



DPC: 24 / 30499547 DC

BSI Group Headquarters

389 Chiswick High Road London W4 4AL

Tel: +44 (0)20 8996 9000

Fax: +44 (0)20 8996 7400

www.bsigroup.com

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Responsible committee: GEL/82 Photovoltaic Energy Systems

Interested committees:

Title: BS EN IEC 62548-1/AMD1 Amendment 1 - Photovoltaic (PV) arrays

Part 1: Design requirements

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- iii) requires additional national guidance or information

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Responsible Committee Secretary: Lilly Malik (BSI)

Direct tel:

E-mail: lilly.malik@bsigroup.com

Introduction

This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

For national standards, comments will be reviewed by the relevant UK national committee and the resulting standards published as a British Standard.

UK Vote

Please indicate whether you consider the UK should submit a negative (with supporting technical reasons) or positive vote on this draft. Please indicate if you are aware of any reason why this draft standard should not be published as a British Standard.

Submission of Comments

- **Annotated drafts are not acceptable and will be rejected.**
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Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx
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1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/Figure/ Table/Note	Type of comment	Commend (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	



82/2297/CD

COMMITTEE DRAFT (CD)

PROJECT NUMBER:

IEC 62548-1/AMD1 ED1

DATE OF CIRCULATION:

2024-08-23

CLOSING DATE FOR COMMENTS:

2024-10-18

SUPERSEDES DOCUMENTS:

82/2286/RR

IEC TC 82 : SOLAR PHOTOVOLTAIC ENERGY SYSTEMS

SECRETARIAT:

United States of America

SECRETARY:

Mr George Kelly

OF INTEREST TO THE FOLLOWING COMMITTEES:

TC 64

HORIZONTAL FUNCTION(S):

ASPECTS CONCERNED:

Electricity transmission and distribution, Safety

This document is still under study and subject to change. It should not be used for reference purposes.

Recipients of this document are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

Recipients of this document are invited to submit, with their comments, notification of any local regulations or technical reasons that may exist and should be considered should this proposal proceed, recognizing that failure to address such requirements could result in the need for new or existing "In Some Countries" clauses. (SEE [AC/22/2007](#) OR [NEW GUIDANCE DOC](#)).

TITLE:

Amendment 1 - Photovoltaic (PV) arrays - Part 1: Design requirements

NOTE FROM TC/SC OFFICERS:

This project was discussed and supported by WG3 during their meeting in 2024-04.

Amendment to IEC 62548-1 2023

Introduction content on page 2 and 3 for information purpose only during the first CD circulation. These 2 pages shall be removed from all later part of project stages.

Introduction

An amendment to IEC 62548-1 2023 is proposed to address two important issues and one editorial one which arose late in the development of this document.

Issue 1:

Clause 7.2.9 regarding Plugs, sockets and connectors in PV circuits.

A comment from the German committee at FDIS stage requested a change to the wording of the last dot point in this clause to assist in preventing pollution which might have occurred if a very large number of plastic dust caps were required. The proposed change to this dot point

Current wording

- unmated connectors (or "connectors not in use") shall be protected by a dust cap (or "protective cap") against ingress of pollution like dust or moisture.

Proposed new wording:

- unmated connectors (or "connectors not in use") shall be protected against ingress of dust or moisture.

NOTE This can be achieved e.g. by their timely connection, or by the use of a protective cover.

Issue 2

Clause 7.2.7.5 Load break plug connections

There is no current IEC standard that qualifies plugs and connectors for PV use and for load break. We proposed the use of both IEC 62852 and IEC 61984 but it has been pointed out that this would still result in a plug which was marked "Do not disconnect under load".

This would defeat the purpose of the plug in a load break situation.

Clause 7.3.1.2 d) now provides a means of isolation by reducing the current to zero by other means and then breaking the plug connection, negating the need for a load break connector.

Clause 7.3.1.2 c) also utilizes non-load-break connectors for isolation.

So a load break connector is not required for this standard at the moment. When a PV load break connector standard is available we may then be able to incorporate a clause allowing its use. So currently there is no need to use load break connectors. We therefore propose to delete the load break connections clause

To address this issue requires:

- Deletion of clause 7.2.7.5 and
- Deletion of clause 7.2.7.1 d) which calls up 7.2.7.5

Issue 3: (editorial)

In the note to figures the reference to 7.2.6 is incorrect and should be changed to 7.2.7

See Figure s 2, 3, 4, 5, 6, Note 2 and Figures 7, 8, 9, 10 Note 1

ALSO in 7.3.1.1 in the first paragraph the reference to 7.2.6 should be changed to 7.2.7

And in 7.3.1.2 first paragraph the reference to 7.2.6 should be changed to 7.2.7

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**PHOTOVOLTAIC (PV) ARRAYS –
DESIGN REQUIREMENTS****FOREWORD**

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- IEC 62548-1 has been prepared by IEC technical committee 82: Solar photovoltaic energy systems. It is an International Standard.
- This first edition cancels and replaces IEC 62548 published in 2016. This edition constitutes a technical revision.
- This edition includes the following significant technical changes with respect to the previous edition:
- a) Revised provisions for systems including DC to DC conditioning units.
 - b) Revision of mounting structure requirements.
 - c) Revised cable requirements.
 - d) Revision of Clause 6 on safety issues which includes provisions for protection against electric shock including array insulation monitoring and earth fault detection.
 - e) Revision of 7.2.7 and 7.3 with respect to isolation means.

- f) Provisions for use of bifacial modules and modules mounted in non-optimal orientations.
- g) New Annex F containing: K_f factor calculations for bifacial and non-optimally oriented systems; anti-PID equipment and arc flash.

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

Draft	Report on voting
82/2174/FDIS	82/2193/RVD

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

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

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

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

- reconfirmed,
- withdrawn, or
- revised.

IMPORTANT – The "colour inside" logo on the cover page of this document 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.

PHOTOVOLTAIC (PV) ARRAYS – DESIGN REQUIREMENTS

1 Scope

This document sets out design requirements for photovoltaic (PV) arrays including DC array wiring, electrical protection devices, switching and earthing provisions. The scope includes all parts of the PV array and final power conversion equipment (PCE), but not including energy storage devices, loads or AC or DC distribution network supplying loads.

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

In systems supplying AC loads or circuits, the safety requirements mentioned in this document are however critically dependent on the inverters associated with PV arrays complying with the requirements of IEC 62109-1, IEC 62109-2 and IEC 62109-3.

Installation requirements are also critically dependent on compliance with the IEC 60364 series (see Clause 4).

PV arrays of less than 100 W and less than 35 V DC open circuit voltage at STC are not covered by this document.

PV arrays in grid interconnected systems connected to medium or high voltage systems are not covered in this document, except as required by IEC TS 62738. Variations and additional requirements for large-scale ground mounted PV power plants with restricted access to personnel are addressed in IEC TS 62738.

Additional requirements may be needed for more specialized installations, for example concentrating systems, tracking systems or building integrated PV.

This document also includes extra protection requirements of PV arrays when they are directly connected with batteries at the DC level.

Attention is drawn to the co-existence of IEC 60364-7-712 and IEC 62548. Both standards have been developed in close coordination, respectively by IEC technical committees 64 and 82.

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 60269-1, *Low-voltage fuses – Part 1: General requirements*

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

- 299 IEC 60364-1, *Low-voltage electrical installations – Part 1: Fundamental principles, assessment*
300 *of general characteristics, definitions*
- 301 IEC 60364-4 (all parts), *Low-voltage electrical installations – Part 4: Protection for safety*
- 302 IEC 60364-4-41:2005, *Low-voltage electrical installations – Part 4-41: Protection for safety –*
303 *Protection against electric shock*
304 IEC 60364-4-41:2005/AMD1:2017
- 305 IEC 60364-4-44:2007, *Low-voltage electrical installations – Part 4-44: Protection for safety –*
306 *Protection against voltage disturbances and electromagnetic disturbances*
307 IEC 60364-4-44:2007/AMD1:2015
308 IEC 60364-4-44:2007/AMD2:2018
- 309 IEC 60364-5 (all parts), *Electrical installations of buildings – Part 5: Selection and erection of*
310 *electrical equipment*
- 311 IEC 60364-5-52, *Low-voltage electrical installations – Part 5-52: Selection and erection of*
312 *electrical equipment – Wiring systems*
- 313 IEC 60364-5-54, *Low-voltage electrical installations – Part 5-54: Selection and erection of*
314 *electrical equipment – Earthing arrangements and protective conductors*
- 315 IEC 60364-6, *Low-voltage electrical installations – Part 6: Verification*
- 316 IEC 60529, *Degrees of protection provided by enclosures (IP Code)*
- 317 IEC 60898-2, *Circuit-breakers for overcurrent protection for household and similar installations*
318 *– Part 2: Circuit-breakers for AC and DC operation*
- 319 IEC 60898-3, *Circuit-breakers for overcurrent protection for household and similar installations*
320 *– Part 3: Circuit-breakers for DC operation*
- 321 IEC 60947-1:2020, *Low-voltage switchgear and controlgear – Part 1: General rules*
- 322 IEC 60947-2, *Low-voltage switchgear and controlgear – Part 2: Circuit-breakers*
- 323 IEC 60947-3, *Low-voltage switchgear and controlgear – Part 3: Switches, disconnectors,*
324 *switch-disconnectors and fuse-combination units*
- 325 IEC 61215 (all parts), *Terrestrial photovoltaic (PV) modules – Design qualification and type*
326 *approval*
- 327 IEC 61439-1, *Low-voltage switchgear and controlgear assemblies – Part 1: General rules*
- 328 IEC 61439-2, *Low-voltage switchgear and controlgear assemblies – Part 2: Power switchgear*
329 *and controlgear assemblies*
- 330 IEC 61643-21, *Low-voltage surge protective devices – Part 21: Surge protective devices*
331 *connected to telecommunications and signalling networks – Performance requirements and*
332 *testing methods*
- 333 IEC 61643-22, *Low-voltage surge protective devices – Part 22: Surge protective devices*
334 *connected to telecommunications and signalling networks – Selection and application principles*

- 335 IEC 61643-31:2018, *Low-voltage surge protective devices – Part 31: Requirements and test*
336 *methods for SPDs for photovoltaic installations*
- 337 IEC 61701, *Photovoltaic (PV) modules – Salt mist corrosion testing*
- 338 IEC 61730-1, *Photovoltaic (PV) module safety qualification – Part 1: Requirements for*
339 *construction*
- 340 IEC 61730-2, *Photovoltaic (PV) module safety qualification – Part 2: Requirements for testing*
- 341 IEC TS 61836:2016, *Solar photovoltaic energy systems – Terms, definitions and symbols*
- 342 IEC 61984, *Connectors – Safety Requirements and tests*
- 343 IEC 62109-1:2010, *Safety of power converters for use in photovoltaic power systems – Part 1:*
344 *General requirements*
- 345 IEC 62109-2, *Safety of power converters for use in photovoltaic power systems – Part 2:*
346 *Particular requirements for inverters*
- 347 IEC 62109-3, *Safety of power converters for use in photovoltaic power systems – Part 3:*
348 *Particular requirements for electronic devices in combination with photovoltaic elements*
- 349 IEC 62305-2:2010, *Protection against lightning – Part 2: Risk management*
- 350 IEC 62305-3, *Protection against lightning – Part 3: Physical damage to structures and life*
351 *hazard*
- 352 IEC 62440:2008, *Electric cables with a rated voltage not exceeding 450/750 V – Guide to use*
- 353 IEC 62446-1, *Photovoltaic (PV) systems – Requirements for testing, documentation and*
354 *maintenance – Part 1: Grid connected systems – Documentation, commissioning tests and*
355 *inspection*
- 356 IEC 62446-2, *Photovoltaic (PV) systems – Requirements for testing, documentation and*
357 *maintenance – Part 2: Grid connected systems – Maintenance of PV systems*
- 358 IEC 62716, *Photovoltaic (PV) modules – Ammonia corrosion testing*
- 359 IEC TS 62738, *Ground-mounted photovoltaic power plants – Design guidelines and*
360 *recommendations*
- 361 IEC TS 62804-1, *Photovoltaic (PV) modules – Test methods for the detection of*
362 *potential-induced degradation – Part 1: Crystalline silicon*
- 363 IEC 62817, *Photovoltaic systems – Design qualification of solar trackers*
- 364 IEC 62852, *Connectors for DC-application in photovoltaic systems – Safety requirements and*
365 *tests*
- 366 IEC 62930:2017, *Electric cables for photovoltaic systems with a voltage rating of 1,5 kV DC*
- 367 IEC 62938, *Photovoltaic (PV) modules – Non-uniform snow load testing*

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

370 IEC 63027, *Photovoltaic power systems – DC arc detection and interruption*

371 IEC 63104, *Solar trackers – Safety requirements*

372 IEC 63112:2021, *Photovoltaic (PV) arrays – Earth fault protection equipment – Safety and*
373 *safety-related functionality*

374 IEC TS 63126:2020, *Guideline for qualifying PV modules, components and materials for*
375 *operation at high temperatures*

376 IEC TS 63209-1, *Photovoltaic modules – Extended-stress testing – Part 1: Modules*

377 IEC TR 63226:2021, *Managing risk related to photovoltaic (PV) systems on buildings*

378 IEC TR 63227, *Lightning and surge voltage protection for photovoltaic (PV) power supply*
379 *systems*

380 **3 Terms, definitions, symbols and abbreviated terms**

381 **3.1 Terms and definitions**

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

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

- 386 • IEC Electropedia: available at <https://www.electropedia.org/>
- 387 • ISO Online browsing platform: available at <https://www.iso.org/obp>

388 **3.1.1**

389 **blocking diode**

390 diode connected in series with module(s), panel(s), sub-arrays and array(s) to block reverse
391 current into such module(s), panel(s), sub-array(s) and array(s)

392 **3.1.2**

393 **bifacial nameplate irradiance**

394 **BNPI**

395 higher irradiance at which nameplate verification is performed for bifacial modules. Bifacial
396 nameplate irradiance (BNPI) is that which corresponds to 1 000 W/m² on the module front, and
397 135 W/m² on the module rear

398 Note 1 to entry: BNPI may be applied in any method allowed by IEC TS 60904-1-2.

399 [SOURCE: IEC 61215-1:2021, 3.11]

400 **3.1.3**

401 **bonding conductor**

402 conductor provided for functional or protective equipotential bonding

3.1.4**bypass diode**

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

3.1.5**charge controller**

power conversion equipment used between a battery and a PV array to regulate charge delivered to the battery

3.1.6**DC conditioning units****DCU**

DC to DC power conversion equipment connected to individual PV modules or groups of PV modules or PV strings to modify the voltage and or current of the PV output

3.1.7**decisive voltage class****DVC**

classification of voltage range used to determine the protective means against electric shock and the requirements of protection between circuits

Note 1 to entry: See decisive voltage class limits in Clause E.1.

[SOURCE: IEC 62477-1:2022,3.15]

3.1.8**disconnecter**

mechanical switching device which provides, in the open position, an isolating distance in accordance with specified requirements

Note 1 to entry: A disconnecter is capable of opening and closing a circuit when either negligible current is broken or made, or when no significant change in the voltage across the terminals of each of the poles of the disconnecter occurs. It is also capable of carrying currents under normal circuit conditions and carrying currents for a specified time under abnormal conditions such as those of short circuit.

[SOURCE: IEC 60050-441:1984, 441-14-05]

3.1.9**double insulation**

insulation comprising both basic insulation and supplementary insulation

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

3.1.10**earth fault****ground fault (US)**

occurrence of an accidental conductive path between a live part and the Earth

Note 1 to entry: The conductive path can consist of faulty insulation, structures (e.g. poles, scaffoldings, cranes, ladders), or vegetation (e.g. trees, bushes) and can have a significant impedance.

[SOURCE: IEC 60050-195:2021, 195-04-14]

3.1.11**extraneous conductive part**

conductive part not forming part of the electrical installation and liable to introduce an electric potential, generally the electric potential of a local earth

[SOURCE: IEC 60050-851:2008, 851-14-57, modified – The note has been deleted.]

3.1.12**extreme annual mean minimum dry bulb temperature**

average of at least 5 years of the lowest yearly measured dry bulb temperatures at a location

3.1.13**independent manual operation****independent manual operation of a mechanical switching device**

stored energy operation where the energy originates from manual power, stored and released in one continuous operation (e.g. spring release), such that the speed and force of the operation are independent of the action of the operator

Note 1 to entry: See Annex F for calculation of K_f .

[SOURCE: IEC 60050-441:1984, 441-16-16, modified – The brackets have been added to the definition.]

3.1.14**live part**

conductive part intended to be energized under normal operating conditions, including the neutral conductor and mid-point conductor, but excluding the PEN conductor, PEM conductor and PEL conductor

Note 1 to entry: This concept does not necessarily imply a risk of electric shock.

[SOURCE: IEC 60050-195:2021, 195-02-19]

3.1.15**low voltage**

voltage exceeding DVC A, but not exceeding 1 000 V AC or 1 500 V DC

3.1.16**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

3.1.17**non-separated PCE**

PCE without at least simple separation between the input and output circuits

3.1.18**partial DCU strings**

PV string where some but not all PV modules have DCUs fitted

Note 1 to entry: These configurations are sometimes used where some, but not all, modules are subject to shading on a regular basis.

3.1.19**DCU strings**

string of DCUs connected in series on the output side of the DCUs where all PV modules or groups of PV modules have DCUs fitted

3.1.20**power conversion equipment****PCE**

electrical device converting one kind of electrical power from a voltage or current source into another kind of electrical power with respect to voltage, current and frequency

Note 1 to entry: Examples include AC-DC converters, DC-AC inverters, DC-DC converters, DC-DC charge controllers, frequency converters, etc. DCUs are a subset of PCEs.

Note 2 to entry: See Figure 2 to Figure 4.

3.1.21**prospective short-circuit current**

RMS value of the available current which would flow from a source connected to a port of the PCE, if the supply conductors from the source are short-circuited by a conductor of negligible impedance located as near as practicable to the supply terminals of the PCE

Note 1 to entry: In general, the prospective short circuit current is represented by the symbol I_{CP} . In the particular case of a PV port, this document uses $I_{CP\ PV}$. See 3.2.11.

[SOURCE: IEC 62477-1:2022, 3.58, modified – The symbol has been removed and an explanation has been added in the note to entry, added the word “available” before “current”. Added “from a source connected to a port of the PCE” after “flow”. Replaced “to the circuit” with “from the source” and replaced “PECS” with “PCE”.]

3.1.22**PV array**

assembly of electrically interconnected PV modules, PV strings or PV sub-arrays and support structure, including DCU strings and partial DCU strings up to:

- the input of the final power conversion equipment (PCE) which supplies loads or an AC or DC distribution network
- DC loads or DC distribution system

Note 1 to entry: For the purposes of this document a PV array is all components up to the DC input terminals of a final PCE 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, including DC-DC converters up to the terminals of the final power conversion equipment (see Figure 2 to Figure 11).

3.1.23**PV array main cable**

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

3.1.24**PV array combiner box**

enclosure where PV sub-arrays are connected and which may also contain overcurrent protection and/or isolation means

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.

3.1.25**PV module**

complete and environmentally protected assembly of interconnected photovoltaic cells

[SOURCE: IEC TS 61836:2016, 3.1.48.7, modified – The adjective “photovoltaic” has been replaced by “PV” in the term.]

3.1.26**PV power generation plant**

type of ground mounted PV installation, which is operated under supervision with restricted access solely for the purpose of providing electrical energy to the distribution system

Note 1 to entry: "Under supervision" means that PV power plants are restricted from access by non-qualified personnel and are continuously monitored for safety and protection, either by on-site personnel or by active remote monitoring. In some documents such as IEC 62109, this type of area is referred to as a "closed electrical operating area".

Note 2 to entry: PV systems on buildings do not fall under the definition of PV power generation plants

3.1.27**PV reverse current**

current supplied by parallel PV strings or sub-arrays into a fault on a string or sub-array and does not include backfeed current

3.1.28**PV string**

circuit of one or more series-connected modules

[SOURCE: IEC TS 61836:2016, 3.3.59.6, modified – The adjective "photovoltaic" has been replaced by "PV", and the words "one or more" have been added for clarity.]

3.1.29**PV string cable**

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

Note 1 to entry: See Figure 2 to Figure 4.

3.1.30**PV string combiner box**

enclosure where PV strings are connected which may also contain overcurrent protection devices and/or isolation means

Note 1 to entry: See Figure 4.

Note 2 to entry: PV string combiner boxes are only relevant for PV arrays that are divided into sub-arrays.

3.1.31**PV sub-array**

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

3.1.32**PV sub-array cable**

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

Note 1 to entry: PV sub-array cables are only relevant for PV arrays that are divided into sub-arrays (see Figure 4).

3.1.33**reinforced insulation**

insulation which provides a degree of protection against electric shock equivalent to double insulation

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

[SOURCE: IEC 60050-195:2021, 195-06-09]

3.1.34**shield**

<of a cable> surrounding earthed metallic layer to confine the electric field within the cable and/or to protect the cable from external electrical influence

Note 1 to entry: Metallic sheaths, armour and earthed concentric conductors may also serve as shields.

[SOURCE: IEC 60050-461:2008, 461-03-04, modified – The words "foils, braids" have been deleted from the note, as well as the second note.]

3.1.35**separation**

prevention of electrical conduction between two circuits or between a circuit and a conductive metal part

Note 1 to entry: Separation in the context of this document means galvanic isolation.

Note 2 to entry: Separation may be achieved to different degrees, e.g. simple separation, protective separation.

3.1.36**simultaneously accessible parts**

conductive parts that can be touched simultaneously by a human being or by livestock

Note 1 to entry: Simultaneously accessible parts may be: live parts, exposed conductive parts, extraneous conductive parts, protective conductors or earth electrodes.

[SOURCE: IEC 60050-826:2022, 826-12-12, modified – In the note, the words "soil or conductive floor" have been replaced by "earth electrodes".]

3.1.37**standard test conditions****STC**

reference values of in-plane irradiance ($G_{I,ref} = 1\,000\text{ W}\cdot\text{m}^{-2}$), PV cell junction temperature (25 °C), and air mass (AM = 1,5) to be used during the testing of any PV device

[SOURCE: IEC TS 61836:2016, 3.4.16.5]

3.1.38**switch-disconnector**

mechanical switching device capable of making, carrying and breaking currents in normal circuit conditions and, when specified, in given operating overload conditions, and able to carry, for a specified time, currents under specified abnormal circuit conditions, such as short-circuit conditions and in the open position, satisfies the isolating requirements specified for a disconnector

Note 1 to entry: A switch-disconnector complies with the requirements for a disconnector.

Note 2 to entry: Switch-disconnectors provide a load break isolation function. In this document these switches will be identified on warning signs and labels as "isolators" for simplicity in interpretation by the public.

3.1.39**system (functionally-earthed)**

system where the PV array has one conductor intentionally connected to earth for purposes other than electrical safety, by means not complying with the requirements for protective bonding

Note 1 to entry: Examples of functional array earthing include earthing one conductor through an impedance, relay, or overcurrent protective device, or systems in which the array is not permanently earthed (opening the earth connection periodically or under fault conditions). Examples shown in Figure B.1.

Note 2 to entry: Use of a resistive network connected between the array and earth to measure the array insulation resistance (impedance monitoring) does not create a functionally-earthed array, as the impedance of such measurement networks is normally very high.

3.1.40**system (non-earth-referenced)**

system where the PV array has none of its conductors intentionally referenced to earth either directly or through the power conversion equipment (PCE)

Note 1 to entry: Examples shown in Figure B.2.

3.1.41**system (non-separated)**

system where the PV array is connected to an intentionally earth-referenced system through a non-separated PCE

Note 1 to entry: Typically this refers to a system with a non-separated inverter, connecting to an earth-referenced AC system, so that when the inverter's connection relay (or other switching device) is closed, the entire system including the PV array is earth-referenced.

Note 2 to entry: Examples shown in Figure B.3.

3.2 Symbols**3.2.1** **$I_{BF\ TOTAL}$**

total continuous backfeed current from all sources other than the PV array itself

Note 1 to entry: This typically includes backfeed from the PCE and any energy storage system that is directly connected to a PV array.

Note 2 to entry: The current that can flow from parallel PV sub-arrays or strings into a faulty sub-array or string is referred to as "PV reverse current" to differentiate it from PCE backfeed current.

Note 3 to entry: In IEC 62109-1:2010 (Ed 1) the backfeed current from the PCE includes reverse currents from all other connected PV inputs. It is planned to change this in Edition 2 of IEC 62109-1."

3.2.2**irradiance** **G**

electromagnetic radiated solar power per unit of area

Note 1 to entry: Expressed in W/m².

[SOURCE: IEC TS 61836:2016, 3.6.25, modified – The adjective "solar" has been added to the definition, and the note has been replaced.]

3.2.3**rated short circuit making capacity** **I_{cm}**

short-circuit making capacity of the equipment at the rated operational voltage

Note 1 to entry: Definition derived from IEC 60947-1:2020.

3.2.4**rated short circuit breaking capacity** I_{cn}

short-circuit breaking capacity of the equipment at the rated operational voltage

Note 1 to entry: Definition derived from IEC 60947-1:2020.

3.2.5**rated operational current** I_e

rated operational current of an equipment stated by the manufacturer and taking into account the rated operational voltage the rated frequency the rated duty, the utilization category and the type of protective enclosure, if appropriate

Note 1 to entry: Definition derived from IEC 60947-1:2020.

3.2.6**conventional enclosed thermal current** I_{the}

value of current stated by the manufacturer used for temperature-rise tests of an equipment when mounted in a specified enclosure

Note 1 to entry: Definition derived from IEC 60947-1:2020.

3.2.7 $I_{MOD_MAX_OCPR}$

PV module maximum overcurrent protection rating determined by IEC 61730-2

Note 1 to entry: This is often specified by module manufacturers as the maximum series fuse rating which refers to the fuse rated current in IEC 60269-1 and IEC 60269-6.

3.2.8 I_n

rated current

3.2.9 $I_{SC\ MOD}$

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

Note 1 to entry: For the purposes of this document the short circuit current of a string is taken as equal to $I_{SC\ MOD}$.**3.2.10** $I_{SC\ BNPI}$

short circuit current of a bifacial PV module or PV string at BNPI test conditions, (see 3.1.2) as specified by the manufacturer in the product specification plate

3.2.11 **$I_{CP\ PV}$**

PCE maximum rated prospective short circuit current at the PV input terminals; i.e. the absolute maximum current the PV input to the PCE is designed to withstand or carry under normal and fault conditions, for that input

Note 1 to entry: At the system design level, this rating would typically be coordinated with the total I_{SC} of the connected PV strings, adjusted for temperature, excess irradiance, etc. as required by installation standards (i.e. not simply the sum of the marked I_{SC} ratings of the connected PV modules, since those markings are based on short-circuit conditions under standard test conditions (STC), and may be exceeded in actual use).

Note 2 to entry: $I_{CP\ PV}$ is used in this document and replaces the previous $I_{SC\ PV}$. The committee is attempting to create a consistent definition across a range of standards. IEC 62109-1:2010, Ed1 uses the symbol $I_{SC\ PV}$, but is being revised in Ed2 under development to use $I_{CP\ PV}$. The current version of the data sheet standard IEC 62894 uses the term $I_{SC\ MAX}$, but is under revision.

3.2.12 **K_I**

DC current rating adjustment factor dependent on site PV module type and installation properties such as module orientation, module shading or module rear side irradiance

3.2.13 **N_S**

total number of parallel-connected PV strings in the PV array

3.2.14 **N_{SA}**

number of parallel-connected PV strings in the PV sub-array

3.2.15 **I_{DCU_OCPR}**

DCU maximum overcurrent protection on the DCU string output side

Note 1 to entry: This may be given as a fuse rating.

3.2.16 **I_{DCU_max}**

DCU maximum output current

3.2.17 **$I_{F\ STRING}$**

fault current that may flow in a string due to other parallel connected strings in the array

3.2.18 **$I_{F\ S-ARRAY}$**

fault current that may flow in a sub-array cable due to parallel connected strings in the array

3.2.19 **$I_{F\ ARRAY}$**

fault current that may flow in an array cable due to parallel connected strings in the array

3.2.20 **U_{DCU_max}**

DCU maximum output voltage

3.2.21**open-circuit maximum voltage** **$U_{OC\ MAX}$**

maximum voltage across an unloaded (open) PV-module -string, DCU string, partial DCU 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 F.

3.2.22 **R_{iso}**

insulation resistance (isolation) between the PV array and earth

3.2.23 **$U_{BUS-MAX}$**

maximum voltage output of a group of DCUs

Note 1 to entry: See Annex J for test requirements.

3.2.24 **$U_{OC\ ARRAY}$**

open circuit voltage at standard test conditions of a PV array, and is equal to:

$$U_{OC\ ARRAY} = U_{OC\ MOD} \times M$$

where

M is the number of series-connected PV modules in any PV string of the PV array

Note 1 to entry: This document assumes that all strings within a PV array are connected in parallel; hence the open circuit voltage of PV sub-arrays and PV strings is equal to $U_{OC\ ARRAY}$.

3.2.25 **$U_{OC\ MOD}$**

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

3.3 Abbreviated terms**3.3.1****PV-EFP**

photovoltaic earth fault protection

3.3.2**PV-EFPE**

photovoltaic earth fault protection equipment

4 Compliance with IEC 60364 series

The design, erection and verification of the PV system shall comply with the requirements of:

- IEC 60364-1,
- IEC 60364-4 (all parts),
- IEC 60364-5 (all parts), and
- IEC 60364-6.

5 PV array system configuration

5.1 General

5.1.1 Functional configuration of a PV system

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

Figure 1 illustrates the general functional configuration of a PV powered system.

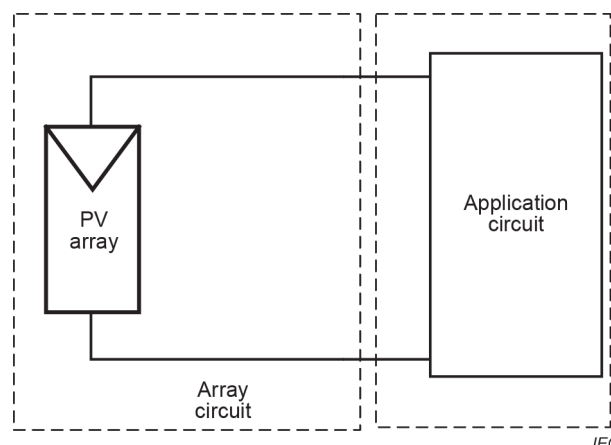


Figure 1 – General functional configuration of a PV powered system

Three kinds of application circuits are considered:

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

5.1.2 PV system topologies

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 that connection and also by the earth status of the application circuit (e.g. inverter or other equipment) to which it is connected. These aspects and the location of an earth connection all affect safety of a PV array (refer to Annex B for examples of earthed and unearthed configurations).

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

The system may be separated or non-separated between the PV array and the application circuit. If separated, the separation may be either integral to the PCE or provided externally by a transformer or other PCE with at least simple separation.

Protective earthing of any of the line or midpoint conductors of the PV array is not permitted.

Functional earthing of one of the line or midpoint conductors of the PV array is permitted where there is at least simple separation between PV array DC power circuits and the AC mains or other earthed power system. The separation may be provided either internally in the PCE or externally via a separate transformer.

Temporary functional earthing is allowed for anti-PID purposes as shown in Annex H. Where a non separated PCE is in use the temporary functional earth connection may be applied only after the PCE is disconnected from the AC mains or other earthed power system.

Where the PCE functionally earths the PV array and provides separation using an external transformer:

- all conductors and equipment located on the AC link between the PCE and the external transformer shall be rated for the common-mode voltage to earth specified by the PCE manufacturer, or shall be separated by a transformer or other equipment such that the common-mode voltage is not present;
- the transformer(s) used shall be rated for the common-mode voltage.

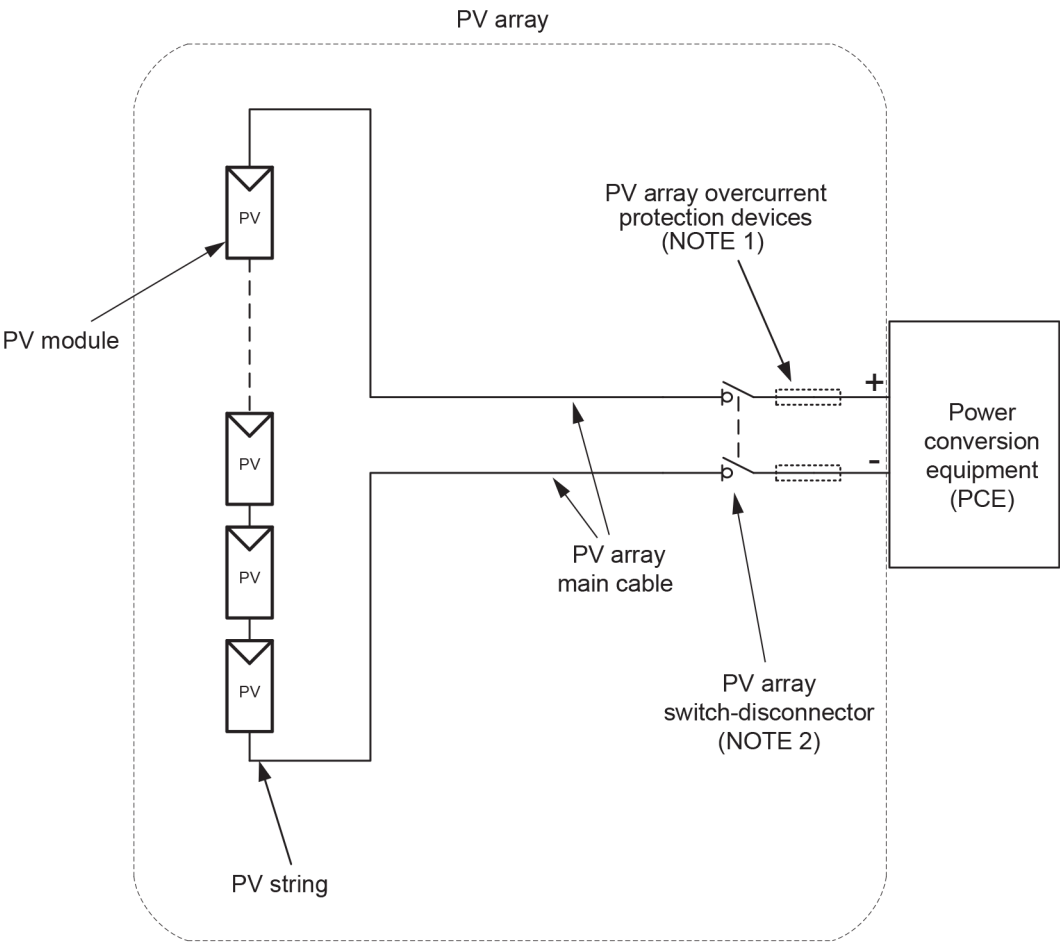
NOTE 1 In a system where the PCE is separated using an external transformer, the AC link between the inverter AC output and the transformer is often unearthed to allow flexibility regarding functional earthing of the PV array. If the PV array is functionally earthed in the PCE, some inverter topologies will impose a high common-mode voltage to earth on the unearthed AC link circuit.

Where the PCE provides separation using an external transformer and more than one PCE is connected in parallel to a common winding, the PCEs shall be specifically rated for parallel connection with each other.

NOTE 2 Parallel connection of PCEs may cause circulating currents through earth if the PCEs are not designed to mitigate such currents.

5.1.3 Array electrical diagrams

The diagrams in Figure 2 to Figure 4 show examples of the basic electrical configurations of single string, multiple parallel string and multi-sub-array PV arrays respectively.

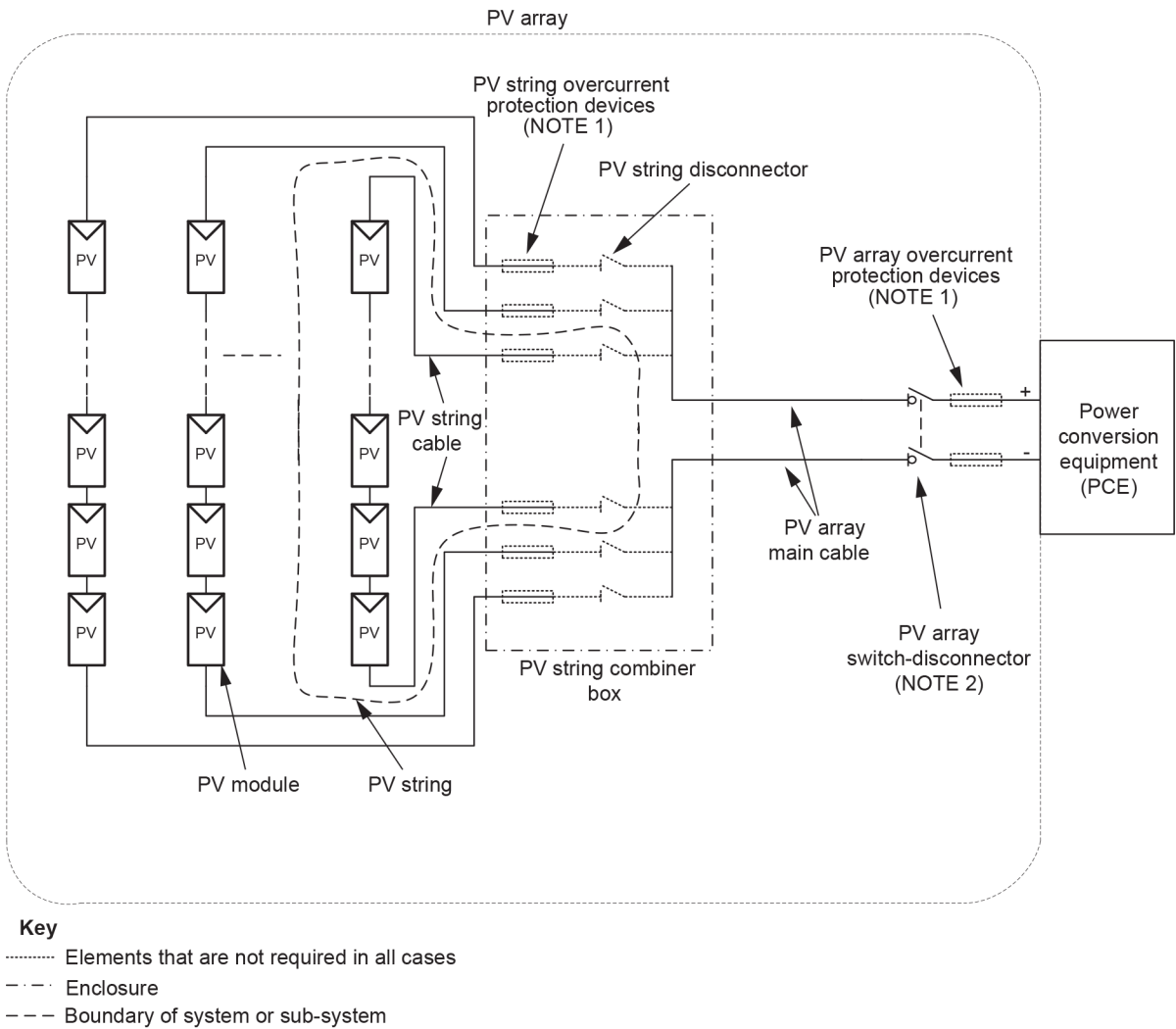


- Key**
- Elements that are not required in all cases
 - Boundary of system or sub-system

IEC

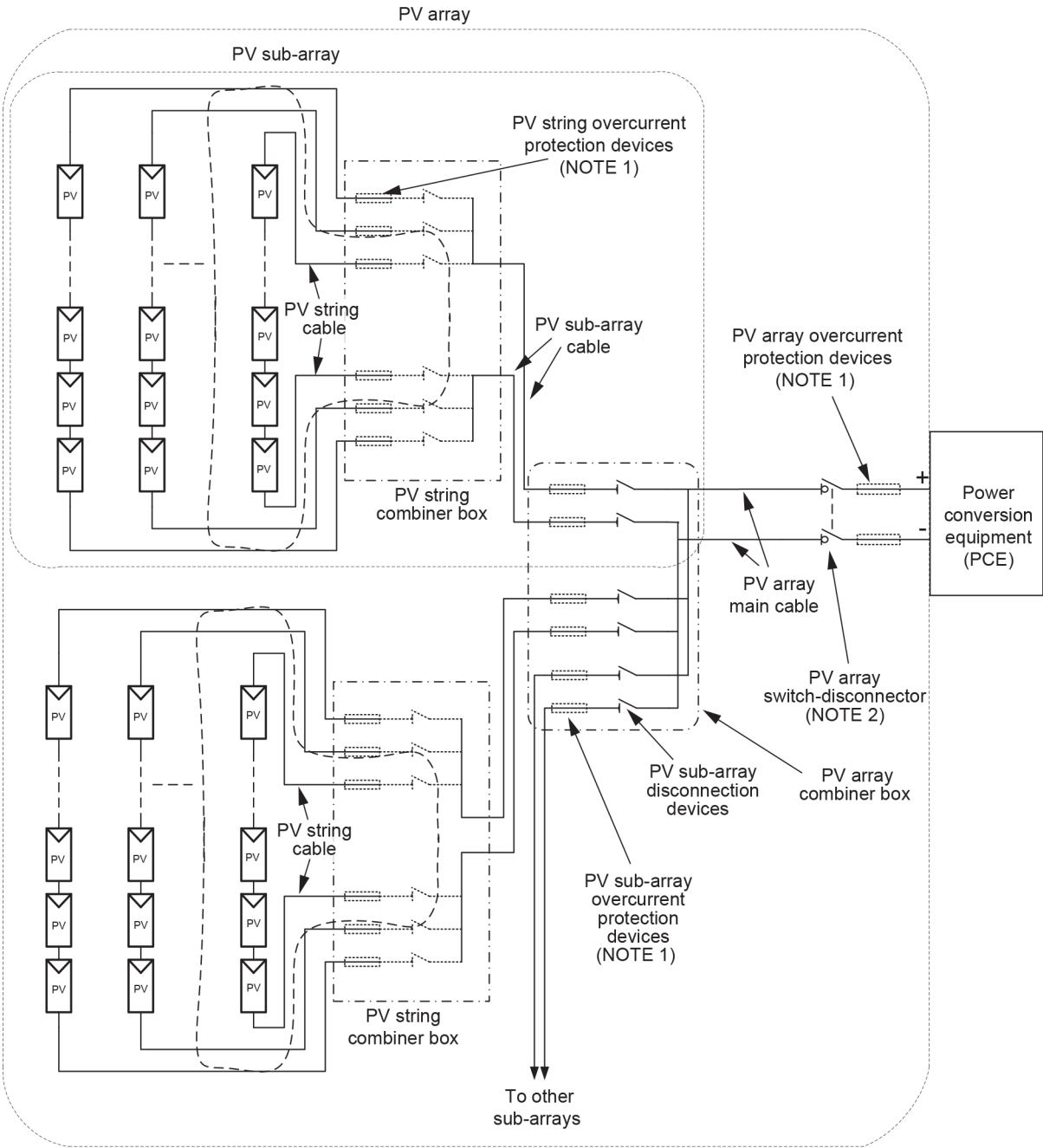
- NOTE 1 Overcurrent protection devices where required (see 6.5).
- NOTE 2 See 7.2.7 and 7.3.1 for PV array isolator/ isolation means with breaking capabilities requirements.
- NOTE 3 Overcurrent protection devices and isolation means with breaking capabilities may be located inside the PCE under certain conditions (see 7.3.1.2).
- NOTE 4 In this example there is only one string so the string cable is also the PV array main cable.

Figure 2 – PV array diagram – single string example



- NOTE 1 Overcurrent protection devices where required (see 6.5).
- NOTE 2 See and 7.3.1 for PV array isolator/ isolation means with breaking capabilities requirements.
- NOTE 3 In some systems, the PV array main cable may not exist and all the PV strings or PV sub-arrays may be terminated in a combiner box immediately adjacent to or inside the PCE.

Figure 3 – PV array diagram – multiple parallel string example

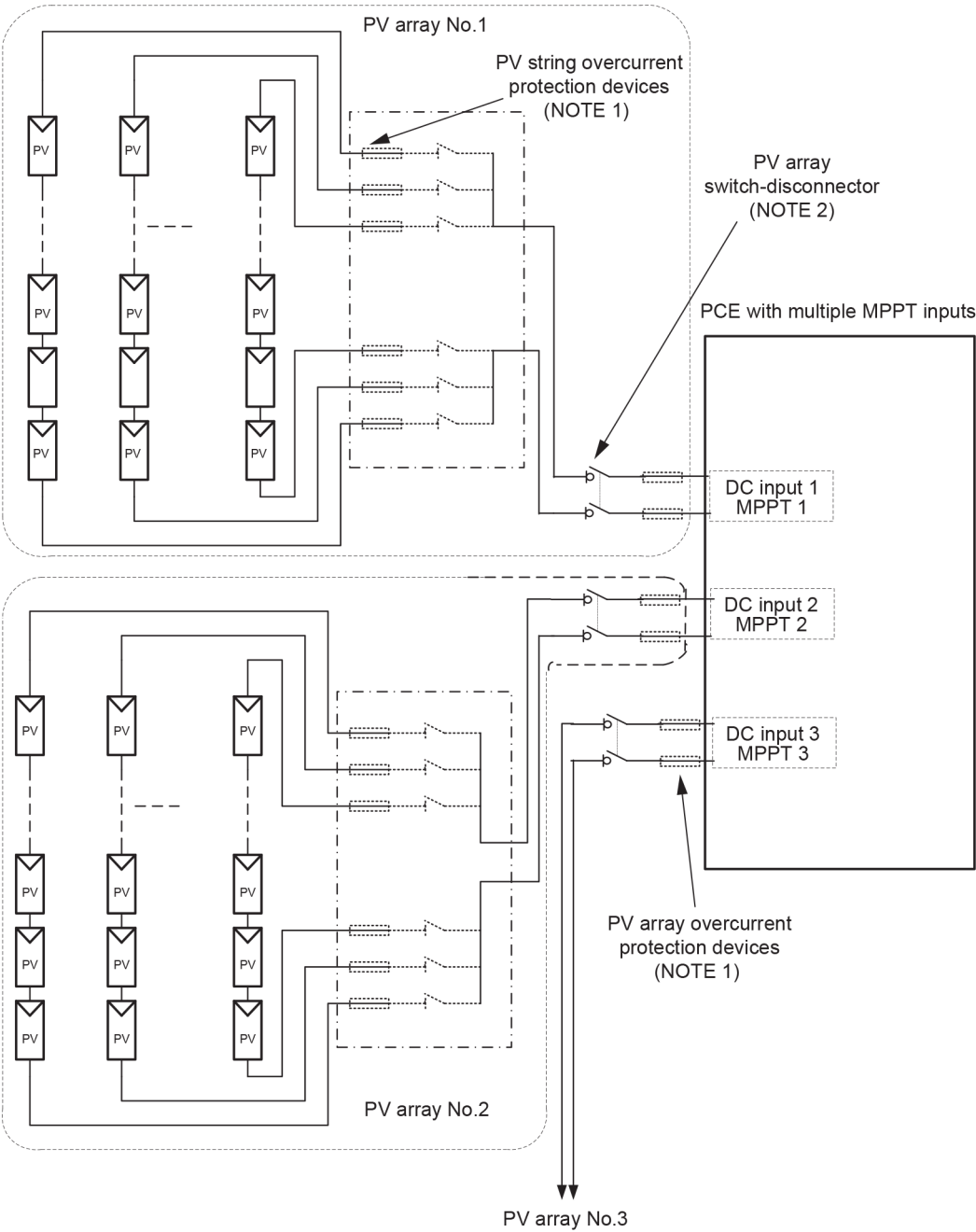


Key

- Elements that are not required in all cases
- . - . Enclosure
- - - Boundary of system or sub-system

- NOTE 1 Overcurrent protection devices where required (see 6.5).
- NOTE 2 See 7.2.7 and 7.3.1 for PV array isolator/ isolation means with breaking capabilities requirements.
- NOTE 3 In some systems, the PV array main cable may not exist and all the PV strings or PV sub-arrays may be terminated in a combiner box immediately adjacent to or inside the PCE.

Figure 4 – PV array diagram – multiple parallel string example with array divided into sub-arrays

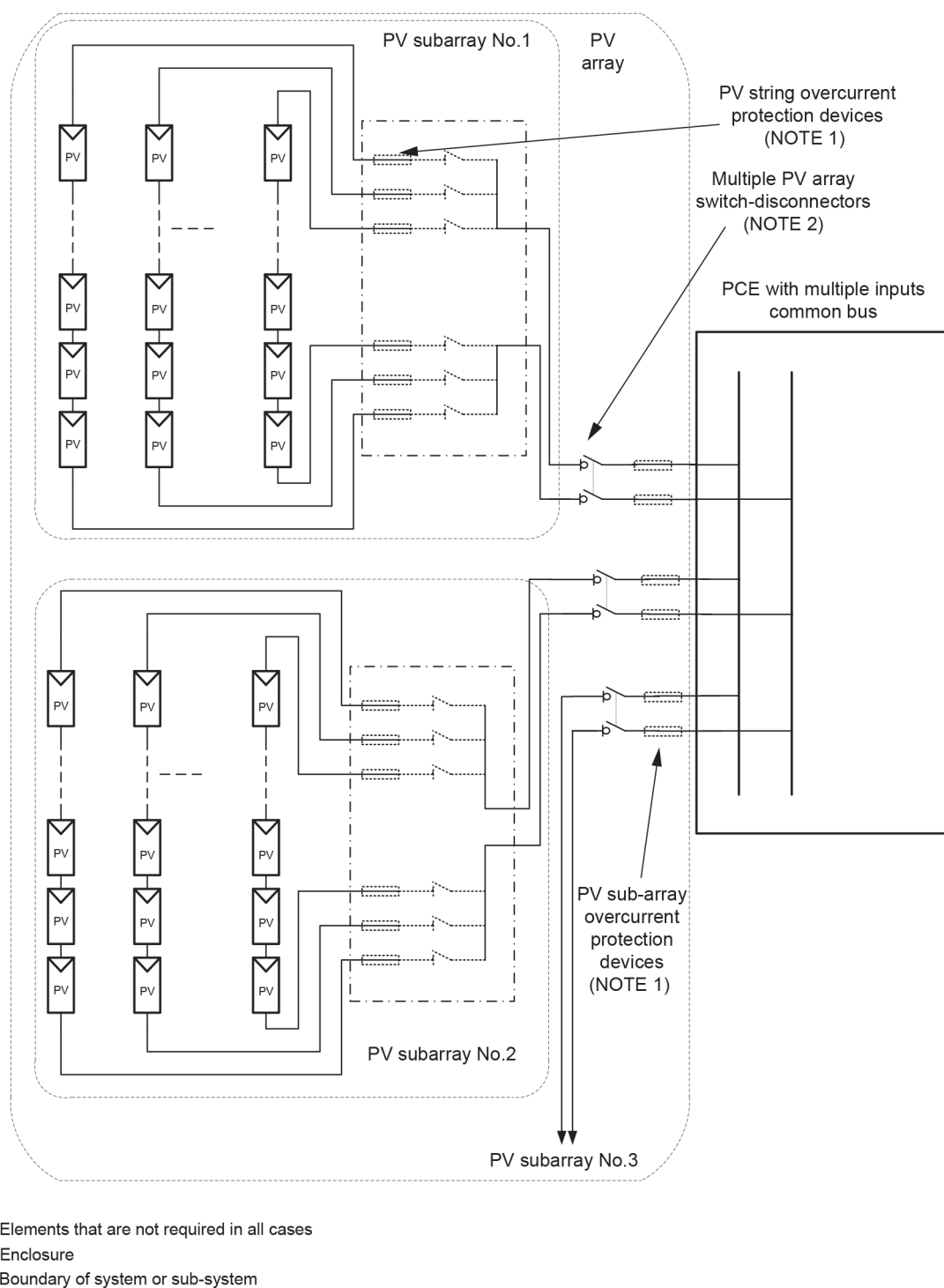


- Key**
- Elements that are not required in all cases
 - - - Enclosure
 - - - Boundary of system or sub-system

NOTE 1 Overcurrent protection devices where required (see 6.5).

NOTE 2 See 7.2.7 and 7.3.1 for PV array isolator/ isolation means with breaking capabilities requirements.

Figure 5 – PV array example using a PCE with multiple MPPT DC inputs



IEC

NOTE 1 Overcurrent protection devices where required (see 6.5).

NOTE 2 See 7.2.7 and 7.3.1 for PV array isolator/ isolation means with breaking capabilities requirements.

Figure 6 – PV array example using a PCE with multiple DC inputs internally connected to a common DC bus

5.1.4 Use of PCE with multiple DC inputs

5.1.4.1 General

PV arrays are often connected to PCEs with multiple DC inputs. 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 any possible backfeed and/or PV reverse currents. Backfeed currents may be provided by other energy sources (i.e. other than PV) connected to the PCE. Reverse currents may be provided from parallel PV strings or sub-arrays. Both backfeed and PV reverse currents, may feed into a faulty section of the array. (See to Figure 5 and Figure 6).

5.1.4.2 PCEs with DC-DC converters on the PV inputs

In the case of PCEs which have multiple PV inputs, where each input is provided with a DC-DC converter (for MPPT or other purposes), and the DC-DC converter is specified by the manufacturer as preventing PV reverse current, the PV section connected to each input (see Figure 5) may be treated for the purposes of this document as a separate PV array.

NOTE 1 The above applies whether the DC-DC converters have internal separation or not provided the PCE manufacturer specifies the ability to block PV reverse current.

NOTE 2 IEC 62109-1 Ed. 2 in preparation includes requirements for qualifying and documenting the ability of DC-DC converters to block PV reverse current.

The overcurrent protection and cable sizing of the array connected to each of those inputs shall take into account any backfeed current from the PCE as required to be specified by the IEC 62109 series.

Each PV array shall have an isolation means with load breaking capabilities to provide isolation of the PCE. The provisions of multiple isolation device with breaking capabilities in 7.3.1 apply, and a warning sign as required in 10.5.2 shall be provided.

5.1.4.3 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, without DC-DC converters, each PV section connected to one of those inputs (refer to Figure 6) shall be considered for the purposes of this document as sub-arrays, and all the PV sections combined shall be classified as the complete PV array.

The overcurrent protection and cable sizing of each sub-array shall take into account any backfeed current from the PCE as required to be specified by the IEC 62109 series, and reverse current from the parallel sub-arrays and strings.

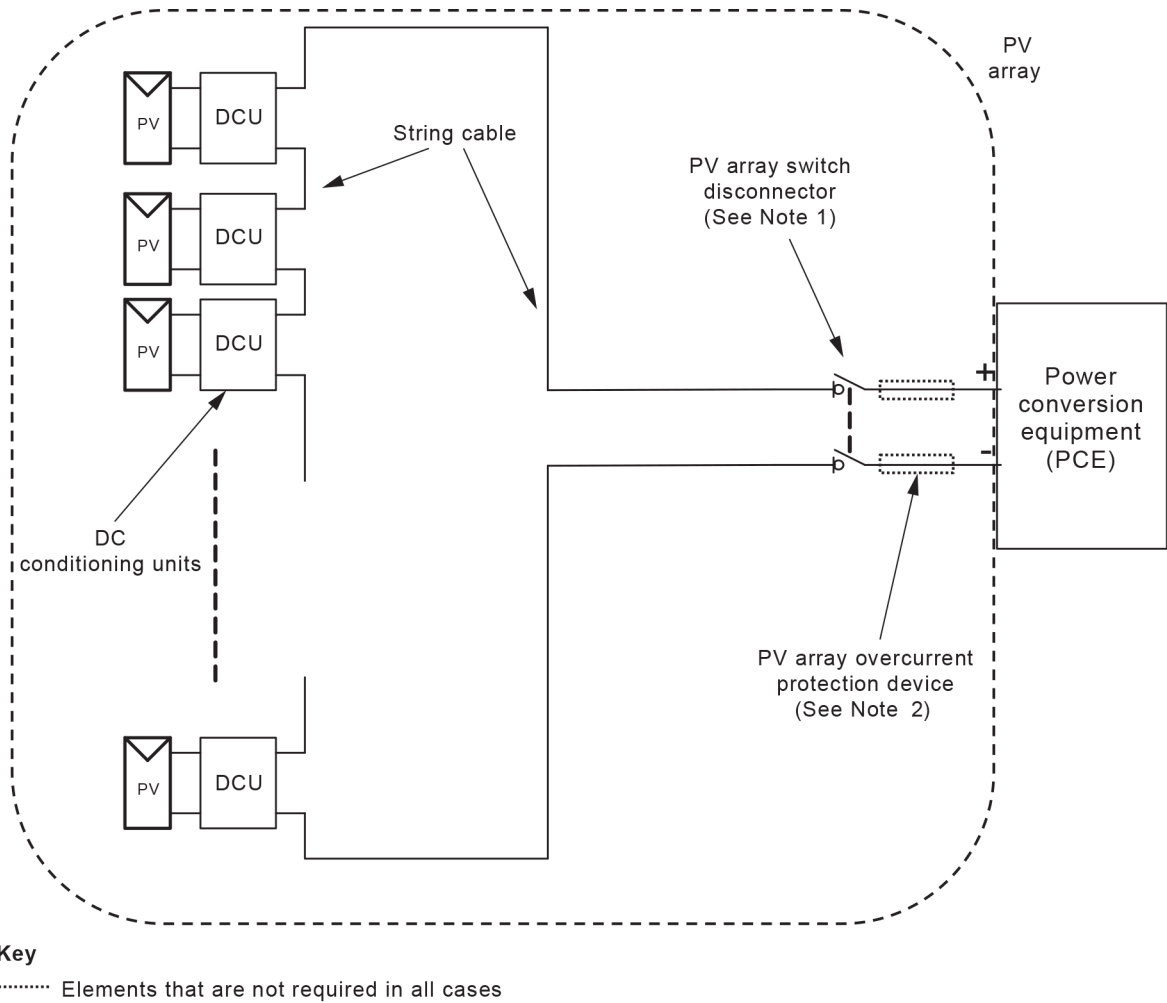
Each PV sub-array shall have an isolation means with load breaking capabilities to provide isolation of the PCE. The provisions of multiple isolation device with breaking capabilities in 7.3.1 apply, and a warning sign as required in 10.5.2 shall be provided.

5.1.5 PV arrays using DCUs

DCUs may be connected to individual PV modules, small groups of PV modules or whole PV strings to allow DC conditioning of the PV output. Figure 7 to Figure 10 show examples of some configurations in use. In some circumstances only some of the PV modules in a string may have DCUs connected (partial DCU string) to provide for modules that have shading on a regular basis. An example is shown in Figure 8.

DCUs shall be qualified to the relevant parts of IEC 62109 series.

The deployment of DCUs has implications for the voltage and current ratings within the PV-array. Refer to Clauses F.1, and F.2.



- NOTE 1 See 7.2.7 and 7.3.1 for PV array isolation device with breaking capabilities requirements.
- NOTE 2 Overcurrent protection devices where required (see 6.5).
- NOTE 3 The individual PV modules in this diagram may be replaced by multiple PV modules in series or parallel.

Figure 7 – PV string constructed using DCUs