PD CLC/TS 50539-12:2013

BSI Standards Publication

Low-voltage surge protective devices — Surge protective devices for specific application including d.c.

Part 12: Selection and application principles — SPDs connected to photovoltaic installations

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National foreword

This Published Document is the UK implementation of CLC/TS 50539-12:2013. It supersedes DD CLC/TS 50539-12:2010 which is withdrawn.

The UK participation in its preparation was entrusted by Technical Committee PEL/37, Surge Arresters - High Voltage, to Subcommittee PEL/37/1, Surge Arresters - Low Voltage.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Low-voltage surge protective devices - Surge protective devices for specific application including d.c. - Part 12: Selection and application principles - SPDs connected to photovoltaic installations

Parafoudres basse tension -
Parafoudres pour applications spécifiques incluant le courant continu -
Partie 12: Principes de choix et d'application -
Parafoudres connectés aux installations photovoltaïques

Überspannungsschutzgeräte für Niederspannung -
Überspannungsschutzgeräte für besondere Anwendungen einschließlich Gleichspannung -
Teil 12: Auswahl und Anwendungsgrundsätze -
Überspannungsschutzgeräte für den Einsatz in Photovoltaik-Installationen

This Technical Specification was approved by CENELEC on 2013-10-21.

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CENELEC

European Committee for Electrotechnical Standardization
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Europäisches Komitee für Elektrotechnische Normung

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Foreword

This document (CLC/TS 50539-12:2013) has been prepared by CLC/TC 37A "Low voltage surge protective devices".

This document supersedes CLC/TS 50539-12:2010.

CLC/TS 50539-12:2013 includes the following significant technical changes with respect to CLC/TS 50539-12:2010:

a) scope and definitions have been revised to align CLC/TS 50539-12 with EN 50539-11;

b) structure of the document has been revised for better clarification;

c) only Type 1 d.c. SPDs can be used for cases described in 6.4;

d) multi-earthed solar systems have been introduced for SPD selection and for current sharing calculation;

e) Table 1 (impulse withstand) has been introduced;

f) current sharing in Annex A has been revised;

g) Annex B has been created;

h) risk assessment has been introduced in Annex C.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

1 Scope

This Technical Specification describes the principles for selection, location, coordination and operation of SPDs to be connected to PV installations. The d.c. side is rated up to 1 500 V d.c. and the a.c. side, if any, is rated up to 1 000 V rms 50 Hz.

The electrical installation starts from a PV generator or a set of interconnected PV modules with their cables, provided by the PV generator manufacturer, up to the user installation or the utility supply point.

For PV installations including batteries, additional requirements will be necessary.

NOTE 1 HD 60364-7-712, CLC/TS 61643-12 and EN 62305-4 are also applicable.

NOTE 2 This Technical Specification deals only with SPDs, and not with SPDs components integrated inside equipment.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

CLC/TS 61643-12, *Low-voltage surge protective devices – Part 12: Surge protective devices connected to low-voltage power distribution systems – Selection and application principles (IEC 61643-12)*

EN 50539-11, *Low-voltage surge protective devices – Surge protective devices for specific application including d.c. – Part 11: Requirements and tests for SPDs in photovoltaic applications*

EN 60664-1:2007, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests (IEC 60664-1:2007)*

EN 61000-4-5, *Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test (IEC 61000-4-5)*

EN 61643-11, *Low-voltage surge protective devices – Part 11: Surge protective devices connected to low-voltage power systems – Requirements and tests methods (IEC 61643-1)*

EN 61643-21, *Low voltage surge protective devices – Part 21: Surge protective devices connected to telecommunications and signalling networks – Performance requirements and testing methods (IEC 61643-21)*

EN 62305-2:2012, *Protection against lightning – Part 2: Risk management (IEC 62305-2:2010, mod.)*

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

HD 60364-4-443, *Electrical installations of buildings – Part 4-44: Protection for safety – Protection against voltage disturbances and electromagnetic disturbances – Clause 443: Protection against overvoltages of atmospheric origin or due to switching (IEC 60364-4-44)*

HD 60364-5-534, *Low-voltage electrical installations – Part 5-53: Selection and erection of electrical equipment – Isolation, switching and control – Clause 534: Devices for protection against overvoltages (IEC 60364-5-53)*

ITU-T Recommendation K.20, *Resistibility of telecommunication equipment installed in a telecommunications centre to overvoltages and overcurrents*

ITU-T Recommendation K.21, *Resistibility of telecommunication equipment installed in customer premises to overvoltages and overcurrents*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
PV generator
assembly of PV arrays connected to one input of the inverter

3.2
PV-installation
erected equipment of a PV power supply system

3.3
open-circuit maximum voltage
$\boldsymbol{U}_{\mathbf{OC\ MAX}}$
maximum voltage across an unloaded (open) PV generator, PV string, PV array or on the d.c. side of the PV inverter

Note 1 to entry: Calculation of $\boldsymbol{U}_{\mathrm{OC\ MAX}}$ is performed in Annex B.

3.4
lightning protection system
LPS
complete system used to reduce physical damage due to lightning flashes to a structure

Note 1 to entry: It consists of both external and internal lightning protection systems.

[SOURCE: EN 62305-1:2011, 3.42]

3.5
surge protective device
SPD
device that contains at least one nonlinear component that is intended to limit surge voltages and divert surge currents

Note 1 to entry: An SPD is a complete assembly, having appropriate connecting means.

[SOURCE: EN 61643-11:2012, 3.1.1]

3.6
external lightning protection system
part of the LPS consisting of an air-termination system, a down-conductor system and an earth-termination system

[SOURCE: EN 62305-1:2002, 3.43]

3.7
separation distance
s
distance between two conductive parts at which no dangerous sparking can occur

[SOURCE: EN 62305-3:2011, 3.28, modified — abbreviation 's' is added]

3.8
lightning equipotential bonding
EB
bonding to the LPS of separated conductive parts, by direct connections or via surge protective devices, to reduce potential differences caused by lightning current

[SOURCE: EN 62305-3:2011, 3.23]

3.9
bonding bar
metal bar on which metal installations, external conductive parts, electric power and telecommunication lines, and other cables can be bonded to an LPS

[SOURCE: EN 62305-3:2011, 3.24]

3.10
bonding conductor
conductor connecting separated conductive parts to LPS

[SOURCE: EN 62305-3:2011, 3.25]

3.11
standard test conditions
STC
test conditions specified in EN 60904-3 for PV cells and PV generators

3.12
open circuit voltage under standard test conditions
$U_{OC\ STC}$
voltage under standard test conditions across an unloaded (open) PV generator, PV string, PV array or on the d.c. side of the PV inverter

3.13
short-circuit current under standard test conditions
$I_{SC\ STC}$
short-circuit current of a PV generator, PV string or PV array under standard test conditions

3.14
external LPS isolated from the structure to be protected
LPS with an air-termination system and down-conductor system positioned in such a way that the path of the lightning current has no contact with the structure to be protected

Note 1 to entry: In an isolated LPS, dangerous sparks between the LPS and the structure are avoided.

[SOURCE: EN 62305-3:2011, 3.3]

3.15
current branch of an SPD
intended current path, between two nodes that contains one or more protective components

Note 1 to entry: A current branch of an SPD may be identical with a mode of protection of a SPD.

Note 2 to entry: This intended current path does not include additional terminals.

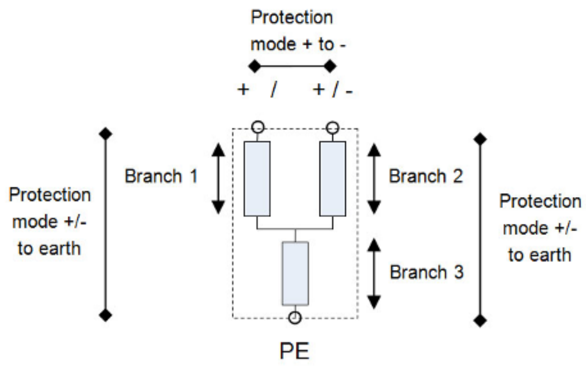


Figure 1 – Current branches vs. modes of protection of an SPD

[SOURCE: EN 50539-11:2013, 3.1.7]

4 Systems and equipment to be protected

Overvoltages can destroy, degrade or cause malfunction of a PV installation. Therefore, PV installations shall be protected in presence of overvoltage risk. The most sensitive parts of the equipment should first be protected: the inverter and the control/monitoring equipment, the PV generator and the wiring (installation itself).

5 Overvoltages in a PV installation

Overvoltages can be found under several conditions in a PV installation. They may be

— caused by direct strike (S1) to the external lightning protection system (LPS) of the building or lightning flashes nearby (S2) the buildings and/or PV installations,

— caused by direct strikes (S3) and lightning induced currents (S4) distributed into the electrical network,

— transmitted from the distribution network due to operations (switching).

NOTE S1, S2, S3 and S4 are abbreviations used in EN 62305 series (sources of damage).

The protection requirements within this document are based on the assumption that the cable interconnecting the d.c. components of the PV installation is sufficiently protected from direct lightning either by appropriate routing or by shielding, e.g. use of appropriate cable management system.

6 Installation and location of SPDs

6.1 General

According to CLC/TS 61643-12 and EN 62305 series, installation and location of SPDs for protection of PV installations depends on multiple factors, the main ones being

— the flash ground density of the location,

— the presence of overhead lines,

— the characteristics of the low-voltage power distribution system (e.g. overhead network or not) and of the equipment to be protected,

— if protection measures are needed to protect the PV-installation against direct lightning impacts with an external LPS.

When installations are protected by an external LPS, the requirements for SPD selection depends on

- the selected class of the LPS (see Annex A: simplified method),
- if the separation distance s is kept between the LPS and the PV installation (isolated LPS) or not kept (non-isolated LPS).

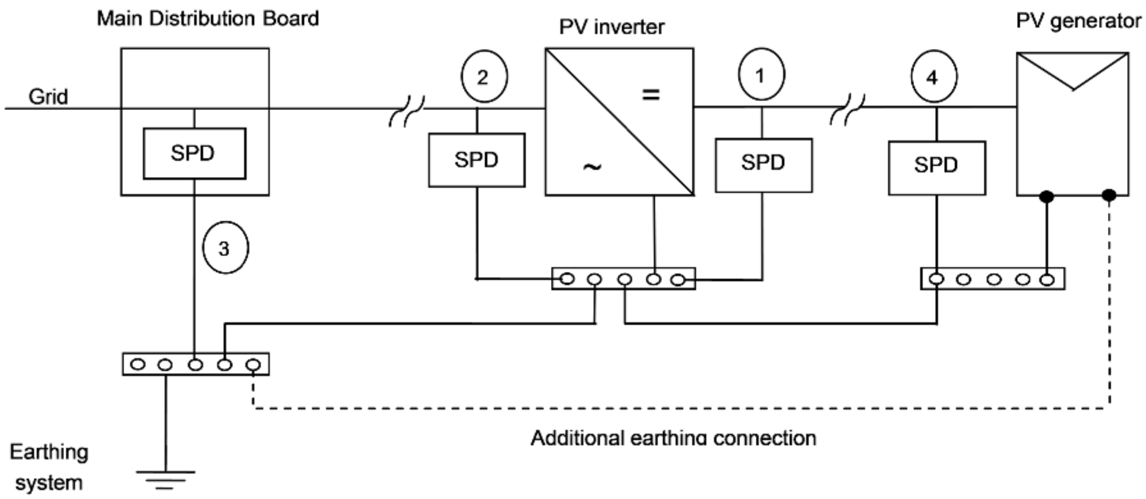
For further detail on external LPS and separation distance requirements, see EN 62305-3.

NOTE The separation distance s is typically less than 1 m.

All SPDs installed on the same line have to be coordinated (see CLC/TS 61643-12).

Examples for installations of SPDs for the different cases are shown in Figure 2 to Figure 5.

6.2 PV installation without external LPS



Key

1 SPD PV type 2 according to EN 50539-11

2 SPD type 2 according to EN 61643-11

3 SPD as required in HD 60364-5-534 and according to EN 61643-11

4 SPD PV type 2 according to EN 50539-11

Figure 2 – Installation of SPDs in case of PV installation without external LPS

In general, one set of SPDs on the d.c. side and one set of SPDs on the a.c. side of the inverter should be installed as close as possible to the inverter.

The SPD in location 2 is not needed (see 9.2.1.4) if the distance between the SPD in location 2 (main distribution board) and the inverter is less than 10 m. In this case, only one SPD is required in location 2 (main distribution board).

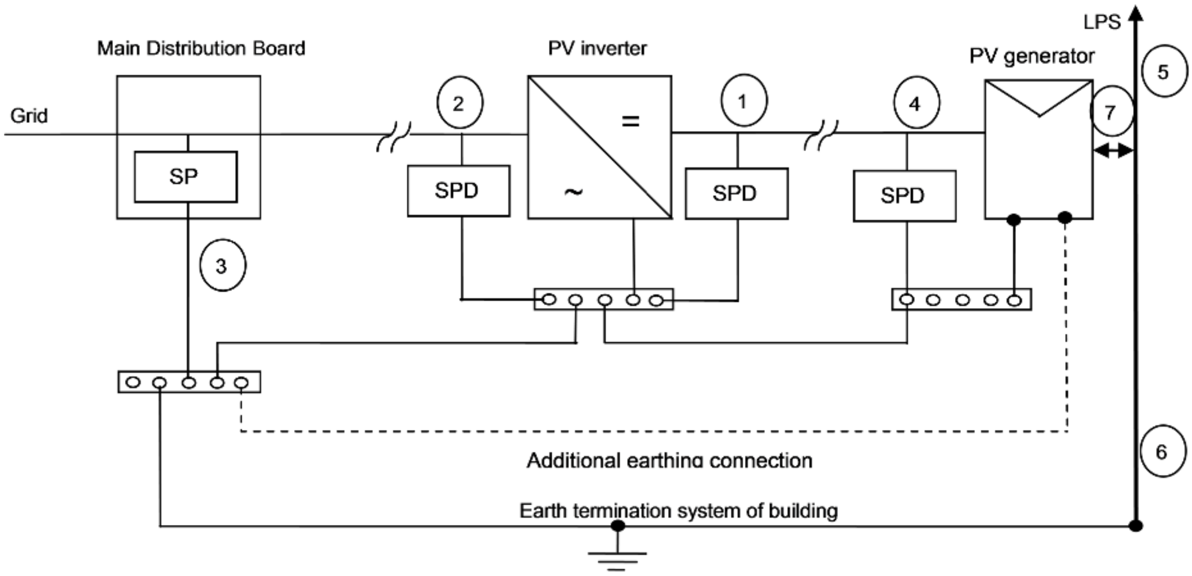
The SPD in location 4 is not needed (see 9.2.2.4) if

— either the distance between inverter and PV generator is less than 10 m,

— or the protection level (U_P) of the SPD installed in location 1 is less than or equal to 50 % of the U_w value of the PV generator (see 9.2.2.3).

6.3 PV installation with external LPS when separation distance s is kept

NOTE This subclause does not apply to multi earthed solar system such as outside free field power plant.



Key

1 SPD PV type 2 according to EN 50539-11

2 SPD type 2 according to EN 61643-11

3 SPD as required in HD 60364-5-534 and according to EN 61643-11

4 SPD PV type 2 according to EN 50539-11

5 air termination system

6 down conductor

7 separation distance is kept or isolated LPS

Figure 3 – Installation of SPDs in case of a building with external LPS when separation distance s is kept

The same requirements expressed in 6.1 are to be applied except that SPD in location 3 is a SPD Type 1 and is mandatory (see CLC/TS 61643-12, HD 60364-5-534 and EN 62305-4).

An additional example of a building with external LPS where the separation distance s is kept and an installation that includes a data acquisition and control system is given in Figure 4. This last example shows how the surge protection of data and control systems linked to the PV installation has to be done. The principle applies to PV installations described in 6.2 and 6.4 as well.

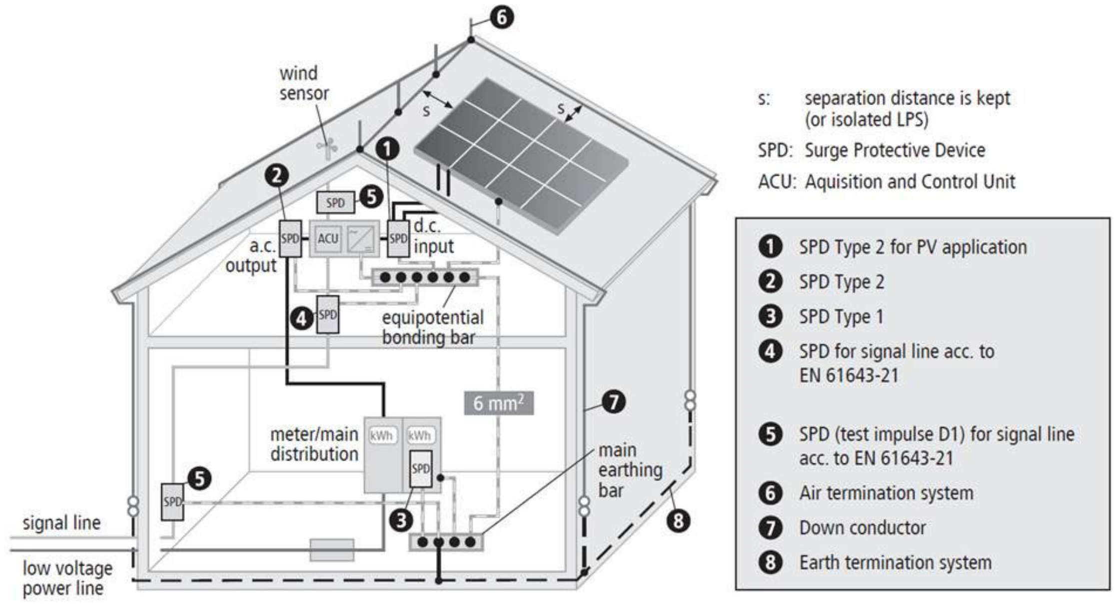
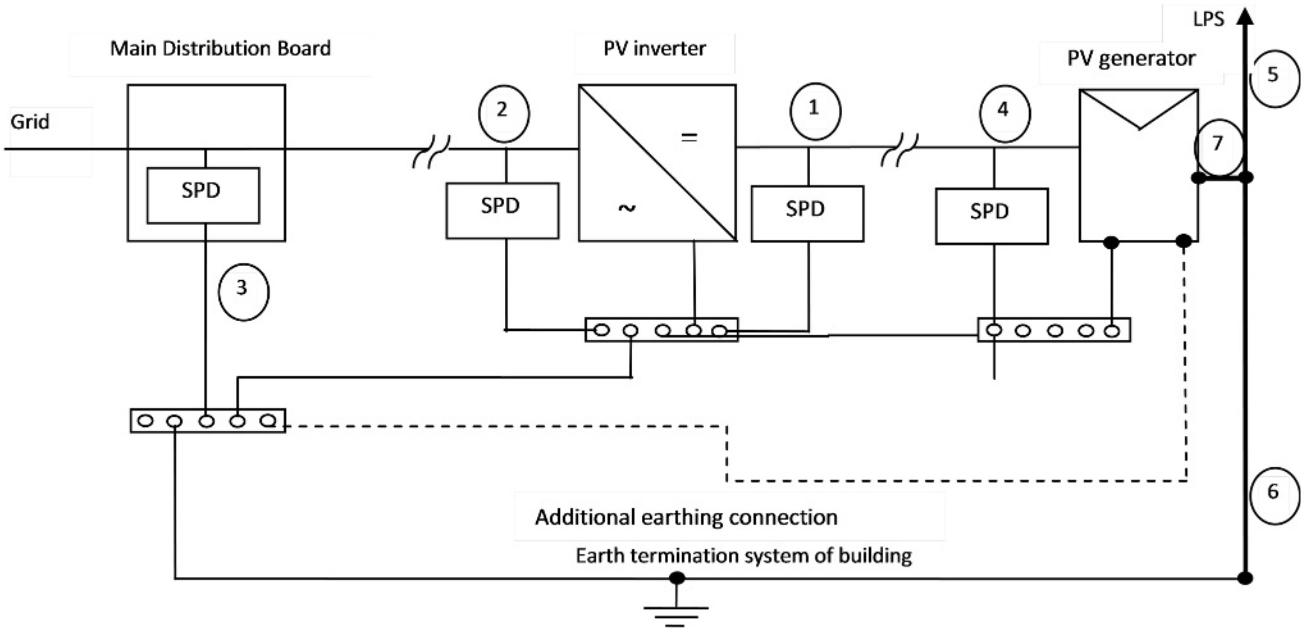


Figure 4 – Installation of SPDs in case of a building with external LPS when separation distance s is kept – Installation with data acquisition and control system

For optimum inverter overvoltage protection, it is recommended to add a direct earthing connection between SPD and inverter.

6.4 PV installation with external LPS when separation distance is not kept

NOTE 1 This subclause also applies to multi-earthed solar system such as outside free field power plant when separation distance is kept.



Key

1 SPD PV type 1 according to EN 50539-11

2 SPD type 1 according to EN 61643-11

3 SPD as required in HD 60364-5-534 and according to EN 61643-11

4 SPD PV type 1 according to EN 50539-11

5 air termination system

6 down conductor

7 equipotential bounding (separation distance is not kept = Non-isolated LPS)

Figure 5 – Installation of SPDs in case of PV installation with external LPS when separation distance s is not kept

In that configuration, the a.c. and d.c. conductors act as parallel conductors to the equipotential bonding conductors.

SPDs are SPD Type 1 for locations 1, 2, 3 and 4 and SPDs for locations 1 and 2 should be installed as close as possible to the inverter. The SPD(s) for location 4 should be installed as close as possible to the PV generator.

In very small PV installation, where the inverter and the main distribution board are connected to the same earthing bar, SPD in location 2 is not mandatory (i.e. inverter in the main distribution board).

NOTE 2 The protection of PV generators may require specific considerations depending on cabling, routing panel arrangement and cable length considering protection costs and possible losses.

7 Equipotential bonding

Protective conductors and other earthing conductors for functional and protective purposes cannot generally be considered as equipotential bonding dedicated for surge and lightning protection.

If the equipotential bonding conductors are considered as down conductors, the minimum cross section shall be 50 mm^2 copper or equivalent.

If the equipotential bonding conductors are intended to carry partial lightning currents, the minimum cross section shall be 16 mm^2 copper or equivalent.

The minimum cross section of the bonding conductor connecting internal metallic installation to the bonding bar shall be 6 mm^2 copper or equivalent.

If the equipotential bonding conductors are intended to carry only induced lightning currents the minimum cross section shall be 6 mm^2 copper or equivalent.

The minimum cross section of the bonding conductor connecting different bonding bars and connecting the bars to the earth termination system is 16 mm^2 copper or equivalent in case of PV installation not connected to the LPS.

If a PV array is protected by a LPS, the minimum separation distance s between the LPS and the metal structure of the PV array should be kept to prevent partial lightning currents flowing via the PV array structure.

See Figure 6 and Figure 7 for examples of minimum cross sections of equipotential bonding conductors that should be as required by CLC/TS 61643-12, HD 60364-5-54 and EN 62305-3.

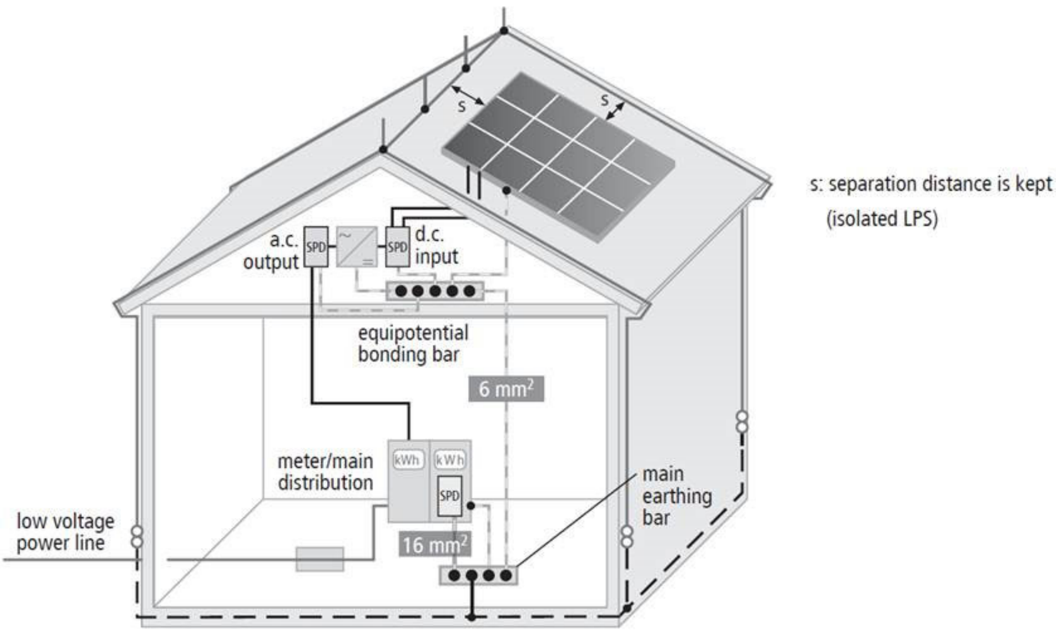


Figure 6 – Building with external LPS:
Dimensions of all equipotential bonding conductors are 6 mm^2 except the one indicated in the figure (earthing of the SPD Type 1 located at the origin of installation)

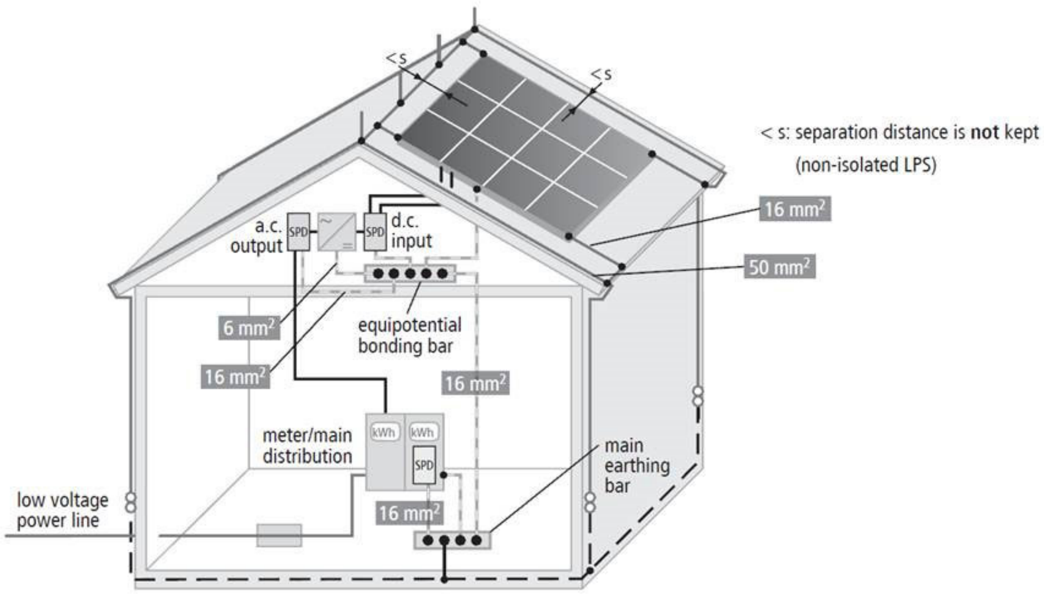


Figure 7 – Building with external LPS: Dimensions of equipotential bonding conductors in case of a non-isolated LPS

A solution to prevent the flow of partial lightning current into the internal metal parts of the PV generator would be the installation of an isolated external LPS as described in EN 62305-3.

8 Surge protective devices (SPD) in PV installations

SPDs shall comply with

— EN 61643-11 for surge protective devices connected to low-voltage power system (a.c. side),

— EN 50539-11 for surge protective devices connected to the d.c of photovoltaic system (d.c. side), and

— EN 61643-21 for surge protective devices connected to telecommunication and signalling lines.

9 Requirements for the implementation of SPDs

9.1 Decision for using SPDs

For the d.c side of PV installation, where the relevant data are available, a risk assessment may be carried out to evaluate if protection by SPD is needed. The method could be the method described in EN 62305-2 or a simplified method as provided in Annex C. If no risk assessment is performed, the d.c. installation shall be protected by SPDs.

For the a.c. side of PV installation the need of SPD shall be determined according to CLC/TS 61643-12, HD 60364-4-443 or EN 62305-2.

9.2 Selection and installation of SPDs for application in PV installation

9.2.1 Selection of SPDs installed at the a.c. side of PV installations

9.2.1.1 General

The selection of SPDs for the protection of the a.c. side of the PV installations has to follow the rules of CLC/TS 61643-12 and HD 60364-5-534. This Technical Specification takes only some specific details for the protection of the equipment on the a.c. side of the PV installation into account.

9.2.1.2 Selection of SPDs with regard to nominal discharge current I_n and impulse current I_{imp}

For SPDs in the main distribution board refer to HD 60364-5-534.

If SPDs Type 2 are required close to the inverter, the minimum nominal discharge current I_n for each mode of protection shall be 5 kA 8/20. A higher value may result in a longer lifetime.

If SPDs Type 1 are required close to the inverter, the minimum impulse current I_{imp} for each mode of protection shall be 12,5 kA 10/350.

Different values of I_{imp} for SPDs in main distribution board may be required as defined by EN 62305 standards. A simplified approach is given in CLC/TS 61643-12 to define the value of I_{imp} depending on the risk Lightning Protection Level (LPL) and number of conductors.

9.2.1.3 Selection of SPDs with regard to protection level (U_P) and system immunity

In order to identify the needed protection level, it is necessary to establish the immunity levels of the equipment as follows:

— power lines and equipment terminals according to EN 61000-4-5, HD 60364-4-443 and EN 60664-1;

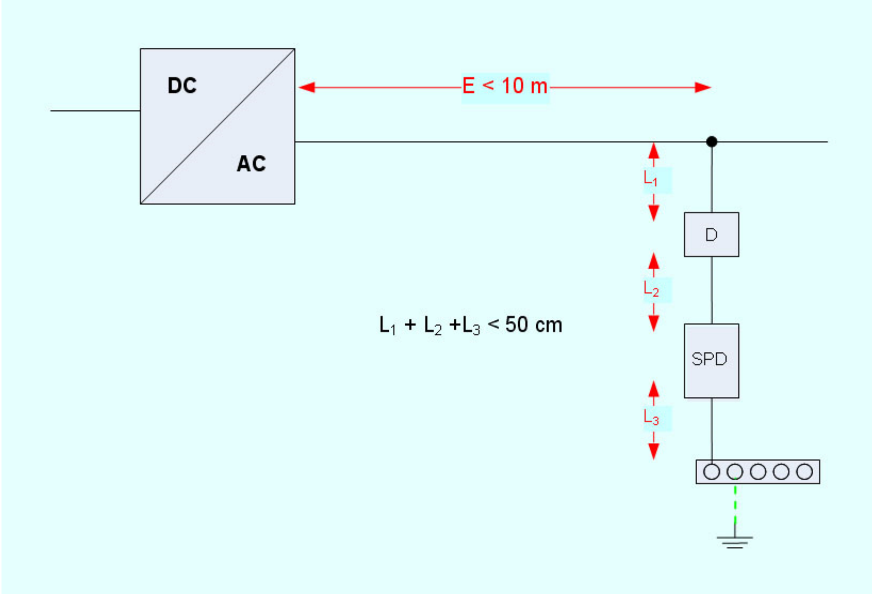
— telecom lines and equipment terminals according to EN 61000-4-5, ITU-T K.20 and ITU-T K.21.

If not otherwise specified, the acceptable overvoltage category is category II. The maximum voltage likely to reach the equipment is fixed to a maximum of 2,5 kV for 230/400V system. This generally implies a protection scheme with several levels of coordinated SPD. The manufacturers of SPDs give the rules for this coordination.

To ensure an effective protection of the equipment, the values of U_P shall be lower than the value of voltage withstand of the equipment to be protected. A safety margin of at least 20 % between the voltage withstand of the equipment and U_P should be kept (CLC/TS 61643-12).

9.2.1.4 Installation of SPD on the a.c. side of PV installations

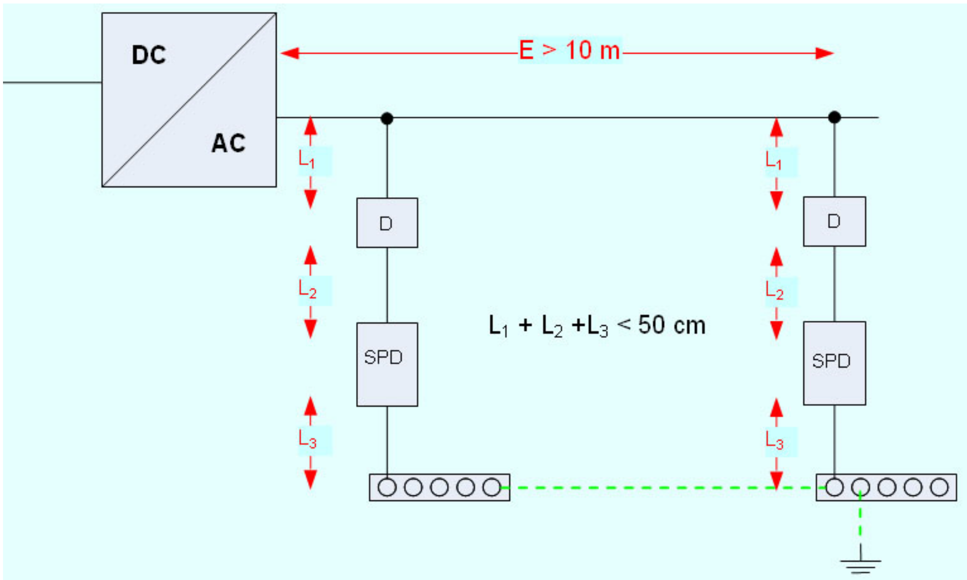
An SPD should be installed as close as possible to the origin of installation, e.g. at the connection point of the PV installation to the public network (Figure 8). For PV installations according to 6.2 and 6.3, if the length of the wiring between this SPD and the inverter (distance E) is greater than 10 m, it is necessary to protect the inverter with a complementary SPD nearby (Figure 9).



Key

E	distance between origin of Installation and inverter
L_1, L_2 and L_3	connecting cable
D	disconnector of the SPD

Figure 8 – Installation of SPDs on the a.c.-side and short distance between origin of installation and PV-inverter (E < 10 m)



Key

E	distance between origin of Installation and inverter
L_1, L_2 and L_3	connecting cable
D	disconnector of the SPD

Figure 9 – Installation of SPDs on the a.c.-side and long distance between origin of installation and PV-inverter (E > 10 m)

As required in CLC/TS 61643-12, the total length of connecting cables (L_1+L_2+L_3) shall be as short as possible.

For PV installation according to 6.4, the 10-meter's rule is not applicable and two sets of SPDs are mandatory, except for very small PV installations, where the inverter and the main distribution board are connected to the same earthing bar (i.e. inverter in the main distribution board).

9.2.2 Selection of SPDs installed at the d.c. side of PV-installation

9.2.2.1 Selection of SPDs with regard to nominal discharge current I_n and impulse current I_{imp}

If SPDs Type 2 are required, the minimum nominal discharge current I_n for each mode of protection shall be 5 kA 8/20. A higher value may result in a longer lifetime depending on SPD technology.

Different values of I_n (higher or lower) may be selected based on technical studies.

If SPD Type 1 are required, and no detailed technical data are available, the minimum impulse current I_{imp} for each mode of protection shall be 12,5 kA 10/350. Different values of I_{imp} (higher or lower) may be selected based on Annex A.

9.2.2.2 Selection of U_{CPV} of SPDs on the d.c. side of PV installations

The maximum continuous operating voltage U_{CPV} of the SPD shall be selected to higher than or equal to the maximum open circuit voltage of the PV generator $U_{OC\ MAX}$, under all conditions (radiation and ambient temperature).

U_{CPV} has to be considered for each mode of protection (+/-, +/earth and -/earth).

Additional information is given in Annex B.

NOTE The voltages between the d.c. conductors and earth depend on the inverter technology and are not always pure d.c. voltages.

9.2.2.3 Selection of SPDs with regard to voltage protection level (U_P) and system immunity

In order to identify the needed voltage protection level, it is necessary to establish the immunity levels of the equipment as follows:

— power lines and equipment terminals according to EN 61000-4-5 and EN 60664-1;

— telecom lines and equipment terminals according to EN 61000-4-5, ITU-T K.20 and ITU-T K.21.

To ensure an effective protection of the equipment, the values of U_P shall be lower than the value of voltage withstand of the equipment to be protected. A safety margin of at least 20 % between the voltage withstand of the equipment and U_P should be kept (CLC/TS 61643-12).

If no other information is given, the withstand voltage for the equipment can be selected from Table 1.

Table 1 – Impulse withstand voltage U_W for equipment between PV generator and inverter

$U_{OC\ MAX}$ V	U_w V		
	PV Generator [a]	Inverter [b]	Other equipment [c]
100	800	2 500 (minimum requirement)	800
150	1 500		1 500
300	2 500		2 500
424	4 000		4 000
600	4 000	4 000	4 000
800	5 000		5 000
849	6 000		6 000
1 000	6 000	6 000	6 000
1 500	8 000	8 000	8 000

NOTE Table 1 doesn´t apply to the a.c side of the inverter.

[a] Component withstand values are based on IEC 61730-2 ed 2.0, Table 8 [8] basic insulation.

[b] Component withstand values are based on EN 62109-1:2010, 7.3.7.1.2 b.

[c] Component withstand values are based on U_{imp} according to EN 60664-1:2007 overvoltage category II

9.2.2.4 Installation of SPD at the d.c.-side of PV installation

A SPD should be installed as close as possible to the inverter. For PV installations according to 6.2 and 6.3, if the length of the wiring between this SPD and the PV generator (distance E, see Figure 8 and Figure 9) is greater than 10 m, it is needed to protect the PV generator with a complementary SPD nearby (see Figure 10).

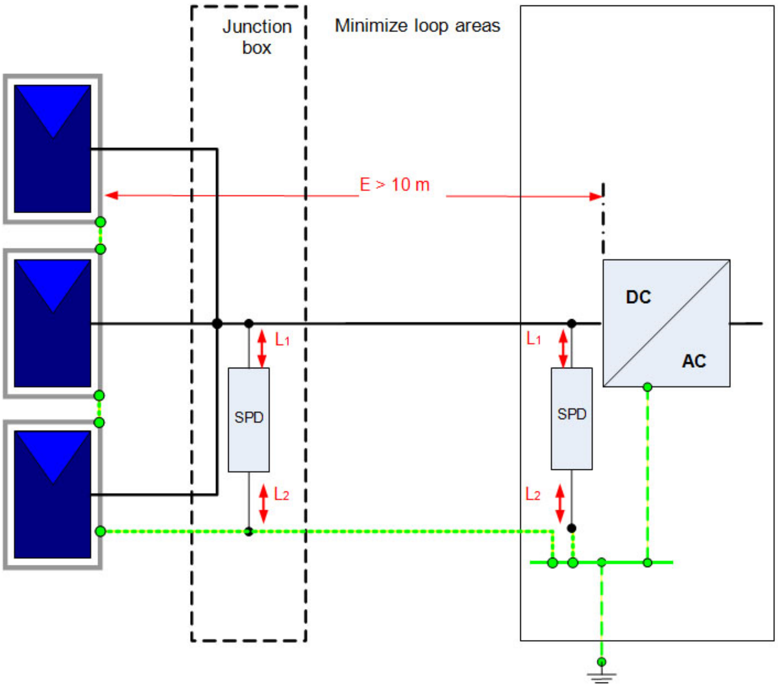


Figure 10 – Example of an overvoltage protection on d.c. side of a PV installation

As required in CLC/TS 61643-12, the total length of connecting cables (L_1+L_2) shall be as short as possible.

If the distance E is greater than 10 m and the protection level U_P is less than 0,5 * U_W (generator), it is possible to use only one set of SPD (generally in front of the inverter).

NOTE For common PV generators, it can be assumed that the impulse withstand U_W (generator) is higher than the impulse withstand U_W (Inverter) of the inverter.

For PV installation according to 6.4, the 10-meter's rule is not applicable and two sets of SPDs are mandatory.

9.2.2.5 Cross-section of connecting conductors to SPDs on the d.c. side of PV installations

The connection of SPDs should be according to the following rules:

- earthing conductors of SPDs Type 1 shall have a minimum cross-sectional area of 16 mm^2 copper or equivalent or equal to the cross sectional area of live connectors, if greater than 16 mm^2;
- earthing conductors of SPDs Type 2 shall have a minimum cross-sectional area of 6 mm^2 copper or equivalent or equal to the cross sectional area of live connectors, if greater than 6 mm^2;
- the cross sectional area of the connecting conductors from the SPD to live conductors shall not be less than the cross sectional of the live conductors of the associated circuit.

To ensure that the live conductors of the PV installation can withstand the surge current stress, the cumulated cross sectional area of these conductors should not be less than 6 mm^2 or 16 mm^2 for SPD Type 2 and SPD Type 1 respectively.

9.2.2.6 Internal connection schemes of SPDs or combination of single mode SPDs on the d.c.-side of PV generator

The surge protection can be either a connection of single mode SPDs or a multipole SPD. The protective components used in SPDs can be voltage limiting components, voltage switching components or a combination of them.

PV installations where none of the live conductors is provided with a solid earth connection, capable to carrying the expected surge or partial lightning currents, are considered as non-earth PV installation with regard to SPD protection and installation configuration.

NOTE 1 A fuse is not considered as solid earth connection.

Examples of SPD's connection configuration to the PV installation are given in the following figures (Figure 11 to Figure 16).

NOTE 2 In Figure 11 to Figure 16, each grey shaded rectangle represents one or more component(s) connected in parallel and/or in series.

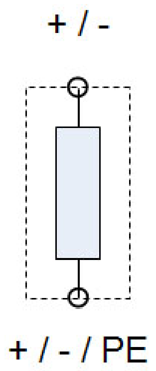


Figure 11 – I-configuration

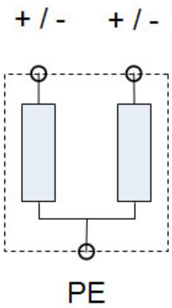


Figure 12 – U-configuration

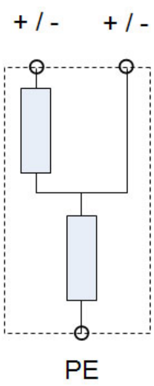


Figure 13 – L-configuration

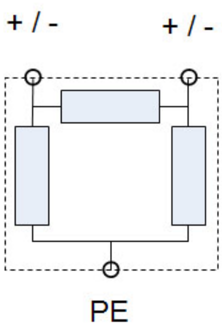


Figure 14 – Δ-configuration

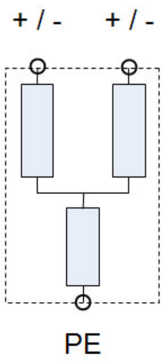


Figure 15 – Y-configuration

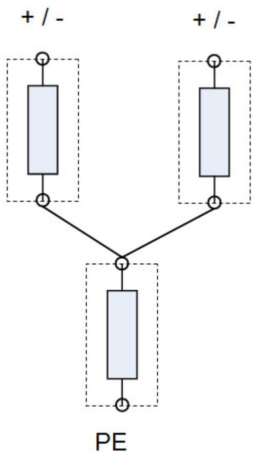


Figure 16 – Single mode SPDs to be connected in Y-configuration

9.2.2.7 Overload behaviour of SPD installed on the d.c. side of PV installation.

SPDs in PV applications can be damaged for the following reasons:

— by thermal runaway due to an excessive amount of constraints following lightning strikes not exceeding its characteristics, but leading to a slow destruction of its internal components;

— by sudden fail due to a stress going beyond of its characteristics, thus leading to a sudden degradation of its impedance.

In both cases, the SPD has a dedicated overload behaviour tested under overload condition procedure of EN 50539-11:

- Short-Circuit Mode (SCM) where the behaviour of the SPD is to turn to a short circuit like state;
- Open Circuit Mode (OCM) where the behaviour of the SPD is to disconnect from the d.c. power.

SPDs with OCM overload behaviour have disconnectors (which can be either internal, external or both).

The short circuit current rating I_{SCPV} of the selected SPD shall be given by the SPD manufacturer and shall be equal or greater than the max current $I_{SC\ MAX}$ which may be provided by the PV generator (further information is given in Annex B).

NOTE 1 Not all PV installation and inverter technologies are able to tolerate a short circuit on the d.c. side. A permanent short circuit to ground may cause a safety risk in some installations. More information is given in HD 60364-7-712.

NOTE 2 Additional requirements may apply when batteries are connected to the d.c. circuits.

10 Maintenance

Due to possible hazard to people and property because of d.c. arcing during exchange, plug-in SPDs with short circuit mode overload behaviour require appropriate external means for disconnection that shall be declared by the manufacturer. For SPDs that cannot be replaced without the use of tool, the disconnection means is required to have isolating capability.

Annex A
(informative)

Determination of the value of I_{imp} or I_n for SPDs for different structures protected by a LPS according to a simplified approach

A.1 Introduction

EN 62305 series consider protection of buildings against lightning effects in a global approach. Protection of the entire installation against direct lightning impacts (protection of the structure itself) and against lightning induced surge overvoltages (protection of the network feeding the installation) is based on a very complete risk analysis (EN 62305-2). For each particular situation, the risk analysis will assign to the installation under study a level of risk ranging from I to IV so called lightning protection level (LPL). When required, a LPS (the lightning protection system is the protection of the building itself) will then be designed and erected to protect the structure in accordance with the LPL needs.

Determination of I_{imp} is a consequence to that LPL. In the following annex, one can find a simplified approach to determine its value.

A.2 PV installation on a building according to 6.4

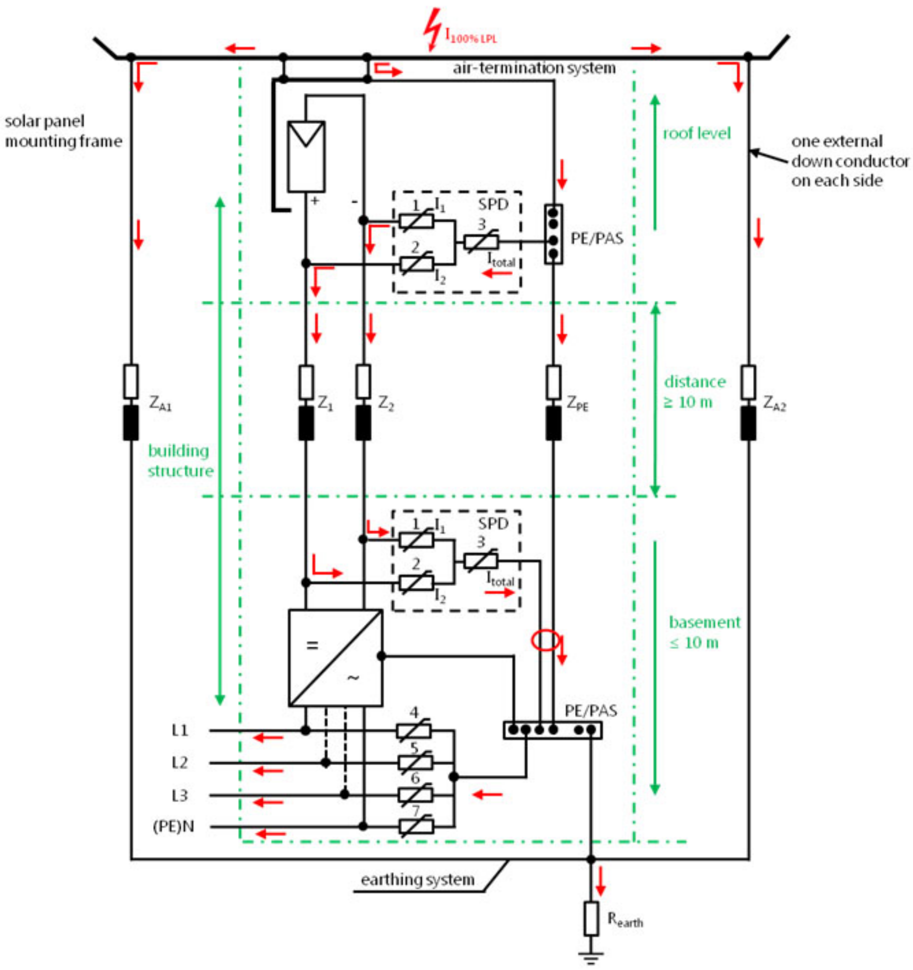
A.2.1 General

The following example is based on measurements and simulations to determine the discharge current sharing on the d.c. side of a PV installation on a building with two external down conductors and for voltage limiting type SPDs (i.e. MOV) used for protection (see Figure A.1).

Especially due to their relatively high impedance, voltage limiting type SPDs used to protect the d.c. side of PV installation will influence current sharing between the d.c. power conductors, the equipotential bonding conductor and the external LPS (down conductors). This has a noticeable influence on the discharge current duration (shorter than 10/350 according to class I). Nevertheless the SPDs will be stressed by impulse currents with more energy content than a 8/20 impulse with the corresponding peak value.

Due to the fact that SPDs are tested with standardised test impulses either 10/350 or 8/20 waveshapes, both impulses have to be applied to the SPDs used in this application. A distinction between 10/350 impulse ($I_{10/350}$) and 8/20 impulse ($I_{8/20}$) makes sense with respect to the simulated reduced impulse time duration.

The results for the different values of $I_{10/350}$ and for $I_{8/20}$ are summarised in Table A.1.



Key

Z_{A1}…Z_{A2}	impedance of the external down conductors
Z_{PE}	impedance of the equipotential bonding conductor
PE/PAS	equipotential bonding bar
Z_1…Z_2	impedance of the d.c. power conductor
I_1…I_2	current for each pole (or branch) of d.c. SPDs (1, 2)
I_{total}	total current of d.c. SPDs (3)
I_4…I_7	current for each pole of a.c. SPDs (4….7)

Figure A.1 – Example of a structure with two external down conductors to determine the value of the discharge current for the selection of SPDs

A.2.2 Case of voltage limiting and combination type SPDs (having voltage switching and limiting components in series)

Table A.1 – Values of $I_{10/350}$ and $I_{8/20}$ for voltage limiting and combination type SPDs (having voltage switching and limiting components in series)

LPL	Maximum current (10/350)	Number of external down conductors							
		2				≥ 4			
		per mode of protection		I_{total} (see Figure A.1)		per mode of protection		I_{total} (see Figure A.1)	
		$I_{8/20}$	$I_{10/350}$	$I_{8/20}$	$I_{10/350}$	$I_{8/20}$	$I_{10/350}$	$I_{8/20}$	$I_{10/350}$
I or unknown	200 kA	17	10	34	20	10	5	20	10
II	150 kA	12,5	7,5	25	15	7,5	3,75	15	7,5
III or IV	100 kA	8,5	5	17	10	5	2,5	10	5

For this application, there are two possibilities:

— either to use a limiting or combination (having voltage switching and limiting components in series) type SPD being declared as Type 1 and Type 2, with $I_{imp} \geq I_{10/350}$ and with $I_n \geq I_{8/20}$,

— or to use a voltage limiting type SPD only declared as Type 1 where $I_{imp} \geq I_{8/20}$ value.

$I_{10/350}$ and $I_{8/20}$ are given in Table A.1

For example, to protect the d.c. side of a PV installation on building with 2 down conductors for LPL III/IV

— either a SPD Type 1 tested with I_{imp} = 5 kA per mode of protection being also a SPD Type 2 tested with I_n = 8,5 kA per mode of protection,

— or a SPD Type 1 tested with I_{imp} = 8,5 kA per mode of protection,

would be suitable.

Due to the different impedance and time behaviour of voltage switching type SPDs the discharge current sharing on the d.c. side of a PV installation differs from the values for voltage limiting type SPDs. Therefore, the values in Table A.2 apply.

A.2.3 Case of voltage switching and combination type SPDs (having voltage switching and limiting components in parallel)

Table A.2 – Values of I_{imp} for voltage switching and combination type SPDs (having voltage switching and limiting components in parallel)

LPL	Maximum current (10/350)	Number of external down conductors			
		2		≥ 4	
		per mode of protection $I_{10/350}$	I_{total} (see Figure A.1)	per mode of protection $I_{10/350}$	I_{total} (see Figure A.1)
I or unknown	200 kA	25	50	12,5	25
II	150 kA	18,5	37,5	9	18
III or IV	100 kA	12,5	25	6,25	12,5

For this application, the solution is to use a switching or combination (voltage switching and limiting components in parallel) SPD Type 1 with $I_{imp} \geq I_{10/350}$ as given in Table A.2.

If the separation distance s is not kept and a metallic connection between LPS and the PV panel frame or the construction frame is required, then the use of a shielded cable for the d.c. power lines is also recommended. In this case, the shield shall be able to carry partial lightning currents equal to I_{total}. The shield shall be bonded to the earth termination system on both sides.

A.3 Outside free field power plant PV installation according to 6.4

A.3.1 General

The following example is a simplified approach based on a structure of an extended PV installation. Free field PV power plants are characterized by multiple earthing and a meshed earthing system. This leads to values of I_{imp} in Table A.3.

A.3.2 Assumption

A PV installation on earth ground is generally considered as an isolated structure (C_d = 1), located in rural area (C_e = 1). This PV installation is typically powered by a HV (C_t = 0,2) three phases aerial (C_i = 1) unshielded (C_{LD} = 1, PLD = 1) power line whose length can be assumed equal to 5 km, when no more precise information is available.

NOTE Parameters $C_{d,}$,C_e... PLD are coming from EN 62305-2.

The LV power line is connected in the main board to the internal line that terminates in the inverter of the PV installation. The PE conductor is typically distributed in the same cable with phase conductors.

A telecommunication line, connected to the control and monitoring equipment, could enter the PV installation too.

The partial lightning currents which flows via the SPDs into the d.c. system depends on

— the class of LPS:

  for outside free field power plant PV installation, LPL III is usually sufficient,

— the earth resistivity:

a higher earth resistivity results in higher partial currents flowing into the d.c. System via the SPDs,

— the mesh size of the earth termination system:

Figure A.2 shows an earth termination system with a mesh size of 20 by 20 m. Larger mesh sizes result in higher partial currents flowing into the d.c. side of the PV installation via the SPDs.

A.3.3 Result

Calculation have shown that a reduction of the current flow duration of the partial lightning currents injected into the d.c. cables via the d.c. SPDs is also characteristic for the lightning current distribution in a large-scale solar power plant. To be able to compare this stress with the SPD parameters specified in the standard, it has to be converted into a standardized 10/350 lightning current impulse by means of the equivalent impulse stress.

Table A.3 shows the values of I_{imp} and I_n for SPDs Type 1 on the d.c. side for an extended PV installation for LPL III and mesh sizes of 20 x 20 m.

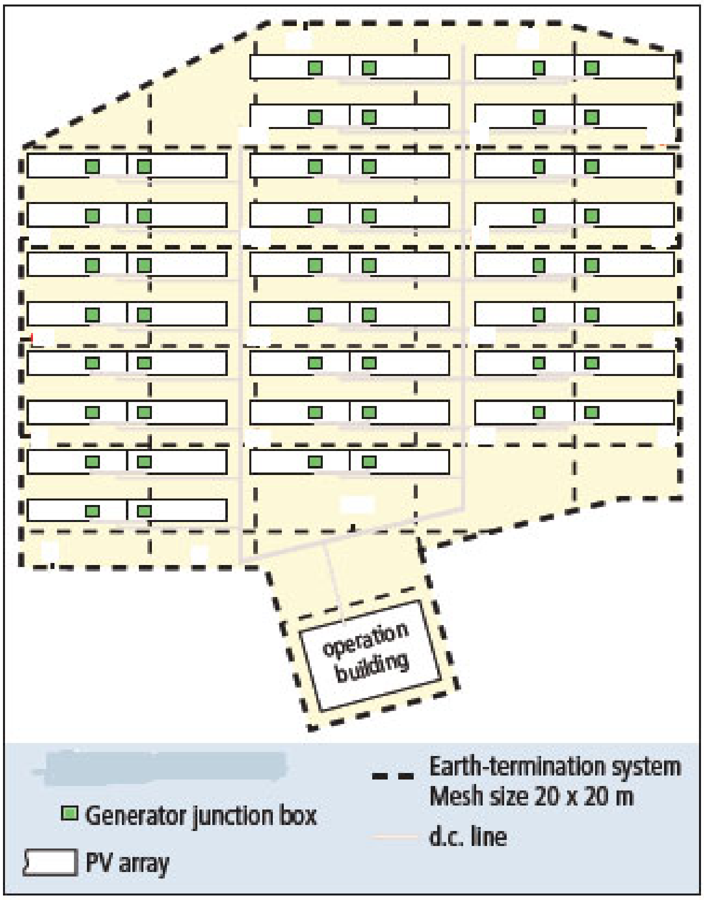


Figure A.2 – Example of a structure of an extended PV installation – Free field PV power plant with multiple earthing and a meshed earthing system

Table A.3 – Values of $I_{10/350}$ and $I_{8/20}$ for SPDs intended to be used in free field PV power plant with multiple earthing and a meshed earthing system

LPL	Maximum current (10/350)	SPDs connected to the d.c. side I_{imp} in kA (10/350), I_n in kA (8/20)					
		limiting or combination (having switching and limiting type components in series) type SPD				switching or combination (having voltage switching and limiting type components in parallel) type SPD	
		$I_{10/350}$		$I_{8/20}$		$I_{10/350}$	
		per mode of protection	I_{total}	per mode of protection	I_{total}	per mode of protection	I_{total}
III or IV	100 kA	5 kA	10 kA	15 kA	30 kA	10 kA	20 kA

For this application, there are three possibilities:

1) either to use one limiting or combination (having voltage switching and limiting type components in series) type SPD (Type 1 and Type 2) with $I_{imp} \geq I_{10/350}$ and with $I_n \geq I_{8/20}$,

2) or to use a limiting or combination (having voltage switching and limiting type components in series) type SPD (Type 1) where $I_{imp} \geq I_{8/20}$,

3) or to use a switching or combination (having voltage switching and limiting type components in parallel) type SPD (Type 1) with $I_{imp} \geq I_{10/350}$,

as given in Table A.3.

For voltage switching type SPDs, I_{imp} = 10 kA per mode of protection is acceptable for all LPL.

The use of a shielded cable for the d.c. power lines between the PV array and the central inverter station is also recommended to reduce the influence onto the d.c. system. In this case, the shield shall be able to carry partial lightning currents equal to I_{total} for each junction box. The shield shall be bonded to the earth termination system on both sides.

Annex B
(informative)

Characteristic of a PV source

B.1 General

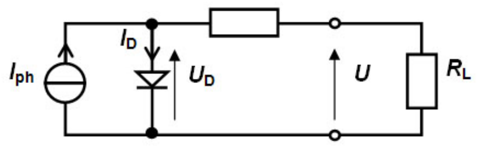
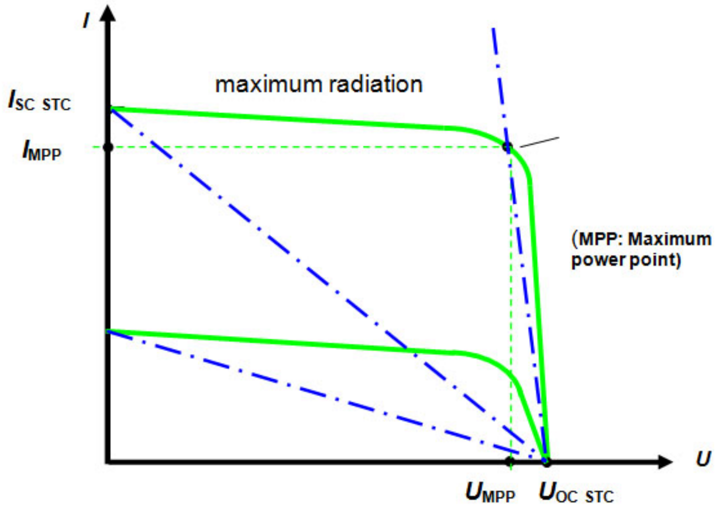


Figure B.1 – Principle of a PV current source



Key

Green graphs are showing the non-linear PV characteristic at different radiations

Blue graphs are showing alternatively 3 different linear sources to cover the PV characteristic for an alternative test method without using a PV source or PV source simulator.

Figure B.2 – V/I characteristic of a non-linear PV current source

For testing a PV – simulator has to be used or a combination of three different linear sources may also be accepted if under testing with linear source(s) the characteristic at low radiation up to the maximum power point comparable with a non-linear PV source will be reached.

SPDs with different internal design and technologies, use of limiting components or switching components or a combination of them, may have a different behaviour depending to the V/I characteristic of the used test source if testing under d.c. power conditions and may produce a line follow current under normal operation. In addition, the failure behaviour under end of live conditions is depending on the V/I characteristic of the used test source. The test source shall be able to simulate the real conditions of a PV installation. A PV generator is a non-linear current source and the present values of voltage and current are depending to the present temperature and sun radiation. The SPDs behaviour, with their internal design and their internal or external disconnectors (fuses), shall be taken under consideration at maximum solar radiation and also at low solar radiation. If linear d.c. sources are used for testing it shall be taken under consideration that comparable results for the use in such specific PV installations are given. This requires a linear source with a higher short circuit current to reach the maximum power point MPP of a real PV source or a PV source simulator.

The maximum d.c. voltage and maximum possible d.c. currents, which may be continuously applied to the SPD's mode of protection used in photovoltaic application have to be calculated.

B.2 Calculation of U_{OCMAX}

$U_{OC\ MAX}$ is the maximum voltage across an unloaded (open circuit) PV generator 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 generators, considering T_{min} the lowest ambient temperature [°C] of the PV installation site and $\acute{\alpha} U_{OC}$ the temperature variation coefficient [%/°C] of U_{OC} voltage provided by the PV generator manufacturer:

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

αU_{OC} is a negative factor, which can be provided by the PV 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 following formula:

$$\alpha U_{OC}\ (\%/°C) = 0{,}1\ \alpha U_{OC}\ (mV/°C) / U_{OC\ STC\ Generator}\ (V)$$

EXAMPLE Example of PV generator with $\acute{\alpha} U_{OC}$ expressed in mV/°C:

– Multicrystaline module, $U_{OC\ STC\ Module}$ = 38,3 V and αU_{OC} = - 133 mV/°C / αU_{OC} → 0,35 %/°C

– T_{min} = -15 °C → (T_{min} – 25) = -40 °C → K_U = 1,14 → $U_{OC\ MAX}$ = 1,14 $U_{OC\ STC}$

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

For amorpheous silicon PV cells, electrical characteristic during the first weeks of operation are higher than the specified characteristics. This phenomenon is indicated by the PV cells 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 generator, $U_{OC\ MAX}$ should be chosen equal to 1,2 $U_{OC\ STC}$.

B.3 Calculation of I_{SCMAX}

The maximum short circuit current of a PV generator 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_i shall be increased to take into account environmental situations, for example increased reflection or solar intensity.

Annex C
(normative)

Simplified risk assessment based on EN 62305-2

The method of risk assessment is based on the evaluation of the critical length L_{crit} and its comparison with L the cumulative length of the d.c. lines.

SPDs shall be installed on the d.c. side of the installation where:

$L \geq L_{crit}$

- L is the maximum wiring length (in meters) between the inverter and the connection points of the PV generators of the different strings with different path as described in Table C.1 (see also Figure C.1);

NOTE If the PV installation contains more than one inverter, L is assumed to be the sum of all feeding lengths to the inverters calculated as above.

- L_{crit} (in meters) depends on the type of PV installation, and is calculated according to Table C.1;
- 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 (EN 62305-2:2012, A.1).

Table C.1 – Calculation of the critical length L_{crit}

Type of installation	Individual residential premises	Free field PV power plant	Service/Industrial/ Agricultural building
L_{crit}	115 / N_g	200 / N_g	450 / N_g
$L \geq L_{crit}$	Surge protection device(s) are compulsory on d.c. side		
$L < L_{crit}$	Surge protection device(s) are not compulsory on d.c. side		

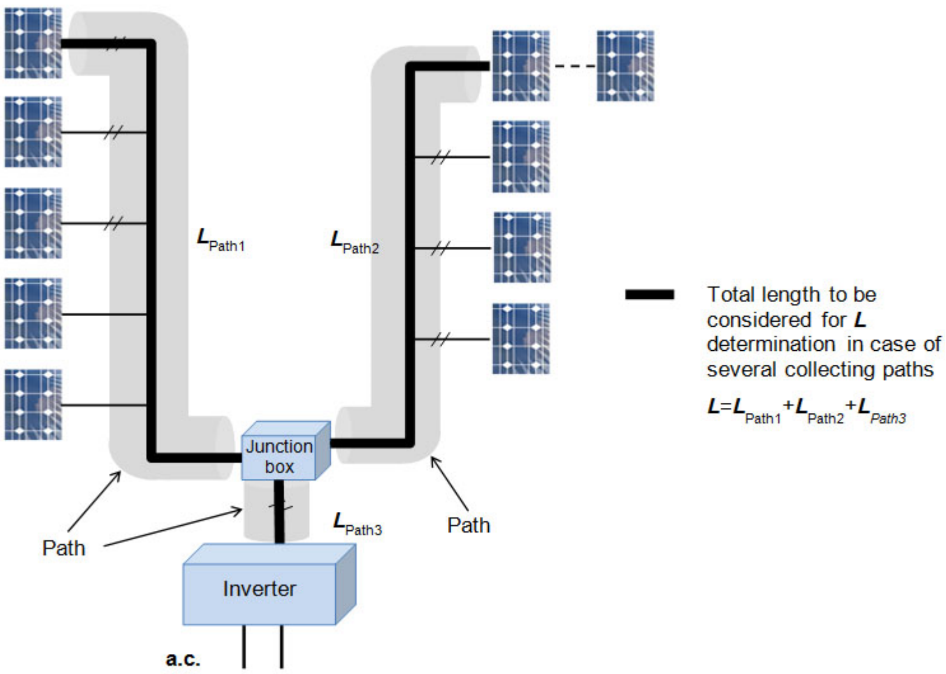


Figure C.1 – L calculation

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1) In preparation.

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