

INTERNATIONAL STANDARD



Low voltage electrical installations ~~of buildings~~ –
Part 7-712: Requirements for special installations or locations – Solar
photovoltaic (PV) power supply systems

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INTERNATIONAL STANDARD



Low voltage electrical installations of buildings –
Part 7-712: Requirements for special installations or locations – Solar
photovoltaic (PV) power supply systems

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ELECTROTECHNICAL COMMISSION

LOW VOLTAGE ELECTRICAL INSTALLATIONS ~~OF BUILDINGS~~ –

Part 7-712: Requirements for special installations or locations – Solar photovoltaic (PV) power supply systems

FOREWORD

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International Standard IEC 60364-7-712 has been prepared by IEC technical committee 64: Electrical installations and protection against electric shock.

This second edition cancels and replaces the first edition, published in 2002. This edition constitutes a technical revision.

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

- a) The technical content has been extensively revised and expanded, taking into account experience gained in the construction and operation of PV installations, and developments made in technology, since the first edition of this standard was published.

The text of this standard is based on the following documents:

FDIS	Report on voting
64/2154/FDIS	64/2163/RVD

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

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

Attention is drawn to the co-existence of IEC 60364-7-712 and IEC 62548 standards. Both standards have been developed in close coordination by different technical committees.

A list of all parts in the IEC 60364 series, published under the general title *Low voltage electrical installations*, can be found on the IEC website.

The reader's attention is drawn to the fact that Annex F lists all of the "in-some-country" clauses on differing practices of a less permanent nature relating to the subject of this standard.

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

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

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INTRODUCTION

For the purpose of this part of IEC 60364 (IEC 60364-7-712), the requirements of the general parts 1 to 6 of IEC 60364 apply.

The IEC 60364-7-7XX parts of IEC 60364 contain particular requirements for special installations or locations which are based on the requirements of the general parts of IEC 60364 (IEC 60364-1 to IEC 60364-6). These IEC 60364-7-7XX parts are considered in conjunction with the requirements of the general parts.

The particular requirements of this part of IEC 60364 supplement, modify or replace certain of the requirements of the general parts of IEC 60364 being valid at the time of publication of this part. The absence of reference to the exclusion of a part or a clause of a general part means that the corresponding clauses of the general ~~requirements contained in parts 1 to 6 of IEC 60364~~ part are applicable (undated reference).

Requirements of other 7XX parts being relevant for installations covered by this part also apply. This part may therefore also supplement, modify or replace certain of these requirements valid at the time of publication of this part.

The clause numbering ~~appearing after 712 refers to the corresponding parts or clauses~~ of this part follows the pattern and corresponding references of IEC 60364. ~~Numbering of clauses does not, therefore, necessarily follow sequentially.~~ The numbers following the particular number of this part are those of the corresponding parts, or clauses of the other parts of the IEC 60364 series, valid at the time of publication of this part, as indicated in the normative references of this document (dated reference). If requirements or explanations additional to those of the other parts of the IEC 60364 series are needed, the numbering of such items appears as 712.101, 712.102, 712.103, etc.

Numbering of figures and tables takes the number of this part followed by a sequential number. For annexes, the numbering of figures and tables takes the letter of the annex, the number of the part and a sequential number.

In the case where new or amended general parts with modified numbering were published after this part was issued, the clause numbers referring to a general part in this 712 part may no longer align with the latest edition of the general part. Dated references should be observed.

LOW VOLTAGE ELECTRICAL INSTALLATIONS ~~OF BUILDINGS~~ –

Part 7-712: Requirements for special installations or locations – Solar photovoltaic (PV) power supply systems

712 Solar photovoltaic (PV) power supply ~~systems~~ installations

NOTE The abbreviation “PV” is used for ~~“solar photovoltaic”~~ “Photovoltaic”. Photovoltaic installations are, hereafter, known as PV installations.

712.1 Scope

This part of IEC 60364 applies to the electrical installation of PV ~~power supply~~ systems ~~including systems with AC modules~~ intended to supply all or part of an installation.

NOTE 1 ~~Standards for PV equipment are being prepared by TC 82.~~

NOTE 2 ~~Requirements for PV power supply systems which are intended for stand-alone operation are under consideration.~~

The equipment of a PV installation, like any other item of equipment, is dealt with only so far as its selection and application in the installation is concerned.

A PV installation starts from a PV module or a set of PV modules connected in series with their cables, provided by the PV module manufacturer, up to the user installation or the utility supply point (point of common coupling).

Requirements of this document apply to

- PV installations not connected to a system for distribution of electricity to the public,
- PV installations in parallel with a system for distribution of electricity to the public,
- PV installations as an alternative to a system for distribution of electricity to the public,
- appropriate combinations of the above.

This document does not cover the specific installation requirements for batteries or other energy storage methods.

NOTE 1 Additional requirements for PV installations with battery storage capabilities on the DC side are under consideration.

NOTE 2 This document does cover the protection requirements of PV arrays which develop as a result of the use of batteries in PV installations.

For systems using DC-DC converters, additional requirements regarding voltage and current rating, switching, and protective devices can apply. These requirements are under consideration.

The object of this document is to address the design safety requirements arising from the particular characteristics of PV installations. DC systems, and PV arrays in particular, pose some hazards in addition to those derived from conventional AC power installations, including the ability to produce and sustain electrical arcs with currents that are not greater than normal operating currents.

In grid connected PV installations the safety requirements of this document are, however, critically dependent on the PCE associated with PV arrays complying with the requirements of IEC 62109-1 and IEC 62109-2.

712.2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

~~IEC 60050(826):1982, International Electrotechnical Vocabulary (IEV) — Chapter 826: Electrical installations of buildings~~

IEC 60228, *Conductors of insulated cables*

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

IEC 60332-1-2, *Tests on electric and optical fibre cables under fire conditions – Part 1-2: Test for vertical flame propagation for a single insulated wire or cable – Procedure for 1 kW pre-mixed flame*

IEC 60364 (all parts), *Low-voltage electrical installations*

IEC 60364-4-41:2005, *Low-voltage electrical installations – Part 4-41: Protection for safety – Protection against electric shock*

IEC 60364-4-43, *Low-voltage electrical installations – Part 4-43: Protection for safety – Protection against overcurrent*

IEC 60364-4-44, *Low-voltage electrical installations – Part 4-44: Protection for safety – Protection against voltage disturbances and electromagnetic disturbances*

~~IEC 60439-1, Low-voltage switchgear and controlgear assemblies – Part 1: Type-tested and partially type-tested assemblies~~

IEC 60670 (all parts), *Boxes and enclosures for electrical accessories for household and similar fixed electrical installations*

~~IEC/TR 60765, General requirements for residual current operated protective devices Amendment 2 (1992)~~

IEC 60898 (all parts), *Electrical accessories – Circuit-breakers for overcurrent protection for household and similar installations*

IEC 60898-2, *Circuit-breakers for overcurrent protection for household and similar installations – Part 2: Circuit-breakers for a.c. and d.c. operation*

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

IEC 60947 (all parts), *Low-voltage switchgear and controlgear*

IEC 60947-1, *Low-voltage switchgear and controlgear – Part 1: General rules*

IEC 60947-2, *Low-voltage switchgear and controlgear – Part 2: Circuit breakers*

IEC 60947-3, *Low-voltage switchgear and controlgear – Part 3: Switches, disconnectors, switch-disconnectors and fuse-combination units*

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

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

IEC 61439 (all parts), *Low-voltage switchgear and controlgear assemblies*

IEC 61439-2, *Low-voltage switchgear and controlgear assemblies – Part 2: Power switchgear and controlgear assemblies*

IEC 61557-8:2014, *Electrical safety in low voltage distribution systems up to 1 000 V a.c. and 1 500 V d.c. – Equipment for testing, measuring or monitoring of protective measures – Part 8: Insulation monitoring devices for IT systems*

IEC 62109 (all parts), *Safety of power converters for use in photovoltaic power systems*

IEC 62109-1:2010, *Safety of power converters for use in photovoltaic power systems – Part 1: General requirements*

IEC 62109-2, *Safety of power converters for use in photovoltaic power systems – Part 2: Particular requirements for inverters*

IEC 62262, *Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK code)*

IEC 62423, *Type F and type B residual current operated circuit-breakers with and without integral overcurrent protection for household and similar uses*

IEC 62446-1, *Photovoltaic (PV) systems – Requirements for testing, documentation and maintenance – Part 1: Grid connected systems – Documentation, commissioning tests and inspection*

IEC 62852:2014, *Connectors for DC-application in photovoltaic systems – Safety requirements and tests*

712.3 Terms and definitions

~~(See also figures 712.1 and 712.2).~~

For the purposes of this document, ~~the definitions of IEC 60050(826) as well as~~ the following terms and definitions 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>

712.3.1

PV cell

photovoltaic cell

solar cell

solar photovoltaic cell

~~basic PV device which can generate electricity when exposed to light such as solar radiation~~
most elementary device that exhibits the photovoltaic effect, i.e the direct non-thermal conversion of radiant energy into electrical energy

Note 1 to entry: The preferred term is "solar photovoltaic cell" or "photovoltaic cell", colloquially referred to as a "solar cell".

[SOURCE: IEC 61836:2007, 3.1.43 a), modified — "that exhibits ... electrical energy" has been added]

712.3.2

PV module

smallest complete environmentally protected assembly of interconnected ~~PV~~ cells

Note 1 to entry: See IEC 60904-3.

712.3.3

PV string

~~circuit in which PV modules are connected in series, in order for a PV array to generate the required output voltage~~ of one or more series-connected modules

[SOURCE: IEC 61836:2007, modified – "or one or more" has been added]

712.3.4

PV array

~~mechanically and electrically integrated assembly of electrically interconnected PV modules, PV strings or PV sub-arrays and other necessary components, to form a DC power supply unit~~

Note 1 to entry: For the purposes of this document a PV array is all components up to the DC input terminals of an inverter or DC loads. A PV array does not include its foundation, tracking apparatus, thermal control, and other such components.

Note 2 to entry: A PV array may consist of a single PV module, a single PV string, or several parallel-connected strings, or several parallel-connected PV sub-arrays and their associated electrical components (see Figure 712.2 to Figure 712.4). For the purposes of this document the boundary of a PV array is the output side of the PV array disconnecting device.

712.3.5

PV array junction box

~~enclosure where all PV strings of any PV array are electrically connected and where protection devices can be located if necessary~~

712.3.6

PV generator

~~assembly of PV arrays~~

712.3.7

PV generator junction box

~~enclosure where all PV arrays are electrically connected and where protection devices can be located if necessary~~

712.3.5

PV sub-array

electrical subset of a PV array formed of parallel connected PV modules or PV strings

712.3.6

PV string cable

cable interconnecting ~~PV~~ the modules ~~to form~~ in a PV string, or connecting the string to a combiner box, PCE or other DC loads

Note 1 to entry: Examples of PV string cable are shown in Figure 712.3 and Figure 712.4.

712.3.7

PV array cable

~~output~~ cable of a PV array that carries the total output current of the array

712.3.10

~~PV DC main cable~~

~~cable connecting the PV generator junction box to the DC terminals of the PV inverter~~

712.3.11

~~PV inverter~~

~~device which converts DC voltage and DC current into AC voltage and AC current~~

712.3.8

PV AC supply cable

cable connecting the AC terminals of the PV ~~inverter~~ PCE to a distribution ~~circuit~~ board of the electrical installation

712.3.9

PV AC supply circuit

circuit connecting the AC terminals of the PV PCE to a distribution board of the electrical installation

712.3.10

PV AC module

integrated module/~~inverter~~ PCE assembly where the electrical interface terminals are ~~AC~~ alternating current only and where no access is provided to the DC side

712.3.11

PV installation

erected equipment of a PV power supply ~~system~~ installation

712.3.12

standard test conditions

STC

~~test conditions specified in IEC 60904-3 for PV cells and PV modules~~

standard set of reference conditions used for the testing and rating of photovoltaic cells and modules as given in the relevant product standard for example IEC 61215

Note 1 to entry: The standard test conditions given in IEC 61215 for PV modules are:

- a) PV cell temperature of 25 °C;
- b) irradiance in the plane of the PV cell or module of 1 000 W/m²;
- c) light spectrum corresponding to an atmospheric air mass of 1,5.

Note 2 to entry: This note applies to the French language only.

712.3.13

open-circuit voltage under standard test conditions

$U_{OC\ STC}$

voltage under standard test conditions across an unloaded (open) PV module, PV string or PV array, ~~PV generator~~, or on the DC side of the PV ~~inverter~~ PCE

712.3.14 **open-circuit maximum voltage**

$U_{OC\ MAX}$
maximum voltage across an unloaded (open) PV module, PV string, or PV array, or on the DC side of the PV PCE

Note 1 to entry: The method for determining $U_{OC\ MAX}$ is given in Annex B.

712.3.15 **short-circuit current under standard test conditions**

$I_{SC\ STC}$
short-circuit current of a PV module, PV string or PV array ~~or PV generator~~ under standard test conditions

712.3.16 **short-circuit maximum current**

$I_{SC\ MAX}$
maximum short-circuit current of a PV module, PV string or PV array

Note 1 to entry: The method for determining $I_{SC\ MAX}$ is given in Annex B.

712.3.17 **backfeed current**

maximum current that can pass from PCE to the PV array and its wiring under normal or single fault conditions

712.3.18 **reverse current**

current that can backfeed into a PV circuit from parallel connected strings or sub-arrays as the result of a fault, for example a short-circuit in the affected circuit

712.3.19 **short-circuit current rating**

$I_{SCP\ V}$
maximum prospective short-circuit current from the PV array for which the SPD, in conjunction with the disconnectors specified, is rated

712.3.20 **DC side**

part of a PV installation from ~~a PV cell~~ the PV modules to the DC terminals of the PV ~~inverter~~ PCE

712.3.21 **AC side**

part of a PV installation from the AC terminals of the PV ~~inverter~~ PCE to the point of connection of the PV supply cable to the electrical installation

~~**712.3.20**~~ ~~**simple separation**~~

~~separation between circuits or between a circuit and earth by means of basic insulation~~

712.3.22 **maximum power point tracking**

MPPT
control strategy whereby PV array operation is always at or near the point on a PV device's current-voltage characteristic where the product of electric current and voltage yields the maximum electrical power under specified operating conditions

Note 1 to entry: This note applies to the French language only.

712.3.23

$I_{MOD_MAX_OCPR}$
PV module maximum overcurrent protection rating

Note 1 to entry: See IEC 61730-2.

712.3.24

blocking diode

diode connected in series with module(s), strings and sub-array(s) to block reverse current

712.3.25

bypass diode

diode connected across one or more cells in the forward current direction

Note 1 to entry: The purpose is to allow the module current to bypass shaded or broken cells to prevent hot spot or hot cell damage resulting from the reverse voltage biasing from the other cells in that module.

712.3.26

functional earthing

FE

earthing a point or points in a system or in an installation or in equipment for purposes other than electrical safety

Note 1 to entry: Such a system is not considered to be an earthed array.

Note 2 to entry: Examples of functional array earthing include earthing one conductor through an impedance, or only temporarily earthing the array for functional or performance reasons.

Note 3 to entry: In a PCE intended for an array not connected to a functional earth that uses a resistive measurement network to measure the array impedance to earth, that measurement network is not considered a form of functional earth.

Note 4 to entry: This note applies to the French language only.

[SOURCE: IEC 60050-826:2004, 826-10-10, modified – the notes have been added]

712.3.27

irradiance

G

electromagnetic radiated solar power per unit of area

Note 1 to entry: Irradiance is expressed in W/m^2 .

[SOURCE: IEC 61836:2007, 3.6.25 modified – the note and sub-entries have been deleted]

712.3.28

$I_{SC\ ARRAY}$
short-circuit current of the PV array at standard test conditions

712.3.29

$I_{SC\ MOD}$
short-circuit current of a PV module or PV string at standard test conditions (STC), as specified by the manufacturer in the product specification plate

Note 1 to entry: As PV strings are a group of PV modules connected in series, the short-circuit current of a string is equal to $I_{SC\ MOD}$.

712.3.30

$I_{SC\ S-ARRAY}$
short-circuit current of a PV sub-array at standard test conditions (STC)

712.3.31

power conversion equipment

PCE

system that converts the electrical power delivered by the PV array into the appropriate frequency and/or voltage values to be delivered to the load, or stored in a battery or injected into the electricity grid

SEE: Figure 712.2 to Figure 712.4.

Note 1 to entry: This note applies to the French language only.

712.3.32

inverter

PCE which converts DC voltage and DC current of the PV array into AC voltage and AC current

Note 1 to entry: This note applies to the French language only.

712.3.33

isolated PCE

PCE with at least simple separation between the main power output circuits and PV circuits

Note 1 to entry: The simple separation may be either integral to the PCE or provided externally, for example a PCE with an external isolating transformer.

Note 2 to entry: In a PCE with more than two external circuits, there may be isolation between some pairs of circuits and no isolation between others. For example, an inverter with PV, battery, and mains circuits may provide isolation between the mains circuit and the PV circuit, but no isolation between the PV and battery circuits.

712.3.34

non-isolated PCE

PCE without the minimum separation between the main power output and PV circuits or with leakage currents greater than the requirements for an isolated PCE

712.3.35

PV array combiner box

enclosure where PV sub-arrays are connected and which may also contain overcurrent protection and/or switch-disconnection devices

Note 1 to entry: Small arrays generally do not contain sub-arrays but are simply made up of strings, whereas large arrays are generally made up of multiple sub-arrays.

712.3.36

PV string combiner box

enclosure where PV strings are connected which may also contain overcurrent protective devices and/or switch-disconnectors

712.3.37

PV sub-array cable

output cable of a PV sub-array that carries the output current of its associated sub-array

712.3.38

U_{OC} ARRAY

open-circuit voltage at standard test conditions of a PV array

712.3.39

V_{OC} MOD

open circuit voltage of a PV module at standard test conditions, as specified by the manufacturer in the product specification

712.30 Assessment of general characteristics

712.31 Purposes, supplies and structure

712.31.101 PV array configuration

712.31.101.1 General

PV arrays are used to supply power to an application circuit.

Figure 712.1 illustrates the general functional configuration of a PV installation.

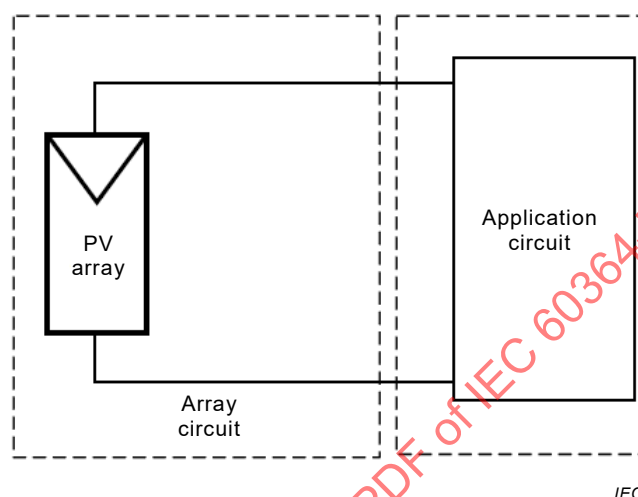


Figure 712.1 – General functional configuration of a PV installation

Three kinds of application circuit are considered:

- PV array is connected to DC loads;
- PV array is connected to AC installation via a PCE which includes at least simple separation;
- PV array is connected to AC installation via a PCE which does not include simple separation.

712.31.101.1.1 PV Installation architectures

The relation of a PV array to earth is determined by whether any earthing of the array for functional reasons is in use, the impedance of the earthing connection and also by the earth status of the application circuit (e.g. PCE or other equipment) to which it is connected. This and the location of the earth connection all affect safety for the PV array (refer to Annex A).

The requirements of manufacturers of PV modules and manufacturers of the PCE to which the PV array is connected shall be taken into account in determining the most appropriate system earthing arrangement.

Protective earthing of any of the conductors of the PV array is not permitted. Earthing of one of the conductors of the PV array for functional reasons is not allowed unless there is at least simple separation from mains earth provided either internally in the PCE or externally via a separate transformer.

If the simple separation is provided externally there shall be no other equipment connected to the same circuit as the PCE.

NOTE A DC current-carrying conductor that is connected to earth is considered to be a live conductor.

712.31.101.1.2 Array electrical diagrams

The diagrams in Figure 712.2 to Figure 712.4 show the basic electrical configurations of single-string, multiple parallel-string and multi-sub-array PV respectively.

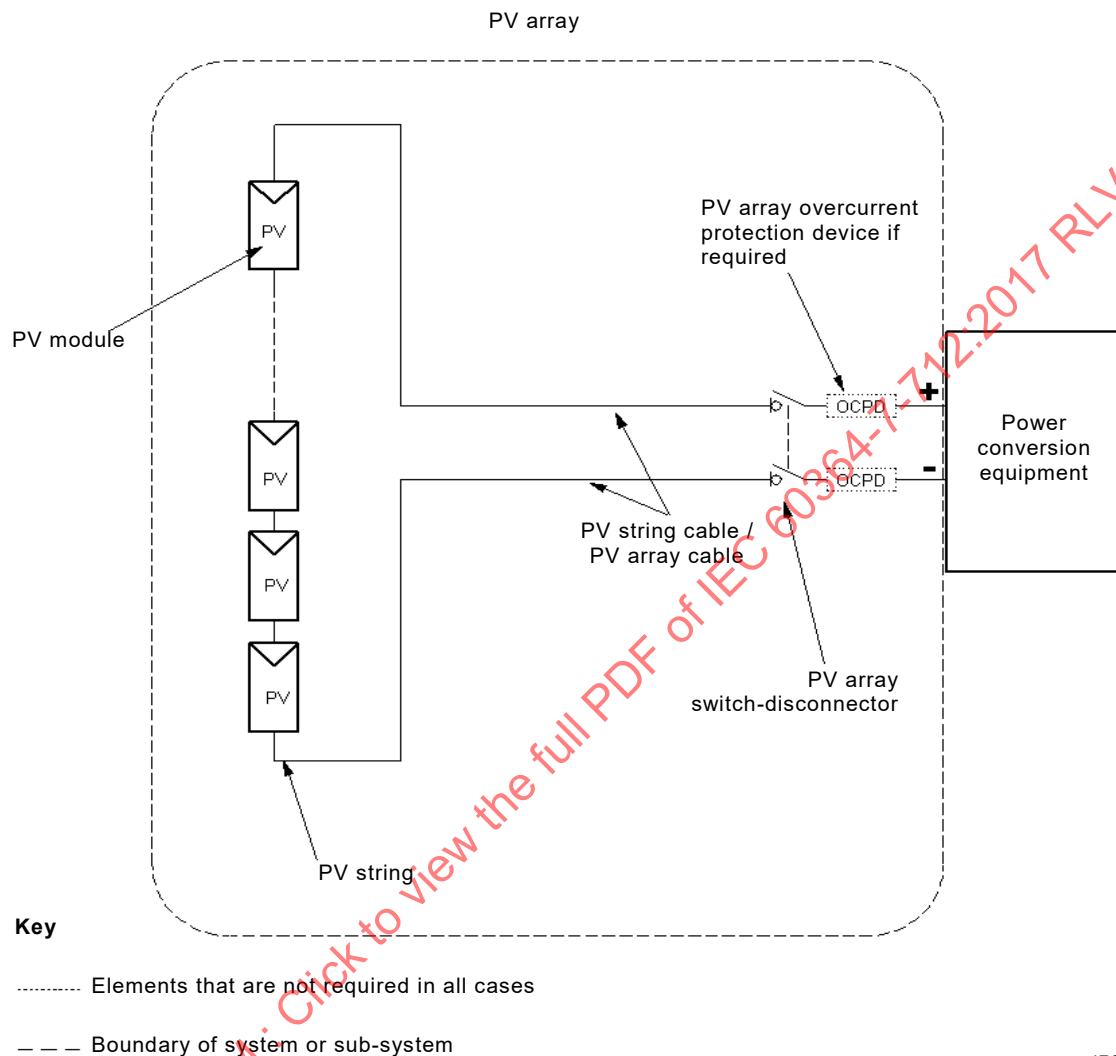


Figure 712.2 – PV array diagram – single string case

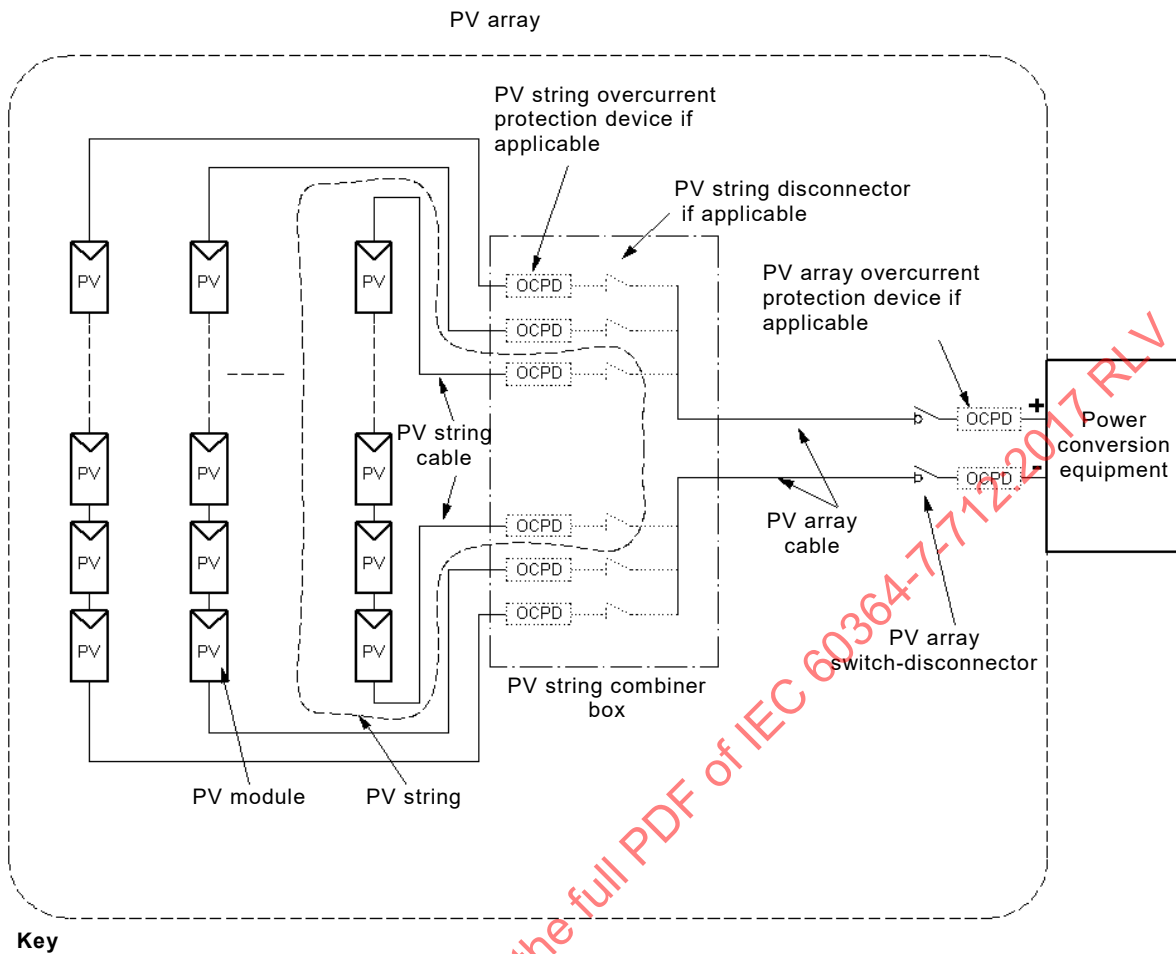


Figure 712.3 – PV array diagram – multiple parallel string case

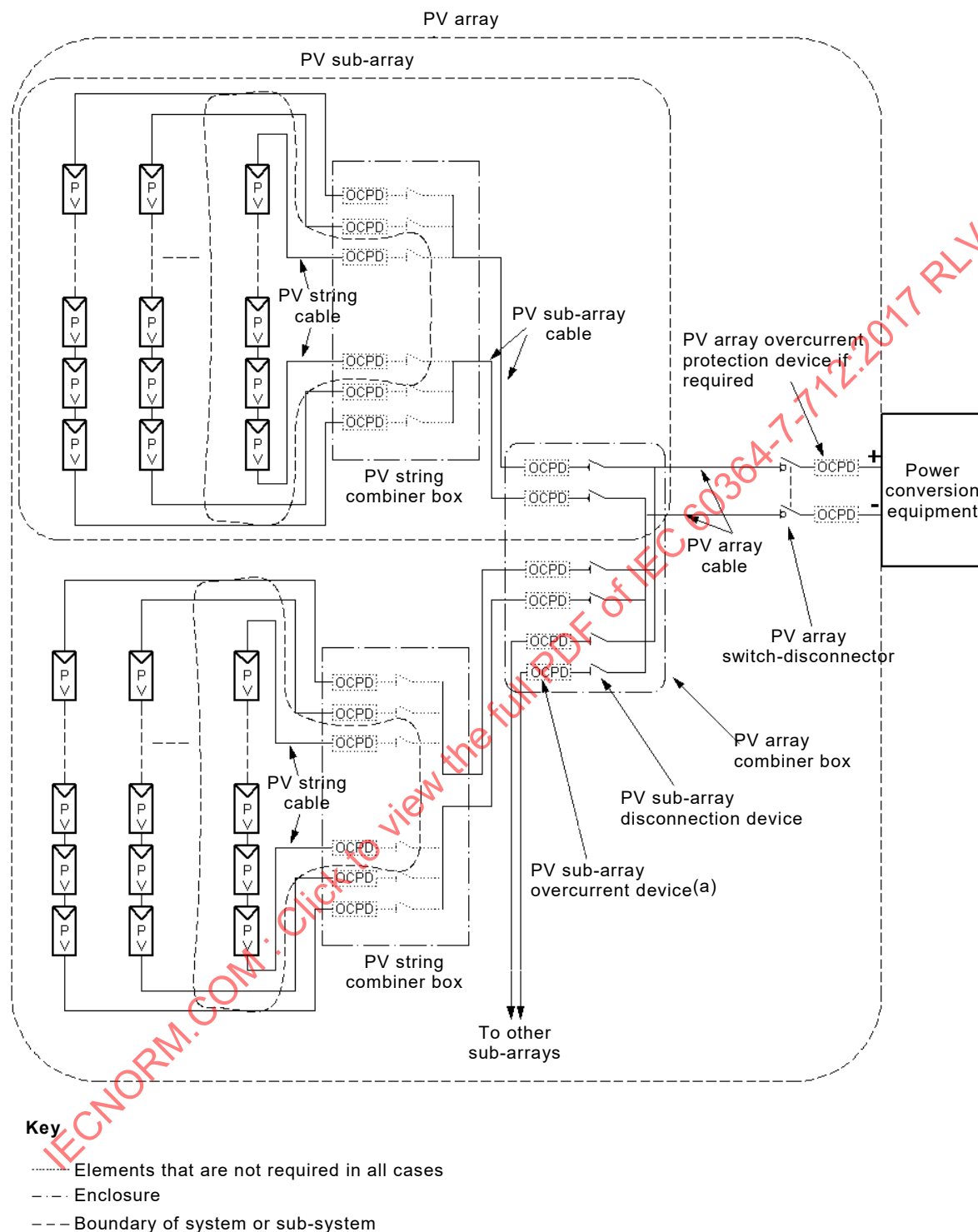
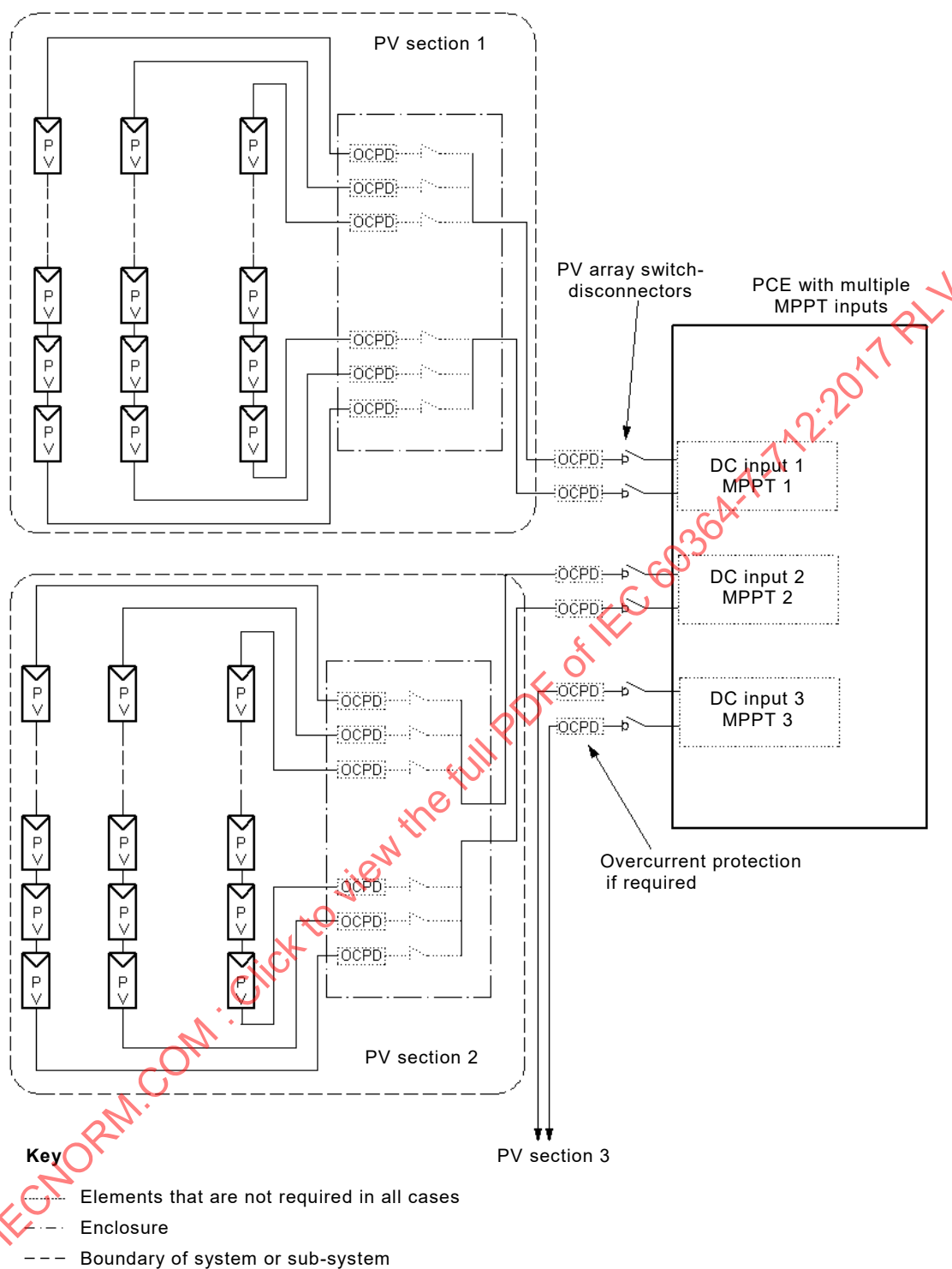
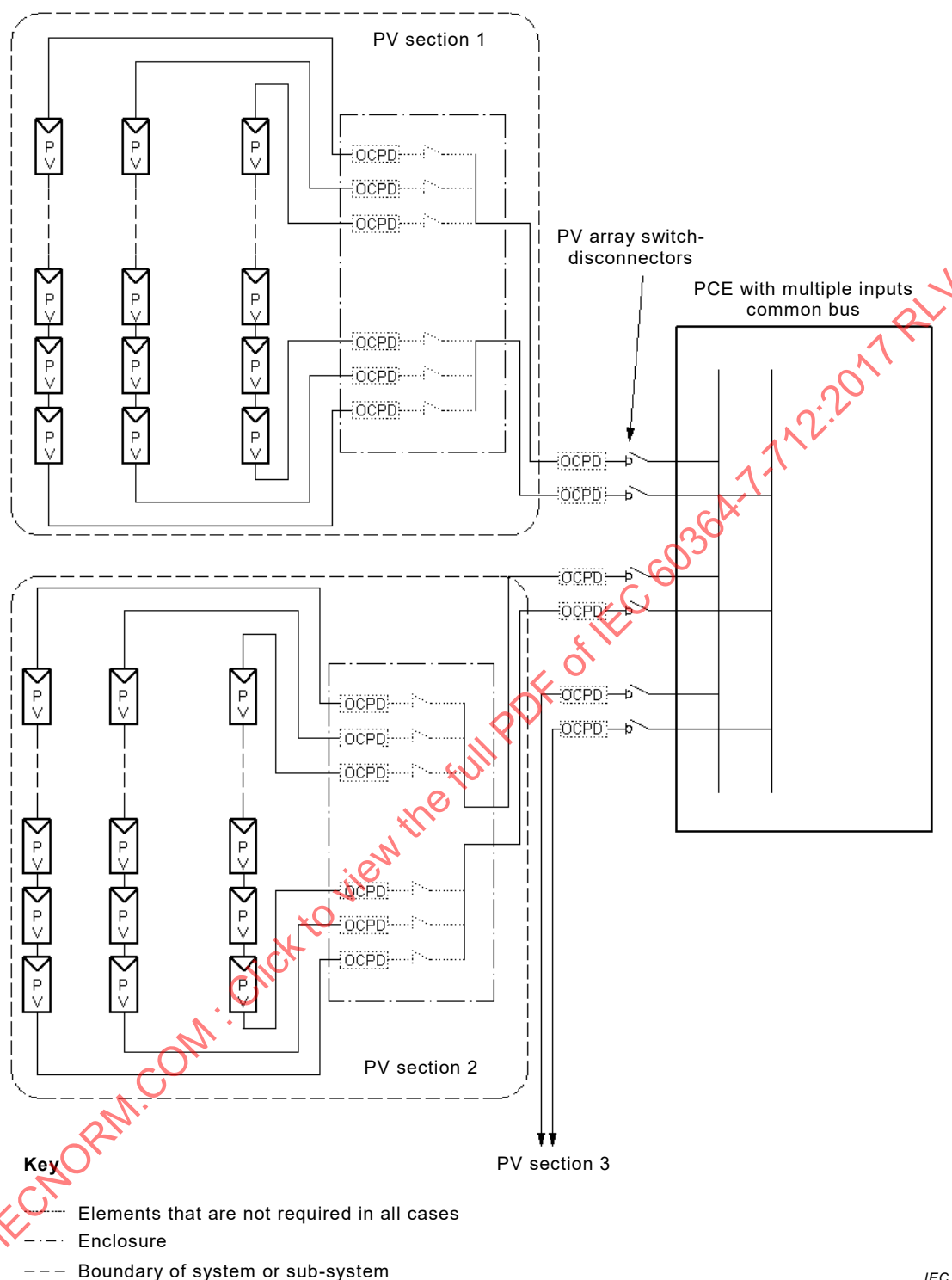


Figure 712.4 – PV array diagram – multiple parallel string case with array divided into subarrays

In Figures 712.2, 712.3 and 712.4, components drawn in dotted format are not needed in all cases. The figures indicate the location in the circuit when they are needed.





712.31.101.1.3 Use of PCE with multiple DC inputs

712.31.101.1.3.1 General

PV arrays are often connected to PCEs with multiple DC inputs. Refer to Figures 712.5 and 712.6. If multiple DC inputs are in use, overcurrent protection and cable sizing within the various sections of the PV array(s) are critically dependent on the limiting of backfeed currents.

712.31.101.1.3.2 PCEs with separate maximum power point tracking (MPPT) inputs

Where a PCE's input circuits provide separate MPPT inputs, the overcurrent protection of the section of the array connected to those inputs shall take into account backfeed current.

Each PV section connected to an input (refer to Figure 712.5) may be treated for the purposes of this document as a separate PV array. Each PV array shall have a switch-disconnector to provide isolation of the PCE. The PV array switch disconnectors may be mechanically integrated in one device and commonly operated.

712.31.101.1.3.3 PCEs with multiple inputs internally connected together in the PCE

Where a PCE's multiple input circuits are internally paralleled onto a common DC bus, each PV section connected to one of those inputs (refer to Figure 712.6) shall be treated for the purposes of this document as a sub-array and all the PV sections combined shall be classified as the complete PV array. Each PV sub-array shall have a switch-disconnector to provide isolation of the PCE. This function may be provided by a common PV array switch disconnector.

712.31.101.1.4 Series-parallel configuration

All PV strings within a PV array connected in parallel shall be of the same technology and have the same number of series connected PV modules (see Figure 712.2 to Figure 712.4), unless such modules are being tracked by separate MPPTs. In addition, all PV modules in parallel within the PV array shall have similar rated electrical characteristics, including short-circuit current, open-circuit voltage, maximum power current, maximum power voltage and rated power (all at STC), unless such modules are being tracked by separate MPPTs.

This is a design issue which needs to be considered by the project implementer, particularly when replacing modules or modifying an existing PV installation.

712.31.101.1.5 Considerations due to prospective fault conditions within a PV array

In any installation, the source of fault currents needs to be identified.

PV installations containing batteries may have high prospective fault currents due to the battery characteristic.

In a PV installation without batteries, the PV cells (and consequently PV arrays) behave like current sources under low impedance faults. Consequently, fault currents may not be much greater than normal full load currents, even under short-circuit conditions.

The fault current depends on the number of strings, the fault location and the irradiance level. This makes short-circuit detection within a PV array very difficult. Electric arcs can be formed in a PV array with fault currents lower than the operating current of an overcurrent protective device.

712.31.101.1.6 Performance issues

A PV array's performance may be affected by many factors, including but not limited to:

- shading or partial shading;
- temperature rise;
- voltage drop in cables;
- soiling of the surface of the array caused by dust, dirt, bird droppings, snow, industrial pollution, etc.;
- orientation;

- PV module degradation.

Care should be taken in selecting a site for the PV array. Nearby trees and buildings may cause shadows to fall on the PV array during some part of the day.

It is important that any shadowing be reduced as much as is practicable. Note that even a small shadow on the array can significantly limit its performance.

Issues of performance degradation due to temperature rise and the need for good ventilation are described in 712.515.101. Care should be taken to keep modules as cool as practicable.

In the design process the sizing of cables within the array and in cable connections from the array to the application circuit affects the voltage drop in those cables under load. This can be particularly significant in PV installations with low output voltage and high output current. It is recommended that under maximum load conditions the voltage drop from the most remote module in the array to the input terminals of the application circuit should not exceed 3 % of the PV array voltage at its maximum power point.

Pollution of the surface of PV modules caused by dust, dirt, bird droppings, snow etc. can significantly reduce the output of the array. Arrangements should be made to clean the modules regularly in situations where significant pollution may be a problem.

~~712.312 Types of distribution systems~~

~~712.312.2 Types of system earthing~~

~~Earthing of one of the live conductors of the DC side is permitted, if there is at least simple separation between the AC side and the DC side.~~

~~NOTE Any connections with earth on the DC side should be electrically connected so as to avoid corrosion.~~

712.4 Protection for safety

712.4.101 General

Calculation of $U_{OC\ MAX}$ and $I_{SC\ MAX}$ is performed in Annex B.

712.4.102 Functional earthing (FE) of a live part on the DC side

For functional reasons, some PV module technologies require a live part to be connected to earth.

Functional earthing of a live part of the DC side of a PCE is permitted, if there is at least simple separation between the AC side and the DC side by means of a transformer having electrically separate primary and secondary windings. The transformer may be either internal or external to the PCE. The transformer winding connected to the PCE shall not be earthed, and the PCE shall be suitable for this.

The functional earthing of a live part shall be performed at a single point of the DC side, near the DC input of the PCE or in the PCE itself.

The earthing should preferably be located between the disconnection device and the DC terminals of the PV PCE.

The requirements of 712.421.101.2.3 shall also be applied.

A cable used for functional earthing shall not be identified by the colour combination green-and-yellow. It is recommended to use the colour pink.

712.41 Protection against electric shock

712.410 Introduction

712.410.101 PV equipment on the DC side shall be considered to be energized, even when the ~~system~~ AC side is disconnected from the grid or when the PCE is disconnected from the ~~AC~~ DC side.

~~The selection and erection of equipment shall facilitate safe maintenance and shall not adversely affect provisions made by the manufacturer of the PV equipment to enable maintenance or service work to be carried out safely.~~

712.410.3.5

Replace the requirements as follows:

The protective measures specified in IEC 60364-4-41:2005, Annex B, i.e. the use of obstacles and placing out of reach, shall not be used.

712.410.3.6

Replace the requirements as follows:

The protective measures specified in IEC 60364-4-41:2005, Annex C, i.e.

- non-conducting location,
 - earth-free local equipotential bonding,
 - electrical separation for the supply of more than one item of current-using equipment,
- shall not be applied.

712.410.102 On the DC side, one of the following protective measures shall be used:

- double or reinforced insulation;
- SELV or PELV.

712.412 Protective measure: double or reinforced insulation

712.412.101 The equipment, for example PV modules, distribution boards or cabinets, used on the DC side shall be Class II or equivalent insulation, according to IEC 61140.

~~712.413 Fault protection~~

~~712.413.1 Protection by automatic disconnection of supply~~

~~NOTE Protection by automatic disconnection of supply on the DC side requires special measures which are under consideration.~~

~~**712.413.1.1.1.1** On the AC side, the PV supply cable shall be connected to the supply side of the protective device for automatic disconnection of circuits supplying current-using equipment.~~

~~**712.413.1.1.1.2** Where an electrical installation includes a PV power supply system without at least simple separation between the AC side and the DC side, an RCD installed to provide fault protection by automatic disconnection of supply shall be type B according to IEC 60755, amendment 2.~~

~~Where the PV inverter by construction is not able to feed DC fault currents into the electrical installation, an RCD of type B according to IEC 60755 amendment 2 is not required~~

~~712.413.2 Protection by use of class II or equivalent insulation should preferably be adopted on the DC side.~~

~~712.413.3 Protection by non-conducting locations is not permitted on the DC side.~~

~~712.413.4 Protection by earth-free local equipotential bonding is not permitted on the DC side.~~

712.414 Protective measure: extra-low-voltage provided by SELV and PELV

712.414.101 For the use of SELV and PELV protective measures on the DC side, $U_{OC\ MAX}$ shall not exceed 60 V DC.

712.414.102 The smooth DC voltage to be considered is the PV array maximum voltage $U_{OC\ MAX}$.

712.42 Protection against thermal effects

712.420.101 Fire safety of PV installations

Applicable national or local fire requirements shall be taken into account.

712.421 Protection against fire caused by electrical equipment

712.421.101 Protection against the effects of insulation faults

712.421.101.1 Protection against the effects of insulation faults without at least simple separation inside the PCE or on the AC side

712.421.101.1.1 The functional earthing of a live part on the DC side is not permitted.

712.421.101.1.2 In the event of an insulation fault on the DC side, either:

- the PCE shall be automatically disconnected from the AC side, or
- the faulty part of the PV array shall be automatically disconnected from the PCE.

NOTE 1 Disconnection can be provided by the PCE; see IEC 62109 (all parts).

NOTE 2 Automatic disconnection can be provided by an RCD.

712.421.101.1.3 In the event of an insulation fault on the DC side, an alarm shall be automatically given (see 712.531.3.101.3).

NOTE If the insulation fault is detected by the PCE, according to IEC 62109 (all parts) an alarm is initiated by the PCE.

712.421.101.2 Protection against the effects of insulation faults with simple separation inside the PCE or on the AC side

712.421.101.2.1 The functional earthing of a live part on the DC side is permitted.

712.421.101.2.2 Without functional earthing of a live part on the DC side, an insulation monitoring device (IMD), or another device offering equally effective monitoring, shall be installed.

NOTE An inverter according to IEC 62109 (all parts) can be used to provide this function.

712.421.101.2.3 Except where the following paragraph applies, PV arrays that have one conductor connected to a functional earth shall be provided with a device or association of devices, in accordance with 712.532.102, that interrupts the current in the functional earthing conductor in the event of an insulation fault on the DC side. The device (or association of devices) shall also give an alarm according to 712.421.101.2.4.

The requirement of the previous paragraph does not apply where the functional earthing is connected to earth via a resistor having a resistance R which meets the following condition:

$$R \geq \frac{U_{oc \max}}{I_n}$$

where

I_n is the value of current given in Table 712.6.

NOTE In the event of an insulation fault, an immediate shut down of the PCE can be necessary for functional reasons.

With functional earthing of a live part on the DC side via a resistor, an insulation monitoring device (IMD), or another device offering equal effective monitoring shall be installed (see 712.531.3).

NOTE A PCE according to IEC 62109 (all parts) can be used to provide this function.

712.421.101.2.4 In the event of an insulation fault on the DC side, an alarm shall be automatically given (see 712.531.3.101.3).

NOTE If the insulation fault is detected by the PCE, according to IEC 62109 (all parts), an alarm is initiated by the PCE.

According to IEC 60364-4-41:2005, 411.6.3.1 it is recommended that a fault be eliminated with the shortest practicable delay.

712.43 Protection against overcurrent

712.430.3 General requirements

712.430.3.101 General

Overcurrent within a PV array can result from faults in array wiring or from fault currents due to short-circuits in modules, in combiner boxes or in module wiring.

PV modules are current limited sources but can be subjected to overcurrents because they can be connected in parallel and also connected to external sources. The overcurrents can be caused by the sum of currents from

- multiple parallel adjacent strings,
- some types of PCEs to which they are connected and/or
- external sources.

712.430.3.102 Requirement for overcurrent protection

Overcurrent protection shall be provided in accordance with 712.430.3.102 to 712.433.1.101 and with PV module manufacturer's requirements.

Overcurrent protective devices required for the protection of PV modules and/or their wiring shall be selected to reliably and consistently operate within 2 h when an overcurrent of 135 % of the nominal device current rating of the PV modules is applied.

712.430.3.103 Requirement for string overcurrent protection

String overcurrent protection shall be used if:

$$((N_s - 1) \times I_{SC_MAX}) > I_{MOD_MAX_OCPR}$$

where:

N_s is the total number of parallel connected strings protected by the nearest overcurrent protective device.

When circuit-breakers with overcurrent protection elements are used, they may also provide the disconnecting means required in 712.536.2.101 to 712.536.2.103.

712.430.3.104 Requirement for sub-array overcurrent protection

Sub-array overcurrent protection shall be provided if more than two sub-arrays are connected in parallel.

712.432 Nature of protective devices

712.432.101 Blocking diodes used to connect the PV strings in parallel shall not be relied upon as a means of protection against overcurrents.

712.432.102 The overcurrent protective devices of the DC side shall be either gPV fuses in accordance with IEC 60269-6 or another device in accordance with IEC 60947 (all parts) or IEC 60898 (all parts).

Devices in accordance with IEC 60947 (all parts) and IEC 60898 (all parts) shall be of types suitable for the expected conditions, in particular for operation with direct current, reverse current and critical current.

712.433 Protection against overload on the DC side current**712.433.1 Coordination between conductors and overload protective devices**

~~Overload protection may be omitted to PV string and PV array cables when the continuous current-carrying capacity of the cable is equal to or greater than 1,25 times I_{SC_STC} at any location.~~

712.433.1.101 Overload protection sizing**712.433.1.101.1 General**

The selected multiplier in 712.433.1.101.2 to 712.433.1.101.4 shall be adjusted to account for PV systems operating in climatic conditions where I_{SC} is expected to routinely exceed STC values.

NOTE Numerous climatic and environmental conditions can result in high short-circuit currents of the PV modules and arrays exceeding STC values, such as geographic locations with unusually high solar resource, reflection from the snow, or other conditions. For example, in the snow case, short-circuit current is affected by ambient temperature, incline angle and azimuth angle of PV module, reflection of snow, geographical features, etc.

712.433.1.101.2 PV string overload protection

Where string overload protection is required, either:

- 1) each PV string shall be protected with an overload protective device, where the nominal overload protection rating of the string overload protective device shall be I_n where:

$$I_n > 1,5 \times I_{SC_MOD} \text{ and}$$

$$I_n < 2,4 \times I_{SC_MOD} \text{ and}$$

$$I_n \leq I_{\text{MOD_MAX_OCPR}}$$

or

- 2) strings may be grouped in parallel under the protection of one overload protective device provided:

$$I_{\text{ng}} > 1,5 \times N_{\text{TS}} \times I_{\text{SC_MOD}} \text{ and}$$

$$I_{\text{ng}} < I_{\text{MOD_MAX_OCPR}} - ((N_{\text{TS}} - 1) \times I_{\text{SC_MOD}})$$

where

I_n is the rated current or current setting of the string overload protective device,

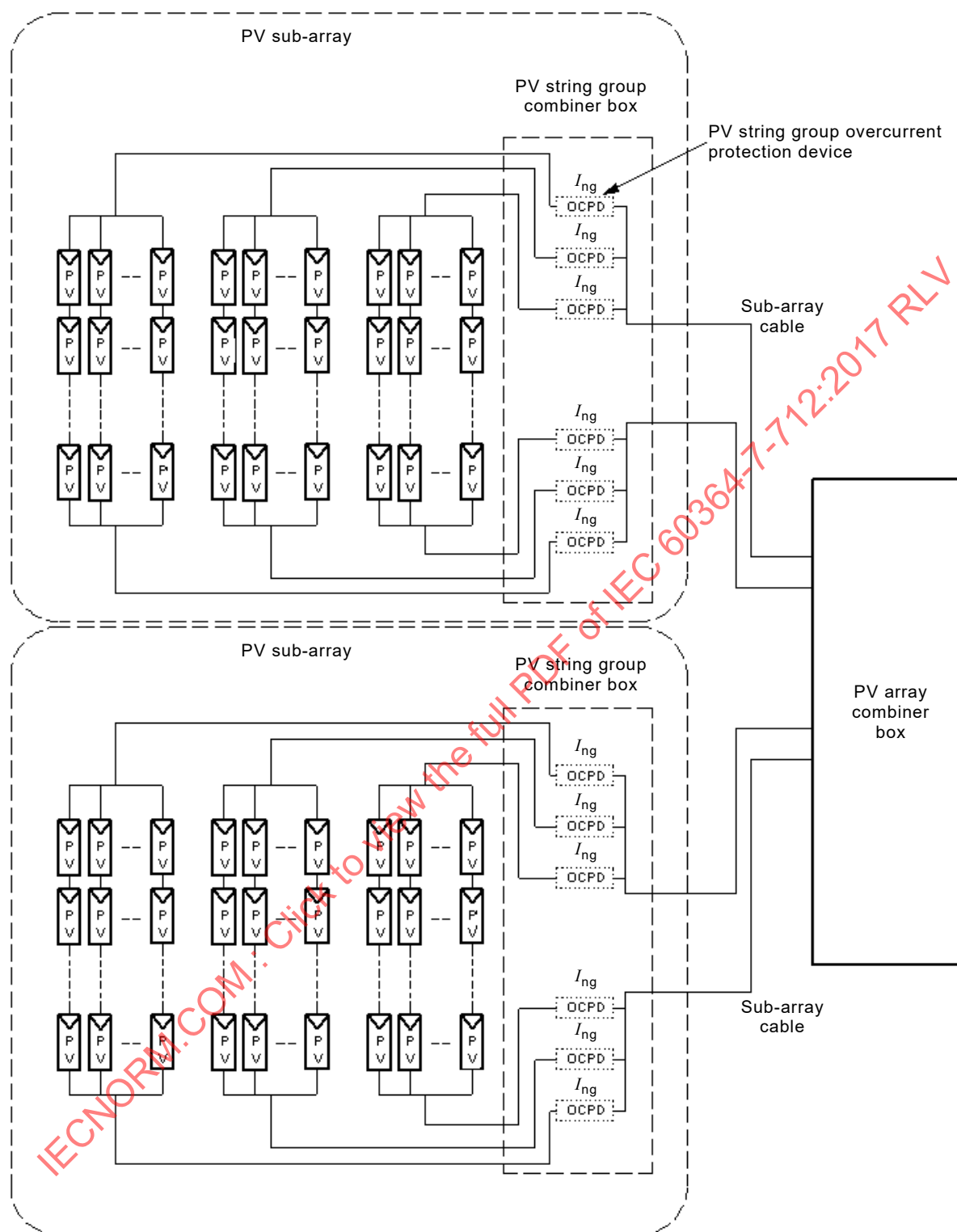
I_{ng} is the rated current or current setting of the group overload protective device,

N_{TS} is the total number of strings in a group under the protection of one overload device.

Where circuit-breakers are used as devices for overload protection, IEC 60364 (all parts) also permits these to fulfil the role of a disconnecting means as required by 712.536.2.101 to 712.536.2.103.

In some PV module technologies, $I_{\text{SC_MOD}}$ is higher than the nominal rated value during the first weeks or months of operation. This should be taken into account when establishing overload protection and cable ratings.

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This is only an example and other switching, disconnecting and/or overload protective devices may be required in individual cases, but for simplicity these are not shown in this figure.

NOTE 1 This is a special case and the design is only possible where the overload protection rating of a PV module is much larger than its normal operating current.

NOTE 2 In case of specific constraints such as side by side mounting of equipment used simultaneously at nominal current and/or high ambient temperature, the choice of rated current for the protective device could be affected.

Figure 712.7 – Example of a PV array diagram where strings are grouped under one overload protective device per group

712.433.1.101.3 PV sub-array overload protection

The rated current or current setting (I_n) of overload protective devices for PV sub-arrays shall be determined with the following formulae:

$$I_n > 1,25 \times I_{SC \text{ S-ARRAY}} \text{ and}$$

$$I_n \leq 2,4 \times I_{SC \text{ S-ARRAY}}$$

The 1,25 multiplier used here instead of the 1,5 multiplier used for strings is to allow designer flexibility. A multiplier of 1,25 should not be used in areas where heightened irradiance occurs frequently as this would be likely to cause nuisance overload protective device operation.

NOTE In case of specific constraints such as side by side mounting of equipment used simultaneously at nominal current and/or high ambient temperature, the choice of current rating of the protective device could be impacted.

712.433.1.101.4 PV array overload protection

PV array cable overload protection is only required for PV installations connected to batteries or where other sources of current may feed into the PV array under fault conditions. The rated current (I_n) of PV array overload protective devices shall be rated as follows:

$$I_n > 1,25 \times I_{SC \text{ S-ARRAY}} \text{ and}$$

$$I_n \leq 2,4 \times I_{SC \text{ ARRAY}}$$

The PV array overload protective devices are commonly installed between the battery or batteries and the charge controller as close as possible to the battery or batteries. If these devices are appropriately rated, they provide protection to both the charge controller and the PV array cable, and consequently no further PV array cable overload protection between the PV array and the charge controller is necessary. The 1,25 multiplier used here instead of the 1,5 multiplier used for strings is to allow designer flexibility. A multiplier of 1,25 should not be used in areas where heightened irradiance occurs frequently as this would be likely to cause nuisance overload operation.

NOTE In case of specific constraints such as side by side mounting of equipment used simultaneously at nominal current and/or high ambient temperature, the choice of current rating of the protective device could be impacted.

712.433.2 Position of devices for overload protection

~~Overload protection may be omitted to the PV main cable if the continuous current-carrying capacity is equal to or greater than 1,25 times $I_{SC \text{ STC}}$ of the PV generator.~~

~~NOTE The requirements of 712.433.1 and 712.433.2 are only relevant for protection of the cables. See as well the manufacturer's instructions for protection of PV modules.~~

712.433.2.101 Overload protection location

Overload protective devices where required by 712.430.3.101 to 712.430.3.104, and 712.433.1.101 for PV array, PV sub-array, and PV strings shall be placed as follows.

- For string overload protective devices, they shall be where the string cables join the sub-array or array cables in the string combiner box (refer to Figures 712.3 and 712.4).
- For sub-array overload protective devices, they shall be where the sub-array cables join the array cables in the array combiner box (refer to Figure 712.4).
- For array overload protective devices, they shall be where the array cables join the application circuit or the PCE (refer to Figures 712.2 to 712.4).

NOTE The location of the overload protective devices at the end of those cables furthest from the PV sub-array or string is to protect from fault currents flowing from other sections of the PV array or from other sources such as batteries. Due to the inherent current limiting characteristics of PV, there is insufficient fault current from the source in the faulted circuit itself to cause the overload protective device to operate.

An overload protective device required for a string cable or sub-array cable shall be placed in each live conductor (i.e. each live conductor not connected to the functional earth).

An exception applies for a string cable not in the same wiring system as sub-array cables, and for a sub-array cable not in the same wiring system as string cables. In these cases, an overload protective device need only be placed in one unearthed live conductor of the string cable or each sub-array cable. The polarity of this conductor shall be the same for all cables thus protected.

712.433.101 Protection of PV array cable

The continuous current-carrying capacity (I_z) of the PV array cable shall be greater than or equal to the maximum short-circuit current of the PV array:

$$I_{SC \text{ MAX}} \text{ of the PV array} \leq I_z$$

712.433.102 Protection of PV AC supply cable

The rated current for the overload protective device of the AC supply cable shall take into account the design current of the PCE. The PCE design current is the maximum AC current given by the PCE manufacturer or, failing that, 1,1 times its rated AC current.

712.434 Protection against short-circuit currents

712.434.101 The PV AC supply cable shall be protected ~~by~~ from the effects of short-circuit ~~or~~ by an overcurrent protective device installed at the connection to ~~the AC mains~~ the designated distribution board of the electrical installation.

712.44 Protection against voltage disturbances and electromagnetic disturbances

712.443 Protection against transient overvoltages of atmospheric origin or due to switching

712.443.101 Taking into account the sensitivity of the setting up of the photovoltaic modules, detailed attention should be paid to the protection of the structure itself (building) against direct effects of the lightning; this subject is covered in IEC 62305 (all parts).

712.443.4 Overvoltage control

712.443.4.101 Protection against transient overvoltage

Where protection against transient overvoltage is required by IEC 60364-4-44:2007, Clause 443, such protection shall also be applied to the DC side of the PV installation.

Depending on the distance between the PCE and the origin of the installation, further protection against transient overvoltage may be required on the AC side.

Where IEC 60364-4-44:2007, Clause 443 does not require protection against transient overvoltage, a risk assessment according to 712.443.5.101 shall be performed.

712.443.5 Risk assessment method

712.443.5.101 Risk assessment for PV installations

Where the relevant data is available, a risk assessment may be carried out to evaluate if protection against transient overvoltage is required.

The method of risk assessment is based on the evaluation of the critical length:

L_{crit} and its comparison with L .

SPDs shall be installed on the DC side of the installation where:

$$L \geq L_{crit}$$

where

- L is the maximum route length (m) between the PCE and the connection points of the photovoltaic modules of the different strings.
- L_{crit} (m) depends on the type of PV installation, and is calculated according to Table 712.1:

Table 712.1 – Calculation of the critical length L_{crit}

Type of installation	PV installation is attached to the building	PV installation is not attached to the building
L_{crit} (m)	$115/N_g$	$200/N_g$
$L \geq L_{crit}$ (m)	SPDs are required on the DC side	

- N_g is the lightning ground flash density (flash/km²/year) relevant to the location to the power line and connected structures. This value may be determined from ground flash location networks in many areas of the world. (IEC 62305-2:2010, Clause A.1 or IEC 60364-4-44:2007/AMD1:2015, 443.5)

712.444 ~~Protection Measures against electromagnetic interference (EMI) in buildings influences~~

~~712.444.4.4 To minimize voltages induced by lightning, the area of all wiring loops shall be as small as possible.~~

712.444.5 Earthing and equipotential bonding

712.444.5.5 Functional earthing conductor

712.444.5.5.101 Functional earthing terminal of PV array

When the PV array is earthed as described in 712.4.102 the connection to earth shall be made at a single point and this point shall be connected to the main earthing terminal of the electrical installation.

NOTE 1 Some electrical installations can have sub-earthing terminals. Connection of the PV functional earth to sub-earthing terminals is acceptable provided it has been considered for this use.

NOTE 2 The functional earth connection can be established inside the PCE.

In PV installations without batteries, this connection point shall be between the PV array and the PCE and as close as possible to the PCE.

In PV installations containing batteries, this connection point shall be between the charge controller and the battery protection device.

NOTE 3 If in some countries disconnection devices are required/allowed to interrupt functional earth conductors; the location of the earth connection is important in regards to interruption.

712.5 Selection and erection of electrical equipment

712.51 Common rules

712.51.101 The method of calculation of $U_{OC\ MAX}$ and $I_{SC\ MAX}$ is given in Annex B.

712.510.3 General

Add the following:

Equipment in outdoor locations shall have a degree of protection of at least IP 44 and a degree of protection against external mechanical impact not less than IK 07 in accordance with IEC 62262.

PV array wiring and associated components are often exposed to UV, wind, water, snow, heating due to direct solar radiation, and other environmental conditions. Particular attention is drawn to the need for measures to allow the escape of water that may accumulate even in watertight enclosures, and the need for measures against heating caused by direct solar radiation.

712.511 Compliance with standards

712.511.1

Add the following:

Support structures and module mounting arrangements shall comply with applicable building codes regulations and standards and module manufacturer's mounting requirements.

712.511.101 PV modules shall comply with the requirements of the relevant equipment standard, ~~e.g. either IEC 61215 for crystalline PV modules (all parts) or IEC 61646. PV modules of class II construction or with equivalent insulation are recommended if $U_{OC\ STC}$ of the PV strings exceeds 120 V DC.~~

~~The PV array junction box, PV generator junction box and switchgear assemblies shall be in compliance with IEC 60439-1.~~

712.511.102 PCEs shall comply with IEC 62109 (all parts).

According to the foreseeable environmental conditions, the PCE shall be selected according to IEC 62109-1:2010, Clause 6.

712.511.103 A combiner box shall comply with IEC 61439-2 or, for household and similar locations, may alternatively comply with IEC 60670 (relevant parts). Switchgear assemblies shall comply with IEC 61439 (relevant parts).

712.512 Operational conditions and external influences

712.512.1 Operational conditions

712.512.1.1 Voltage

~~Electrical equipment on the DC side shall be suitable for direct voltage and direct current.~~

~~PV modules may be connected in series up to the maximum allowed operating voltage of the PV modules and the PV inverter, whichever is lower. Specifications for this equipment shall be obtained from the equipment manufacturer.~~

~~If blocking diodes are used, their reverse voltage shall be rated for $2 \times U_{OC\ STG}$ of the PV string. The blocking diodes shall be connected in series with the PV strings.~~

712.512.1.1.101 Open-circuit maximum voltage $U_{OC\ MAX}$

The open-circuit maximum voltage $U_{OC\ MAX}$ is determined in accordance with Annex B, Clause B1.

712.512.1.1.102 Component requirements

712.512.1.1.102.1 General

All components shall comply with the following requirements:

- be rated for DC use where applicable;
- have a voltage rating equal to or greater than the open-circuit maximum voltage determined in 712.512.1.1.101;
- have a current rating equal to or greater than that shown in Table 712.2.

For some PV technologies the I_{sc} current available during the first few weeks of operation is considerably greater than the normal rated value. In some technologies the I_{sc} increases over time. Equipment shall be rated for the highest expected current value.

Where the DC voltage is conditioned (e.g. where a DC/DC converter is used), equipment shall be rated for the highest expected current and voltage values.

712.512.1.1.102.2 PV module class

Where the protective measure used on the DC side is double or reinforced insulation according to 712.412, PV modules shall be selected according to class II or equivalent insulation according to IEC 61140.

Where the protective measure used on the DC side is extra-low voltage by means of SELV or PELV, according to 712.414, PV modules shall be selected according to class III or class II or equivalent insulation according to IEC 61140.

712.512.1.1.102.3 Combiner box class

Where the protective measure used on the DC side is double or reinforced insulation according to 712.412, combiner boxes shall be selected according to class II or equivalent insulation according to IEC 61140.

Where the protective measure used on the DC side is extra-low voltage by means of SELV or PELV, according to 712.414, combiner boxes shall be selected according to class III or class II or equivalent insulation according to IEC 61140.

~~712.512.2.1 As specified by the manufacturer, the PV modules shall be installed in such a way that there is adequate heat dissipation under conditions of maximum solar radiation for the site.~~

712.513 Accessibility

712.513.101 The selection and erection of a PV installation shall facilitate safe maintenance and shall not adversely affect provisions made by the manufacturer of the electrical

equipment to enable maintenance or service work to be carried out safely. Combiner boxes which contain overcurrent and/or switching devices shall be capable of being reached for inspection, maintenance or repairs without necessitating the dismantling of structural parts, cupboards, benches or the like.

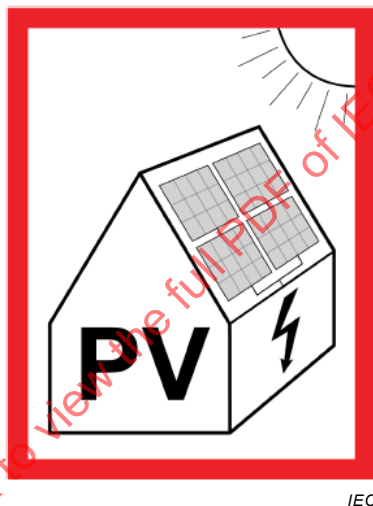
712.514 Identification

712.514.101 Safety marking

For reasons of safety of the various operators (maintenance personnel, inspectors, public distribution network operators, emergency aid services, etc.), it is essential to indicate the presence of a photovoltaic installation on a building.

A sign, such as shown in Figure 712.8, shall be fixed

- at the origin of the electrical installation, and
- at the metering position, if remote from the origin, and
- at the consumer unit or distribution board to which the supply from the PCE is connected.



NOTE National committees or national regulations should decide on the labels and locations of such markings.

Figure 712.8 – Example of an indication showing the presence of a photovoltaic installation on a building

712.514.102 Live parts marking

Each point of access to live parts on the DC side, such as distribution boards and cabinets, shall have a permanent marking for example bearing the text 'SOLAR DC – Live parts can remain energized after isolation'.

712.514.103 Isolation marking

All PCEs should bear a marking indicating that, before any servicing operation, the PCE shall be isolated from all supplies.

712.514.104 Equipment marking

All electrical equipment shall be marked according to the requirements for marking in IEC or to local standards and regulations when applicable. Markings shall be in the local language or

use appropriate local warning symbols. English examples of sign texts are included in Annex C.

712.514.105 Requirements for signs

Examples of signs are given in Annex C.

712.514.106 Labelling of disconnection devices

712.514.106.1 General

Disconnection devices shall be marked with an identification name or number according to the PV array wiring diagram.

All switches shall have the ON and OFF positions clearly indicated.

712.514.106.2 PV array disconnecting device

The PV array DC switch disconnecter shall be identified by a sign affixed in a prominent location adjacent to the switch disconnecter.

Where multiple disconnection devices are used that are not ganged (refer to 712.536.2.103) signage shall be provided warning of multiple DC sources and the need to turn off all switch disconnectors to safely isolate equipment.

712.514.107 Documentation

Documentation shall be provided in accordance with IEC 62446-1.

A set of operational instructions for the insulation fault alarm referred to in 712.531.3.101.3 shall be provided to the PV installation owner, which explains the need for immediate action to investigate and to correct the fault.

712.514.2 Wiring systems

Add the following:

The identification of AC and DC circuits shall be such that they are clearly distinguishable from each other (e.g. by labels or different coloured cables).

712.515 Prevention of mutual detrimental influence

712.515.101 Selection and erection of PV modules in relation with external influences

712.515.101.1 Thermal aspects

Provisions shall be made in the mounting arrangement of PV modules to allow for the maximum expansion/contraction of the modules under expected operating temperatures, according to the manufacturer's recommendations. Similar provisions shall be made for other applicable metallic components, including mounting structures, conduits and cable trays.

712.515.101.2 Mechanical loads on PV structures

The PV array support structures shall comply with national standards and regulations with respect to loading characteristics. Particular attention should be given to wind and snow loads on PV arrays.

712.515.101.3 Wind

PV modules, module mounting frames, and the methods used for attaching frames to buildings or to the ground shall be rated for the maximum expected wind speeds at the location according to local codes.

In assessing this component, the wind speed observed (or known) on site shall be used, with due consideration to wind events (cyclones, tornadoes, hurricanes, etc.). The PV array structure shall be secured in an appropriate manner or in accordance with local building standards.

Wind force applied to the PV array will generate a significant load for building structures. This load shall be accounted for in assessing the capability of the building to withstand the resulting forces.

712.515.101.4 Material accumulation on PV array

Snow, ice, or other material may build up on the PV array and shall be accounted for when selecting suitably rated modules, calculating the supporting structure for the modules and likewise, when calculating the building capability to support the array.

NOTE Immediately after snow falls these loads are often evenly distributed. After some time they can be very unevenly distributed as the snow starts to slide down. This can lead to significant damage to the module and support structure.

712.515.101.5 Corrosion

Module mounting frames, and the methods used for attaching modules to frames and frames to buildings or to the ground, shall be made from corrosion resistant materials suitable for the lifetime and duty of the equipment, for example aluminium, galvanized steel, treated timber.

If aluminium is installed in a marine or other highly corrosive environment, it shall be anodized to a thickness and specification suitable for the location and duty of the equipment. Corrosive gases, such as ammonia in farming environments, also need to be taken into account.

Measures shall be taken to prevent electrochemical corrosion between dissimilar metals. This may occur between structures and the building and also between structures, fasteners and PV modules.

Stand-off materials shall be used to reduce electrochemical corrosion between galvanically dissimilar metal surfaces, for example nylon washers, rubber insulators.

Manufacturer's instructions and local codes should be consulted regarding the design of mounting systems and any other connections such as earthing connections.

712.52 Wiring systems**712.521 Types of wiring systems****712.521.101 Type**

712.521.101.1 Cables used within the PV array shall:

- be suitable for DC application;
- have a voltage rating of equal to or greater than the open-circuit maximum voltage determined in clause 712.512.1.1.101;
- have a temperature rating according to the application, taking into account that PV modules frequently operate at temperatures of the order of 40 K above ambient

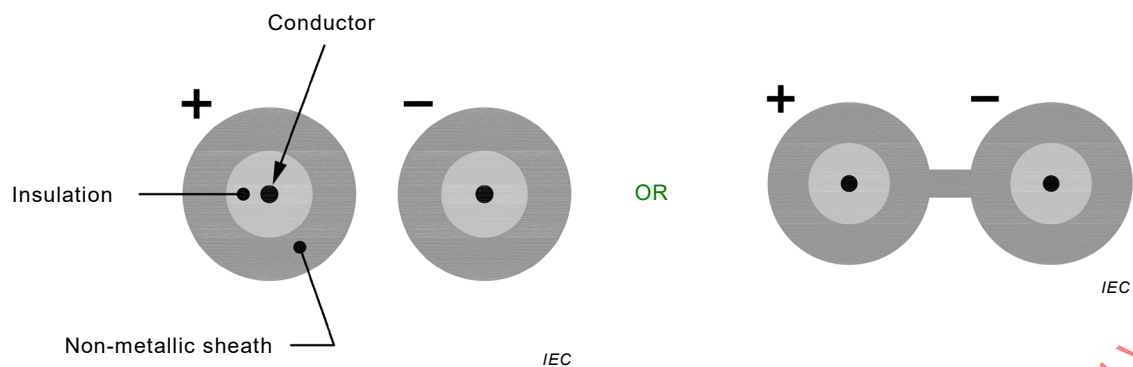
temperature and therefore cable insulation of wiring installed in contact or near PV modules shall be rated accordingly;

- if exposed to the environment, be UV-resistant, or be protected from UV light by appropriate protection, or be installed in UV-resistant conduit or trunking;
- be suitable for the expected conditions of exposure to water;
- where copper conductors are used, have tinned, multistranded conductors in order to reduce degradation of the cable over time;
- in all installations operating at voltages exceeding extra-low voltage, be selected so as to minimize the risk of insulation faults (This is commonly achieved using cables having insulation and a non-metallic sheath, selected and installed in accordance with IEC 60364-4-41:2005, 412.2.4.1, particularly for cables that are exposed or laid in metallic tray or conduit. This can also be achieved by reinforcing the protection of the wiring as shown in Figure 712.9);
- be flame retardant as defined in IEC 60332-1-2;
- have conductors classified according to minimum class 5 of IEC 60228 where subject to movement (such as for tracking installations or where string cables are exposed to wind), or a minimum of class 2 of IEC 60228 where not subject to movement.

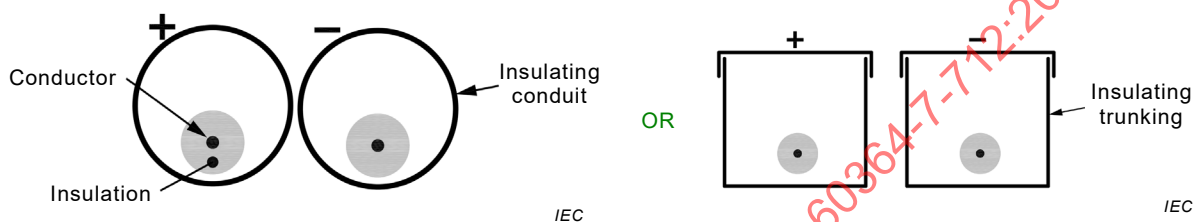
NOTE 1 Some countries require halogen free cables when those cables are routed through a building

NOTE 2 IEC 62930, Electric cables for Photovoltaic systems, is under development.

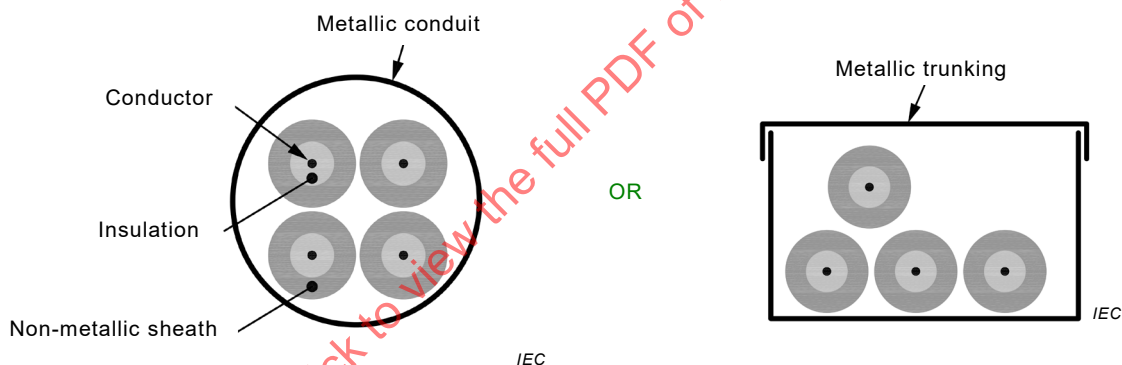
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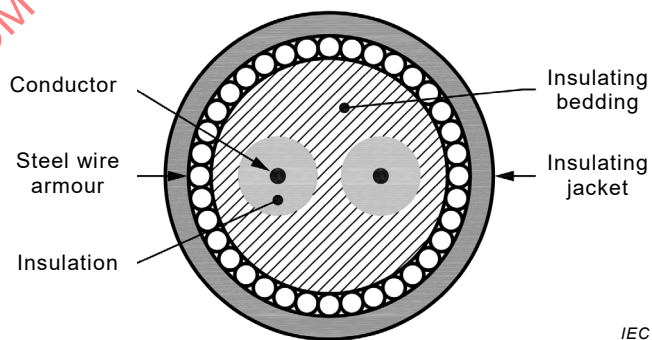
a) Single or multi conductor cable where each conductor is both insulated and sheathed



b) Insulated conductor cable – in insulated conduit/trunking



c) Single conductor cable – in metallic conduit/trunking



d) Steel wire armoured cable (usually suitable only for main DC cable)

Figure 712.9 – Examples of cables with reinforced protection

712.521.101.2 Cables on the DC side shall be selected and erected so as to minimize the risk of earth faults and short circuits.

712.521.102 General

All connections shall be verified for tightness and polarity during installation to reduce the risk of faults and possible arcs during commissioning, operation and future maintenance.

712.521.103 Wiring loops

To reduce the magnitude of transient overvoltages, the PV array wiring shall be laid in such a way that the area of conductive loops is minimum (e.g. by laying cables in parallel as shown in Figure 712.10)

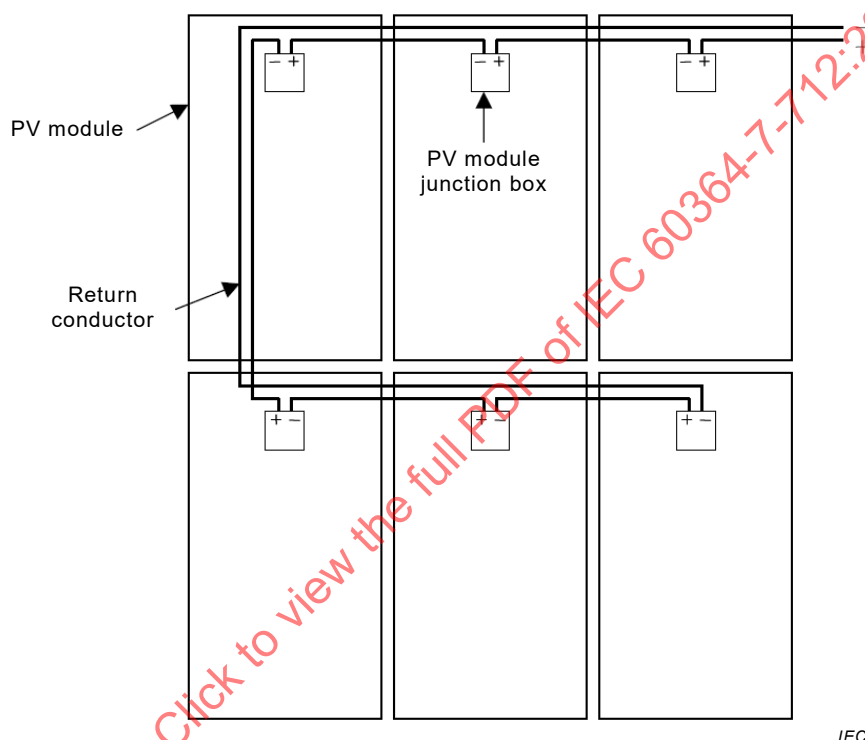


Figure 712.10 – PV string wiring with minimum loop area

712.521.104 String wiring

In the case where wiring of PV strings between modules is not protected by conduit or other enclosures, in addition to the requirements for all array wiring the following requirements shall also apply:

- cables are protected from mechanical damage, and
- the cable is so installed as to relieve tension in order to prevent the conductor from coming free from the connection.

712.522 Selection and erection of wiring systems in relation to external influences

~~712.522.8.1 PV string cables, PV array cables and PV DC main cables shall be selected and erected so as to minimize the risk of earth faults and short circuits.~~

~~NOTE This may be achieved for example by reinforcing the protection of the wiring against external influences by the use of single-core sheathed cables.~~

~~712.522.8.3 Wiring systems shall withstand the expected external influences such as wind, ice formation, temperature and solar radiation.~~

712.522.101 Installation method

Cables shall be supported so they do not suffer fatigue due to wind/snow affects. They shall also be protected from sharp edges. Cables shall be supported so that their properties and installation requirements are maintained over the stated life of the PV plant. All non-metallic cable management systems exposed to sunlight shall be of a UV resistant type.

NOTE Conduit, ducting and cable ties installed under an array might still be exposed to reflected UV radiation. Metallic cable ties can have sharp edges which over time and subject to wind affects could cause cable damage.

712.523 Current-carrying capacities

712.523.101 The ambient temperature for cables subjected to direct heating from the underside of PV modules shall be considered to be at least 70 °C.

712.524 Cross-sectional areas of conductors

712.524.1

Add the following:

Cable sizes for PV string cables, PV sub-array cables and PV array cable shall be determined with regard to overcurrent protection ratings where in use, the minimum current rating (refer to Table 712.2), the voltage drop and prospective fault current. The largest cable size obtained from these criteria shall be applied.

PV arrays not connected to batteries are current limited sources but because of parallel connection of strings, and sub-arrays, abnormally high currents can flow in array wiring under fault conditions. Overcurrent protection is specified where required and cables shall be capable of handling the worst case current from any remote part of the array through the nearest overcurrent protective device plus the worst case current available from any adjacent parallel strings.

712.524.1.101.1

The minimum cable sizes for PV array wiring, based on current-carrying capacity (I_z), shall be based upon a current rating calculated from Table 712.2.

In some PV module technologies $I_{SC\ MOD}$ is higher than the nominal rated value during the first weeks or months of operation, and in other technologies $I_{SC\ MOD}$ increases over time. This shall be taken into account when establishing cable ratings.

Table 712.2 – Minimum current rating of circuits

Relevant circuit	Protection	Minimum current upon which cable cross sectional area and or other circuit ratings shall be chosen
PV string	PV string overcurrent protection not provided	Current rating (I_n) of the nearest downstream overcurrent protective device $+ 1,25 \times I_{SC \text{ MOD}} \times (N_s - 1)$ where: N_s is the total number of parallel connected strings protected by the nearest overcurrent protective device. NOTE i) The nearest downstream overcurrent protection may be the sub-array protection and if this is not present then it may be the array overcurrent protection if present. ii) When no overcurrent protection is used in the complete array then N_s is the total number of parallel connected strings in the complete PV array; and the rated current (I_n) of the nearest overcurrent protective device is replaced by zero.
	PV string overcurrent protection provided	Current rating (I_n) of the PV string overcurrent protective device (refer to 712.430.3.101 to 712.430.3.104, 712.433.1.101 and 712.433.2.101)
PV sub-array	PV sub-array overcurrent protection not provided	The greater of the following: a) Current rating (I_n) of the PV array overcurrent protective device + $1,25 \times$ sum of short circuit current of all other sub-arrays b) $1,25 \times I_{SC \text{ S-ARRAY}}$ (of relevant array) NOTE When PV array overcurrent protection is not used, the I_n is replaced by zero in Equation (a).
	PV sub-array overcurrent protection provided	Current rating (I_n) of the PV sub-array overcurrent protective device (refer to 712.430.3.101 to 712.430.3.104, 712.433.1.101 and 712.433.2.101)
PV array	PV array overcurrent protection not provided	$1,25 \times I_{SC \text{ ARRAY}}$
	PV array overcurrent protection provided	Current rating (I_n) of the PV array overcurrent protective device (refer to 712.430.3.101 to 712.430.3.104, 712.433.1.101 and 712.433.2.101)

Where a PCE or other power conversion device is capable of providing backfeed current into the array under fault conditions, the value of this backfeed current shall be taken into account in all calculations of circuit current ratings. In some circumstances the backfeed current will have to be added to the circuit rating as calculated in Table 712.2.

NOTE The value of backfeed current provided by power conversion equipment (PCE) can be obtained from information provided by the PCE manufacturer.

712.525 Voltage drop in consumers installations

712.525.101 Voltage drop in PV installations

For efficiency reasons, other than electrical safety and correct functioning of equipment, consideration shall be given to the voltage drop in the PV installation. See 712.31.101.1.6. National requirements should be considered.

When the PV installation is generating power, the voltage at the PCE terminals is higher than the voltage at the grid connection point. This voltage difference should be kept to a minimum in order to prevent the PCE from nuisance tripping on overvoltage.

The recommendations of IEC 60364-5-52:2009, Annex G apply.

712.526 Electrical connections

712.526.1

Add the following:

Male and female connectors mated together shall be of the same type from the same manufacturer i.e. a male connector from one manufacturer and a female connector from another manufacturer or vice versa shall not be used to make a connection.

Connectors shall comply with the following requirements:

- be rated for DC use (IEC 62852);
- have a voltage rating equal to or greater than the open-circuit maximum voltage determined in 712.512.1.1.101;
- be protected from contact with live parts in connected and disconnected state (e.g. shrouded);
- have a current rating equal to or greater than the current-carrying capacity for the circuit to which they are fitted (refer to Table 712.2);
- be capable of accepting the cable used for the circuit to which they are fitted;
- require a deliberate force to disconnect;
- if accessible by untrained people, then shall be of the locking type where two independent actions are required to disconnect;
- have a temperature rating suitable for their installation location;
- if multi-polar, be polarized;
- comply with Class II for PV installations operating above 35 V;
- if exposed to the environment, be rated for outdoor use, be UV-resistant and be of an IP rating suitable for the location;
- shall be installed in such a way as to minimize strain on the connectors (e.g. supporting the cable on either side of the connector);
- plugs and socket outlets normally used for the connection of household equipment to low voltage AC power shall not be used in PV arrays.

NOTE The purpose of this requirement is to prevent confusion between AC and DC circuits within an installation.

712.526.101 Connectors on the DC side

For PV installations not using SELV or PELV protective measures on the DC side, only connectors especially suitable for the DC side of PV installations shall be used.

Connectors in a location accessible to persons other than skilled or instructed persons shall either be of a type which can only be disconnected by means of a key or a tool or shall be installed within an enclosure which can only be opened by means of a key or a tool.

712.526.102 Wiring installation in combiner boxes

The following provisions apply to the installation of wiring systems combiner boxes.

Where conductors enter a combiner box without conduit, a tension relief arrangement shall be used to avoid cable disconnections inside the box (for example by using a gland connector).

All cable entries when installed shall maintain the IP rating of the enclosure.

NOTE Water condensation inside combiner boxes can be a problem in some locations; provision can be made to drain water build-up.

712.527 Selection and erection of wiring systems to minimize spread of fire

Under consideration.

712.528 Proximity of wiring systems to other services

Under consideration.

712.529 Selection and erection of wiring systems in relation to maintainability, including cleaning

Under consideration.

712.53 Isolation, switching and control

712.530.3 General and common requirements

712.530.3.101 Residual current devices

Where an RCD is used for protection of the PV AC supply circuit, the RCD shall be of type B in accordance with IEC 62423, unless:

- the manufacturer's instructions state that the inverter provides at least simple separation between the AC side and the DC side, or
- the installation provides at least simple separation between the inverter and the RCD by means of separate windings of a transformer, or
- the inverter is in accordance with IEC 62109-1 and the manufacturer's instructions do not require the use of a type B RCD, in which case the type of RCD shall be in accordance with the manufacturer's instructions.

712.531 Devices for protection against indirect contact (fault protection) by automatic disconnection of supply

712.531.101 Detection, disconnection and alarm requirements

Requirements for detection of insulation faults, actions required and alarms depend on the type of system earthing and whether the PCE provides electrical separation of the PV array from the output circuit (e.g. the grid). Table 712.3 shows the requirements for measurements of PV array insulation resistance to earth and PV array RCM as well as the actions and alarms required if a fault is detected.

**Table 712.3 – Requirements for different system types
based on PCE isolation and PV array functional earthing**

		System type		
		Non-isolated PCE + No functional earth on PV array	Isolated PCE + No functional earth on PV array	Isolated PCE + Functionally earthed PV array
PV array insulation resistance to earth	Measurement	According to 712.531.3.101.1		
	Action on fault	a) If the AC side is not part of an IT system: Shut down PCE and disconnect all live conductors of the AC circuit or all poles of the faulty portion of the PV array from the PCE b) If the AC side is part of an IT system: No action (PCE is allowed to operate).	Connection to the AC circuit is allowed (PCE is allowed to operate)	
	Alarm on fault	Indicate a fault in accordance with 712.531.3.101.3		
PV array residual current monitoring	Measurement	According to 712.531.3.101.2	Not required	According to 712.531.3.101.2
	Action on fault	Shut down PCE and disconnect all live conductors of the AC circuit or all poles of the faulty portion of the PV array from the PCE		Functional earth connection shall be disconnected (see 712.531.3.101.2); connection to the AC circuit is allowed. (PCE is allowed to operate)
	Alarm on fault	Indicate a fault in accordance with 712.531.3.101.3		Indicate a fault in accordance with 712.531.3.101.3
Instead of shutting down the PCE and disconnecting the AC circuit it is allowed to isolate the faulted parts of the PV array.				
Functional earthing has to be carried out according to 712.4.102.				
Systems using non-isolated PCEs where the AC circuit is referenced to earth are not allowed to use functional earthing on the PV side of the PCE see 712.4.102.				

712.531.3 Insulation monitoring devices

712.531.3.101 Requirements for PV arrays operating at above 60 V

712.531.3.101.1 Array insulation resistance detection

The requirements in 712.531.3.101.1 regarding detection and response to abnormal array insulation resistance to earth are intended to reduce hazards due to degradation of insulation.

A means shall be provided to measure the insulation resistance from the PV array to earth before starting operation and at least once every 24 h. This can be done by an insulation measuring device according to IEC 61557-2, or by an insulation monitoring device (IMD) according to Annex C of IEC 61557-8:2014, to prevent a possible high risk of fire.

This functionality for insulation resistance monitoring or measurement may be provided within the PCE.

Minimum threshold values for detection shall be according to Table 712.4.

**Table 712.4 – Minimum insulation resistance thresholds
for detection of failure of insulation to earth**

PV array rating, kW	R limit, kΩ
≤20	30
> 20 and ≤ 30	20
> 30 and ≤ 50	15
> 50 and ≤ 100	10
> 100 and ≤ 200	7
> 200 and ≤ 400	4
> 400 and ≤ 500	2
≥ 500	1

It is recommended that the threshold of detection for insulation resistance should, where possible, be set at values greater than the minimum values specified in these calculations. A higher value will increase the safety of the PV installation by detecting potential faults earlier.

It is necessary to disconnect the PV array functional earth connection during the measurement.

The action on fault required is dependent on the type of PCE in use, as follows:

- for isolated PCEs, shall indicate a fault in accordance with 712.531.3.101.3 (operation is allowed); the fault alarm shall be maintained until the array insulation resistance has recovered to a value higher than the limit above;
- for non-isolated PCEs, shall indicate a fault in accordance with 712.531.3.101.3, and shall not connect to any earthed output circuit (e.g. the mains); the device may continue to make the measurement, may stop indicating a fault and may allow connection to the output circuit if the array insulation resistance has recovered to a value higher than the limit above.

712.531.3.101.2 Residual current monitoring system

Where required by Table 712.3, residual current monitoring shall be provided that functions whenever the PCE is connected to an earth referenced output circuit with the automatic disconnection means closed. The residual current monitoring means shall measure the true RMS (both AC and DC components) residual current.

If the PCE AC output connects to a circuit that is isolated from earth, and the PV array is not functionally earthed, residual current monitoring is not required.

Detection shall be provided to monitor for excessive continuous residual current, and excessive sudden changes in residual current according to the following limits:

- a) Continuous residual current: where the RCM indicates a residual current above the limits, disconnection by a switching device shall operate within 0,3 s and indicate a fault in accordance with 712.531.3.101.3 if the continuous residual current exceeds:
 - maximum 300 mA for PCEs with continuous output power rating ≤ 30 kVA;
 - maximum 10 mA per kVA of rated continuous output power for PCEs with continuous output power rating > 30 kVA.

NOTE It is possible to implement distributed residual current monitoring for example at sub-array level or in smaller subsections of the array. This can be beneficial especially in large arrays as it enables smaller thresholds of detection to be implemented. This can lead to more rapid identification of potential faults and can assist in identifying the section of the array that may be affected.

The RCM may attempt to initiate re-connection if the leakage current threshold is below that specified in this subclause and the array insulation resistance meets the limit in 712.531.3.101.1.

- b) Sudden changes in residual current: the PCE shall disconnect from any earth referenced output circuits (e.g. the mains) within the time specified in Table 712.5 and indicate a fault in accordance with 712.531.3.101.3 if a sudden increase in the RMS residual current is detected exceeding the value in the table.

Table 712.5 – Response time limits for sudden changes in residual current

Residual current sudden change	Maximum time for disconnection from earth referenced circuit
30 mA	0,3 s
60 mA	0,15 s
150 mA	0,04 s
NOTE These values of residual current and time were originally taken from the RCD standard IEC 61008-1 but are no longer related to protection against electric shock in the meaning of this document.	

The RCM may attempt to initiate re-connection if the leakage current threshold is below that specified in this subclause and the array insulation resistance meets the limit in 712.531.3.101.2.

712.531.3.101.3 Insulation fault alarm

To provide an indication as required by 712.531.3.101.1, an insulation fault alarm shall be installed. When activated the alarm is to continue its operation until the PV installation is shut down and/or the insulation fault is corrected.

The alarm shall be of a form that ensures that the operator or owner of the PV installation becomes aware of the fault. For example, the alarm may give a visible or audible signal placed in an area where operational staff or owners will be aware of the signal or another form of fault communication such as Email, SMS or similar.

Many PCEs have insulation fault detection and indication in the form of indicator lights. However, typical PCE mounting locations mean that this indication may not be noticed. IEC 62109-2 requires that PCEs have a local alarm and also a means of signalling an insulation fault externally.

712.532 Devices for protection against thermal effects

712.532.101 Protection against the effects of insulation faults which includes the use of an IMD

Where an IMD is used in connection with protection against the effects of insulation faults, it shall be in accordance with IEC 61557-8.

If the IMD is an integral part of the PCE, the insulation monitoring function has to be in accordance with Annex D of IEC 62109-2: 2014.

NOTE 1 Protection against the effects of insulation faults by IMD is a possible choice where AC and DC sides are galvanically separated without functional earthing of a live part on the DC side (see 712.532.102)

NOTE 2 An IMD can also be necessary for reasons other than fire prevention, for example for continuous operation without interruption by a first fault.

In PV arrays > 100 kWp an automatic insulation fault location system according to IEC 61557-9 is recommended.

712.532.102 Protection against the effects of insulation faults by disconnecting the functional earthing conductor

The device or association of devices required by 712.421.101.2.3 shall:

- meet the relevant requirements of IEC 60364-4-43,
- be rated for the maximum voltage of the PV array $U_{OC\ MAX}$,
- have a rated breaking capacity not less than the maximum short circuit current of the PV array $I_{SC\ MAX}$, and
- have a rated current not exceeding that given in Table 712.6.

Table 712.6 – Rated current of automatic disconnecting device in the functional earthing conductor

Total PV array power rating (kWp)	Rated current I_n (A)
0 to 25	1
>25 to 50	2
>50 to 100	3
>100 to 250	4
>250	5

Some module technologies require a functional earth on either the positive or negative main conductor to bleed charge away from the PV cells. This is a functional/operational requirement or it may be required to prevent degradation of the cells. It is recommended that the manufacturer's instructions be followed. It is also recommended that, where possible, the functional earthing to bleed charge from the cells be via a resistor and not directly to earth. The recommended resistor value should be the highest resistor value allowable as per the manufacturer's instructions.

712.533 Devices for protection against overcurrent

712.533.1 General requirements

712.533.101 Overcurrent protective devices of the DC side

The overcurrent protective devices of the DC side shall be:

- gPV fuses in accordance with IEC 60269-6, or ,
- circuit-breakers in accordance with IEC 60947-2 or IEC 60898-2 for which the manufacturer declares their suitability for use in PV installations.

These devices shall comply with the following specific measures:

- the rated operating voltage (U_e) shall be greater than or equal to the voltage $U_{OC\ MAX}$ of the PV array;
- the rated current I_n as defined in 712.433.1.101;
- the rated breaking capacity shall be at least equal to $I_{SC\ MAX}$ of the PV array and fault current from any other connected power sources, such as batteries or generators;

- designed for direct current use;
- be able to switch off critical current as defined in IEC 60947-1;

NOTE The symbol  (IEC 60417-5031:2003-02) is used on some devices to indicate suitability for DC application.

- operation of the overcurrent protective devices shall be independent of the direction of current flow.

712.534 Devices for protection against transient overvoltages

712.534.4 Selection and erection of SPDs

712.534.4.4 Selection of SPDs

712.534.4.4.101 Selection of SPDs on the DC side

712.534.4.4.101.1 General

Due to the very specific electrical setup of PV installations on the DC side, only SPDs especially dedicated to PV installations shall be used to protect the DC side of such installations. The manufacturer of SPDs shall give the relevant information.

When the PCE incorporates SPDs on the DC side, they are considered as fulfilling the surge protective function only if the manufacturer of the PCE specifies their convenient use for the DC side of PV installations and their specifications are adequate for the place of the installation (I_n , I_{max} , I_{imp} , I_{SCPv} , according 712.534.4.4.101). Otherwise, protection shall be provided by external SPDs.

NOTE Varistors included in the PCE are not considered as SPDs.

The voltage protection level U_p of external SPDs shall be determined in relation to the characteristics of the devices incorporated in the PCEs. The PCE manufacturer shall in that case provide the voltage level needed for the selection of external SPDs.

The characteristics of SPDs installed on the DC side are defined as follows in 712.534.4.4.101.2 to 712.534.4.4.101.7.

712.534.4.4.101.2 Selection of SPD test class

Generally SPDs will be class II test. If protection against effects of direct lightning strokes is specified and separation distance S is not kept in accordance with IEC 62305 (all parts), class I test SPDs shall be used (generally in conjunction with class II test SPDs).

712.534.4.4.101.3 Selection of SPD voltage protection level U_p

Where no information is provided by the manufacturer, the impulse withstand voltage U_w shall be considered equal to that in Table 712.7 for the modules and conversion equipment.

**Table 712.7 – Impulse withstand voltage U_w
where no information is available**

$U_{OC\ MAX}$ (V)	U_w (kV)	
	PV module	Inverter
100	0,8	-
150	1,5	-
300	2,5	-
400	-	3,1
600	4	4,2
800	-	5,1
1 000	6	5,6
1 500	8	8,5

712.534.4.4.101.4 Selection of SPD maximum continuous operating voltage U_{cpv}

The value of the maximum voltage acceptable by the surge protective device U_{cpv} shall be selected according to the maximum no-load voltage of the PV array $U_{OC\ MAX}$. The voltage U_{cpv} shall be greater than or equal to the maximum voltage $U_{OC\ MAX}$ of the PV array.

An SPD shall be selected and arranged with regard to the maximum voltage $U_{OC\ MAX}$ between:

- its live terminals (+ and – terminals), and
- its live terminals (+ and – terminals) and earth.

712.534.4.4.101.5 Selection of SPD nominal discharge current I_n

The minimum value of nominal discharge current I_n of Class II tested SPDs shall be 5 kA.

NOTE A nominal discharge current exceeding the minimum value will give the surge protective device a longer service life.

712.534.4.4.101.6 Selection of SPD short circuit current rating I_{SCPv} and of protective device associated with the surge protective device

If required by the manufacturer, the surge protective device shall be provided with an external automatic disconnecting device selected in accordance with the manufacturer's specification. The device shall be selected to operate whatever the current produced by the PV modules.

An external disconnecting device is required as an SPD could fail to a short-circuit condition.

The short-circuit current rating I_{SCPv} shall be selected according to the maximum current that can be delivered by the PV array I_{SCMAX} . The current I_{SCPv} shall be greater than or equal to I_{SCMAX} of the PV array. Surge protective devices for which this parameter is not given shall not be used.

712.534.4.4.101.7 Selection of class I tested SPDs impulse current I_{imp}

If the impulse current I_{imp} cannot be calculated, I_{imp} shall not be less than 12,5 kA. This value is referring to lightning protection level LPL III.

712.534.4.4.102 Erection of SPDs on the DC side

SPDs on the DC side shall be located as close as possible to the PCE.

To provide protection, additional SPDs may be required, further from the PCE.

NOTE 1 An example is where the distance between the entrance of the DC cable into a building and the PCE is longer than 10 m.

NOTE 2 The surge voltage level on the equipment depends on its distance away from the SPD. Beyond 10 m, the value of this voltage can be doubled due to the effect of resonance (amplification phenomena due to the high frequencies of the lightning surges).

712.534.4.10 Connecting conductors of SPDs

Add the following:

- When SPDs are installed on both AC and DC sides of the inverter in separate switchboards, it is recommended to minimize the distance between those switchboards.
- For DC SPD connections to the main earthing terminal the conductors shall have a minimum cross section of 6 mm² copper or equivalent for Class II tested SPDs and 16 mm² copper or equivalent for Class I tested SPDs.

712.536 Isolation and switching

712.536.2 Isolation

~~712.536.2.1.1 To allow maintenance of the PV inverter, means of isolating the PV inverter from the DC side and the AC side shall be provided.~~

~~NOTE Further requirements with regard to the isolation of a PV installation operating in parallel with the public supply system are given in 551.7 of IEC 60364-5-55⁴.~~

~~712.536.2.2 Devices for isolation~~

~~712.536.2.2.1 In the selection and erection of devices for isolation and switching to be installed between the PV installation and the public supply, the public supply shall be considered the source and the PV installation shall be considered the load.~~

~~712.536.2.2.5 A switch-disconnector shall be provided on the DC side of the PV inverter.~~

~~712.536.2.2.5.1 All junction boxes (PV generator and PV array boxes) shall carry a warning label indicating that active parts inside the boxes may still be live after isolation from the PV inverter.~~

712.536.2.101 Disconnections means

Disconnecting means with isolation function shall be provided for the inverter, on both the DC side and the AC side.

Disconnecting means with isolation function shall be provided in PV array to isolate circuits and equipment.

712.536.2.102 Location of the switch-disconnector for the PCE

The switch-disconnector shall be so located that maintenance of the PCE (e.g. change of a PCE module, change of fans, cleaning of filters) is possible without risk of electrical hazards. The switch-disconnector may be in the same enclosure with the PCE.

In case of multiple DC inputs the above requirements apply to each input.

⁴ IEC 60364-5-55, *Electrical installations of buildings — Part 5-55: Selection and erection of electrical equipment — Other equipment*.

712.536.2.103 Devices for isolation within the PV array

Devices shall be provided in accordance with Table 712.8.

Table 712.8 – Disconnection device requirements in PV array installations

Circuit or part of circuit	Means of isolation	Requirement
String	Disconnection device ^a	Recommended
Sub-array	Disconnection device ^a	Required
	Means of isolation offering load-breaking capabilities ^b	Recommended
Array	Means of isolation offering load-breaking capabilities	Required
^a Sheathed (touch safe) connector, fuse combination unit, or isolator are examples of suitable disconnection devices.		
^b Where a switch-disconnector is used, this may also provide the isolation function.		

Means of isolation that are not capable of breaking load current shall be marked to indicate that they are no-load break devices, and shall be accessible only by means of a tool or key.

Where multiple sub-array disconnection devices are installed close to the PCE (i.e. within 2 m and within line of sight), a PV array cable need not be provided and therefore there is no need for a PV array load breaking switch. In this case the switches for the sub-arrays shall all be load breaking switches.

Where multiple disconnection devices are required to isolate the PCE, a warning sign shall be provided indicating the need to isolate multiple supplies.

712.536.5 Functional switching (control)

712.536.5.101 Disconnectors and switch-disconnectors

All switch-disconnectors shall be selected and erected to comply with the following requirements:

- not have exposed live metal parts in connected or disconnected state;
- have a current rating equal to or greater than that required for the circuit conductors;
- not be polarity sensitive (fault currents in a PV array may flow in the opposite direction of normal operating currents).

Switch-disconnectors shall be compliant with IEC 60947-3 and have mechanisms that have independent manual operation.

712.54 Earthing arrangements and protective conductors ~~and protective bonding conductors~~

~~Where protective equipotential bonding conductors are installed, they shall be parallel to and in close contact as possible with DC cables and AC cables and accessories.~~

712.542 Earthing arrangements

712.542.101 Functional earthing

For mechanical protection, the minimum cross-sectional area for a functional earthing conductor is 4 mm² copper or equivalent.

712.542.102 Separate earth electrode

If a separate earth electrode is provided for the PV array, this electrode shall be connected to the main earthing terminal of the electrical installation by main equipotential bonding conductors.

712.542.103 Bonding of PV metal structures

Where such bonding is necessary (e.g. to facilitate the correct operation of the array insulation resistance detection referred to in 712.531.3.101.1), the metallic structures supporting the PV modules (including metallic cable trays) shall be bonded.

Such bonding may be necessary, for example, where a transformerless PCE induces an electrostatic charge.

The bonding conductor shall be connected to any suitable PE terminal.

Where these metal structures are of aluminium, appropriate connection devices shall be used.

The bonding conductors (insulated or bare) shall have a minimum cross section of 4 mm² copper or equivalent.

PV array bonding conductors shall be run as close to the positive and negative PV array and or sub-array conductors as possible to reduce induced voltages due to lightning. See also 712.521.103.

NOTE The bonding referred to in 712.542.103 also ensures the protection against the effects of discharge of electrostatic charges.

712.55 Other equipment**712.55.101 Measures to prevent DC on-load interruption**

In order to prevent arcing, every device without breaking capacity that could be used to open a DC circuit shall be secured against inadvertent or unauthorized operation.

NOTE 1 Examples of devices to which this requirement applies are SPD carriages and fuse carriers.

NOTE 2 This can be achieved by locating the device in a lockable space or enclosure or by padlocking.

712.55.102 Blocking diodes

Blocking diodes shall not be used as an alternative to overcurrent protective devices.

Blocking diodes may be used to prevent reverse currents in sections of a PV array.

If used, blocking diodes shall comply with the following requirements:

- have a voltage rating at least 2 times $U_{OC\ MAX}$;
- have a current rating I_{MAX} of at least 1,4 times the short circuit current at STC of the circuit that they are intended to protect; that is:
 - $1,4 \times I_{SC\ MOD}$ for PV strings;
 - $1,4 \times I_{SC\ S-ARRAY}$ for PV sub-arrays;
 - $1,4 \times I_{SC\ ARRAY}$ for PV arrays;
- be installed so no live parts are exposed;
- be protected from degradation due to environmental factors.

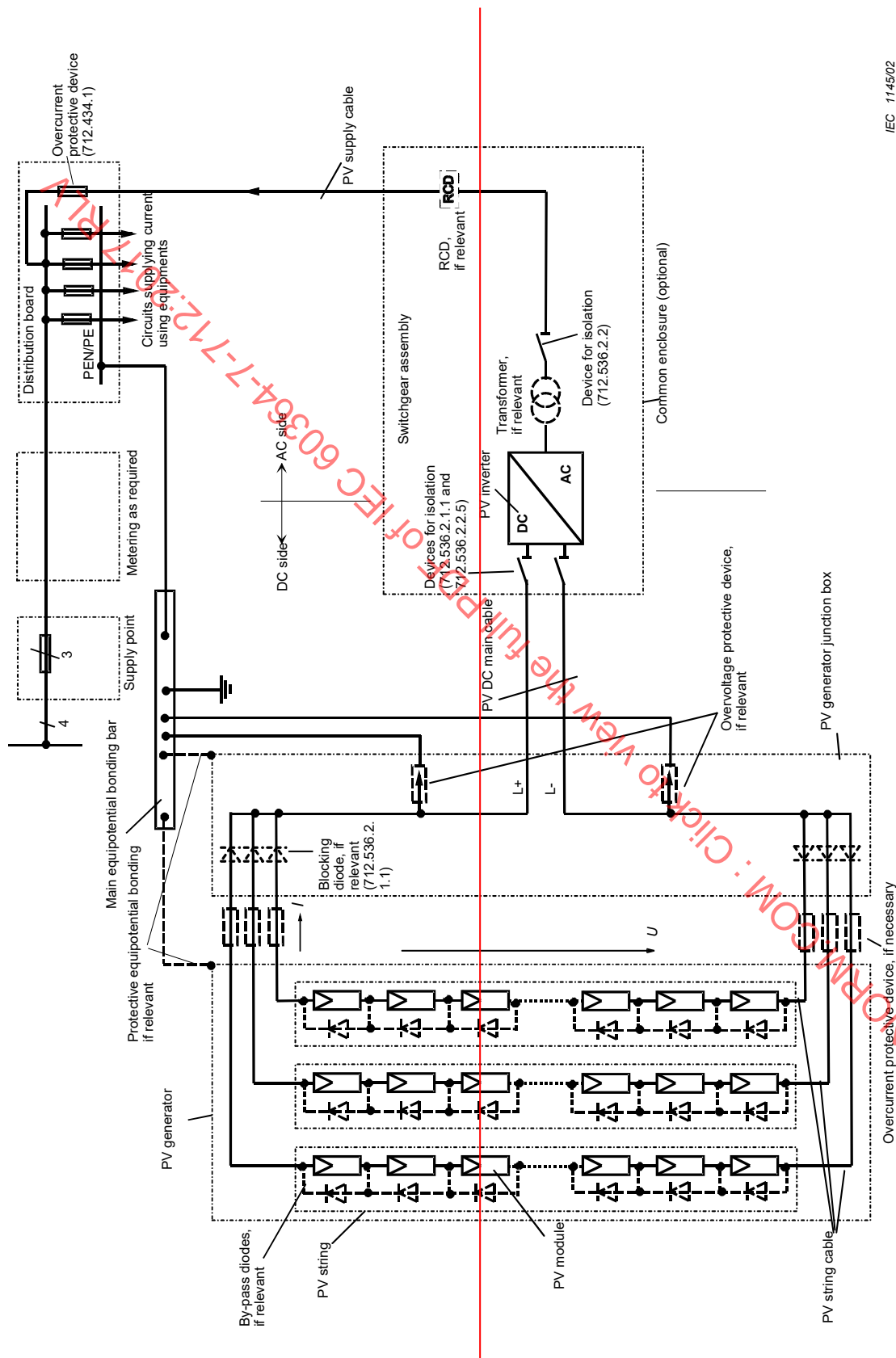
The use of blocking diodes is shown in detail in Annex D.

NOTE See 712.433.1.101 for requirements for adjusting I_{sc} multipliers for certain climatic conditions.

712.6 Inspection and testing

IEC 62446-1 gives requirements for system documentation, commissioning tests and inspection which are additional to the requirements of this document.

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IEC 1145/02

Figure 712.1 -- PV installation -- General schema -- One array

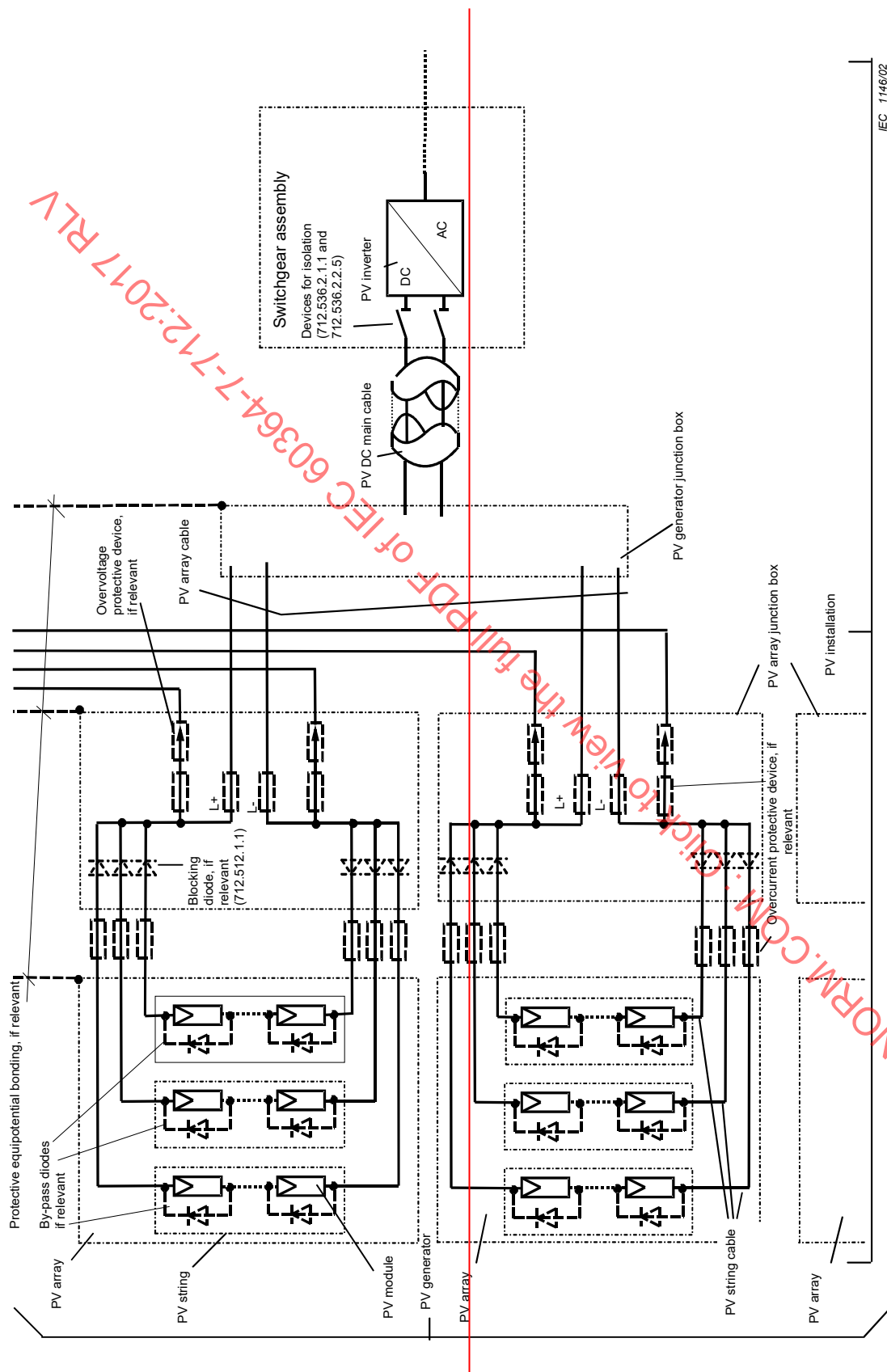
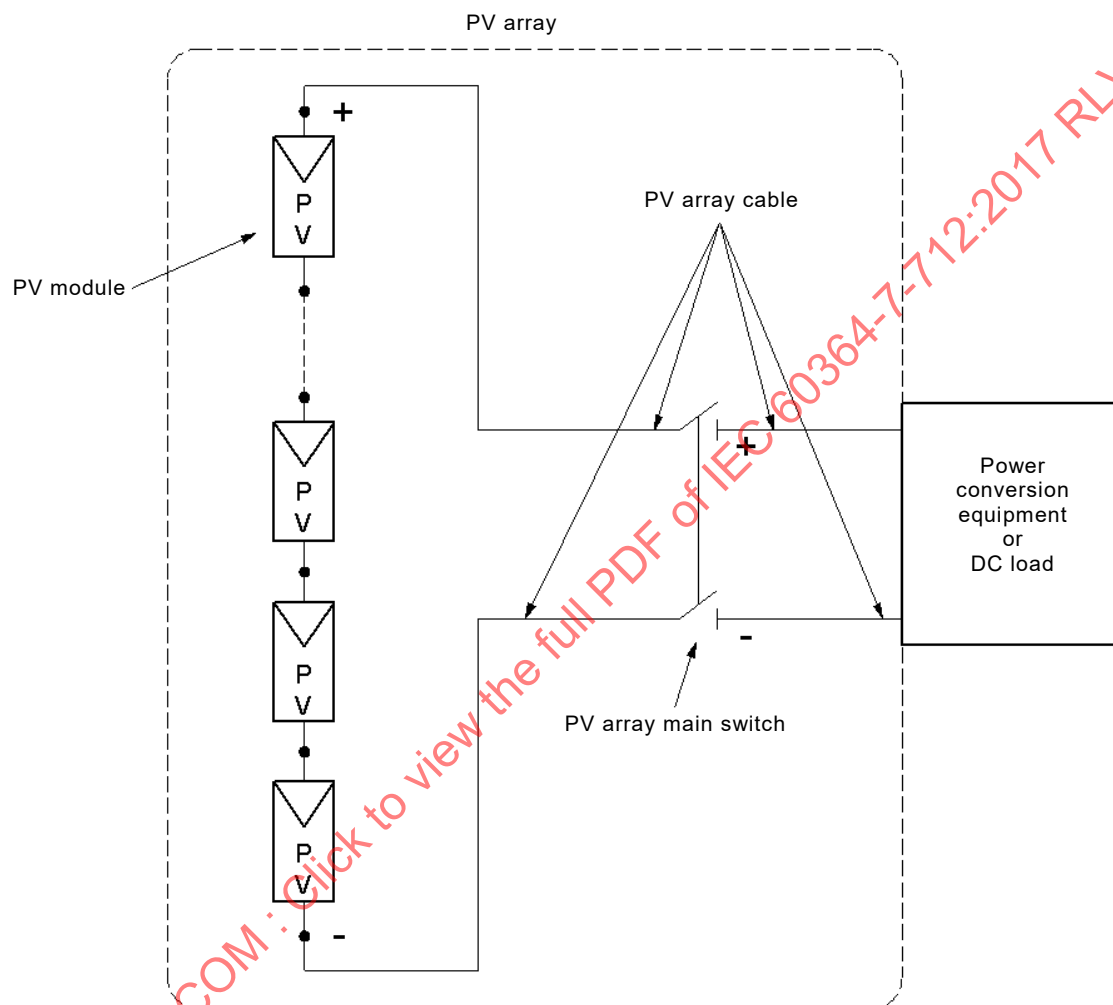


Figure 712.2 – PV installation – Example with several arrays

Annex A (informative)

PV installation information

Figures A.712.1 to A. 712.6 provide information on PV installation, as referred to in 712.31.101.1.1.



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Figure A.712.1 – Single string PV array

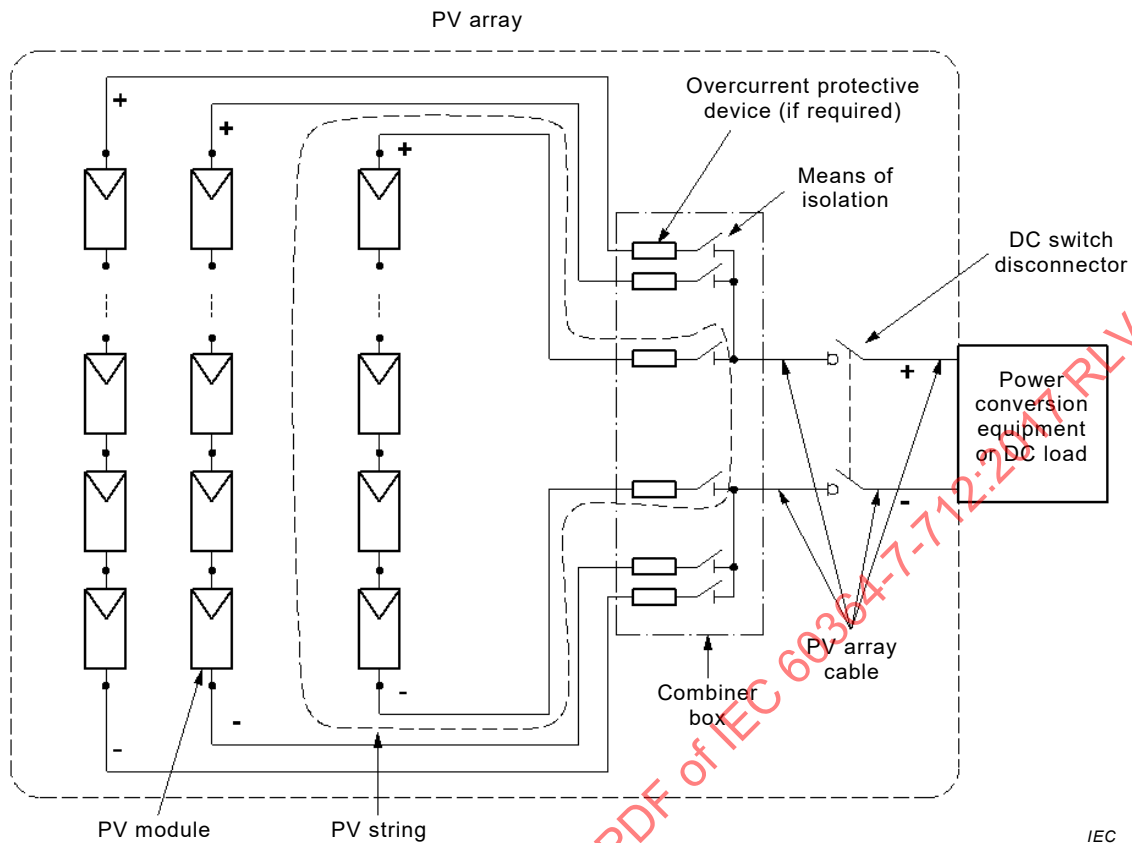


Figure A.712.2 – Parallel connected multi-string PV array

The following types of application circuit are considered:

- PV array is connected to AC loads via a PCE with a transformer inside the PCE;
- PV array is connected to AC loads via a PCE with a transformer outside of the PCE;
- PV array is connected to AC loads via a PCE without a transformer.

In Table A.712.1, several configurations are considered. No consideration is given to earthing of exposed conductive parts.

Table A.712.1 – PV DC configurations

DC/DC side	Figures	Application circuit	Consequence on the status of the PV array
Unearthed	Figure A.712.3	AC side connected via a PCE with a transformer inside of the PCE	Floating
	Figure A.712.4	AC side connected via a PCE without a transformer	Fixed by the status of the neutral or a line conductor of the supply circuit
Earthed	Figure A.712.5	AC side connected via a PCE with a transformer inside of the PCE	Fixed to earth
	Figure A.712.6	AC side connected via a PCE without a transformer inside of the PCE but a transformer outside of the PCE	Fixed to earth

The following Figures A.712.3 to A.712.6 illustrate the arrangements listed in Table A.712.1:

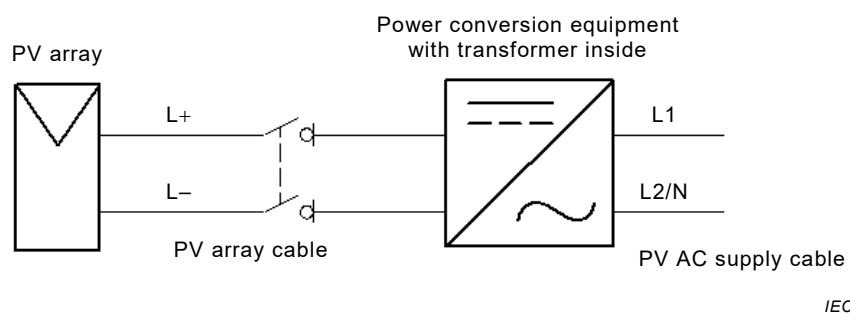


Figure A.712.3 – Unearthed PV array connected to the AC side via a PCE with transformer

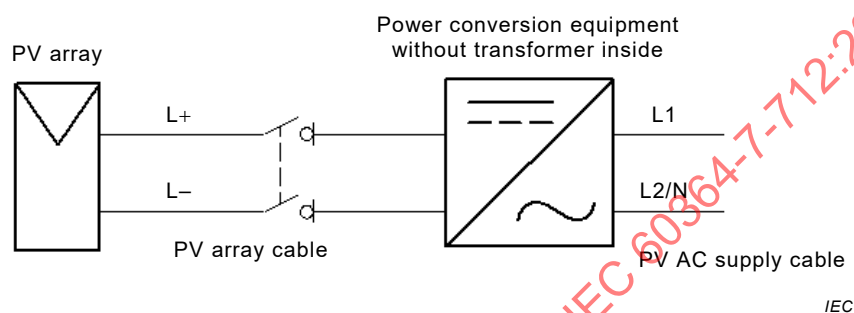


Figure A.712.4 – Unearthed PV array connected to the AC side via a PCE without a transformer

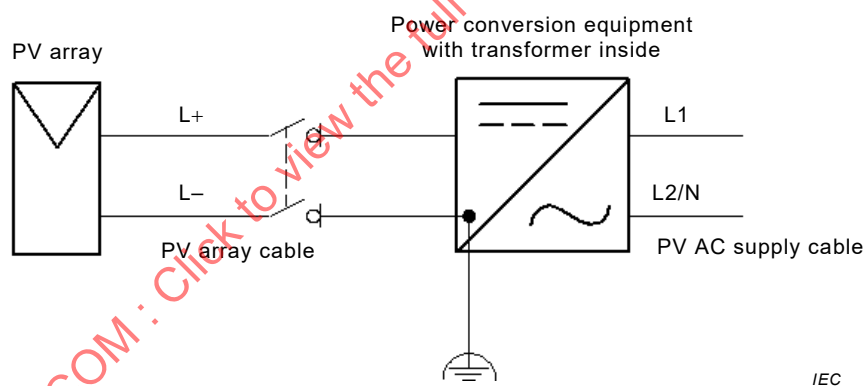


Figure A.721.5 – Earthed PV array connected to the AC side via a PCE with transformer

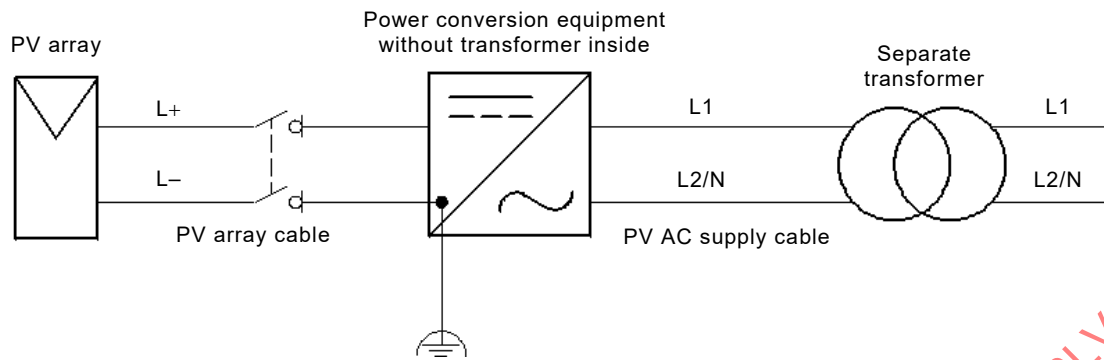


Figure A.712.6 –Earthed PV array connected to the AC side via a PCE without a transformer, the transformer being separate

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Annex B (normative)

Calculation of $U_{OC\ MAX}$ and $I_{SC\ MAX}$

B.1 Calculation of $U_{OC\ MAX}$

$U_{OC\ MAX}$ is the maximum voltage across an unloaded (open circuit) PV module or PV string or PV array, calculated by the following formula:

$$U_{OC\ MAX} = K_U U_{OC\ STC}$$

The correction factor K_U takes into account the increase of open circuit voltage of modules, considering T_{min} the lowest ambient temperature of the PV installation site and αU_{OC} the temperature variation coefficient of U_{OC} voltage provided by the PV module manufacturer:

$$K_U = 1 + (\alpha U_{OC} / 100) (T_{min} - 25)$$

where

αU_{OC} is the temperature variation coefficient of U_{OC} module voltage, in $\%/^{\circ}\text{C}$;

T_{min} is the lowest temperature of the PV installation site, in $^{\circ}\text{C}$.

αU_{OC} is a negative factor, which can be provided by the module manufacturer either in $\text{mV}/^{\circ}\text{C}$ or in $\%/^{\circ}\text{C}$. When αU_{OC} is expressed in $\text{mV}/^{\circ}\text{C}$, work it out in $\%/^{\circ}\text{C}$ by using the formula:

$$\alpha U_{OC} (\%/^{\circ}\text{C}) = 0,1 \alpha U_{OC} (\text{mV}/^{\circ}\text{C}) / U_{OC\ STC_Module} (\text{V})$$

NOTE Example of module with αU_{OC} expressed in $\text{mV}/^{\circ}\text{C}$. The following calculation is an example:

- Multicrystalline module, $U_{OC\ STC_Module} = 38,3\ \text{V}$ and $\alpha U_{OC} = -133\ \text{mV}/^{\circ}\text{C}$
 $\rightarrow \alpha U_{OC} = -0,35\ \%/^{\circ}\text{C}$
- $T_{min} = -15\ ^{\circ}\text{C} \rightarrow (T - 25) = -40\ ^{\circ}\text{C} \rightarrow K_U = 1,14 \rightarrow U_{OC\ MAX} = 1,14 U_{OC\ STC}$
 $\rightarrow U_{OC\ MAX} = 1,14 \times 38,3 = 43,7\ \text{V}$

αU_{OC} can have very different values depending on the technology of PV modules.

For amorphous silicon modules, electrical characteristics during the first weeks of operation are higher than the specified characteristics. This phenomenon is indicated by the module manufacturer and has to be considered in the calculation of $U_{OC\ MAX}$.

Without information of the expected minimum temperature of the site or without information about the temperature coefficient of the PV module, $U_{OC\ MAX}$ shall be chosen equal to $1,2 U_{OC\ STC}$.

B.2 Calculation of $I_{SC\ MAX}$

The maximum short-circuit current of a PV module or PV string or PV array is calculated by the following formula:

$$I_{SC\ MAX} = K_I I_{SC\ STC}$$

Minimum value for K_I is 1,25.

Under certain conditions, K_f shall be increased to take into account environmental situations, for example increased reflection or solar intensity.

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Annex C (informative)

Examples of signs

Annex C provides examples (see Figures C.712.1 and C.712.2) of appropriate signs as specified in 712.514.102 to 712.514.106.



**Figure C.712.1 – Example of sign required on
PV array combiner boxes (712.514.102)**

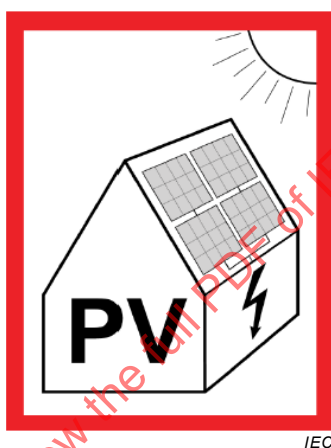


**Figure C.712.2 – Example of switchboard
sign for identification of PV on a building**

The sign should comply with the local fire services information requirements.

National committees or national regulations should decide on the labels and locations of such markings.

Annex D (informative)

Blocking diode

D.1 General

Annex D describes blocking diodes intended to be used to prevent reverse current in a PV array.

D.2 Use of blocking diodes to prevent overcurrent/fault current in arrays

A blocking diode is an effective means of stopping reverse current in PV arrays. Overcurrent/fault current in arrays is generally caused by current flowing from one section of an array operating normally into a section of an array containing a fault. The fault current is in the reverse direction. Provided correctly rated and functioning blocking diodes are in use in the PV array, reverse currents are prevented and fault currents either eliminated or significantly reduced (see examples in Figure D.712.3).

In some countries blocking diodes are allowed to replace overcurrent protective devices. This is an effective method of overcurrent/fault prevention provided the reliability of blocking diodes over time can be ensured.

D.3 Some considerations relating to short-circuit

D.3.1 Short-circuit in PV string

If a short-circuit develops in a string without blocking diodes as shown in Figure D.712.1 a), a fault current will flow around the faulted modules and extra fault current in the reverse direction will flow in some modules with the source of that current being from other strings. The reverse current can be interrupted by an overcurrent protective device provided the current is greater than the interrupting current of the overcurrent device. This may not be the case under low illumination conditions.

The situation of the same fault with an array with blocking diodes in each string is shown in Figure D.712.1 b). The fault current around the faulted modules cannot be intercepted with the blocking diode, however, the amount of fault current can be significantly reduced by the blocking diode obstructing the reverse current supplied from other strings as shown in Figure D.712.1 b). This functionality for this type of fault is useful for all PV installations whether the PV array is earthed or not and whether the PCE is a separated PCE or not.

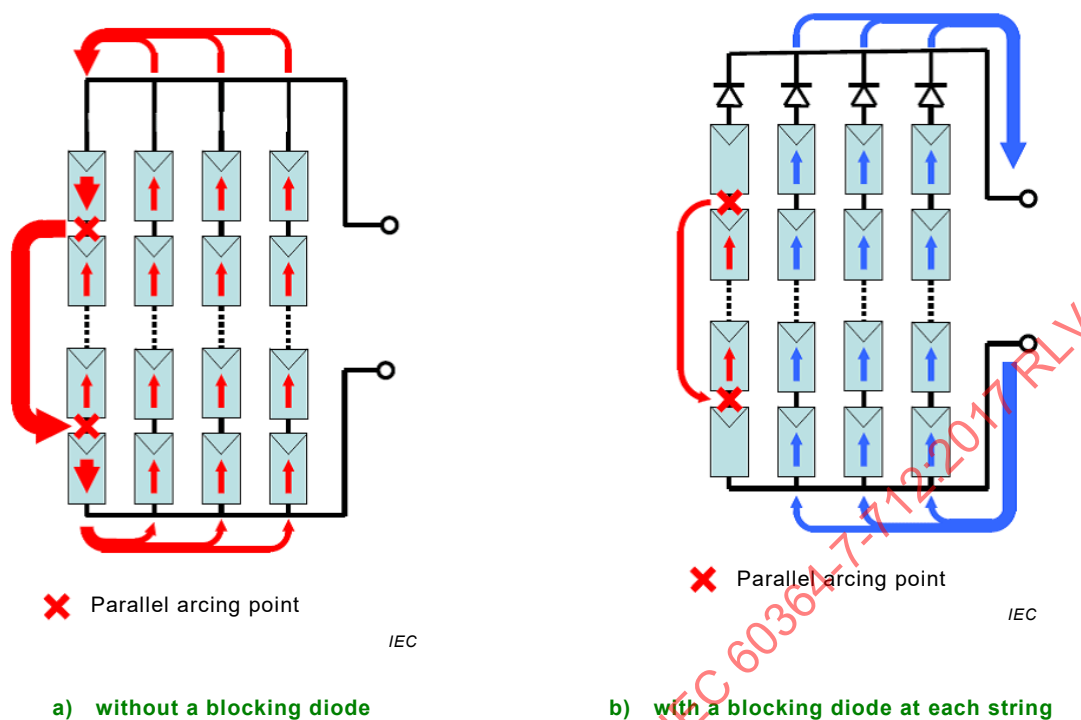


Figure D.712.1 – Effect of blocking diode at short circuit in PV string

D.3.2 Insulation fault in PV string for the array with a functional earth

Figure D.712.2 shows the fault current paths when an insulation fault occurs in a string of a PV array which is installed with a negative side functional earth. The worst case fault occurs when the fault is closest to the top of the string (i.e. the side furthest away from earth). In this case the blocking diodes need to be installed in the positive side of the strings.

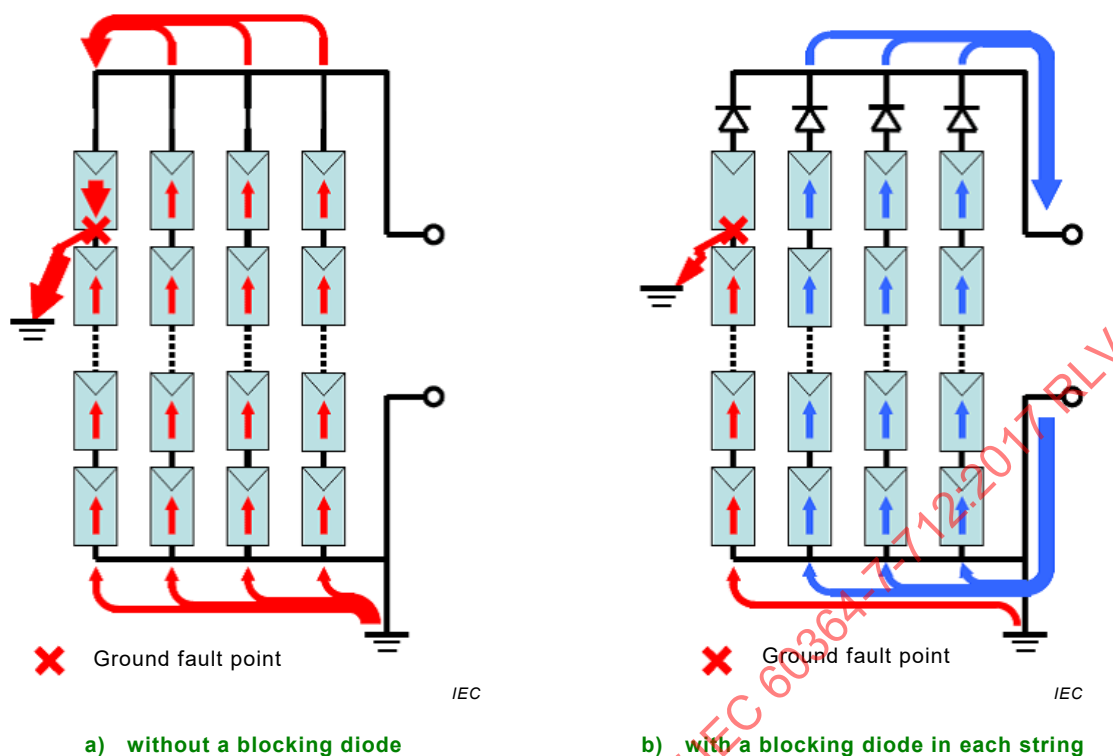


Figure D.712.2 – Effect of blocking diode where there is an insulation fault on a PV installation with earthing on the DC negative side

Figure D.712.3 shows the fault current paths when an insulation fault occurs in a string of a PV array which is installed with a positive side functional earth. The worst case fault occurs when the fault is closest to the bottom of the string (i.e. the side furthest away from earth). In this case the blocking diodes need to be installed in the negative side of the strings.

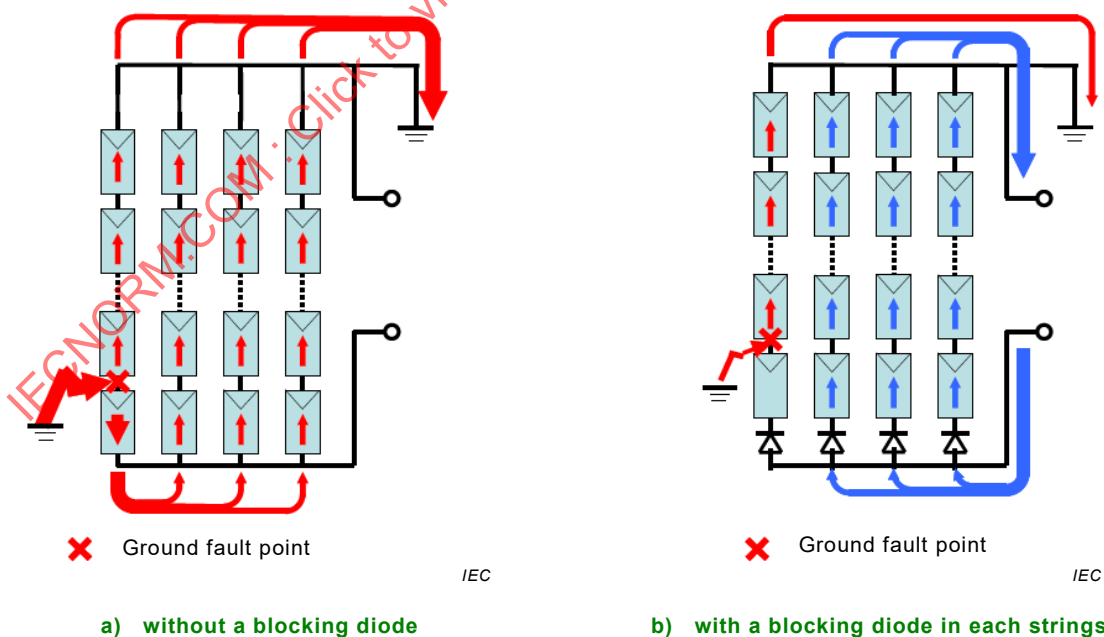


Figure D.712.3 – Effect of blocking diode where there is a fault on a PV installation with earthing on the DC positive side

In these cases Figure D.712.2 and Figure D.712.3 clearly show the advantage of a blocking diode in eliminating the fault current contribution from adjacent strings of the array. This diagram shows the situation of a directly earthed array with no impedance in the earth connection. It is preferred in this document to install functional earths with limiting resistors in the earth connection. If this method is used the potential fault current under these conditions is significantly reduced by the effect of the resistance limiting the maximum current.

D.4 Specification of blocking diode

See 712.55.102.

D.5 Heat dissipation design for blocking diode

Because the voltage drop of the blocking diode in the forward current operation might exceed 1 V, it is necessary to consider a heat dissipation design of diode for reliability. A heatsink may be required to keep diode junction temperatures within safe limits. A heat dissipation design methodology is shown in the following procedures:

- Calculate maximum current I_{MAX} by PV module current $I_{SC\ MOD}$ in STC.
 $I_{MAX} = 1,4 \times I_{SC\ MOD}$ (Use a higher factor depending on operating conditions)
- Obtain the operating forward voltage of the blocking diode V_{D_OP} at I_{MAX} from the operating characteristics of the diode.
- Calculate power dissipation P_{CAL}
 $P_{CAL} = V_{D_OP} \times I_{MAX}$
- Calculate the thermal resistance R_{TH} according to the following expression so that the junction temperature T_J of the blocking diode should not exceed the limit value in consideration of ambient temperature T_{AMB} .
 $R_{TH} = (T_J - T_{AMB}) / P_{CAL}$
- If the thermal resistance required is less than the diode's junction to case plus case to air thermal resistance, then a heatsink will be required.

When there is a possibility of increased short-circuit current of the PV module, for example due to the reflection of snow or other conditions, the multiplier for the calculation of I_{MAX} should be larger than 1,4.

Annex E (informative)

Arc fault detection and interruption in PV arrays

Unlike traditional electrical products, PV modules and wiring do not have an overall enclosure to contain arcs and fires resulting from component or wiring faults. Many PV installations operate at DC voltages which are very capable of sustaining DC arcs.

There are three main categories of arcs in PV installations (refer to Figure E.712.1).

- series arc which may result from a faulty connection or a series break in wiring;
- a parallel arc which may result as a partial short circuit between adjacent wiring which is at different potentials;
- arcs to earth which result from failure of insulation.

If an arc develops due to a fault in a PV array this can result in significant damage to the array and may also result in damage to adjacent wiring and building structures. The most serious arc is likely to be a parallel arc because of the energy that is available to feed this type of arc, especially when the arc is between the main PV array conductors. This document requires cables in PV array wiring to be suitable to be used with Class II equipment, and because of this requirement parallel arcs are very unlikely, unless caused as a result of significant insulation damage due to fire damage or severe mechanical damage to cables.

The most likely type of arc to occur in a PV installation is a series arc. This is because PV installations typically contain a very large number of series connections. Series arcs are generally able to be stopped quickly by removing the electrical load from the PV array. In the case of grid connected PV installations this can be accomplished easily by shutting down the PCE. Parallel arcs are much more difficult to extinguish but are also much less likely to occur.

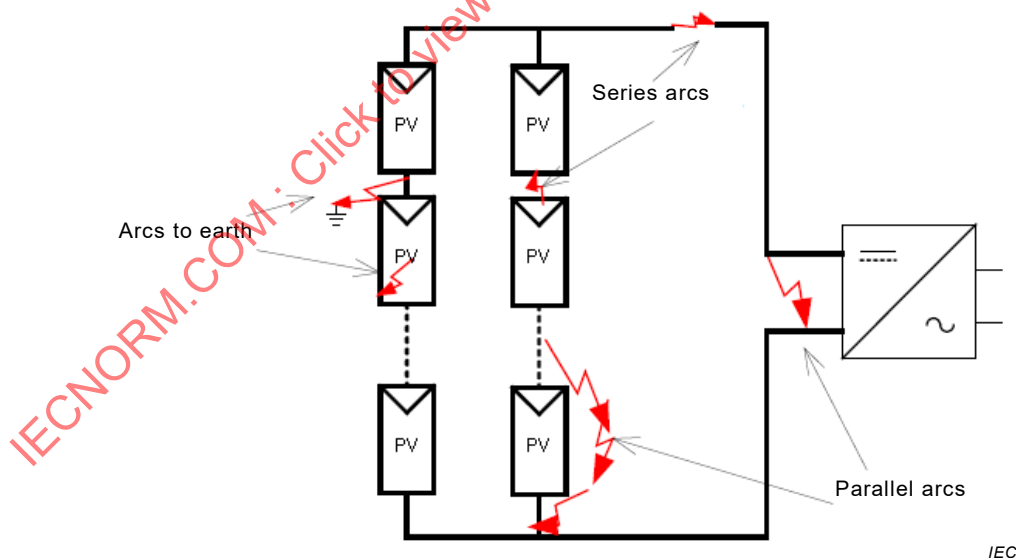


Figure E.712.1 – Examples of types of arcs in PV arrays

If a series arc is not extinguished quickly it may propagate to involve other conductors and produce parallel arcs. It is therefore desirable to have a method of detecting and interrupting arcs in PV installations quickly. A new standard has been developed by Underwriters Laboratories – UL1699B “Photovoltaic (PV) DC Arc-Fault Circuit Protection” and manufacturers are in the process of developing equipment to meet this standard. The purpose of the arc-fault circuit protection equipment is to detect and discriminate accurately arcs in PV arrays and to take action to interrupt the arc.

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Annex F
(informative)

List of notes concerning certain countries

Country	Subclause N°	Nature (permanent or less permanent according to IEC Directives)	Rationale (detailed justification for the requested country note)	Wording
AT	712.414.101			In Austria, due the “particular characteristics of PV installations”, as stated in the scope of this document and the fact, that such equipment is as well used by ordinary persons only a limit of 35 V is acceptable.
AT	712.521.101.1			In Austria, halogen free low smoke DC cables are required when those cables are routed inside buildings.
NO	712.536.2			In Norway, where double or reinforced insulation is used as protective measure for protection against electric shock on the DC side, means of isolation shall be provided between sections of PV modules limiting the $U_{OC\ MAX}$ of the section to 120 V DC.
CH	712.542.103			In Switzerland, in buildings with a LPS the minimum cross section of copper is 10 mm ² .

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IEC 60364-7-712:2002, *Electrical installations of buildings – 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 <http://www.graphical-symbols.info/equipment>)

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

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

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

IEC 61008-1, *Residual current operated circuit-breakers without integral overcurrent protection for household and similar uses (RCCBs) – Part 1: General rules*

IEC 61277, *Terrestrial photovoltaic (PV) power generating systems – General and guide²*

IEC 61557-2, *Electrical safety in low voltage distribution systems up to 1 000 V a.c. and 1 500 V d.c. – Equipment for testing, measuring or monitoring of protective measures – Part 2: Insulation resistance*

IEC 61557-9, *Electrical safety in low voltage distribution systems up to 1 000 V a.c. and 1 500 V d.c. – Equipment for testing, measuring or monitoring of protective measures – Part 9: Equipment for insulation fault location in IT systems*

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

IEC 61829, *Photovoltaic (PV) array – On-site measurement of current-voltage characteristics*

² Withdrawn.

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

IEC 62246-1, *Reed switches – Part 1: Generic specification*

IEC 62305 (all parts), *Protection against lightning*

IEC 62305-2:2010, *Protection against lightning – Part 2: Risk management*

IEC 62305-4, *Protection against lightning – Part 4: Electrical and electronic systems within structures*

IEC 62930, *Electric cables for photovoltaic systems*³

UL1699B, *Photovoltaic (PV) DC Arc-Fault Circuit Protection*

³ Under preparation. Stage at the time of publication: IEC CCDV 62930:2016.

INTERNATIONAL STANDARD

NORME INTERNATIONALE



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

**Installations électriques basse tension –
Partie 7-712: Exigences applicables aux installations ou emplacements
spéciaux – Installations d'énergie solaire photovoltaïque (PV)**

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

LOW VOLTAGE ELECTRICAL INSTALLATIONS –

**Part 7-712: Requirements for special installations or locations –
Solar photovoltaic (PV) power supply systems**

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 60364-7-712 has been prepared by IEC technical committee 64: Electrical installations and protection against electric shock.

This second edition cancels and replaces the first edition, published in 2002. This edition constitutes a technical revision.

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

- a) The technical content has been extensively revised and expanded, taking into account experience gained in the construction and operation of PV installations, and developments made in technology, since the first edition of this standard was published.

The text of this standard is based on the following documents:

FDIS	Report on voting
64/2154/FDIS	64/2163/RVD

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

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

Attention is drawn to the co-existence of IEC 60364-7-712 and IEC 62548 standards. Both standards have been developed in close coordination by different technical committees.

A list of all parts in the IEC 60364 series, published under the general title *Low voltage electrical installations*, can be found on the IEC website.

The reader's attention is drawn to the fact that Annex F lists all of the “in-some-country” clauses on differing practices of a less permanent nature relating to the subject of this standard.

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

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

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

INTRODUCTION

For the purpose of this part of IEC 60364 (IEC 60364-7-712), the requirements of the general parts 1 to 6 of IEC 60364 apply.

The IEC 60364-7-7XX parts of IEC 60364 contain particular requirements for special installations or locations which are based on the requirements of the general parts of IEC 60364 (IEC 60364-1 to IEC 60364-6). These IEC 60364-7-7XX parts are considered in conjunction with the requirements of the general parts.

The particular requirements of this part of IEC 60364 supplement, modify or replace certain of the requirements of the general parts of IEC 60364 being valid at the time of publication of this part. The absence of reference to the exclusion of a part or a clause of a general part means that the corresponding clauses of the general part are applicable (undated reference).

Requirements of other 7XX parts being relevant for installations covered by this part also apply. This part may therefore also supplement, modify or replace certain of these requirements valid at the time of publication of this part.

The clause numbering of this part follows the pattern and corresponding references of IEC 60364. The numbers following the particular number of this part are those of the corresponding parts, or clauses of the other parts of the IEC 60364 series, valid at the time of publication of this part, as indicated in the normative references of this document (dated reference). If requirements or explanations additional to those of the other parts of the IEC 60364 series are needed, the numbering of such items appears as 712.101, 712.102, 712.103, etc.

Numbering of figures and tables takes the number of this part followed by a sequential number. For annexes, the numbering of figures and tables takes the letter of the annex, the number of the part and a sequential number.

In the case where new or amended general parts with modified numbering were published after this part was issued, the clause numbers referring to a general part in this 712 part may no longer align with the latest edition of the general part. Dated references should be observed.

LOW VOLTAGE ELECTRICAL INSTALLATIONS –

Part 7-712: Requirements for special installations or locations – Solar photovoltaic (PV) power supply systems

712 Solar photovoltaic (PV) power supply installations

NOTE The abbreviation “PV” is used for “Photovoltaic”. Photovoltaic installations are, hereafter, known as PV installations.

712.1 Scope

This part of IEC 60364 applies to the electrical installation of PV systems intended to supply all or part of an installation.

The equipment of a PV installation, like any other item of equipment, is dealt with only so far as its selection and application in the installation is concerned.

A PV installation starts from a PV module or a set of PV modules connected in series with their cables, provided by the PV module manufacturer, up to the user installation or the utility supply point (point of common coupling).

Requirements of this document apply to

- PV installations not connected to a system for distribution of electricity to the public,
- PV installations in parallel with a system for distribution of electricity to the public,
- PV installations as an alternative to a system for distribution of electricity to the public,
- appropriate combinations of the above.

This document does not cover the specific installation requirements for batteries or other energy storage methods.

NOTE 1 Additional requirements for PV installations with battery storage capabilities on the DC side are under consideration.

NOTE 2 This document does cover the protection requirements of PV arrays which develop as a result of the use of batteries in PV installations.

For systems using DC-DC converters, additional requirements regarding voltage and current rating, switching, and protective devices can apply. These requirements are under consideration.

The object of this document is to address the design safety requirements arising from the particular characteristics of PV installations. DC systems, and PV arrays in particular, pose some hazards in addition to those derived from conventional AC power installations, including the ability to produce and sustain electrical arcs with currents that are not greater than normal operating currents.

In grid connected PV installations the safety requirements of this document are, however, critically dependent on the PCE associated with PV arrays complying with the requirements of IEC 62109-1 and IEC 62109-2.

712.2 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 60228, *Conductors of insulated cables*

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

IEC 60332-1-2, *Tests on electric and optical fibre cables under fire conditions – Part 1-2: Test for vertical flame propagation for a single insulated wire or cable – Procedure for 1 kW pre-mixed flame*

IEC 60364 (all parts), *Low-voltage electrical installations*

IEC 60364-4-41:2005, *Low-voltage electrical installations – Part 4-41: Protection for safety – Protection against electric shock*

IEC 60364-4-43, *Low-voltage electrical installations – Part 4-43: Protection for safety – Protection against overcurrent*

IEC 60364-4-44, *Low-voltage electrical installations – Part 4-44: Protection for safety – Protection against voltage disturbances and electromagnetic disturbances*

IEC 60670 (all parts), *Boxes and enclosures for electrical accessories for household and similar fixed electrical installations*

IEC 60898 (all parts), *Electrical accessories – Circuit-breakers for overcurrent protection for household and similar installations*

IEC 60898-2, *Circuit-breakers for overcurrent protection for household and similar installations – Part 2: Circuit-breakers for a.c. and d.c. operation*

IEC 60947 (all parts), *Low-voltage switchgear and controlgear*

IEC 60947-1, *Low-voltage switchgear and controlgear – Part 1: General rules*

IEC 60947-2, *Low-voltage switchgear and controlgear – Part 2: Circuit breakers*

IEC 60947-3, *Low-voltage switchgear and controlgear – Part 3: Switches, disconnectors, switch-disconnectors and fuse-combination units*

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 61439 (all parts), *Low-voltage switchgear and controlgear assemblies*

IEC 61439-2, *Low-voltage switchgear and controlgear assemblies – Part 2: Power switchgear and controlgear assemblies*

IEC 61557-8:2014, *Electrical safety in low voltage distribution systems up to 1 000 V a.c. and 1 500 V d.c. – Equipment for testing, measuring or monitoring of protective measures – Part 8: Insulation monitoring devices for IT systems*

IEC 62109 (all parts), *Safety of power converters for use in photovoltaic power systems*

IEC 62109-1:2010, *Safety of power converters for use in photovoltaic power systems – Part 1: General requirements*

IEC 62109-2, *Safety of power converters for use in photovoltaic power systems – Part 2: Particular requirements for inverters*

IEC 62262, *Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK code)*

IEC 62423, *Type F and type B residual current operated circuit-breakers with and without integral overcurrent protection for household and similar uses*

IEC 62446-1, *Photovoltaic (PV) systems – Requirements for testing, documentation and maintenance – Part 1: Grid connected systems – Documentation, commissioning tests and inspection*

IEC 62852:2014, *Connectors for DC-application in photovoltaic systems – Safety requirements and tests*

712.3 Terms and definitions

For the purposes of this document, the following terms and definitions 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>

712.3.1

PV cell

photovoltaic cell

solar cell

solar photovoltaic cell

most elementary device that exhibits the photovoltaic effect, i.e the direct non-thermal conversion of radiant energy into electrical energy

Note 1 to entry: The preferred term is "solar photovoltaic cell" or "photovoltaic cell", colloquially referred to as a "solar cell".

[SOURCE: IEC 61836:2007, 3.1.43 a), modified — "that exhibits ... electrical energy" has been added]

712.3.2

PV module

smallest complete environmentally protected assembly of interconnected cells

Note 1 to entry: See IEC 60904-3.

712.3.3

PV string

circuit of one or more series-connected modules

[SOURCE: IEC 61836:2007, modified – "or one or more" has been added]

712.3.4

PV array

assembly of electrically interconnected PV modules, PV strings or PV sub-arrays

Note 1 to entry: For the purposes of this document a PV array is all components up to the DC input terminals of an inverter or DC loads. A PV array does not include its foundation, tracking apparatus, thermal control, and other such components.

Note 2 to entry: A PV array may consist of a single PV module, a single PV string, or several parallel-connected strings, or several parallel-connected PV sub-arrays and their associated electrical components (see Figure 712.2 to Figure 712.4). For the purposes of this document the boundary of a PV array is the output side of the PV array disconnecting device.

712.3.5

PV sub-array

electrical subset of a PV array formed of parallel connected PV modules or PV strings

712.3.6

PV string cable

cable interconnecting the modules in a PV string, or connecting the string to a combiner box, PCE or other DC loads

Note 1 to entry: Examples of PV string cable are shown in Figure 712.3 and Figure 712.4.

712.3.7

PV array cable

cable of a PV array that carries the total output current of the array

712.3.8

PV AC supply cable

cable connecting the AC terminals of the PV PCE to a distribution board of the electrical installation

712.3.9

PV AC supply circuit

circuit connecting the AC terminals of the PV PCE to a distribution board of the electrical installation

712.3.10

PV AC module

integrated module/PCE assembly where the electrical interface terminals are alternating current only and where no access is provided to the DC side

712.3.11

PV installation

erected equipment of a PV power supply installation

712.3.12

standard test conditions

STC

standard set of reference conditions used for the testing and rating of photovoltaic cells and modules as given in the relevant product standard for example IEC 61215

Note 1 to entry: The standard test conditions given in IEC 61215 for PV modules are:

- PV cell temperature of 25 °C;
- irradiance in the plane of the PV cell or module of 1 000 W/m²;
- light spectrum corresponding to an atmospheric air mass of 1,5.

Note 2 to entry: This note applies to the French language only.

712.3.13

open-circuit voltage under standard test conditions

$U_{OC\ STC}$

voltage under standard test conditions across an unloaded (open) PV module, PV string, or PV array, or on the DC side of the PV PCE

712.3.14

open-circuit maximum voltage

$U_{OC\ MAX}$

maximum voltage across an unloaded (open) PV module, PV string, or PV array, or on the DC side of the PV PCE

Note 1 to entry: The method for determining $U_{OC\ MAX}$ is given in Annex B.

712.3.15

short-circuit current under standard test conditions

$I_{SC\ STC}$

short-circuit current of a PV module, PV string, or PV array under standard test conditions

712.3.16

short-circuit maximum current

$I_{SC\ MAX}$

maximum short-circuit current of a PV module, PV string or PV array

Note 1 to entry: The method for determining $I_{SC\ MAX}$ is given in Annex B.

712.3.17

backfeed current

maximum current that can pass from PCE to the PV array and its wiring under normal or single fault conditions

712.3.18

reverse current

current that can backfeed into a PV circuit from parallel connected strings or sub-arrays as the result of a fault, for example a short-circuit in the affected circuit

712.3.19

short-circuit current rating

I_{SCPV}

maximum prospective short-circuit current from the PV array for which the SPD, in conjunction with the disconnectors specified, is rated

712.3.20

DC side

part of a PV installation from the PV modules to the DC terminals of the PV PCE

712.3.21

AC side

part of a PV installation from the AC terminals of the PV PCE to the point of connection of the PV supply cable to the electrical installation

712.3.22

maximum power point tracking

MPPT

control strategy whereby PV array operation is always at or near the point on a PV device's current-voltage characteristic where the product of electric current and voltage yields the maximum electrical power under specified operating conditions

Note 1 to entry: This note applies to the French language only.

712.3.23

$I_{MOD_MAX_OCPR}$

PV module maximum overcurrent protection rating

Note 1 to entry: See IEC 61730-2.

712.3.24

blocking diode

diode connected in series with module(s), strings and sub-array(s) to block reverse current

712.3.25

bypass diode

diode connected across one or more cells in the forward current direction

Note 1 to entry: The purpose is to allow the module current to bypass shaded or broken cells to prevent hot spot or hot cell damage resulting from the reverse voltage biasing from the other cells in that module.

712.3.26

functional earthing

FE

earthing a point or points in a system or in an installation or in equipment for purposes other than electrical safety

Note 1 to entry: Such a system is not considered to be an earthed array.

Note 2 to entry: Examples of functional array earthing include earthing one conductor through an impedance, or only temporarily earthing the array for functional or performance reasons.

Note 3 to entry: In a PCE intended for an array not connected to a functional earth that uses a resistive measurement network to measure the array impedance to earth, that measurement network is not considered a form of functional earth.

Note 4 to entry: This note applies to the French language only.

[SOURCE: IEC 60050-826:2004, 826-13-10, modified – the notes have been added]

712.3.27

irradiance

G

electromagnetic radiated solar power per unit of area

Note 1 to entry: Irradiance is expressed in W/m^2 .

[SOURCE: IEC 61836:2007, 3.6.25 modified – the note and sub-entries have been deleted]

712.3.28

$I_{SC\ ARRAY}$

short-circuit current of the PV array at standard test conditions

712.3.29

$I_{SC\ MOD}$

short-circuit current of a PV module or PV string at standard test conditions (STC), as specified by the manufacturer in the product specification plate

Note 1 to entry: As PV strings are a group of PV modules connected in series, the short-circuit current of a string is equal to $I_{SC\ MOD}$.

712.3.30

$I_{SC\ S-ARRAY}$

short-circuit current of a PV sub-array at standard test conditions (STC)

712.3.31

power conversion equipment

PCE

system that converts the electrical power delivered by the PV array into the appropriate frequency and/or voltage values to be delivered to the load, or stored in a battery or injected into the electricity grid

SEE: Figure 712.2 to Figure 712.4.

Note 1 to entry: This note applies to the French language only.

712.3.32

inverter

PCE which converts DC voltage and DC current of the PV array into AC voltage and AC current

Note 1 to entry: This note applies to the French language only.

712.3.33

isolated PCE

PCE with at least simple separation between the main power output circuits and PV circuits

Note 1 to entry: The simple separation may be either integral to the PCE or provided externally, for example a PCE with an external isolating transformer.

Note 2 to entry: In a PCE with more than two external circuits, there may be isolation between some pairs of circuits and no isolation between others. For example, an inverter with PV, battery, and mains circuits may provide isolation between the mains circuit and the PV circuit, but no isolation between the PV and battery circuits.

712.3.34

non-isolated PCE

PCE without the minimum separation between the main power output and PV circuits or with leakage currents greater than the requirements for an isolated PCE

712.3.35

PV array combiner box

enclosure where PV sub-arrays are connected and which may also contain overcurrent protection and/or switch-disconnection devices

Note 1 to entry: Small arrays generally do not contain sub-arrays but are simply made up of strings, whereas large arrays are generally made up of multiple sub-arrays.

712.3.36

PV string combiner box

enclosure where PV strings are connected which may also contain overcurrent protective devices and/or switch-disconnectors

712.3.37

PV sub-array cable

output cable of a PV sub-array that carries the output current of its associated sub-array

712.3.38

U_{OC} ARRAY

open-circuit voltage at standard test conditions of a PV array

712.3.39

V_{OC} MOD

open circuit voltage of a PV module at standard test conditions, as specified by the manufacturer in the product specification

712.31 Purposes, supplies and structure

712.31.101 PV array configuration

712.31.101.1 General

PV arrays are used to supply power to an application circuit.

Figure 712.1 illustrates the general functional configuration of a PV installation.

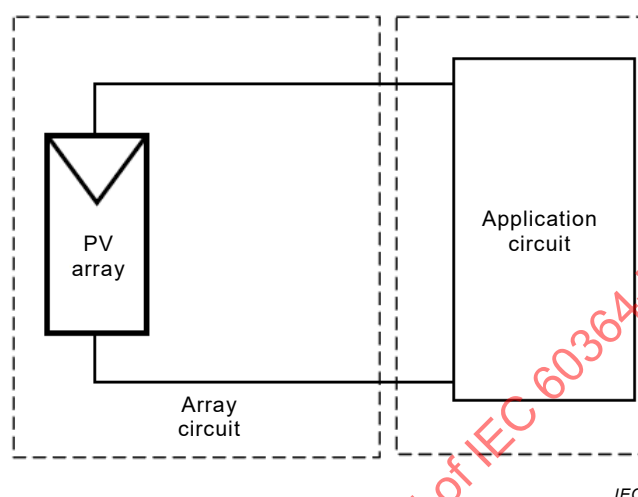


Figure 712.1 – General functional configuration of a PV installation

Three kinds of application circuit are considered:

- PV array is connected to DC loads;
- PV array is connected to AC installation via a PCE which includes at least simple separation;
- PV array is connected to AC installation via a PCE which does not include simple separation.

712.31.101.1.1 PV installation architectures

The relation of a PV array to earth is determined by whether any earthing of the array for functional reasons is in use, the impedance of the earthing connection and also by the earth status of the application circuit (e.g. PCE or other equipment) to which it is connected. This and the location of the earth connection all affect safety for the PV array (refer to Annex A).

The requirements of manufacturers of PV modules and manufacturers of the PCE to which the PV array is connected shall be taken into account in determining the most appropriate system earthing arrangement.

Protective earthing of any of the conductors of the PV array is not permitted. Earthing of one of the conductors of the PV array for functional reasons is not allowed unless there is at least simple separation from mains earth provided either internally in the PCE or externally via a separate transformer.

If the simple separation is provided externally there shall be no other equipment connected to the same circuit as the PCE.

NOTE A DC current-carrying conductor that is connected to earth is considered to be a live conductor.

712.31.101.1.2 Array electrical diagrams

The diagrams in Figure 712.2 to Figure 712.4 show the basic electrical configurations of single-string, multiple parallel-string and multi-sub-array PV respectively.

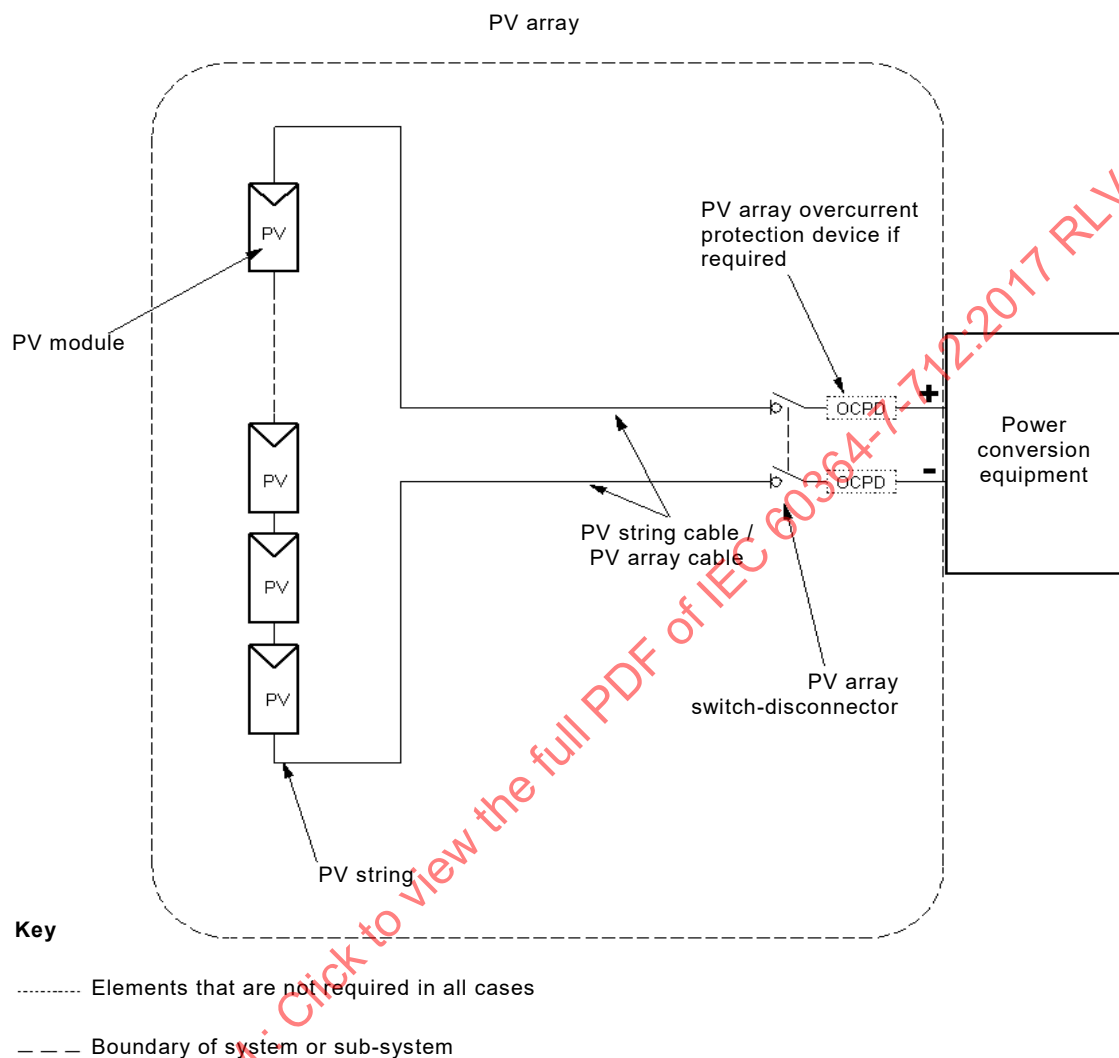


Figure 712.2 – PV array diagram – single string case

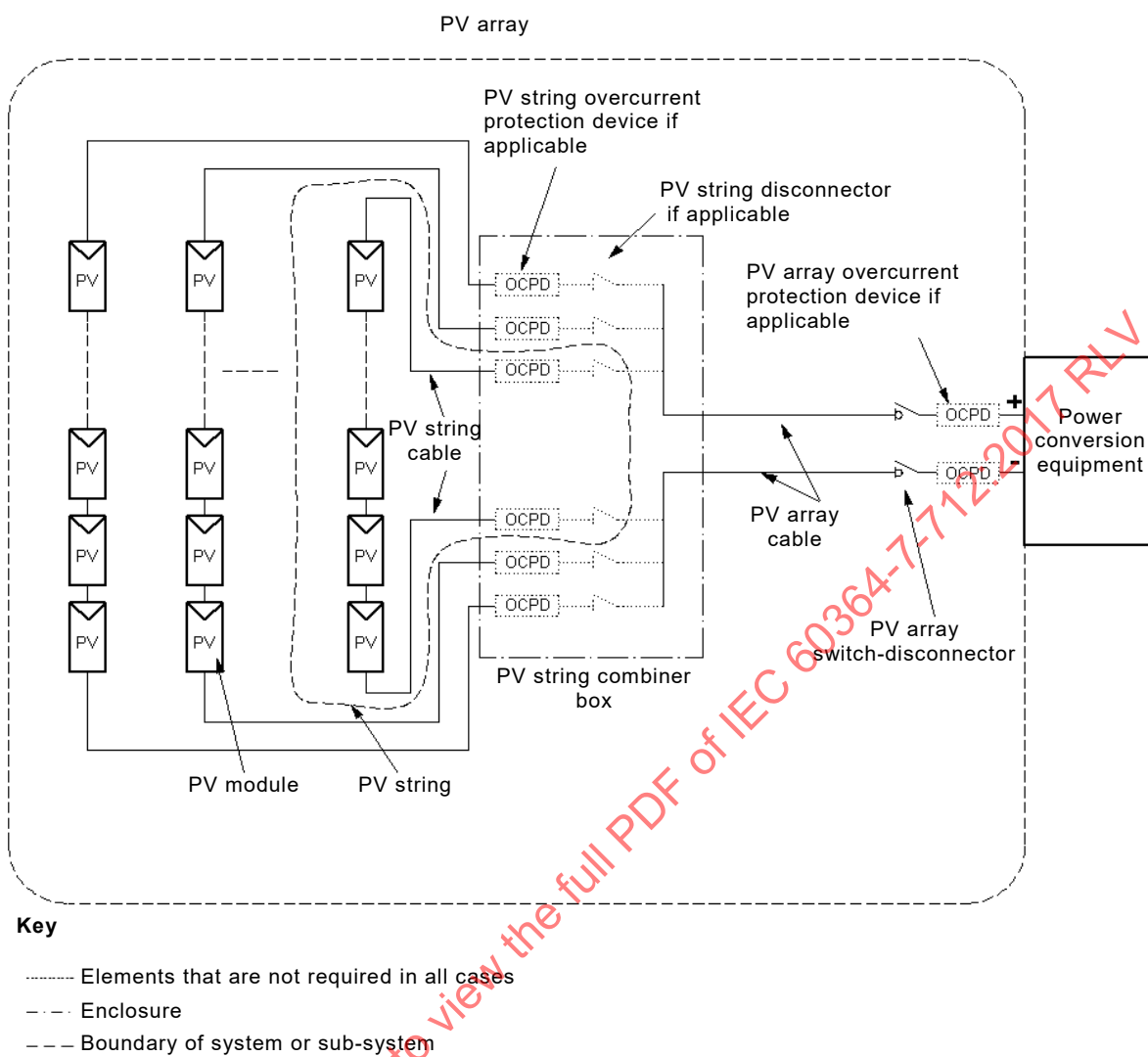


Figure 712.3 – PV array diagram – multiple parallel string case

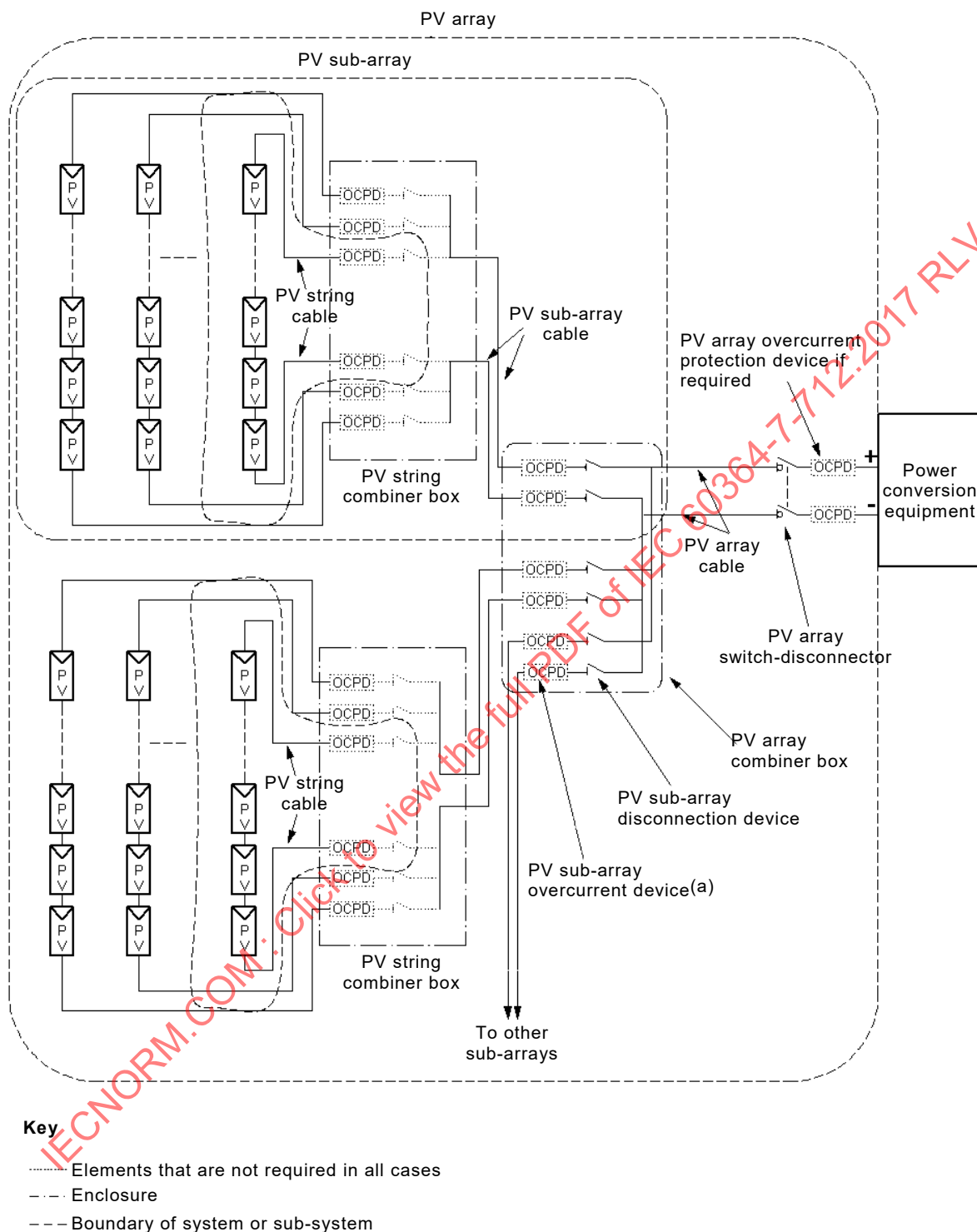


Figure 712.4 – PV array diagram – multiple parallel string case with array divided into subarrays

In Figures 712.2, 712.3 and 712.4, components drawn in dotted format are not needed in all cases. The figures indicate the location in the circuit when they are needed.

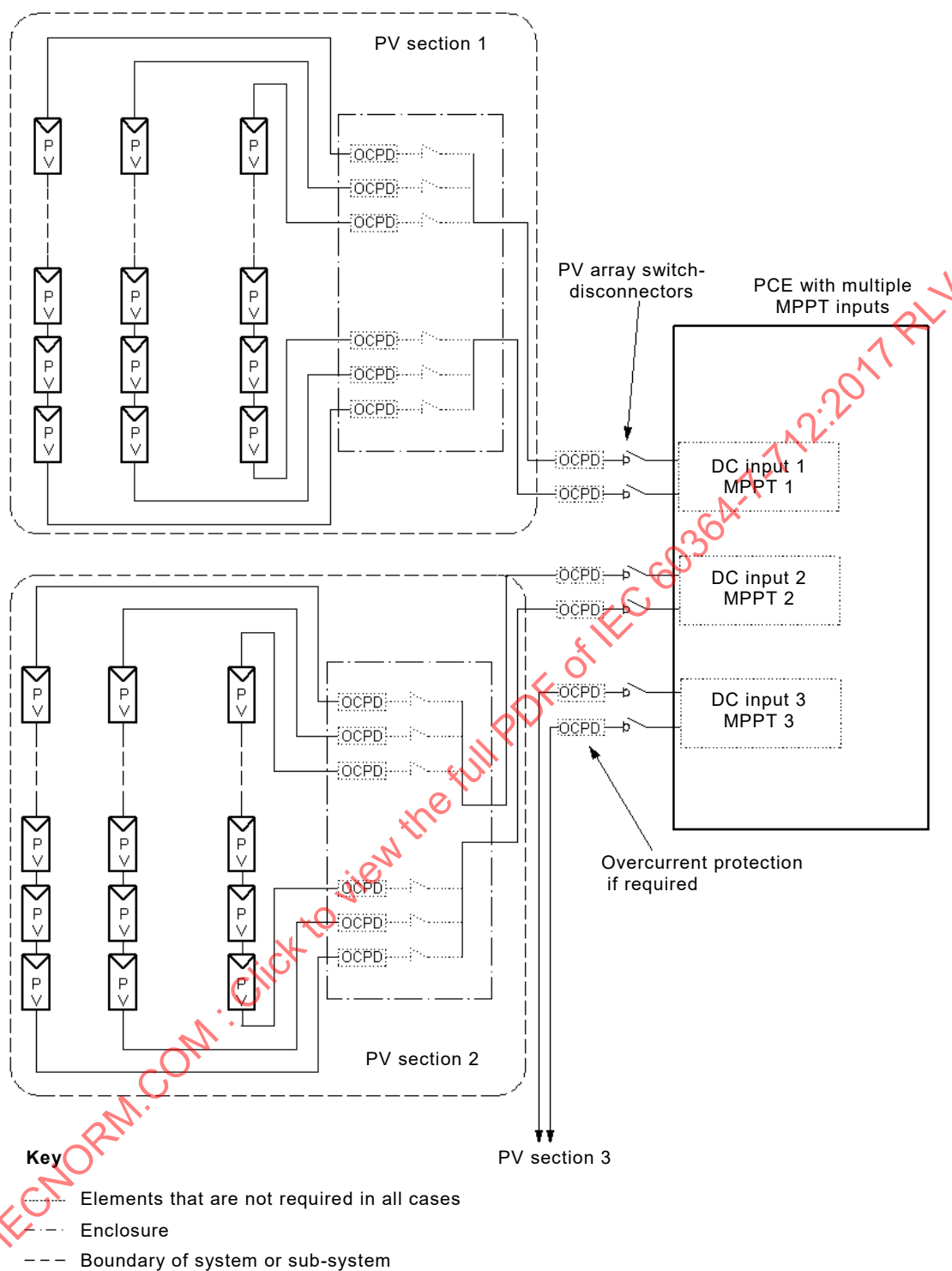


Figure 712.5 – PV array using a PCE with multiple MPPT DC inputs

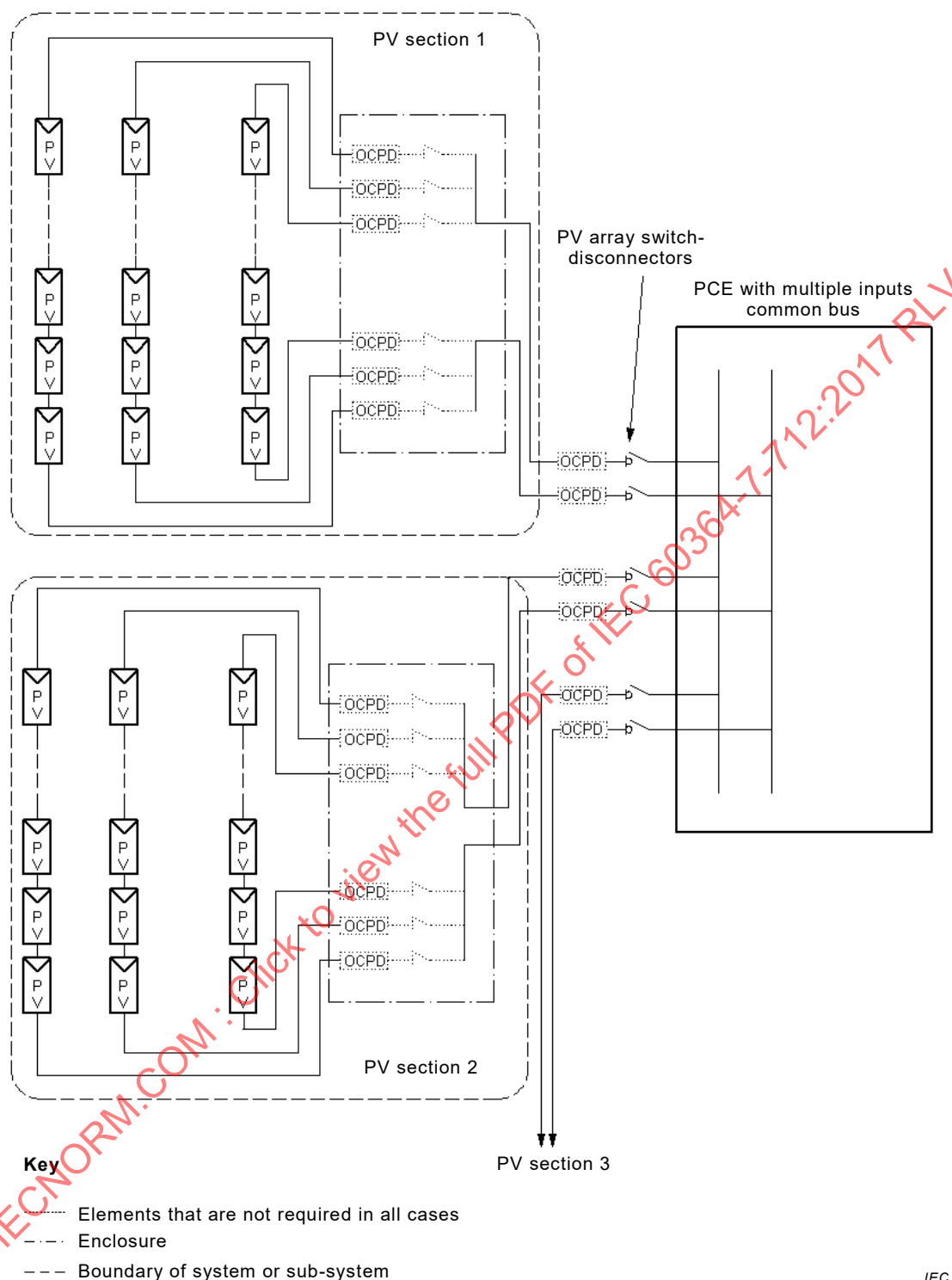


Figure 712.6 – PV array using a PCE with multiple DC inputs internally connected to a common DC bus

712.31.101.1.3 Use of PCE with multiple DC inputs

712.31.101.1.3.1 General

PV arrays are often connected to PCEs with multiple DC inputs. Refer to Figures 712.5 and 712.6. If multiple DC inputs are in use, overcurrent protection and cable sizing within the various sections of the PV array(s) are critically dependent on the limiting of backfeed currents.

712.31.101.1.3.2 PCEs with separate maximum power point tracking (MPPT) inputs

Where a PCE's input circuits provide separate MPPT inputs, the overcurrent protection of the section of the array connected to those inputs shall take into account backfeed current.

Each PV section connected to an input (refer to Figure 712.5) may be treated for the purposes of this document as a separate PV array. Each PV array shall have a switch-disconnector to provide isolation of the PCE. The PV array switch disconnectors may be mechanically integrated in one device and commonly operated.

712.31.101.1.3.3 PCEs with multiple inputs internally connected together in the PCE

Where a PCE's multiple input circuits are internally paralleled onto a common DC bus, each PV section connected to one of those inputs (refer to Figure 712.6) shall be treated for the purposes of this document as a sub-array and all the PV sections combined shall be classified as the complete PV array. Each PV sub-array shall have a switch-disconnector to provide isolation of the PCE. This function may be provided by a common PV array switch disconnector.

712.31.101.1.4 Series-parallel configuration

All PV strings within a PV array connected in parallel shall be of the same technology and have the same number of series connected PV modules (see Figure 712.2 to Figure 712.4), unless such modules are being tracked by separate MPPTs. In addition, all PV modules in parallel within the PV array shall have similar rated electrical characteristics, including short-circuit current, open-circuit voltage, maximum power current, maximum power voltage and rated power (all at STC), unless such modules are being tracked by separate MPPTs.

This is a design issue which needs to be considered by the project implementer, particularly when replacing modules or modifying an existing PV installation.

712.31.101.1.5 Considerations due to prospective fault conditions within a PV array

In any installation, the source of fault currents needs to be identified.

PV installations containing batteries may have high prospective fault currents due to the battery characteristic.

In a PV installation without batteries, the PV cells (and consequently PV arrays) behave like current sources under low impedance faults. Consequently, fault currents may not be much greater than normal full load currents, even under short-circuit conditions.

The fault current depends on the number of strings, the fault location and the irradiance level. This makes short-circuit detection within a PV array very difficult. Electric arcs can be formed in a PV array with fault currents lower than the operating current of an overcurrent protective device.

712.31.101.1.6 Performance issues

A PV array's performance may be affected by many factors, including but not limited to:

- shading or partial shading;
- temperature rise;
- voltage drop in cables;
- soiling of the surface of the array caused by dust, dirt, bird droppings, snow, industrial pollution, etc.;
- orientation;

- PV module degradation.

Care should be taken in selecting a site for the PV array. Nearby trees and buildings may cause shadows to fall on the PV array during some part of the day.

It is important that any shadowing be reduced as much as is practicable. Note that even a small shadow on the array can significantly limit its performance.

Issues of performance degradation due to temperature rise and the need for good ventilation are described in 712.515.101. Care should be taken to keep modules as cool as practicable.

In the design process the sizing of cables within the array and in cable connections from the array to the application circuit affects the voltage drop in those cables under load. This can be particularly significant in PV installations with low output voltage and high output current. It is recommended that under maximum load conditions the voltage drop from the most remote module in the array to the input terminals of the application circuit should not exceed 3 % of the PV array voltage at its maximum power point.

Pollution of the surface of PV modules caused by dust, dirt, bird droppings, snow etc. can significantly reduce the output of the array. Arrangements should be made to clean the modules regularly in situations where significant pollution may be a problem.

712.4 Protection for safety

712.4.101 General

Calculation of $U_{OC\ MAX}$ and $I_{SC\ MAX}$ is performed in Annex B.

712.4.102 Functional earthing (FE) of a live part on the DC side

For functional reasons, some PV module technologies require a live part to be connected to earth.

Functional earthing of a live part of the DC side of a PCE is permitted, if there is at least simple separation between the AC side and the DC side by means of a transformer having electrically separate primary and secondary windings. The transformer may be either internal or external to the PCE. The transformer winding connected to the PCE shall not be earthed, and the PCE shall be suitable for this.

The functional earthing of a live part shall be performed at a single point of the DC side, near the DC input of the PCE or in the PCE itself.

The earthing should preferably be located between the disconnection device and the DC terminals of the PV PCE.

The requirements of 712.421.101.2.3 shall also be applied.

A cable used for functional earthing shall not be identified by the colour combination green-and-yellow. It is recommended to use the colour pink.

712.41 Protection against electric shock

712.410 Introduction

712.410.101 PV equipment on the DC side shall be considered to be energized, even when the AC side is disconnected from the grid or when the PCE is disconnected from the DC side.

712.410.3.5

Replace the requirements as follows:

The protective measures specified in IEC 60364-4-41:2005, Annex B, i.e. the use of obstacles and placing out of reach, shall not be used.

712.410.3.6

Replace the requirements as follows:

The protective measures specified in IEC 60364-4-41:2005, Annex C, i.e.

- non-conducting location,
 - earth-free local equipotential bonding,
 - electrical separation for the supply of more than one item of current-using equipment,
- shall not be applied.

712.410.102 On the DC side, one of the following protective measures shall be used:

- double or reinforced insulation;
- SELV or PELV.

712.412 Protective measure: double or reinforced insulation

712.412.101 The equipment, for example PV modules, distribution boards or cabinets, used on the DC side shall be Class II or equivalent insulation, according to IEC 61140.

712.414 Protective measure: extra-low-voltage provided by SELV and PELV

712.414.101 For the use of SELV and PELV protective measures on the DC side, $U_{OC\ MAX}$ shall not exceed 60 V DC.

712.414.102 The smooth DC voltage to be considered is the PV array maximum voltage $U_{OC\ MAX}$.

712.42 Protection against thermal effects**712.420.101 Fire safety of PV installations**

Applicable national or local fire requirements shall be taken into account.

712.421 Protection against fire caused by electrical equipment**712.421.101 Protection against the effects of insulation faults****712.421.101.1 Protection against the effects of insulation faults without at least simple separation inside the PCE or on the AC side**

712.421.101.1.1 The functional earthing of a live part on the DC side is not permitted.

712.421.101.1.2 In the event of an insulation fault on the DC side, either:

- the PCE shall be automatically disconnected from the AC side, or
- the faulty part of the PV array shall be automatically disconnected from the PCE.

NOTE 1 Disconnection can be provided by the PCE; see IEC 62109 (all parts).

NOTE 2 Automatic disconnection can be provided by an RCD.

712.421.101.1.3 In the event of an insulation fault on the DC side, an alarm shall be automatically given (see 712.531.3.101.3).

NOTE If the insulation fault is detected by the PCE, according to IEC 62109 (all parts) an alarm is initiated by the PCE.

712.421.101.2 Protection against the effects of insulation faults with simple separation inside the PCE or on the AC side

712.421.101.2.1 The functional earthing of a live part on the DC side is permitted.

712.421.101.2.2 Without functional earthing of a live part on the DC side, an insulation monitoring device (IMD), or another device offering equally effective monitoring, shall be installed.

NOTE An inverter according to IEC 62109 (all parts) can be used to provide this function.

712.421.101.2.3 Except where the following paragraph applies, PV arrays that have one conductor connected to a functional earth shall be provided with a device or association of devices, in accordance with 712.532.102, that interrupts the current in the functional earthing conductor in the event of an insulation fault on the DC side. The device (or association of devices) shall also give an alarm according to 712.421.101.2.4.

The requirement of the previous paragraph does not apply where the functional earthing is connected to earth via a resistor having a resistance R which meets the following condition:

$$R \geq \frac{U_{oc\ max}}{I_n}$$

where

I_n is the value of current given in Table 712.6.

NOTE In the event of an insulation fault, an immediate shut down of the PCE can be necessary for functional reasons.

With functional earthing of a live part on the DC side via a resistor, an insulation monitoring device (IMD), or another device offering equal effective monitoring shall be installed (see 712.531.3).

NOTE A PCE according to IEC 62109 (all parts) can be used to provide this function.

712.421.101.2.4 In the event of an insulation fault on the DC side, an alarm shall be automatically given (see 712.531.3.101.3).

NOTE If the insulation fault is detected by the PCE, according to IEC 62109 (all parts), an alarm is initiated by the PCE.

According to IEC 60364-4-41:2005, 411.6.3.1 it is recommended that a fault be eliminated with the shortest practicable delay.

712.43 Protection against overcurrent

712.430.3 General requirements

712.430.3.101 General

Overcurrent within a PV array can result from faults in array wiring or from fault currents due to short-circuits in modules, in combiner boxes or in module wiring.

PV modules are current limited sources but can be subjected to overcurrents because they can be connected in parallel and also connected to external sources. The overcurrents can be caused by the sum of currents from

- multiple parallel adjacent strings,
- some types of PCEs to which they are connected and/or
- external sources.

712.430.3.102 Requirement for overcurrent protection

Overcurrent protection shall be provided in accordance with 712.430.3.102 to 712.433.1.101 and with PV module manufacturer's requirements.

Overcurrent protective devices required for the protection of PV modules and/or their wiring shall be selected to reliably and consistently operate within 2 h when an overcurrent of 135 % of the nominal device current rating of the PV modules is applied.

712.430.3.103 Requirement for string overcurrent protection

String overcurrent protection shall be used if:

$$((N_s - 1) \times I_{SC_MAX}) > I_{MOD_MAX_OCPR}$$

where:

N_s is the total number of parallel connected strings protected by the nearest overcurrent protective device.

When circuit-breakers with overcurrent protection elements are used, they may also provide the disconnecting means required in 712.536.2.101 to 712.536.2.103.

712.430.3.104 Requirement for sub-array overcurrent protection

Sub-array overcurrent protection shall be provided if more than two sub-arrays are connected in parallel.

712.432 Nature of protective devices

712.432.101 Blocking diodes used to connect the PV strings in parallel shall not be relied upon as a means of protection against overcurrents.

712.432.102 The overcurrent protective devices of the DC side shall be either gPV fuses in accordance with IEC 60269-6 or another device in accordance with IEC 60947 (all parts) or IEC 60898 (all parts).

Devices in accordance with IEC 60947 (all parts) and IEC 60898 (all parts) shall be of types suitable for the expected conditions, in particular for operation with direct current, reverse current and critical current.

712.433 Protection against overload current

712.433.1 Coordination between conductors and overload protective devices

712.433.1.101 Overload protection sizing

712.433.1.101.1 General

The selected multiplier in 712.433.1.101.2 to 712.433.1.101.4 shall be adjusted to account for PV systems operating in climatic conditions where I_{sc} is expected to routinely exceed STC values.

NOTE Numerous climatic and environmental conditions can result in high short-circuit currents of the PV modules and arrays exceeding STC values, such as geographic locations with unusually high solar resource, reflection from the snow, or other conditions. For example, in the snow case, short-circuit current is affected by ambient temperature, incline angle and azimuth angle of PV module, reflection of snow, geographical features, etc.

712.433.1.101.2 PV string overload protection

Where string overload protection is required, either:

- 1) each PV string shall be protected with an overload protective device, where the nominal overload protection rating of the string overload protective device shall be I_n where:

$$I_n > 1,5 \times I_{SC_MOD} \text{ and}$$

$$I_n < 2,4 \times I_{SC_MOD} \text{ and}$$

$$I_n \leq I_{MOD_MAX_OCPR}$$

or

- 2) strings may be grouped in parallel under the protection of one overload protective device provided:

$$I_{ng} > 1,5 \times N_{TS} \times I_{SC_MOD} \text{ and}$$

$$I_{ng} < I_{MOD_MAX_OCPR} - ((N_{TS} - 1) \times I_{SC_MOD})$$

where

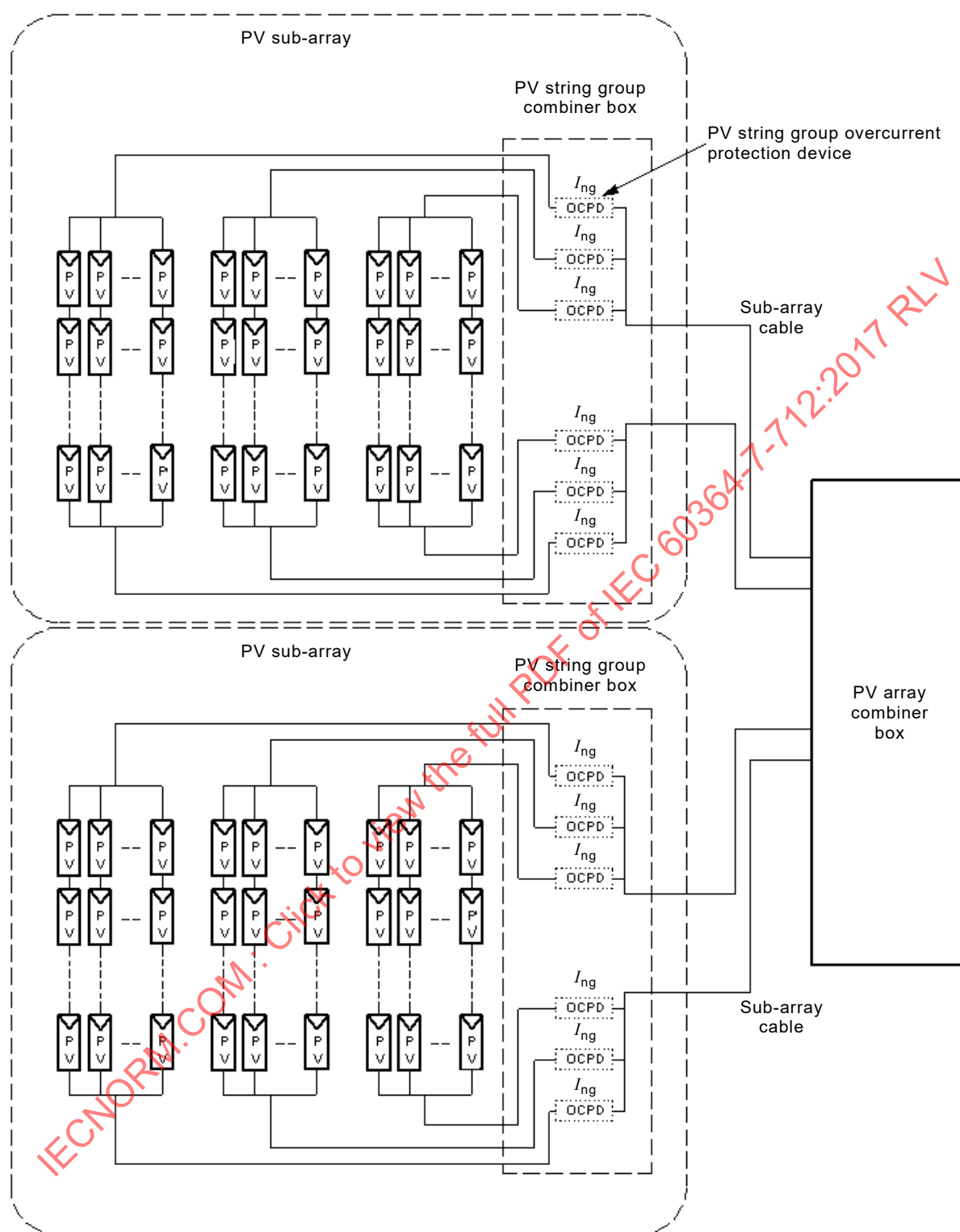
I_n is the rated current or current setting of the string overload protective device,

I_{ng} is the rated current or current setting of the group overload protective device,

N_{TS} is the total number of strings in a group under the protection of one overload device.

Where circuit-breakers are used as devices for overload protection, IEC 60364 (all parts) also permits these to fulfil the role of a disconnecting means as required by 712.536.2.101 to 712.536.2.103.

In some PV module technologies, I_{SC_MOD} is higher than the nominal rated value during the first weeks or months of operation. This should be taken into account when establishing overload protection and cable ratings.



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This is only an example and other switching, disconnecting and/or overload protective devices may be required in individual cases, but for simplicity these are not shown in this figure.

NOTE 1 This is a special case and the design is only possible where the overload protection rating of a PV module is much larger than its normal operating current.

NOTE 2 In case of specific constraints such as side by side mounting of equipment used simultaneously at nominal current and/or high ambient temperature, the choice of rated current for the protective device could be affected.

Figure 712.7 – Example of a PV array diagram where strings are grouped under one overload protective device per group

712.433.1.101.3 PV sub-array overload protection

The rated current or current setting (I_n) of overload protective devices for PV sub-arrays shall be determined with the following formulae:

$$I_n > 1,25 \times I_{SC \text{ S-ARRAY}} \text{ and}$$

$$I_n \leq 2,4 \times I_{SC \text{ S-ARRAY}}$$

The 1,25 multiplier used here instead of the 1,5 multiplier used for strings is to allow designer flexibility. A multiplier of 1,25 should not be used in areas where heightened irradiance occurs frequently as this would be likely to cause nuisance overload protective device operation.

NOTE In case of specific constraints such as side by side mounting of equipment used simultaneously at nominal current and/or high ambient temperature, the choice of current rating of the protective device could be impacted.

712.433.1.101.4 PV array overload protection

PV array cable overload protection is only required for PV installations connected to batteries or where other sources of current may feed into the PV array under fault conditions. The rated current (I_n) of PV array overload protective devices shall be rated as follows:

$$I_n > 1,25 \times I_{SC \text{ S-ARRAY}} \text{ and}$$

$$I_n \leq 2,4 \times I_{SC \text{ ARRAY}}$$

The PV array overload protective devices are commonly installed between the battery or batteries and the charge controller as close as possible to the battery or batteries. If these devices are appropriately rated, they provide protection to both the charge controller and the PV array cable, and consequently no further PV array cable overload protection between the PV array and the charge controller is necessary. The 1,25 multiplier used here instead of the 1,5 multiplier used for strings is to allow designer flexibility. A multiplier of 1,25 should not be used in areas where heightened irradiance occurs frequently as this would be likely to cause nuisance overload operation.

NOTE In case of specific constraints such as side by side mounting of equipment used simultaneously at nominal current and/or high ambient temperature, the choice of current rating of the protective device could be impacted.

712.433.2 Position of devices for overload protection

712.433.2.101 Overload protection location

Overload protective devices where required by 712.430.3.101 to 712.430.3.104, and 712.433.1.101 for PV array, PV sub-array, and PV strings shall be placed as follows.

- For string overload protective devices, they shall be where the string cables join the sub-array or array cables in the string combiner box (refer to Figures 712.3 and 712.4).
- For sub-array overload protective devices, they shall be where the sub-array cables join the array cables in the array combiner box (refer to Figure 712.4).
- For array overload protective devices, they shall be where the array cables join the application circuit or the PCE (refer to Figures 712.2 to 712.4).

NOTE The location of the overload protective devices at the end of those cables furthest from the PV sub-array or string is to protect from fault currents flowing from other sections of the PV array or from other sources such as batteries. Due to the inherent current limiting characteristics of PV, there is insufficient fault current from the source in the faulted circuit itself to cause the overload protective device to operate.

An overload protective device required for a string cable or sub-array cable shall be placed in each live conductor (i.e. each live conductor not connected to the functional earth).

An exception applies for a string cable not in the same wiring system as sub-array cables, and for a sub-array cable not in the same wiring system as string cables. In these cases, an overload protective device need only be placed in one unearthed live conductor of the string cable or each sub-array cable. The polarity of this conductor shall be the same for all cables thus protected.

712.433.101 Protection of PV array cable

The continuous current-carrying capacity (I_z) of the PV array cable shall be greater than or equal to the maximum short-circuit current of the PV array:

$$I_{SC\ MAX\ of\ the\ PV\ array} \leq I_z$$

712.433.102 Protection of PV AC supply cable

The rated current for the overload protective device of the AC supply cable shall take into account the design current of the PCE. The PCE design current is the maximum AC current given by the PCE manufacturer or, failing that, 1,1 times its rated AC current.

712.434 Protection against short-circuit currents

712.434.101 The PV AC supply cable shall be protected from the effects of short-circuit by an overcurrent protective device installed at the connection to the designated distribution board of the electrical installation.

712.44 Protection against voltage disturbances and electromagnetic disturbances

712.443 Protection against transient overvoltages of atmospheric origin or due to switching

712.443.101 Taking into account the sensitivity of the setting up of the photovoltaic modules, detailed attention should be paid to the protection of the structure itself (building) against direct effects of the lightning; this subject is covered in IEC 62305 (all parts).

712.443.4 Overvoltage control

712.443.4.101 Protection against transient overvoltage

Where protection against transient overvoltage is required by IEC 60364-4-44:2007, Clause 443, such protection shall also be applied to the DC side of the PV installation.

Depending on the distance between the PCE and the origin of the installation, further protection against transient overvoltage may be required on the AC side.

Where IEC 60364-4-44:2007, Clause 443 does not require protection against transient overvoltage, a risk assessment according to 712.443.5.101 shall be performed.

712.443.5 Risk assessment method

712.443.5.101 Risk assessment for PV installations

Where the relevant data is available, a risk assessment may be carried out to evaluate if protection against transient overvoltage is required.

The method of risk assessment is based on the evaluation of the critical length:

L_{crit} and its comparison with L .

SPDs shall be installed on the DC side of the installation where:

$$L \geq L_{\text{crit}}$$

where

- L is the maximum route length (m) between the PCE and the connection points of the photovoltaic modules of the different strings.
- L_{crit} (m) depends on the type of PV installation, and is calculated according to Table 712.1:

Table 712.1 – Calculation of the critical length L_{crit}

Type of installation	PV installation is attached to the building	PV installation is not attached to the building
L_{crit} (m)	$115/N_g$	$200/N_g$
$L \geq L_{\text{crit}}$ (m)	SPDs are required on the DC side	

- N_g is the lightning ground flash density (flash/km²/year) relevant to the location to the power line and connected structures. This value may be determined from ground flash location networks in many areas of the world. (IEC 62305-2:2010, Clause A.1 or IEC 60364-4-44:2007/AMD1:2015, 443.5)

712.444 Measures against electromagnetic influences

712.444.5 Earthing and equipotential bonding

712.444.5.5 Functional earthing conductor

712.444.5.5.101 Functional earthing terminal of PV array

When the PV array is earthed as described in 712.4.102 the connection to earth shall be made at a single point and this point shall be connected to the main earthing terminal of the electrical installation.

NOTE 1 Some electrical installations can have sub-earthing terminals. Connection of the PV functional earth to sub-earthing terminals is acceptable provided it has been considered for this use.

NOTE 2 The functional earth connection can be established inside the PCE.

In PV installations without batteries, this connection point shall be between the PV array and the PCE and as close as possible to the PCE.

In PV installations containing batteries, this connection point shall be between the charge controller and the battery protection device.

NOTE 3 If in some countries disconnection devices are required/allowed to interrupt functional earth conductors; the location of the earth connection is important in regards to interruption.

712.5 Selection and erection of electrical equipment

712.51 Common rules

712.51.101 The method of calculation of $U_{\text{OC MAX}}$ and $I_{\text{SC MAX}}$ is given in Annex B.

712.510.3 General

Add the following:

Equipment in outdoor locations shall have a degree of protection of at least IP 44 and a degree of protection against external mechanical impact not less than IK 07 in accordance with IEC 62262.

PV array wiring and associated components are often exposed to UV, wind, water, snow, heating due to direct solar radiation, and other environmental conditions. Particular attention is drawn to the need for measures to allow the escape of water that may accumulate even in watertight enclosures, and the need for measures against heating caused by direct solar radiation.

712.511 Compliance with standards

712.511.1

Add the following:

Support structures and module mounting arrangements shall comply with applicable building codes regulations and standards and module manufacturer's mounting requirements.

712.511.101 PV modules shall comply with the requirements of the relevant equipment standard, either IEC 61215 (all parts) or IEC 61646.

712.511.102 PCEs shall comply with IEC 62109 (all parts).

According to the foreseeable environmental conditions, the PCE shall be selected according to IEC 62109-1:2010, Clause 6.

712.511.103 A combiner box shall comply with IEC 61439-2 or, for household and similar locations, may alternatively comply with IEC 60670 (relevant parts). Switchgear assemblies shall comply with IEC 61439 (relevant parts).

712.512 Operational conditions and external influences

712.512.1 Operational conditions

712.512.1.1 Voltage

712.512.1.1.101 Open-circuit maximum voltage $U_{OC\ MAX}$

The open-circuit maximum voltage $U_{OC\ MAX}$ is determined in accordance with Annex B, Clause B1.

712.512.1.1.102 Component requirements

712.512.1.1.102.1 General

All components shall comply with the following requirements:

- be rated for DC use where applicable;
- have a voltage rating equal to or greater than the open-circuit maximum voltage determined in 712.512.1.1.101;
- have a current rating equal to or greater than that shown in Table 712.2.

For some PV technologies the I_{sc} current available during the first few weeks of operation is considerably greater than the normal rated value. In some technologies the I_{sc} increases over time. Equipment shall be rated for the highest expected current value.

Where the DC voltage is conditioned (e.g. where a DC/DC converter is used), equipment shall be rated for the highest expected current and voltage values.

712.512.1.1.102.2 PV module class

Where the protective measure used on the DC side is double or reinforced insulation according to 712.412, PV modules shall be selected according to class II or equivalent insulation according to IEC 61140.

Where the protective measure used on the DC side is extra-low voltage by means of SELV or PELV, according to 712.414, PV modules shall be selected according to class III or class II or equivalent insulation according to IEC 61140.

712.512.1.1.102.3 Combiner box class

Where the protective measure used on the DC side is double or reinforced insulation according to 712.412, combiner boxes shall be selected according to class II or equivalent insulation according to IEC 61140.

Where the protective measure used on the DC side is extra-low voltage by means of SELV or PELV, according to 712.414, combiner boxes shall be selected according to class III or class II or equivalent insulation according to IEC 61140.

712.513 Accessibility

712.513.101 The selection and erection of a PV installation shall facilitate safe maintenance and shall not adversely affect provisions made by the manufacturer of the electrical equipment to enable maintenance or service work to be carried out safely. Combiner boxes which contain overcurrent and/or switching devices shall be capable of being reached for inspection, maintenance or repairs without necessitating the dismantling of structural parts, cupboards, benches or the like.

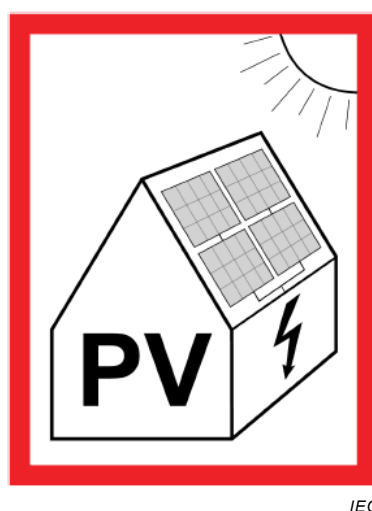
712.514 Identification

712.514.101 Safety marking

For reasons of safety of the various operators (maintenance personnel, inspectors, public distribution network operators, emergency aid services, etc.), it is essential to indicate the presence of a photovoltaic installation on a building.

A sign, such as shown in Figure 712.8, shall be fixed

- at the origin of the electrical installation, and
- at the metering position, if remote from the origin, and
- at the consumer unit or distribution board to which the supply from the PCE is connected.



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NOTE National committees or national regulations should decide on the labels and locations of such markings.

Figure 712.8 – Example of an indication showing the presence of a photovoltaic installation on a building

712.514.102 Live parts marking

Each point of access to live parts on the DC side, such as distribution boards and cabinets, shall have a permanent marking for example bearing the text 'SOLAR DC – Live parts can remain energized after isolation'.

712.514.103 Isolation marking

All PCEs should bear a marking indicating that, before any servicing operation, the PCE shall be isolated from all supplies.

712.514.104 Equipment marking

All electrical equipment shall be marked according to the requirements for marking in IEC or to local standards and regulations when applicable. Markings shall be in the local language or use appropriate local warning symbols. English examples of sign texts are included in Annex C.

712.514.105 Requirements for signs

Examples of signs are given in Annex C.

712.514.106 Labelling of disconnection devices

712.514.106.1 General

Disconnection devices shall be marked with an identification name or number according to the PV array wiring diagram.

All switches shall have the ON and OFF positions clearly indicated.

712.514.106.2 PV array disconnecting device

The PV array DC switch disconnecter shall be identified by a sign affixed in a prominent location adjacent to the switch disconnecter.

Where multiple disconnection devices are used that are not ganged (refer to 712.536.2.103) signage shall be provided warning of multiple DC sources and the need to turn off all switch disconnectors to safely isolate equipment.

712.514.107 Documentation

Documentation shall be provided in accordance with IEC 62446-1.

A set of operational instructions for the insulation fault alarm referred to in 712.531.3.101.3 shall be provided to the PV installation owner, which explains the need for immediate action to investigate and to correct the fault.

712.514.2 Wiring systems

Add the following:

The identification of AC and DC circuits shall be such that they are clearly distinguishable from each other (e.g. by labels or different coloured cables).

712.515 Prevention of mutual detrimental influence

712.515.101 Selection and erection of PV modules in relation with external influences

712.515.101.1 Thermal aspects

Provisions shall be made in the mounting arrangement of PV modules to allow for the maximum expansion/contraction of the modules under expected operating temperatures, according to the manufacturer's recommendations. Similar provisions shall be made for other applicable metallic components, including mounting structures, conduits and cable trays.

712.515.101.2 Mechanical loads on PV structures

The PV array support structures shall comply with national standards and regulations with respect to loading characteristics. Particular attention should be given to wind and snow loads on PV arrays.

712.515.101.3 Wind

PV modules, module mounting frames, and the methods used for attaching frames to buildings or to the ground shall be rated for the maximum expected wind speeds at the location according to local codes.

In assessing this component, the wind speed observed (or known) on site shall be used, with due consideration to wind events (cyclones, tornadoes, hurricanes, etc.). The PV array structure shall be secured in an appropriate manner or in accordance with local building standards.

Wind force applied to the PV array will generate a significant load for building structures. This load shall be accounted for in assessing the capability of the building to withstand the resulting forces.

712.515.101.4 Material accumulation on PV array

Snow, ice, or other material may build up on the PV array and shall be accounted for when selecting suitably rated modules, calculating the supporting structure for the modules and likewise, when calculating the building capability to support the array.

NOTE Immediately after snow falls these loads are often evenly distributed. After some time they can be very unevenly distributed as the snow starts to slide down. This can lead to significant damage to the module and support structure.

712.515.101.5 Corrosion

Module mounting frames, and the methods used for attaching modules to frames and frames to buildings or to the ground, shall be made from corrosion resistant materials suitable for the lifetime and duty of the equipment, for example aluminium, galvanized steel, treated timber.

If aluminium is installed in a marine or other highly corrosive environment, it shall be anodized to a thickness and specification suitable for the location and duty of the equipment. Corrosive gases, such as ammonia in farming environments, also need to be taken into account.

Measures shall be taken to prevent electrochemical corrosion between dissimilar metals. This may occur between structures and the building and also between structures, fasteners and PV modules.

Stand-off materials shall be used to reduce electrochemical corrosion between galvanically dissimilar metal surfaces, for example nylon washers, rubber insulators.

Manufacturer's instructions and local codes should be consulted regarding the design of mounting systems and any other connections such as earthing connections.

712.52 Wiring systems

712.521 Types of wiring systems

712.521.101 Type

712.521.101.1 Cables used within the PV array shall:

- be suitable for DC application;
- have a voltage rating of equal to or greater than the open-circuit maximum voltage determined in clause 712.512.1.1.101;
- have a temperature rating according to the application, taking into account that PV modules frequently operate at temperatures of the order of 40 K above ambient temperature and therefore cable insulation of wiring installed in contact or near PV modules shall be rated accordingly;
- if exposed to the environment, be UV-resistant, or be protected from UV light by appropriate protection, or be installed in UV-resistant conduit or trunking;
- be suitable for the expected conditions of exposure to water;
- where copper conductors are used, have tinned, multistranded conductors in order to reduce degradation of the cable over time;
- in all installations operating at voltages exceeding extra-low voltage, be selected so as to minimize the risk of insulation faults (This is commonly achieved using cables having insulation and a non-metallic sheath, selected and installed in accordance with IEC 60364-4-41:2005, 412.2.4.1, particularly for cables that are exposed or laid in metallic tray or conduit. This can also be achieved by reinforcing the protection of the wiring as shown in Figure 712.9);
- be flame retardant as defined in IEC 60332-1-2;
- have conductors classified according to minimum class 5 of IEC 60228 where subject to movement (such as for tracking installations or where string cables are exposed to wind), or a minimum of class 2 of IEC 60228 where not subject to movement.

NOTE 1 Some countries require halogen free cables when those cables are routed through a building

NOTE 2 IEC 62930, Electric cables for Photovoltaic systems, is under development.

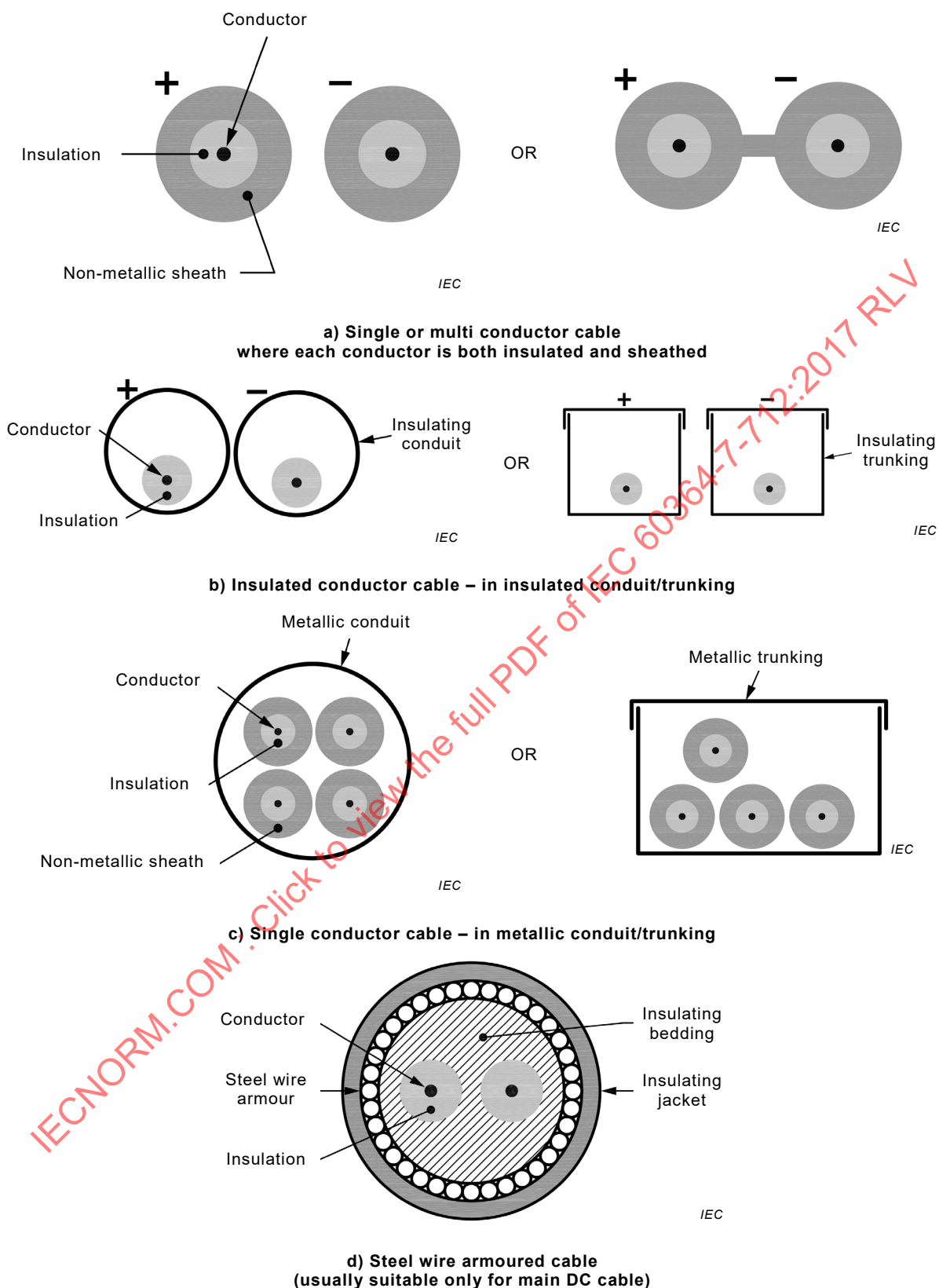


Figure 712.9 – Examples of cables with reinforced protection

712.521.101.2 Cables on the DC side shall be selected and erected so as to minimize the risk of earth faults and short circuits.

712.521.102 General

All connections shall be verified for tightness and polarity during installation to reduce the risk of faults and possible arcs during commissioning, operation and future maintenance.

712.521.103 Wiring loops

To reduce the magnitude of transient overvoltages, the PV array wiring shall be laid in such a way that the area of conductive loops is minimum (e.g. by laying cables in parallel as shown in Figure 712.10)

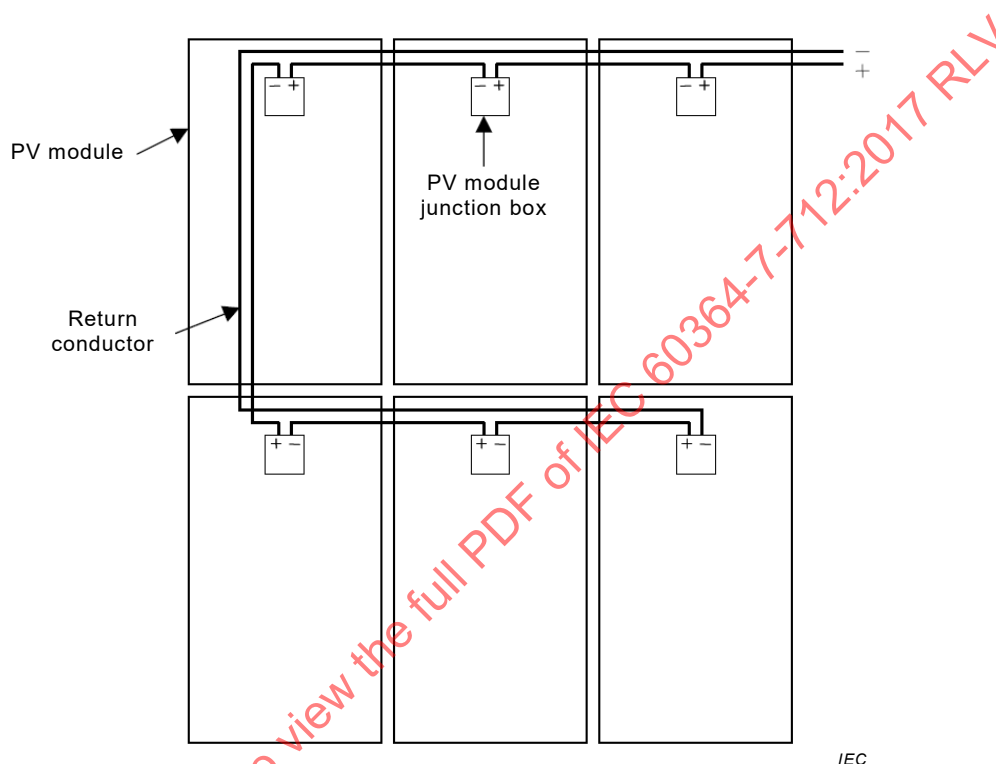


Figure 712.10 – PV string wiring with minimum loop area

712.521.104 String wiring

In the case where wiring of PV strings between modules is not protected by conduit or other enclosures, in addition to the requirements for all array wiring the following requirements shall also apply:

- cables are protected from mechanical damage, and
- the cable is so installed as to relieve tension in order to prevent the conductor from coming free from the connection.

712.522 Selection and erection of wiring systems in relation to external influences

712.522.101 Installation method

Cables shall be supported so they do not suffer fatigue due to wind/snow affects. They shall also be protected from sharp edges. Cables shall be supported so that their properties and installation requirements are maintained over the stated life of the PV plant. All non-metallic cable management systems exposed to sunlight shall be of a UV resistant type.

NOTE Conduit, ducting and cable ties installed under an array might still be exposed to reflected UV radiation. Metallic cable ties can have sharp edges which over time and subject to wind affects could cause cable damage.

712.523 Current-carrying capacities

712.523.101 The ambient temperature for cables subjected to direct heating from the underside of PV modules shall be considered to be at least 70 °C.

712.524 Cross-sectional areas of conductors**712.524.1**

Add the following:

Cable sizes for PV string cables, PV sub-array cables and PV array cable shall be determined with regard to overcurrent protection ratings where in use, the minimum current rating (refer to Table 712.2), the voltage drop and prospective fault current. The largest cable size obtained from these criteria shall be applied.

PV arrays not connected to batteries are current limited sources but because of parallel connection of strings, and sub-arrays, abnormally high currents can flow in array wiring under fault conditions. Overcurrent protection is specified where required and cables shall be capable of handling the worst case current from any remote part of the array through the nearest overcurrent protective device plus the worst case current available from any adjacent parallel strings.

712.524.1.101.1

The minimum cable sizes for PV array wiring, based on current-carrying capacity (I_z), shall be based upon a current rating calculated from Table 712.2.

In some PV module technologies $I_{SC\ MOD}$ is higher than the nominal rated value during the first weeks or months of operation, and in other technologies $I_{SC\ MOD}$ increases over time. This shall be taken into account when establishing cable ratings.

Table 712.2 – Minimum current rating of circuits

Relevant circuit	Protection	Minimum current upon which cable cross sectional area and or other circuit ratings shall be chosen
PV string	PV string overcurrent protection not provided	Current rating (I_n) of the nearest downstream overcurrent protective device $+ 1,25 \times I_{SC\ MOD} \times (N_s - 1)$ where: N_s is the total number of parallel connected strings protected by the nearest overcurrent protective device. NOTE i) The nearest downstream overcurrent protection may be the sub-array protection and if this is not present then it may be the array overcurrent protection if present. ii) When no overcurrent protection is used in the complete array then N_s is the total number of parallel connected strings in the complete PV array; and the rated current (I_n) of the nearest overcurrent protective device is replaced by zero.
	PV string overcurrent protection provided	Current rating (I_n) of the PV string overcurrent protective device (refer to 712.430.3.101 to 712.430.3.104, 712.433.1.101 and 712.433.2.101)
PV sub-array	PV sub-array overcurrent protection not provided	The greater of the following: a) Current rating (I_n) of the PV array overcurrent protective device + $1,25 \times$ sum of short circuit current of all other sub-arrays b) $1,25 \times I_{SC\ S-ARRAY}$ (of relevant array) NOTE When PV array overcurrent protection is not used, the I_n is replaced by zero in Equation (a).
	PV sub-array overcurrent protection provided	Current rating (I_n) of the PV sub-array overcurrent protective device (refer to 712.430.3.101 to 712.430.3.104, 712.433.1.101 and 712.433.2.101)
PV array	PV array overcurrent protection not provided	$1,25 \times I_{SC\ ARRAY}$
	PV array overcurrent protection provided	Current rating (I_n) of the PV array overcurrent protective device (refer to 712.430.3.101 to 712.430.3.104, 712.433.1.101 and 712.433.2.101)

Where a PCE or other power conversion device is capable of providing backfeed current into the array under fault conditions, the value of this backfeed current shall be taken into account in all calculations of circuit current ratings. In some circumstances the backfeed current will have to be added to the circuit rating as calculated in Table 712.2.

NOTE The value of backfeed current provided by power conversion equipment (PCE) can be obtained from information provided by the PCE manufacturer.

712.525 Voltage drop in consumers installations

712.525.101 Voltage drop in PV installations

For efficiency reasons, other than electrical safety and correct functioning of equipment, consideration shall be given to the voltage drop in the PV installation. See 712.31.101.1.6. National requirements should be considered.

When the PV installation is generating power, the voltage at the PCE terminals is higher than the voltage at the grid connection point. This voltage difference should be kept to a minimum in order to prevent the PCE from nuisance tripping on overvoltage.

The recommendations of IEC 60364-5-52:2009, Annex G apply.

712.526 Electrical connections

712.526.1

Add the following:

Male and female connectors mated together shall be of the same type from the same manufacturer i.e. a male connector from one manufacturer and a female connector from another manufacturer or vice versa shall not be used to make a connection.

Connectors shall comply with the following requirements:

- be rated for DC use (IEC 62852);
- have a voltage rating equal to or greater than the open-circuit maximum voltage determined in 712.512.1.1.101;
- be protected from contact with live parts in connected and disconnected state (e.g. shrouded);
- have a current rating equal to or greater than the current-carrying capacity for the circuit to which they are fitted (refer to Table 712.2);
- be capable of accepting the cable used for the circuit to which they are fitted;
- require a deliberate force to disconnect;
- if accessible by untrained people, then shall be of the locking type where two independent actions are required to disconnect;
- have a temperature rating suitable for their installation location;
- if multi-polar, be polarized;
- comply with Class II for PV installations operating above 35 V;
- if exposed to the environment, be rated for outdoor use, be UV-resistant and be of an IP rating suitable for the location;
- shall be installed in such a way as to minimize strain on the connectors (e.g. supporting the cable on either side of the connector);
- plugs and socket outlets normally used for the connection of household equipment to low voltage AC power shall not be used in PV arrays.

NOTE The purpose of this requirement is to prevent confusion between AC and DC circuits within an installation.

712.526.101 Connectors on the DC side

For PV installations not using SELV or PELV protective measures on the DC side, only connectors especially suitable for the DC side of PV installations shall be used.

Connectors in a location accessible to persons other than skilled or instructed persons shall either be of a type which can only be disconnected by means of a key or a tool or shall be installed within an enclosure which can only be opened by means of a key or a tool.

712.526.102 Wiring installation in combiner boxes

The following provisions apply to the installation of wiring systems combiner boxes.

Where conductors enter a combiner box without conduit, a tension relief arrangement shall be used to avoid cable disconnections inside the box (for example by using a gland connector).

All cable entries when installed shall maintain the IP rating of the enclosure.

NOTE Water condensation inside combiner boxes can be a problem in some locations; provision can be made to drain water build-up.

712.527 Selection and erection of wiring systems to minimize spread of fire

Under consideration.

712.528 Proximity of wiring systems to other services

Under consideration.

712.529 Selection and erection of wiring systems in relation to maintainability, including cleaning

Under consideration.

712.53 Isolation, switching and control

712.530.3 General and common requirements

712.530.3.101 Residual current devices

Where an RCD is used for protection of the PV AC supply circuit, the RCD shall be of type B in accordance with IEC 62423, unless:

- the manufacturer's instructions state that the inverter provides at least simple separation between the AC side and the DC side, or
- the installation provides at least simple separation between the inverter and the RCD by means of separate windings of a transformer, or
- the inverter is in accordance with IEC 62109-1 and the manufacturer's instructions do not require the use of a type B RCD, in which case the type of RCD shall be in accordance with the manufacturer's instructions.

712.531 Devices for protection against indirect contact (fault protection) by automatic disconnection of supply

712.531.101 Detection, disconnection and alarm requirements

Requirements for detection of insulation faults, actions required and alarms depend on the type of system earthing and whether the PCE provides electrical separation of the PV array from the output circuit (e.g. the grid). Table 712.3 shows the requirements for measurements of PV array insulation resistance to earth and PV array RCM as well as the actions and alarms required if a fault is detected.

**Table 712.3 – Requirements for different system types
based on PCE isolation and PV array functional earthing**

		System type		
		Non-isolated PCE + No functional earth on PV array	Isolated PCE + No functional earth on PV array	Isolated PCE + Functionally earthed PV array
PV array insulation resistance to earth	Measurement	According to 712.531.3.101.1		
	Action on fault	a) If the AC side is not part of an IT system: Shut down PCE and disconnect all live conductors of the AC circuit or all poles of the faulty portion of the PV array from the PCE b) If the AC side is part of an IT system: No action (PCE is allowed to operate).	Connection to the AC circuit is allowed (PCE is allowed to operate)	
	Alarm on fault	Indicate a fault in accordance with 712.531.3.101.3		
PV array residual current monitoring	Measurement	According to 712.531.3.101.2	Not required	According to 712.531.3.101.2
	Action on fault	Shut down PCE and disconnect all live conductors of the AC circuit or all poles of the faulty portion of the PV array from the PCE		Functional earth connection shall be disconnected (see 712.531.3.101.2); connection to the AC circuit is allowed. (PCE is allowed to operate)
	Alarm on fault	Indicate a fault in accordance with 712.531.3.101.3		Indicate a fault in accordance with 712.531.3.101.3
Instead of shutting down the PCE and disconnecting the AC circuit it is allowed to isolate the faulted parts of the PV array.				
Functional earthing has to be carried out according to 712.4.102.				
Systems using non-isolated PCEs where the AC circuit is referenced to earth are not allowed to use functional earthing on the PV side of the PCE see 712.4.102.				

712.531.3 Insulation monitoring devices

712.531.3.101 Requirements for PV arrays operating at above 60 V

712.531.3.101.1 Array insulation resistance detection

The requirements in 712.531.3.101.1 regarding detection and response to abnormal array insulation resistance to earth are intended to reduce hazards due to degradation of insulation.

A means shall be provided to measure the insulation resistance from the PV array to earth before starting operation and at least once every 24 h. This can be done by an insulation measuring device according to IEC 61557-2, or by an insulation monitoring device (IMD) according to Annex C of IEC 61557-8:2014, to prevent a possible high risk of fire.

This functionality for insulation resistance monitoring or measurement may be provided within the PCE.

Minimum threshold values for detection shall be according to Table 712.4.

**Table 712.4 – Minimum insulation resistance thresholds
for detection of failure of insulation to earth**

PV array rating, kW	R limit, k Ω
≤ 20	30
> 20 and ≤ 30	20
> 30 and ≤ 50	15
> 50 and ≤ 100	10
> 100 and ≤ 200	7
> 200 and ≤ 400	4
> 400 and ≤ 500	2
≥ 500	1

It is recommended that the threshold of detection for insulation resistance should, where possible, be set at values greater than the minimum values specified in these calculations. A higher value will increase the safety of the PV installation by detecting potential faults earlier.

It is necessary to disconnect the PV array functional earth connection during the measurement.

The action on fault required is dependent on the type of PCE in use, as follows:

- for isolated PCEs, shall indicate a fault in accordance with 712.531.3.101.3 (operation is allowed); the fault alarm shall be maintained until the array insulation resistance has recovered to a value higher than the limit above;
- for non-isolated PCEs, shall indicate a fault in accordance with 712.531.3.101.3, and shall not connect to any earthed output circuit (e.g. the mains); the device may continue to make the measurement, may stop indicating a fault and may allow connection to the output circuit if the array insulation resistance has recovered to a value higher than the limit above.

712.531.3.101.2 Residual current monitoring system

Where required by Table 712.3, residual current monitoring shall be provided that functions whenever the PCE is connected to an earth referenced output circuit with the automatic disconnection means closed. The residual current monitoring means shall measure the true RMS (both AC and DC components) residual current.

If the PCE AC output connects to a circuit that is isolated from earth, and the PV array is not functionally earthed, residual current monitoring is not required.

Detection shall be provided to monitor for excessive continuous residual current, and excessive sudden changes in residual current according to the following limits:

- a) Continuous residual current: where the RCM indicates a residual current above the limits, disconnection by a switching device shall operate within 0,3 s and indicate a fault in accordance with 712.531.3.101.3 if the continuous residual current exceeds:
 - maximum 300 mA for PCEs with continuous output power rating ≤ 30 kVA;
 - maximum 10 mA per kVA of rated continuous output power for PCEs with continuous output power rating > 30 kVA.

NOTE It is possible to implement distributed residual current monitoring for example at sub-array level or in smaller subsections of the array. This can be beneficial especially in large arrays as it enables smaller thresholds of detection to be implemented. This can lead to more rapid identification of potential faults and can assist in identifying the section of the array that may be affected.

The RCM may attempt to initiate re-connection if the leakage current threshold is below that specified in this subclause and the array insulation resistance meets the limit in 712.531.3.101.1.

- b) Sudden changes in residual current: the PCE shall disconnect from any earth referenced output circuits (e.g. the mains) within the time specified in Table 712.5 and indicate a fault in accordance with 712.531.3.101.3 if a sudden increase in the RMS residual current is detected exceeding the value in the table.

Table 712.5 – Response time limits for sudden changes in residual current

Residual current sudden change	Maximum time for disconnection from earth referenced circuit
30 mA	0,3 s
60 mA	0,15 s
150 mA	0,04 s
NOTE These values of residual current and time were originally taken from the RCD standard IEC 61008-1 but are no longer related to protection against electric shock in the meaning of this document.	

The RCM may attempt to initiate re-connection if the leakage current threshold is below that specified in this subclause and the array insulation resistance meets the limit in 712.531.3.101.2.

712.531.3.101.3 Insulation fault alarm

To provide an indication as required by 712.531.3.101.1, an insulation fault alarm shall be installed. When activated the alarm is to continue its operation until the PV installation is shut down and/or the insulation fault is corrected.

The alarm shall be of a form that ensures that the operator or owner of the PV installation becomes aware of the fault. For example, the alarm may give a visible or audible signal placed in an area where operational staff or owners will be aware of the signal or another form of fault communication such as Email, SMS or similar.

Many PCEs have insulation fault detection and indication in the form of indicator lights. However, typical PCE mounting locations mean that this indication may not be noticed. IEC 62109-2 requires that PCEs have a local alarm and also a means of signalling an insulation fault externally.

712.532 Devices for protection against thermal effects

712.532.101 Protection against the effects of insulation faults which includes the use of an IMD

Where an IMD is used in connection with protection against the effects of insulation faults, it shall be in accordance with IEC 61557-8.

If the IMD is an integral part of the PCE, the insulation monitoring function has to be in accordance with Annex D of IEC 62109-2: 2014.

NOTE 1 Protection against the effects of insulation faults by IMD is a possible choice where AC and DC sides are galvanically separated without functional earthing of a live part on the DC side (see 712.532.102)

NOTE 2 An IMD can also be necessary for reasons other than fire prevention, for example for continuous operation without interruption by a first fault.

In PV arrays > 100 kWp an automatic insulation fault location system according to IEC 61557-9 is recommended.

712.532.102 Protection against the effects of insulation faults by disconnecting the functional earthing conductor

The device or association of devices required by 712.421.101.2.3 shall:

- meet the relevant requirements of IEC 60364-4-43,
- be rated for the maximum voltage of the PV array $U_{OC\ MAX}$,
- have a rated breaking capacity not less than the maximum short circuit current of the PV array $I_{SC\ MAX}$, and
- have a rated current not exceeding that given in Table 712.6.

Table 712.6 – Rated current of automatic disconnecting device in the functional earthing conductor

Total PV array power rating (kWp)	Rated current I_n (A)
0 to 25	1
>25 to 50	2
>50 to 100	3
>100 to 250	4
>250	5

Some module technologies require a functional earth on either the positive or negative main conductor to bleed charge away from the PV cells. This is a functional/operational requirement or it may be required to prevent degradation of the cells. It is recommended that the manufacturer's instructions be followed. It is also recommended that, where possible, the functional earthing to bleed charge from the cells be via a resistor and not directly to earth. The recommended resistor value should be the highest resistor value allowable as per the manufacturer's instructions.

712.533 Devices for protection against overcurrent

712.533.1 General requirements

712.533.101 Overcurrent protective devices of the DC side

The overcurrent protective devices of the DC side shall be:

- gPV fuses in accordance with IEC 60269-6, or ,
- circuit-breakers in accordance with IEC 60947-2 or IEC 60898-2 for which the manufacturer declares their suitability for use in PV installations.

These devices shall comply with the following specific measures:

- the rated operating voltage (U_e) shall be greater than or equal to the voltage $U_{OC\ MAX}$ of the PV array;
- the rated current I_n as defined in 712.433.1.101;
- the rated breaking capacity shall be at least equal to $I_{SC\ MAX}$ of the PV array and fault current from any other connected power sources, such as batteries or generators;
- designed for direct current use;

- be able to switch off critical current as defined in IEC 60947-1;

NOTE The symbol  (IEC 60417-5031:2003-02) is used on some devices to indicate suitability for DC application.

- operation of the overcurrent protective devices shall be independent of the direction of current flow.

712.534 Devices for protection against transient overvoltages

712.534.4 Selection and erection of SPDs

712.534.4.4 Selection of SPDs

712.534.4.4.101 Selection of SPDs on the DC side

712.534.4.4.101.1 General

Due to the very specific electrical setup of PV installations on the DC side, only SPDs especially dedicated to PV installations shall be used to protect the DC side of such installations. The manufacturer of SPDs shall give the relevant information.

When the PCE incorporates SPDs on the DC side, they are considered as fulfilling the surge protective function only if the manufacturer of the PCE specifies their convenient use for the DC side of PV installations and their specifications are adequate for the place of the installation (I_n , I_{max} , I_{imp} , I_{SCPv} , according 712.534.4.4.101). Otherwise, protection shall be provided by external SPDs.

NOTE Varistors included in the PCE are not considered as SPDs.

The voltage protection level U_p of external SPDs shall be determined in relation to the characteristics of the devices incorporated in the PCEs. The PCE manufacturer shall in that case provide the voltage level needed for the selection of external SPDs.

The characteristics of SPDs installed on the DC side are defined as follows in 712.534.4.4.101.2 to 712.534.4.4.101.7.

712.534.4.4.101.2 Selection of SPD test class

Generally SPDs will be class II test. If protection against effects of direct lightning strokes is specified and separation distance S is not kept in accordance with IEC 62305 (all parts), class I test SPDs shall be used (generally in conjunction with class II test SPDs).

712.534.4.4.101.3 Selection of SPD voltage protection level U_p

Where no information is provided by the manufacturer, the impulse withstand voltage U_w shall be considered equal to that in Table 712.7 for the modules and conversion equipment.

**Table 712.7 – Impulse withstand voltage U_w
where no information is available**

$U_{OC\ MAX}$ (V)	U_w (kV)	
	PV module	Inverter
100	0,8	-
150	1,5	-
300	2,5	-
400	-	3,1
600	4	4,2
800	-	5,1
1 000	6	5,6
1 500	8	8,5

712.534.4.4.101.4 Selection of SPD maximum continuous operating voltage U_{cpv}

The value of the maximum voltage acceptable by the surge protective device U_{cpv} shall be selected according to the maximum no-load voltage of the PV array $U_{OC\ MAX}$. The voltage U_{cpv} shall be greater than or equal to the maximum voltage $U_{OC\ MAX}$ of the PV array.

An SPD shall be selected and arranged with regard to the maximum voltage $U_{OC\ MAX}$ between:

- its live terminals (+ and – terminals), and
- its live terminals (+ and – terminals) and earth.

712.534.4.4.101.5 Selection of SPD nominal discharge current I_n

The minimum value of nominal discharge current I_n of Class II tested SPDs shall be 5 kA.

NOTE A nominal discharge current exceeding the minimum value will give the surge protective device a longer service life.

712.534.4.4.101.6 Selection of SPD short circuit current rating I_{SCPv} and of protective device associated with the surge protective device

If required by the manufacturer, the surge protective device shall be provided with an external automatic disconnecting device selected in accordance with the manufacturer's specification. The device shall be selected to operate whatever the current produced by the PV modules.

An external disconnecting device is required as an SPD could fail to a short-circuit condition.

The short-circuit current rating I_{SCPv} shall be selected according to the maximum current that can be delivered by the PV array I_{SCMAX} . The current I_{SCPv} shall be greater than or equal to I_{SCMAX} of the PV array. Surge protective devices for which this parameter is not given shall not be used.

712.534.4.4.101.7 Selection of class I tested SPDs impulse current I_{imp}

If the impulse current I_{imp} cannot be calculated, I_{imp} shall not be less than 12,5 kA. This value is referring to lightning protection level LPL III.

712.534.4.4.102 Erection of SPDs on the DC side

SPDs on the DC side shall be located as close as possible to the PCE.

To provide protection, additional SPDs may be required, further from the PCE.

NOTE 1 An example is where the distance between the entrance of the DC cable into a building and the PCE is longer than 10 m.

NOTE 2 The surge voltage level on the equipment depends on its distance away from the SPD. Beyond 10 m, the value of this voltage can be doubled due to the effect of resonance (amplification phenomena due to the high frequencies of the lightning surges).

712.534.4.10 Connecting conductors of SPDs

Add the following:

- When SPDs are installed on both AC and DC sides of the inverter in separate switchboards, it is recommended to minimize the distance between those switchboards.
- For DC SPD connections to the main earthing terminal the conductors shall have a minimum cross section of 6 mm² copper or equivalent for Class II tested SPDs and 16 mm² copper or equivalent for Class I tested SPDs.

712.536 Isolation and switching

712.536.2 Isolation

712.536.2.101 Disconnections means

Disconnecting means with isolation function shall be provided for the inverter, on both the DC side and the AC side.

Disconnecting means with isolation function shall be provided in PV array to isolate circuits and equipment.

712.536.2.102 Location of the switch-disconnector for the PCE

The switch-disconnector shall be so located that maintenance of the PCE (e.g. change of a PCE module, change of fans, cleaning of filters) is possible without risk of electrical hazards. The switch-disconnector may be in the same enclosure with the PCE.

In case of multiple DC inputs the above requirements apply to each input.

712.536.2.103 Devices for isolation within the PV array

Devices shall be provided in accordance with Table 712.8.

Table 712.8 – Disconnection device requirements in PV array installations

Circuit or part of circuit	Means of isolation	Requirement
String	Disconnection device ^a	Recommended
Sub-array	Disconnection device ^a	Required
	Means of isolation offering load-breaking capabilities ^b	Recommended
Array	Means of isolation offering load-breaking capabilities	Required
^a Sheathed (touch safe) connector, fuse combination unit, or isolator are examples of suitable disconnection devices.		
^b Where a switch-disconnector is used, this may also provide the isolation function.		

Means of isolation that are not capable of breaking load current shall be marked to indicate that they are no-load break devices, and shall be accessible only by means of a tool or key.

Where multiple sub-array disconnection devices are installed close to the PCE (i.e. within 2 m and within line of sight), a PV array cable need not be provided and therefore there is no need for a PV array load breaking switch. In this case the switches for the sub-arrays shall all be load breaking switches.

Where multiple disconnection devices are required to isolate the PCE, a warning sign shall be provided indicating the need to isolate multiple supplies.

712.536.5 Functional switching (control)

712.536.5.101 Disconnectors and switch-disconnectors

All switch-disconnectors shall be selected and erected to comply with the following requirements:

- not have exposed live metal parts in connected or disconnected state;
- have a current rating equal to or greater than that required for the circuit conductors;
- not be polarity sensitive (fault currents in a PV array may flow in the opposite direction of normal operating currents).

Switch-disconnectors shall be compliant with IEC 60947-3 and have mechanisms that have independent manual operation.

712.54 Earthing arrangements and protective conductors

712.542 Earthing arrangements

712.542.101 Functional earthing

For mechanical protection, the minimum cross-sectional area for a functional earthing conductor is 4 mm² copper or equivalent.

712.542.102 Separate earth electrode

If a separate earth electrode is provided for the PV array, this electrode shall be connected to the main earthing terminal of the electrical installation by main equipotential bonding conductors.

712.542.103 Bonding of PV metal structures

Where such bonding is necessary (e.g. to facilitate the correct operation of the array insulation resistance detection referred to in 712.531.3.101.1), the metallic structures supporting the PV modules (including metallic cable trays) shall be bonded.

Such bonding may be necessary, for example, where a transformerless PCE induces an electrostatic charge.

The bonding conductor shall be connected to any suitable PE terminal.

Where these metal structures are of aluminium, appropriate connection devices shall be used.

The bonding conductors (insulated or bare) shall have a minimum cross section of 4 mm² copper or equivalent.

PV array bonding conductors shall be run as close to the positive and negative PV array and or sub-array conductors as possible to reduce induced voltages due to lightning. See also 712.521.103.

NOTE The bonding referred to in 712.542.103 also ensures the protection against the effects of discharge of electrostatic charges.

712.55 Other equipment

712.55.101 Measures to prevent DC on-load interruption

In order to prevent arcing, every device without breaking capacity that could be used to open a DC circuit shall be secured against inadvertent or unauthorized operation.

NOTE 1 Examples of devices to which this requirement applies are SPD carriages and fuse carriers.

NOTE 2 This can be achieved by locating the device in a lockable space or enclosure or by padlocking.

712.55.102 Blocking diodes

Blocking diodes shall not be used as an alternative to overcurrent protective devices.

Blocking diodes may be used to prevent reverse currents in sections of a PV array.

If used, blocking diodes shall comply with the following requirements:

- have a voltage rating at least 2 times $U_{OC\ MAX}$;
- have a current rating I_{MAX} of at least 1,4 times the short circuit current at STC of the circuit that they are intended to protect; that is:
 - $1,4 \times I_{SC\ MOD}$ for PV strings;
 - $1,4 \times I_{SC\ S-ARRAY}$ for PV sub-arrays;
 - $1,4 \times I_{SC\ ARRAY}$ for PV arrays;
- be installed so no live parts are exposed;
- be protected from degradation due to environmental factors.

The use of blocking diodes is shown in detail in Annex D.

NOTE See 712.433.1.101 for requirements for adjusting I_{sc} multipliers for certain climatic conditions.

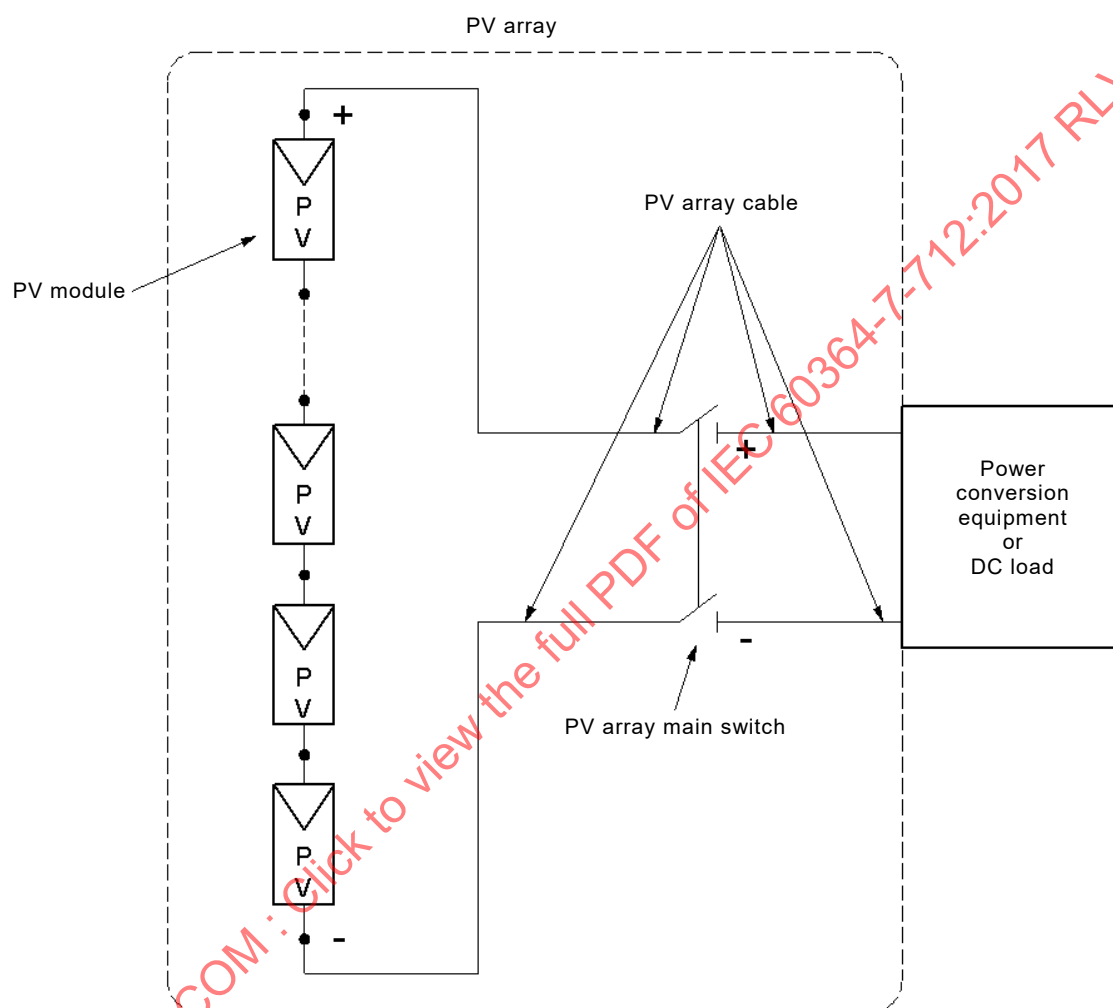
712.6 Inspection and testing

IEC 62446-1 gives requirements for system documentation, commissioning tests and inspection which are additional to the requirements of this document.

Annex A (informative)

PV installation information

Figures A.712.1 to A. 712.6 provide information on PV installation, as referred to in 712.31.101.1.1.



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Figure A.712.1 – Single string PV array

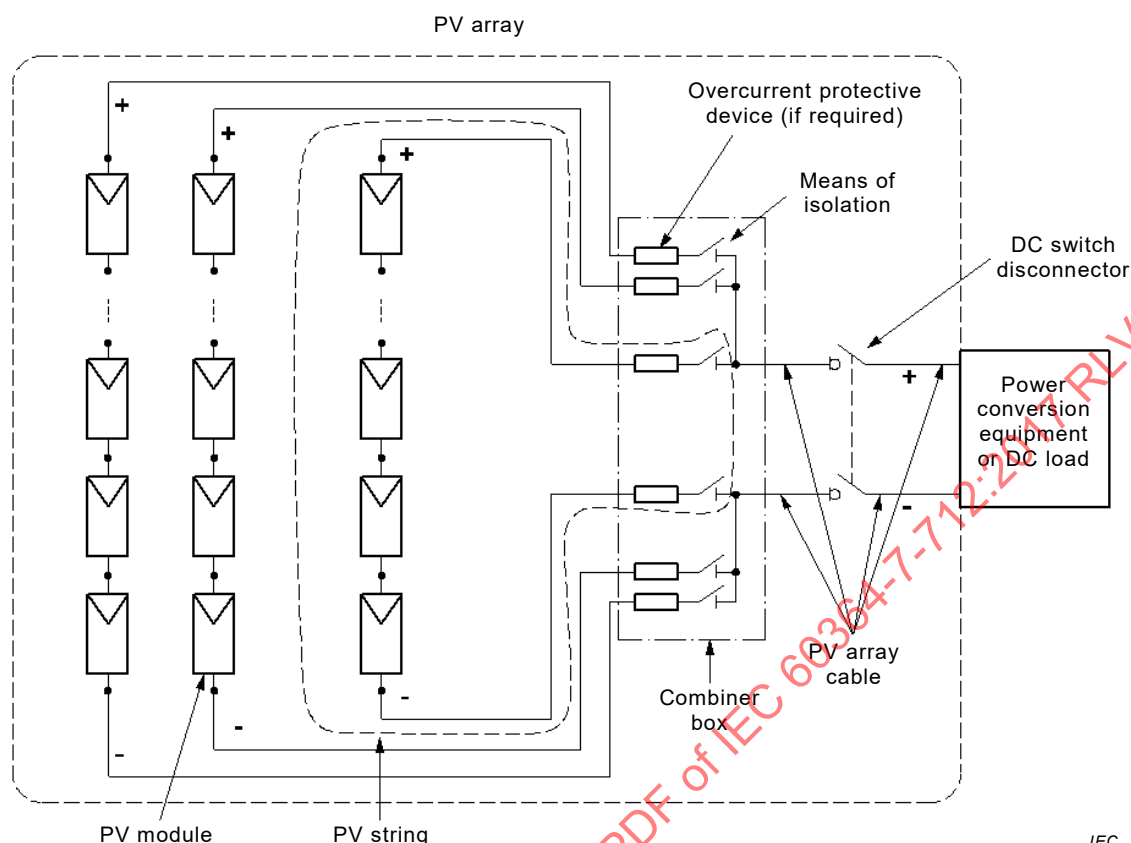


Figure A.712.2 – Parallel connected multi-string PV array

The following types of application circuit are considered:

- PV array is connected to AC loads via a PCE with a transformer inside the PCE;
- PV array is connected to AC loads via a PCE with a transformer outside of the PCE;
- PV array is connected to AC loads via a PCE without a transformer.

In Table A.712.1, several configurations are considered. No consideration is given to earthing of exposed conductive parts.

Table A.712.1 – PV DC configurations

DCDC side	Figures	Application circuit	Consequence on the status of the PV array
Unearthed	Figure A.712.3	AC side connected via a PCE with a transformer inside of the PCE	Floating
	Figure A.712.4	AC side connected via a PCE without a transformer	Fixed by the status of the neutral or a line conductor of the supply circuit
Earthed	Figure A.712.5	AC side connected via a PCE with a transformer inside of the PCE	Fixed to earth
	Figure A.712.6	AC side connected via a PCE without a transformer inside of the PCE but a transformer outside of the PCE	Fixed to earth

The following Figures A.712.3 to A.712.6 illustrate the arrangements listed in Table A.712.1:

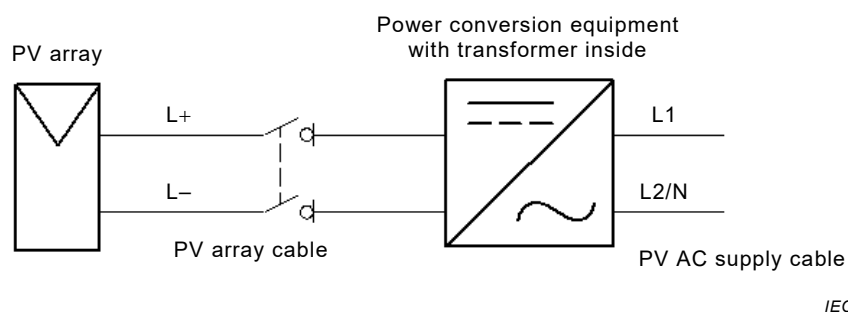


Figure A.712.3 – Unearthed PV array connected to the AC side via a PCE with transformer

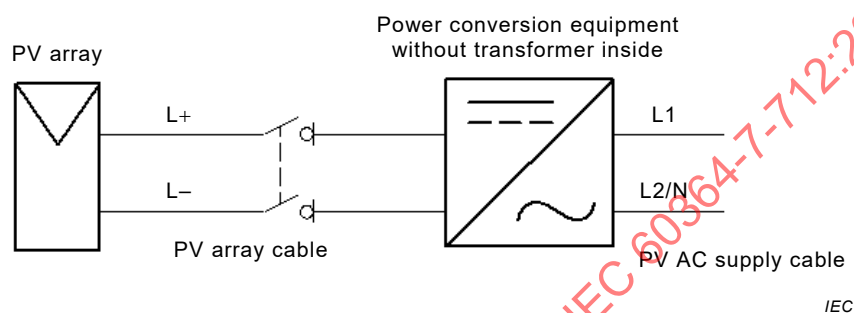


Figure A.712.4 – Unearthed PV array connected to the AC side via a PCE without a transformer

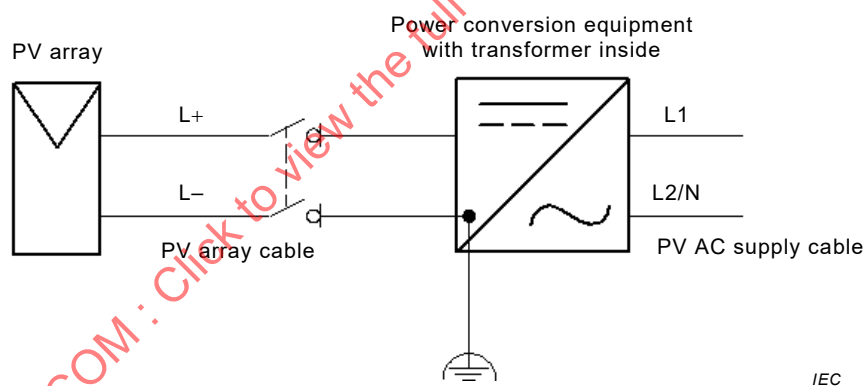


Figure A.721.5 – Earthed PV array connected to the AC side via a PCE with transformer

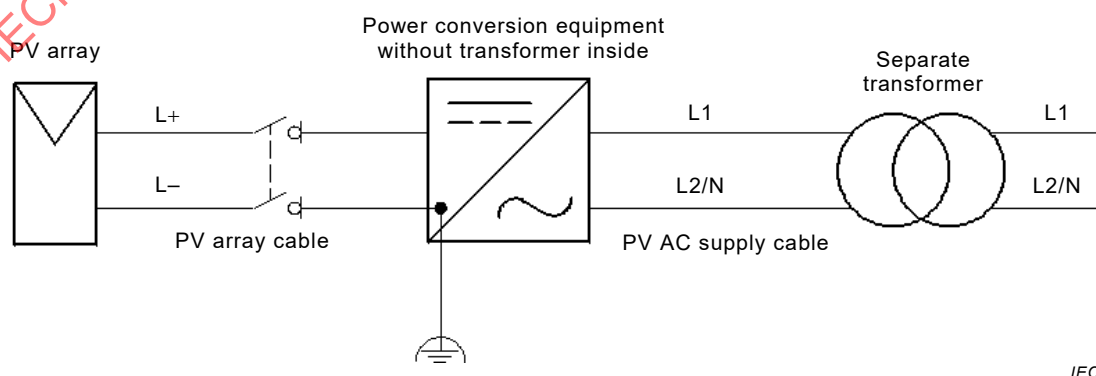


Figure A.712.6 – Earthed PV array connected to the AC side via a PCE without a transformer, the transformer being separate

Annex B (normative)

Calculation of $U_{OC\ MAX}$ and $I_{SC\ MAX}$

B.1 Calculation of $U_{OC\ MAX}$

$U_{OC\ MAX}$ is the maximum voltage across an unloaded (open circuit) PV module or PV string or PV array, calculated by the following formula:

$$U_{OC\ MAX} = K_U U_{OC\ STC}$$

The correction factor K_U takes into account the increase of open circuit voltage of modules, considering T_{min} the lowest ambient temperature of the PV installation site and αU_{OC} the temperature variation coefficient of U_{OC} voltage provided by the PV module manufacturer:

$$K_U = 1 + (\alpha U_{OC} / 100) (T_{min} - 25)$$

where

αU_{OC} is the temperature variation coefficient of U_{OC} module voltage, in %/°C;

T_{min} is the lowest temperature of the PV installation site, in °C.

αU_{OC} is a negative factor, which can be provided by the module manufacturer either in mV/°C or in %/°C. When αU_{OC} is expressed in mV/°C, work it out in %/°C by using the formula:

$$\alpha U_{OC} (\%/^{\circ}C) = 0,1 \alpha U_{OC} (mV/^{\circ}C) / U_{OC\ STC_Module} (V)$$

NOTE Example of module with αU_{OC} expressed in mV/°C. The following calculation is an example:

- Multicrystalline module, $U_{OC\ STC_Module} = 38,3\ V$ and $\alpha U_{OC} = -133\ mV/^{\circ}C$
 $\rightarrow \alpha U_{OC} = -0,35\ \%/^{\circ}C$
- $T_{min} = -15\ ^{\circ}C \rightarrow (T - 25) = -40^{\circ}C \rightarrow K_U = 1,14 \rightarrow U_{OC\ MAX} = 1,14 U_{OC\ STC}$
 $\rightarrow U_{OC\ MAX} = 1,14 \times 38,3 = 43,7\ V$

αU_{OC} can have very different values depending on the technology of PV modules.

For amorphous silicon modules, electrical characteristics during the first weeks of operation are higher than the specified characteristics. This phenomenon is indicated by the module manufacturer and has to be considered in the calculation of $U_{OC\ MAX}$.

Without information of the expected minimum temperature of the site or without information about the temperature coefficient of the PV module, $U_{OC\ MAX}$ shall be chosen equal to $1,2 U_{OC\ STC}$.

B.2 Calculation of $I_{SC\ MAX}$

The maximum short-circuit current of a PV module or PV string or PV array is calculated by the following formula:

$$I_{SC\ MAX} = K_I I_{SC\ STC}$$

Minimum value for K_I is 1,25.

Under certain conditions, K_1 shall be increased to take into account environmental situations, for example increased reflection or solar intensity.

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Annex C (informative)

Examples of signs

Annex C provides examples (see Figures C.712.1 and C.712.2) of appropriate signs as specified in 712.514.102 to 712.514.106.



**Figure C.712.1 – Example of sign required on
PV array combiner boxes (712.514.102)**

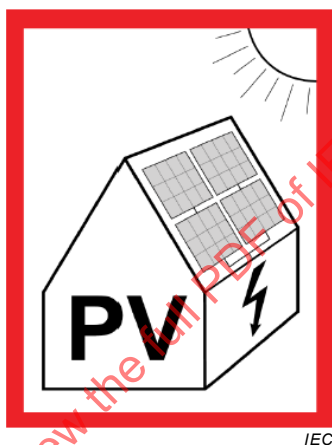


**Figure C.712.2 – Example of switchboard
sign for identification of PV on a building**

The sign should comply with the local fire services information requirements.

National committees or national regulations should decide on the labels and locations of such markings.

Annex D (informative)

Blocking diode

D.1 General

Annex D describes blocking diodes intended to be used to prevent reverse current in a PV array.

D.2 Use of blocking diodes to prevent overcurrent/fault current in arrays

A blocking diode is an effective means of stopping reverse current in PV arrays. Overcurrent/fault current in arrays is generally caused by current flowing from one section of an array operating normally into a section of an array containing a fault. The fault current is in the reverse direction. Provided correctly rated and functioning blocking diodes are in use in the PV array, reverse currents are prevented and fault currents either eliminated or significantly reduced (see examples in Figure D.712.3).

In some countries blocking diodes are allowed to replace overcurrent protective devices. This is an effective method of overcurrent/fault prevention provided the reliability of blocking diodes over time can be ensured.

D.3 Some considerations relating to short-circuit

D.3.1 Short-circuit in PV string

If a short-circuit develops in a string without blocking diodes as shown in Figure D.712.1 a), a fault current will flow around the faulted modules and extra fault current in the reverse direction will flow in some modules with the source of that current being from other strings. The reverse current can be interrupted by an overcurrent protective device provided the current is greater than the interrupting current of the overcurrent device. This may not be the case under low illumination conditions.

The situation of the same fault with an array with blocking diodes in each string is shown in Figure D.712.1 b). The fault current around the faulted modules cannot be intercepted with the blocking diode, however, the amount of fault current can be significantly reduced by the blocking diode obstructing the reverse current supplied from other strings as shown in Figure D.712.1 b). This functionality for this type of fault is useful for all PV installations whether the PV array is earthed or not and whether the PCE is a separated PCE or not.

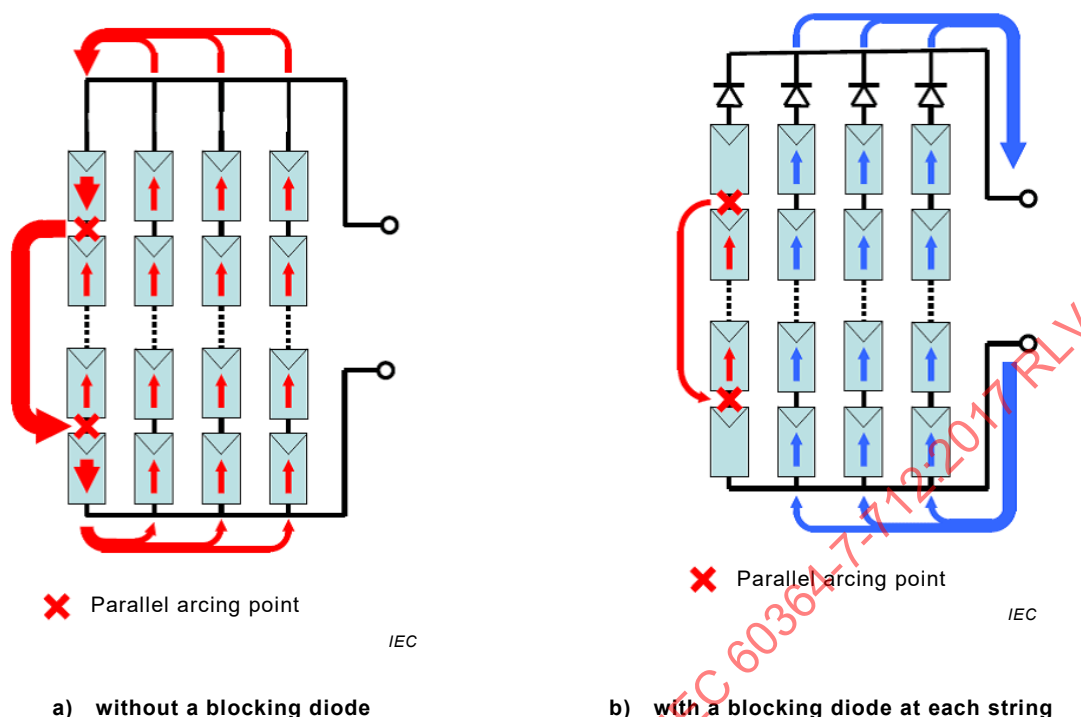


Figure D.712.1 – Effect of blocking diode at short circuit in PV string

D.3.2 Insulation fault in PV string for the array with a functional earth

Figure D.712.2 shows the fault current paths when an insulation fault occurs in a string of a PV array which is installed with a negative side functional earth. The worst case fault occurs when the fault is closest to the top of the string (i.e. the side furthest away from earth). In this case the blocking diodes need to be installed in the positive side of the strings.

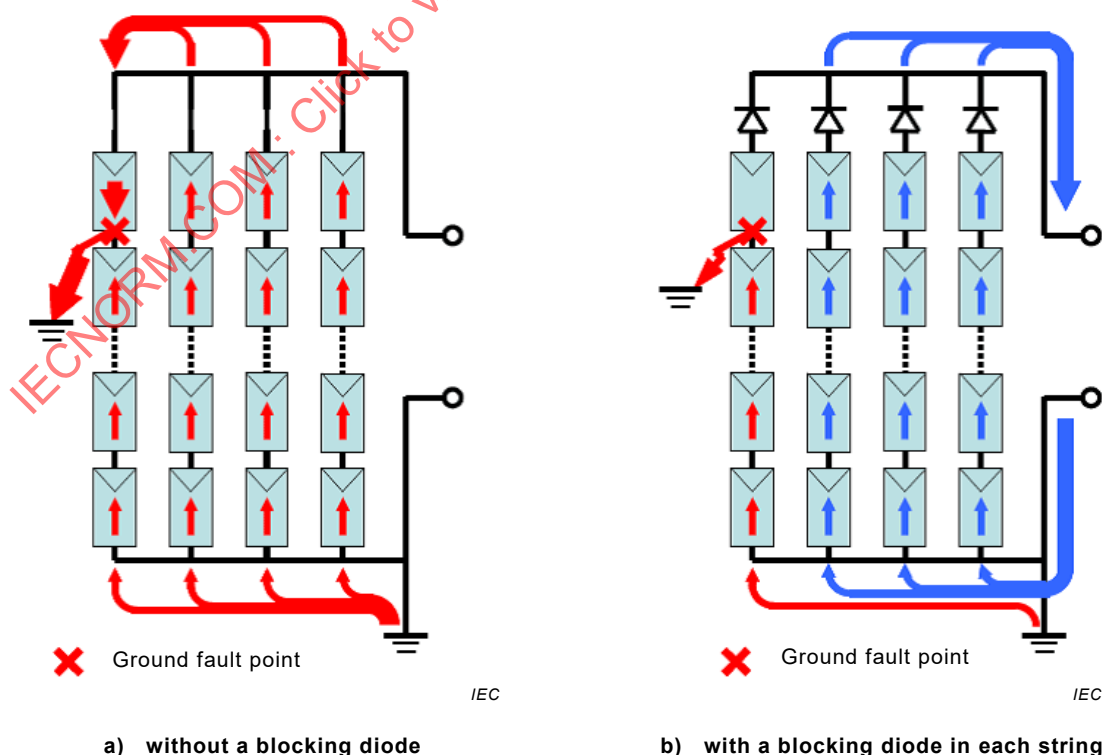


Figure D.712.2 – Effect of blocking diode where there is an insulation fault on a PV installation with earthing on the DC negative side

Figure D.712.3 shows the fault current paths when an insulation fault occurs in a string of a PV array which is installed with a positive side functional earth. The worst case fault occurs when the fault is closest to the bottom of the string (i.e. the side furthest away from earth). In this case the blocking diodes need to be installed in the negative side of the strings.

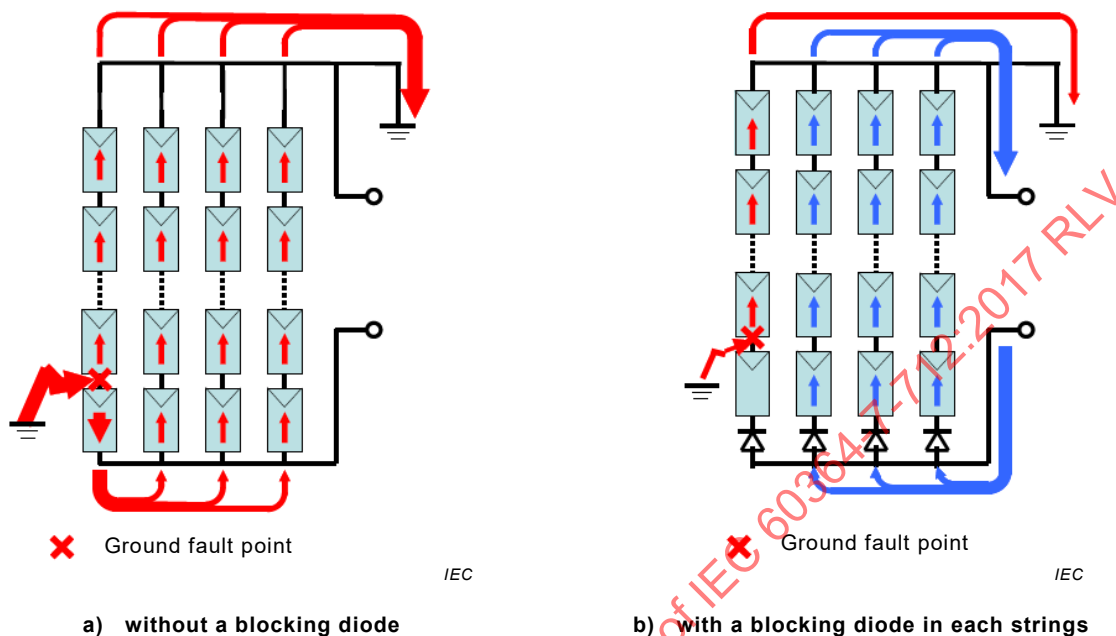


Figure D.712.3 – Effect of blocking diode where there is a fault on a PV installation with earthing on the DC positive side

In these cases Figure D.712.2 and Figure D.712.3 clearly show the advantage of a blocking diode in eliminating the fault current contribution from adjacent strings of the array. This diagram shows the situation of a directly earthed array with no impedance in the earth connection. It is preferred in this document to install functional earths with limiting resistors in the earth connection. If this method is used the potential fault current under these conditions is significantly reduced by the effect of the resistance limiting the maximum current.

D.4 Specification of blocking diode

See 712.55.102.

D.5 Heat dissipation design for blocking diode

Because the voltage drop of the blocking diode in the forward current operation might exceed 1 V, it is necessary to consider a heat dissipation design of diode for reliability. A heatsink may be required to keep diode junction temperatures within safe limits. A heat dissipation design methodology is shown in the following procedures:

- Calculate maximum current I_{MAX} by PV module current $I_{SC\ MOD}$ in STC.
 $I_{MAX} = 1,4 \times I_{SC\ MOD}$ (Use a higher factor depending on operating conditions)
- Obtain the operating forward voltage of the blocking diode V_{D_OP} at I_{MAX} from the operating characteristics of the diode.
- Calculate power dissipation P_{CAL}
 $P_{CAL} = V_{D_OP} \times I_{MAX}$
- Calculate the thermal resistance R_{TH} according to the following expression so that the junction temperature T_J of the blocking diode should not exceed the limit value in consideration of ambient temperature T_{AMB} .

$$R_{TH} = (T_J - T_{AMB})/P_{CAL}$$

- If the thermal resistance required is less than the diode's junction to case plus case to air thermal resistance, then a heatsink will be required.

When there is a possibility of increased short-circuit current of the PV module, for example due to the reflection of snow or other conditions, the multiplier for the calculation of I_{MAX} should be larger than 1,4.

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Annex E (informative)

Arc fault detection and interruption in PV arrays

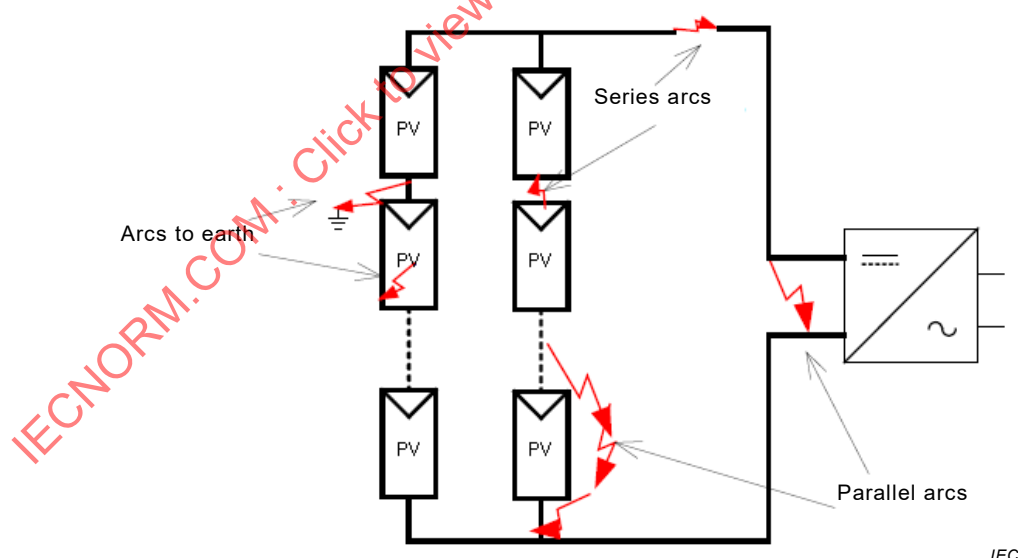
Unlike traditional electrical products, PV modules and wiring do not have an overall enclosure to contain arcs and fires resulting from component or wiring faults. Many PV installations operate at DC voltages which are very capable of sustaining DC arcs.

There are three main categories of arcs in PV installations (refer to Figure E.712.1).

- series arc which may result from a faulty connection or a series break in wiring;
- a parallel arc which may result as a partial short circuit between adjacent wiring which is at different potentials;
- arcs to earth which result from failure of insulation.

If an arc develops due to a fault in a PV array this can result in significant damage to the array and may also result in damage to adjacent wiring and building structures. The most serious arc is likely to be a parallel arc because of the energy that is available to feed this type of arc, especially when the arc is between the main PV array conductors. This document requires cables in PV array wiring to be suitable to be used with Class II equipment, and because of this requirement parallel arcs are very unlikely, unless caused as a result of significant insulation damage due to fire damage or severe mechanical damage to cables.

The most likely type of arc to occur in a PV installation is a series arc. This is because PV installations typically contain a very large number of series connections. Series arcs are generally able to be stopped quickly by removing the electrical load from the PV array. In the case of grid connected PV installations this can be accomplished easily by shutting down the PCE. Parallel arcs are much more difficult to extinguish but are also much less likely to occur.



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Figure E.712.1 – Examples of types of arcs in PV arrays

If a series arc is not extinguished quickly it may propagate to involve other conductors and produce parallel arcs. It is therefore desirable to have a method of detecting and interrupting arcs in PV installations quickly. A new standard has been developed by Underwriters Laboratories – UL1699B “Photovoltaic (PV) DC Arc-Fault Circuit Protection” and manufacturers are in the process of developing equipment to meet this standard. The purpose of the arc-fault circuit protection equipment is to detect and discriminate accurately arcs in PV arrays and to take action to interrupt the arc.

Annex F
(informative)

List of notes concerning certain countries

Country	Subclause N°	Nature (permanent or less permanent according to IEC Directives)	Rationale (detailed justification for the requested country note)	Wording
AT	712.414.101			In Austria, due the “particular characteristics of PV installations”, as stated in the scope of this document and the fact, that such equipment is as well used by ordinary persons only a limit of 35 V is acceptable.
AT	712.521.101.1			In Austria, halogen free low smoke DC cables are required when those cables are routed inside buildings.
NO	712.536.2			In Norway, where double or reinforced insulation is used as protective measure for protection against electric shock on the DC side, means of isolation shall be provided between sections of PV modules limiting the $U_{OC\ MAX}$ of the section to 120 V DC.
CH	712.542.103			In Switzerland, in buildings with a LPS the minimum cross section of copper is 10 mm ² .

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

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

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

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

IEC 61008-1, *Residual current operated circuit-breakers without integral overcurrent protection for household and similar uses (RCCBs) – Part 1: General rules*

IEC 61277, *Terrestrial photovoltaic (PV) power generating systems – General and guide*¹

IEC 61557-2, *Electrical safety in low voltage distribution systems up to 1 000 V a.c. and 1 500 V d.c. – Equipment for testing, measuring or monitoring of protective measures – Part 2: Insulation resistance*

IEC 61557-9, *Electrical safety in low voltage distribution systems up to 1 000 V a.c. and 1 500 V d.c. – Equipment for testing, measuring or monitoring of protective measures – Part 9: Equipment for insulation fault location in IT systems*

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

IEC 61829, *Photovoltaic (PV) array – On-site measurement of current-voltage characteristics*

¹ Withdrawn.

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

IEC 62246-1, *Reed switches – Part 1: Generic specification*

IEC 62305 (all parts), *Protection against lightning*

IEC 62305-2:2010, *Protection against lightning – Part 2: Risk management*

IEC 62305-4, *Protection against lightning – Part 4: Electrical and electronic systems within structures*

IEC 62930, *Electric cables for photovoltaic systems*²

UL1699B, *Photovoltaic (PV) DC Arc-Fault Circuit Protection*

² Under preparation. Stage at the time of publication: IEC CCDV 62930:2016.

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INSTALLATIONS ELECTRIQUES BASSE TENSION –

Partie 7-712: Exigences applicables aux installations ou emplacements spéciaux – Installations d'énergie solaire photovoltaïque (PV)

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La Norme internationale IEC 60364-7-712 a été établie par le comité d'études 64 de l'IEC: Installations électriques et protection contre les chocs électriques.

Cette deuxième édition annule et remplace la première édition parue en 2002. Cette édition constitue une révision technique.

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

- a) le contenu technique a été considérablement revu et étendu, pour tenir compte du retour d'expérience dans la construction et l'exploitation des installations photovoltaïques, et des développements technologiques depuis la parution de la première édition de cette norme.

Le texte de cette norme est issu des documents suivants:

FDIS	Rapport de vote
64/2154/FDIS	64/2163/RVD

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

Cette publication a été rédigée selon les Directives ISO/IEC, Partie 2.

L'attention est attirée sur la co-existence des normes IEC 60364-7-712 et IEC 62548. Ces deux normes ont été élaborées en étroite collaboration par deux comités techniques différents.

Une liste de toutes les parties de la série IEC 60364, publiées sous le titre général *Installations électriques à basse tension*, peut être consultée sur le site web de l'IEC.

L'attention du lecteur est attirée sur le fait que l'Annexe F énumère tous les articles traitant des différences à caractère moins permanent inhérentes à certains pays, concernant le sujet de la présente norme.

Le comité a décidé que le contenu de cette publication ne sera pas modifié avant la date de stabilité indiquée sur le site web de l'IEC sous "<http://webstore.iec.ch>" dans les données relatives à la publication recherchée. A cette date, la publication sera

- reconduite,
- supprimée,
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INTRODUCTION

Pour les besoins de la présente partie (IEC 60364-7-712), les exigences des parties générales 1 à 6 de l'IEC 60364 s'appliquent.

Les parties 7-7XX de l'IEC 60364 contiennent des exigences particulières pour les installations et emplacements spéciaux, qui sont fondées sur les exigences des parties générales de l'IEC 60364 (parties 1 à 6). Ces parties IEC 60364-7-7XX sont prises en compte conjointement avec les exigences des parties générales.

Les exigences particulières de la présente partie de l'IEC 60364 complètent, modifient ou remplacent certaines des exigences des parties générales de l'IEC 60364 en vigueur au moment de la publication de la présente partie. L'absence de référence à l'exclusion d'une partie ou d'un article d'une partie générale signifie que les articles correspondants de la partie générale sont applicables (références non datées).

Les exigences des autres parties 7XX pertinentes pour les installations couvertes par la présente partie s'appliquent également. Par conséquent, la présente partie peut également compléter, modifier ou remplacer certaines de ces exigences en vigueur au moment de sa publication.

La numérotation des articles de la présente partie suit la structure et les références correspondantes de l'IEC 60364. Les numéros placés derrière le numéro spécifique de la présente partie sont ceux des parties ou des articles correspondants des autres parties de l'IEC 60364, en vigueur au moment de la publication de la présente partie, comme indiqué dans les références normatives du présent document (références datées). Si des exigences ou des explications en plus de celles des autres parties de l'IEC 60364 sont nécessaires, la numérotation de tels éléments se fait de la manière suivante 712.101, 712.102, 712.103, etc.

La numérotation des figures et des tableaux est constituée du numéro de la partie concernée suivi d'un numéro séquentiel. En ce qui concerne les annexes, la numérotation des figures et des tableaux est constituée de la lettre de l'annexe, du numéro de la partie et d'un numéro séquentiel.

Si des parties générales nouvelles ou amendées étaient publiées avec une numérotation modifiée après la parution de la présente partie, les numéros d'articles se référant à une partie générale dans cette partie 7-712 pourraient ne plus correspondre avec la dernière édition des parties générales. Il conviendrait alors de prendre en compte les références datées.

INSTALLATIONS ELECTRIQUES BASSE TENSION –

Partie 7-712: Exigences applicables aux installations ou emplacements spéciaux – Installations d'énergie solaire photovoltaïque (PV)

712 Installations d'énergie solaire photovoltaïque (PV)

NOTE Dans la suite du texte, le terme abrégé «PV» est utilisée pour «photovoltaïque». Ainsi les installations photovoltaïques sont ci-après appelées installations PV.

712.1 Domaine d'application

La présente partie de l'IEC 60364 s'applique à l'installation électrique de systèmes PV conçus pour alimenter tout ou partie d'une installation.

Les équipements d'une installation PV, ainsi que tout autre élément, ne sont traités que du point de vue de leur choix et mise en œuvre dans l'installation.

Une installation PV commence d'un module PV ou d'un ensemble de modules PV reliés en série au moyen de leurs câbles, fournis par le fabricant de modules PV, jusqu'à l'installation de l'utilisateur ou le point d'alimentation du réseau de distribution public (point de couplage commun).

Les exigences du présent document s'appliquent

- aux installations PV non reliées à un réseau de distribution public,
- aux installations PV parallèlement à un réseau de distribution public,
- aux installations PV comme variante à un réseau de distribution public,
- à des combinaisons appropriées des installations ci-dessus.

Le présent document ne concerne pas les exigences d'installation spécifiques relatives aux batteries ou autres méthodes de stockage d'énergie.

NOTE 1 Des exigences supplémentaires applicables aux installations PV ayant des capacités de stockage dans des batteries du côté courant continu sont actuellement à l'étude.

NOTE 2 Le présent document traite des exigences de protection des groupes PV, qui s'imposent du fait de l'utilisation de batteries dans les installations PV.

Pour les systèmes utilisant des convertisseurs continu-continu, des exigences supplémentaires relatives à la tension assignée, au courant assigné, à la coupure et aux dispositifs de protection peuvent s'appliquer. Ces exigences sont à l'étude.

L'objet du présent document est de traiter des exigences de sécurité de conception découlant des caractéristiques particulières des installations PV. Les systèmes à courant continu, en particulier les groupes PV, présentent certains dangers qui viennent s'ajouter à ceux des systèmes d'alimentation en courant alternatif conventionnels, notamment leur tendance à produire et à maintenir des arcs électriques sous des intensités de courant ne dépassant pas celles des courants de fonctionnement normaux.

Toutefois, dans les installations PV connectées au réseau électrique, les exigences de sécurité du présent document dépendent essentiellement du PCE associé aux groupes PV conformes aux exigences des normes IEC 62109-1 et IEC 62109-2.

712.2 Références normatives

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

IEC 60228, *Ames des câbles isolés*

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

IEC 60332-1-2, *Essais des câbles électriques et à fibres optiques soumis au feu – Partie 1-2: essai de propagation verticale de la flamme sur conducteur ou câble isolé – Procédure pour flamme à pré-mélange de 1 kW*

IEC 60364 (toutes les parties), *Installations électriques à basse tension*

IEC 60364-4-41:2005, *Installations électriques à basse tension – Partie 4-41: Protection pour assurer la sécurité – Protection contre les chocs électriques*

IEC 60364-4-43, *Installations électriques à basse tension – Partie 4-43: Protection pour assurer la sécurité – Protection contre les surintensités*

IEC 60364-4-44, *Installations électriques à basse tension – Partie 4-44: Protection pour assurer la sécurité – Protection contre les perturbations de tension et les perturbations électromagnétiques*

IEC 60670 (toutes les parties), *Boîtes et enveloppes pour appareillage électrique pour installations électriques fixes pour usages domestiques et analogues*

IEC 60898, (toutes les parties), *Disjoncteurs pour la protection contre les surintensités pour installations domestiques et analogues*

IEC 60898-2, *Disjoncteurs pour la protection contre les surintensités pour installations domestiques et analogues – Partie 2: Disjoncteurs pour le fonctionnement en courant alternatif et en courant continu*

IEC 60947 (toutes les parties), *Appareillage à basse tension*

IEC 60947-1, *Appareillage à basse tension – Partie 1: Règles générales*

IEC 60947-2, *Appareillage à basse tension – Partie 2: Disjoncteurs*

IEC 60947-3, *Appareillage à basse tension – Partie 3: Interrupteurs, sectionneurs, interrupteurs-sectionneurs et combinés-fusibles*

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

IEC 61215 (toutes les parties), *Modules photovoltaïques (PV) pour application terrestre – Qualification de la conception et homologation*

IEC 61439 (toutes les parties), *Ensembles d'appareillage à basse tension*

IEC 61439-2, *Ensembles d'appareillage à basse tension – Partie 2: Ensembles d'appareillage de puissance*

IEC 61557-8:2014, *Sécurité électrique dans les réseaux de distribution basse tension de 1 000 V c.a. et 1 500 V c.c. – Dispositifs de contrôle, de mesure ou de surveillance de mesures de protection – Partie 8: Contrôleur permanent d'isolement pour réseaux IT*

IEC 62109 (toutes les parties), *Sécurité des convertisseurs de puissance utilisés dans les systèmes photovoltaïques*

IEC 62109-1:2010, *Safety of power converters for use in photovoltaic power systems – Part 1: General requirements* (disponible en anglais seulement)

IEC 62109-2, *Sécurité des convertisseurs de puissance utilisés dans les systèmes photovoltaïques – Partie 2: Exigences particulières pour les onduleurs*

IEC 62262, *Degrés de protection procurés par les enveloppes de matériels électriques contre les impacts mécaniques externes (Code IK)*

IEC 62423, *Interrupteurs automatiques à courant différentiel résiduel de type B et de type F avec et sans protection contre les surintensités incorporée pour usages domestiques et analogues*

IEC 62446-1, *Systèmes photovoltaïques (PV) – Exigences pour les essais, la documentation et la maintenance – Partie 1: Systèmes connectés au réseau électrique – Documentation, essais de mise en service et examen*

IEC 62852:2014, *Connecteurs pour applications en courant continu pour systèmes photovoltaïques – Exigences de sécurité et essais*

712.3 Termes et définitions

Pour les besoins du présent document, les termes et définitions suivants s'appliquent.

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

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

712.3.1

cellule PV

cellule photovoltaïque

cellule solaire

cellule photovoltaïque solaire

dispositif le plus élémentaire présentant l'effet photovoltaïque, c'est-à-dire la conversion directe non thermique de l'énergie rayonnante en énergie électrique

Note 1 à l'article: Le terme préférentiel est "cellule photovoltaïque solaire" ou "cellule photovoltaïque", communément désignée "cellule solaire".

[SOURCE: IEC 61836:2007, 3.1.43 a), modifiée — "présentant ... énergie électrique" a été ajouté]

712.3.2

module PV

plus petit ensemble complet, protégé des intempéries, de cellules interconnectées

Note 1 à l'article: Voir l'IEC 60904-3.

712.3.3

chaîne PV

circuit constitué d'un ou de plusieurs modules connectés en série

[SOURCE: IEC 61836:2007, modifiée – "d'un ou de plusieurs" a été rajouté]

712.3.4

groupe PV

ensemble de modules PV, de chaînes PV ou de sous-groupes PV interconnectés électriquement

Note 1 à l'article: Pour les besoins du présent document, un groupe PV représente tous les composants jusqu'aux bornes d'entrée du côté courant continu de l'onduleur ou des charges en courant continu. Un groupe PV ne comprend pas les fondations des supports, le système de suivi de trajectoire, les dispositifs de contrôle thermique et autres accessoires.

Note 2 à l'article: Un groupe PV peut être constitué d'un seul module PV, d'une seule chaîne PV ou de plusieurs chaînes montées en parallèle, ou de plusieurs sous-groupes PV montés en parallèle ainsi que des composants électriques qui leur sont associés (voir Figures 712.2 à 712.4). Pour les besoins du présent document, la limite d'un groupe PV est le côté sortie du dispositif de sectionnement du groupe PV.

712.3.5

sous-groupe PV

sous-ensemble électrique d'un groupe PV constitué de modules PV ou de chaînes PV connectés en parallèle.

712.3.6

câble de chaîne PV

câble servant à interconnecter les modules en chaîne PV ou à connecter la chaîne à un coffret de regroupement, un PCE ou d'autres charges en courant continu

Note 1 à l'article: Des exemples de câble de chaîne PV sont donnés à la Figure 712.3 et la Figure 712.4.

712.3.7

câble de groupe PV

câble de sortie d'un groupe PV transportant le courant de sortie total du groupe

712.3.8

câble d'alimentation PV en courant alternatif

câble reliant les bornes du côté courant alternatif du PCE PV à un tableau de répartition de l'installation électrique

712.3.9

circuit d'alimentation PV en courant alternatif

circuit reliant les bornes du côté courant alternatif du PCE PV à un tableau de répartition de l'installation électrique

712.3.10

module alternatif PV

ensemble intégré module/PCE pour lequel les bornes d'interface sont uniquement en courant alternatif et pour lequel il n'est prévu aucun accès du côté courant continu

712.3.11

installation PV

équipements mis en œuvre dans une installation d'alimentation PV

712.3.12

conditions d'essai normalisées

STC

ensemble normalisé de conditions de référence utilisées pour les essais et le dimensionnement des cellules et des modules photovoltaïques, comme indiqué dans la norme produit pertinente, par exemple IEC 61215

Note 1 à l'article: Les conditions d'essai normalisées indiquées dans l'IEC 61215 pour les modules PV sont:

- a) une température de cellule PV de 25 °C;
- b) un éclairement énergétique dans le plan de la cellule ou du module PV de 1 000 W/m²;
- c) un spectre lumineux correspondant à une masse d'air atmosphérique de 1,5.

Note 2 à l'article: Le terme abrégé «STC» est dérivé du terme anglais développé correspondant «standard test conditions».

712.3.13

tension en circuit ouvert dans des conditions d'essai normalisées

$U_{OC\ STC}$

tension, dans des conditions d'essai normalisées, aux bornes d'un module PV, d'une chaîne PV ou d'un groupe PV non chargé (ouvert) ou aux bornes, côté courant continu, du PCE PV

712.3.14

tension maximale en circuit ouvert

$U_{OC\ MAX}$

tension maximale aux bornes d'un module PV, d'une chaîne PV ou d'un groupe PV non chargé (ouvert) ou aux bornes, côté courant continu, du PCE PV

Note 1 à l'article: La méthode de détermination de $U_{OC\ MAX}$ est donnée à l'Annexe B.

712.3.15

courant de court-circuit dans des conditions d'essai normalisées

$I_{SC\ STC}$

courant de court-circuit d'un module PV, d'une chaîne PV ou d'un groupe PV dans des conditions d'essai normalisées

712.3.16

courant maximal de court-circuit

$I_{SC\ MAX}$

courant maximal de court-circuit d'un module PV, d'une chaîne PV ou d'un groupe PV

Note 1 à l'article: La méthode de détermination de $I_{SC\ MAX}$ est donnée à l'Annexe B.

712.3.17

courant de retour

courant maximal pouvant passer du PCE au groupe PV et à son câblage dans des conditions normales ou de premier défaut

712.3.18

courant inverse

courant pouvant réalimenter un circuit PV à partir de chaînes ou de sous-groupes connectés en parallèle par suite d'un défaut, par exemple un court-circuit dans le circuit affecté

712.3.19

courant de court-circuit assigné

I_{SCPV}

valeur maximale présumée d'un courant de court-circuit du groupe PV pour lequel sont prévues les caractéristiques assignées du parafoudre, associées à ses sectionneurs spécifiés

712.3.20**côté courant continu**

partie d'une installation PV située entre les modules PV et les bornes du côté courant continu du PCE PV

712.3.21**côté courant alternatif**

partie d'une l'installation PV située entre les bornes côté courant alternatif du PCE PV et le point de connexion du câble d'alimentation PV à l'installation électrique

712.3.22**suivi du point de fonctionnement à puissance maximale****MPPT**

stratégie de contrôle dans laquelle le fonctionnement du groupe PV est toujours égal au ou proche du point des caractéristiques de tension-courant du dispositif PV, auquel le produit du courant et de la tension génère la tension électrique maximale dans des conditions de fonctionnement spécifiées

Note 1 à l'article: Le terme abrégé «MPPT» est dérivé du terme anglais développé correspondant «maximum power point tracking».

712.3.23

$I_{MOD_MAX_OCPR}$

valeur assignée maximale de protection contre les surintensités du module PV

Note 1 à l'article: Voir l'IEC 61730-2.

712.3.24**diode antiretour**

diode connectée en série à un ou plusieurs modules, chaînes et sous-groupes pour bloquer le courant inverse

712.3.25**diode de dérivation**

diode connectée en parallèle à une ou plusieurs cellules dans le sens direct du courant

Note 1 à l'article: L'objectif est de permettre au courant du module de contourner les cellules voilées ou en défaut pour empêcher des dommages dus à des points chauds ou des cellules chaudes qui résulteraient de la polarisation par une tension inverse des autres cellules de ce module.

712.3.26**mise à la terre pour des raisons fonctionnelles****FE**

mise à la terre d'un ou de plusieurs points d'un réseau, d'une installation ou d'un matériel pour des raisons autres que la sécurité électrique

Note 1 à l'article: Un tel système n'est pas considéré comme étant un groupe relié à la terre.

Note 2 à l'article: Des exemples de mise à la terre d'un groupe pour des raisons fonctionnelles comprennent la mise à la terre d'un conducteur à travers une impédance, ou seulement la mise à la terre temporaire du groupe pour des raisons fonctionnelles ou de performance.

Note 3 à l'article: Dans un PCE conçu pour un groupe non relié à une terre fonctionnelle qui utilise un réseau de mesure résistif pour mesurer l'impédance du groupe par rapport à la terre, ce réseau de mesure n'est pas considéré comme une forme de terre fonctionnelle.

Note 4 à l'article: Le terme abrégé «FE» est dérivé du terme anglais développé correspondant «functional earthing».

[SOURCE: IEC 60050:2004, 826-13-10, modifiée – les notes ont été ajoutées]

712.3.27**éclairage énergétique***G*

alimentation photovoltaïque rayonnée électromagnétique par unité de zone

Note 1 à l'article: L'éclairage énergétique est exprimé en W/m^2 .

[SOURCE: IEC 61836:2007, 3.6.25 modifiée – la note et les sous-articles ont été supprimés]

712.3.28*I_{SC} ARRAY*

courant de court-circuit du groupe PV dans des conditions d'essai normalisées

712.3.29*I_{SC} MOD*

courant de court-circuit d'un module ou d'une chaîne PV dans des conditions d'essai normalisées (STC) conformément aux spécifications indiquées par le fabricant sur la plaque signalétique du produit

Note 1 à l'article: Comme les chaînes PV sont un groupe de modules PV connectés en série, le courant de court-circuit d'une chaîne est égal à $I_{SC\ MOD}$.

712.3.30*I_{SC} S-ARRAY*

courant de court-circuit d'un sous-groupe PV dans des conditions d'essai normalisées (STC)

712.3.31**équipement de conversion de puissance****PCE**

système convertissant la puissance électrique fournie par le groupe PV pour lui donner des valeurs de fréquence et/ou de tension appropriées pour l'alimentation d'une charge, le stockage dans une batterie ou l'injection dans le réseau électrique

VOIR: Figures 712.2 à 712.4.

Note 1 à l'article: Le terme abrégé «PCE» est dérivé du terme anglais développé correspondant «power conversion equipment».

712.3.32**onduleur**

PCE qui convertit la tension continue et le courant continu du groupe PV en une tension alternative et un courant alternatif

Note 1 à l'article: Le terme abrégé «PCE» est dérivé du terme anglais développé correspondant «power conversion equipment».

712.3.33**PCE isolé**

PCE avec au moins une séparation galvanique entre les circuits de sortie de l'alimentation principale et les circuits PV

Note 1 à l'article: La séparation galvanique peut être intégrée au PCE ou bien externe, par exemple un PCE avec un transformateur d'isolement externe.

Note 2 à l'article: Dans un PCE avec plus de deux circuits externes, il peut y avoir un isolement galvanique entre certaines paires de circuits et pas d'isolement galvanique entre d'autres paires. Par exemple, un onduleur avec un circuit PV, un circuit de batterie et un circuit d'alimentation peut fournir un isolement galvanique entre le circuit du réseau de distribution et le circuit PV, mais ne pas en fournir entre le circuit PV et le circuit de batterie.

712.3.34**PCE non isolé**

PCE sans séparation galvanique entre les circuits de sortie de l'alimentation principale et les circuits PV ou avec des courants de fuite supérieurs aux limites exigées pour les PCE isolés

712.3.35**coffret de regroupement de groupes PV**

enveloppe dans laquelle les sous-groupes PV sont connectés et qui peut également contenir des appareillages de protection contre les surintensités et/ou des appareillages de coupure et sectionnement

Note 1 à l'article: En général, les groupes de petites dimensions ne contiennent pas de sous-groupes et sont simplement constitués de chaînes, contrairement aux groupes importants qui sont généralement constitués de plusieurs sous-groupes.

712.3.36**coffret de regroupement de chaînes PV**

enveloppe dans laquelle les chaînes PV sont connectées et qui peut également contenir des appareillages de protection contre les surintensités et/ou des appareillages de coupure et sectionnement

712.3.37**câble de sous-groupe PV**

câble de sortie d'un sous-groupe PV transportant le courant de sortie du sous-groupe auquel il est associé

712.3.38

$U_{OC\ ARRAY}$

tension en circuit ouvert d'un groupe PV dans des conditions d'essai normalisées

712.3.39

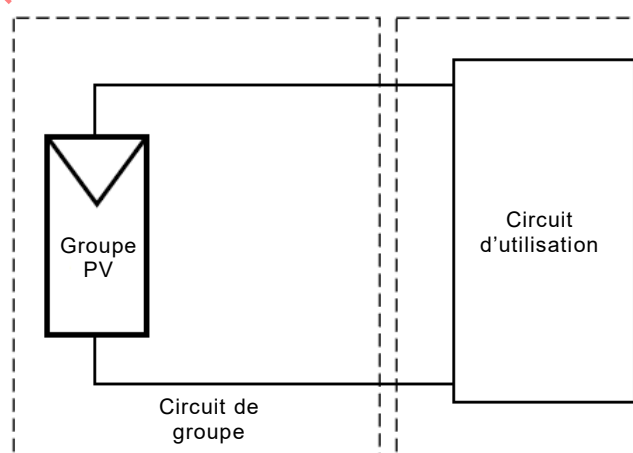
$V_{OC\ MOD}$

tension en circuit ouvert d'un module PV dans des conditions d'essai normalisées, tel que spécifié par le fabricant dans la spécification du produit

712.31 Objet, alimentations et structure**712.31.101 Configuration de groupe PV****712.31.101.1 Généralités**

Les groupes PV servent à alimenter un circuit d'utilisation.

La Figure 712.1 représente la configuration fonctionnelle générale d'une installation PV.



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Figure 712.1 – Configuration fonctionnelle générale d'une installation PV

Trois types de circuits d'utilisation sont envisagés:

- le groupe PV est connecté à des charges en courant continu;
- le groupe PV est connecté à une installation à courant alternatif via un PCE comportant au moins une séparation galvanique;
- le groupe PV est connecté à une installation à courant alternatif via un PCE ne comportant pas de séparation galvanique.

712.31.101.1.1 Architectures de l'installation PV

La liaison d'un groupe PV à la terre est déterminée par l'utilisation éventuelle d'une mise à la terre du groupe pour des raisons fonctionnelles, par l'impédance de cette connexion de terre, ainsi que par l'état de mise à la terre du circuit d'utilisation (par exemple, PCE ou autre équipement) auquel il est raccordé. Ces éléments, ainsi que l'emplacement de la connexion de terre, affectent la sécurité du groupe PV (voir l'Annexe A).

Les exigences des fabricants de modules PV et de PCE auxquels le groupe PV est connecté doivent être prises en compte dans la détermination des mesures les plus appropriées pour la mise à la terre du système.

Une mise à la terre pour des raisons de protection n'est admise pour aucun des conducteurs du groupe PV. La mise à la terre d'un des conducteurs du groupe PV pour des raisons fonctionnelles n'est pas admise sauf s'il existe au moins une séparation galvanique avec la mise à la terre du réseau de distribution au sein même du PCE ou depuis l'extérieur via un transformateur distinct.

Si une séparation galvanique est fournie de façon externe, il ne doit pas y avoir d'autres équipements reliés au même circuit que le PCE.

NOTE Un conducteur à courant continu relié à la terre est considéré comme un conducteur sous tension.

712.31.101.1.2 Schémas électriques des groupes

Les schémas de la Figure 712.2 à la Figure 712.4 représentent les configurations électriques de base d'un système PV à une chaîne, à plusieurs chaînes en parallèle et à plusieurs sous-groupes, respectivement.

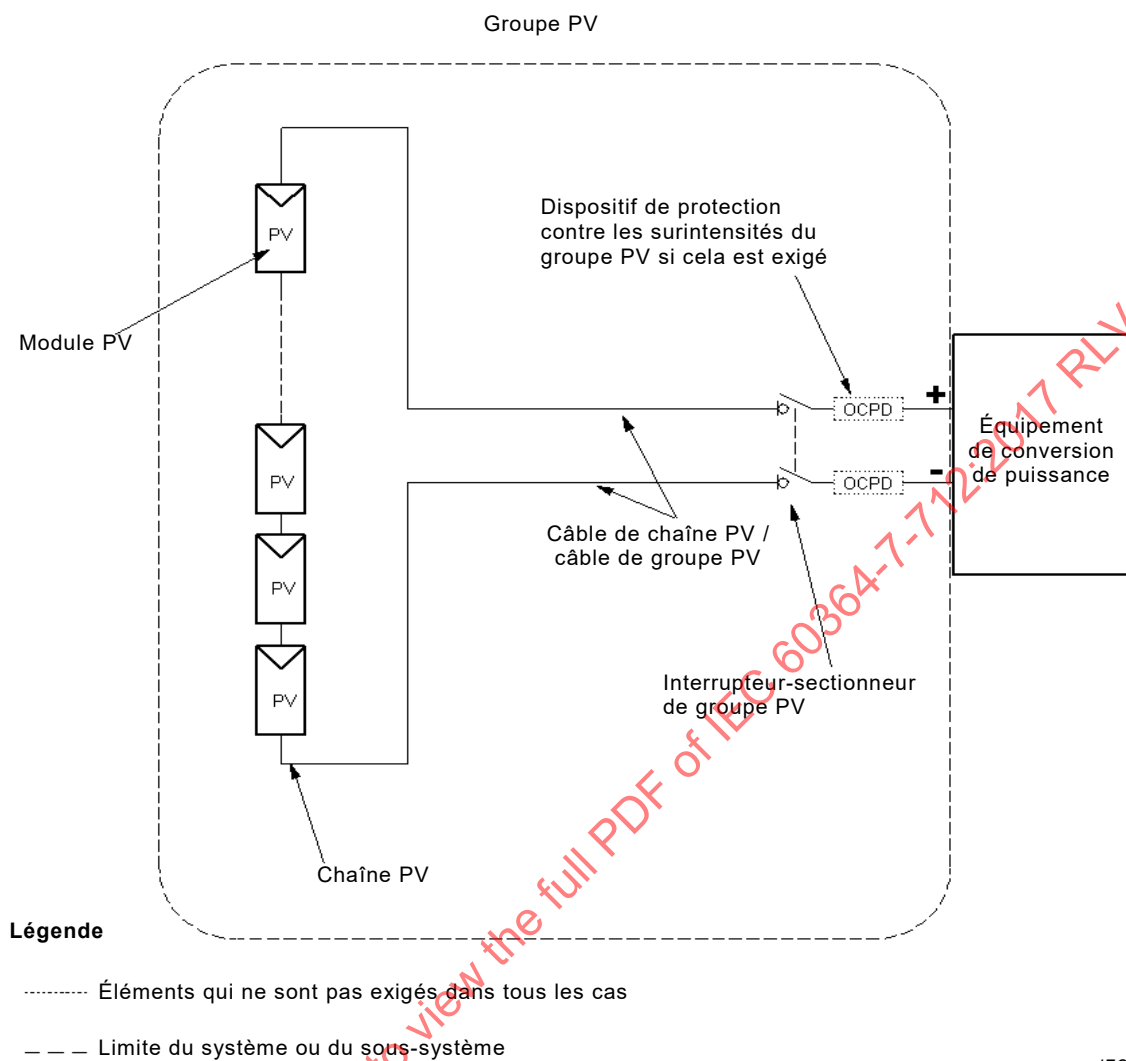
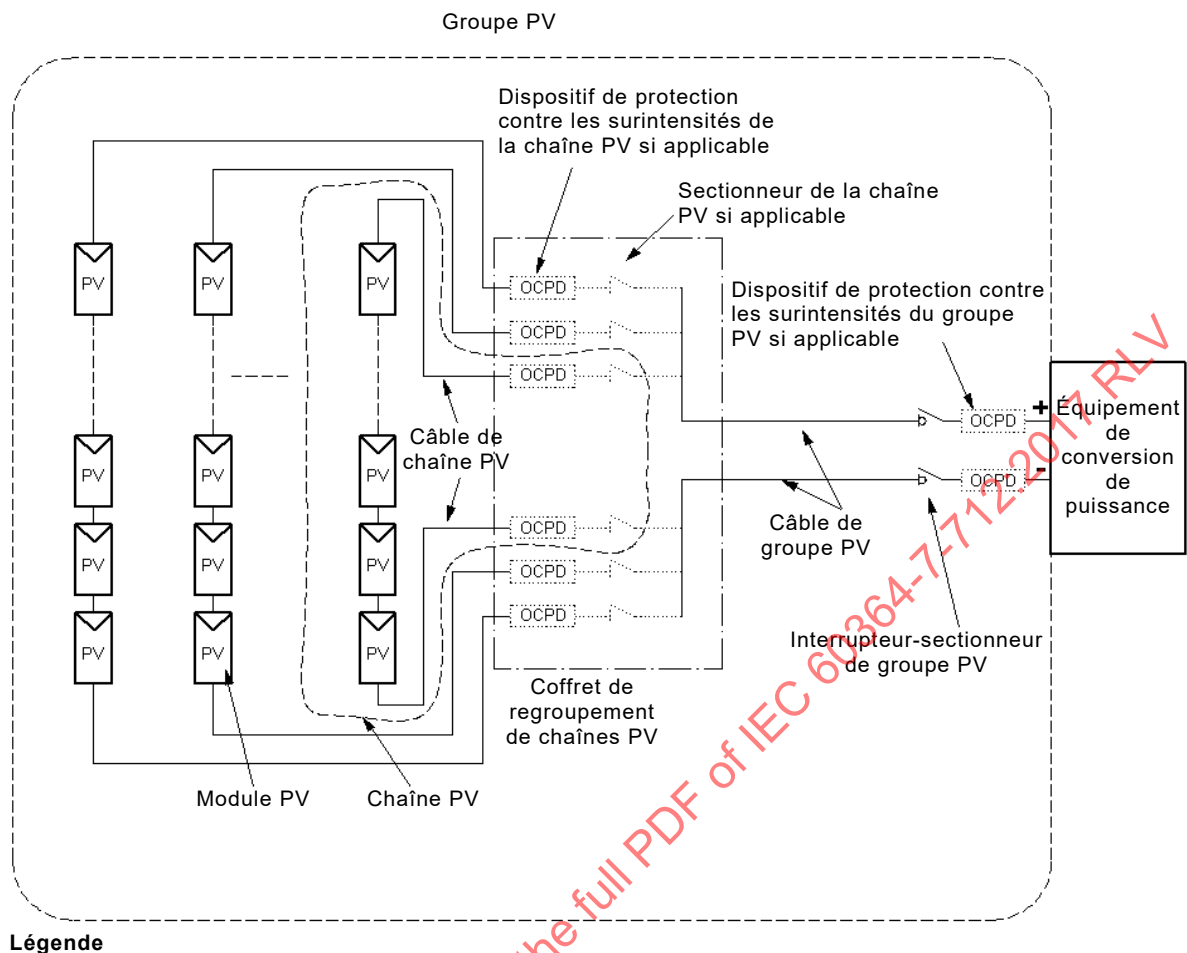


Figure 712.2 – Schéma d'un groupe PV – cas d'une chaîne unique

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Figure 712.3 – Schéma d'un groupe PV – cas de plusieurs chaînes en parallèle

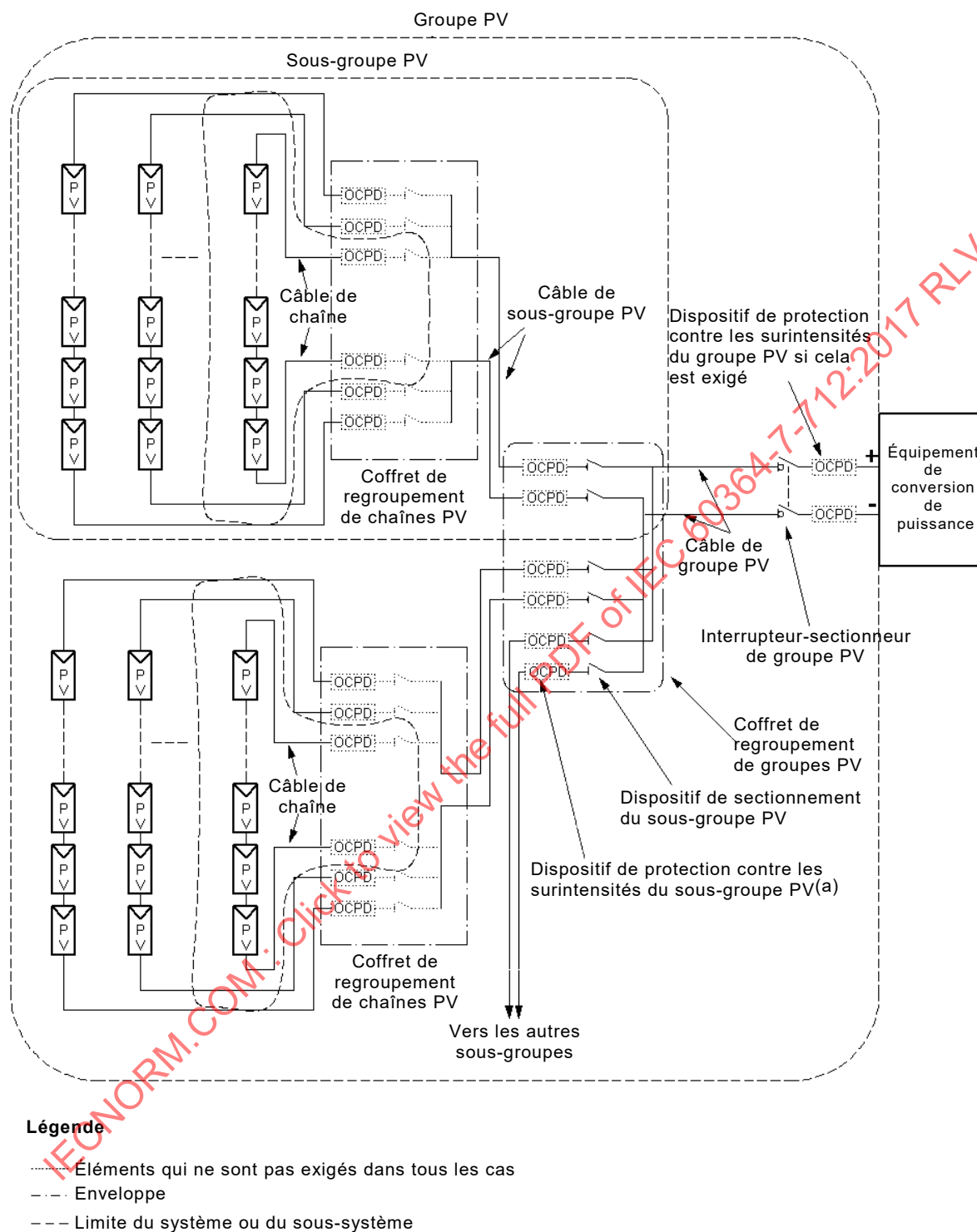


Figure 712.4 – Schéma d'un groupe PV – cas de plusieurs chaînes en parallèle avec groupe divisé en sous-groupes

Dans les Figures 712.2, 712.3 et 712.4, les composants représentés en pointillés ne sont pas nécessaires dans tous les cas. Les Figures indiquent l'emplacement, dans le circuit, des composants qui sont nécessaires.

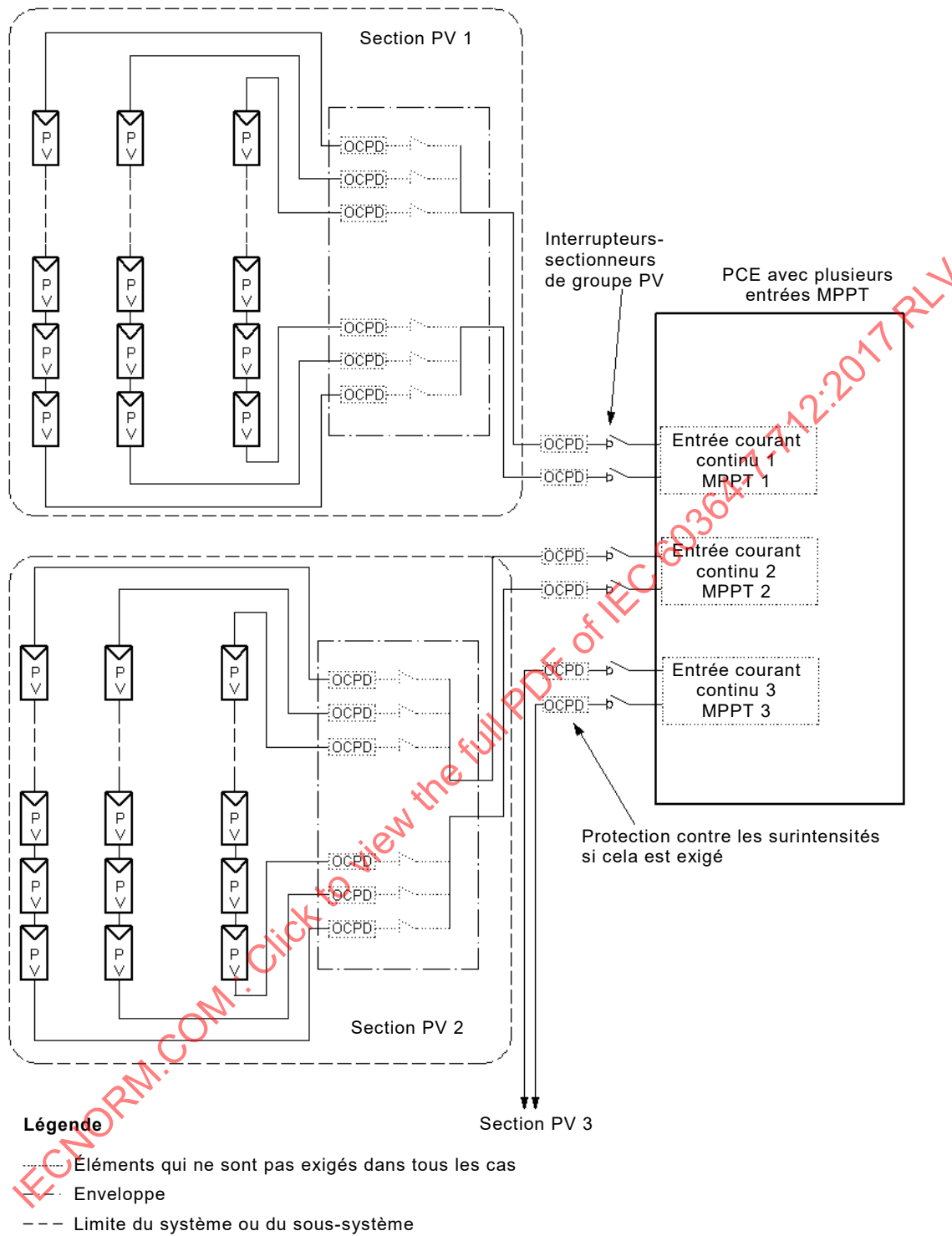


Figure 712.5 – Groupe PV qui utilise un PCE avec plusieurs entrées en courant continu MPPT

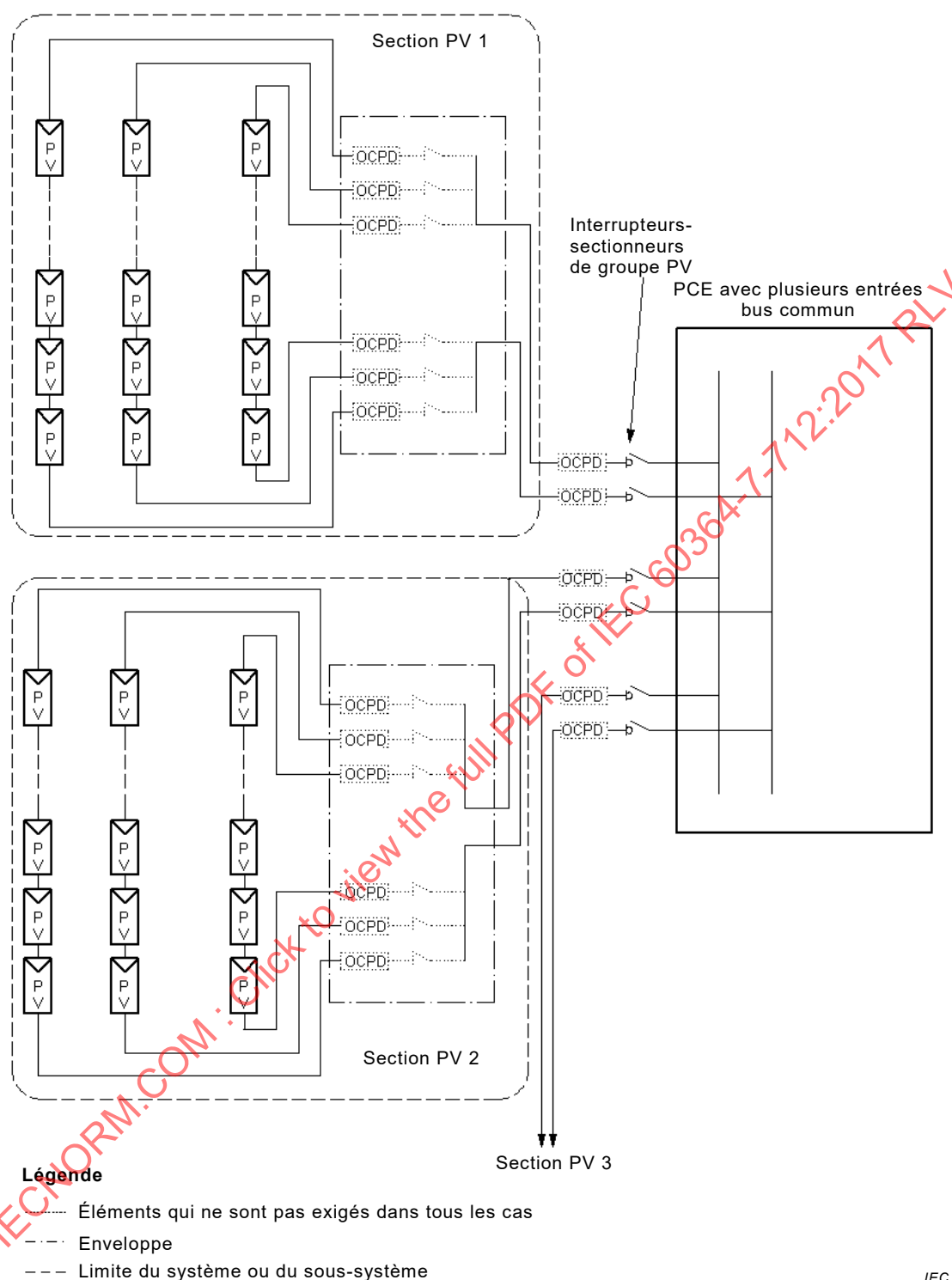


Figure 712.6 – Groupe PV qui utilise un PCE avec plusieurs entrées en courant continu connectées en interne à un bus commun en courant continu

712.31.101.1.3 Utilisation d'un PCE avec plusieurs entrées en courant continu

712.31.101.1.3.1 Généralités

Les groupes PV sont souvent connectés à des PCE avec plusieurs entrées en courant continu. Voir les Figures 712.5 et 712.6. Si plusieurs entrées en courant continu sont utilisées, la protection contre les surintensités et le dimensionnement du câble dans les différentes

sections du groupe ou des groupes PV dépendent largement des limitations des courants de retour.

712.31.101.1.3.2 PCE avec des entrées de suivi du point de fonctionnement à puissance maximale (MPPT) séparées

Lorsque les circuits d'entrée d'un PCE fournissent des entrées MPPT séparées, la protection contre les surintensités de la section du groupe connectée à ces entrées doit prendre en compte tout courant de retour.

Chaque section PV connectée à une entrée (voir la Figure 712.5) peut être traitée dans le cadre du présent document comme un groupe PV distinct. Chaque groupe PV doit avoir un interrupteur-sectionneur pour assurer le sectionnement du PCE. Les interrupteurs-sectionneurs du groupe PV peuvent être intégrés mécaniquement à un dispositif et facilement manœuvrés.

712.31.101.1.3.3 PCE avec plusieurs entrées interconnectées en interne dans le PCE

Lorsque plusieurs circuits d'entrée d'un PCE sont mis en parallèle en interne dans un bus commun en courant continu, chaque section PV connectée à l'une de ces entrées (voir la Figure 712.6) doit être traitée dans le cadre du présent document comme un sous-groupe et toutes les sections PV combinées doivent être classées comme appartenant au groupe PV complet. Chaque sous-groupe PV doit avoir un interrupteur-sectionneur pour assurer le sectionnement du PCE. Cette fonction peut être remplie par un interrupteur-sectionneur commun au groupe PV.

712.31.101.1.4 Configuration série-parallèle

Toutes les chaînes PV d'un groupe PV connecté en parallèle doivent être de la même technologie et avoir le même nombre de modules PV connectés en série (voir Figure 712.2 à Figure 712.4), sauf si de tels modules sont suivis par des MPPT distincts. Tous les modules PV connectés en parallèle dans le groupe PV doivent en outre posséder les mêmes caractéristiques électriques assignées, y compris le courant de court-circuit, la tension en circuit ouvert, le courant à la puissance maximale, la tension à la puissance maximale et la puissance assignée (toutes aux conditions d'essai normalisées), sauf si de tels modules sont suivis par des MPPT distincts.

Il s'agit là d'un problème de conception qu'il est nécessaire de prendre en considération par le chef de projet, en particulier lors du remplacement de modules ou de la modification d'une installation PV existante.

712.31.101.1.5 Considérations dues aux conditions de défaut présumées d'un groupe PV

Quel que soit le type d'installation, il est nécessaire d'identifier l'origine des courants de défaut.

Les installations PV contenant des batteries peuvent avoir des courants de défaut présumés élevés dus aux caractéristiques des batteries.

Dans une installation PV sans batteries, les cellules PV (et par conséquent les groupes PV) se comportent comme des sources de courant en cas de défauts à basse impédance. Les courants de défaut peuvent donc ne pas être beaucoup plus élevés que les courants de pleine charge normaux, même en situation de court-circuit.

Le courant de défaut dépend du nombre de chaînes, de l'emplacement du défaut et du niveau d'ensoleillement. Cela rend les courts-circuits très difficiles à détecter dans les groupes PV.

Des arcs électriques peuvent se former dans un groupe PV avec des courants de défaut plus faibles que le courant de fonctionnement d'un dispositif de protection contre les surintensités.

712.31.101.1.6 Questions de performance

Les performances d'un groupe PV peuvent être affectées par de nombreux facteurs, y compris, sans toutefois s'y limiter, ce qui suit:

- les ombres, même partielles;
- l'échauffement;
- une chute de tension dans les câbles;
- des salissures sur la surface du groupe provoquées par la poussière, des impuretés, des déjections d'oiseaux, la neige, la pollution industrielle, etc.;
- l'orientation;
- la dégradation du module PV.

Le site d'implantation du groupe PV doit être choisi avec soin. Le groupe PV peut être ombragé à certains moments de la journée par des arbres ou des bâtiments situés à proximité.

Il est important de réduire autant que possible toute source d'ombre. Noter que même une petite ombre sur le groupe peut considérablement limiter ses performances.

Les problèmes de dégradation des performances dus à l'échauffement et au besoin d'une ventilation adaptée sont décrits au 712.515.101. Il convient de maintenir les modules aussi froids que possible.

Lors du processus de conception, le dimensionnement des câbles dans le groupe et dans les connexions de câbles entre le groupe et le circuit d'utilisation affecte la chute de tension dans ces câbles en présence d'une charge. Cela peut revêtir une importance particulière dans les installations PV caractérisées par une tension de sortie basse et un courant de sortie élevé. Selon les recommandations indiquées, il convient que, dans les conditions de charge maximale, la chute de tension entre le module le plus éloigné du groupe et les bornes d'entrée du circuit d'utilisation ne dépasse pas 3 % de la tension du groupe PV au point de fonctionnement à puissance maximale.

La pollution de la surface des modules PV causée par la poussière, la saleté, les déjections d'oiseaux, la neige, etc., peut diminuer considérablement le rendement du groupe. Il convient d'organiser le nettoyage régulier des modules si la pollution peut constituer un problème important.

712.4 Protection pour assurer la sécurité

712.4.101 Généralités

Les calculs de $U_{OC\ MAX}$ et $I_{SC\ MAX}$ sont décrits à l'Annexe B.

712.4.102 Mise à la terre pour des raisons fonctionnelles (FE) d'une partie active du côté courant continu

Pour des raisons fonctionnelles, certaines technologies de modules PV exigent qu'une polarité active soit reliée à la terre.

La mise à la terre pour des raisons fonctionnelles d'une polarité active du côté courant continu d'un PCE est admise, s'il existe au moins une séparation galvanique entre le côté courant alternatif et le côté courant continu assurée par un transformateur dont les enroulements primaire et secondaire sont séparés électriquement. Le transformateur peut

être soit à l'intérieur soit à l'extérieur du PCE. L'enroulement du transformateur raccordé au PCE ne doit pas être relié à la terre, le PCE doit donc être conçu en conséquence.

La mise à la terre pour des raisons fonctionnelles d'une partie active doit être réalisée en un seul point du côté courant continu, à proximité de l'entrée en courant continu du PCE ou dans le PCE proprement dit.

Il convient de préférence que la mise à la terre soit située entre le dispositif de sectionnement et les bornes du côté courant continu du PCE PV.

Les exigences de 712.421.101.2.3 doivent aussi être appliquées.

Un câble utilisé pour la mise à la terre pour des raisons fonctionnelles ne doit pas être identifié par la combinaison de couleurs vert-jaune. Il est recommandé d'utiliser du rose.

712.41 Protection contre les chocs électriques

712.410 Introduction

712.410.101 Le matériel PV du côté courant continu doit être considéré sous tension, même lorsque le côté courant alternatif est déconnecté du réseau ou lorsque le PCE est déconnecté du côté courant continu.

712.410.3.5

Remplacer les exigences comme suit:

Les mesures de protection spécifiées à l'Annexe B de l'IEC 60364-4-41:2005, c'est-à-dire l'utilisation d'obstacles et la mise hors de portée, ne doivent pas être appliquées.

712.410.3.6

Remplacer les exigences comme suit:

Les mesures de protection spécifiées à l'Annexe C de l'IEC 60364-4-41:2005, c'est-à-dire

- emplacement non conducteur,
 - liaisons équipotentielles locales non reliées à la terre,
 - séparation électrique pour l'alimentation de plusieurs éléments consommateurs de courant,
- ne doivent pas être appliquées.

712.410.102 Du côté courant continu, l'une des mesures de protection suivantes doit être appliquée:

- double isolation ou isolation renforcée;
- TBTS ou TBTP.

712.412 Mesure de protection: isolation double ou renforcée

712.412.101 Le matériel, par exemple les modules PV, les tableaux ou les armoires de répartition, les câbles, utilisé du côté courant continu doit être de classe II ou isolation équivalente, conformément à l'IEC 61140.

712.414 Protection par très basse tension (TBTS et TBTP)

712.414.101 Pour l'utilisation de mesures de protection TBTS et TBTP du côté courant continu, $U_{OC\ MAX}$ ne doit pas dépasser 60 V courant continu.

712.414.102 La tension continue lissée à prendre en compte est la tension maximale $U_{OC\ MAX}$ du groupe PV.

712.42 Protection contre les effets thermiques**712.420.101 Sécurité incendie des installations PV**

Les exigences de prévention des incendies applicables au plan national ou local doivent être prises en compte.

712.421 Protection contre l'incendie provoqué par un matériel électrique**712.421.101 Protection contre les effets de défauts d'isolement****712.421.101.1 Protection contre les effets de défauts d'isolement avec PCE sans séparation galvanique du côté courant alternatif**

712.421.101.1.1 La mise à la terre pour des raisons fonctionnelles d'une partie active du côté courant continu n'est pas admise.

712.421.101.1.2 En cas de défaut d'isolement du côté courant continu:

- le PCE doit être automatiquement déconnecté du côté courant alternatif, ou
- la partie en défaut du groupe PV doit être automatiquement déconnectée du PCE.

NOTE 1 La déconnexion peut être assurée par le PCE; voir l'IEC 62109 (toutes les parties).

NOTE 2 La coupure automatique peut être assurée par un DDR (dispositif à courant différentiel résiduel)

712.421.101.1.3 Une alarme doit être déclenchée automatiquement en cas de défaut d'isolement du côté courant continu (voir 712.531.3.101.3).

NOTE Si le défaut d'isolement est détecté par le PCE, conformément à l'IEC 62109 (toutes les parties), une alarme est déclenchée par le PCE.

712.421.101.2 Protection contre les effets de défauts d'isolement avec PCE avec séparation galvanique du côté courant alternatif

712.421.101.2.1 La mise à la terre pour des raisons fonctionnelles d'une partie active du côté courant continu est admise.

712.421.101.2.2 Sans mise à la terre pour des raisons fonctionnelles d'une partie active du côté courant continu, il doit être installé un contrôleur permanent d'isolement (CPI) ou tout autre dispositif assurant une surveillance effective équivalente.

NOTE Pour assurer cette fonction, il peut être utilisé un onduleur conforme à l'IEC 62109 (toutes les parties).

712.421.101.2.3 Sauf dans les cas où l'alinéa suivant est appliqué, les groupes PV qui ont un conducteur connecté à une terre fonctionnelle doivent être équipés d'un dispositif ou d'un ensemble de dispositifs, conformément à 712.532.102, qui sert à interrompre le courant dans le conducteur de mise à la terre fonctionnelle en cas de défaut d'isolement du côté courant continu. Le dispositif (ou l'ensemble de dispositifs) doit également déclencher une alarme conformément à 712.421.101.2.4.

L'exigence de l'alinéa précédent n'est pas applicable lorsque le conducteur de mise à la terre fonctionnelle est relié à la terre au moyen d'une résistance caractérisée par une résistance R satisfaisant à la condition suivante:

$$R \geq \frac{U_{oc \max}}{I_n}$$

où

I_n est la valeur du courant donnée au Tableau 712.6.

NOTE En cas de défaut d'isolement, un arrêt immédiat du PCE peut être nécessaire pour des raisons fonctionnelles.

En cas de mise à la terre pour des raisons fonctionnelles d'une partie active du côté courant continu via une résistance, il doit être installé un contrôleur permanent d'isolement (CPI) ou tout autre dispositif assurant une surveillance effective équivalente (voir 712.531.3).

NOTE Pour assurer cette fonction, il peut être utilisé un PCE conforme à l'IEC 62109 (toutes les parties).

712.421.101.2.4 Une alarme doit être automatiquement déclenchée en cas de défaut d'isolement du côté courant continu (voir 712.531.3.101.3).

NOTE Si le défaut d'isolement est détecté par le PCE, conformément à l'IEC 62109 (toutes les parties), une alarme est déclenchée par le PCE.

Conformément à 411.6.3.1 de l'IEC 60364-4-41:2005, il est recommandé d'éliminer le défaut aussi tôt que possible.

712.43 Protection contre les surintensités

712.430.3 Règles générales

712.430.3.101 Généralités

Les surintensités dans un groupe PV peuvent provenir de défauts dans le câblage du groupe ou de courants de défaut dus à des courts-circuits dans les modules, dans les coffrets de regroupement ou dans le câblage du module.

Les modules PV sont des sources de courant limitées mais peuvent être sujets à des surintensités, car ils peuvent être connectés en parallèle ou à des sources externes. Les surintensités peuvent être provoquées par la somme des courants issus de

- plusieurs chaînes parallèles adjacentes,
- certains types de PCE auxquels ils sont connectés et/ou
- des sources externes.

712.430.3.102 Exigence pour la protection contre les surintensités

La protection contre les surintensités doit être assurée conformément aux spécifications de 712.430.3.102 à 712.433.1.101 et aux exigences du fabricant du module PV.

Des dispositifs de protection contre les surintensités exigés pour la protection des modules PV et/ou de leur câblage doivent être sélectionnés pour assurer un fonctionnement fiable et régulier pendant 2 h lorsqu'une surintensité de 135 % du courant assigné nominal des modules PV est appliquée.

712.430.3.103 Exigence pour la protection contre les surintensités des chaînes

Une protection contre les surintensités des chaînes doit être mise en place si:

$$((N_s - 1) \times I_{SC_MAX}) > I_{MOD_MAX_OCPR}$$

où

N_s est le nombre total de chaînes reliées en parallèle protégées par le dispositif de protection contre les surintensités le plus proche.

Lorsque des disjoncteurs équipés d'éléments de protection contre les surintensités sont utilisés, ils peuvent aussi constituer le moyen de coupure exigé de 712.536.2.101 à 712.536.2.103.

712.430.3.104 Exigence pour la protection contre les surintensités des sous-groupes

La protection contre les surintensités des sous-groupes doit être assurée si plus de deux sous-groupes sont connectés en parallèle.

712.432 Nature des dispositifs de protection

712.432.101 Les diodes antiretour utilisées pour connecter en parallèle les chaînes PV ne doivent pas être considérées comme moyen de protection contre les surintensités.

712.432.102 Les dispositifs de protection contre les surintensités du côté courant continu doivent être soit des fusibles «gPV» conformes à l'IEC 60269-6 ou tout autre dispositif conforme à l'IEC 60947 (toutes les parties) ou l'IEC 60898 (toutes les parties).

Les dispositifs conformes à l'IEC 60947 (toutes les parties) et l'IEC 60898 (toutes les parties) doivent pouvoir s'adapter aux conditions prévues, en particulier pour l'exploitation en courant direct, en courant inverse et en courant critique.

712.433 Protection contre les courants de surcharge

712.433.1 Coordination entre les conducteurs et les dispositifs de protection

712.433.1.101 Dimensionnement de la protection contre les surcharges

712.433.1.101.1 Généralités

Le facteur de correction choisi de 712.433.1.101.2 à 712.433.1.101.4 doit être ajusté pour tenir compte des systèmes PV exploités dans des conditions climatiques dans lesquelles il est attendu que I_{sc} dépasse systématiquement les valeurs STC.

NOTE De nombreuses conditions climatiques et environnementales peuvent entraîner des courants de courts-circuits élevés dépassant les valeurs STC dans les modules et groupes PV, telles que des emplacements géographiques renfermant une quantité exceptionnellement élevée de ressources solaires, le reflet de la neige, ou d'autres conditions. Par exemple, dans le cas de la neige, le courant de court-circuit est affecté par la température ambiante, l'angle d'inclinaison et l'angle d'azimut du module PV, les reflets de la neige, les caractéristiques géographiques, etc.

712.433.1.101.2 Protection contre les surcharges des chaînes PV

Si une protection contre les surcharges des chaînes est exigée:

- 1) chaque chaîne PV doit être protégée par un dispositif de protection contre les surcharges dont la valeur assignée nominale de protection contre les surcharges doit être I_n où:

$$I_n > 1,5 \times I_{SC_MOD} \text{ et}$$

$$I_n < 2,4 \times I_{SC_MOD} \text{ et}$$

$$I_n \leq I_{MOD_MAX_OCPR}$$

ou

- 2) les chaînes peuvent être raccordées en parallèle sous la protection d'un dispositif de protection contre les surcharges, à condition que:

$$I_{ng} > 1,5 \times N_{TS} \times I_{SC_MOD} \text{ et}$$

$$I_{ng} < I_{MOD_MAX_OCPR} - ((N_{TS} - 1) \times I_{SC_MOD})$$

où

I_n est le courant assigné ou le courant de réglage du dispositif de protection contre les surcharges des chaînes,

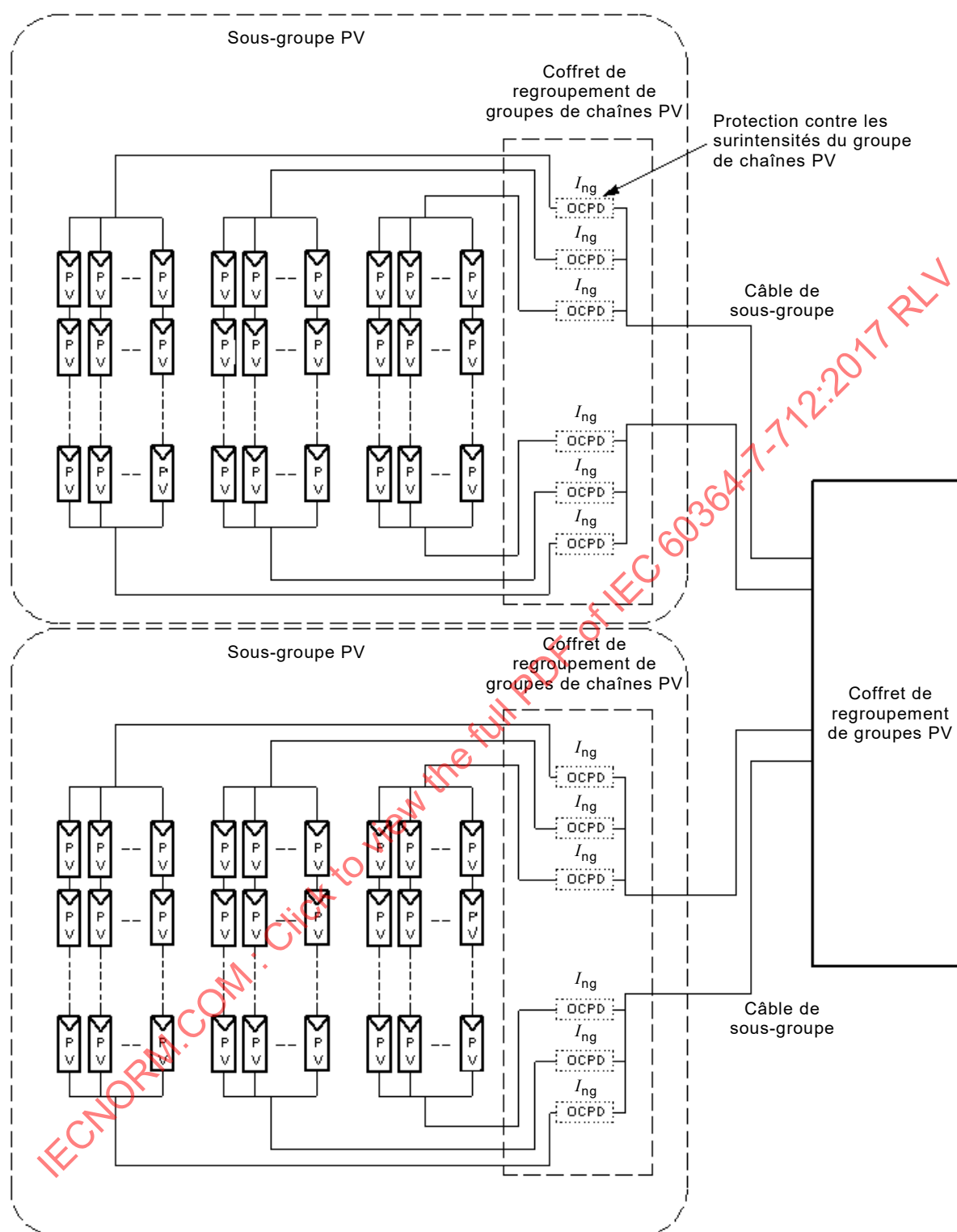
I_{ng} est le courant assigné ou le courant de réglage du dispositif de protection contre les surcharges des groupes,

N_{TS} est le nombre total de chaînes d'un groupe protégées par un même dispositif de protection contre les surcharges.

Si des disjoncteurs sont utilisés comme dispositifs de protection contre les surcharges, l'IEC 60364 (toutes les parties) leur permet également de jouer le rôle de moyen de coupure comme exigé de 712.536.2.101 à 712.536.2.103.

Pour certaines technologies de modules PV, I_{SC_MOD} est supérieur à la valeur assignée nominale durant les premières semaines ou les premiers mois de fonctionnement. Il convient d'en tenir compte au moment de définir la protection contre les surcharges et les caractéristiques assignées des câbles.

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Il ne s'agit que d'un exemple et d'autres dispositifs de protection contre les surcharges, de coupure et/ou de sectionnement peuvent être exigés dans certains cas, qui ne sont pas représentés dans la présente figure pour plus de simplicité.

NOTE 1 Il s'agit d'un cas particulier et la conception n'est possible que lorsque la valeur assignée de la protection contre les surcharges d'un module PV est largement supérieure à la valeur du courant de fonctionnement normal.

NOTE 2 La présence de contraintes spécifiques telles que le montage côte à côte du matériel utilisé simultanément à un courant nominal et/ou à une température ambiante élevée, peut affecter le choix du courant assigné pour le dispositif de protection.

Figure 712.7 – Exemple de schéma de groupe PV dans lequel les chaînes sont raccordées sous un dispositif de protection contre les surcharges par groupe

712.433.1.101.3 Protection contre les surcharges des sous-groupes PV

Le courant assigné ou le courant de réglage (I_n) des dispositifs de protection contre les surcharges destinés aux sous-groupes PV doit être déterminé au moyen des formules suivantes:

$$I_n > 1,25 \times I_{SC \text{ S-ARRAY}} \text{ et}$$

$$I_n \leq 2,4 \times I_{SC \text{ S-ARRAY}}$$

Le facteur de correction de 1,25 utilisé ici à la place du facteur de correction de 1,5 utilisé pour les chaînes sert à laisser une certaine flexibilité pour la conception. Il convient de ne pas utiliser un facteur de correction de 1,25 dans les régions présentant des éclairagements énergétiques souvent intenses, car cela pourrait provoquer le déclenchement intempestif des dispositifs de protection contre les surcharges.

NOTE La présence de contraintes spécifiques telles que le montage côte à côte du matériel utilisé simultanément à un courant nominal et/ou à une température ambiante élevée, peut affecter le choix du courant assigné du dispositif de protection.

712.433.1.101.4 Protection contre les surcharges des groupes PV

La protection contre les surcharges du câble de groupe PV n'est exigée que pour les installations PV connectées à des batteries ou si d'autres sources de courants peuvent alimenter le groupe PV dans des conditions de défaut. Le courant assigné (I_n) des dispositifs de protection contre les surcharges des groupes PV doit être calculé de la façon suivante:

$$I_n > 1,25 \times I_{SC \text{ S-ARRAY}} \text{ et}$$

$$I_n \leq 2,4 \times I_{SC \text{ ARRAY}}$$

Les dispositifs de protection contre les surcharges d'un groupe PV sont souvent installés entre la batterie ou les batteries et le contrôleur de charge, le plus près possible de la batterie ou des batteries. Si ces dispositifs sont correctement assignés, ils assurent à la fois la protection du contrôleur de charge et celle du câble de groupe PV. Dans ce cas, aucune autre installation de protection contre les surcharges dans le câble de groupe PV, entre le groupe PV et le contrôleur de charge, n'est nécessaire. Le facteur de correction de 1,25 utilisé ici à la place du facteur de correction de 1,5 utilisé pour les chaînes sert à laisser une certaine flexibilité pour la conception. Il convient de ne pas utiliser un facteur de correction de 1,25 dans les régions présentant des éclairagements énergétiques souvent intenses, car cela pourrait provoquer des surcharges intempestives.

NOTE La présence de contraintes spécifiques telles que le montage côte à côte du matériel utilisé simultanément à un courant nominal et/ou à une température ambiante élevée, peut affecter le choix du courant assigné du dispositif de protection.

12.433.2 Emplacement des dispositifs de protection contre les surcharges

712.433.2.101 Emplacement de la protection contre les surcharges

Les dispositifs de protection contre les surcharges exigés de 712.430.3.101 à 712.430.3.104 et en 712.433.1.101 pour les groupes PV, les sous-groupes PV et les chaînes PV doivent être placés de la façon suivante.

- Pour les dispositifs de protection contre les surcharges des chaînes, ils doivent se situer à la jonction des câbles de chaînes avec les câbles du sous-groupe ou du groupe dans le coffret de regroupement de chaînes (voir les Figures 712.3 et 712.4).
- Pour les dispositifs de protection contre les surcharges des sous-groupes, ils doivent se situer à la jonction des câbles de sous-groupes avec les câbles du groupe dans le coffret de regroupement de groupes (voir la Figure 712.4).

- Pour les dispositifs de protection contre les surcharges des groupes, ils doivent se situer à la jonction des câbles de groupes avec le circuit d'utilisation ou le PCE (voir les Figures 712.2 à 712.4).

NOTE L'emplacement des dispositifs de protection contre les surcharges à l'extrémité de ces câbles la plus éloignée du sous-groupe ou de la chaîne PV est destiné à assurer une protection contre les courants de défaut qui proviennent d'autres sections du groupe PV ou d'autres sources telles que des batteries. En raison des caractéristiques de limitation du courant inhérentes aux systèmes PV, le courant de défaut provenant de la source dans le circuit défaillant proprement dit ne suffit pas à déclencher le dispositif de protection contre les surcharges.

Un dispositif de protection contre les surcharges exigé pour un câble de chaîne ou un câble de sous-groupe doit être placé dans chaque conducteur sous tension (c'est-à-dire chaque conducteur sous tension non relié à la terre fonctionnelle).

Une exception s'applique aux câbles de chaînes ne faisant pas partie de la même canalisation électrique que les câbles de sous-groupes et aux câbles de sous-groupes ne faisant pas partie de la même canalisation électrique que les câbles de chaînes. Dans ces cas, il est seulement nécessaire de placer un dispositif de protection contre les surcharges dans un conducteur sous tension non relié à la terre du câble de chaîne ou de chaque câble de sous-groupe. La polarité de ce conducteur doit être la même pour tous les câbles ainsi protégés.

712.433.101 Protection du câble de groupe PV

Le courant permanent admissible I_z du câble de groupe PV doit être supérieur ou égal au courant de court-circuit maximal du groupe PV:

$$I_{SC \text{ MAX du groupe PV}} \leq I_z$$

712.433.102 Protection du câble d'alimentation PV en courant alternatif

Le courant assigné du dispositif de protection contre les surcharges du câble d'alimentation en courant alternatif doit tenir compte du courant d'emploi du PCE. Le courant d'emploi du PCE est le courant alternatif maximal indiqué par le fabricant du PCE ou, à défaut, 1,1 fois son courant alternatif assigné.

712.434 Protection contre les courants de court-circuit

712.434.101 Le câble d'alimentation PV côté courant alternatif doit être protégé contre les effets de courts-circuits par un dispositif de protection contre les surintensités installé au niveau de la connexion du tableau de répartition dédié de l'installation électrique.

712.44 Protection contre les perturbations de tension et les perturbations électromagnétiques

712.443 Protection contre les surtensions transitoires d'origine atmosphérique ou dues à des manœuvres

712.443.101 En tenant compte de la sensibilité du montage des modules photovoltaïques, il convient de prêter une attention particulière à la protection de la structure proprement dite (bâtiment) contre les effets directs de la foudre; ce sujet est couvert dans l'IEC 62305 (toutes les parties).

712.443.4 Maîtrise des surtensions

712.443.4.101 Protection contre les surtensions transitoires

Lorsque l'IEC 60364-4-44:2007, Clause 443 exige une protection contre les surtensions transitoires, cette protection doit également être appliquée du côté courant continu de l'installation PV.