing a PV module's current above the value reported on the nameplate shall not be directed onto the front side or the back side of the PV module.

Additionally, the documentation should report if the PV modules were evaluated according to the following standards, including which specific testing sequences were used.

- IEC 61701, *Photovoltaic (PV) modules – Salt mist corrosion testing*
Include which test method used (based on corrosivity classification).
- IEC 62716, *Photovoltaic (PV) modules – Ammonia corrosion testing*
Include test sequence 1 or 2 (crystalline Si or thin-film).
- IEC 62109-3, *Safety of power converters for use in photovoltaic power systems – Part 3: particular requirements for electronic devices in combination with photovoltaic elements*
 - Include MIE Type A or B (depending on whether electronics can be tested separately from the module).

- IEC TS 63126, *Guidelines for qualifying PV modules, components and materials for operation at high temperatures*

Include temperature Level 1 or 2 (based on selection of testing for combinations of deployment location and mounting configuration).

6.2.3.3 Mounting

Documentation shall include adequate information and instructions for each mounting method as listed in the manufacturer's mounting instructions, additionally:

- a statement indicating the minimum mechanical means for securing the PV module (as evaluated during the mechanical load test (MST 34) of IEC 61730-2) and the conformity to the mechanical load requirements of the series IEC 61215, as applicable;
- limitations to the mounting situation (e.g. slope, orientation, mounting means, cooling, specific spacing and any other condition that can influence the safety of the PV module installation);

NOTE The minimum spacing will depend on the 98th percentile module operating temperature for a specific location.

- if adhesives are used for mounting (i.e. for flexible modules), the type of adhesive and the allowable substrates;
- if adhesives are specified for use in the field to provide mechanical securement to specific roof coverings or mounting systems (such as flexible modules adhered to a roof membrane or modules adhered to metal rails), the manufacturer and unique part number of the adhesive, as well as the required surface preparation, adhesive application process, and curing conditions.

6.2.3.4 Connectors/wiring

Documentation shall include a detailed description of the following information related to the connectors and wiring method:

- the minimum cable diameters, rated voltage, current and temperature rating of cables for PV modules intended for field wiring and that cables used need to comply with IEC 62930, type 131 or type 133; or EN 50618;
- any limitations on wiring methods and wire management that apply to the junction box for the PV module;
- a statement that wiring to interconnect modules shall be rated for the application. It is important that the user is aware of national installation codes;
- type of terminals for field wiring;
- specific model/types together with the manufacturer name/brand of the PV connector(s) to which the PV module connectors can be mated;

NOTE 1 Connector mismatch issues are described in IEC TR 63225.

NOTE 2 Statement of the connector model/type only (such as "MC4 compatible") does not comply with this requirement.

- the bonding method(s) to be used (if applicable). Either they have to be all provided or specified hardware shall be identified in the documentation;
- the type and ratings of bypass diode to be used (if applicable).

6.2.3.5 Fire ratings

The documentation shall include either a statement indicating the fire rating(s) and the applied standard or a statement that resistance to external fire sources was not evaluated, as well as the limitations to the achieved rating (e.g. installation slope, substructure or other applicable installation information).

The documentation for roof mounting shall include details of the specific parameter(s) when the fire rating is dependent on a specific mounting structure, specific spacing, or specific means of attachment to the roof or structure.

6.3 Electrical components and insulation

6.3.1 General

PV modules can consist of the following electrical components and insulation:

- the internal wiring, e.g. solar cell and cell interconnects (see 6.3.2);
- external wiring and output cables (see 6.3.3);
- connectors (see 6.3.5);
- junction boxes for PV modules (see 6.3.6);
- frontsheet and backsheet (see 6.3.7);
- insulation barriers (see 6.3.8);
- electrical connections (see 6.3.9);
- encapsulant (see 6.3.10);
- bypass diodes (see 6.3.11).

6.3.2 Internal wiring

Internal wiring shall have sufficient current carrying capacity for the relevant application. Depending on the pollution degree at the place where the internal wiring is located, precautions against corrosion shall be taken wherever applicable. Examples for protection against corrosion are given in 6.5.3.1. In case that insulation for the internal wiring is necessary, it shall fulfil the relevant requirements for the relevant application according to 6.5.2.2.

Compliance is checked by inspection (MST 01) and by reverse current overload test (MST 26).

6.3.3 External wiring and cables

External wires and cables shall fulfil the requirements of IEC 62930 and shall be type 131 or type 133. Cables according to EN 50618 are allowed as alternative to IEC 62930 type 131.

6.3.4 Module overcurrent protection rating

Guidance to determine overcurrent protection rating is provided by IEC 60269-6 as verified by MST 26 of IEC 61730-2. Nominal fuse ratings (I_n) are typically equal to or larger than 1,4 times I_{SC} . For bifacial PV modules, the rating shall be evaluated for $I_{SC-aBSI}$.

6.3.5 Connectors

External DC connectors shall fulfil the requirements of IEC 62852, and additional requirements in 6.5.2.2. Connectors shall be marked in accordance with 6.2.2.

6.3.6 Junction boxes

Junction boxes for PV modules shall fulfil the requirements of IEC 62790 and additional requirements in 6.5.2.2.3.

Module level testing after installation and termination of the ribbons is required to validate adhesion/connection of the junction box to the module and minimum clearance and creepage distances.

6.3.7 Frontsheets and backsheets

Polymeric frontsheets and backsheets shall fulfil the requirements of IEC 62788-2-1. Each shall be designated as a frontsheet or backsheet based on the testing requirements. Backsheets are restricted for use with indirect or limited direct sunlight equal to or lower than 300 W/m².

Materials intended for use with prolonged exposure to direct sunlight greater than 300 W/m² shall meet the requirements for frontsheets in IEC 62788-2-1.

Backsheets are qualified to IEC 62788-2-1 according to the UV cut-off of the combination encapsulant and glass used in testing. This cut-off shall be the same or lower than for the combination of the encapsulant and glass used in the module design.

The DTI requirements listed in Table 3 and Table 4 may be fulfilled by single or multiple layers of RUI as described in IEC 62788-2-1.

Adhesion of the frontsheet and backsheet, e.g. to the encapsulant or to the glass, shall be appropriate. Compliance is checked at the module level by passing the IEC 61730-2 test sequences.

6.3.8 Insulation barriers

An insulation barrier shall withstand all relevant mechanical, electrical, thermal, and environmental stresses. In general, a polymeric insulation barrier shall meet the relevant requirements of 6.5.2. It shall be held in place and shall not be adversely affected to the extent that its required electrical and mechanical properties fall below the minimum acceptable values for the application. The removal of the insulation barrier shall only be possible by using a tool. Compliance is checked by passing the IEC 61730-2 test sequence.

6.3.9 Electrical connections

6.3.9.1 General

Electrical connections shall be so designed that contact pressure is not transmitted through insulating material other than ceramic, pure mica, or other material with suitable characteristics, unless there is sufficient resiliency in the metallic parts to compensate for any shrinkage or yielding of the insulating material.

Prevention shall be taken that connections do not become loose, e.g. by using a washer.

Compliance is checked by IEC 61730-2 visual inspection (MST 01), continuity test of equipotential bonding (MST 13) and screw connection test (MST 33), where applicable.

The end of a stranded conductor shall not be consolidated by soft soldering in those places where the conductor is subject to contact pressure, unless the method of clamping is designed in such a way to reduce the likelihood of a bad contact or if the soldered portion is maintained outside the contact area of the connection.

Precautions shall be taken that under operation clamping units or other terminations are not subjected to thermal and mechanical stress that might impair electrical conductivity.

6.3.9.2 Terminals for external cables and PV connector ribbons

Terminals for electrical connections shall be suitable for the type and range of conductor cross-sectional areas according to specification of the manufacturer. They shall meet the requirements of IEC 62790 and additional RTE, RTI, and TI requirements of 6.5.2.2.3.

Insulated terminals shall be designed in such a way to prevent any possible displacement that could result in a reduction of clearances and creepage distances.

6.3.9.3 Splices and connections inside a PV module

Splices and connections inside a PV module other than those for terminals of external cables and PV connector ribbons shall be mechanically secured and shall provide electrical continuity. Electrical connections shall be soldered, welded, conductively adhered, crimped, or otherwise securely connected. A soldered or conductively adhered joint shall be additionally mechanically secured.

Encapsulation is considered as a means of mechanical securement for soldered and conductively adhered electrical connections in a PV module.

6.3.10 Encapsulants

Encapsulants are considered as a part of the laminate. They provide protection against ingress of dust and moisture and compliance with the requirements of IEC 61730-2 shall demonstrate this for pollution degree 2.

Relevant properties and test methods for encapsulants at component level are described in IEC 62788-1 (all parts). They are not required to be tested separately, but shall be evaluated in relation to the application.

Encapsulants in general are considered as functional insulation, and shall have adequate insulation properties to maintain spacings. The technical properties of the encapsulant shall be suitable for the intended application. In particular:

- the rated range of operating temperature shall include the temperature range of the intended application;
- the insulation resistance and the dielectric strength shall be suitable for the intended application.

Compliance is checked by passing the IEC 61730-2 test sequence.

As part of the insulation coordination, some minimum dimensions may be recategorized if the encapsulant has demonstrated properties:

- an assigned material group as determined by the CTI rating according to IEC 60112 (6.6.3.3);
- a flammability rating of at least HB according to IEC 60695-11-10 (6.6.4.4).

6.3.11 Bypass diodes

Bypass diodes shall be rated to withstand the current and voltage for their intended use. Compliance is checked by bypass diode thermal test (MST 25), hot-spot endurance test (MST 22), bypass diode functionality test (MST 07) and visual inspection (MST 01).

6.4 Mechanical and electromechanical connections

6.4.1 General

This subclause 6.4 defines the minimum requirements for mechanical connections providing the mechanical stability of the PV modules (e.g. with a frame) as well as for those connections providing both mechanical and electrical functions (e.g. via equipotential bonding).

Typically found in a PV module are the following mechanical connections:

- connections within a frame;

- PV module mounting interfaces such as frame or backrail to glass, or backsheet via adhesive (silicone, rubber, etc.);
- frame to clamp of a mounting system;
- means for equipotential bonding;
- means for the attachment of junction box to the PV modules (e.g. silicone, tape, etc.); and
- mechanical connections within the laminate.

Mechanical connections shall be able to durably withstand the thermal, mechanical, and environmental stresses occurring in the final application without decreasing the integrity of the connection below safe levels.

Compliance is checked by inspection (MST 01) and during the mechanical load test (MST 34), module breakage test (MST 32), materials creep test (MST 37) and, if applicable, continuity of equipotential bonding test (MST 13). Modules of Class 0 (i.e. for use in restricted access areas) are not required to pass the module breakage test (MST 32).

Individual material requirements are given in 6.5. Parts intended to be removed shall only be detachable with the aid of tools. Lids that are attached without screws shall have one or several detectable features, e.g. recesses, which enable tools to be deployed in order to remove them without damaging the lid or the feature(s). If the lid is removed correctly, the tool shall not come into contact with the live parts.

For mechanical connections, friction between surfaces on its own, such as simple spring pressure, is not acceptable as the sole means to prevent the turning or the loosening of a part.

Physical properties or constructions that provide an interference or a form fit to prevent any unintended movement or any rotation of the component comply with this requirement.

6.4.2 Screw connections

If the failure of a screw and/or of a mechanical connection can cause the PV module to become unsafe, such screws and mechanical connections shall withstand the mechanical stresses occurring in normal use. Screws shall not be made of a material that is soft or liable to creep.

EXAMPLE 1 Zinc and some grades of aluminium are soft materials.

Screws operated for maintenance purposes shall not be made of insulating material if their replacement by a metal screw could impair supplementary or reinforced insulation.

Screws used to provide mechanical stability and continuity for equipotential bonding, e.g. fixing screws in frames and other components, shall comply with the requirement in the first paragraph of 6.4.2. At least one screw per electrical mechanical connection shall ensure the electrical connection between the metallic components.

Compliance is checked by inspection (MST 01) and by test for general screw connection (MST 33a).

Screws used for mechanical and electrical connections with a nominal diameter of less than 3 mm shall screw into metal.

For screws used for mechanical and electrical connections, two full threads shall engage into the metal.

Screwed and other fixed connections between different parts of the PV module shall be made in such a way that they do not come loose through torsion, bending stresses, vibration, etc., as it could occur in normal use.

EXAMPLE 2 Soldering, welding, lock nuts and setscrews are means for preventing the loosening of connections.

Compliance is checked by inspection (MST 01) and by test for locking screws (MST 33b).

6.4.3 Rivets

Rivets that have the double function of being concurrently electrical and mechanical connections shall be locked against loosening. A noncircular shank or an appropriate notch can be sufficient and therefore they may be used.

6.4.4 Thread-cutting screws

Thread-cutting screws and self-tapping screws shall not be used for the interconnection of current-carrying parts if they are made of metal that is either soft or liable to creep, such as zinc or aluminium.

Thread-forming screws (sheet metal screws) shall not be used for the connection of current-carrying parts, unless they clamp these parts directly in contact with each other and are provided with suitable locking means.

Thread-cutting (self-tapping) screws shall not be used for the connection of current-carrying parts, unless they generate a full form standard machine screw thread. However, screws of the latter type shall not be used if they are likely to be operated by the user or by the installer.

Thread-cutting and thread-forming screws, used to provide continuity for equipotential bonding, shall be such that it is not necessary to disturb the connection in normal use.

For equipotential bonding, one screw is permitted if two full threads engage the metal.

6.4.5 Form/press/tight fit

Form/press/tight fits of metallic components not separately equipotentially bonded shall be electrically connected.

EXAMPLE Corner joints in metallic frames are typical connections that are not separately equipotentially bonded.

Compliance is checked by inspection (MST 01), module breakage test (MST 32), static mechanical load test (MST 34) and test of continuity of equipotential bonding (MST 13) carried out before and after the MST 32 and MST 34 tests.

6.4.6 Connections by adhesives

Typical connections by adhesives that are made during the module production and are subject of 6.4.6 are used for:

- mounting of junction box;
- mounting of backrails or frames;
- fixing of backsheet and/or frontsheet to edge seals;
- fixing of backsheet and/or frontsheet to the encapsulant;
- fixing of the module to a substrate relied upon for mounting;
- etc.

For flexible modules, the modules shall be mounted in accordance with the manufacturer's documentation with prescribed substrate and adhesive/mounting means during testing. If the manufacturer's specified application allows mounting in a rigid or flexible mounting condition, testing shall be done on the worst case condition. The specific substrate(s) that was (were) adhered to the module in the tests shall be noted in the documentation.

Compliance is checked by tests of IEC 61730-2:2023, Figure 1.

Adhesion of a polymer relied upon for insulation to another insulating layer shall be appropriate for the application.

If the connection by adhesive is to be considered as cemented joint, the requirements according to 6.6.4.3 shall be applied.

6.4.7 Other connections

Other connections such as, for example, welded or soldered, shall be investigated by visual inspection (MST 01).

Other connections that are relied upon for equipotential bonding shall be checked with test of continuity of equipotential bonding (MST 13).

Materials and processes for creating the connections shall be appropriate for the intended use.

NOTE Further guidance on checking soldered connections can be found in IEC 61191-1.

6.5 Materials

6.5.1 General

This subclause 6.5 defines requirements for materials used in a PV module. General compliance is checked with tests in accordance with IEC 61730-2.

The choice of materials is not limited to the materials listed in this subclause 6.5. Non-conductive materials like glass or ceramic materials can also be used as insulating materials. For dimensioning purposes, any non-conductive material may be considered as an insulator whereas compliance to requirements of 6.6 shall be followed.

6.5.2 Polymeric materials

6.5.2.1 General

Polymeric materials shall be able to durably and safely withstand the electrical, mechanical, thermal, environmental, and corrosive stresses occurring in the application, and shall be resistant to electrical and mechanical property degradation.

Subclauses 6.5.2.2 to 6.5.2.4 describe general requirements and test methods. For several components, methods for meeting these requirements are given in individual International Standards. For PV modules to qualify to this document, those components shall be evaluated by the methods and meet the requirements described in the applicable documents on the component level, namely:

- IEC 62788-2-1 for frontsheets and backsheets;
- IEC 62790 for junction-boxes for PV modules;
- IEC 62852 for connectors for DC-application in PV systems;
- IEC 62930 (or EN 50618 for type 131) for electric cables for PV systems.

6.5.2.2 Polymeric materials used as electrical insulation

6.5.2.2.1 General

Polymeric materials can serve multiple insulation functions, e.g. as insulation to external parts and insulation between:

- internal live parts and accessible conductive parts;

- live parts and accessible surfaces;
- internal live parts at different potential.

An insulation material that serves more than one function shall comply with all applicable requirements. In case of multiple similar requirements, the most stringent requirement applies.

A material which serves as functional insulation shall be appropriate according to 6.6.4.4. A material relied upon for insulation in thin layers shall be appropriate for the application according to 6.6.4.2. Each insulation material shall be evaluated in the thinnest significant thickness used for the specific application.

Insulation shall not be impaired by short-term or long-term thermal stresses that can occur in manufacturing processes, transportation, and during normal operation, by electrical stress and weathering to an extent that it does not comply with the requirements in this document.

6.5.2.2.2 Endurance to electrical stress

Materials used as electrical insulation shall withstand electrical stresses which occur in the application.

Materials relied upon for insulation (RUI) shall have sufficient breakdown strength and shall comply with 6.6.4.2.

The test method for frontsheets and backsheets is described in IEC TS 62788-2. For other polymeric insulating materials not listed in 6.5.2, refer to IEC 60243-1 and IEC 60243-2.

A polymeric material which is part of a potential tracking path shall be resistant to surface tracking, in coordination with the design dimensions in 6.6.3.

- If pollution degree 1 is demonstrated, the micro-environment is such that material groups are not relevant.
- For higher pollution degrees, minimum creepage distances are determined based on the material groups based on a CTI rating according to IEC 60112. For polymeric insulating materials without a CTI rating, 150 % of the material group III creepage distance is applied. For frontsheets or backsheets, the lamination protrusion test of IEC 62788-2-1 is used to establish the layers for which a material group (or lack of) is used to establish the minimum creepage in 6.6.3.3.

Additionally, the following PV module tests in IEC 61730-2 apply:

- insulation test (MST 16) before and after preconditioning;
- wet leakage current test (MST 17);
- impulse voltage test (MST 14).

6.5.2.2.3 Endurance to thermal stress – RTE (RTI) or TI (mechanical/electrical)

Materials used as RUI shall have a minimum RTE, RTI or TI in accordance with IEC 60216-5 or IEC 60216-1 of at least 90 °C. To ensure that the electrical and mechanical properties are provided through the expected lifetime, the TI and RTE (RTI) values shall be evaluated as mechanical and electrical properties according to IEC 60216-2.

Relevant RTI values evaluated in accordance with UL 746B are allowed as an alternative to RTE.

6.5.2.2.4 Endurance to environmental stress

Polymeric materials shall be durable to environmental stresses occurring in the application.

Accelerated ageing is used to verify the ability of the material to withstand simulated environmental stresses, including heat, moisture, and UV radiation. The material's endurance shall be checked by compliance with IEC 61730-2 at module level. Components shall comply with the requirements in the individual applicable International Standards.

Ageing tests are typically combined with visual inspection as well as with material tests before and after exposure to specific stress factors, in order to assess changes of mechanical and electrical material characteristics giving rise to safety hazards.

6.5.2.3 Flammability

PV modules can be exposed to external fire conditions during their lifetime. Therefore, they shall be tested for their fire resistance against exposure to a fire source originating from outside the PV module. Such a source can include the building on which the PV modules are installed or into which they are integrated; the fire source can also originate from an adjacent building. Fire-resistance requirements for a PV module intended for building applications are defined in local or national building codes.

BAPV and BIPV are subject to specific fire-related safety requirements originating from national building codes. Fundamental requirements for fire safety are not yet internationally harmonized. It is therefore not possible to define general requirements on this topic in this document.

EXAMPLE BIPV and BAPV can serve as roof covering materials, elements for building integration or that are mounted on buildings.

External polymeric parts of the PV module whose deterioration could impair the safety shall comply with all the following additional requirements:

- minimum flammability class: V-1 according to IEC 60695-11-10, for all external polymeric parts with the exception of insulation in thin layers (those are covered only by MST 24);
- ignitability test (MST 24) in the final application (either at level of laminate or PV module);
- polymeric parts which are not components of the laminate whose deterioration could impair the safety of the PV module are evaluated with the module level ignitability test MST 24.

NOTE Such parts can also be subject to additional local code requirements.

For polymeric materials between two parts of different potential, internal spacings may be recategorized as described in 6.6.4.4 if either the encapsulant(s) have a minimum of HB in the flammability test according to IEC 60695-11-10, or a method to verify spacings is established in the production process.

6.5.2.4 Rigid polymeric materials used for mechanical functions

Rigid polymeric materials used for mechanical functions (e.g. polymeric frame, integrated brackets, back rail) shall pass tests as described below.

- 1) Mechanical strength at lower temperatures, IEC 62790:2020, 5.3.8 followed by MST 01 (visual inspection) of IEC 61730-2.
- 2) Weather resistance test, IEC 62790:2020, 5.3.11 followed by MST 01 (visual inspection) of IEC 61730-2.
- 3) Flammability class, IEC 60695-11-10 (minimum V-1).
- 4) Ball pressure test, IEC 60695-10-2 (90 °C, < 2 mm diameter).
- 5) RTI/RTE/TI (≥ 90 °C), IEC 60216-5 (mechanical parts only), IEC 60216-6 (mechanical parts only), UL 746B (mechanical only with impact).

6.5.3 Metallic materials

6.5.3.1 General

Metallic components in PV modules shall be designed to withstand a minimum corrosion atmospheric category level C2 as specified in Table B.1 in ISO 9224:2012, Annex B. Higher levels (C3 or C4) of protection against corrosion can be necessary depending on the location where the PV modules are installed.

In accordance with IEC 60950-1, metallic parts designed for applications in climates with wet or humid conditions shall not be in contact with other metallic parts if their electrochemical potentials differ more than 600 mV. Electrochemical potential differences larger than this limit are allowed only if the contact points between the different metallic materials are designed to remain dry. The material combinations listed in Table J.1 of IEC 60950-1:2005 serve as guideline to determine generic electrochemical potentials between two materials. Electrochemical potentials have to be considered for each specific materials pair.

Iron or mild steel as a part of the product shall be plated, painted, or enamelled for protection against corrosion. The minimum corrosion protection shall be at least equivalent to that ensured by a zinc coating of 0,015 mm thickness. Simple sheared or cut edges and punched holes as features in protected metallic parts are not required to be additionally protected, provided that a possible corrosion of these features does not impair the mechanical bonding, mounting or structural performance of the PV module.

Compliance is checked by inspection (MST 01).

6.5.3.2 Current-carrying parts

Under normal operation, current-carrying parts shall have a sufficient mechanical strength and electrical conductivity. If environmental conditions can cause corrosion, current-carrying materials (metal, polymeric based, etc.) shall be protected against corrosion, e.g. by coating.

In case of current-carrying parts consisting of metal coated for protection against corrosion, the coating shall be capable of preventing corrosion according to either one of ISO 1456, ISO 1461, ISO 2081, or ISO 2093. If the current-carrying parts can be stressed by abrasion, coated metallic parts are not allowed.

Other materials shall be protected accordingly.

6.5.4 Adhesives

Adhesives shall be appropriate for the application. Compliance is checked by relevant tests of IEC 61730-2, including lap shear strength test (MST 36), peel test (MST 35), robustness of terminations test (MST 42), mechanical load test (MST 34), and visual inspection (MST 01), accessibility test (MST 11), wet leakage current test (MST 17) pre- and post-test sequences, where applicable.

If an adhesive is relied upon for insulation (RUI) it shall additionally meet the requirements of 6.5.2.2.3

6.6 Protection against electric shock

6.6.1 General

PV modules shall be provided with adequate protection against contact with hazardous live parts and shall pose no risk of electric shock.

6.6.2 Protection against accessibility to hazardous live parts

6.6.2.1 General

PV modules shall be constructed to provide adequate protection against accessibility to hazardous live parts ($> 35 \text{ V DC}$).

For Class 0 PV modules, accessible parts shall be separated from hazardous live parts by at least basic insulation.

Class II PV modules shall be so constructed and enclosed that only parts separated from hazardous live parts by double or reinforced insulation are accessible.

In Class III PV modules live parts are not considered as hazardous, so a separation from accessible parts is not needed. To ensure sufficient functionality and protection against hazardous lighting arc, live parts of different polarity shall be separated by at least functional insulation.

Compliance is checked by visual inspection (MST 01) and by accessibility test (MST 11).

Polymeric materials used for realizing protection against accessibility of hazardous live parts by means of enclosure, insulation barrier or RUI shall comply with the requirements of 6.5.2.

6.6.2.2 Protection by means of enclosures and insulation barriers

Enclosures or insulation barriers shall be so designed that, after mounting, the live parts are not accessible. This requirement shall be fulfilled even if there is any deformation of the housing and/or cover as a result of mechanical and thermal stress, which can occur during normal use. Furthermore, the degree of protection of the housing shall not be impaired by this possible deformation.

Parts of enclosures and insulation barriers that provide protection in accordance with these requirements shall not be removable without the use of a tool. Lids attached without screws shall have one or several detectable features, e.g. recesses, which enable tools to be deployed in order to remove them. If the lid is removed correctly, the tool shall not come into contact with the live parts.

An insulation barrier shall be held in place and shall not be adversely affected by influences expected during normal operation to the extent that its necessary electrical and mechanical properties fall below the minimum acceptable values for the application.

Parts shall be prevented from loosening or turning, if such loosening or turning can result in a risk of fire, electric shock, or personal injury.

6.6.2.3 Protection by means of insulation of live parts

An insulation material providing the sole insulation between a live part and an accessible metallic part, or between uninsulated live parts not at the same potential, shall be of adequate thickness and of a material appropriate for the application.

Any conductive part, which is not separated by at least basic insulation from parts that can operate at a potential above 35 V DC , is considered to be a live part. A metallic accessible part is considered to be conductive if its surface is bare or is covered by an insulating layer that does not comply with the requirements of basic insulation.

An overview of the required insulation is given in Table 2, based on IEC 61140.

Table 2 – Required type of insulation

Protection class (from IEC 61140)	Protection required against direct contact	Insulation between live parts and accessible metal parts	Insulation between live parts and accessible surfaces	Insulation between live parts of different potential inside a PV module
Class 0	Yes	B	B	F
Class II	Yes	R	R	F
Class III	No	F	F	F
F: functional insulation. B: basic insulation. R: reinforced insulation or double insulation.				

The insulation type designation can impose coordinated material and spacing requirements, as described in 6.6.3.

Neighbouring solar cells connected in series have no special insulation requirements if the maximum power dissipation between two neighbouring cells is less than 15 W (based on solar cell rating).

NOTE For a typical c-Si cell with an open-circuit voltage of ~0,7 V and short-circuit current ~9,0 A, the above criterion is met (6,3 W).

6.6.3 Insulation coordination

6.6.3.1 General

For purposes of insulation coordination, spacing of live parts and materials selection are interrelated and shall be considered in coordination with each other.

IEC 60664-1 is the reference document for evaluating the minimum required values and for measuring existing clearances and creepage distances and provides the general requirements of insulation coordination used in this document. Further requirements and an explanation of how the requirements in this document were derived are provided in Annex B.

The requirements for clearance and creepage distances are given in the top portions of Table 3 for Class II modules, and Table 4 for Class 0 modules.

For Class III modules (system voltage ≤ 35 V), insulation coordination requires at least functional insulation between live parts of different potential within the PV module, with the values for creepage distance and clearance from Table 4. DTI is not required.

Further details are provided in the following clauses on influencing factors such as pollution degree, material group, creepage distance, and clearance. Examples of specific use cases are given in Annex C.

The requirements listed here for clearances and creepage distances do not apply to the inherent dimensions within specified components.

Independent from the inherent dimensions within the module and specified components, the requirements for insulation coordination shall also be fulfilled after mounting and termination of the components. So, it shall be verified that after the junction box is mounted the ribbons are routed such that the distances between the ribbons and the outer accessible surface meet the minimum spacing requirements. In the case of a backsheet containing an aluminium layer, clearance and creepage distance between the backsheet and the ribbons shall be met (see Figure C.8).

Table 3 – Minimum clearances (cl), creepage distances (cr) and distances through solid insulation for Class II PV modules

Voltages ^{b, c}		≤ 35 V DC ^e			100 V DC			150 V DC			300 V DC			600 V DC			1 000 V DC			1 500 V DC					
	Pollution degree	cl	cr		cl	cr		cl	cr		cl	cr		cl	cr		cl	cr		cl	cr				
		Material groups																							
		I	II	III		I	II	III		I	II	III		I	II	III		I	II	III		I	II	III	
Clearances ^{a, b} and creepage ^g distances (mm)																									
1) Double/Reinforced Insulation ^f	1	0,4		0,5		0,6		1,4		3,4		6,4		10,4											
	2	0,5	1,2 1,7 2,4		1,5	1,4 2,0 2,8		3,0	1,6 2,2 3,1		5,5	3,0 4,2 6,0		8,0	6,1 8,6 12,0		14,0	10,0 14,2 20,0		19,4	15,0 20,8 30,0		30,0		
2) Basic/Functional Insulation:	1	0,1	0,2		0,3		0,3		0,7		1,7		3,2		5,2										
	2	0,2	0,6 1,0 1,2	0,5	0,7 1,0 1,4		1,5	0,8 1,1 1,6		3,0	1,5 2,1 3,0		5,5	3,0 4,3 6,0		8,0	5,0 7,1 10,0		11,0	7,5 10,4 15,0		15,0			
Distances through materials (mm), according to voltages																									
3) DTFI – Functional Insulation: distance between live parts of different potential (one encapsulant, see Figure C.3)																									
a) no additional test		0,2			0,5			1,5			3,0			5,5			8,0			11,0					
b) with additional tests (6.6.4.4)					0,3			0,3			0,7			1,7			3,2			5,2					
4) Thin films (DTI)		0,03			0,03			0,03			0,03			0,06			0,15			0,3					
5) Cemented joints		0,2			0,3			0,5			1,0			1,5			2,0			3,5					

- a If a measured clearance between internal live parts and outer accessible surfaces is less than the minimum value (but greater than or equal to the creepage distance), the insulation test and impulse voltage test of IEC 61730-2 MST 57 shall verify that the distance is adequate
- b The relevant voltage which is applicable is the system voltage, except for line 2). For voltages at intermediate values, interpolation may be used.
- c For line 2) this is intended for the case with two different encapsulants. The working voltage between parts of different potential at STC is relevant; for bifacial modules, use aBSI.
- d If a measured clearance between live parts of different potential is less than the minimum value (but greater than or equal to the creepage distance), the insulation test of MST 57 shall verify that the distance is adequate and fire hazard shall be mitigated.
- e For designs where the working voltage is below 20 V, values directly from IEC 60664-1 may be applied.
- f For line 1) in the case where double insulation comes from multiple portions of tracking paths (different material groups or pollution degrees), the spacing for each tracking path shall fulfil the requirements of basic insulation according to line 1) of Table 4.
- g If a material group has not been defined, the minimum creepage value is 150 % of the value for material group III (pollution degree 2 only).

Table 4 – Minimum clearances (cl), creepage distances (cr) and distances through solid insulation for Class 0 PV modules

Voltages ^{b,1}		≤ 35 V DC ^e		100 V DC		150 V DC		300 V DC		600 V DC		1 000 V DC		1 500 V DC														
Pollution degree		cl	cr	cl	cr	cl	cr	cl	cr	cl	cr	cl	cr	cl	cr													
		Material groups																										
		I	II	III	I	II	III	I	II	III	I	II	III	I	II	III												
Clearances ^{a,b} and creepage ^g distances (mm)																												
1) Basic Insulation: Distance between internal live parts and outer accessible surfaces ^a OR 2) Distance between live parts of different potential inside a PV module ^{c,d}	1	0,1	0,2		0,3		0,3		0,3		0,7		1,7		3,2		5,2											
	2	0,2	0,6	1,0	1,2	0,5	0,7	1,0	1,4	1,5	0,8	1,1	1,6	3,0	1,5	2,1	3,0	5,5	3,0	4,3	6,0	8,0	5,0	7,1	10,0	11,0	7,5	10,4
Distances through materials (mm), according to voltages																												
3) DTFI – Functional Insulation: distance between live parts of different potential (one encapsulant, see Figure C.3)																												
a) No additional test	0,2		0,5		1,5		3,0		5,5		8,0		11,0															
b) With additional tests (6.6.4.4)			0,3		0,3		0,7		1,7		3,2		5,2															
4) Thin films (DTI)	not applicable		0,03		0,03		0,03		0,06		0,15		0,3															
5) Cemented joints	not applicable		0,2		0,25		0,5		0,7		1,0		1,7															